

STANDARDS LAB.

STANDARDS
LABORATORY



catalog

S

1865



GENERAL RADIO COMPANY

WEST CONCORD, MASSACHUSETTS, USA

THIS *50th Anniversary* CATALOG
CONTAINS THE MOST IMPRESSIVE COLLECTION OF
ELECTRONIC INSTRUMENTS, STANDARDS, AND COM-
PONENTS EVER CATALOGED BY GENERAL RADIO



catalog **S**

JULY 1965

You'll find these **NEW** products of particular interest:

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■ A truly automatic capacitance bridge that's the talk of the industry	63
■ A megohm bridge that measures to 1000 teraohms (10^{15} ohms)	74
■ GR900 Precision Coaxial Elements—the best available for low residual VSWR to 9 Gc/s	95
■ A complete frequency and time standard of exceptionally high performance and reliability	112
■ Counters for measuring frequencies to 1, 10, 100, or 500 Mc/s	119
■ A 10:1 solid-state scaler useful to 100 Mc/s; extends the range of most counters by a factor of 10	125
■ Frequency Synthesizers—100-kc, 1-Mc, and 12-Mc models—with 60 variations from which to choose	155
■ A moderately priced 2c-to-2Mc oscillator that has everything you want... it can even be synchronized to external signals	135
■ A pulse generator with plug-in modules for producing over 30,000 pulse combinations	161
■ A tone-burst generator that acts as a coherent gate for any input signal	167
■ A sampling recorder that faithfully reproduces transients	180
■ A full-fledged sound-level meter that's small and lightweight ($1\frac{3}{4}$ lb)	16
■ A high-speed stroboscope that operates on either line or batteries	213

There are many others. For your convenience all new items are clearly designated as such in the Table of Contents and on the individual pages.

For further information, quotations, demonstrations, please call our nearest office (see inside cover) or mail us one of the postcards at the rear.



GENERAL RADIO COMPANY

WEST CONCORD, MASSACHUSETTS • USA

NEW ENGLAND • NEW YORK • PHILADELPHIA • SYRACUSE • WASHINGTON • CLEVELAND
ORLANDO • CHICAGO • DALLAS • LOS ANGELES • SAN FRANCISCO • TORONTO • MONTREAL

GENERAL RADIO COMPANY

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SALES ENGINEERING OFFICES

General Radio Sales Engineering Offices are maintained in the following areas in the United States and Canada. These offices are staffed by competent factory-trained engineers. We invite your inquiries for technical, commercial, and service information.

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*SERVICE, INCLUDING REPAIRS, CALIBRATION, AND SPARE PARTS STOCK, AVAILABLE AT THESE OFFICES.

OVERSEAS REPRESENTATIVES

For a list of representatives in other countries, see inside back cover.



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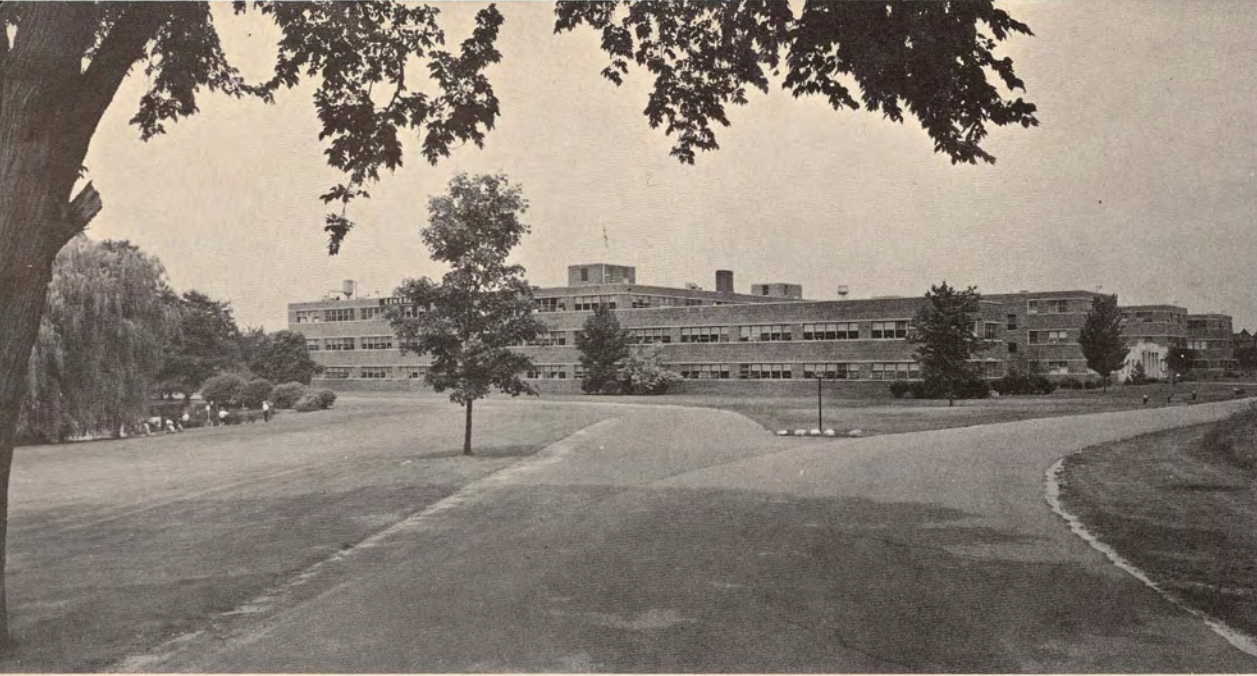
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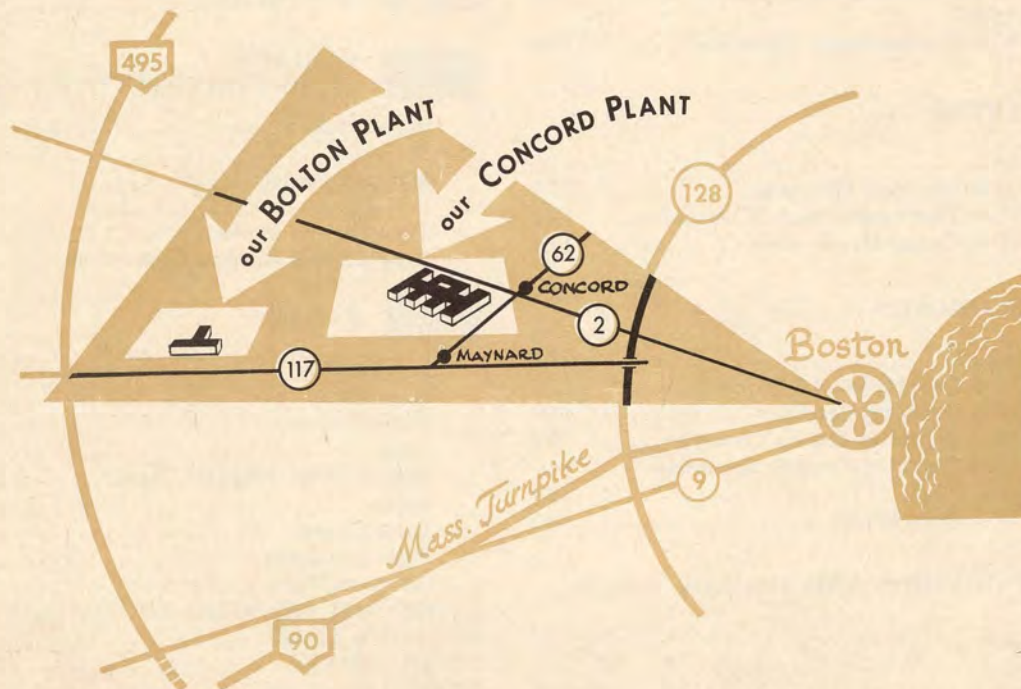
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COME VISIT US

We are always glad to see our customers at our plants as well as at our Sales Engineering Offices. The best time to visit us is between 10 AM and 3 PM any day except Saturdays, Sundays, and legal holidays in Massachusetts.

Our West Concord plant is at 22 Baker Avenue, near the intersection of State Routes 2 and 62, about 25 miles northwest of Boston. Our Bolton plant is on State Route 117, about a mile east of its intersection with Interstate Route 495. The accompanying map shows key routes to the two plants. Excellent train service is available to West Concord from Boston's North Station.





General Radio's First Plant



General Radio's Concord Plant Today

OUR FIFTIETH ANNIVERSARY

The publication of this catalog comes at the time of our fiftieth anniversary. General Radio is thus the oldest company in the United States, probably in the world, continuously in the business of manufacturing electronic test equipment. Melville Eastham founded GR in 1915, specifically to manufacture measuring equipment for the electronics (then "radio") industry. The first General Radio plant was in Cambridge, Massachusetts, where the Company remained until its move, in 1958, to the present site in West Concord.

General Radio's "Catalogue A" included the following items: a universal wavemeter (150 to 9000 meters), four inductance standards (0.05 to 5.00 mH), an Ayrton-Perry variable inductance, a variable air condenser, an audibility meter for measuring telephone signal strength, a decade resistance box, and several standard resistors and condensers. As the technology of electrical measurement advanced (helped in no small way by General Radio innovations), instruments grew in sophistication and versatility, to the level represented in the pages of this catalog. Despite the changes, it is easy to see, behind the relatively primitive devices of Catalogue A and the modern instruments of Catalog S, a common genealogical link — the craftsmanship of a specialist in measurement.

For General Radio, the half century from 1915 to 1965 has been a period of almost constant growth both in size and in capability as an instrument manufacturer. Our history is distinguished by many commercial "firsts": the heterodyne wave analyzer, the continuously adjustable autotransformer, the audio oscillator (including the beat-frequency and RC types), the electronic stroboscope, the transfer-function and immittance bridge, the hermaphrodite coaxial connector, the butterfly circuit, the standard-signal generator, the sound-level meter — these and many more instruments and devices were introduced in commercial form as GR products.

The fact of fifty years is of only passing interest. Far more important to our customers is the experience that fifty years in the instrument business implies. That experience is a bonus ingredient in every General Radio product.



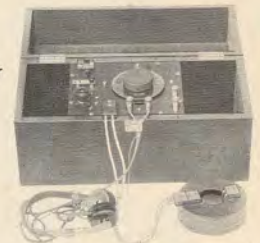
Type 1680-A Automatic Capacitance Bridge Assembly

Type 216 Capacity Bridge 1920



Type 1150-BH Digital Frequency Meter

Type 105 Wavemeter 1916



Type 1531-A Strobotac[®] electronic stroboscope

Type 631 Strobotac[®] 1935



Type 1521-B Graphic Level Recorder

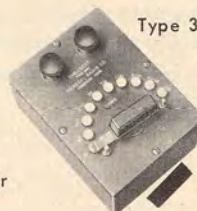
Type 338 String Oscillograph 1928



Type 213 Audio Oscillator 1923



Type 1311-A Audio Oscillator



Type 340 Rheostat 1930

Type W20MT3A Metered Variac[®] autotransformer



OUR COMPANY

General Radio is an employee-owned manufacturer of electrical and electronic measuring instruments for science and industry. Our administrative offices and main plant are at West Concord, Massachusetts. A new plant in nearby Bolton, Massachusetts specializes in the development and manufacture of signal generators and of microwave instruments and devices.

Our sales engineering and service network includes offices in 13 metropolitan areas in North America and subsidiaries in Zurich and London.

General Radio sells standard, proprietary, off-the-shelf products, listed in this catalog. In addition, systems are custom-assembled to serve special requirements, notably in the data-handling area. The Company has also developed a number of special-purpose instruments for various Government agencies and for industry. General Radio does not sell consulting services, patents, or proprietary rights or processes.

OUR PEOPLE

Because of the highly technical nature of our products, there is a high proportion of professional employees among the 1000-plus workers who make up General Radio. We have been called "an engineer's company," and it is true that the engineering personality and discipline are present in most of the Company's operations.

Every employee is, directly or indirectly, a part owner of the Company, shares in its fortunes, and is jealous of his Company's reputation for quality. The extra



reliability and years of life built into GR instruments are the result of both a deliberate corporate dedication to quality and an employee-by-employee commitment to the same principle.

ENGINEERING

The great majority of our development engineers have advanced degrees, and many are among the leaders in their fields. In every one of its product areas, GR has the advantage of many years of valuable development experience. Since the average annual engineering turnover is almost nil (well under 2%, excluding retirees), there is an impressive continuity of experience to serve as a base for the constant growth of our engineering staff.

MANUFACTURING

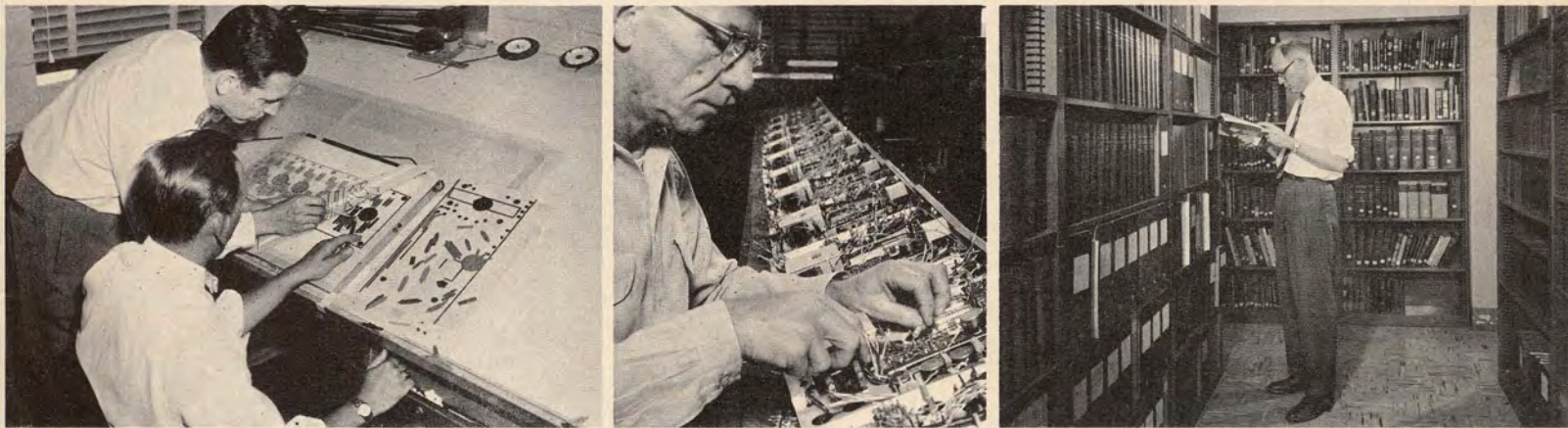
Our all-male manufacturing operations also benefit from very low turnover. The highly skilled men who assemble GR instruments average well over 10 years on the job. Each of these men assembles the complete instrument (there are no assembly lines at GR); their craftsmanship is one of the reasons why we can back up our products with a two-year warranty.

Quality, of course, begins long before instrument assembly. Components must meet rigid standards, and, for closest control of quality, we make many of them ourselves. We also do our own plating and painting, braid our own cables, wind our own potentiometers. For those components we buy, we still demand GR-grade quality.

From such preoccupation with quality come instruments that perform, and perform, and perform. Instruments built 25 or 30 years ago that are still going strong. Instruments in this catalog that will still be in use in the next century. Instruments that, for all their quality, are manufactured efficiently and are priced competitively.

SALES ENGINEERING

All GR sales engineers have technical degrees and intensive home-office training in both the technical and commercial aspects of sales engineering. The GR sales engineer sells our entire product line, from stroboscopes to sound-level meters, from capacitance bridges to coaxial connectors. He is thus a uniquely



qualified consultant in the broad field of measurement instrumentation. He is, moreover, a salaried employee of General Radio, known and respected for his expert, honest advice, even when the application calls for a competitor's product.

Sales Engineering Offices are located in 13 metropolitan areas in the United States and Canada. Repair centers at six of these locations are staffed by factory-trained service technicians.

General Radio has long served its many customers overseas through a network of representatives, most of whom have been associated with GR for many years. To supplement this coverage, we have in the last few years added two overseas subsidiaries, General Radio (Overseas), based in Zurich, and General Radio (U.K.) Ltd., located near London.



SALES, SHIPPING AND SERVICE INFORMATION



NOTE: The following information applies only to transactions originating in the United States and Canada. Customers in other countries will find pertinent sales, shipping, and service information in the International Edition of this catalog.

WE SELL DIRECT

We believe that we serve our domestic customers best by serving them directly. The men who sell GR instruments are engineers, in the strictest sense. They are General Radio employees, qualified to act for the Company, and they are paid salaries, not commissions. Every GR sales engineer is an experienced, expert consultant on electrical measurement, and his advice is yours for the asking.

A GR sales policy of long standing is the single price to all, published as an essential part of a product's specifications. The prices given in this catalog are what we charge for our products, the only discounts being the quantity discounts noted below.

(Variac® autotransformers are sold in the U.S. both direct

and through distributors, either way at the same advertised prices.)

HOW TO ORDER

Always order by both catalog number and complete description. For example:

Catalog No. 1900-9801, Type 1900-A Wave Analyzer, Bench Model.

Ac-operated instruments are supplied wired for operation on 115-volt power lines, unless otherwise specified. Most ac-operated instruments can also be supplied for nominal power-line voltages of 220, 230, and 240 volts, as indicated in the specifications under *Power Required*. Be sure to specify operating voltage and frequency if other than a nominal 115 volts, 50 to 60 cycles.

USA	2 POUNDS				5 POUNDS				25 POUNDS				40 POUNDS			
	Air Freight	Air Express	Air Parcel Post	REA	Air Freight	Air Express	Air Parcel Post	REA	Air Freight	Air Express	Truck*	REA	Air Freight	Air Express	Truck*	REA
ATLANTA	\$12.60	\$6.60	\$1.34	\$3.50	\$12.60	\$6.60	\$3.02	\$3.50	\$12.60	\$10.75	\$6.46	\$5.60	\$12.60	\$14.86	\$6.46	\$6.10
BUFFALO	11.20	6.60	1.23	3.60	11.20	6.60	2.73	3.60	11.20	6.75	5.67	4.87	11.20	8.46	5.67	4.87
CHICAGO	13.25	6.60	1.34	3.80	13.25	6.60	3.02	3.80	13.25	10.75	6.62	6.00	13.25	14.86	6.62	6.39
CLEVELAND	11.45	6.60	1.23	3.70	11.45	6.60	2.73	3.70	11.45	8.35	6.23	5.40	11.45	11.02	6.23	5.42
DALLAS	16.90	6.60	1.55	3.70	16.90	6.60	3.71	3.70	16.90	16.35	9.40	6.75	16.90	23.82	9.40	7.79
DETROIT	11.35	6.60	1.23	3.75	11.35	6.60	2.73	3.75	11.35	8.35	6.64	5.65	11.35	11.02	6.64	5.84
HOUSTON	15.90	6.60	1.55	3.75	15.90	6.60	3.71	3.75	15.90	16.35	9.72	6.80	15.90	23.82	9.72	7.83
LOS ANGELES	24.75	6.60	1.68	3.95	24.75	7.67	4.08	3.95	24.75	22.75	12.16	8.35	24.75	34.06	12.16	9.75
ST. LOUIS	12.75	6.60	1.47	3.85	12.75	6.60	3.39	3.85	12.75	11.55	7.51	6.30	12.75	16.14	7.51	6.93
SEATTLE	23.65	6.60	1.68	3.90	23.65	7.67	4.08	3.90	23.65	22.75	12.16	8.30	23.65	34.06	12.16	9.65
CANADA**	Air Freight	Air Express	Air Mail	REA	Air Freight	Air Express	Air Mail	REA	Air Freight	Air Express	Truck*	REA	Air Freight	Air Express	Truck*	REA
CALGARY	\$12.55	\$6.60	\$2.56	\$4.75	\$12.55	\$8.20	\$6.40	\$4.75	\$12.55	\$25.40	\$10.43	\$8.74	\$18.30	\$38.30	\$10.43	\$11.74
MONTREAL	9.50	6.60	2.56	4.02	9.50	6.60	6.40	4.02	9.50	6.60	6.50	5.12	9.50	7.90	6.50	5.96
OTTAWA	9.50	6.60	2.56	4.03	9.50	6.60	6.40	4.03	9.50	6.60	6.08	5.28	9.50	7.90	6.08	6.22
QUEBEC	9.50	6.60	2.56	4.03	9.50	6.60	6.40	4.03	9.50	7.40	6.50	5.78	9.50	9.50	6.50	6.72
TORONTO	9.50	6.60	2.56	4.62	9.50	6.60	6.40	4.62	9.50	8.40	6.93	5.59	10.70	11.10	6.93	7.20
VANCOUVER	14.00	6.60	2.56	4.85	14.00	8.60	6.40	4.85	14.00	27.40	12.16	9.48	20.30	41.50	12.16	12.89
WINNIPEG	10.50	6.60	2.56	4.43	10.50	7.00	6.40	4.43	10.50	18.40	7.40	8.01	14.70	27.10	7.40	9.43
USA	75 POUNDS			100 POUNDS			200 POUNDS			400 POUNDS						
Air Freight	Air Express	Truck*	REA	Air Freight	Air Express	Truck*	REA	Air Freight	Air Express	Truck*	REA	Air Freight	Air Express	Truck*	REA	
ATLANTA	\$16.35	\$24.45	\$6.46	\$6.10	\$17.00	\$31.30	\$6.46	\$6.13	\$28.90	\$61.90	\$11.80	\$10.40	\$55.80	\$123.80	\$23.60	\$20.80
BUFFALO	12.10	12.45	5.67	4.87	12.10	15.30	5.67	4.90	19.00	29.90	8.62	7.80	36.00	59.80	17.24	15.60
CHICAGO	17.00	24.45	6.62	6.39	17.00	31.30	6.62	6.42	28.25	61.90	11.04	10.80	55.60	123.80	22.08	21.60
CLEVELAND	12.95	17.25	6.23	5.42	12.95	21.70	6.23	5.45	20.45	42.70	8.88	8.80	39.60	85.40	17.76	17.60
DALLAS	22.00	41.25	9.40	7.79	22.00	53.70	9.40	7.82	39.10	106.70	16.10	13.90	76.80	213.40	32.20	27.80
DETROIT	13.50	17.25	6.64	5.84	13.50	21.70	6.64	5.87	21.65	42.70	10.12	9.70	41.80	85.20	20.24	19.40
HOUSTON	21.40	41.25	9.72	7.83	21.40	53.70	9.72	7.86	37.90	106.70	16.72	14.00	74.60	213.40	33.44	28.00
LOS ANGELES	31.70	60.45	12.16	9.75	31.70	79.30	12.16	12.00	58.20	157.90	24.32	25.00	115.60	315.80	48.64	50.00
ST. LOUIS	16.50	26.85	7.51	6.93	17.35	34.50	7.51	6.96	29.50	68.30	12.28	12.00	58.20	136.60	24.56	24.00
SEATTLE	31.10	60.45	12.16	9.65	31.10	79.30	12.16	11.90	57.05	157.90	24.32	25.00	112.40	315.80	48.64	50.00
CANADA**	Air Freight	Air Express	Truck*	REA	Air Freight	Air Express	Truck*	REA	Air Freight	Air Express	Truck*	REA	Air Freight	Air Express	Truck*	REA
CALGARY	\$31.25	\$68.40	\$10.43	\$18.77	\$32.85	\$89.90	\$10.43	\$23.94	\$62.20	\$179.10	\$20.86	\$48.38	\$123.60	\$358.20	\$41.72	\$96.26
MONTREAL	13.45	11.40	6.50	7.90	13.45	13.90	6.50	9.45	23.40	27.10	6.98	18.40	53.00	54.20	13.96	36.30
OTTAWA	14.35	11.40	6.08	8.38	14.35	13.90	6.08	10.08	25.20	27.10	8.10	19.66	49.60	54.20	16.20	38.82
QUEBEC	12.95	14.40	6.50	8.88	12.95	17.90	6.50	10.08	22.40	35.10	7.42	19.66	44.00	70.20	14.84	38.82
TORONTO	16.75	17.40	6.93	9.82	16.75	21.90	6.93	11.40	30.00	43.10	9.16	22.30	59.20	86.20	18.32	44.10
VANCOUVER	35.00	74.40	12.16	20.98	36.75	97.90	12.16	26.88	70.00	195.10	24.32	53.26	139.20	390.20	48.64	106.02
WINNIPEG	24.50	47.40	7.40	14.47	25.15	61.90	7.40	18.22	46.80	123.10	14.80	35.94	92.80	246.20	29.60	71.38

NOTES: Additional charges, based on value of goods shipped, apply on all shipments not forwarded by truck or rail freight forwarder. For all such shipments, full invoice value will be declared unless specific alternate instructions are received.

* Or rail freight forwarder.

** Canadian rates do not include handling or brokerage fees, duties, or any other taxes.

Special features and modifications not listed in the specifications (such as, for instance, extra calibrations) are available at extra cost. Please include in your order information on any nonstandard features desired.

SHIPPING INSTRUCTIONS

Unless specific instructions accompany the order, we shall use our judgment as to the best method of shipment. Repair parts and other items needed quickly will be shipped by air if requested. The table on the preceding page shows the cost of four different methods of shipment to major cities in the United States and Canada, door-to-door.

The price of the instrument includes packing but does not include the cost of shipping. Shipping containers are not returnable.

OUR ADDRESS

Communications may be addressed to General Radio Company, West Concord, Massachusetts, or to one of the Sales Engineering Offices listed on the inside front cover of this catalog.

Customers may call on whichever Sales Engineering Office is most convenient for them. Areas regularly served by the various offices are listed on the inside front cover. States not listed are covered by the Sales Engineering Department at West Concord.

We have direct teleprinter connections with both Western Union and Bell System TWX. Our cable address is GEN-RADCO CONCORD (MASS), and our TWX call numbers are 617-369-5708. Complete addresses and telephone numbers for our Sales Engineering Offices are listed on the inside front cover.

PRICES

All prices given in this catalog are established on a direct-to-customer basis, with no discounts other than the quantity discounts noted below. Prices are FOB our plant, West Concord, Massachusetts, and are exclusive of all taxes now in effect or that may be imposed hereafter by Federal, State, or local governments. Prices given are subject to change without notice. Formal price quotations remain in effect for 30 days.

Canadian customers may obtain prices FOB Toronto from our Sales Engineering Offices in Toronto or Montreal.

CONDITIONS OF SALE

Determination of prices, terms, and conditions of sale, and final acceptance of orders are made only at our plant in West Concord, Massachusetts.

Terms are net 30 days if credit has been arranged; otherwise, unless payment is received before shipment, shipment will be made COD.

QUANTITY DISCOUNTS

Quantity discounts apply only to Variac[®] autotransformers and to parts, not to instruments. When 10 or more identical parts or autotransformers are ordered at the same time for single shipment to the same place, with ultimate destination in the continental United States (not including the Canal Zone) or Canada, the following quantity discounts apply unless otherwise noted:

Quantity	Discount
10 through 19	5 percent
20 through 99	10 percent
100 or more	15 percent

MINIMUM BILLING

The minimum billing per order is \$10.00. This applies to all purchases except repair parts and cash-with-order transactions.

SOURCE-INSPECTION SURCHARGE

A surcharge of 1 percent (\$2.50 minimum) applies on all orders requiring inspection at our plant either by one of the Government services or by the customer's own inspection department or other private agency. The inspection surcharge applies on each shipment inspected and covers only our costs.

SPECIFICATION CHANGES

We reserve the right to discontinue any item without notice and to change specifications at any time without incurring any obligation to incorporate new features in instruments or parts previously sold.

WARRANTY

We warrant that each new instrument sold by us is free from defects in material and workmanship and that, properly used, it will perform in full accordance with applicable specifications for a period of two years after original shipment. Any instrument or component that is found within the two-year period not to meet these standards, after examination by our factory, district office, or authorized repair agency personnel, will be repaired or, at our option, replaced without charge, except for tubes or batteries that have given normal service.

SERVICE AND PARTS

Repair service is available from our plant at West Concord, Massachusetts, or from our field service facilities (see inside front cover).

Repair parts may be ordered from our home plant or our field service laboratories. When ordering repair parts, please specify the part number and description of the item and the type and serial numbers of the instrument in which it is used.

Before returning an instrument for repair, please write to us, requesting a Returned Material Tag, which includes packing and shipping instructions to ensure protection in transit. Also state the type and serial numbers of the instrument, date of purchase, and details concerning the difficulty.

EXPORT ORDERS

Customers outside the United States and Canada are served by General Radio, by its subsidiaries, General Radio (Overseas) and General Radio (U.K.) Ltd., and by the group of export representatives listed inside the rear cover of this catalog. All communications should be directed to the appropriate export representative. For countries not listed, inquiries should be addressed to General Radio Company, West Concord, Massachusetts, U.S.A., or, for customers in Europe, to General Radio Company (Overseas), Helenastrasse 3, Zurich 8008, Switzerland.

Full information on export transactions is given in the International Edition of this catalog, available on request from General Radio Company, West Concord, Massachusetts, USA.



ABBREVIATIONS, SYMBOLS, AND PREFIXES

In this catalog, as in other General Radio publications, our use of symbols, prefixes, and abbreviations follows the recommendations of the International Electrotechnical Commission, the American Standards Association, the Institute of Electrical and Electronics Engineers, and various other scientific and engineering organizations. Where there is not agreement among these groups, we generally choose the usage favored by the majority.

ABBREVIATIONS AND SYMBOLS

A	ampere
ac	alternating current
AFC	automatic frequency control
a-m	amplitude modulation
ASA	American Standards Association
ASTM	American Society for Testing Materials
AVC	automatic volume control
avg	average
B	susceptance
BCD	binary-coded decimal
C	capacitance
C	Celsius (Centigrade)
CIF	cost, insurance, freight
cm	centimeter
COD	cash on delivery
c/s	cycle per second
CW	continuous wave
D	dissipation factor
dB	decibel
dBm	decibel referred to one milliwatt
dc	direct current
dia	diameter
E	voltage
EIA	Electronics Industries Association
emf	electromotive force
F	farad, Fahrenheit
f	frequency
fm	frequency modulation
FOB	free on board
G	conductance
g	gram, gravitational constant
Gc/s	gigacycle per second
g_m	transconductance
H	henry
h_f	forward current-transfer ratio
h_i	short-circuit input impedance
h_o	open-circuit output admittance
h_r	reverse voltage-transfer ratio
Hz	Hertz
I	current
ID	inside diameter
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers

i-f	intermediate frequency
in	inch
IRE	Institute of Radio Engineers
ISO	International Standards Organization
j	$\sqrt{-1}$
kc/s	kilocycle per second
kV	kilovolt
kVA	kilovoltampere
kW	kilowatt
k Ω	kilohm
L	inductance
lb	pound
LC	inductance-capacitance
log	logarithm
m	mass
m	meter
mA	milliampere
max	maximum
mbar	millibar
Mc/s	megacycle per second
mH	millihenry
mil	0.001 inch
min	minimum, minute
mm	millimeter
mV	millivolt
mW	milliwatt
m Ω	milliohm
M Ω	megohm
ns	nanosecond
n Ω	nanohm
oz	ounce
p	page, parallel (as L_p)
pf	power factor
pF	picofarad
ppm	parts per million
pps	pulses per second
p-to-p	peak-to-peak
prf	pulse repetition frequency
Q	quality factor (storage factor)
R	resistance
®	registered trademark
RC	resistance-capacitance
re	referred to
rf	radio frequency
RH	relative humidity
rms	root-mean-square
rpm	revolutions per minute
s	second, series (as L_s)
shf	super-high frequency
sq	square
sync	synchronous, synchronizing
T	period

t	time
uhf	ultra-high frequency
v	velocity
V	volt
VA	volt ampere
vhf	very-high frequency
vlf	very-low frequency
W	watt
wt	weight
X	reactance
Y	admittance
Z	impedance
α	short-circuit forward current-transfer ratio (common base)
β	short-circuit forward current-transfer ratio (common emitter)
Γ	reflection coefficient
Δ	increment
δ	loss angle
θ	phase angle
λ	wavelength
μA	microampere
μbar	microbar
μF	microfarad
μH	microhenry
μs	microsecond
μV	microvolt
Ω	ohm
$\bar{\Omega}$	mho
ω	angular velocity ($2\pi f$)

PREFIXES

Orders of magnitude from 10^{-18} to 10^{12} are designated by the following prefixes:

Order	Prefix	Symbol
10^{12}	tera	T
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^2	hecto	h
10	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

POWER-SUPPLY CONSIDERATIONS

General Radio ac-operated instruments will meet the published specifications when operated from power lines whose voltages and frequencies are within the limits stated in the specifications under the heading *Power Required*.

Most instruments have input voltage ranges of 105 to 125 and 210 to 250 volts and will therefore operate on nominal power-line voltages of 115, 220, 230, and 240 volts. In certain instruments an additional range of 195 to 235 volts is included. The voltage range for which an instrument is wired is marked at the power-input plug or cord. Proper fuses for this voltage range are fitted in the fuse holders.

When the power-line voltage on which the instrument is to be operated is specified on the order, the necessary changes in connections, fuses, and nameplate are made at the factory. This change can also be made easily by the user, in accordance with directions given in the instruction manual.



Certain instruments are available for use only on power lines of 220, 230, and 240 volts (nominal). Such instruments are identified by the suffix Q18 in the type designation.

For most instruments, the normal operating frequency range is 50 to 60 cycles per second. Instruments identified by the suffix Q1 in the type designation are for 50-cycle operation only.

All ac-operated instruments are supplied with three-wire power cords, designed for standard three-wire receptacles.

BATTERY OPERATION

Portable, battery-operated instruments are shipped with dry-cell batteries in place but disabled to prevent drain and leakage during shipment. To render the instrument operative, the user need only remove the yellow insulating disks from the battery terminals.

PUBLICATIONS

A monthly publication, the *General Radio Experimenter*, discusses new products and applications as well as general technical subjects. Sent free on request, this periodical is distributed to over 100,000 readers throughout the world.

Other General Radio publications include the *Handbook of Noise Measurement*, *Handbook of Voltage Control*, *Handbook of High-Speed Photography*, and instrument notes, booklets, and reprinted articles on a wide range of technical subjects.

PATENTS

Many of our products are manufactured and sold under United States Letters Patent owned by the General Radio Company or under license grants from other companies. To simplify the listing of these patents they are given here in a single list and referred to at each instrument only by appropriate reference number.

1. "Certain vacuum-tube amplifier devices, electric wave filters, vacuum-tube oscillators, and sound-level meters are licensed by Western Electric Company, Inc., under all United States Letters Patent owned or controlled by American Telephone and Telegraph Company, or Western Electric Company, Inc., and any or all other United States patents with respect to which Western Electric Company, Inc., has the right to grant a license, solely for utilization in research, investigation, measurement, testing, instruction and development work in pure and applied science, including engineering and industrial fields."

2. 2,578,429.

3. Patent 2,586,397.

4. Patent 2,548,457.

5. Patent 2,802,907.

6. Licensed under designs, patents and patent appli-

cations of Edgerton, Germeshausen and Grier.

7. Patent 3,067,388.

8. Patent Applied For.

9. Patent Re 24,204.

10. Patent 3,050,685.

11. Patent 3,022,944.

12. Patent 3,012,197.

13. Patent 2,977,540.

14. Patent 2,763,733.

15. Patent D 187,740.

16. Patent 2,970,258.

17. Patent 2,538,122.

18. Patent 2,581,133.

19. Patent 2,872,639.

20. Patent 2,943,277.

21. Patent 2,942,172.

22. Patent 2,966,257.

23. Patent 2,506,648.

24. Patent 2,702,736.

25. Patent 2,715,718.

26. Patent 2,786,140.

27. Patent 3,156,870.



ACOUSTICS



General Radio's comprehensive line of acoustical and audio-frequency instruments provides the essential elements for the efficient evaluation of noise and vibration and for the measurement of other acoustical phenomena. The basic instruments described in this section comprise a sound-level meter, a vibration meter, and a variety of transducers and calibrators, for the quantitative measurement of both air-borne and solid-borne vibrations.

These are supplemented by:

- (1) A group of analyzers, which operate from the electrical output of the sound-level meter* to measure the amplitude and frequency of the components of the sound or vibration spectrum. These include narrow-band, 1/3-octave, and octave-band instruments, as well as a peak-reading device for evaluating impact-type sounds. (See pages 27-35.)
- (2) A preamplifier that operates directly from a microphone or vibration pickup to increase the sensitivity of any of the analyzers or to allow the use of long cables between the transducer and an instrument without loss in sensitivity. (See page 17.)
- (3) Audio-frequency oscillators, a random-noise generator, tone-burst generator, and pulse generators for exciting acoustical and electrical systems under test. (See pages 130, 160, 169.)
- (4) Graphic recorders for automatic spectrum analysis, reverberation-time measurements, and permanent records of measurements. (See page 177.)
- (5) Stroboscopes for visual analysis of vibration phenomena. (See page 210.)
- (6) Impedance bridges for determining the characteristics of transducers and other acoustical devices. (See page 41.)
- (7) Auxiliary equipment, such as frequency meters and amplifiers. (See pages 36 and 119.)

With GR instruments, one can make the measurements necessary for rating and evaluating practically any industrial noise problem. They can be used by nontechnical personnel and are designed for long life and trouble-free operation. The use of these and other noise-measuring instruments is discussed thoroughly in the *Handbook of Noise Measurement*, published by General Radio Company, and available at one dollar a copy, postpaid.

SOUND-LEVEL MEASUREMENTS

The standard sound-level meter is the basic sound-measuring instrument and has been improved in each successive model in performance, in convenience, and in versatility, culminating in the Type 1551-C Sound-Level Meter. The Type 1565-A Sound-Level Meter is a simplified version, particularly designed for convenience in use, small size, and low cost. Both instruments meet the requirements of the current American Standard Specification for General-Purpose Sound Level Meter and the IEC Recommendation.†

The excellent, general-purpose piezoelectric ceramic microphone supplied as standard equipment is stable and rugged, has a smooth frequency response, and is relatively unaffected by normal temperature changes. It can be mounted directly on the instrument or separately with connection by extension cable when it is necessary to avoid the effects of the observer on the acoustical measurement. For very wide band measurements the Type 1551-P1 Condenser Microphone System is available.

Either of these instruments can be used to measure over-all level, the first important measure of a noise. A frequency analysis is also often desirable to estimate the effects of the noise, to track down the source, and to determine efficient control measures.

OCTAVE-BAND AND NARROWER-BAND MEASUREMENTS — SPECTRUM ANALYSIS

The Type 1558 Octave-Band Noise Analyzers and Type 1564-A Sound and Vibration Analyzer can be used directly with a ceramic microphone to measure octave-, 1/3-octave-, and 1/10-octave-band sound-pressure levels in the range from 44 to 150 dB, which yields adequate data for comparison with most hearing-damage criteria, test codes, and noise ordinances. For even lower band levels, the Type 1560-P40 Preamplifier can be used, or the electrical output of the Type 1551-C Sound-Level Meter can be analyzed. This output is the amplified electrical replica of the acoustic signal at the microphone, and it has a wide dynamic range. Its frequency spectrum can be analyzed by the Octave-Band Noise Analyzers, the Sound and Vibration Analyzer, with both 1/10-octave and 1/3-octave bandwidths, and the Type 1900-A Wave Analyzer with 3-, 10-, and 50-cycle bandwidths.

IMPACT NOISE

The measurement of impact noise can be made simply with the sound-level meter and the Type 1556-B Impact-Noise Analyzer. This analyzer can also measure electrical noise peaks in communication circuits.

CALIBRATION

Although GR sound-measuring instruments are inherently reliable and stable, after long periods of use their performance may change. To ensure that important changes will be discovered and corrected, the Type 1552-B Sound-Level Calibrator has been developed. When driven by the Type 1307-A Transistor Oscillator at a 2-volt level, it supplies a known (400-cycle) acoustic signal to the microphone for over-all calibration of the system.

* The TYPE 1564-A Sound and Vibration Analyzer and the TYPE 1558 Octave-Band Analyzers can also be operated directly from a microphone or vibration pickup.

† ASA S1.4-1961; IEC Publication 123, 1961.

Greatest accuracy of calibration is achieved with the Type 1559-B Microphone Reciprocity Calibrator. This device, which uses the closed-coupler reciprocity method of calibration, will determine the sensitivity of GR microphones over a frequency range of 20 to 8000 c/s. It is also a precision acoustic source, as well as a sound-level calibrator.

VIBRATION MEASUREMENTS

GR vibration-measuring equipment includes the Type 1553 Vibration Meters to measure the acceleration, velocity, displacement, and jerk* of a vibrating element; the Type 1564-A Sound and Vibration Analyzer or the Type 1900-A Wave Analyzer to analyze the vibration; and the Type 1560 Vibration Pickup Systems to convert the sound-level meter to a vibration meter. The Octave-Band Noise Analyzers and the Sound and Vibration Analyzer can also be operated directly from the output of a vibration pickup. These instruments are easily calibrated with the Type 1557-A Vibration Calibrator, a self-contained electromagnetic shaker.

Stroboscopes comprise another important group of vibration measuring instruments. They permit vibrating objects to be viewed intermittently and produce the optical effect of slowing down or stopping a periodic vibration.

LEVEL RECORDERS

The Type 1521-B Graphic Level Recorder can record the level and spectral distribution of sound and vibration, operating from the output of the sound-level meter, the vibration meter, or one of the analyzers. The frequency dials of the Type 1564-A Sound and Vibration Analyzer and the Type 1900-A Wave Analyzer can be driven by the recorder for

* Jerk = rate of change of acceleration.

automatic plotting of the spectrum. Reverberation measurements can also be made with this recorder.

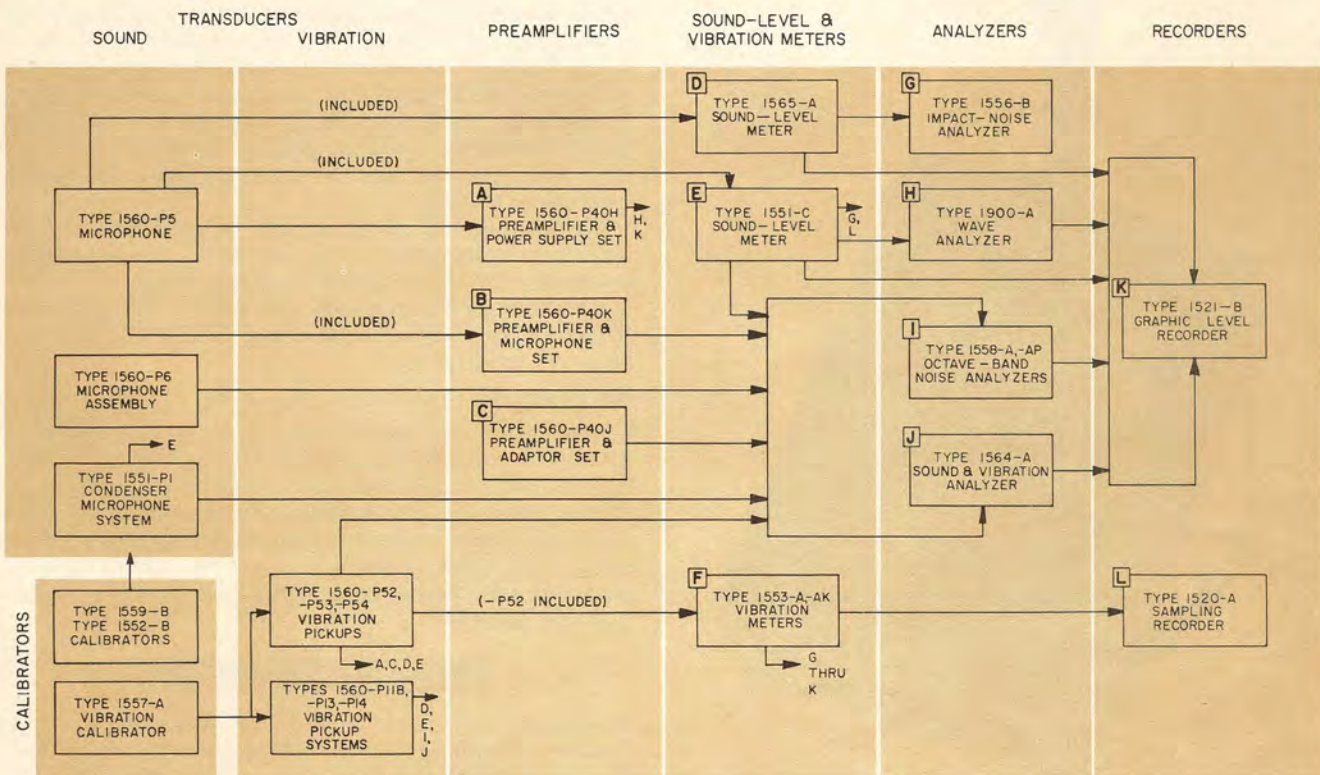
The Type 1520-A Sampling Recorder can record the instantaneous value of the wave from the output of a vibration meter or a sound-level meter. Its high speed makes it particularly useful for studying transient signals.

MEASUREMENT POWER SOURCES

The Type 1304-B Beat-Frequency Audio Generator can drive transducers with pure tones to excite vibratory and acoustical systems. If the response is recorded on the Type 1521-B Graphic Level Recorder, a plot of the transfer-response level in decibels versus frequency on a standard logarithmic scale is obtained. An output of the Type 1910-A Wave Analyzer can also be used to drive transducers or networks, and the response can be detected by the same analyzer and plotted automatically on the Type 1521-B Graphic Level Recorder. When higher power is needed, the Type 1308-A Audio Oscillator and Power Amplifier is recommended.

The Type 1390-B Random-Noise Generator can supply a useful broad-band noise. When its output is fed to one of the General Radio analyzers, the analyzer output is a narrower band of noise that is tunable over the range of the analyzer. Such a signal has many applications in acoustical testing, particularly in architectural acoustics and psychoacoustics. For transient-response measurements, square-wave and pulse generators can provide steep-wavefront signals, and the tone-burst generator provides a signal that is particularly useful in acoustical testing.

The accompanying diagram shows the functional relations among these various instruments, which collectively make up the General Radio Sound-Measuring System.





The standard sound-level meter, whose essential characteristics are specified by the American Standards Association and the International Electrotechnical Commission, is the accepted instrument for the measurement of both product noise and environmental noise by industry, laboratories, and noise-abatement groups.

Typical users include:

Machine and Appliance Manufacturers, in industrial and development laboratories as well as on the production line. The sound-level meter provides a means of establishing noise standards and of accepting or rejecting products on the basis of noise tests.

Acoustical Engineers and Physicists, for the measurement of machinery and product noise and for determining the acoustical properties of buildings, vehicles, and materials.

Industrial Hygienists and Psychologists, in surveys of the psychological and physiological effects of noise and for the determination of satisfactory noise environments in factories and offices.

Public Authorities, for measuring noise levels in streets, highways, airports and other public places.

General Radio manufactures two sound-level meters. The Types 1565-A and 1551-C Sound-Level Meters are both designed to meet ASA and IEC specifications. The Type 1565-A Sound-Level Meter is a simplified version, particularly designed for convenience in use, small size, and low cost. As a result it does not have the ultimate sensitivity, the added frequency range, the internal calibration, and the low output distortion of the larger Type 1551-C Sound-Level Meter. The Type 1551-C Sound-Level Meter provides the greater versatility that is needed when a variety of measurements must be made. But, as is often the case, when no more than a single weighted sound-level measurement at levels above 44 dB is required, the Type 1565-A Sound-Level Meter is admirably suited to the job. If over-all sound levels need to be recorded, either instrument can be used with the graphic level recorder; and for impact noise, the impact-noise analyzer is essential.

Type 1551-C SOUND-LEVEL METER

FEATURES:

- Compact, and portable — weighs less than 8 pounds with batteries.
- Rugged ceramic microphone. ■ Low internal noise level. ■ Low distortion.
- Simple to operate. ■ Uses standard batteries.
- Meets requirements of ASA S1.4-1961 and IEC Publication 123, 1961.
- Two-speed meter movement permits measurement of either steady or fluctuating sound.
- Wide sound-level range — from 24 to 150 dB. ■ Wide dynamic range.
- Wide frequency response of amplifiers and circuit from 20 c/s to 20 kc/s.
- Internal calibration system for standardizing gain.
- Rms response in accordance with ASA S1.4-1961.



USES: In addition to its primary use as a self-contained sound-level meter, the TYPE 1551-C Sound-Level Meter is the heart of an extensive sound-measuring system, which includes spectrum analyzers, special-purpose microphones, calibrators, and vibration pickups. Many other accessories, such as graphic level recorders and tape recorders, can also be operated from the sound-level-meter output.

This sound-level meter can also be used as a portable amplifier, attenuator, and voltmeter for laboratory measurements in the audio-frequency range.

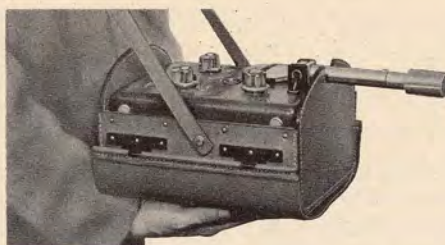
Its many applications are described in detail in the *Handbook of Noise Measurement*, a copy of which is available to each user.

DESCRIPTION: The TYPE 1551-C Sound-Level Meter consists of an omnidirectional microphone, a calibrated attenuator, an amplifier, standard weighting networks, and an indicating meter. The complete instrument, including batteries, is mounted in an aluminum case. The microphone can be used in several positions and, when not in use, folds down into a storage position, automatically disconnecting batteries. An ac power-supply unit is available.

SPECIFICATIONS

Sound-Level Range: From 24 to 150 dB (re 0.0002 μ bar).

Frequency Characteristics: Four response characteristics, A, B, C, or 20-kc, as selected by a panel switch. The A-, B-, and C-weight-



(Left) Microphone in the storage position (batteries automatically disconnected). (Center) The sound-level meter operated in its leather carrying case, microphone in the horizontal operating position. (Right) The sound-level meter ac-operated with the Type 1262-B Power Supply, which plugs directly into the base of the sound-level meter.

ing positions are in accordance with ASA S1.4-1961 and IEC Publication 123, 1961. Frequency response for the 20-ke position is flat from 20 c/s to 20 kc/s, so that complete use can be made of very wide-band microphones such as the TYPE 1551-P1 Condenser Microphone Systems.

Microphone: Highly stable ceramic type. Accessory condenser microphone is available. (See page 19.)

Sound-Level Indication: Sound level is indicated by the sum of the meter and attenuator readings. The clearly marked, open-scale meter covers a span of 16 dB with calibration from -6 to +10 dB. The attenuator is calibrated in 10-dB steps from 30 to 140 dB above 0.0002 μ bar.

Output: 1.4 V behind 7000 Ω (panel meter at full scale). The output can be used to drive analyzers, recorders, oscilloscopes, and headphones. Harmonic distortion (panel meter at full scale) less than 1%.

Input Impedance: 25 M Ω in parallel with 50 pF.

Meter: Rms response, and fast and slow meter speeds in accordance with ASA S1.4-1961 and IEC R123, 1961.

Calibration: Built-in calibration circuit standardizes the sensitivity of the electrical circuits within ± 1 dB at 400 c/s, as specified in ASA standards. The TYPE 1552-B Sound-Level Calibrator (page 21) is available for making periodic acoustical checks on the over-all calibration, including microphone. Microphone can be accurately calibrated with the TYPE 1559-B Microphone Reciprocity Calibrator (page 22), which can also be used for over-all acoustical checks.

Environmental Effects:

Temperature and Humidity: Microphone is not damaged at temperatures from -30 to +95°C and relative humidities from 0 to 100%. When standardized by its internal calibration system or a TYPE 1552-B Sound Level Calibrator, the instrument will operate within catalog specifications (for panel-meter indications above 0 dB) over the temperature range of 0 to 60°C and the relative humidity range of 0 to 90%.

Magnetic Fields: When exposed to a 60-cycle, 1-oersted (80 A/m) field, the sound-level meter will indicate 60 dB (C weighting) when oriented for maximum sensitivity to the magnetic field.

Electrostatic Fields: Aluminum case provides sufficient shielding, so that normally encountered electrostatic fields have no effect.

Vibration: Case is fitted with soft rubber feet and amplifier is resiliently mounted for vibration isolation. When the instrument is set on its feet on a shake table and vibrated at 10 mils p-to-p displacement over the frequency range of 10 c/s to 55 c/s, the unwanted signals generated do not exceed an equivalent C-weighted sound-pressure level of 45 dB when motion is vertical, 60 dB when motion is lengthwise, or 40 dB when motion is sidewise.

Power Supply: Two 1½-V size D flashlight cells and one 67½-V battery (Burgess XX45 or equivalent) are supplied. An ac power supply, the TYPE 1262-B, is available.

Accessories Supplied: Telephone plug.

Accessories Available: TYPE 1551-P2 Leather Case (permits operation of the instrument without removal from the case). TYPE 1560-P95 Adaptor Cable, for connecting output to TYPE 1521-B Graphic Level Recorder. For other accessories, including analyzers, see pages 17 to 34.

Mechanical Data: Aluminum cabinet, finished in gray crackle.

Width		Height		Depth		Net Weight*		Shipping Weight*	
in	mm	in	mm	in	mm	lb	kg	lb	kg
7¼	185	9¼	235	6⅞	160	7¼	3.6	16	7.5

* With batteries (add 2 pounds for leather case).

For a more detailed description, see *General Radio Experimenter*, August 1961.

Catalog Number	Description	Price
1551-9703	Type 1551-C Sound-Level Meter	\$450.00
8410-9499	Set of Replacement Batteries	4.25
1551-9602	Type 1551-P2 Leather Carrying Case	25.00
1560-9695	Type 1560-P95 Adaptor Cable	3.00

PATENT NOTICE. See Note 12, page 11.

MILITARY SPECIFICATIONS: We can supply Type 1551-C Sound-Level Meters to meet the specifications of MIL-STD-740. Price and details on request.

Type 1262-B POWER SUPPLY

Attaches to the TYPE 1551-C Sound-Level Meter for AC-Line Operation

Catalog No.	Volts	Input c/s	Watts	Dimensions	Weight		Price
					Net	Shipping	
1262-9702	105-125 or 210-250	50-400	2	5, 7¼, 3⅞ in (130, 185, 80 mm)	2½ lb (1.2 kg)	8 lb (3.7 kg)	\$95.00

Type 1565-A SOUND-LEVEL METER

FEATURES:

- Meets requirements of ASA S1.4-1961, IEC Publication 123, 1961.
- Pocket sized and light weight — 1¾ pounds. ■ Powered by single 1.5-volt C cell.
- Uses rugged and stable lead-zirconate-titanate ceramic microphone.
- Rms response in accordance with ASA S1.4-1961.
- Use of only solid-state elements virtually eliminates microphonics.

USES: Although not so versatile in application as the TYPE 1551, this instrument is a standard sound-level meter capable of accurate noise measurements, in conformity with national and international standards. It is particularly useful for rapid surveys, for periodic checks on noisy environments, and for production testing of manufactured products.

DESCRIPTION: The TYPE 1565-A Sound-Level Meter is a pocket-sized, light-weight instrument that can be held

and operated with one hand. It includes most of the features usually found only in larger, more expensive instruments. It consists of an omnidirectional microphone, which drives a cascade of amplifier stages and a panel-control attenuator. Standard frequency weighting is introduced along the amplifier chain, which ultimately drives a panel meter and output jack. The microphone can be replaced with an adaptor for connection to sources fitted with a 3-terminal male microphone connector.

SPECIFICATIONS

Sound-Level Range: 44 to 140 dB (re 0.0002 μ bar).
Weighting: A, B, and C weighting in accordance with American Standard ASA S1.4-1961 and IEC Publication 123, 1961.
Microphone: Lead-zirconate-titanate ceramic unit.
Output: At least 1.5 V behind 20 k Ω when meter reads full scale. Output is intended primarily for driving a TYPE 1556-B Impact-Noise Analyzer, a graphic level recorder, or headphones. Harmonic distortion, 2% or less for frequencies above 200 c/s and 5% or less for frequencies below 200 c/s (panel meter at full scale).
Meter: Rms response, and fast and slow meter speeds, in accordance with ASA S1.4-1961 and IEC Publication 123, 1961.
Auxiliary Input Provision: A TYPE 1560-P96 Adaptor is available to allow connection to any source fitted with a male 3-terminal microphone connector. Input impedance is approximately 13 M Ω in parallel with 25 pF. For correct weighting, source impedance must be 380 pF \pm 5%.
Calibration: Sound-level meter can be pressure calibrated at 400 c/s with a TYPE 1552-B Sound-Level Calibrator or at any frequency in the range from 20 to 2000 c/s with a TYPE 1559-B Microphone Reciprocity Calibrator.
Operating Temperature Range: 0 to 50°C.

Storage Temperature Range: -20° to +70°C (battery removed).
Operating Humidity Range: 0 to 90% R.H.
Temperature Coefficient of Sensitivity: Approximately +0.03 dB/°C.
Effect of Magnetic Field: Equivalent C-weighted sound level of a 1-oersted (80 A/m) 60-cycle field is about 47 dB when meter is oriented for maximum indication.
Power Supply: One 1½-V size C flashlight cell. Battery life approximately 35 hours for 2 h/day service.
Accessories Available: TYPE 1565-P1 Leather Carrying Case. TYPE 1560-P96 Adaptor to adapt input to mate with 3-terminal male microphone connector necessary for connection to vibration pickup, page 20. TYPE 1560-P95 Adaptor Cable to connect output to TYPE 1521-B Graphic Level Recorder or other devices fitted with jack-top binding posts on ¼-in centers.

Mechanical Data:

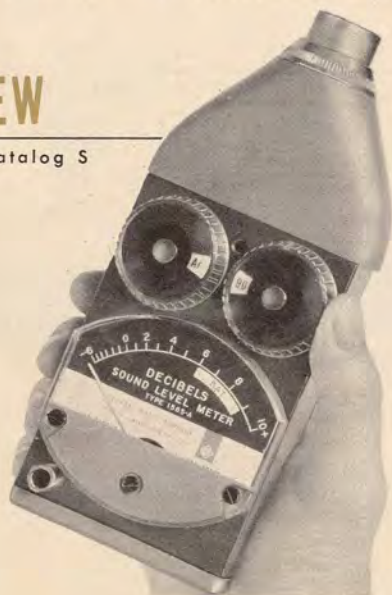
Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
3¼	78	7¾	190	2½	54	1¼	0.8	5	2.3

See also *General Radio Experimenter*, October-November 1964.

Catalog Number	Description	Price
1565-9701	Type 1565-A Sound-Level Meter	\$240.00
1565-9601	Type 1565-P1 Leather Carrying Case	15.00
1560-9695	Type 1560-P95 Adaptor Cable	3.00
1560-9696	Type 1560-P96 Adaptor to 3-terminal male microphone connector	11.00
8410-9899	Replacement Battery	.20

NEW

in catalog 5



Sound-Level Meter in leather carrying case.



WAVE ANALYSIS



ANALYZERS

The instruments described in this section are used to determine the components and the wave shape of complex electrical signals, acoustic noise, or mechanical vibrations. The choice of an instrument for evaluating the individual components of such a signal depends upon the character of the signal, the information that is needed, and how the results are to be used.

HETERODYNE ANALYZER — FIXED BANDWIDTH

If, for example, the signal is a periodic one that is reasonably stable in frequency, each spectrum component is readily measured with the Type 1900-A Wave Analyzer. The very high selectivity of this analyzer, with its bandwidths of 3, 10, and 50 c/s, is independent of the frequency to which the analyzer is tuned. These selectivity characteristics, which are obtained through the use of quartz-crystal filters, are particularly useful in the measurement of intermodulation distortion of amplifiers and other audio equipment. When this analyzer is used as an electronic voltmeter in the measurement of the transmission characteristics of electrical wave filters or as a null detector for impedance bridges, the excellent selectivity is of particular value in avoiding the effects of interfering signals, hum, noise, and distortion products. When used as a bridge detector, the analyzer will also supply the generator signal for operating the bridge.

If the signal is a random noise, whether it is electrically generated noise or acoustic noise transformed by a microphone into an electrical signal, the 50-cycle bandwidth of this analyzer can be very useful in the frequency analysis of such a signal, particularly when the spectrum is automatically plotted.

CONSTANT-PERCENTAGE-BANDWIDTH ANALYZER

The Type 1564-A Sound and Vibration Analyzer finds its greatest use in the measurement of the components of noise, either electrical or acoustic, when the bandwidth of the Type 1900-A Wave Analyzer is too narrow for rapid analysis, and in the measurement of noises and complex waveforms whose frequency components fluctuate. It provides two bandwidths, which are constant percentages of the center frequency: 1/3 octave (23%) and 1/10 octave (7%).

Although its tuning is continuous, if one assumes that the analyzer divides its range from 2.5 to 25,000 c/s into contiguous bands according to its effective bandwidth, it will have about 135 bands without appreciable overlap for the 1/10-octave bandwidth and about 41 bands for the 1/3-octave bandwidth. This contrasts with approximately 18,000, 5400, and 1080 bands for the 3-, 10-, and 50-cycle bandwidths, respectively, of the wave analyzer, whose frequency coverage is 20 c/s to 54 kc/s.

RECORDING ANALYZERS

Either of the above-mentioned analyzers can be combined with the Type 1521-B Graphic Level Recorder to form a recording analyzer. The analyzer dial is driven automatically by the recorder, and chart paper is available to fit the scale of each type of analyzer. These combinations are listed and illustrated on pages 29 and 31. With such a combination, complex spectra can be plotted automatically over the complete frequency range of the analyzer.

TUNED AMPLIFIER

Approximate magnitudes of spectrum components can be determined by measurement with the Type 1232-A Tuned Amplifier and Null Detector (page 104). This highly sensitive instrument has a bandwidth of about 5% and is tunable from 20 c/s to 20 kc/s.

OCTAVE-BAND ANALYZER

For many noise measurements a simpler division of the spectrum is desired than that provided by either the Type 1564-A Sound and Vibration Analyzer or the Type 1900-A Wave Analyzer. Much time can be saved in the evaluation of the general spectral distribution of a noise through the use of a wide-band device such as the Type 1558 Octave-Band Analyzers. These divide the audio spectrum into ten bands. Like the more selective analyzers, the octave-band analyzer can also be used as a selective voltmeter when it is desired to exclude certain bands of frequencies or individual frequencies from a signal.

DISTORTION METER

The Type 1932-A Distortion and Noise Meter is a specialized yet versatile device for the measurement of distortion in audio-frequency systems. Here the complete signal is used as a reference value; the fundamental component is suppressed. The remainder, which includes distortion components, hum, and noise, is then measured to give a single-number distortion rating. When used with a cathode-ray oscilloscope, this instrument is a versatile testing tool, immediately indicating optimum conditions whenever adjustments are made that affect distortion and noise.

STEEP WAVEFRONTS

With impact-type acoustic noise and electrical noise, which have extremely steep wavefronts, a frequency analysis is usually of little value. The important characteristics of such signals are the peak amplitude and the duration or decay time. To evaluate these quantities, the Type 1556-B Impact-Noise Analyzer is used.



Type 1900-A WAVE ANALYZER

FEATURES:

- Wide frequency range — 20 to 54,000 c/s. ■ Three bandwidths — 3, 10, and 50 c/s.
- 30 microvolts to 300 volts, full scale.
- Outputs for dc recorder and graphic level recorder (80-dB dynamic range).
- Tunable filter — output at selected frequency is provided.
- Tracking generator — analyzer can be used as both source and detector.
- Self-contained voltage-calibrating system.
- Input impedance of one megohm on all voltage ranges.
- Three meter speeds for easier noise analysis. ■ Mirror-backed meter.
- Linear frequency scale for optimum tuning characteristics over full range.
- AFC holds analyzer in tune despite small drifts in input frequency.
- In-line frequency readout. ■ Incremental-frequency dial for high resolution.

USES: The wave analyzer is used for measuring the components of, or analyzing the spectra of, complex electrical signals, including those which are replicas of acoustic noise or mechanical vibrations.

Individual components of periodic complex waveforms such as harmonic or intermodulation distortion are readily separated and measured, owing to the excellent selectivity available.

This analyzer is particularly suited for analyzing noise, because its bandwidth in cycles per second is independent of the center frequency. The required averaging time is, therefore, constant, and the calculation of spectrum level is simple. Furthermore, when the 50-cycle bandwidth is used, the averaging time required is reasonably short.

The analyzer can also be used as a tunable filter, so that the individual components of a complex input signal can be used to drive other instruments, such as frequency counters, when a highly accurate measure of the component frequencies is desired, or to drive earphones. When a wide-band noise generator drives the analyzer, the output is a tunable narrow band of noise. Such a signal is useful in a number of psychological and architectural-acoustics tests.

In the "tracking generator" mode of operation the output is a sine-wave signal tunable over the 54-ke

range and always in tune with the analyzer. When this signal is used to drive a bridge or other network, the output can be measured by the analyzer, whose selectivity reduces the interference from extraneous noise, hum, and distortion.

For automatic waveform analysis, outputs are provided for driving the TYPE 1521 Graphic Level Recorder as well as dc recorders.

The TYPE 1560-P40H Preamplifier and Power Supply Set is available to extend the full-scale sensitivity to 3 microvolts and to increase the input impedance.

DESCRIPTION: The TYPE 1900-A Wave Analyzer is a heterodyne type of voltmeter. The intermediate-frequency amplifier at 100 kc/s includes a highly selective quartz-crystal filter whose bandwidth can be switched to 3, 10, and 50 c/s. The use of a heterodyne system makes it possible to vary the response frequency although the filter frequency is fixed. The 100-ke output of the filter is indicated on a meter and is also available at the panel. In one mode of operation the output is also heterodyned back to the original frequency. In another mode the local oscillator beats with a 100-ke quartz-crystal oscillator to function as a beat-frequency oscillator. These two outputs are also available at panel terminals as FILTERED INPUT COMPONENT and INDICATED FREQUENCY, respectively.



SPECIFICATIONS

FREQUENCY

Range: 20 to 54,000 c/s. The frequency is indicated on a counter and a dial with a linear graduation, 10 c/s per division.

Accuracy of Calibration: $\pm(1/2\% + 5 \text{ c/s})$ up to 50 kc/s; $\pm 1\%$ beyond 50 kc/s.

Incremental-Frequency Dial (ΔF): $\pm 100 \text{ c/s}$. Accuracy is $\pm 2 \text{ c/s}$ below 2 kc/s, $\pm 5 \text{ c/s}$ up to 54 kc/s.

Automatic Frequency Control: At frequencies below 10 kc/s, total range of frequency lock is 400 c/s for the 50-cycle band and 150 c/s for the 10-cycle band, as defined by 3-dB drop in response from full-scale deflection. At 50 kc/s, the lock ranges decrease to one-half these values.

SELECTIVITY Three bandwidths (3, 10, and 50 c/s).

Effective bandwidth for noise equal to nominal bandwidth within $\pm 10\%$ for 10- and 50-cycle bands and $\pm 20\%$ for 3-cycle band.

3-Cycle Band: At least 30 dB down at $\pm 6 \text{ c/s}$ from center frequency, at least 60 dB down at $\pm 15 \text{ c/s}$, at least 80 dB down at $\pm 25 \text{ c/s}$ and beyond.

10-Cycle Band: At least 30 dB down at $\pm 20 \text{ c/s}$, at least 60 dB down at $\pm 45 \text{ c/s}$, at least 80 dB down at $\pm 80 \text{ c/s}$ and beyond.

50-Cycle Band: At least 30 dB down at $\pm 100 \text{ c/s}$, at least 60 dB down at $\pm 250 \text{ c/s}$, at least 80 dB down at $\pm 500 \text{ c/s}$ and beyond.

INPUT

Impedance: 1 M Ω shunted by 30 pF on all ranges.

Voltage Range: 30 μV to 300 V, full scale, in 3, 10 series. A decibel scale is also provided.

Voltage Accuracy: After calibration by internal source, the accuracy up to 50 kc/s is $\pm(3\%$ of indicated value + 2% of full scale) except for the effects of internal noise when the attenuator knob is in the maximum-sensitivity position. From 50 to 54 kc/s, the above 3% error becomes 6%.

Residual Modulation Products and Hum: At least 75 dB down.

OUTPUT

100-kc Output: Amplitude is proportional to amplitude of selected

component in analyzer input signal. With the TYPE 1521-B Graphic Level Recorder connected, full-scale output is at least 3 V. Dynamic range from overload point to internal noise is $>80 \text{ dB}$ with attenuator knob fully clockwise.

Recording Analyzer: See the TYPE 1910-A Recording Analyzer. The recorder is described on page 178.

DC Output: 1 mA in 1500 Ω , full scale, one side grounded.

Filtered Input Component: Output at least 1 V across 600- Ω load for full-scale meter deflection with output control at maximum.

Tracking Analyzer (Indicated Frequency): 20 c/s to 54 kc/s; output is at least 2 V across 600- Ω load with output control at maximum.

GENERAL

Terminals: Input, binding posts; output, telephone jacks.

Power Required: 105 to 125 or 210 to 250 V, 50 to 60 c/s, approximately 40 W.

Accessories Supplied: TYPE 1560-P95 Adaptor Cable, phone plug, TYPE CAP-22 Power Cord, spare fuses.

Accessories Available: TYPE 1900-P1 Link Unit for coupling to TYPE 1521-B Graphic Level Recorder (page 178); TYPE 1560-P40H Preamp and Power Supply Set (page 18).

MECHANICAL DATA Rack-Bench Cabinet (see page 258)

Model	Width		Height		Depth		Net Weight		Shipping Weight	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Bench	19	485	16 1/4	415	15 1/4	390	56	26	140	64
Rack	19	485	15 3/4	400	13 1/4*	340	56	26	140	64

* Behind panel

For a more detailed description, see *General Radio Experimenter*, April 1964.

Type 1910-A RECORDING WAVE ANALYZER

The Recording Wave Analyzer consists of the following items:

TYPE 1900-A Wave Analyzer

TYPE 1521-B (or -BQ1) Graphic Level Recorder, with medium-speed motor (see page 178)

TYPE 1521-P10B Drive Unit

TYPE 1900-P1 Link Unit

1521-9464 Chart Paper, 10 rolls

1521-9465 Chart Paper, 10 rolls

TYPE 1521-P3 80-dB Potentiometer*

The recording analyzer is shipped completely assembled with end frames. Supports for installation in a standard 19-inch rack are supplied.

* In addition to the 40-dB potentiometer installed in the recorder.

MECHANICAL DATA Rack-Bench Cabinet (see page 258)

Model	Width		Height		Depth		Net Weight		Shipping Weight	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Bench	19	485	25 1/4	645	15 1/4	390	116	53	227	104
Rack	19	485	24 1/2	625	13 1/4*	340	116	53	227	104

* Behind panel



NEW

in catalog S

Catalog Number	Description	Price
1900-9801	Type 1900-A Wave Analyzer, Bench Model	\$2150.00
1900-9811	Type 1900-A Wave Analyzer, Rack Model	2150.00
1910-9701	Type 1910-A Recording Wave Analyzer (for 60-cycle supply)	3500.00
1910-9494	Type 1910-AQ1 Recording Wave Analyzer (for 50-cycle supply)	on request

PATENT NOTICE. See Notes 1, 15, and 18, page 11.



Type 1564-A SOUND AND VIBRATION ANALYZER

FEATURES:

- Wide frequency range — 2.5 c/s to 25 kc/s. ■ True logarithmic frequency scale.
- High input impedance — 25 megohms in parallel with 80 pF.
- Direct reading in either volts or, when used with microphone, in dB re 0.0002 μ bar.
- Operates from either power line or rechargeable battery.
- Internal amplitude calibration system. ■ All-solid-state circuits.
- Rms detector with three averaging times.
- Detent at ASA preferred frequencies can be engaged with panel control.

USES: The TYPE 1564-A Sound and Vibration Analyzer is designed primarily for measuring the amplitude and frequency of the components of complex sound and vibration spectra. Its 1/3-octave (23%) and 1/10-octave (7%) noise bandwidths provide the flexibility needed for analysis of both line (single frequency) and continuous spectra. The high input impedance of the analyzer permits direct connection of piezoelectric transducers for measuring sound pressures from 44 to 150 dB re 0.0002 μ bar and acceleration from 0.0007 g to 100 g.

The TYPE 1560-P40 Preamplifier is available to extend the full scale sensitivity of the analyzer to 30 μ V (24 dB SPL or 70 μ g minimum level) and to allow use of the transducer at the end of a long extension cable. See page 17. Alternatively, for high sensitivity, the analyzer can be driven from a sound-level meter or vibration meter.

Automatic range switching is provided so that the TYPE 1521-B Graphic Level Recorder can record auto-

matically the spectrum of the signal under analysis. The combination of analyzer and recorder is available as the TYPE 1911-A Recording Sound and Vibration Analyzer.

The analyzer can be used in conjunction with the TYPE 1390-B Random-Noise Generator for transfer and reverberation measurements using 1/3- or 1/10-octave bands of random noise.

The analyzer is also a useful tuned voltmeter or general-purpose wave analyzer for work at audio and subaudio frequencies. The TYPE 1560-P41 Audio-Frequency Voltage Probe is available for convenient connection to high impedance electric circuits. See below.

DESCRIPTION: The TYPE 1564-A Sound and Vibration Analyzer consists of a high impedance amplifier, a continuously tunable filter having a noise bandwidth of either 1/3 or 1/10 octave, an output amplifier, and a meter. The center frequency of the filter is continuously adjustable. An all-pass, or flat, characteristic permits measurement of the over-all signal amplitude.

SPECIFICATIONS

FREQUENCY

Range: From 2.5 c/s to 25 kc/s in four decade ranges.

Dial Calibration: Logarithmic.

Accuracy of Calibration: $\pm 2\%$ of frequency-dial setting.

Filter Characteristics: Noise bandwidth is either 1/3 octave or 1/10 octave. One-third-octave characteristic has at least 30-dB attenuation at one-half and twice the selected frequency (see plot). One-tenth-octave characteristic has at least 40-dB attenuation at one-half and twice the selected frequency. Ultimate

attenuation is 70 dB or greater for both characteristics. For both bandwidths peak response is uniform ± 1 dB from 5 c/s to 10 kc/s and ± 1.5 dB from 2.5 c/s to 25 kc/s.

INPUT

Impedance: 25 M Ω in parallel with 80 pF (independent of attenuator setting).

Voltage Range: 0.3 mV to 30 V full scale in 10-dB steps.

Microphone: TYPE 1560-P6 Microphone Assembly or the TYPE 1560-P40K Preamplifier and Microphone Set (page 17) is recommended.



OUTPUT

Voltage: At least 1.0 V open circuit when meter reads full scale.

Impedance: 6000 Ω. Any load can be connected.

Meter: Three scales, 0 - 3 V; 0 - 10 V; -6 to +10 dB.

Recording Analyzer: Automatic range switching at the end of each frequency decade allows convenient continuous recording of spectra with the Type 1521-B Graphic Level Recorder. See below for recording analyzer assembly.

GENERAL

Amplitude Calibration: Built-in, feedback-type calibration system permits amplitude calibration at any frequency.

Detector: Rms with three averaging times. Faster two speeds conform with ASA standard for sound-level meters.

Power Required: Operates from 105 to 125 or 210 to 230 V, 50-60 c/s, or from nickel-cadmium battery supplied. Battery provides 25 h of operation when fully charged and requires 14 h for charging.

Accessories Supplied: TYPE CAP-22 Power Cord, shielded cable, and detented knob and dial assembly.

Accessories Available: TYPE 1560-P6 Microphone Assembly for direct acoustic pickup; TYPES 1560-P52, -P53, -P54 Vibration Pickups for solid-borne vibrations; TYPE 1560-P41 Audio-Frequency Voltage Probe for voltage measurements; TYPE 1560-P40K Preamplifier and Microphone Set (power is available for the TYPE 1560-P40 Preamplifier at the input connector).

MECHANICAL DATA Flip-Tilt Case (see page 258)

Model	Width		Height		Depth		Net Weight		Shipping Weight	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Portable	10¼	260	8⅞	210	8	205	14½	7	17	8
Rack	19	485	10½	270	6*	155	15½	7.5	28	13

* Behind panel

For a more detailed description, see *General Radio Experimenter*, September-October 1963.

Catalog No.	Description	Price
1564-9701	Type 1564-A Sound and Vibration Analyzer, Portable Model	\$1150.00
1564-9820	Type 1564-A Sound and Vibration Analyzer, Rack Model	1150.00
1560-9520	Type 1560-P40K Preamplifier and Microphone Set	251.00

PATENT NOTICE. See Notes 12, 15, and 22, page 11.

TYPE 1911-A RECORDING SOUND AND VIBRATION ANALYZER

The recording analyzer consists of the following components:

TYPE 1564-A Sound and Vibration Analyzer (rack model)

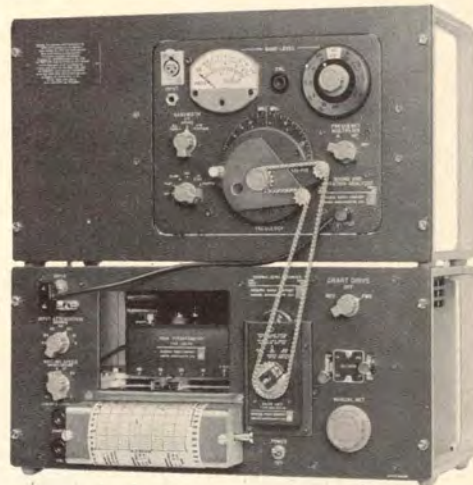
TYPE 1521-B (or -BQ1) Graphic Level Recorder, with medium-speed motor (see page 178)

TYPE 1521-P10B Drive Unit

TYPE 1521-P15 Link Unit, with interchangeable 16- and 24-tooth sprockets

1521-9469 Chart Paper, 10 rolls

The recording analyzer is shipped completely assembled with end frames. Hardware for installation in a standard 19-inch rack is supplied.



NEW

in catalog 5

Catalog No.	Description	Price
1911-9701	Type 1911-A Recording Sound and Vibration Analyzer (for 60-cycle supply)	\$2315.00
1911-9494	Type 1911-AQ1 Recording Sound and Vibration Analyzer (for 50-cycle supply)	on request

TEST PROBE FOR VOLTAGE MEASUREMENT WITH THE ANALYZER

The TYPE 1560-P41 Audio-Frequency Voltage Probe consists of a 10:1 RC divider. It presents a high impedance to the circuit under test and connects to the analyzer with a 4-foot cable. It is supplied with a variety of probe tips, including plugs, to fit jack-top binding posts on ¼-inch centers.

Input Impedance: 25 MΩ in parallel with 20 pF.

Net Weight: ¼ lb (115 gram).



Catalog No.	Description	Price
1560-9641	Type 1560-P41 Audio-Frequency Voltage Probe	\$45.00



Type 1558 OCTAVE-BAND NOISE ANALYZER

USES:

The TYPE 1558 Octave-Band Noise Analyzer is used for the rapid analysis of broadband noises, where a knowledge of individual frequency components is not required. For the measurement of octave-band sound-pressure levels above 44 dB re 0.0002 μ bar, the analyzer can be used directly with a piezoelectric microphone. For lower levels, it can be operated from the output of the TYPE 1560-P40 Preamplifier or the TYPE 1551-C Sound-Level Meter.

It is particularly useful for:
Measurement of aircraft, vehicle, and machinery noise.

Measurement of environmental noise, as in offices and factories, where speech-interference level is important.

Studies of environmental noise as related to hearing damage.

Production testing and noise-level acceptance tests.
Loudness determinations.

Acoustical studies of rooms and materials.

DESCRIPTION: Two models of the octave-band noise analyzer are available. The TYPE 1558-A has bands as specified by the ASA Standard for Octave-Band Filters, Z 24.10-1953. In the TYPE 1558-AP, the bands are centered at the ASA Preferred Frequencies for Acoustical Measurements, ASA S 1.6-1960.* In addition, the -A model has bandpass filters that extend the range at both ends beyond the range specified in the standard.

Essentially, the analyzer consists of a high-impedance amplifier, a filter, an output amplifier, and a meter. The amplifier frequency response can be set to be either flat or C-weighted. A built-in reference allows calibration for microphones ranging in sensitivity from -52 to -62 dB re 1 volt/ μ bar. RC active filters are used, resulting in small size, light weight, and lack of interference from stray magnetic fields. The high input impedance and preamplification permit the use of piezoelectric microphones and vibration pickups. The analyzer

* Also specified by ISO Recommendation 402 and German Standard DIN45-401.

is portable and powered by rechargeable nickel-cadmium batteries.

FEATURES:

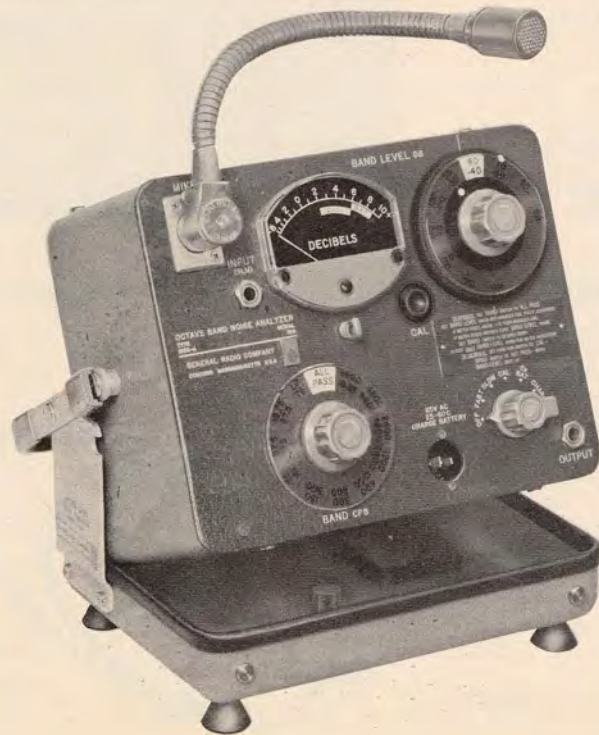
- Direct use with piezoelectric microphones for levels in the range from 44 to 150 dB (down to 24 dB with preamplifier).
- Small, compact, and portable — weighs less than 9 pounds.
- Measures level in 10 octave bands.
- Uses rechargeable nickel-cadmium battery.
- All-solid-state circuitry.
- Internal calibration system.
- Rms response in accordance with ASA S1.4-1961.

ACCESSORY MICROPHONE and PREAMPLIFIER

The TYPE 1560-P6 Microphone Assembly consists of a ceramic microphone unit attached to a short length of flexible conduit, which in turn mounts on a swivel base. The microphone assembly plugs into the MIKE input connector on the panel of the octave-band analyzer.

It has a flat response to sounds of random incidence from 20 c/s to 8 kc/s. It will withstand temperatures from -30 to 95°C and relative humidity from 0 to 100%. It shows little change in sensitivity and internal impedance with temperature.

The sensitivity of the analyzer can be extended to 24 dB by use of the TYPE 1560-P40K Preamplifier and Microphone Set. The preamplifier also allows the microphone to be used at the end of a long extension cable.



The Type 1558-A Octave-Band Noise Analyzer with the Type 1560-P6 Microphone Assembly.

1558

SPECIFICATIONS

Filter Characteristics:† Level at center frequency in bands from 37.5 to 9600 c/s is uniform ± 1 dB. Maximum deviation from ALL PASS level at center frequency in any band is 1 dB. For bands from 37.5 to 9600 response at nominal cutoff frequency is (3.5 ± 1) dB below response at center frequency. Attenuation is at least 30 dB at one-half the lower nominal cutoff frequency and twice the upper nominal cutoff frequency for all octave bands. Attenuation is at least 50 dB at one-fourth the lower nominal cutoff frequency and four times the upper nominal cutoff frequency for all octave bands. The 75-cycle low-pass filter has at least 35-dB attenuation at 200 c/s and at least 50-dB attenuation at 400 c/s.

† Measured with signal applied at INPUT (SLM) terminals.

Bands: Type 1558-A		
Lower Cutoff Frequency-c/s	Upper Cutoff Frequency-c/s	Center Frequency* c/s
18.75	37.5	26.5†
37.5	75.0	53.0†
75.0	150	106
150	300	212
300	600	424
600	1200	849
1200	2400	1700
2400	4800	3390
4800	9600	6790
9600	19,200	13,590†
LP	75	
ALL PASS		

* Geometric mean. † These bands are not required by Z24.10.

For TYPE 1558-AP, center frequencies are 31.5, 63, 125, 250, 500, 1000, 2000, 4000, 8000, 16,000 c/s.

Sound-Pressure-Level Range: 44 to 150 dB above 0.0002 μ bar in any band when TYPE 1560-P6 Microphone Assembly is used.

Input: Impedance at MIKE terminals is approximately 50 pF in parallel with 50 M Ω . It is intended for use with high-impedance transducers such as the TYPE 1560-P6 Microphone Assembly.

Impedance at INPUT (SLM) terminals is approximately 100 k Ω . Maximum input is 3 V. Low-input terminal, connected to case, is intended for connection to output of a sound-level meter.

Amplifier Frequency Characteristic: Can be set to be either C weighting, which is specified by the American Standards Association (ASA S1.4-1961 SLM), or 20 kc/s, an essentially flat response.

Output: Output is at least 1 V behind 6000 Ω (panel meter at full scale). Any load can be connected across the output terminals.



Relay-rack model is adapted from portable model; see page 258.

Meter: Rms response and FAST and SLOW meter speeds in accordance with ASA S1.4-1961.

Internal Calibration: A built-in reference allows the gain of the analyzer to be calibrated for use with piezoelectric microphones having sensitivities from -52 to -62 dB re 1 V/ μ bar. The absolute accuracy for ALL PASS is then within 1 dB over a wide range of atmospheric conditions.

Batteries: Two 9.6-V rechargeable nickel-cadmium batteries give 30-h operation. They are recharged from a 25- to 60-cycle power line. Full charge takes about 14 h.

Accessories Supplied: Carrying strap, power cord for charging battery, shielded cable for connection to sound-level meter.

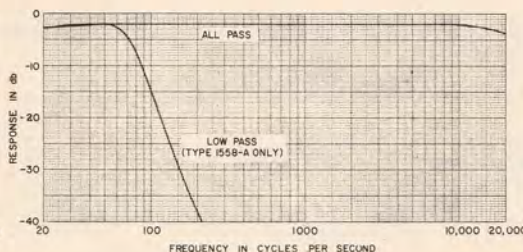
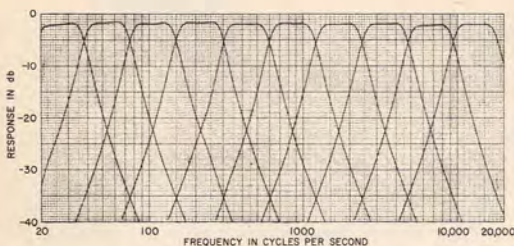
Accessories Available: TYPE 1560-P6 Microphone Assembly. TYPE 1560-P40K Preamplifier and Microphone Set. Power is available for the TYPE 1560-P40 Preamplifier at the MIKE connector.

Mechanical Data: Flip-Tilt Case (see page 258)

Model	Width		Height		Depth		Net Weight		Shipping Weight	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Portable	1 1/4	260	9 1/4	235	7 1/4	185	8 3/4	4	12	5.5
Rack	19	485	8 3/4	225	5*	130	9	4.1	22	10

* Behind panel

For a more detailed description, see *General Radio Experimenter*, October 1962.



(Left) Filter characteristics of the Type 1558-A. The Type 1558-AP characteristics are similar, except that the center frequencies are changed, as specified in the data above. (Right) Lowpass and allpass characteristics of the Type 1558.

Catalog Number	Description	Price
1558-9701	Type 1558-A Octave-Band Noise Analyzer (ASA Standard), Portable Model	\$815.00
1558-9820	Type 1558-A Octave-Band Noise Analyzer (ASA Standard), Rack Model	815.00
1558-9829	Type 1558-AP Octave-Band Noise Analyzer (ASA Preferred Frequencies), Portable Model	795.00
1558-9822	Type 1558-AP Octave-Band Noise Analyzer (ASA Preferred Frequencies), Rack Model	795.00
1560-9606	Type 1560-P6 Microphone Assembly	75.00
1560-9520	Type 1560-P40K Preamplifier and Microphone Set	251.00

PATENT NOTICE. See Notes 15 and 22, page 11.

Type 1556-B IMPACT-NOISE ANALYZER



This device evaluates the characteristics of impact-type sounds and electrical noise impulses, which cannot be satisfactorily measured with conventional noise-meters.

IMPACT NOISES

include those produced by punch presses, forging hammers, fire alarms, pile drivers, office machinery, and similar equipment. From the standpoint of hearing damage, some of these sounds constitute a serious problem for industry. They have hitherto been measurable only by complicated methods employing oscilloscopes.

The two characteristics of impact sounds that seem most significant are the peak amplitude and the duration, or decay time. This analyzer measures both of these quantities and also a quasi-peak value that is useful in determining the variation among repetitive peak values.

Peak value is the maximum sound-pressure level reached by the noise; quasi-peak is a continuously indicating measure of the high sound-pressure levels reached just before the time of indication; time-average is a measure of the average level over a predetermined period of time, which, when subtracted from peak level, is a measure of the time duration of the sound.

For these applications, the TYPE 1556-B Impact-Noise Analyzer operates from the output of a TYPE 1551 or TYPE 1565-A Sound-Level Meter and, when a vibra-

tion pickup is used in place of the microphone on the sound-level meter, will measure vibration impacts. It will also operate from octave-band analyzers, tape recorders, and vibration meters.

ELECTRICAL NOISE PEAKS

in a wire communication circuit can be measured with this instrument as one of the tests to determine the adequacy of the circuit for transmitting data pulses to and from computers and other business machines. In such measurements, many peaks may be measured in a short time, and, after each peak, the stored signal must be erased before the next pulse occurs. To facilitate this, to reduce operator fatigue, and to minimize acoustic noise from the switching process, a RESET pushbutton is provided, which can also be operated by an ordinary camera cable release.

CIRCUIT

A battery-operated, degenerative, transistor amplifier simultaneously drives three ac voltmeter circuits, which comprise rectifiers, storage capacitors, and a dc electronic voltmeter. The electrical storage system (a capacitor charged by a rectifier) makes it possible to measure three characteristics of an impulse — peak, quasi-peak, and time-average — with a single meter.

SPECIFICATIONS

Input: Any voltage from 1 to 10 V for normal range. Inputs below 1 V reduce the range of reading.

Input Impedance: Between 25,000 and 100,000 Ω , depending on the setting of the LEVEL control.

Frequency Range: 5 c/s to 20 kc/s.

Level Indication: Meter calibrated in dB from -10 to +10. Attenuator switch increases range by 10 dB.

Peak Reading: Rise time is less than 50 μ s for a value within 1 dB of peak value (for rectangular pulses). Storage time at normal room temperature is greater than 10 s for a 1-dB change in value.

Quasi-Peak Reading: Rise time of less than $\frac{1}{4}$ ms and decay time of 600 \pm 120 ms for rectifier circuit.

Time-Average Reading: Charge time of rectifier circuit selected by seven-position switch, having times of 0.002, 0.005, 0.01, 0.02, 0.05, 0.1, and 0.2 s for the resistance-capacitance time constant. Storage time at normal room temperature is greater than 1 min for a 1-dB change in value.

Input Terminals: Cord with phone plug at one end.

Batteries: One 1 $\frac{1}{2}$ -V size-D flashlight cell and one 45-V battery are supplied. Typical battery life is 100 hours.

Cabinet: Aluminum; carrying case supplied. Cabinet can be fastened directly to one end of a TYPE 1551 Sound-Level Meter.



The Type 1556-B Impact-Noise Analyzer attaches to the Type 1551-C Sound-Level Meter as shown here.

Mechanical Data: Aluminum Case

Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
7 $\frac{1}{2}$	190	6 $\frac{1}{2}$	170	4 $\frac{1}{2}$	110	4 $\frac{1}{2}$	2.1	12	5.5
Catalog No.		Description						Price	
1556-9702		Type 1556-B Impact-Noise Analyzer						\$240.00	



MEASURES BOTH ELECTRICAL AND ACOUSTICAL NOISE PEAKS

Type 1932-A DISTORTION AND NOISE METER



USES: The TYPE 1932-A Distortion and Noise Meter measures distortion, noise, and hum level in audio-frequency circuits.

It finds many uses in the electronics laboratory and in the production testing of radio receivers as a wide-range, highly sensitive voltmeter for such measurements as signal-to-noise ratio, AVC characteristics, and hum level. With the aid of an oscilloscope, individual hum and distortion components can be identified.

DESCRIPTION: The principal elements of the unit are a high-gain amplifier with an RC interstage coupling unit that balances to a sharp null, a calibrated attenuator for adjusting the sensitivity, and a vacuum-tube voltmeter. Degeneration maintains stability in amplifier gain and a flat transmission characteristic, except within an octave of the null frequency. The null frequency is continuously

variable. The null network eliminates the fundamental of the audio-frequency signal, leaving only the distortion products, which are indicated directly on the meter.

The null network is switched out of the circuit for noise and hum measurements, and the instrument then operates as a highly sensitive voltmeter. Two input circuits are provided: (1) a transformer for bridging a 600-ohm line; and (2) a direct connection to the 100,000-ohm gain control.

FEATURES:

- Continuous frequency adjustment over audio range.
- Quick frequency selection.
- Frequencies up to 55,000 c/s are passed by the amplifier circuits, so that distortion measurements can be made on fundamental frequencies up to 18,000 c/s.
- Distortion as low as 0.1% can be measured.

SPECIFICATIONS**RANGES OF MEASUREMENT**

Distortion: 0.3%, 1%, 3%, 10%, or 30%, full-scale.

Frequency: 50 to 18,000 c/s fundamental; with bridging-transformer input, harmonics up to 30 kc/s; with 100,000-Ω input, harmonics up to 55 kc/s.

Noise: 80 dB below reference calibration level, or 80 dB below an audio-frequency signal of zero dbm level, at maximum sensitivity.

ACCURACY

Distortion: ±5% of full scale ± residual distortion, where distortion is the ratio of harmonics + noise to total input signal.

Noise, dBm: ±5% of full scale for specified bandwidths.

Residual Distortion and Hum Level: 50 to 150 c/s, 0.07%; 150 to 5000 c/s, 0.02%; 5000 to 18,000 c/s, 0.10%.*

Residual Noise Level: At least 80 dB down.

INPUT

Impedance: 100,000 Ω, unbalanced, and 600-Ω bridging input (10,000 Ω), balanced or unbalanced.

GENERAL

Meter: Scale is calibrated in percentage and dB. The ballistic characteristic is similar to that of a VU meter.

* Can be reduced to 0.02% by use of low-level calibration techniques.

Terminals: Terminals are provided at the rear for permanent wiring connections. A Western Electric jack is provided at the panel also, as an auxiliary input circuit. Plugging into this jack automatically disconnects the rear connectors.

Power Required: 105 to 125 or 210 to 250 V, 50 to 60 c/s. The line input power is 65 W.

Accessories Supplied: TYPE CAP-22 Power Cord, spare fuses.

Accessories Required: For measuring the distortion in oscillators and other audio-frequency sources, no additional equipment is required. For measurements on amplifiers, lines, and other communications networks, a low-distortion oscillator is required. When the modulated output of a radio transmitter is to be measured, a linear demodulator having minimum undistorted output of 1.5 V, rms, can be used.

Mounting: Relay-rack panel. End frames are available for bench use. (See price list below.)

MECHANICAL DATA

Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
19	485	7	180	12†	305	35½	16.5	41	19

† Behind panel

Catalog No.	Description	Price
1932-9701	Type 1932-A Distortion and Noise Meter	\$850.00
5310-9478	Type FRI-412-2 Aluminum End Frames	15.00 Pair

FOR DISTORTION AND NOISE-LEVEL MEASUREMENTS ON AUDIO EQUIPMENT AND CIRCUITS





The two amplifiers listed in this section are broadband instruments, adaptable to a variety of applications encountered in the electronics laboratory. The Type 1206-B Unit Amplifier, with a 3-watt output, covers subaudio, audio, and ultrasonic frequencies. The Type 1233-A Power Amplifier, a 15-watt instrument, operates well up into the rf range.

Other amplifiers, with many applications in addition to those for which they are primarily designed, are listed in other sections of the catalog. Among them are:

TUNED AMPLIFIER: Type 1232-A Tuned Amplifier and Null Detector, page 104, is a selective amplifier, tunable continu-

ously from 20 c/s to 20 kc/s, and at 50 kc/s and 100 kc/s; it also has a broadband characteristic, 20 c/s to 100 kc/s.

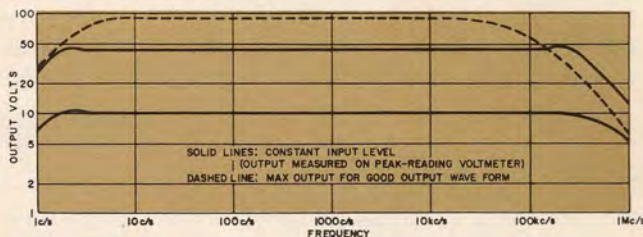
DC AMPLIFIER: Type 1230-A Electrometer, page 174, amplifies weak voltages and currents to operate a recorder.

HIGH-GAIN AMPLIFIER: Type 1551-C Sound-Level Meter, page 14, has a full-scale sensitivity of 20 microvolts and a range of 126 dB.

HIGH-POWER AUDIO AMPLIFIER: The amplifier portion of the Type 1308-A Audio Oscillator and Power Amplifier will produce from 20 to 200 watts from a 2-volt input. See page 137.

Type 1206-B UNIT AMPLIFIER

This well-designed, high-quality, compact amplifier delivers 3 watts at audio and ultrasonic frequencies. It has many uses in the laboratory — as a bridge amplifier, as a driver for low-power electronic and electro-acoustical devices, and as an amplifier for use with the TYPE 1210-C Unit R-C Oscillator. Single-ended, push-pull circuit produces excellent low-frequency response.



SPECIFICATIONS

INPUT

Voltage: Less than 1 V for full power output.

Impedance: 100,000 Ω in parallel with 35 pF.

OUTPUT

Power: With TYPE 1203 Unit Power Supply, 600- Ω load: 3 W from 10 c/s to 50 kc/s; 1.5 W from 5 c/s to 100 kc/s; 0.5 W at 250 kc/s.

Load Impedance: 600 Ω optimum. Blocking capacitor is 100 μ F. (Internal impedance about 100 Ω .)

Distortion: Less than 1% harmonic distortion with 2-W output (2% with 3 W) into 600 Ω from 20 c/s to 40 kc/s.

Ac Hum in Output: Less than 15 mV, rms, with TYPE 1203 Unit Power Supply; less than 3 mV, rms, with TYPE 1201 Unit Regulated Power Supply.

Voltage Gain: Continuously adjustable. Max gain is 50 to 1 (34 dB), with no load; 42.5 to 1 (32.6 dB) into 600 Ω .

Frequency Response: (See curve above.) Down less than 3 dB at 2 c/s and 500 kc/s at 10-V (or less) output, with gain control set at maximum. See also power output specification.

Pulse Response:	No Load	600 Ω
Droop in 30-cycle square wave	15%	20%
Approx rise time: 50 V, p-to-p	1 μ s	2 μ s
100 V, p-to-p	2 μ s	4 μ s
Max output, p-to-p magnitude	260 V	120 V

GENERAL

Power Required: TYPE 1203 Unit Power Supply or TYPE 1201 Unit Regulated Power Supply (page 215). Will operate satisfactorily from a 400-cycle supply.

Accessories Supplied: Two multipoint connectors.

Accessories Available: Relay-rack adaptor panel (7 in high).

MECHANICAL DATA Unit-Instrument Cabinet (see page 258)

	Width		Height		Depth		Net Weight		Shipping Weight	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
With Power Supply	15	380	5 3/4	145	6 1/4	160	9	4.1	11	5

See also *General Radio Experimenter*, November 1953.

Catalog Number	Description	Price
1206-9702	Type 1206-B Unit Amplifier	\$95.00
1203-9702	Type 1203-B Unit Power Supply (for 105-125 V line)	55.00
1203-9818	Type 1203-BQ18 Unit Power Supply (for 195-250 V line)	on request
0480-9986	Type 480-P4U3 Relay-Rack Adaptor Panel (for Amplifier and Power Supply)	12.00

PATENT NOTICE. See Notes 5, 9, and 14, page 11.



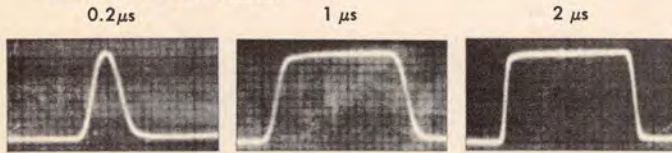
Amplifier plugs into the Unit Power Supply. Units lock together to form a rigid assembly.



Type 1233-A POWER AMPLIFIER

USES: The wide frequency range and high power output of this amplifier make it adaptable to many uses in electronic and electro-acoustical laboratories. Typical uses are:

- Exciting antennas for radiation-pattern and impedance measurements.



Output pulse waveforms 20-cycle to 3-Mc range; input-pulse rise time, 0.03 μ s; three pulse lengths shown.

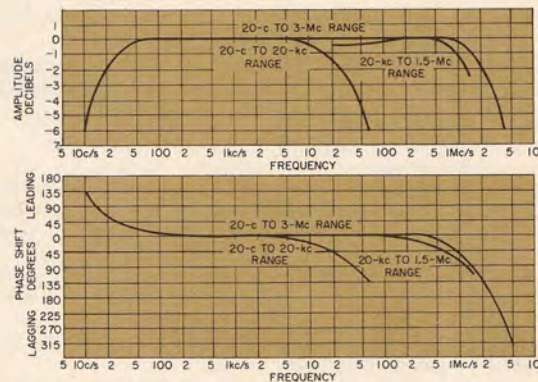
- Driving acoustic generators.
- Amplifying received signals for operating remote modulation and frequency monitors.
- Amplifying weak signals for oscilloscope deflection.

DESCRIPTION: The excellent frequency response of this amplifier is obtained in three push-pull, broadband circuits with series-peaked interstage couplings. The two power ranges use toroidal output transformers; the voltage-amplification range uses a series-peaked video-output network with gradual roll-off above 3 Mc/s. Ranges are selected by panel switch. Meter reads output volts and can be switched to read plate current of output tubes.

SPECIFICATIONS

- Input Voltage:** Less than 0.2 V for full output.
- Input Impedance:** 100,000 Ω in parallel with 37 pF (grounded).
- Power Required:** 105 to 125 or 210 to 250 V, 40 to 60 c/s; 120 W at zero output; 140 W max. On 400-cycle supply, max output is 10 W.
- Voltmeter:** Full-wave-average type; 150, 50, and 15 V, full scale; accuracy $\pm 10\%$, compensated to 3 Mc/s.
- Terminals:** Input and output, TYPE 874 Coaxial Connectors with ground post for double-plug connection; TYPE 938 Binding Posts for balanced output. For adaptors to other coaxial types, see page 81.
- Accessories Supplied:** Two TYPE 274-MB Double Plugs, TYPE CAP-22 Power Cord, spare fuses.
- Mechanical Data:** Relay-Rack Panel with end frames for bench use.

Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
19½	495	7½	190	15½	395	46½	21.5	56	26



(Above) Typical response curves. The smooth roll-off at the high end ensures good transient response. (Below) Phase shift versus frequency for Type 1233-A Power Amplifier.

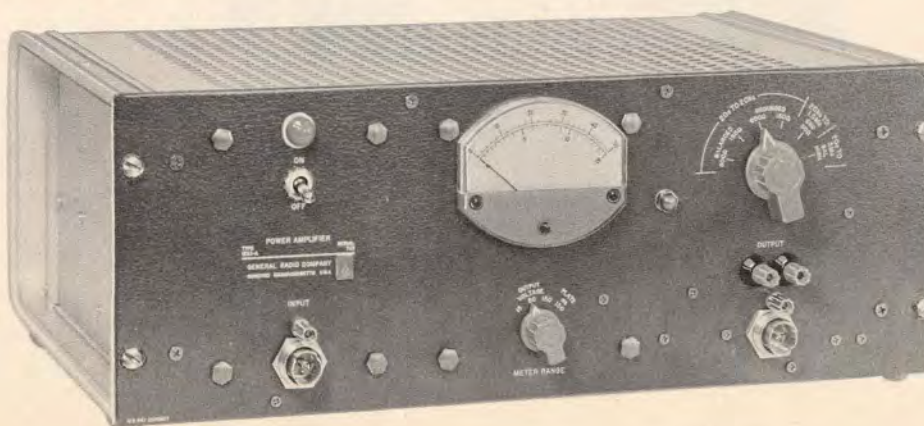
Range Switch Position	Operating Freq Range	Power*	Output Voltage	Optimum Load Impedance	Rise Time	Distortion at Rated Output	Noise Level
20 c/s to 20 kc/s	20 c/s — 20 kc/s 50 c/s — 15 kc/s	8 W 15 W		600 or 150 Ω		4%	60 dB below 15 W or equivalent to 200 μ V input.
20 kc/s to 1.5 Mc/s	20 kc/s — 1.5 Mc/s 20 kc/s — 0.5 Mc/s	8 W 15 W		50 Ω grounded		4%	70 dB below 15 W or equivalent to 63 μ V input.
20 c/s to 3 Mc/s	20 c/s — 3 Mc/s		150 V, p-to-p, bal; 50 V grounded	CRO deflection plates; 1 M Ω , 36-in leads	0.1 μ s	4%	Less than 0.6 V, p-to-p, bal, or equivalent to 600 μ V p-to-p input.

Disconnected Any single frequency, 20 c/s to 5 Mc/s; 15 W, with external tuned output transformer

* Rated output is obtainable at 105-V line; output is greater for higher line voltages.

Catalog Number	Description	Price
1233-9701	Type 1233-A Power Amplifier	\$690.00

PATENT NOTICE. See Notes 4 and 15, page 11.



20 c/s TO 3 Mc/s



ATTENUATORS

Calibrated attenuators are basic instruments for measurement of voltage ratios, linearity, circuit gain or loss, transmission efficiency, and for the calibration of meters and other measuring devices. Described in this section are

resistive decade attenuators, precise voltage dividers, and an audio-frequency Microvoltage* for use with an audio oscillator to standardize low output voltages.

*Trademark registered in U.S.A.

Type 546-C AUDIO-FREQUENCY MICROVOLTER*

FEATURES:

- Converts an audio oscillator to an audio signal generator.
- An excellent frequency characteristic — up to 100 kc/s.
- Excellent accuracy for absolute voltage levels as well as for voltage ratios.
- Decibel and voltage scales.

DESCRIPTION: This instrument consists, essentially, of a constant-impedance attenuator and a voltmeter that standardizes the input to the attenuator. A switch controls the output voltage in decade steps, while an individually calibrated dial provides continuous control over each decade.

USE: The TYPE 546-C Audio-Frequency Microvoltage used in conjunction with an oscillator is a useful source of small, known, audio-frequency voltages for response measurements of amplifiers, transformers, and other audio equipment. The Microvoltage can also be used to measure small voltages by substitution methods.

SPECIFICATIONS

Output-Voltage Range: From 0.5 μ V to 1.0 V open circuit, when the input voltage is set to the reference value (2.2 V).

Accuracy: Open-circuit output voltage, $\pm(3\% + 0.5 \mu$ V) for output settings above 1 μ V and for frequencies between 20 and 20,000 c/s. For frequencies up to 100 kc/s, $\pm 5\%$ for output settings above 100 μ V. These specifications apply only where waveform and temperature errors are negligible.

Ratios of output voltage at a given frequency, $\pm(2\% + 0.5 \mu$ V) up to 100 kc/s. Above 20 kc/s this accuracy applies only at levels above 100 μ V.

The Microvoltage can be used on dc with an external dc meter. Internal meter can be calibrated for dc.

Output Impedance: Approximately 600 Ω , constant with setting within $\pm 5\%$. No correction of the output voltage is necessary for load impedances of the order of 100,000 Ω and greater.

Input Impedance: Approximately 600 Ω , substantially independent of output setting on all but the highest multiplier position.

Waveform Error: When this instrument is used as a calibrated attenuator or voltage divider, accuracy is independent of waveform. Absolute accuracy of output-voltage calibration depends on the characteristics of the input copper-oxide rectifier voltmeter, which has a small waveform error that can usually be neglected when the Microvoltage is used with ordinary laboratory oscillators. The rectifier-type voltmeter introduces some distortion unless source impedance is very low. With a 600- Ω source, distortion introduced is about 0.2%.



The Microvoltage with the Type 1210-C Unit R-C Oscillator.

Temperature Error: Ratios are independent of temperature. Absolute accuracy is affected slightly by temperature because of change in the voltmeter characteristics. Correction for temperatures from 65 to 95°F is furnished. The effects of humidity are negligible.

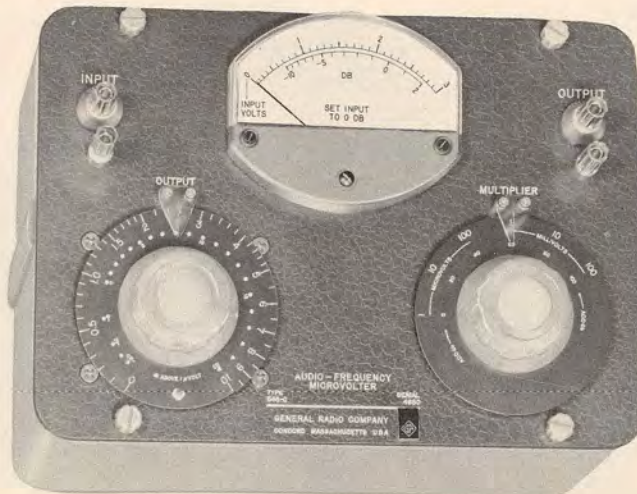
Input Requirements: 2.2 V across 600 Ω , or 8 mW.

Mechanical Data: Lab-Bench Cabinet (see page 258)

Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
10	255	7¼	185	6¼	160	6½	3	13	6

Catalog Number	Description	Price
0546-9703	Type 546-C Audio-Frequency Microvoltage*	\$195.00

PATENT NOTICE. See Note 15, page 11.





Type 1450 DECADE ATTENUATOR — 0-110 dB

FEATURES:

Wide range of attenuation values in small steps.
 Accuracy is maintained even at low radio frequencies.
 Convenient, decade-type switches are arranged for break-before-make operation to prevent "blasting" and meter damage. They can be adjusted for make-before-break operation if requested at time of ordering.

USES: The TYPE 1450 Decade Attenuator provides accurate steps of attenuation for power-level measurements, transmission-efficiency tests, and gain or loss measurements on transistors, filters, amplifiers, and similar equipment. It can also be used as a power-level control in circuits not equipped with other volume controls.

DESCRIPTION: The resistors used in each decade are mounted in compartments in an aluminum housing, which is completely shielded by the addition of alumi-

num covers. Each decade consists of four T-pads series-connected by cam-operated switches, arranged with positive detents. All cams are mounted on a control shaft, which is provided with ball bearings. Each pad is completely shielded, and a shield is interposed between the input and output series elements of each pad. Each decade has eleven positions, 0 to 10 inclusive, so the decades overlap. There are no stops on the 0.1- and 1-dB-per-step decades, so that quick return from full to zero attenuation is facilitated.

SPECIFICATIONS

Attenuation Range: 110 or 111 dB in steps of 1 or 0.1 dB, respectively.

Terminal Impedance: 600 Ω in either direction. An etched plate indicates the mismatch loss for other than 600-Ω circuits.

Accuracy: Each individual resistor is adjusted within ±0.25% of its correct value. The low-frequency error in attenuation is less than ±0.02 dB ± 0.25% of indicated dB setting plus a switch-resistance error of 0.003 dB (for -TA) or 0.005 dB (for -TB), when attenuator is terminated at both ends in a pure resistance of 600 Ω. For differences in attenuation between any two settings, switch-resistance error virtually disappears. To maintain accuracy at high attenuations, special wiring methods are employed to the "low" INPUT post.

Frequency Discrimination (with low terminal at panel potential): Less than 0.1 dB ± 1% of the indicated value at frequencies below 200 kc/s. For increments in attenuation, the 1% tolerance extends to approximately 1 Mc/s.

Maximum Input Power: 1 W.

Switches: Cam-type switches are used with twelve positions covering 360°. Dials are numbered from 0 to 10 inclusive, and the twelfth point is also connected to 0. Stops are provided in the switch mechanism for the 100-dB decade. No stops are provided to prevent complete rotation of the 10- and 1-dB decades, but

spacers, which are provided, can be used under the mounting screws to act as stops for the knob, if desired.

Characteristic Impedance: 600 Ω both directions. One end must be terminated in 600 Ω.

Terminals: Low-thermal-emf jack-top binding posts with 3/4-inch spacing; common terminal insulated from chassis; ground terminal provided.

Shielding: Each decade is individually shielded, and all shields are connected to the panel, to which the "G" post is also connected. Terminals are insulated from panel, the "low" ones being connected together. The user is thus given free choice of grounding point for the "low" side, including connection to the panel post by the link provided.

Mechanical Data: Lab-Bench Cabinet (see page 258)

	Width		Height		Depth		Net Weight		Shipping Weight	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
-TA	10	255	5 3/4	145	12 1/4	315	10 3/4	4.9	17	8
-TB	12	305	5 3/4	145	12 1/4	315	14 1/2	7	20	9.5
-TAR	19	495	5 3/4	145	12 1/4	315	12	5.5	22 1/2	10.5
-TBR	19	495	5 3/4	145	12 1/4	315	15 1/2	7.5	26	12

Catalog Number	Description	dB Attenuation		Price
		Max	Per Step	
1450-9891	Type 1450-TA Decade Attenuator, Bench Model	110	1	\$285.00
1450-9894	Type 1450-TAR Decade Attenuator, Rack Model	110	1	295.00
1450-9893	Type 1450-TB Decade Attenuator, Bench Model	111	0.1	390.00
1450-9895	Type 1450-TBR Decade Attenuator, Rack Model	111	0.1	400.00



Type 1450-TB



Type 1450-TA



Type 1454 DECADE VOLTAGE DIVIDER

FEATURES:

- Two models, 10,000 ohms and 100,000 ohms. ■ Constant input resistance.
- Linearity, 0.005% of full scale.
- High accuracy, 0.04% of indicated ratio.
- Low-thermal-emf binding posts. ■ Complete shielding.

USES: The TYPE 1454 Decade Voltage Divider provides accurately known voltage ratios from 0.0001 to 1.0000 for use in determining voltage transmission ratios by direct comparison or by null methods, in linearity measurements and in meter calibration.

Its high input impedance, high resolution, and high accuracy make it a widely used laboratory accessory for dc and audio-frequency measurements.

DESCRIPTION: Four decade resistors of the 510-type are connected in a Kelvin-Varley circuit. The voltage drop in switches and wiring is compensated by a resistor so that accuracy is maintained down to the lowest settings. The case provides an electrostatic shield, to which the separate ground terminal is connected. The divider circuit can be used either grounded or floating, as desired.

SPECIFICATIONS

Voltage Ratio: 0.0001 to 1.0000 in steps of 0.0001.

Linearity: $\pm 0.005\%$ of full scale at dc and low-audio frequencies for input voltages below one-half of maximum rating (see below).

Accuracy: $\pm 0.04\%$ of indicated ratio $\pm 4 \times 10^{-8}$ of full scale for input voltage below one-half of maximum rating (see below). With low terminals common, there is an additional $\pm 2 \times 10^{-7}$ of full scale error.

Frequency Characteristics: If the external capacitance across the output terminals of the TYPE 1454-A is less than 50 pF, the frequency error is less than 0.1% to 20 kc/s for any setting. For the TYPE 1454-AH, the limit is 2 kc/s for the same capacitance.

Input Resistance: TYPE 1454-A, 10,000 Ω . TYPE 1454-AH, 100,000 Ω .

Maximum Input Voltage: For TYPE 1454-A, 230 V, rms (or dc), for 40°C rise of resistors of the input decade. Input voltage should be limited to 120 for maximum accuracy. At maximum rated voltage the total error can approach $\pm 0.1\%$. For TYPE 1454-AH, 700 V, rms, limited to 350 V for maximum accuracy.

Resistance Units: TYPE 510 Decade Resistors.

Temperature Coefficient: Of each resistor, less than $\pm 0.002\%$ per degree C. Since the voltage ratios are determined by resistors of

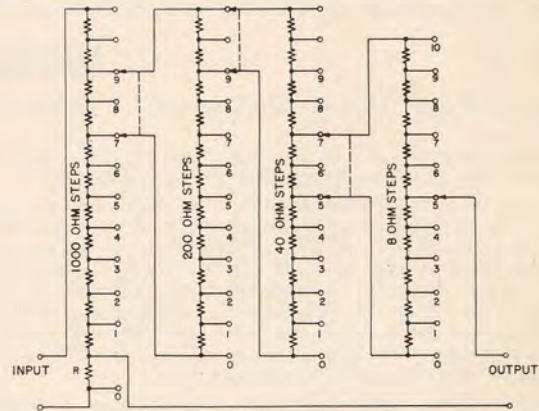


TABLE I

	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0	0	189	356	501	624	725	804	861	896	909
0.1	900	1069	1216	1341	1444	1525	1584	1621	1636	1629
0.2	1600	1749	1876	1981	2064	2125	2164	2181	2176	2149
0.3	2100	2229	2336	2421	2484	2525	2544	2541	2516	2469
0.4	2400	2509	2596	2661	2704	2725	2724	2701	2656	2589
0.5	2500	2589	2656	2701	2724	2725	2704	2661	2596	2509
0.6	2400	2469	2516	2541	2544	2525	2484	2421	2336	2229
0.7	2100	2149	2176	2181	2164	2125	2064	1981	1876	1749
0.8	1600	1629	1636	1621	1584	1525	1444	1341	1216	1069
0.9	900	909	896	861	804	725	624	501	356	189

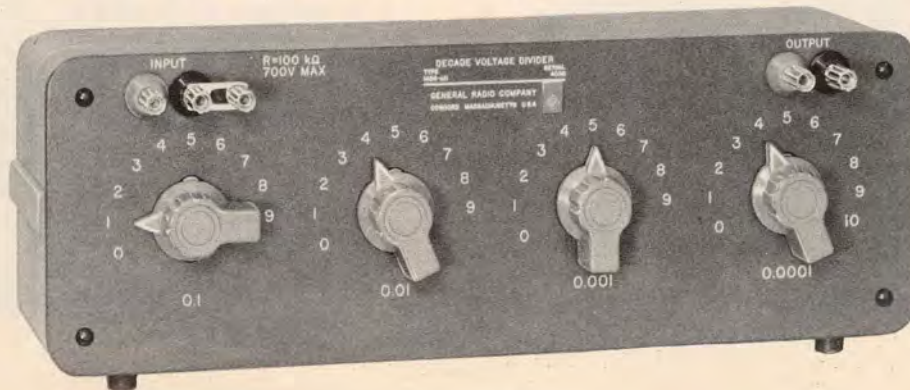
similar construction, ambient temperature effects are very small.

Output Resistance: Varies with output setting, from zero to approximately 2700 Ω for the TYPE 1454-A, from zero to approximately 27,000 Ω for the TYPE 1454-AH, depending primarily on the setting of the highest decade in use. Directions for accurate calculation of the output resistance are given in the instruction manual. Approximate values can be determined by interpolation from the figures in the table at the left, which apply to the 10,000- Ω model; for the 100,000- Ω model, multiply the values by 10.

Mechanical Data: Lab-Bench Cabinet (see page 258)

Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
15 3/4	400	5	130	5 1/2	135	7 1/4	3.3	9	4.1

Catalog Number	Description	Price
1454-9701	Type 1454-A Decade Voltage Divider (10,000 ohms)	\$160.00
1454-9817	Type 1454-AH Decade Voltage Divider (100,000 ohms)	160.00





IMPEDANCE MEASUREMENT



Null methods have long been recognized as the most precise and convenient way to measure all types of impedance — resistive and reactive, inductive and capacitive, from low frequencies to uhf. Most null-type instruments evolved from the century-old Wheatstone Bridge, still the fundamental circuit for measuring dc resistance. Other null circuits, such as the admittance meter and transfer-function bridge, have been developed by General Radio to meet the diverse requirements of modern measurement. In all, GR produces 19 bridges, covering virtually the entire field of impedance measurement. Some of these bridges include built-in generator and detector and are thus complete, self-contained measurement systems. Others are available in combination with various General Radio oscillators and detectors, as complete assemblies.

DC BRIDGES

The Wheatstone bridge measures an unknown resistance, R_X , in terms of calibrated standards of resistance connected as shown in Figure 1. The relation is:

$$R_X = \frac{R_N R_B}{R_A} \quad (1)$$

which is satisfied when the voltage across the detector terminals is zero.

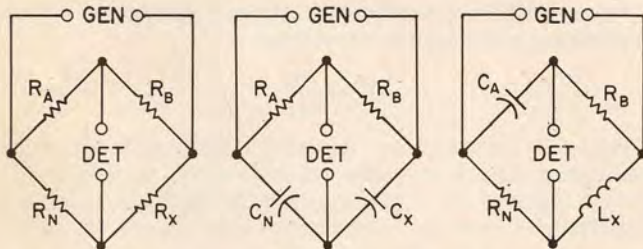


Figure 1. The general Wheatstone bridge circuit. Figures 2 and 3. Circuits for capacitance bridges in which like reactances (left) or unlike reactances (right) are compared.

AC BRIDGES

The Wheatstone bridge circuit is easily adapted to ac measurement. With complex impedances, two balance conditions must be satisfied, one for the resistive component and one for the reactive component. At balance:

$$Z_X = R_X + jX_X = Z_N Y_A Z_B \quad (2)$$

$$\text{or } Y_X = G_X + jB_X = Y_N Z_A Y_B \quad (3)$$

Equation (2) expresses the unknown in terms of impedance components; equation (3) expresses the unknown as an admittance. To satisfy these equations, at least one of the three arms A, B, or N must be complex.

The reactance X_X can be measured in terms of a similar reactance in an adjacent arm (Figure 2) or an unlike reactance in the opposite arm (Figure 3).

The complex arm required to satisfy the balance conditions of equation (2) or (3) is a combination of a resistance and a reactance, in series or in parallel. With a *series* combination in an arm *adjacent* to the unknown or a *parallel* combination in the arm *opposite* the unknown, the bridge measures the equivalent series components of the unknown. Conversely, an adjacent parallel or an opposite series combination will yield a measurement of equivalent parallel components. (Every impedance can be expressed in terms of either series or parallel equivalents, as discussed below.) Examples of various combinations as used in the Type 1608-A Impedance Bridge are shown on page 49.

If both components of this complex arm are adjustable, the balances for the real and imaginary parts of the unknown will be independent of each other and orthogonal. If only one component of the combination is adjustable, this component will be proportional to either the *D* or the *Q* of the unknown impedance. If the adjustable component is the more prominent of the two, as it is when very low-*Q* inductors are measured, the balance convergence is slow, if not impossible. The general-purpose Type 1650-A Impedance Bridge uses a mechanical ganging of the bridge controls (called ORTHO-NULL®) to facilitate convergence.

D AND Q

An important characteristic of an inductor or a capacitor, and often of a resistor, is the ratio of resistance to reactance or of conductance to susceptance. The ratio is called dissipation factor, *D*, and its reciprocal is storage factor, *Q*. These terms are defined in Figure 4 in terms of phase angle θ and loss angle δ . Dissipation factor is directly proportional to energy dissipated, and storage factor to energy stored, per cycle. Power factor ($\cos \theta$ or $\sin \delta$) differs from dissipation factor by less than 1% when their magnitudes are less than 0.1.

In Figure 4, *R* and *X* are series resistance and reactance, and *G* and *B* are parallel conductance and susceptance, of the impedance or admittance involved.

Dissipation factor, *D*, which varies directly with power loss, is commonly used for capacitors. Storage factor, *Q*, is more often used for inductors because it is a measure of the voltage

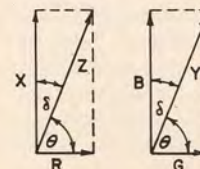


Figure 4. Vector diagram showing the relations between factors *D* and *Q*, and angles θ and δ .

$$D = \cot \theta = \frac{R}{X} = \frac{G}{B} = \frac{1}{Q} = \tan \delta$$

$$\text{Power Factor} = \cos \theta = \frac{R}{Z}$$

$$Q = \tan \theta = \frac{X}{R} = \frac{B}{G} = \frac{1}{D} = \cot \delta$$

IMPEDANCE MEASUREMENT

step-up in a tuned circuit. Q is also used for resistors, in which case it is usually very small.

Most General Radio capacitance and inductance bridges also measure D or Q .

Series and Parallel Components

Many GR impedance bridges give the user the option of measuring the unknown in terms of either its series or parallel equivalents. The choice is a matter of convenience for the problem at hand. Since the distinction between series and parallel equivalents is sometimes overlooked in texts, we will briefly summarize the relationships here.

Regardless of physical configuration, every impedance can be expressed, for any given frequency, as either a series or a parallel combination of resistance and reactance, as shown in Figure 5. The relations between the elements of Figure 5 are:

$$R_P = \frac{1}{G_P} = \frac{R_S^2 + X_S^2}{R_S} = R_S(1 + Q^2)$$

$$X_P = \frac{1}{B_P} = \frac{R_S^2 + X_S^2}{X_S} = X_S(1 + D^2)$$

In terms of series and parallel capacitive and inductive reactances, these relations become:

$$C_P = C_S \left(\frac{1}{1 + D^2} \right)$$

$$C_S = C_P (1 + D^2)$$

$$L_P = L_S \left(1 + \frac{1}{Q^2} \right)$$

$$L_S = L_P \left(\frac{Q^2}{1 + Q^2} \right)$$

Where:

$$Q = \frac{X_S}{R_S} = \frac{R_P}{X_P} = \frac{B_P}{G_P} = \frac{\omega L_S}{R_S} = \frac{R_P}{\omega L_P} = \frac{1}{D}$$

and

$$D = \frac{1}{Q} = \frac{R_S}{X_S} = \frac{X_P}{R_P} = \frac{G_P}{B_P} = \frac{\omega R_S C_S}{1} = \frac{1}{\omega R_P C_P} = \frac{1}{Q}$$

If Q is 10 or more (or if D is 0.1 or less), the difference between series and parallel reactance is no more than 1%. For very low Q 's or high D 's, however, the difference is substantial: when $Q = 1$, X_P is twice X_S . If there were no losses in the reactive elements (i.e., $D = 0$), X_S and X_P would be equal.

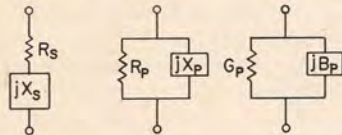
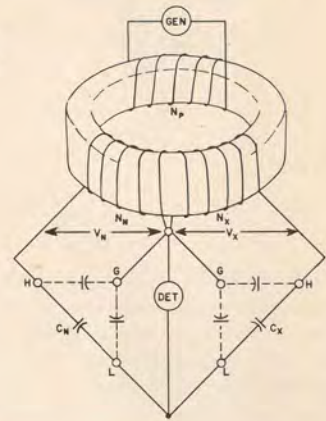


Figure 5. Series and parallel components of impedance.

Substitution Methods

In many ac bridges, the unknown is connected in series or in parallel with the main adjustable component, and balances are made before and after the unknown is connected. The magnitude of the unknown then equals the change made in the adjustable component, since the total impedance of the unknown arm remains constant. The chief advantage of this substitution technique is that its accuracy depends only on the calibration of the adjustable arm and not on the other bridge arms (as long as they are constant). The substitution

Figure 6. A capacitance bridge with transformer ratio arms.



principle can also be used to advantage with any bridge if the balances are made with an external, calibrated, adjustable component.

BRIDGES WITH ACTIVE ELEMENTS

If a potentiometer-amplifier combination is connected as a bridge element, fixed capacitance and conductance standards can be used, with current adjusted by variation of voltage rather than of impedance magnitude. The principle is used in the Type 1633-A Incremental-Inductance Bridge, which can accurately measure nonlinear elements.

THE TRANSFORMER RATIO-ARM BRIDGE

Transformer ratio arms, introduced almost a century ago, have recently come into considerable favor because of certain outstanding advantages. Ratio accuracies of a few parts per million are possible, even for transformer ratios of up to 1000 to 1, and the ratio is virtually unaffected by age, temperature, and voltage.

Figure 6 shows a transformer bridge in elementary form. The balance condition for capacitance is

$$\frac{C_X}{C_N} = \frac{N_N}{N_X}$$

Figure 6 also explains the exceptional ability of the transformer bridge to make three-terminal measurements without the use of a guard circuit or auxiliary balance. Capacitances from the H terminals appear across the low-impedance transformer winding, while those from the L terminals are across the detector, where they do not enter the balance expression. These capacitances are thus excluded from the measurement of direct capacitance, C_X , between H and L terminals. Because this type of bridge can tolerate relatively large capacitances from both sides of the unknown to the guard point, long cables with guard shields can be used for remote measurement, and circuit capacitances can often be measured *in situ*.

Conventional bridges can also be adapted for three-terminal measurements (although they generally cannot tolerate as low an impedance to guard). On the Types 1650-A and 1608-A Impedance Bridges, any stray capacitance is in parallel with a standard capacitor of at least $0.1 \mu\text{F}$ and usually has negligible effect. A Wagner-type guard circuit (Type 716-P4) is available for use with the Type 716-C Capacitance Bridge. On the Type 1650-A Impedance Comparator an electronic amplifier provides a guard point.

LIMIT BRIDGES AND COMPARATORS

In limit bridges, the unbalance voltage of the bridge actuates a meter, which indicates the degree of deviation of one impedance from another. The Type 1652-A Resistance Limit Bridge, which includes an adjustable standard resistor, can limit-test resistors over a wide range. The Type 1605-A Impedance Comparator indicates the magnitude and phase differences between the unknown and an external standard. On this instrument, the availability of several sensitive ranges enables the user to measure small differences very accurately. For instance, the nominal $\pm 3\%$ accuracy of the comparator is translated into an actual measurement accuracy of $\pm 0.009\%$ on the $\pm 0.3\%$ full-scale range if suitable standards are used.

THE AUTOMATIC BRIDGE

The ultimate in convenience is a bridge that balances itself. The Type 1680-A Automatic Capacitance Bridge, introduced in this catalog, fully automates the balance procedure — selecting range, balancing, and indicating both capacitance and loss in digital in-line form.

The implications of such automatic measurement are far-reaching. The conversion of bridge-measured data into digital and binary-coded form (the Type 1680-A has a binary-coded decimal output) gives the bridge access to the whole modern arsenal of data-processing equipment — printers, tape-punchers, sorters, etc. Speed is one obvious byproduct of automatic equipment: GR's new automatic bridge takes about one-half second to achieve balance.

COAXIAL-LINE INSTRUMENTS

The Slotted Line

The upper-frequency limit of conventional bridge circuits using lumped-parameter elements depends on the magnitude of the residual impedances of the elements and leads. The corrections for these usually become unmanageable at frequencies above a few hundred megacycles, and circuits based on coaxial-line techniques are more satisfactory.

One of the basic methods of measuring the impedance of a coaxial device is the measurement of the standing-wave ratio it introduces in a uniform line. The measurement is best made by a slotted line, an instrument consisting of a length of coaxial air line with a longitudinal slot in its outer conductor and an electrostatic probe, which enters the line through the slot. The probe is moved along the length of the line, sampling the field inside. Thus are the magnitudes and positions of voltage maxima and minima determined and, from this information, the impedance of an unknown connected to the line. In this instrument the impedance standard is the line itself, and its accuracy depends primarily on its physical dimensions.

General Radio offers two slotted lines: the Type 874-LBA, for general impedance measurements, and the highly accurate Type 900-LB, the most advanced slotted line available commercially.

The Admittance Meter

The Type 1602-B UHF Admittance Meter uses adjustable loops to sample the currents flowing in three coaxial lines fed from a common source and terminated, respectively, in the unknown, a standard conductance, and a standard susceptance. The loops are adjusted so that the combined output from them is zero (a null balance). Scales associated with

the three loops give the value of the unknown directly, in terms of admittance.

The Transfer-Function and Imittance Bridge

The Type 1607-A Transfer-Function and Imittance Bridge is similar to the Admittance Meter described above but also permits four-terminal measurements, such as those of forward and reverse transconductance and transsusceptance, transimpedance, and input-output voltage and current ratios. This bridge is widely used to evaluate the transfer characteristics of transistors and tubes in the vhf and uhf ranges.

GENERATORS AND DETECTORS

Several GR bridges include both generator and detector. Some others — the Types 1615-A, 716-C, and 716-CS1 Capacitance Bridges and the Types 1632 and 1633 Inductance Bridges — are available as complete measuring assemblies, with generator, detector, interconnecting cables, relay rack, and other accessories. Unless one obtains such a complete system, he must carefully choose generator and detector to ensure satisfactory measurement results. (Even with a complete system, the user may at times wish to connect a different generator or detector to the bridge, and almost all GR bridges include panel connectors for such use.)

The chief generator requirements are good frequency stability, adequate power output, and low harmonic content. A wide choice of GR oscillators is available (see pages 128 to 159), covering the frequency range from audio to microwave.

Desirable detector characteristics are

- (1) High sensitivity, preferably the ability to detect a few microvolts.
- (2) High selectivity, to reject harmonics, noise, and other interfering signals. This is particularly important in measurements on iron-core coils and other nonlinear elements.
- (3) Logarithmic or nearly logarithmic response, to minimize gain adjustment during the balancing procedure.
- (4) Good shielding, to prevent errors from extraneous pickup.

At audio frequencies, GR's Type 1232-A Tuned Amplifier and Null Detector is recommended for its high sensitivity and for its general versatility in the lab. The Type 1212-A Unit Null Detector is useful up to several megacycles. Crystal mixers are available for both the detectors, extending their frequency ranges to about 60 Mc/s. At these and higher frequencies, the heterodyne type of detector is preferred, because of its wide frequency range and excellent shielding. Type DNT detectors (see pages 108 and 109) operate from 70 kc/s to 2000 Mc/s.

One of the most popular generator-detector combinations, the Type 1311-A Audio Oscillator (50 c/s to 10 kc/s) with the Type 1232-A Tuned Amplifier and Null Detector, is now available in a single assembly as the Type 1240-A Generator-Detector Assembly (see page 106).

CONNECTIONS — SHIELDING

Adequate ground connection and shielded generator and detector leads are always important, but they are particularly so at high frequencies. At audio and low radio frequencies, electrostatic shielding of leads is usually enough; above a few megacycles, coaxial leads, securely grounded to the detector, generator, and bridge shields, are necessary. GR's patch cords and cables (see pages 85 and 257) are recommended for bridge connections.



Type	Description	Ranges	Nominal Accuracy	Frequency
CRL BRIDGES (for measurement of electrical components)				
1650-A (page 50)	Battery operated, portable, with built-in generator and detector.	C 1 pF-1000μF R 1mΩ-1MΩ L 1μH-1000H also D & Q	±1% ±1% ±1% ±5%	dc, 1kc/s (20c/s - 20kc/s with external gen- erator)
1608-A (page 48)	For precise, accurate component selection, lab measurements; built-in generator and detector.	C 0.05pF-1100μF R 0.05mΩ-1.1MΩ L 0.05μH-1100H G 0.05nΩ-1.1Ω also D & Q	±0.1% ±0.1% ±0.1% ±0.1% ±5%, ±2%	dc, 1kc/s (20c/s - 20kc/s with external gen- erator)
IMPEDANCE BRIDGES				
1603-A (page 45)	Audio frequency. Balances for any Z, from 0 to ∞.	R, X 0-1000Ω G, B 0-1000μΩ	±1% ±1%	20c/s - 20kc/s
916-AL (page 53)	Measure antennas, lines, components at radio frequencies.	X ±11kΩ at 100kc/s R 0-1000Ω	±2% ±1%	50kc/s - 5Mc/s
1606-A (page 52)		X ±5000Ω at 1 Mc/s R 0-1000Ω	±2% ±1%	0.4 - 60Mc/s
1605-A (page 46)	For rapid sorting and matching. Meter indicates deviation. Operates from power line.	ΔZ ±0.01% to ±10% Δθ ±0.001 to ±0.1 radian	±3% of reading (±0.01% on most sensitive ranges)	0.1, 1, 10, 100kc/s
CAPACITANCE BRIDGES				
716-C (page 60)	Wide frequency range.	C 100pF-1μF, Direct C 100-1000pF, Direct C 0.1-1000pF, Subst D 0.00002-0.56	±0.1% ±0.1% ±0.05% ±2%	1kc/s 30c/s-300kc/s 30c/s-300kc/s 30c/s-300kc/s
716-CS1 (page 61)	1-Mc version of Type 716-C	C 0.1-1100pF D 0.00002-0.56	±0.1% ±2%	0.5 - 3Mc/s
1615-A (page 58)	High accuracy. Intercomparison accuracy, 1 ppm.	C 10 ⁻¹⁷ - 10 ⁻⁶ F D 10 ⁻⁶ - 1 G 10 ⁻⁶ - 100μΩ	±0.01% ±0.1% ±1%	50c/s-10kc/s
1611-B (1611-BQ1) (page 67)	Power-line frequency, for testing insulators, bushings, cables, polarized electrolytic capacitors.	C 0-11,000μF D 0-60% (50%)	±1% ±2%	60 (or 50), 120c/s with ex- ternal generator
1680-A (page 63)	Automatic balancing: with generator, digital readout, and BCD data output. Ac-line operated.	C 0.01pF-100μF C 100pF-1000μF D 0.0001-1.0 G 0.1nΩ-1.0Ω	±0.1% ±0.1% ±1% ±0.1%	400, 1000c/s 120c/s
INDUCTANCE BRIDGES				
1632-A (page 68)	High precision. 6-figure resolution for inter-comparison of standard inductors.	L 0.001μH-1111H G 0.01μΩ-1111Ω	±0.1% ±1%	20c/s-1kc/s (to 10kc/s with re- duced accuracy)
1633-A (page 70)	Incremental inductance. For measurement of iron-core coils at high excitation levels. Includes detector.	L 0.2μH-1000H R 10mΩ-1MΩ Q 1-∞	±1% ±2% ±2%	direct-reading at 9 frequencies, 50c/s-15.75kc/s
DC RESISTANCE BRIDGES (see also TYPES 1650-A and 1608-A above and TYPE 1230-A Electrometer, page 174.)				
1652-A (page 73)	Limit bridge for production-line or laboratory; operates from ac line.	R 1Ω-1MΩ	±0.5% as limit bridge, ±0.25% by null method	dc
1644-A (page 74)	High resistance. Internal test voltages 10-1000 V in 1-2-5 steps. Ac-line operated.	R 10 ³ - 10 ¹⁵ Ω	±1%	dc
1862-C (page 75)	Megohmmeter (Not a bridge)	0.5 × 10 ⁶ - 2 × 10 ¹² Ω	±3% to ±12%	dc
VHF, UHF BRIDGES AND SLOTTED LINES				
1602-B (page 54)	For X, Y, and VSWR measurements on coaxial lines, antennas, networks, components.	B, G 0.01mΩ-0.01Ω X, R 0.1Ω-0.1MΩ	±3%	20-1500Mc/s
1607-A (page 56)	Transfer-function bridge for 4-terminal measurements on transistors, tubes, and networks. Also 2-terminal measurements.	B, G 0-400mΩ X, R 0-1000Ω Also Z ₂₁ , Y ₂₁ , V ₂ /V ₁ , and I ₂ /I ₁	±5%	25-1500Mc/s
900-LB (page 101)	High-precision slotted line.	VSWR	±0.13% at 300Mc/s, ±1% at 9Gc/s	300Mc/s-9Gc/s
874-LBA (page 83)	General-purpose slotted line.	VSWR	±2.5% at 300Mc/s, ±10.0% at 5Gc/s	300Mc/s-5Gc/s
SPECIAL-PURPOSE BRIDGE				
1661-B (page 69)	Measures vacuum-tube characteristics; α, β, and h factors of transistors with calculation.	μ 0.001-10,000 g _m 0.02-50,000μS r _p 50Ω-20MΩ	±2%	270-400c/s, 1kc/s



Type 1603-A Z-Y BRIDGE

FEATURES: ■ Balances for any unknown impedance 0 to ∞ . ■ Covers entire audio-frequency range. 1% accuracy to 7 kc/s (to 20 kc/s for resistance and conductance). Fast, convenient operation. ■ Can measure grounded, direct, or balanced impedances.

USES: This remarkable bridge can easily be balanced for any impedance connected to its terminals. For example, it can be used to measure:

- R , L , and C components, or any combination of them.
- Impedances of active networks.
- Complex impedance characteristics of transformers, transducers, transmission networks, and transistors.
- Frequency characteristics of components, such as electrolytic capacitors and sonar elements.

DESCRIPTION: The basic circuit is a resistance-capaci-

tance bridge, and a substitution method of measurement is used. Low impedances are measured directly in terms of R and X , and high impedances (low admittances) are measured directly in terms of G and B . R and G readings are independent of frequency. X and B are direct reading at 100 c/s, 1 kc/s, and 10 kc/s.

By selection of detector connections, one can measure (1) the grounded impedance, (2) the direct impedance, or (3) the impedance of the equivalent delta circuit, balanced or unbalanced, of the unknown element.

SPECIFICATIONS

RANGES OF MEASUREMENT

Frequency: 20 c/s to 20 kc/s.

Impedance and Admittance: $-\infty$ to $+\infty$.

Unknown is measured as an impedance if the resistance is less than 1000 Ω and the reactance is less than 1000 $(f_o/f)\Omega$.

Unknown is measured as an admittance if the absolute conductance is less than 1000 $\mu\mathcal{S}$ and the absolute susceptance is less than 1000 $(f/f_o)\mu\mathcal{S}$.

ACCURACY (with unknown grounded)

R: $\pm 1\%$ $\pm (2 \mu\Omega$ on main R dial or 0.2Ω on ΔR dial) $\pm 0.0002f_{kc}X$

G: $\pm 1\%$ $\pm (2 \mu\mathcal{S}$ on main G dial or $0.2 \mu\mathcal{S}$ on ΔG dial) $\pm 0.0002f_{kc}B$

X: $\pm 1\%$ $\pm (2f_o/f \Omega$ on main X dial or $0.2 f_o/f \Omega$ on ΔX dial) $\pm 0.0002f_{kc}R$

B: $\pm 1\%$ $\pm (2f/f_o \mu\mathcal{S}$ on main B dial or $0.2f/f_o \mu\mathcal{S}$ on ΔB dial) $\pm 0.0002f_{kc}G$

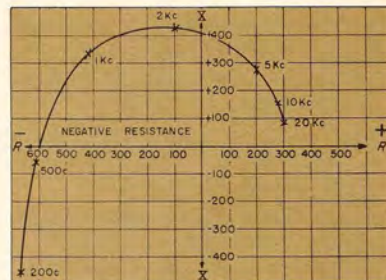
These expressions are valid for R and G up to 20 kc/s; for X and B the 1% term is valid up to 7 kc/s; above 7 kc/s it becomes 2%, above 15 kc/s, 3%. Slightly larger errors occur at high frequencies for direct or delta measurements.

GENERAL

Generator: External only (not supplied); 20 c/s to 20 kc/s; TYPE 1210-C, 1310-A, or 1311-A Oscillator recommended. Max safe voltage on bridge is 130 V, rms, giving less than 32 V on unknown.

Detector: External only (not supplied); TYPE 1232-A Tuned Amplifier and Null Detector recommended.

Input impedance of a feedback circuit; data taken with Type 1603-A Z-Y Bridge.



Accessories Supplied: TYPE 274-NP Patch Cord, TYPE 874-R34 Patch Cord.

Accessories Required: Generator and detector.

MECHANICAL DATA Lab-Bench Cabinet (see page 258)

Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
12½	320	13½	345	8½	220	21½	10	31	14.5

For a more detailed description, ask for General Radio Reprint E-102.

Catalog Number	Description	Price
1603-9701	Type 1603-A Z-Y Bridge	\$515.00



A UNIVERSAL AUDIO-FREQUENCY IMPEDANCE-MEASURING INSTRUMENT

Type 1605-A IMPEDANCE COMPARATOR



FEATURES:

- High-speed meter indication — no balancing operation required.
- High accuracy.
- Four internal frequencies — 100 c/s, 1 kc/s, 10 kc/s, and 100 kc/s.
- Versatile — compares impedances of any phase angle.
- Wide impedance range — 2 ohms to 20 megohms.
- 0.01%, full-scale (-AH models).
- Compares both impedance magnitude and phase angle simultaneously and indicates direction of unbalance.
- Guard point for reducing effect of stray impedance.
- Completely self-contained.
- Terminals at rear for operation of automatic selection devices, oscilloscope, or recorder.
- Meters are protected from off-scale damage.

USES: Typical uses for this highly precise instrument include:

Rapid testing, sorting, and matching of precision components, etched boards, subassemblies and complex networks, either manually or in combination with automatic sorting equipment.

Measuring the effects of time, temperature, humidity, and pressure on components, with high precision and continuous indication.

Rapid test for tracking of ganged potentiometers and variable capacitors.

Frequency characteristics of components.

Easy comparison of quantities usually requiring laboratory techniques, such as:

Small impedance differences.

D of low-loss dielectric materials.

$D \left(= \frac{1}{Q} \right)$ of inductors.

Q or phase angle of wire-wound resistors or potentiometers.

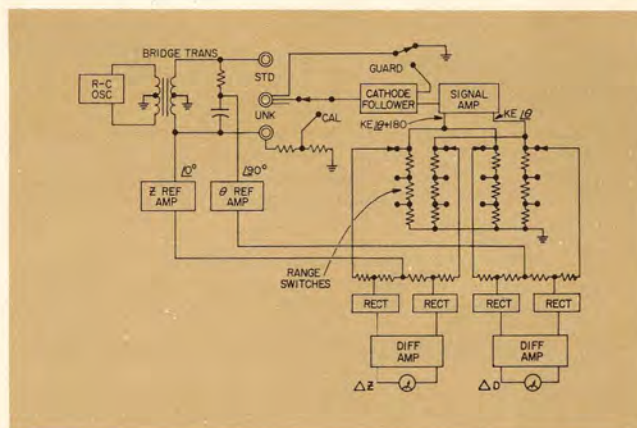
Balance of transformer windings.

Semiconductor capacitances.

Capacitance drift with temperature.

Can also be used as a null bridge with the addition of an adjustable standard, such as the TYPE 1422 Precision Capacitor or the TYPE 1412-BC Decade Capacitor.

DESCRIPTION: This completely self-contained impedance comparator indicates directly on two panel meters the difference in impedance and phase angle between two elements connected to its terminals. Three highly de-



Block schematic of the Type 1605-A Impedance Comparator.

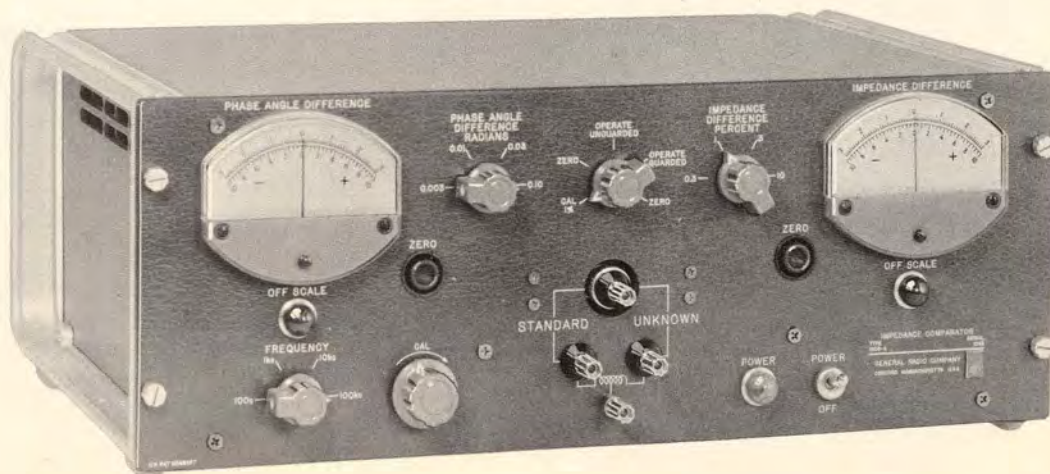
sirable characteristics not usually obtained together are combined in this unique instrument:

- high accuracy
- high speed
- wide ranges of impedance and frequency.

As a result, not only does it bring laboratory accuracy to production-line inspection, but, conversely, it brings the speed of the production test to measurements in the laboratory.

The basic circuit of the comparator is a bridge, with the unknown and standard impedances serving as two

RAPID, ACCURATE R-L-C LIMIT BRIDGE



of the bridge arms and the halves of a center-tapped transformer secondary winding serving as the other two arms. An internal RC oscillator driving the transformer primary winding produces test voltage frequencies of 100 c/s, 1 kc/s, 10 kc/s, and 100 kc/s. The bridge unbalance voltage, resulting from inequality of standard and unknown impedances, is separated into in-phase and out-of-phase components, which are amplified and indicated directly by two meters reading, respectively, impedance-magnitude difference in percent and phase-angle difference in radians.

The transformer is designed to have as high a degree of coupling as possible between the two halves of its secondary winding. The coefficient of coupling achieved is greater than 0.9997, and the open-circuit voltages of the two halves are balanced within 1 part in 10⁶. This makes possible measurement of differences as low as 0.01% on the TYPE 1605-A and 0.003% on the TYPE 1605-AH and minimizes the loading effect of external impedances on the bridge transformer.

An unusual type of cathode-follower circuit provides a very high input impedance for the bridge detector and also a guard terminal, which makes possible the measurement of high impedances at a distance from the instrument, as in an environmental test chamber.



The GR Impedance Comparator in use for production testing of capacitors at Centralab's Milwaukee plant.

For operating external selector circuits, meter voltages are available at the rear of the instrument; a plug connector is supplied.

Calibration can quickly be checked at any time by means of a simple built-in network.

SPECIFICATIONS

RANGES AND ACCURACY

Type 1605-A: Measurement	Impedance Range	Impedance-Magnitude Difference	Phase-Angle Difference**	Accuracy	
Resistance or Impedance Magnitude	2Ω to 20 MΩ	±0.3%, ±1%, ±3%, ±10%, full scale. Can be adjusted for maximum of 50%.	±0.03, ±0.01, ±0.03, ±0.1, radian, full scale.	Difference readings accu- rate to within ±3% of full scale; i.e., for the ±0.3% impedance differ- ence scale, accuracy is 0.009% of the impedance being measured.	
Capacitance	40 pF* to 800 μF				
Inductance	20 μH to 10,000 H				
Type 1605-AH:					
Resistance or Impedance Magnitude	20Ω to 20 MΩ	±0.1%, ±0.3%, ±1%, ±3%, full scale. Can be adjusted for maximum of 15%.	±0.001, ±0.003, ±0.01, ±0.03 radian, full scale.		
Capacitance	40 pF to 80 μF				
Inductance	200 μH to 10,000 H				

* To 0.1 pF with reduced accuracy.

** Phase-angle difference is very nearly equal to D difference for capacitors and inductors, or to Q difference for resistors, as long as D or Q is less than 0.1.

GENERAL

Test Frequency and Voltage: Internal only, 100 c/s, 1 kc/s, 10 kc/s, 100 kc/s, all ±3%. Voltage across standard and unknown is approximately 0.3 V for TYPE 1605-A and 1 V for TYPE 1605-AH.

Power Required: 105 to 125 or 210 to 250 V, 50 to 60 c/s, approximately 100 W. Operates satisfactorily on 400 c/s if line voltage is at least 115 V.

Accessories Supplied: TYPE CAP-22 Power Cord, telephone plug, external-meter plug, coaxial adaptor-plate assembly (fits panel terminals), spare fuses.

Models with other meter ranges and other frequencies are available on special order.

MECHANICAL DATA Rack-Bench Cabinet (see page 258)

Model	Width		Height		Depth		Net Weight		Shipping Weight	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Bench	19	485	7 ¼	185	13 ½	345	29 ½	13.5	37	17
Rack	19	485	7	180	12*	305	29 ½	13.5	37	17

* Behind panel.

For a more detailed description, ask for General Radio Reprint E-103.

Catalog Number	Description	Price
1605-9801	Type 1605-A Impedance Comparator, Bench Model	\$925.00
1605-9811	Type 1605-A Impedance Comparator, Rack Model	925.00
1605-9951	Type 1605-AH Impedance Comparator, Bench Model	925.00
1605-9961	Type 1605-AH Impedance Comparator, Rack Model	925.00

PATENT NOTICE. See Notes 4 and 15, page 11.



Type 1608-A IMPEDANCE BRIDGE

FEATURES:

- 0.1% basic accuracy for *C*, *R*, *L*, and *G*. Excellent phase-angle accuracy.
- Digital readout for *C*, *R*, *L*, and *G*; decimal point and unit indicated automatically.
- Appropriate *D* and *Q* scales illuminated automatically.
- Measures impedances of any phase angle.
- Rapid balancing with concentric coarse and fine controls for main balance.
- Self-contained generator and detector.

USES: This precise bridge will measure modern precision components requiring an accuracy of 0.1% — capacitance, inductance, and ac resistance and conductance, as well as dc resistance. An almost error-free readout and rapid-balance adjustments allow accurate and fast laboratory or production tests. Six internal ac bridges cover all possible phase angles so that any network can be measured, even such “black boxes” as filters, transducers, and equalizers.

Ac resistance and conductance measurements are made at a frequency of 1 kc/s. A *Q* adjustment for precise balancing gives phase information useful in predicting their high-frequency performance. This bridge is also useful for measuring high-loss reactances, such as rf chokes, without a sliding null. The high-phase precision of ±0.0005 radian makes *D* or *Q* measurements meaningful on low-loss reactances, which must often have tight *D* or *Q* tolerances, for use in precision networks.

A wide range of resistors at EIA-specified dc voltages, three-terminal capacitors and small capacitors remotely located, voltage-biased capacitors or current-biased inductors and resistors can be measured. Almost any impedance is measurable over the audio-frequency range.

The ability to measure small capacitances by a three-terminal connection makes possible the measurement of the capacitance between components, wires, or

mounting structures. Long, shielded cables can be used without significantly affecting the accuracy of the measurement.

For production testing of components a test jig, TYPE 1650-P1, is available.

DESCRIPTION: This self-contained bridge system includes six bridges, along with suitable ac and dc sources and detectors. The bridge elements are precision units. The wire-wound resistors are similar to those used in General Radio decade resistance boxes; the standard capacitor is a combination silver-mica and stabilized-polystyrene unit, with a low temperature coefficient.

The readout system is digital for *C*, *R*, *L*, and *G*, as well as for the *Q* of resistors. *D* and *Q* for capacitors and inductors are read from a dial with the correct scale illuminated. Decimal points and units are indicated automatically, and there are no multiplying factors for any quantity at 1 kc/s or dc.

The *C-R-L-G* readout has both coarse and fine adjustments controlled by concentric knobs.

The 1-kc frequency-selective networks for the internal oscillator and tuned detector are on a plug-in module, which can be easily replaced with modules available for other internal test frequencies. Provision is made for use with an external oscillator and detector. Three dc supplies are included to obtain maximum sensitivity over a wide range of resistance.



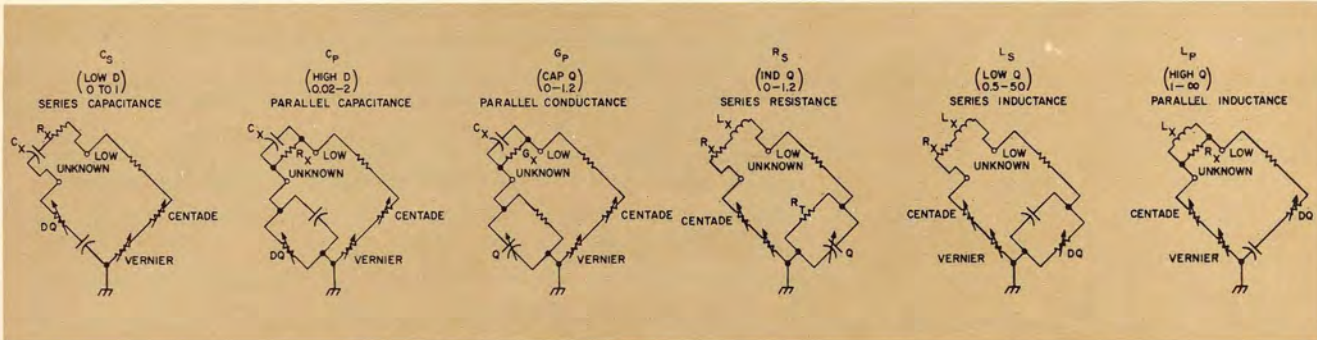
SPECIFICATIONS

RANGES AND ACCURACY

Measurement	Range	*1-kc Accuracy		Additional Error (for higher frequency and large phase angle)†
		±0.1% ± 0.005% of full scale	±0.2% ± 0.005% of full scale	
Capacitance, series or parallel	0.05 pF to 1100 μF, in 7 ranges	lowest 6 ranges	highest range	(±0.001 f_{kc}^2 ± 0.1 D f_{kc} ± 0.5 D ²)% of measured value
Inductance, series or parallel	0.05 μH to 1100 H, in 7 ranges	highest 6 ranges	lowest range	(±0.002 f_{kc}^2 ± 0.00001 f_{kc}^4 ± 0.1 Q)% of measured value
Resistance (series)	0.05 mΩ to 1.1 MΩ, ac or dc	highest 6 ranges	lowest range	
Conductance (parallel)	0.05 nS to 1.1 mS, ac or dc (20,000 MΩ to 0.9Ω)	lowest 6 ranges	highest range	
D (at 1 kc/s)	0.0005 to 1 of series capacitance, 0.02 to 2 of parallel capacitance	D or 1/Q ±0.0005 ± 5% at 1 kc/s or lower, ±0.0005 f_{kc} ± 5% above 1 kc/s		
Q (at 1 kc/s)	0.5 to 50 of series inductance, 1 to 2000 of parallel inductance	±0.0005 f_{kc} ± 2%		
	0.0005 to 1.2 (inductive) of series resistance, 0.0005 to 1.2 (capacitive) of parallel conductance			

* Residual terminal impedance: $R \approx 0.001 \Omega$, $L \approx 0.15 \mu H$, $C \approx 0.25 pF$.

† Bridge is usable up to 20 kc/s. Dc resistance and conductance accuracy is same as for 1 kc/s, except accuracy is limited by sensitivity at range extremes. Balances to 0.1% are possible from 1 Ω to 1 MΩ with internal supply and detector.



Elementary schematics of the capacitance, conductance, resistance, and reactance bridges.

GENERAL

Generator: Internal, 1 kc/s ± 1% module normally supplied; plug-in modules for other frequencies available on special order. Level control provided. With external generator, frequency range of bridge is 20 c/s to 20 kc/s. TYPE 1310-A or the TYPE 1210-C Oscillator recommended if external generator required. Internal dc supply 3.5, 35, and 350 V, adjustable; power limited to 1/3 W or less.

Detector: Internal or external; ac; can be used either flat or selective at frequency of plug-in module (normally 1 kc/s); other frequencies available; second-harmonic rejection about 25 dB. Sensitivity control provided. TYPE 1232-A Tuned Amplifier and Null Detector recommended when external generator is used.

Dc Bias: Capacitors can be biased to 500 V from external source; bias current can be applied to inductors up to 40 mA.

Power Required: 105 to 125 or 210 to 250 V, 50 to 60 c/s; 10 W.

Accessories Supplied: TYPE CAP-22 Power Cord, spare fuses, spare indicator lamps.

Accessories Available: TYPE 1650-P1 Test Jig (page 51).

MECHANICAL DATA Rack-Bench Cabinet (see page 258)

Model	Width		Height		Depth		Net Weight		Shipping Weight	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Bench	19	485	12 1/2	320	11 1/2	295	36 3/4	17	54	24.5
Rack	19	485	12 1/4	315	10*	285	34 3/4	16.8	54	24.5

* Behind panel.

For a more detailed description, see *General Radio Experimenter*, March 1962.

Catalog Number	Description	Price
1608-9801	Type 1608-A Impedance Bridge, Bench Model	\$1300.00
1608-9811	Type 1608-A Impedance Bridge, Rack Model	1300.00



Type 1650-A IMPEDANCE BRIDGE

FEATURES:

- Completely self-contained and portable.
- Wide impedance range, covering all commonly used components.
- ORTHONULL® balance finder to facilitate low-Q balances.
- Visual null meter — taut-band suspension.
- Transistor oscillator and detector powered by commonly available D cells.
- Dc bias can be applied. ■ Easy-to-read dials.

USES: The TYPE 1650-A Impedance Bridge will measure the inductance and storage factor, *Q*, of inductors,* the capacitance and dissipation factor, *D*, of capacitors, and the ac and dc resistance of all types of resistors.

In the laboratory it is extremely useful for measuring the circuit constants in experimental equipment, testing preliminary samples, and identifying unlabeled parts. In the shop and on the test bench it has many applications for testing and component sorting.

Three-terminal measurements can be made in the presence of considerable stray capacitance to ground.

DESCRIPTION: This bridge is completely self-contained and portable. Battery-powered, low-drain transistor oscillator and detector are included. The panel meter indicates both dc and ac bridge unbalances.

* Including such low-Q inductors as rf coils measured at 1 kc/s.

The measured quantities, *R*, *L*, *C*, *D*, and *Q*, are indicated directly on dials with constant-percentage-accuracy logarithmic scales. Multiplier and the units of measurement are indicated by the range setting.

The bridge circuit elements are high-quality, stable components that ensure long-term accuracy. The ORTHONULL® balance finder, a patented mechanical-ganging device, is used to make a low-Q (high-D) balance possible without a sliding null. This mechanism, which may be switched in or out as desired, adds accuracy as well as convenience to low-Q measurements that are practically impossible on other impedance bridges.

The Flip-Tilt case provides a handle and a captive, protective cover that allows the bridge panel to be tilted and held firmly at any angle. The portable model uses dry cells; the rack model has a built-in, rechargeable battery and charger. Battery and charger are also available, as listed below, for use with portable model.

SPECIFICATIONS

RANGES OF MEASUREMENT	ACCURACY
Capacitance 1 pF to 1100 μF, series or parallel, 7 ranges.	At internal 1-kc frequency or at 20 c/s to 20 kc/s, externally supplied.† ±1% of measured value or ±1 pF (residual C ≈ 0.5 pF).
Inductance 1 μH to 1100 H, series or parallel, 7 ranges.	At 1 kc/s or 20 c/s to 20 kc/s,† ±1% of measured value or ±1 μH (residual L ≈ 0.2 μH).
Resistance ac or dc, 1 mΩ to 11 MΩ, 8 ranges.	At 1 kc/s or 20 c/s to 5 kc/s, ±1% or ±1 mΩ (residual R ≈ 1 mΩ). At dc, ±1% of measured value from 1Ω to 100 kΩ. External dc supply required for 1% accuracy above 100 kΩ.
Dissipation Factor, D , at 1 kc/s. 0.001 to 1 of series C. 0.1 to 50 of parallel C.	±5% of indication ±0.001 at 1 kc/s or lower.
Storage Factor, Q , at 1 kc/s 0.02 to 10 of series L. 1 to 1000 of parallel L.	$\frac{1}{Q} = \pm 5\%$ of indication ± 0.001 at 1 kc/s or lower.

† Bridge operates up to 100 kc/s with reduced accuracy.



COMPLETELY SELF-CONTAINED
UNIVERSAL BRIDGE

GENERAL

Generator: Internal; 1 kc/s \pm 2%. TYPE 1310-A or TYPE 1311-A Oscillator recommended if external generator is required. Internal dc supply, 6 V, 60 mA, maximum.

Detector: Internal or external; internal detector response flat or selective at 1 kc/s; sensitivity control provided. TYPE 1232-A Tuned Amplifier and Null Detector is recommended if external detector is required.

DC Polarization: Capacitors can be biased to 600 V from external dc power supply for series capacitance measurements.

Power Required: Portable model, 4 D cells, supplied; rack model, rechargeable, 6-volt, nickel-cadmium battery, supplied. Battery capacity is adequate for 40 hours of use in ac measurements, 8 hours minimum in dc measurements. Charging time, 10 hours.

Accessories Required: None. Earphones can be used for high precision at extremes of bridge ranges.

Accessories Available: TYPE 1650-P1 Test Jig.

MECHANICAL DATA Flip-Tilt Case or Rack Mount (see page 258)

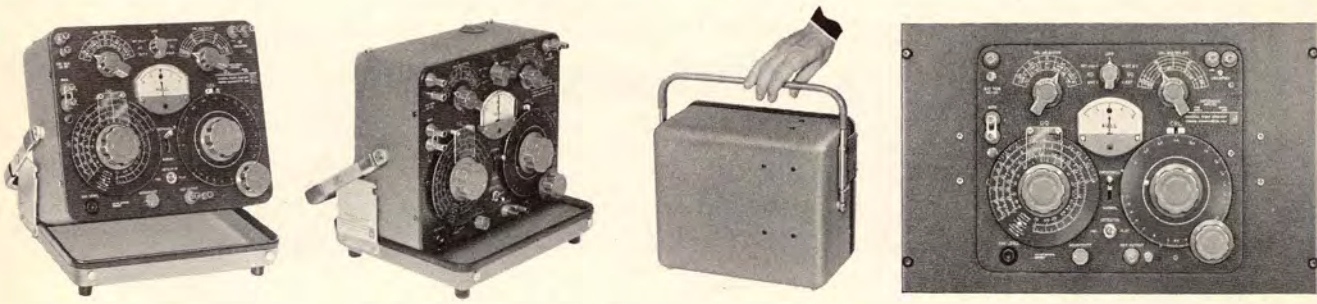
Model	Width		Height		Depth		Net Weight		Shipping Weight	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Portable*	12 3/4	325	12 1/2	320	7 3/4	200	17	8	21	10
Rack	19	485	12 1/2	320	5 1/2	130	18	8.5	30	13.5

* Case closed. † Behind panel.

For a more detailed description, ask for General Radio Reprint E-108.

Catalog Number	Description	Price
1650-9701	Type 1650-A Impedance Bridge, Portable Model (with dry cells)	\$475.00
1650-9540	Type 1650-A Impedance Bridge, Rack Model (with rechargeable battery and charger, for 115-volt supply)	540.00
1650-9570	Type 1650-A Impedance Bridge, Rack Model (with rechargeable battery and charger, for 230-volt supply)	on request
1650-9602	Type 1650-P2 Battery and Charger, for 115-volt supply	55.00
1650-9568	Type 1650-P2Q18 Battery and Charger, for 230-volt supply	on request

PATENT NOTICE, See Notes 15, 19, and 22, page 11.



Flip-Tilt case holds bridge firmly tilted at almost any angle and provides protection when bridge is not in use.

Type 1650-A Impedance Bridge, for relay-rack mounting.

Type 1650-P1 TEST JIG

This test-jig adaptor is used to connect components quickly to a pair of terminals and can be placed on the bench directly in front of the operator. Thus, the test jig and TYPE 1650-A Impedance Bridge make a rapid and efficient component sorting device when the panel meter of the bridge is used as a limit indicator.

The test jig makes a three-terminal connection to the bridge, so that the residual zero capacitance is negligible. The lead resistance (0.08 ohm total) has effect only when very low impedances are measured, and the lead capacitance affects only the measurement of the Q of inductors, introducing a small error in D (or $\frac{1}{Q}$) of less than 0.007.

Net Weight: 10 oz (285 grams).
Shipping Weight: 4 lb (1.9 kg).

Catalog No.	Description	Price
1650-9601	Type 1650-P1 Test Jig	\$20.00



MINIMIZES EFFECTS OF LEAD CAPACITANCE

Type 1606-A RADIO-FREQUENCY BRIDGE



- FEATURES:**
- Wide, frequency range — 400 kc/s to 60 Mc/s.
 - Direct reading in ohms.
 - Fast, simple operation.
 - Accurate, reliable measurements.
 - Small, light, and rugged — suitable for field or laboratory.

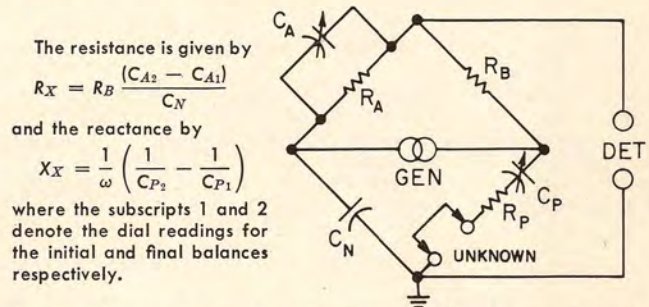
USES: The TYPE 1606-A Radio-Frequency Bridge measures impedances simply and accurately at frequencies from 400 kc/s to 60 Mc/s. It measures directly the resistance and reactance of antennas, transmission lines, networks, and components. It is particularly well suited for measuring low values of impedance of rf devices. Its range can be extended by means of an external parallel capacitor to measure high impedances.

DESCRIPTION: Measurements are made by a series-substitution method in which the bridge is first balanced by means of capacitors C_P and C_A with a short circuit across the unknown terminals. The short is then removed, the unknown impedance connected, and the bridge rebalanced.

The unknown reactance at 1 Mc/s is read directly in ohms from the dial of C_P , and the unknown resistance in ohms from the dial of C_A .

The resistive component is measured in terms of a fixed resistor (R_B), a fixed capacitor (C_N), and a variable capacitor (C_A). This feature is an important factor in the high-frequency performance of the bridge, because residual parameters can be made much smaller in a fixed resistor and a variable capacitor than in a variable resistor.

The TYPE 1606-A Bridge incorporates several important features. A single, internal transformer, used



to couple an external generator to the bridge circuit, covers the entire 150:1 frequency range, and its triple shielding keeps undesired couplings to an insignificant level.

The variable air capacitors in this bridge are designed for low inductance and low losses. The complete rotor and stator sections are milled out of solid blocks of aluminum, a construction that avoids losses at the joints between plates and spacers and provides the utmost stability.

The entire mechanical design is such that the instrument can operate under difficult environmental conditions similar to those specified for testing military electronics equipment, which makes the TYPE 1606-A bridge an excellent instrument for field use.

SPECIFICATIONS

RANGES OF MEASUREMENT

Frequency: 400 kc/s to 60 Mc/s.

Satisfactory but somewhat less accurate operation can be obtained at frequencies as low as 100 kc/s and somewhat above 60 Mc/s.

Reactance: $\pm 5000 \Omega$ at 1 Mc/s. This range varies inversely as the frequency; at other frequencies the dial reading must be divided by the frequency in Mc/s.

Resistance: 0 to 1000 Ω .

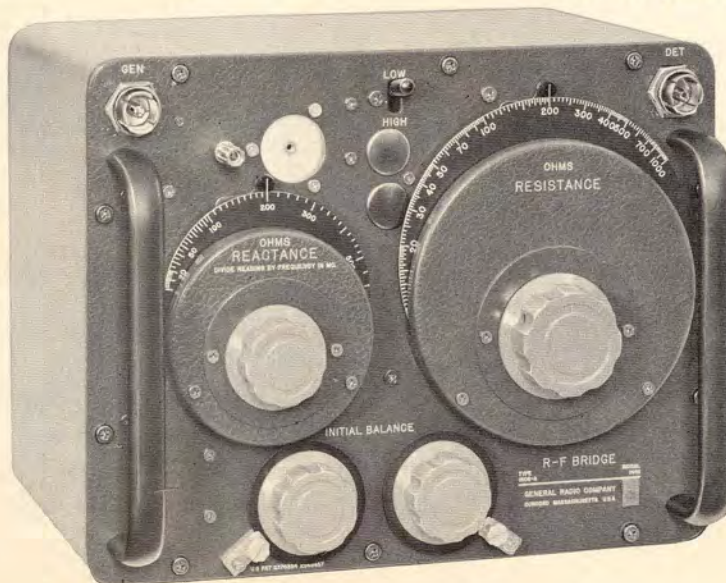
ACCURACY

Reactance: At frequencies up to 50 Mc/s, $\pm (2\% + 1 \Omega + 0.0008 Rf)$ where R is the measured resistance in ohms and f is the frequency in Mc/s.

Resistance: At frequencies up to 50 Mc/s,

$$\pm \left[1\% + 0.0024f^2 \left(1 + \frac{R}{1000} \right) \right] \% \pm \frac{10^{-4} X}{f} \Omega + 0.1 \Omega$$

(where X is the measured reactance in ohms). Subject to correction for residual parameters.



FOR THE MEASUREMENT OF
ANTENNAS, LINES, NETWORKS,
AND COMPONENTS
FROM 400 kc/s TO 60 Mc/s

GENERAL

Generator: External only (not supplied), to cover desired frequency range. Recommended, TYPE 1211-C and TYPE 1215-C Unit Oscillators, TYPE 1330-A Bridge Oscillator, TYPE 1310-A Oscillator, TYPE 1001-A and TYPE 1021-AV Standard-Signal Generators.

Detector: External only (not supplied). A heterodyne detector, TYPE DNT-6 (page 109), is recommended for use above 3 Mc/s. A well shielded radio receiver is also satisfactory.

Accessories Supplied: 2 leads of different lengths to connect unknown impedance to bridge terminals; 1/2-in spacer and 3/4-in spacer to mount component to be measured directly on bridge terminals; 2 TYPE 874-R22LA Patch Cords to connect generator and detector.

Accessories Available: Luggage-type carrying case. See price table below.

MECHANICAL DATA Welded Aluminum Cabinet

Width		Height		Depth		Net Weight		Shipping Weight		
in	mm	in	mm	in	mm	lb	kg	lb	kg	
12 1/2	320	9 1/2	245	10 1/4	260	23	10.5	30	14	
With carrying case							29	13.5	31	14.5

For a more detailed description, see *General Radio Experimenter*, June 1955.

Catalog Number	Description	Price
1606-9701	Type 1606-A Radio-Frequency Bridge	\$825.00
1606-9601	Type 1606-P1 Luggage-Type Carrying Case	25.00

PATENT NOTICE. See Note 4, page 11.

Type 916-AL RADIO FREQUENCY BRIDGE

The TYPE 916-AL Radio-Frequency Bridge uses the same series-substitution circuit as the TYPE 1606-A to cover the low and medium frequencies between 50 kc/s and 5 Mc/s.

An important feature is the ΔX dial, which greatly facilitates the measurement of large capacitances and small inductances.

SPECIFICATIONS

RANGES OF MEASUREMENT

Frequency: 50 kc/s to 5 Mc/s. Satisfactory operation for many measurements can be obtained at frequencies as low as 15 kc/s.

Reactance: ±11,000 Ω at 100 kc/s. This range varies inversely as the frequency; at other frequencies the dial readings must be divided by the frequency in hundreds of kc/s.

ΔX Dial: 100 Ω at 100 kc/s.

Resistance: 0 to 1000 Ω.

ACCURACY

Reactance: Below 3 Mc/s, $\pm(2\% + 0.2 \times \frac{100}{f_{kc}} \Omega + 3.5f_{kc}^2 R \times 10^{-10}\Omega)$, where R is the measured resistance in ohms and f_{kc} is the frequency in kc/s. The errors increase at frequencies above 3 Mc/s; at 5 Mc/s, the accuracy is $\pm(2\% + 0.01\Omega + 2.3R^{1.4} \times 10^{-3}\Omega)$.

Resistance: Below 5 Mc/s, $\pm(1\% + 0.1\Omega)$, subject to correction for residual parameters at low frequencies. The correction depends upon the frequency and upon the magnitude of the unknown reactance component.

GENERAL

Generator: External only (not supplied). TYPE 1330-A Bridge Oscillator, TYPE 1211-C Unit Oscillator, TYPE 1001-A Standard-Signal Generator recommended.

Detector: External only (not supplied). A heterodyne detector, the TYPE DNT-5 (page 109), is recommended. A well shielded radio receiver is also a satisfactory detector.

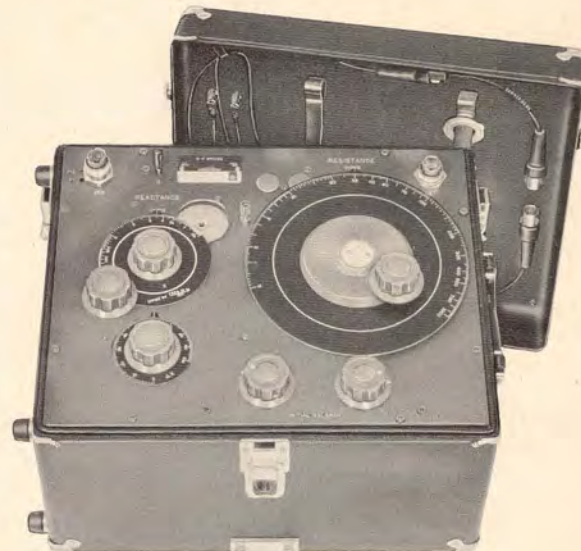
Accessories Supplied: 2 leads of different lengths to connect unknown impedance to bridge terminals; 2 input transformers, one to cover lower portion of frequency range, the other the higher portion; 2 TYPE 874-R22LA Patch Cords to connect generator and detector.

MECHANICAL DATA Luggage-Type Cabinet, Shielded.

Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
13 1/2	345	17	435	11 1/4	290	34 1/2	16	45	20.5

For a more detailed description, see *General Radio Experimenter*, March 1949.

50 kc/s to 5 Mc/s



Catalog Number	Description	Price
0916-9831	Type 916-AL Radio-Frequency Bridge	\$925.00

PATENT NOTICE. See Note 4, page 11.

Type 1602-B UHF ADMITTANCE METER

AND VSWR BRIDGE

FEATURES:

- Direct reading in conductance and susceptance, independent of frequency.
- With line stretcher, can indicate impedance (resistance and reactance).
- Can measure vswr directly, with TYPE DNT Detector or any other linear detector
- No sliding balance — resistive and reactive adjustments are independent.
- Wide frequency range — direct reading from 40 to 1500 Mc/s.
- Accurate, rapid, easy to use.

USES: This null-type instrument measures impedance and admittance in coaxial systems such as antennas, lines, and networks.

It can be used for adjusting a network to a predetermined admittance, for matching one network to another, and for matching antennas and other networks to 50-ohm circuits.

As a comparator, the Admittance Meter is used to determine impedance magnitude, reflection-coefficient magnitude, and voltage standing-wave ratio.

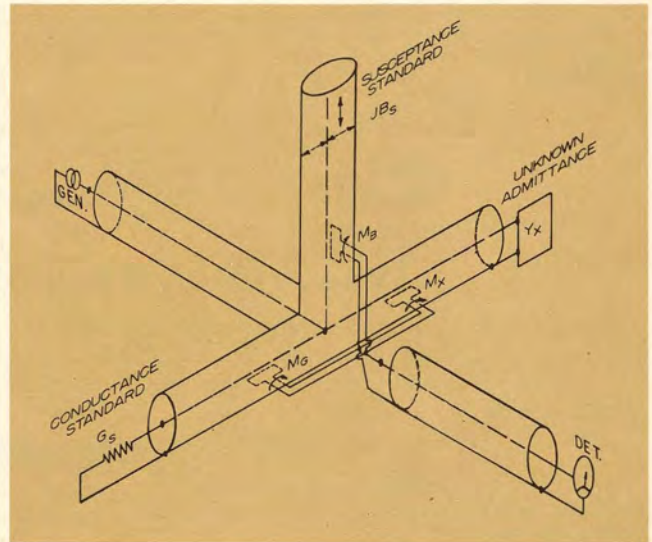
A full line of accessories is available to adapt the Admittance Meter to specific types of measurements:

The TYPE 874-LK20L Constant-Impedance Adjustable Line, which can be set to one-half wavelength to eliminate corrections for the length of transmission line between the unknown and the measuring point. When the line is set to one-quarter wavelength, the Admittance Meter dials read in impedance parameters, i.e., the series resistance and reactance of the unknown.

The TYPE 874-UBL Balun, for use with balanced impedances.

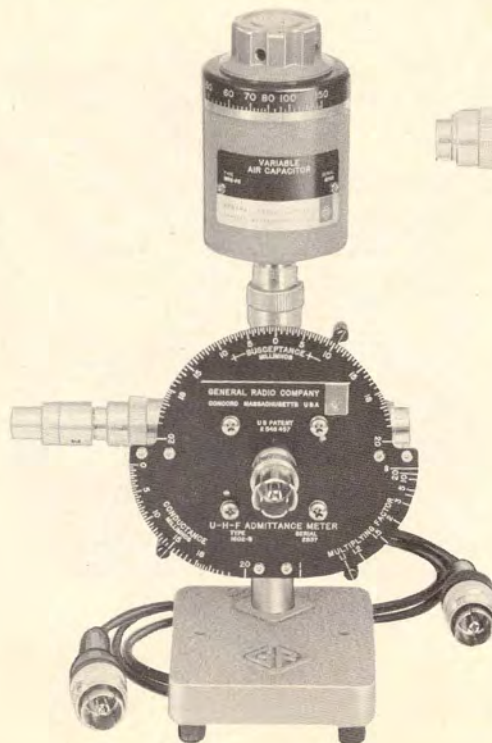
The TYPE 874-ML Component Mount, for the connection of lumped elements (resistors, capacitors, or inductors).

Low-vswr adaptors (which can be locked in place) for most types of military connectors and (nonlocking)



Schematic diagram of admittance-meter circuit, with standards, generator, and null detector connected for admittance measurements.

for rigid vhf and uhf transmission lines used with tv transmitting antennas. With these adaptors and the adjustable line mentioned above, the over-all accuracy



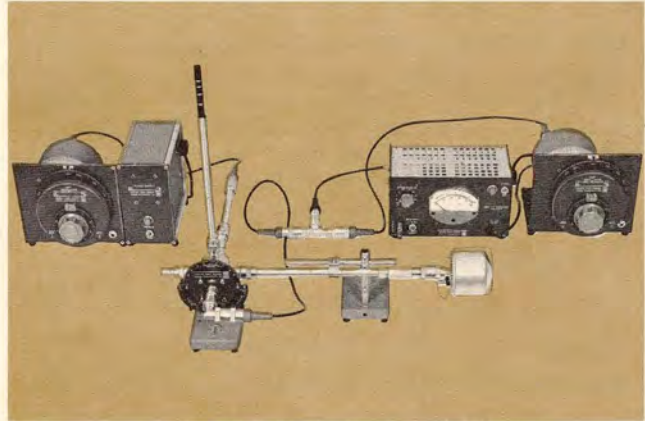
A COAXIAL BRIDGE FOR UHF-VHF ADMITTANCE, IMPEDANCE, AND VSWR MEASUREMENT FROM 20 TO 1500 Mc/s

of measurement is more than adequate for measurements in the design, test, and installation of antennas.

DESCRIPTION: The TYPE 1602-B UHF Admittance Meter comprises a coaxial line to which the unknown is connected, a shielded pickup loop to sample the current, a second line and loop terminated in a pure resistance, and a third line and loop terminated in a pure reactance. All are fed from the same voltage source, so that their input voltages are in phase, and the current in each line is proportional to the admittance. The voltage induced in each loop is proportional to the current in the corresponding line and is dependent upon the orientation of the loop, which is adjustable. Variation of this orientation is equivalent to variation of the magnitude of the impedances (including the standards).

The three loops are connected in parallel, and the voltage from the loop in the unknown line is canceled by adjustment of the loops coupled to the standard lines until a null is reached. The conductance and susceptance of the unknown are read directly from the scales of the standard loops, while the scale of the loop in the unknown line indicates the multiplying factor.

This arrangement produces the effect of continuously variable elements by using known fractions of the currents in fixed elements.



The Admittance Meter assembled for component measurements, with Unit Oscillator and DNT Detector. A line stretcher (Type 874-LKL) connects the component mount to the unknown terminal of the Admittance Meter.

SPECIFICATIONS

RANGES OF MEASUREMENT

Frequency: 40 to 1500 Mc/s (direct reading). Range can be extended downward to 20 Mc/s, if a frequency correction is applied to the susceptance reading.

Conductance: 0.01 to 4000 mΩ.
Susceptance: -4000 to +4000 mΩ.

ACCURACY

Up to 1000 Mc/s, from 0 to 20 mΩ, ±(3% + 0.2 mΩ)
 from 20 to ∞ mΩ, ±(3√M% + 0.2 mΩ) where M is the scale-multiplying factor.
 Above 1000 Mc/s, errors increase slightly, and, at 1500 Mc/s, the basic figure of 3% in the expression above becomes 5%. For matching impedances to 50 Ω, the accuracy is 3% up to 1500 Mc/s. The 0.2-mΩ fixed error can be reduced significantly with the multiplier plates.

GENERAL

Terminals: All terminals are GR874 Coaxial Connectors and are locking-type, except for the detector terminal. Adaptors to other types of coaxial connectors (page 81) can be used on the generator and detector terminals.

Generator: External only (not supplied). Unit Oscillators (pages 139 to 144) are recommended. Generator must supply 1 to 10 V.

Detector: External only (not supplied). Sensitivity must be 10 μV or better. TYPE DNT Detectors recommended.

Accessories Supplied: 2 TYPE 1602-P4 50-Ω Terminations for conductance standards, TYPE 1602-P1 Adjustable Stub and TYPE 1602-P3 Variable Air Capacitor for susceptance standards, 2 TYPE 874-R22LA Patch Cords for connections to generator and

detector. TYPE 1602-P10 and P-11 Multiplier Plates, wooden storage case.

Accessories Available: TYPE 874-FBL Bias Insertion Unit, coaxial adaptors, line-stretcher, balun, component mount, Smith charts (see pages 76 to 94.)

MECHANICAL DATA

Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
5½	140	7½	190	5½	140	8¼	3.8	18	8.5

For a more detailed description, see *General Radio Experimenter*, May 1950, August 1953, May 1960.

Catalog Number	Description	Price
1602-9702	Type 1602-B UHF Admittance Meter	\$365.00
0874-9631	Type 874-LK20L Constant-Impedance Adjustable Line	42.00
0874-9663	Type 874-ML Component Mount	35.00

PATENT NOTICE. See Note 4, page 11.

OTHER COAXIAL IMPEDANCE-MEASURING DEVICES: Type 1607-A Transfer-Function and Immittance Bridge (page 56), Types 874-LBA and 900-LB Slotted Lines (pages 82 and 100).



FEATURES:

Measures effective network parameters of transistors, diodes, tubes, and two-terminal and four-terminal networks, active and passive.
 Simple to operate. Suitable for both laboratory and routine production measurements.
 Wide frequency range — 25 to 1500 Mc/s. ■ Direct reading.
 Component mounts available for transistors and tubes. ■ Bias terminals provided.

USES: The Transfer-Function and Immittance* Bridge is a null-type instrument for vhf and uhf measurements of the forward and reverse complex transfer functions and the input and output impedances and admittances of four-terminal electrical networks, either active or passive. The complex impedance or admittance of two-terminal circuits or components can also be measured easily.

Among these measurements are:

Transistors — h_f (α or β), and $|\beta|$, h_r , h_i , h_o , Y_c , Y_o , Y_f , Y_r .

Tunnel Diodes — Equivalent circuit parameters.

Vacuum Tubes — μ , Y_{21} and Y_{12} , Y_{11} and Y_{22} .

General two-terminal or four-terminal networks —

Z_{11} , Z_{22} , Z_{21} , Z_{12} and Y_{11} , Y_{22} , Y_{21} , Y_{12} .

I_2/I_1 , I_1/I_2 and E_2/E_1 , E_1/E_2 .

Ungrounded components —

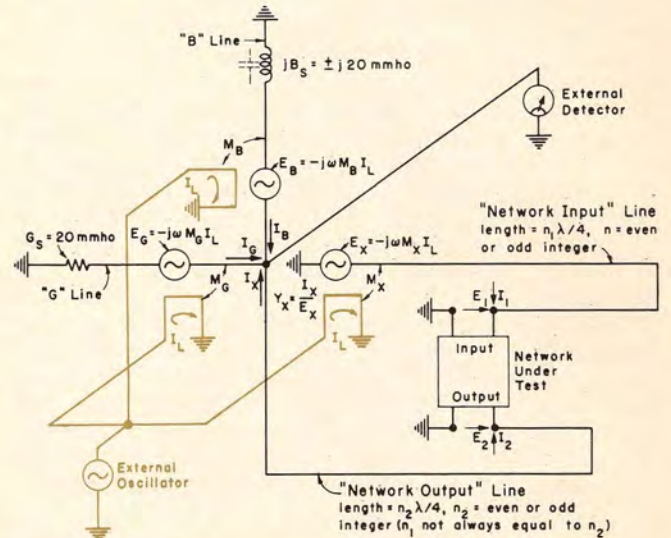
Inductors — inductance and self-resonance.

Capacitors — capacitance and resonances.

Resistors — resistance and shunt capacitance.

Components, Coaxial Lines, and Other Grounded Elements — Z , Y , $|T|$, $VSWR$.

DESCRIPTION: The TYPE 1607-A Transfer-Function and Immittance Bridge comprises three identical loops, fed from a common source and magnetically coupled to three coaxial lines. One of these lines is terminated with a resistance standard, one with a reactance standard, and one with the network to be tested. The coupling of each loop is adjusted until a null is obtained on an external detector in which the three lines are termi-



Schematic diagram of rf circuits of the Transfer-Function and Immittance Bridge.

nated. Each loop has a calibrated scale and the settings at null condition indicate the value of the unknown.

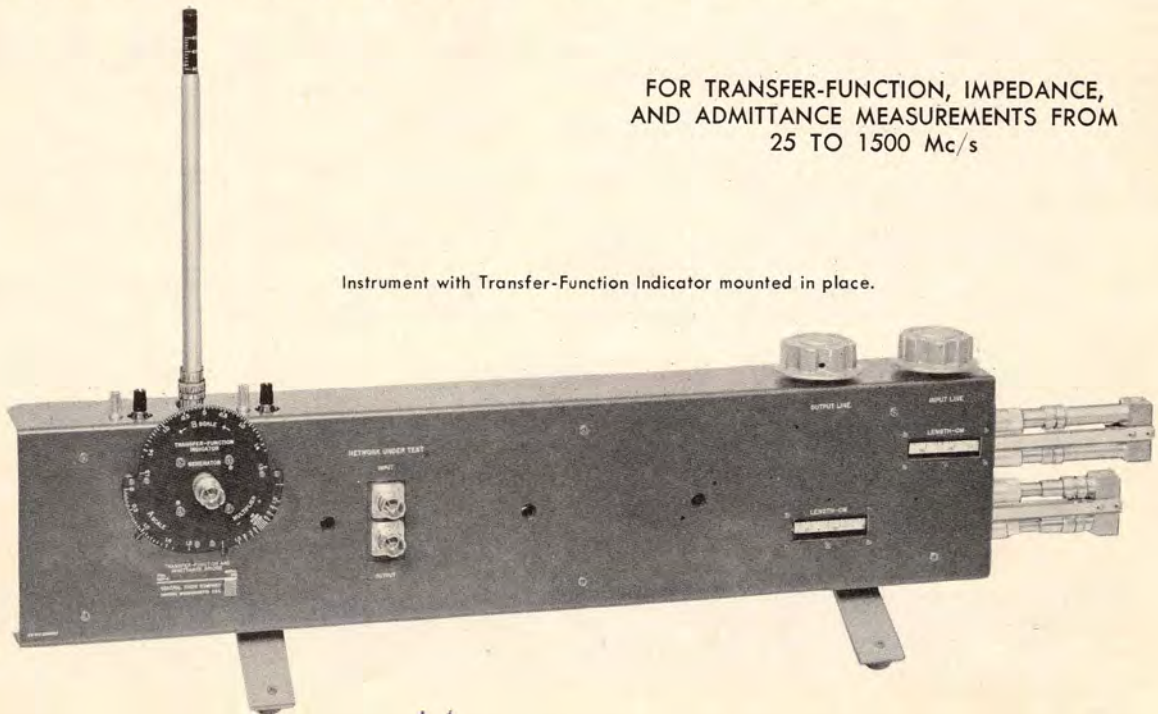
Two interchangeable loop-and-scale assemblies (Transfer-Function Indicator and Immittance Indicator, respectively) allow either four-terminal or two-terminal networks to be measured with equal ease.

Two built-in constant-impedance, adjustable-length lines eliminate lead corrections.

* Immittance = impedance and/or admittance.

FOR TRANSFER-FUNCTION, IMPEDANCE,
 AND ADMITTANCE MEASUREMENTS FROM
 25 TO 1500 Mc/s

Instrument with Transfer-Function Indicator mounted in place.



1607

SPECIFICATIONS

Frequency Range: 25 to 1500 Mc/s, with reduced accuracy above 1000 Mc/s, or when flexible cable is used in the lines. The use of cable is generally required below 150 Mc/s and is optional at other frequencies.

Measurement Range:	Accuracy: (up to 1000 Mc/s)
Voltage and Current Ratios (R) 0-30, 0-300†	$2.5(1 + \sqrt{R})\% + 0.025^*$
Transimpedance (Z_{21}) 0-1500 Ω , 0-15,000 Ω †	$2.5 \left(1 + \sqrt{\frac{Z_{21}}{50}} \right) \% + 1.25 \Omega^*$
Transadmittance (Y_{21}) 0-600 mS, 0-6000 mS†	$2.5 \left(1 + \sqrt{\frac{Y_{21}}{20}} \right) \% + 0.5 \text{ mS}^*$
Impedance (Z_{11}) 0-1000 Ω , 0-10,000 Ω †	$2.0 \left(1 + \sqrt{\frac{Z_{11}}{50}} \right) \% + 1.0 \Omega^*$
Admittance (Y_{11}) 0-400 mS, 0-4000 mS†	$2.0 \left(1 + \sqrt{\frac{Y_{11}}{20}} \right) \% + 0.4 \text{ mS}^*$

* When the 0.1 multiplier plate is used, these errors are significantly reduced.
† With multiplier plate.

Dc Bias: Bias terminals are provided. Maximum current, 2.5 A, continuous; higher currents are permissible for short periods; maximum voltage, 400 V.

Generator and Detector: External only, not included; GR Unit Oscillators and DNT Detectors are recommended. See pages 139 and 108.

Accessories Supplied: Range-Extension Unit; Transfer-Function Indicator; Immittance Indicator; 6 terminations (open, short, matched, etc.); standards; 10-dB attenuator; 8 air lines (21.5 and 43 cm); 3 U-line sections; constant-impedance adjustable line; a special tee; two 0.1 multiplier plates; 10 patch cords; storage for instrument and accessories.

Accessories Required: Mount for unknown device. For coaxial adaptors, see page 81. See below for mounts available. Note that termination kit is required for some transistor mounts.

Accessories Available: Transistor, component, and tube mounts as listed below.

Mechanical Data: (Complete, in storage case)

Width		Height		Depth		Net Wt		Ship Wt	
in	mm	in	mm	in	mm	lb	kg	lb	kg
40	1020	11½	295	14½	370	63	29	132	61

For a more detailed description, ask for General Radio Reprint E109.

Catalog Number	Description	Price
1607-9701	Type 1607-A Transfer-Function and Immittance Bridge	\$1925.00

PATENT NOTICE. See Note 4, page 11.

ACCESSORY MOUNTS

Mount Type	Transistor and diode packages accepted
1607-P101 and -P102	TO-5, -9, -11, -39, and similar packages
1607-P111	TO-1, -18, -23, -24, and similar packages
1607-P201	Type 6AN4 and similarly based tubes
1607-P401	TO-12 and similar packages

Catalog No.	Description	Price
1607-9992	Type 1607-P101 Transistor Mount,* JEDEC-30, grounded base, 0.2-in-dia pin circle	\$60.00
1607-9993	Type 1607-P102 Transistor Mount,* JEDEC-30, grounded emitter, 0.2-in-dia pin circle	60.00
1607-9994	Type 1607-P111 Transistor Mount,* 0.1-in-dia pin circle, grounded base.	70.00
1607-9995	Type 1607-P201 Tube Mount, grounded cathode, 7-pin miniature.	85.00
1607-9996	Type 1607-P401 Tetrode Transistor Mount,* grounded base, 0.2-in-dia pin circle.	75.00
1607-9997	Type 1607-P601 Ungrounded Component Mount.	25.00

* For transistors whose maximum lead length is 5/16 inch.

Mounts For Long-Lead Transistors

These mounts or test jigs are used when transistor leads up to two inches in length must be retained. The leads plug into hollow contact tubes in the mount; as a result, the leads from about 1/32 inch from the header out to the lead tips are completely shielded. Bends or irregularities in the leads, therefore, do not affect the measurement. The coaxial line that connects to the transistor is small in size, thus minimizing the discontinuity at the transistor-to-mount connection and improving the measurement accuracy. Additional advantages are: Complete accessibility to the socket, provision for bolting a heat-sink to the mount body, and provision of a fourth lead in the mount, which is dc ground.

The electrical length of the mounts to the reference plane, which is 0.025 inch below the top of the socket, is 9.5 cm approximately. Appropriate open-circuit, short-circuit, and U-section

units are required. These are available as the TYPE 1607-P40 Termination Kit.

Three-terminal measurements can be performed with both the previous series (listed above) and this new series of mounts.

SPECIFICATIONS

Mount Type	Transistor and diode packages accepted
1607-P41 and -P42	TO-5, 9, 11, 12, 16, 26, 31, 33, 37, 38, 39, 43; MD-14; MM-4, 8; MT-13, 20, 28, 37; RO-2, 3, 4, 5, 10, 24, 30, 32, 34, 46, 49, 50, 61, 62, 79, etc.
1607-P43 and -P44	TO-18, 28, 52, 54; MT-30, -38; RO-44, 48, 51, 64, 65, 66, 70, 73, 78; U-3; X-8; etc.

Accessory Supplied: One TYPE 1607-P30 Damper (to prevent oscillation).

Accessories Required: TYPE 1607-P40 Termination Kit.

Net Weight: Mount, approximately 12 oz (0.4 kg); Termination Kit, approximately 1 lb (0.5 kg).

Shipping Weight: One mount, 2 lb (1 kg); Termination Kit, 2½ lb (1.2 kg).

Catalog No.	Description	Price
1607-9641	Type 1607-P41 Transistor Mount, long-lead, 4-lead grounded-base; 0.2-in-dia pin circle.	\$115.00
1607-9642	Type 1607-P42 Transistor Mount, long-lead, 4-lead grounded-emitter or grounded collector; 0.2-in-dia pin circle.	115.00
1607-9643	Type 1607-P43 Transistor Mount, long-lead, 4-lead grounded-base; 0.1-in-dia pin circle.	115.00
1607-9644	Type 1607-P44 Transistor Mount, long-lead, 4-lead grounded-emitter or grounded-collector; 0.1-in-dia pin circle.	115.00
1607-9640	Type 1607-P40 Termination Kit (Consists of Type 874-U10 U-line Section, Type 874-WN10 Short-Circuit Termination, Type 874-WO10 Open-Circuit Termination.)	42.50



Type 1615-A CAPACITANCE BRIDGE

FEATURES:

- 0.01% direct-reading accuracy; comparison accuracy, one ppm.
- 6-figure resolution for capacitance; one ppm for dissipation factor.
- Wide capacitance range — 10^{-5} pF to $11 \mu\text{F}$.
- Loss can be measured as either dissipation factor or conductance.
- Lever-type balance controls.
- In-line readout in *C*, *D*, and *G* with automatically positioned decimal point.
- Makes both 2- and 3-terminal measurements.
- Low terminal at ground for 2-terminal measurements.

USES: Accurate and precise measurements of capacitance and dissipation factor.

Measurement of circuit capacitances.

Dielectric measurements.

Intercomparison of capacitance standards differing in magnitude by as much as 1000:1.

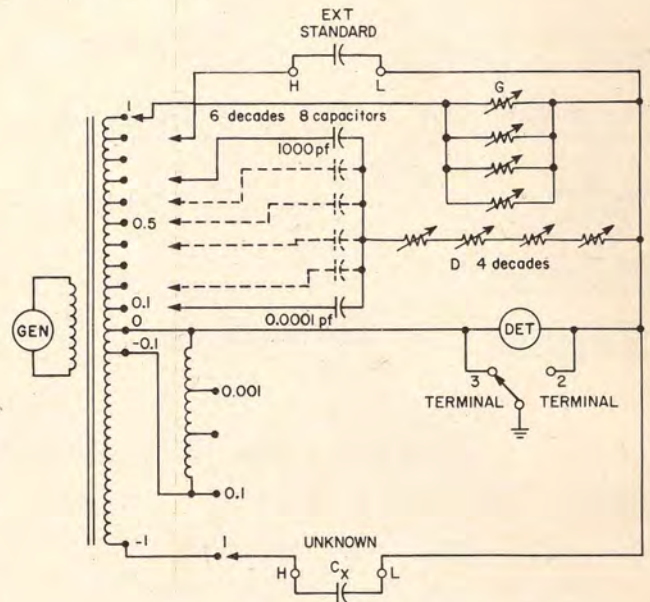
DESCRIPTION: High accuracy is achieved through the use of precisely wound transformer ratio arms and highly stable standards. The standards are fabricated from Invar and are hermetically sealed in nitrogen. Eight standard capacitors are used, in decade values from 1000 pF to 0.00001 pF. The internal standards can be easily compared with one another.

The circuit, shown here in elementary form, is also clearly delineated on the panel. Changes in connections and grounds are automatically indicated as the bridge terminals are switched for different measurement conditions.

The loss balance can be made in terms of either dissipation factor or conductance.

The impedance of the transformer ratio arms has been kept very low, so that accurate three-terminal measurements can be made even in the presence of capacitances to ground as large as $1 \mu\text{F}$. Accurate measurements can be made with the unknown connected by means of long cables. The bridge has the necessary internal shielding to permit one terminal of the unknown to be directly grounded, so that both true two-terminal and three-terminal measurements can be made over the whole capacitance range.

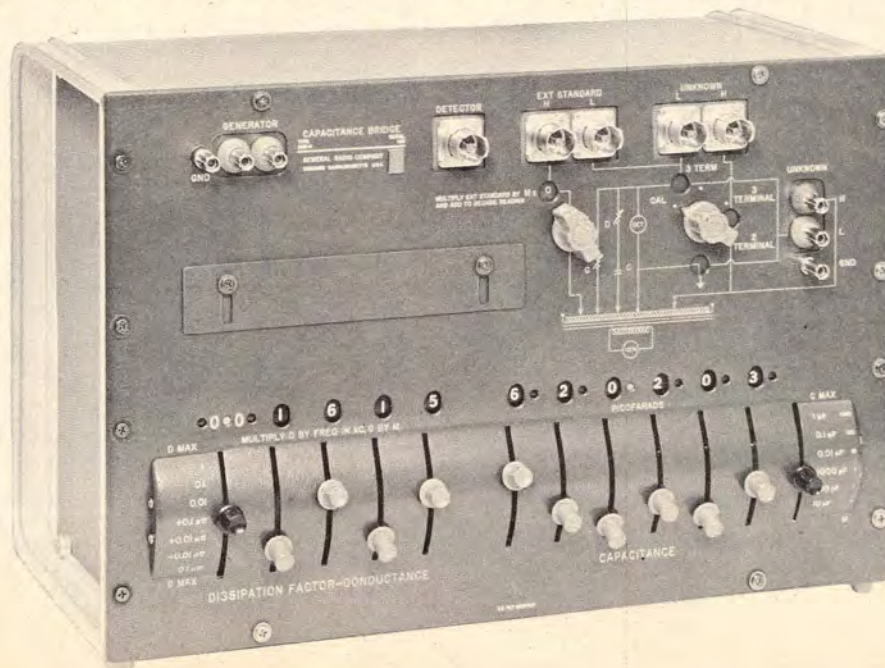
For both capacitance and dissipation factor, the balance controls are smoothly operating, lever-type



Elementary schematic diagram of the capacitance bridge.

switches. The readout is digital, and the decimal point is automatically positioned. Each capacitance decade has a -1 position to facilitate rapid balancing.

The TYPE 1615-A Capacitance Bridge brings to the measurement of capacitance, to the intercomparison of standards, and to the measurement of dielectric properties an unusual degree of accuracy, precision, range, and convenience.



TYPE 1615-P1 RANGE-EXTENSION CAPACITOR

This plug-in 0.01- μ F unit extends the capacitance range of the TYPE 1615-A Capacitance Bridge by a factor of 10 to a maximum of 11.11110 μ F. It plugs

into the EXT STD terminals of the bridge and its trimmer is then adjusted to agreement with the bridge internal standards.

Dimensions: Diameter $3\frac{1}{16}$, length $4\frac{7}{8}$ in (78, 125 mm).
Net Weight: 1 lb (0.5 kg); **Shipping Weight:** 3 lb (1.4 kg).

SPECIFICATIONS

RANGES OF MEASUREMENT

Capacitance, 10 aF to 1.11110 μ F (10^{-17} to 10^{-6} farad) in 6 ranges, direct-reading, 6-figure resolution; least count 10^{-17} F (10 aF). With Range-Extension Capacitor, upper limit is 11.11110 μ F.

Dissipation Factor, D, At 1 kc/s, 0.000001 to 1, 4-figure resolution; least count, 0.000001; range varies directly with frequency.

Conductance, G, 10^{-6} μ S to 100 μ S, 2 ranges +, 2 ranges -, 4-figure resolution, least count 10^{-6} μ S independent of frequency; range varies with C range.

FREQUENCY: Approx 50 c/s to 10 kc/s. Useful with reduced accuracy to 100 kc/s. Below 100 c/s, resolution beyond 0.01% or 0.01 pF may require special detectors.

GENERAL

Standards: Hermetically sealed in nitrogen; 1000, 100, 10, 1, 0.1, 0.01, 0.001, 0.0001 pF. Temperature coefficient of capacitance is less than 5 ppm/ $^{\circ}$ C for the 1000-, 100-, and 10-pF standards, slightly greater for the smaller units.

Generator: External only (not supplied). TYPE 1310-A or TYPE 1311-A Audio Oscillator recommended. Max safe generator voltage $30 \times f_{kc}$ V, 300 V max. If generator and detector connections are interchanged, 150 to 500 V can be applied, depending on switch settings.

Detector: External only (not supplied). TYPE 1232-A Tuned Amplifier and Null Detector recommended.

ACCURACY

At 1 kc/s, $\pm(0.01\% + 0.00003 \text{ pF})$. At higher frequencies and with high capacitance, additional error is $[\pm 2 \times 10^{-5}\% + 2 \times 10^{-3}\% (C_{\mu F}) \pm 3 \times 10^{-7} \text{ pF}] \times f_{kc}^2$.

At lower frequencies and with low capacitance, accuracy may be limited by bridge sensitivity.

Comparison, accuracy, unknown to external standard, 1 ppm.

$$\pm[0.1\% \text{ of measured value} + 1 \times 10^{-5} (1 + f_{kc})]$$

$$\pm[1\% \text{ of measured value} + (1 \times 10^{-5} + 6 \times 10^{-2} f_{kc}^2 C_{\mu F}) \mu S]$$

Accessories Supplied: TYPE 874-WO Open-Circuit Termination, TYPE 874-R22A Patch Cord, TYPE 274-NL Patch Cord.

MECHANICAL DATA Rack-Bench Cabinet (see page 258)

Model	Width		Height		Depth		Net Weight		Shipping Weight	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Bench	19	485	12 $\frac{3}{4}$	325	10 $\frac{1}{2}$	270	38 $\frac{1}{2}$	17.5	58	27
Rack	19	485	12 $\frac{1}{4}$	315	8 $\frac{1}{2}$ *	220	38 $\frac{1}{2}$	17.5	58	27

* Behind panel.

For a more detailed description, see *General Radio Experimenter*, September 1962.

Catalog Number	Description	Price
1615-9801	Type 1615-A Capacitance Bridge, Bench Model	\$1475.00
1615-9811	Type 1615-A Capacitance Bridge, Rack Model	1475.00
1615-9601	Type 1615-P1 Range-Extension Capacitor	35.00

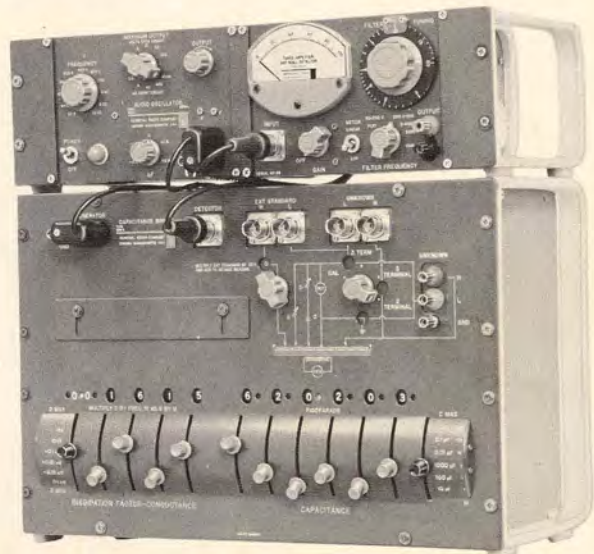
PATENT NOTICE. See Note 4, page 11.

Type 1620-A CAPACITANCE-MEASURING ASSEMBLY

The TYPE 1620-A Capacitance-Measuring Assembly consists of the TYPE 1615-AM Capacitance Bridge with the TYPE 1311-A Audio Oscillator and the TYPE 1232-A Tuned Amplifier and Null Detector, thus providing a complete system for the precise measurement of capacitance over the range of 10 aF to 1 μ F (10^{-17} to 10^{-6} farad). Frequency range is approximately 50 c/s to 10 kc/s. The sensitivity of the system provides resolution beyond 0.01% except for measurements of capacitors above 0.1 μ F and below 100 pF at frequencies below 100 c/s.

Oscillator and detector are mounted side by side as shown in the photograph. The end frames are bolted together to make a rigid assembly without the use of a relay rack. Connection cables are supplied.

The oscillator operates from the power line, the detector from internal batteries.



Catalog No.	Description	Price
1620-9701	Type 1620-A Capacitance-Measuring Assembly	\$2090.00



Type 716-C CAPACITANCE BRIDGE

- FEATURES:** ■ Wide frequency range, 30 c/s to 300 kc/s. ■ Direct-reading dials. ■ Convenient to operate. ■ Flexible in application.

USES: This direct-reading bridge measures capacitance and dissipation factor by either direct or substitution method. It can measure 3-terminal capacitance by addition of the TYPE 716-P4 Guard Circuit.

It is well suited to the measurement of the dielectric properties of insulating materials — dielectric constant, dissipation factor, loss factor, phase angle — and their change with frequency, temperature, and humidity.

By substitution methods it can measure capacitance beyond the range of the internal standards, the inductance and *Q* of large inductors, the inductance and resistance of cables, the resistance and parallel capaci-

tance of high-valued resistors, and the conductance and parallel resistance of electrolytes.

DESCRIPTION: The TYPE 716-C Capacitance Bridge is a modified Schering bridge. To obtain a wide and direct-reading capacitance range at 1 kc/s, the ratio arms are switched to give decade multipliers of 1 to 1000. At other frequencies, the maximum direct-reading capacitance is that of the internal standard, which is a worm-driven, precision, variable capacitor. Careful shielding to eliminate the effects of stray capacitance permits a direct-reading accuracy of 0.1%.

SPECIFICATIONS

RANGES OF MEASUREMENT	ACCURACY At 30 c/s to 300 kc/s
Capacitance (direct-reading) 100 pF to 1.1 μF at 1 kc/s; 100 pF to 1150 pF at 100 c/s, 10 kc/s, and 100 kc/s.	±0.1% ±(0.6 pF × capacitance multiplier setting) when <i>D</i> < 0.01. Residual <i>C</i> is approx 1 pF.
Capacitance (substitution) 0.1 pF to 1050 pF with internal standard. 0.1 pF up to value of available standard with external standard.	±1.2 pF. Correction chart for the precision capacitor is supplied, which allows a substitution measurement accuracy of ±0.05% or ±0.6 pF. With additional precision calibration of standard capacitor, ±0.05% or ±0.2 pF.
D (direct reading) 0.00002 to 0.56	±0.0005 or ±2% of dial reading, whichever is larger.
D (substitution) 0.00002 to 0.56 × $\frac{C_{STD}}{C_{UNK}}$	±0.00005 or ±2% for the change in <i>D</i> when the change is less than 0.06. Corrections are supplied for greater <i>D</i> 's.

GENERAL

Temperature and Humidity Effects: Bridge accuracy not significantly affected by variations of temperature from 65 to 95°F. Precise measurements of dissipation factor should not be attempted when the bridge has been exposed to abnormally high relative humidity, unless it is first dried by heat or a desiccant.

Generator: External only (not supplied); 30 c/s to 300 kc/s; 1 W max, which allows 200 V at 1 kc/s or 50 V at 60 c/s. If generator and detector connections are interchanged, 700 V can be applied at 1 kc/s and lower. TYPE 1311-A or 1310-A Oscillator recommended.

Detector: External only (not supplied). TYPE 1232-A Tuned Amplifier and Null Detector recommended for audio range; for higher frequencies, add TYPE 1232-P1 Mixer and local oscillator.

Accessories Supplied: TYPE 274-NL Shielded Patch Cord, TYPE 874-R34 Patch Cord.

Accessories Available: TYPE 1422 Precision Capacitor and TYPES 505, 1409, and 1401 Fixed Capacitors as balancing capacitors for substitution measurements. TYPE 1690-A Dielectric Sample Holder for dielectric measurements. TYPE 716-P4 Guard Circuit for 3-terminal measurements.

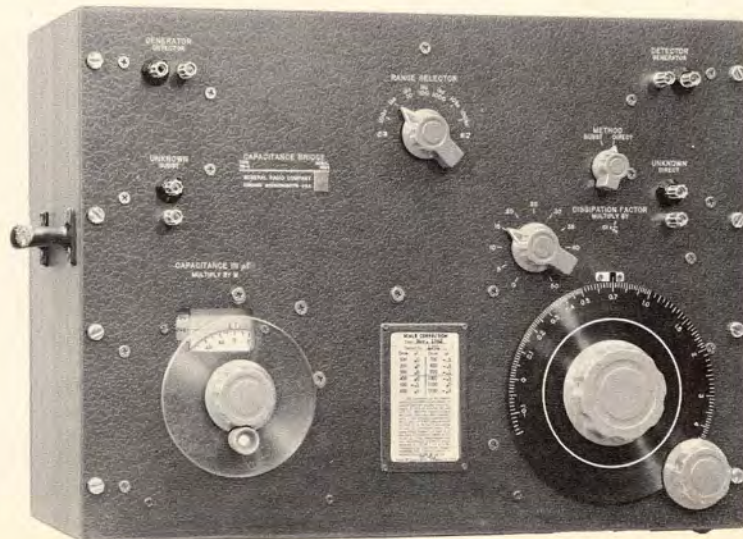
MECHANICAL DATA Wood Cabinet or Relay Rack (see page 258)

Model	Width		Height		Depth		Net Wt		Ship Wt	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Cabinet	21 3/4	555	14 1/4	365	11 1/4	290	40 1/2	18.5	55	25
Rack	19	485	14	360	9*	230	30 1/2	14	45	20.3

* Behind panel.

See also *General Radio Experimenter*, April 1947.

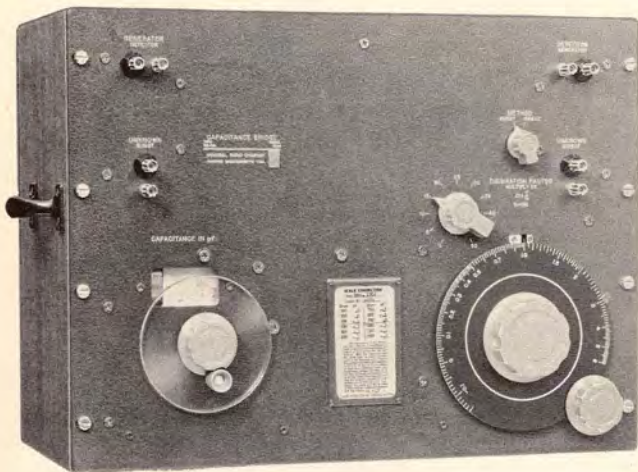
Catalog Number	Description	Price
0716-9803	Type 716-C Capacitance Bridge, Cabinet Model	\$875.00
0716-9483	Type 716-CP Capacitance Bridge, with Precision Calibration, Cabinet Model	925.00
0716-9813	Type 716-C Capacitance Bridge, Rack Model	835.00
0716-9484	Type 716-CP Capacitance Bridge, with Precision Calibration, Rack Model	885.00





Type 716-CS1 CAPACITANCE BRIDGE

SPECIFICATIONS



FOR CAPACITANCE MEASUREMENTS UP TO 1150 pF AT 1 Mc/s

Both commercial and military specifications for capacitors of 1000 pF and less call for measurements of capacitance and dissipation factor at a frequency of 1 Mc/s. The TYPE 716-CS1 Capacitance Bridge has been designed specifically for these measurements. It is also satisfactory for measuring dielectrics with the TYPE 1690-A Dielectric Sample Holder at the ASTM test frequency of 1 Mc/s.

This bridge, a modification of the standard TYPE 716-C model, has a single capacitance range and a more limited frequency range.

Ranges of Measurement:

Capacitance — Direct-reading, 100 to 1150 pF; substitution, 0.1 to 1050 pF.

Dissipation Factor — Same as TYPE 716-C.

Accuracy: At 1 Mc/s, same as stated for TYPE 716-C at 1 kc/s. Same accuracy can be obtained from 0.1 to 3 Mc/s if corrections are made for effects of residual impedances and if adequate selectivity is provided by null detector. Correction charts are supplied. Useful to 5 Mc/s with reduced accuracy.

Generator: External only (not supplied); TYPE 1214-M Unit Oscillator recommended for measurements at 1 Mc/s only. TYPE 1211-C Unit Oscillator recommended for measurements over range of 0.5 to 3 Mc/s.

Detector: External only (not supplied); TYPE 1212-A Unit Null Detector with TYPE 1212-P2 1-Mc Filter recommended for measurements at 1 Mc/s only. TYPE 1232-A Tuned Amplifier and Null Detector with TYPE 1232-P1 Mixer and a local oscillator recommended for measurements at frequencies other than 1 Mc/s.

Accessories Supplied: 2 TYPE 874-R34 Patch Cords, to fit the above generators and detectors.

Accessories Available: TYPE 1422 Precision Capacitor and TYPES 505, 1409, and 1401 Capacitors as balancing capacitors for substitution measurements. TYPE 1690-A Dielectric Sample Holder for dielectric measurements.

Other specifications same as those for standard TYPE 716-C.

See also *General Radio Experimenter*, February 1952.

Catalog No.	Description	Price
0716-9843	Type 716-CS1 Capacitance Bridge, Cabinet Model	\$800.00
0716-9485	Type 716-CS1P Capacitance Bridge, with Precision Calibration, Cabinet Model	850.00
0716-9846	Type 716-CS1 Capacitance Bridge, Rack Model	760.00
0716-9486	Type 716-CS1P Capacitance Bridge, with Precision Calibration, Rack Model	810.00

PATENT NOTICE. See Note 4, page 11.

See page 58 for complete assemblies of bridge, generator, detector, and guard circuit.

Type 716-P4 GUARD CIRCUIT

The guard circuit facilitates three-terminal measurements of capacitors, such as guarded dielectric samples at frequencies up to 300 kc/s. It is particularly useful in the measurement of components and materials over

wide ranges of frequency, temperature, and humidity, because it eliminates from the measurement the effects of the leads from the bridge to the sample.

SPECIFICATIONS

Capacitance Range: Designed for use with the 1-multiplier range, 100–1150 pF, of the TYPE 716-C Capacitance Bridge. The range can be extended by the addition of external capacitance to the standard arm of the bridge.

Frequency Range: 30 c/s to 300 kc/s.

Guard Balance Capacitor: Any value of capacitance up to 1000 pF between the guard point and the high measuring terminal can be balanced out.

Accessories Supplied: One TYPE 874-Q2 Coaxial Adaptor and one TYPE 838-B Alligator Clip.

Mechanical Data: Wood Cabinet or Relay Rack (see page 258)

Model	Width		Height		Depth		Net Weight		Shipping Weight	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Cabinet	19	485	9 1/8	235	8 3/4	225	23	10.5	37	17
Rack	19	485	8 3/4	225	7 1/2*	190	17	8	29	13.5

* Behind panel.

Catalog No.	Description	Price
0716-9943	Type 716-P4 Guard Circuit, Cabinet Model	\$350.00
0716-9945	Type 716-P4 Guard Circuit, Rack Model	330.00

PATENT NOTICE. See Note 4, page 11.





Type 1610 CAPACITANCE-MEASURING ASSEMBLIES

USES: Each TYPE 1610 Capacitance-Measuring Assembly is a complete system for the measurement of capacitance and dissipation factor by either direct or substitution methods.

DESCRIPTION: The TYPE 1610-B Capacitance-Measuring Assembly, which includes a guard circuit, makes both 2-terminal and 3-terminal measurements over the frequency range of 20 c/s to 100 kc/s. Thus it is well suited for studies of the frequency characteristics of dielectric samples and components in conditioning chambers.

When only 2-terminal measurements are to be made, the guard circuit is unnecessary, and the TYPE 1610-B2 Capacitance-

Measuring Assembly, which covers the same frequency range, is used.

The TYPE 1610-AH Capacitance-Measuring Assembly is used for 2-terminal measurements at 1 Mc/s. The Dielectric Sample Holder, TYPE 1690-A (page 66), is recommended for use with any of these assemblies in the measurement of solid-dielectric specimens. All assemblies include cabinet rack, rack adaptor panels, connecting cables, spare fuses, and power cord.

SPECIFICATIONS

RANGES OF MEASUREMENT		Type 1610-B	Type 1610-B2	Type 1610-AH
Frequency		20 c/s to 20 kc/s, 50 kc/s, 100 kc/s		1 Mc/s
C	Direct, 2-terminal	100 pF to 1.1 μf at 1 kc/s; 100 pF to 1150 pF at other frequencies		100 pF to 1150 pF
	Substitution, 2-terminal	0.1 pF to 1050 pF		
	Direct, 3-terminal	100 pF to 1150 pF		
	Substitution, 3-terminal	0.1 pF to 1050 pF		
D	Direct	0.0002 to 0.56		
	Substitution	0.0002 to 0.56 multiplied by C_{STD}/C_{UNK}		

ACCURACY, NOMINAL

Capacitance: ±0.1%. Dissipation Factor: ±2% of dial. For complete statement, see bridge specifications.

GENERAL

	105 to 125 volts,† 50 to 60 c/s*		
	50 watts	50 watts	100 watts
Power Supply	105 to 125 volts,† 50 to 60 c/s*		
Dimensions	Width 22½, height 43, depth 20 inches (570, 1090, 510 mm), over-all		
Net Weight	203 pounds (93 kg)	180 pounds (83 kg)	150 pounds (69 kg)
Shipping Weight	280 pounds (128 kg)	260 pounds (119 kg)	241 pounds (111 kg)
Catalog Number	1610-9702	1610-9422	1610-9817
Price	\$1970.00	\$1620.00	\$1350.00

* Assembly will operate satisfactorily at power-supply frequencies up to 400 c/s, provided that supply voltage is at least 115 V.

† TYPE 1610-BQ18 for 210- to 250-V, 50- to 60-cycle supply. Catalog Number: 1610-9818. Price: \$1975.00.

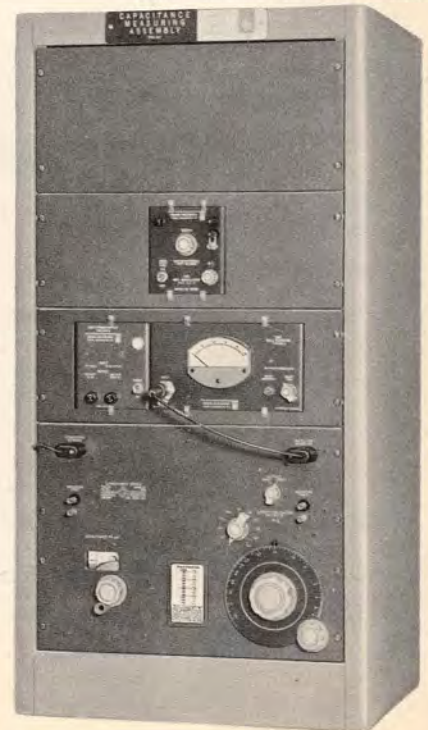
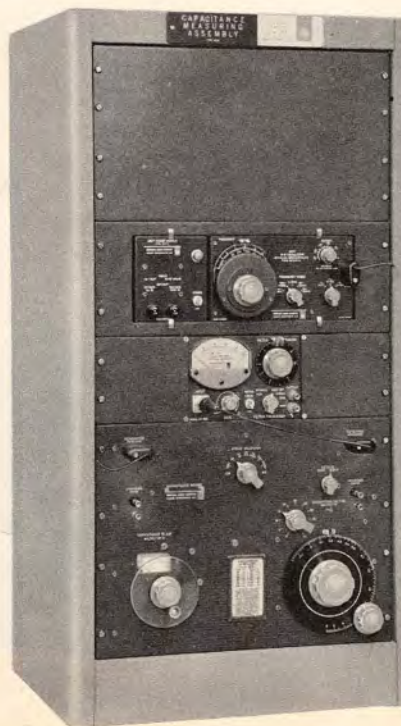
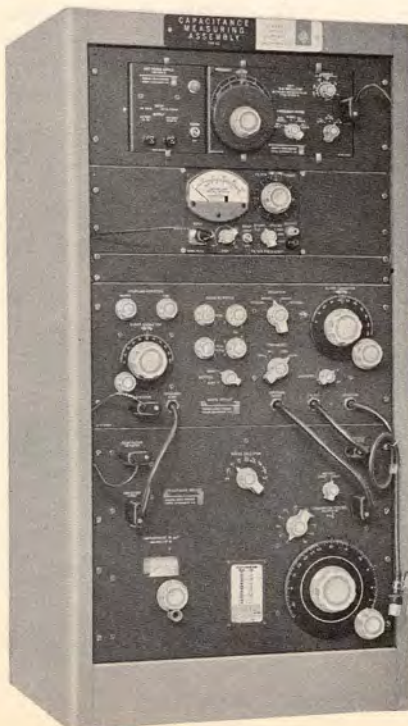
TYPE 1610-B2Q18 for 210- to 250-V, 50- to 60-cycle supply. Catalog Number: 1610-9482. Price: \$1625.00.

PATENT NOTICE. See Notes 4 and 15, page 11.

Type 1210-C Unit R-C Oscillator
 Type 1203-B Unit Power Supply
Type 1610-B Type 1232-A Null Detector
 Type 716-P4 Guard Circuit
 Type 716-C Capacitance Bridge

Type 1210-C Unit R-C Oscillator
 Type 1203-B Unit Power Supply
Type 1610-B2 Type 1232-A Null Detector
 Type 716-C Capacitance Bridge

Type 1214-M Unit Oscillator
 Type 1212-A Unit Null Detector
Type 1610-AH Type 1212-P2 1-Mc Filter
 Type 1203-B Unit Power Supply
 Type 716-CS1 Capacitance Bridge



Type 1680-A AUTOMATIC CAPACITANCE BRIDGE ASSEMBLY



FEATURES:

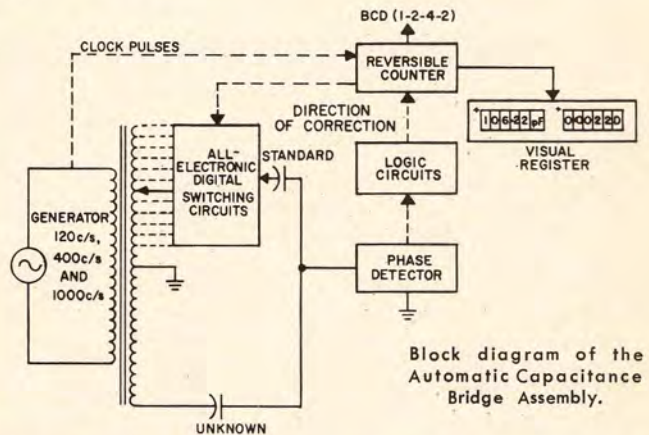
- Completely automatic — selects range, makes balance, presents digital output data, displays values of both capacitance and dissipation factor (or conductance) with proper decimal point and units on illuminated indicators.
- Accurate — $\pm 0.1\%$ of reading.
- A true bridge circuit; both capacitance and loss are balanced simultaneously. Accuracy ensured by stable, passive standards.
- Fast — completes balance in 0.5 second at 1 kc/s under worst conditions — can continuously track small changes.
- Wide range — 0.01 pF to 1000 μ F.
- Three-terminal, guarded bridge circuit eliminates errors from lead capacitance.
- Modular, plug-in construction; built-in test programs, operated from front panel for rapid checkout and convenient servicing.
- BCD output data, 1-2-4-2 code.

USES: This automatic bridge assembly is an accurate, fast, and economical test device for production and laboratory applications where a great many capacitance measurements are needed. Its range and accuracy cover most capacitor-measurement requirements.

In component-inspection applications, measurement rate is up to ten times faster than is possible with manually balanced bridges. A simple test fixture, the TYPE 1680-P1, is available for rapid manual connection of capacitors. With a suitable limit comparator, automatic testing and sorting are possible.

In capacitor production applications, this bridge can be used as an integral part of automatic manufacturing processes to monitor production automatically.

In qualification testing, quality control, and reliability studies, freedom from stray-capacitance effects permits accurate measurements at the end of long cables, such as those necessary to connect to capacitors in environmental chambers. Lead resistance is negligible in the measurement of all but very large capacitors (see accuracy curves). Control and output signals are provided for use in data-acquisition systems that include scanners and automatic data-logging equipment such as card punches, tape punches, and electric typewriters.



Block diagram of the Automatic Capacitance Bridge Assembly.

For fastest measurements of capacitors that differ widely in value from unit to unit.

HOLD RANGE — Prevents bridge from dropping to lower ranges. Retains a common decimal-point location for ease in comparison of a series of recorded values.

TRACK CONTINUOUS — Tracks changing capacitance and loss, supplying a continuous indication of the values of the coefficient detector.

AUTOMATIC RANGE — Provides fully automatic range switching as well as automatic balancing.

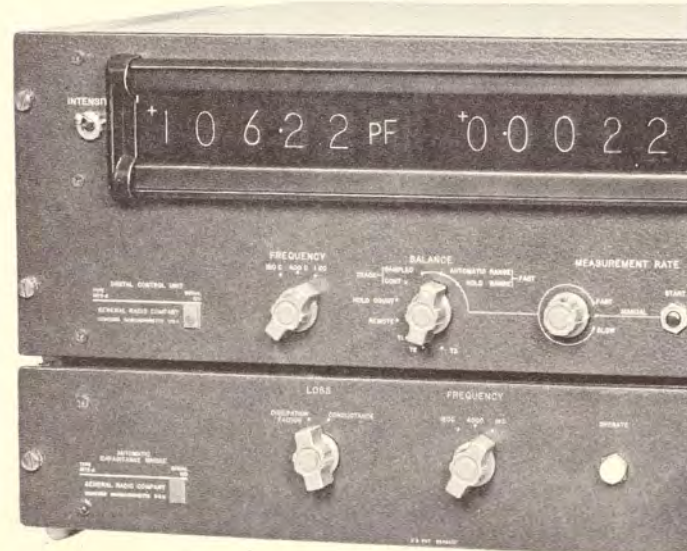
the unknown — useful for temperature-termination and similar measurements.
AMPLIFIED — Like the TRACKING-CONTINUED tracks changing C and D but balances

of the values of the coefficient detector.
TRACK SA...
TINUOUS mode,



NEW

in catalog S



Type 1680-A Automatic Capacitance Bridge Assembly

CAPACITANCE BRIDGES

and supplies indication only on command, as set either by a front-panel control or remotely. For fastest measurement of components near a fixed value, as in sorting.

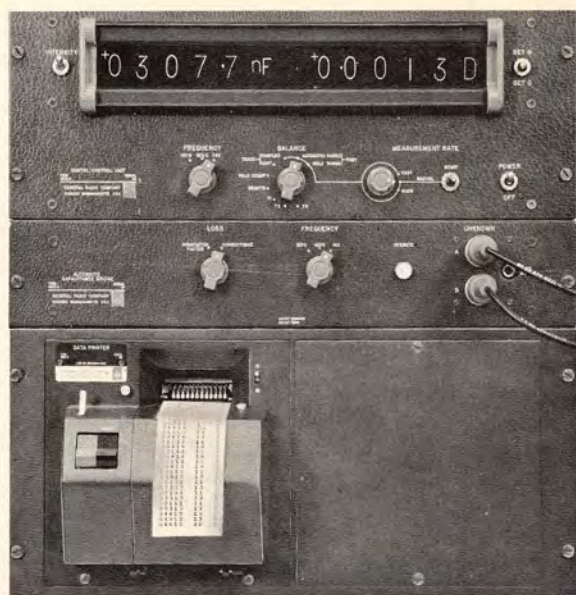
Additional switch positions (T1, T2, and T3) are provided for use in checking internal operations.

ACCESSORY EQUIPMENT

Output and control signals are provided for use with data-logging systems. A suitable data printer is listed on the next page and completely described on page 183. For analog plotting, a digital-to-analog converter and a graphic level recorder are described on page 182. Systems for limit comparison, punched cards, and punched-tape output are available. Inquiries are invited for systems incorporating such auxiliary devices.

DESCRIPTION: The Automatic Capacitance Bridge Assembly is a fully automatic, all-solid-state, three-terminal, capacitance bridge. It is a true bridge, relying on stable, passive standards for its accuracy. The bridge not only provides four different operating modes to fit a variety of measurement requirements but also includes built-in test programs for rapid, convenient checkout of all internal circuit modules.

The circuit is a transformer-ratio-arm bridge (see diagram). It is in balance when the currents through the standard capacitor and the unknown capacitor are equal so that the current in the phase detector is zero. The range is chosen automatically by dry-reed and mercury-wetted relays, which select decade taps on a ratio transformer. The phase detector determines whether the current passing through the unknown arm of the bridge is higher or lower than that through the standard arm and produces an error signal, which indicates whether more or less voltage is required on the standard capacitor to reach a balance. This information is used by a reversible counter, which controls, through electronic switching circuits, the voltage on the standard capacitor. The counter counts in a direction to minimize the error signal until balance is reached. At balance, the value of the unknown is displayed on an in-line digital readout, which indicates capacitance, dissipation factor or conductance, decimal points, and units. This information is also presented in binary-coded-decimal form for use with printers and other data-handling equipment.



The Type 1680-A Automatic Capacitance Bridge Assembly with the Type 1137-A Data Printer.

Components in the automatic capacitance bridge are arranged in modules consisting of plug-in, fiber-glass-epoxy, etched-circuit boards. A malfunction can be readily traced to an individual module by means of the internal test programs. The defective module can then be removed and serviced, or replaced, with minimum down time.

The TYPE 1680-A Automatic Capacitance Bridge Assembly is the first in a series of GR automatic bridges. It is constructed in two parts, the TYPE 1672-A Digital Control Unit, which has most of the logic and digital circuitry, and the TYPE 1673-A Automatic Capacitance Bridge, which contains the bridge circuits. This system permits other bridges to be added to or substituted for the capacitance bridge as they become available. Thus, the utility of the Digital Control Unit can be extended to cover a wide range of measurement applications.

SPECIFICATIONS

		At 120 c/s	At 400 c/s	At 1000 c/s
RANGES	Capacitance (parallel)*:	100 pF-1000 μ F	0.01 pF-100 μ F	0.01 pF-100 μ F
	Conductance (parallel):	0.1 μ mho-1.0 mho	100 pmho-1.0 mho	100 pmho-1.0 mho
	Dissipation Factor (direct reading) (Measured as conductance):	0.0001-1.00 (100%) 0 to ∞	0.0001-1.00 (100%) 0 to ∞	0.0001-1.00 (100%) 0 to ∞
BASIC ACCURACY (see curves)	Capacitance:	0.1% of reading	0.1% of reading	0.1% of reading
	Conductance:	0.1% of reading	0.1% of reading	0.1% of reading
	Dissipation Factor:	1% of reading	1% of reading	1% of reading
SPEED OF BALANCE (approx) (Speed may be somewhat slower than that listed when dissipation factor is measured near the low end of each range.)	Fast Modes:			
	No range changes	2.5 seconds	0.35 second	0.25 second
	With range changes	5.0 seconds	0.6 second	0.5 second
	Tracking Modes:			
	10-count change	1.0 second	0.1 second	0.1 second
	100-count change	2.0 seconds	0.35 second	0.2 second
1000-count change	11.0 seconds	2.6 seconds	1.1 seconds	

* For series capacitance measurements a correction (chart supplied) can be used: If $D_x = 0.1$ (10%), correction = 1%.
If $D_x = 0.03$ (3%), correction = 0.1%.

EFFECTS OF LEADS: There is no error introduced by stray capacitance if shielded cables are used. Series resistance of leads can cause errors on the highest range. Accuracy curves include the effects of up to 50 mΩ of external cable.

VOLTAGE ACROSS UNKNOWN: 1 V on lower capacitance ranges, decreasing to 1 mV on highest range. Can be set (internally) as low as 1/10 of these values with a proportionate loss in resolution.

DISPLAY: Two 5-digit banks of bright-light, numerical indicators, with decimal points and units of measurement. Lamp burnout does not affect instrument operation or coded output. Lamps can be replaced from front panel.

DC BIAS: Can be introduced from external source.

REMOTE CONTROL: Start and balance controls can be activated remotely by contact closures.

OUTPUT SIGNALS

Numerical Data: 10 digits BCD 1-2-4-2 code.

Range Code (1 to 7): 1 digit BCD 1-2-4-2 code.

Print Command at Completion of Balance: Change from "1" level to "0" level — returns to "1" level at end of display interval.

Signal Levels: "1" level, 0 V; "0" level, -12 V; both with respect to reference line, which is at +6 V above chassis ground. Impedance of lines = 12 kΩ.

MEASUREMENT RATE: Panel control allows adjustment of measurement rate so that display time between measurements is between approximately 0.1 and 5 s. The rate can be set manually (or remotely) at any rate compatible with balance time.

OPERATION AT OTHER MEASUREMENT FREQUENCIES: With internal modification, the measurement frequencies can be changed to any frequency between 100 c/s and 2 kc/s.

DIFFERENCE MEASUREMENTS: By the addition of a suitable standard to terminals provided, the bridge can be made to indicate the deviation, either positive or negative, from a nominal value.

Accessory Type 1680-P1 Test Fixture facilitates connection of capacitors to the bridge. Capacitor leads are inserted in the clips and the bridge balances when bar marked PRESS is pressed.



GENERAL

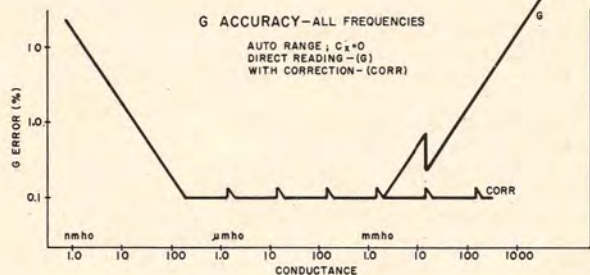
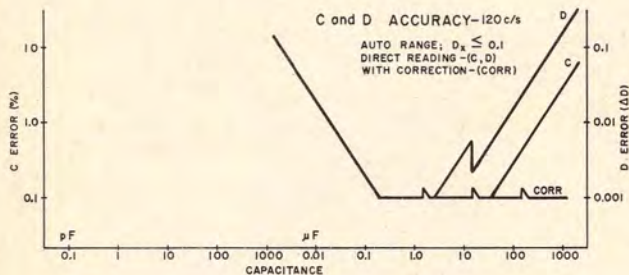
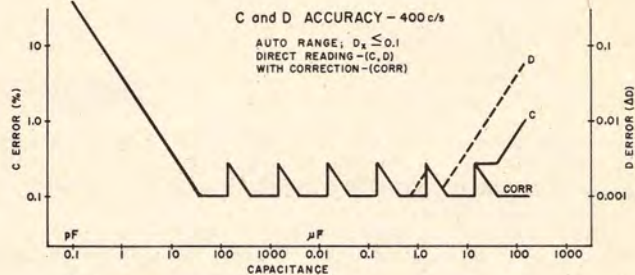
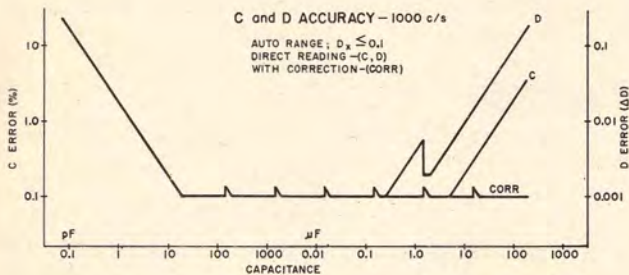
Power Required: 105 to 125 V, 195 to 235, or 210 to 250 V, 50 to 60 c/s, 100 W. Internal 120-cycle oscillator is locked to power line for 60-cycle operation.

Auxiliary Controls: A rear-panel sensitivity control can be used to minimize balance time by a decrease in resolution.

Mechanical Data: The Automatic Capacitance Bridge Assembly consists of two components, TYPE 1672-A Digital Control Unit and TYPE 1673-A Automatic Capacitance Bridge. End frames for bench mount (see photo) and hardware for rack mount are both supplied.

Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
19	485	10½	270	18*	460	71	33	145	67

* Behind panel.



Catalog Number	Description	Price
1680-9701	Type 1680-A Automatic Capacitance Bridge Assembly	\$4850.00
1137-9744	Type 1137-A Data Printer,** 6-column BCD, Rack Model	1565.00
1136-9502	Type 1136-A Digital-to-Analog Converter,† Rack Model	680.00
1680-9601	Type 1680-P1 Test Fixture	75.00

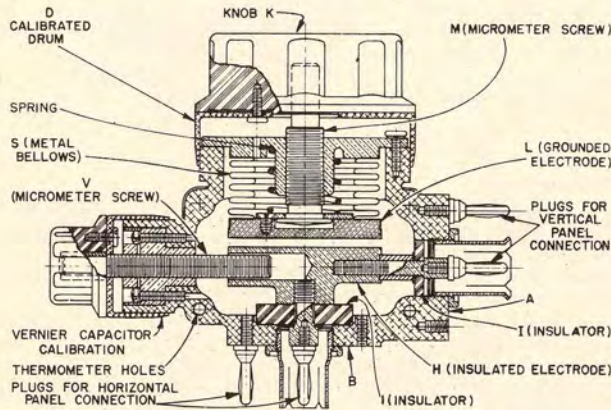
** See page 183. † See page 182.
 PATENT NOTICE. See Notes 4 and 8, page 11.



Type 1690-A DIELECTRIC SAMPLE HOLDER

FEATURES:

- Specimens can be measured over a wide range of frequencies with the same holder in different measuring circuits.
- Precision calibration provided for each unit.
- Calibration takes account of corrections for edge fringing and stray capacitance.
- Rigid casting supports entire structure. ■ Complete shielding.
- Large, easily read dials.



USES: The TYPE 1690-A Dielectric Sample Holder is a micrometer-driven sample holder of the Hartshorn type,* used for the measurement of dielectric constant and dissipation factor of specimens of dielectric materials in the form of standard ASTM 2-inch diameter disks. It is suitable for any flat sample whose largest dimen-

*L. Hartshorn and W. H. Ward, *Proceedings of the Institution of Electrical Engineers*, Vol. 79, pp. 597-609 (1936).

sion is not over 2 inches and whose thickness is not over 0.3 inch.

It can be used with resonant circuits for susceptance-variation or frequency-variation measurements, with the TYPES 1615-A, 716-C and 716-CS1 Capacitance Bridges, the TYPES 874-LBA and 900-LB Slotted Lines, and the TYPE 1602-B UHF Admittance Meter.

A precision micrometer screw, M, with large instrument knob, K, drives the movable grounded electrode, L, with respect to a fixed, insulated electrode, H. An accurately divided drum, D, indicates the electrode spacing. The micrometer screw is electrically shunted by a metal bellows, S, to assure a positive, low-resistance connection. A release mechanism automatically disengages the drive to prevent damage when the electrodes are in contact. The movable electrode adjusts itself to the plane of the specimen surface.

The vernier capacitor with micrometer screw, V, is for use in the susceptance-variation method of measurement.

The assembly is mounted in a rugged aluminum casting, B, which it shields on four sides. Two removable cover plates, which permit access to the electrodes, complete the shielding. The holder can be mounted on either horizontal or vertical panels.

SPECIFICATIONS

Electrodes: Diameter, 2.000 in \pm 0.0025 in. Surfaces ground optically flat within a few wavelengths.

Electrode Spacing: Adjustable from zero to 0.3 in, indicated by micrometer reading in mils.

Vernier: Incremental capacitance is 5 pF, nominal.

Calibration: For main capacitor, a chart gives calculated air capacitance as a function of spacing. Correction curve gives the measured deviations from calculated values over range from 300 mils to 10 mils spacing. In accordance with recommended ASTM practice, calibration is referred to the calculated geometric value at a spacing of 100 mils. Accuracy is $\pm 0.2\% \pm 0.1$ mil.

For vernier capacitor, correction chart is provided, from which capacitance differences can be determined to an accuracy of ± 0.004 pF.

Zero Capacitance: Approximately 11 pF.

Operating Temperature: Up to 100°C.

Frequency: No significant error occurs at frequencies below 100 Mc/s.

Accessories Supplied: TYPE 1690-P1 Adaptor Assembly for mounting to TYPES 1615-A, 716-C and -CS1 Capacitance Bridges; hardware for mounting sample holder on TYPES 1611-B and 1644-A Bridges and TYPE 1862-C Megohmmeter.

Accessories Available: TYPE 1690-P2 Adaptor Assembly to TYPE 874-LBA Slotted Line or TYPE 1602-B UHF Admittance Meter.

Mechanical Data: Carrying and storage case supplied.

Dimensions: 6¼ by 5¾ by 4½ in (160, 150, 115 mm) over-all.

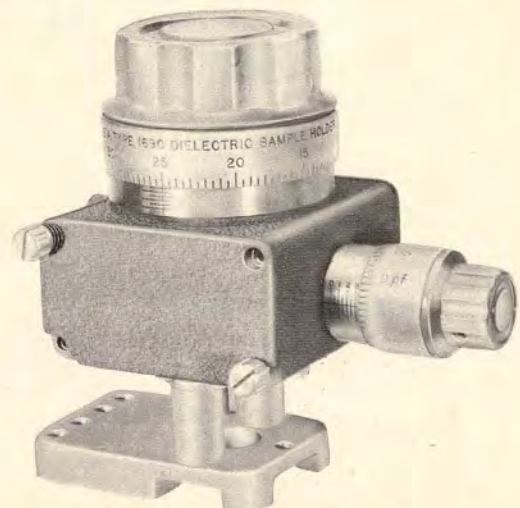
Net Weight: 3¾ lb (1.8 kg), including case.

Shipping Weight: 13 lb (6 kg).

For a more detailed description, see the *General Radio Experimenter*, August 1951.

Catalog No.	Description	Price
1690-9701	Type 1690-A Dielectric Sample Holder	\$435.00
1690-9602	Type 1690-P2 Adaptor Assembly (for connection to coaxial equipment)	20.00

PATENT NOTICE. See Note 4, page 11.



Type 1633-A INCREMENTAL-INDUCTANCE BRIDGE

FEATURES:

- Measures L and R or Q directly at nine frequencies. ■ Wide ranges of measurement.
- High ac and dc power-handling capacity — up to 1250 volts and 50 amperes.
- Dc and ac can be impressed simultaneously on the coil being measured.
- Known induction levels can be set and maintained through a test procedure.
- No sliding balance. ■ Both generator and detector can be grounded.
- Extensive safety precautions have been taken to avoid shock hazard to the operator and damage to the equipment.

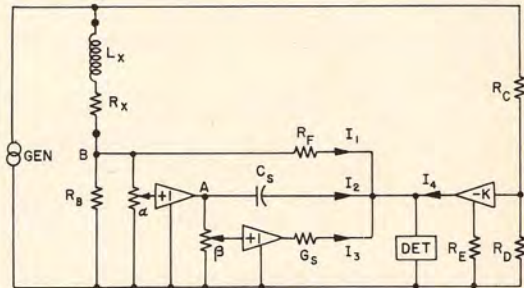
USES: The measurement of incremental inductance, or the inductance of a coil over very wide ranges of dc and ac excitation, is important to both manufacturers and users of silicon steel and other magnetic alloys, ferrites, chokes, transformers, and filters. Such measurements can be made accurately and conveniently with the TYPE 1633-A Incremental-Inductance Bridge. It can also be used to measure nonlinear resistors and the ac impedance, with dc superposed, of rectifiers, Zener diodes, thermistors, and other semiconductor devices. Complete assemblies of bridge and power supplies are listed on page 72.

DESCRIPTION: This bridge uses a new circuit, which includes active elements,* in order to obtain wide operating ranges of inductance and current without the use of excessive numbers of resistance and capacitance decades. For each range a single fixed capacitor and a single resistor are used, and the effect of changing magnitudes is simulated by changes in the applied voltage.

The active elements are three multistage, transistor, feedback amplifiers, designed to have parameters at least an order of magnitude more stable than is required for the desired bridge accuracy. Two are used for isolation, and, with their associated potentiometers, they form variable-voltage sources, with low output impedance, to simulate changes in magnitude of the fixed standards, C_s and G_s . The third amplifier is a phase inverter.

At balance, $I_1 + I_2 + I_3 + I_4 = 0$, and

$$L_x \sim \alpha R_B C_s, \quad R_x \sim \beta R_B G_s, \quad Q \sim \frac{\omega C_s}{\beta G_s}$$

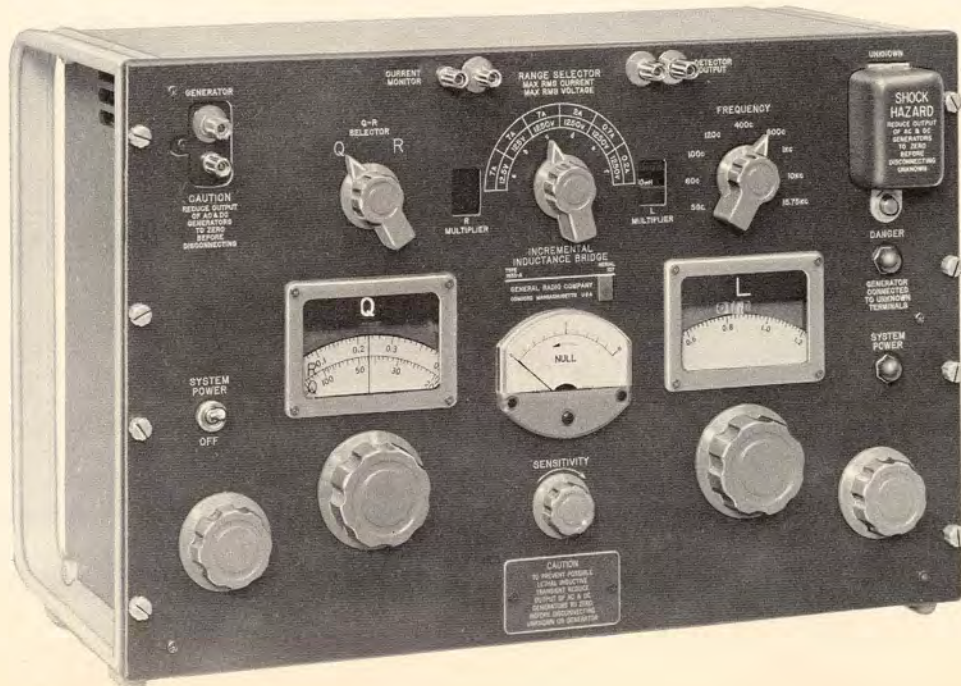


Where α and β = fractions of potentiometer voltage applied to the isolation amplifiers,
 R_B = ratio-arm resistance,
 C_s and G_s = capacitance and conductance standards.

Up to 7 amperes, rms (combined ac and dc), at up to 1250 volts, can be impressed on the sample, and, with a TYPE 1633-P1 Range-Extension Unit, up to 50 amperes. Three power supplies are available, a dc supply, a line-frequency supply, and a variable-frequency oscillator, which are designed specifically for use with the bridge. Most conventional power supplies are not suitable. See Specifications.

The internal detector is highly selective at nine frequencies between 50 c/s and 15.75 kc/s. Owing to high detector sensitivity and low noise, measurements can be made at excitation levels below one volt on the highest inductance ranges and 10 millivolts in the lowest range.

* H. P. Hall, R. G. Fulks, "The Use of Active Devices in Precision Bridges," *Electrical Engineering*, May 1962.



Type 1630 INDUCTANCE-MEASURING ASSEMBLIES



These assemblies are complete systems for the measurement of the inductance and loss of coils with ferromagnetic cores. They are particularly well suited for coil measurements at high levels of dc and ac excitation. Each assembly consists of the Incremental-Inductance Bridge, two power supplies (one dc and one ac), a cabinet-type rack, and the necessary cables for interconnections.

The power supplies can produce 200-voltampere outputs into a wide range of load impedances and are designed to pass the large dc and ac currents required.

Space is provided at the top of the rack for the addition of an oscilloscope, which permits the current waveform or the hysteresis loop to be viewed during the measurements.

TYPE 1630-AL INDUCTANCE-MEASURING ASSEMBLY

For measurements at power-line frequency (50-60 c/s).

Component Units:

TYPE 1633-A Incremental-Inductance Bridge	70	See page
TYPE 1265-A Adjustable Dc Power Supply	222	
TYPE 1266-A Adjustable Ac Power Supply	222	

TYPE 1630-AV INDUCTANCE-MEASURING ASSEMBLY

For measurements at 50, 60, 100, 120, 400, and 800 c/s, and 1, 10, and 15.75 kc/s.

Component Units:

TYPE 1633-A Incremental-Inductance Bridge	70	See page
TYPE 1265-A Dc Power Supply	222	
TYPE 1308-A Audio Oscillator and Power Amplifier	137	

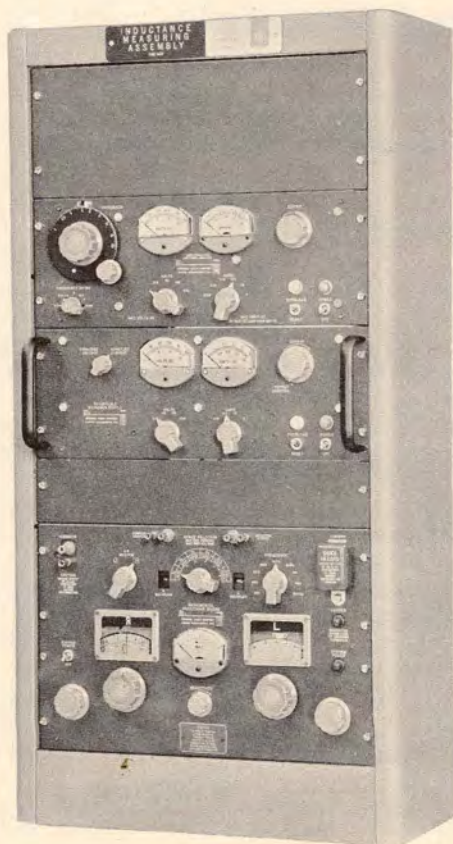
The TYPE 1308-A Audio Oscillator and Power Amplifier provides continuous coverage from 20 c/s to 20 kc/s. When measurements are required at frequencies other than the nine internal-bridge-detector frequencies, the TYPE 1232-A Tuned Amplifier and Null Detector should be used. Order also TYPE 480-P308 Rack Adaptor Set, so that the detector can be installed in the rack.

Mechanical Data:

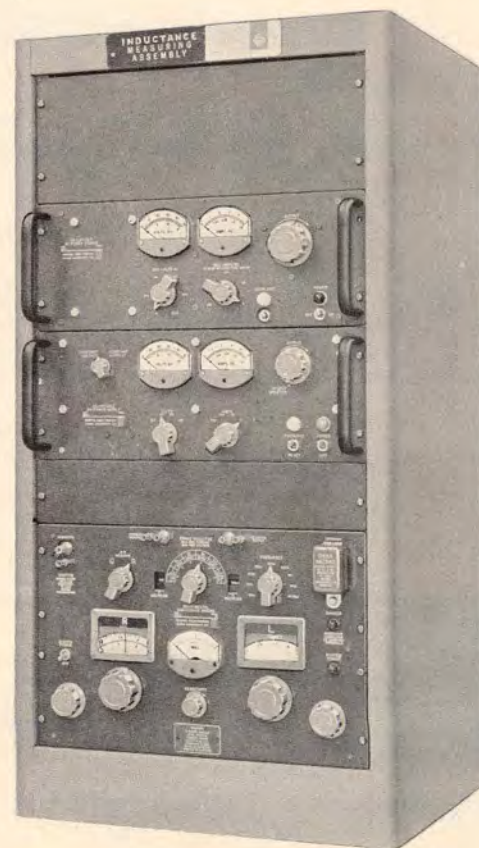
Type	Width		Height		Depth		Net Weight		Shipping Weight	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
1630-AL	22½	580	43	1100	20	510	250	115	400	185
1630-AV	22½	580	43	1100	20	510	310	145	460	215

Catalog Number	Description	Price
1630-9831	Type 1630-AL Inductance-Measuring Assembly	\$2685.00
1630-9827	Type 1630-AV Inductance-Measuring Assembly	3470.00

PATENT NOTICE. See Notes 1 and 15, page 11.



Type 1630-AL



Type 1630-AV

SPECIFICATIONS

RANGES OF MEASUREMENT

ACCURACY

Measurement	Frequency	Full-Scale Ranges						Lowest Scale Division	Accuracy
		a	b	c	d	e	f		
Inductance	50, 60, 100, 120 c/s	10 mH	100 mH	1 H	10 H	100 H	1000 H	20 μH	±(1% of reading or 0.1% of full scale) ±(2π/100 × f _{kc} /Q _x)%
	400, 800, 1000 c/s	1 mH	10 mH	100 mH	1 H	10 H	100 H	2 μH	
	10, 15.75 kc/s	100 μH	1 mH	10 mH	100 mH	1 H	10 H	0.2 μH	
Resistance	All	10 Ω	100 Ω	1 kΩ	10 kΩ	100 kΩ	1 MΩ	10 mΩ	±(2% of reading or 0.1% of full scale) ± $\frac{Q_x f_{kc}}{2\pi} \%$
Q		∞ to 1, direct reading at above frequencies						1000	1/Q accuracy = ±2% ±0.001 ± 0.0005f _{kc}
Max rms volts		12.5	125	1250	1250	1250	1250		
Max rms amperes*		7	7	7	2	0.7	0.2	Max rms current = $\sqrt{I_{dc}^2 + I_{ac}^2}$	

* If application requires more than 7 A, TYPE 1633-P1 Range-Extension Unit, which contains a 0.1-Ω resistor, can be externally connected to shunt R_B on the 3 lowest bridge ranges; inductance and resistance values are then reduced by a factor of 10. With this resistor, measurements up to 50 A, ac or dc, are possible.

GENERAL

Generator: External only (not supplied). For optimum performance when dc bias is used, ac supply must be able to withstand large dc currents in output circuit, and dc supply large ac currents. For dc bias, TYPE 1265-A Adjustable DC Power Supply, 200 W; for line-frequency measurements, TYPE 1266-A Adjustable AC Power Source, 200 VA; over the audio-frequency range, use TYPE 1308-A Audio Oscillator and Power Amplifier, 200 VA.

Detector: Internal or external. Internal, selective at any one of above 9 frequencies ±1%; second-harmonic response about 60 dB below fundamental. External, for continuous coverage from 20 c/s to 20 kc/s, use TYPE 1232-A Tuned Amplifier and Null Detector.

Power Required: 105 to 125 or 210 to 250 V, about 60 W, 50 to 60 c/s.

Accessories Supplied: TYPE CAP-22 Power Cord, spare fuses.

Accessories Available: TYPE 1633-P1 Range-Extension Unit.

MECHANICAL DATA Rack-Bench Cabinet (see page 258)

Model	Width		Height		Depth		Net Weight		Shipping Weight	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Bench	19	485	12¾	325	10¼	260	31	14.5	48	21.8
Rack	19	485	12¼	315	8¾*	225	29	13.2	48	21.8

* Behind panel

For a more detailed description, see *General Radio Experimenter*, May 1962.

FOR COMPLETE MEASUREMENT ASSEMBLIES, SEE NEXT PAGE.

Catalog Number	Description	Price
1633-9801	Type 1633-A Incremental-Inductance Bridge, Bench Model	\$1050.00
1633-9811	Type 1633-A Incremental-Inductance Bridge, Rack Model	1050.00

PATENT NOTICE. See Notes 1 and 15, page 11.

Type 1633-P1 RANGE-EXTENSION UNIT

The TYPE 1633-P1 Range-Extension Unit can be used with the TYPE 1633-A Incremental-Inductance Bridge to extend the current ratings to 50 amperes. It connects a 250-watt, 0.1-ohm resistor in parallel with one of the bridge arms.

High-current terminals capable of accommodating leads up to ¼ inch in diameter are provided on the range-extension unit for the generator and unknown. A cable is furnished for connection to the bridge.



When the range-extension unit is connected, the operation of the bridge is unchanged, but only the a, b, and c ranges can be used. Bridge readings must be multiplied by 0.1. The upper limit of measurement is 100 mH up to 120 c/s and 10 mH up to 1 kc/s.

The use of the TYPE 1633-P1 Range-Extension Unit at frequencies up to 400 c/s can cause up to 1% additional error in the bridge readings. Correction can be made for the larger error occurring at higher frequencies. The temperature coefficient of the resistor is less than 20 ppm per degree Centigrade.

Any current up to 30 amperes continuous, or 50 amperes intermittent, ac or dc, can be used. Continuous operation at 50 amperes without forced-air cooling is not recommended.

Dimensions: Width 10½, height 4¼, depth 5 inches (270, 110, 130 mm).

Net Weight: 5¼ lb (2.4 kg). **Shipping Weight:** 7 lb (3.2 kg).

Catalog No.	Description	Price
1633-9601	Type 1633-P1 Range-Extension Unit	\$125.00

Type 1652-A RESISTANCE LIMIT BRIDGE



FEATURES:

- Rapid, accurate for limit tests.
- Equally useful for null measurements.
- Large, open-scale meter, color coded.
- Wide range — one ohm to one megohm.
- Ac-operated — no batteries needed.

USES: This resistance limit bridge is intended for the production testing of resistors at dc. It can be used:

- To indicate deviation from nominal value.
- To match pairs of resistors.
- To compare resistors to a standard sample.
- To measure resistance by the null method.

For manufacturers and users of resistors, this bridge is a rapid and accurate means for sorting into tolerance classifications, for selection to close tolerances, and for matching pairs of resistors for balanced circuits.

In the laboratory, its accuracy is adequate for all but the most exacting requirements, and it will measure resistors up to one megohm.

For automatic sorting, a relay and amplifier can be connected to actuate a selector mechanism.

DESCRIPTION: The circuit is a conventional equal-arm Wheatstone bridge, supplied from a constant-voltage dc source. The meter indicates percent deviation directly. The internal standard consists of seven TYPE 510 Decade-Resistance Units and is adjustable in 0.1-ohm steps from one ohm to 1,111,111 ohms.

For limit testing, the standard is set to the desired nominal value, and the percentage deviation is read from the meter. Terminals are provided for connection of a test jig such as the TYPE 1650-P1 (page 51).

For matching pairs, the resistor to be matched is substituted for the internal standard.

For null measurements, the internal standard is adjusted to equality with the unknown resistor.

SPECIFICATIONS

RESISTANCE RANGES	ACCURACY
As Limit Bridge With internal standard, 1 to 1,111,111 Ω	$\pm 0.5\%$ of measured value
With external standard, 1 to 2,000,000 Ω	$\pm 0.2\%$ + tolerance of standard
Meter reads from -20 to $+20\%$; standard EIA (RETMA) $\pm 5\%$ and $\pm 10\%$ tolerances indicated by gold and silver lettering, respectively.	
As Null Bridge With internal standard, 1 to 1,111,111 Ω	$\pm 0.25\%$ of measured value above 100 Ω ; $\pm 0.4\%$ between 10 Ω and 1 Ω .
With external standard, 1 to 2,000,000 Ω	$\pm 0.2\%$ + tolerance of standard
For matching, 1 to 2,000,000 Ω	$\pm 0.2\%$

Test Voltage:	0.9 V	1 V	1.1 V
Meter Indication	-20%	0	$+20\%$

Power Required: 105 to 125 or 210 to 250 V, 60 c/s (50-c model available), about 30 W.

Accessories Supplied: TYPE CAP-22 Power Cord, spare fuses.

Mechanical Data: Rack-Bench Cabinet (see page 258)

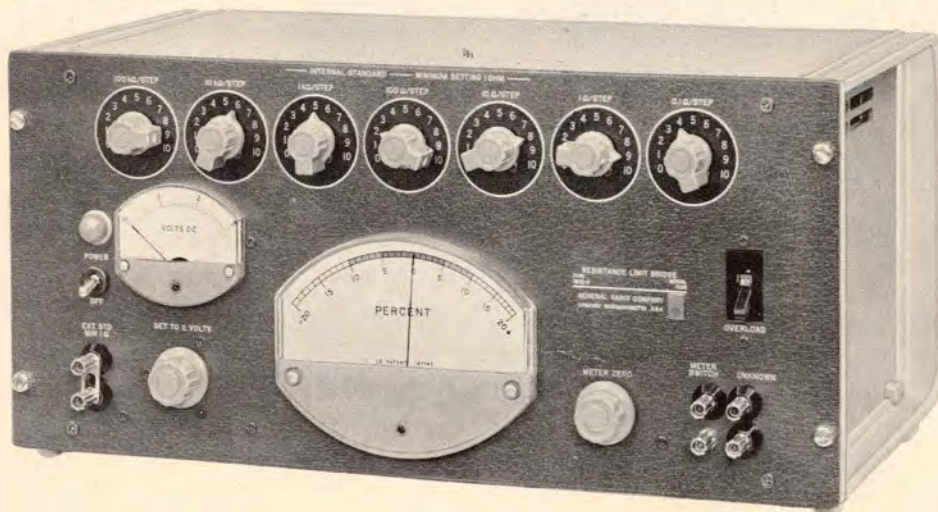
Model	Width		Height		Depth		Net Weight		Shipping Weight	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Bench	19	485	9	230	12 $\frac{1}{4}$	315	29	13.5	43	19.6
Rack	19	485	8 $\frac{3}{4}$	225	11*	280	29	13.5	43	19.6

* Behind panel.

See also *General Radio Experimenter*, January 1952.

Catalog Number	Description	Price
1652-9801	Type 1652-A Resistance Limit Bridge (for 60-cycle supply), Bench Model	\$660.00
1652-9811	Type 1652-A Resistance Limit Bridge (for 60-cycle supply), Rack Model	660.00
1652-9495	Type 1652-AQ1 Resistance Limit Bridge (for 50-cycle supply), Bench Model	on request
1652-9496	Type 1652-AQ1 Resistance Limit Bridge (for 50-cycle supply), Rack Model	on request

PATENT NOTICE. See Note 15, page 11.



Type 1644-A MEGOHM BRIDGE

FEATURES:

10^3 to 10^{15} ohms. ■ 1% accuracy to 10^{12} ohms.
 $\Delta R\%$ dial for matching resistors and measuring small differences, and for voltage- and temperature-coefficient measurements.
 Self-checking against internal wire-wound standards.
 High-sensitivity, electrometer-tube detector. ■ Guard terminals provided.
 Seven fixed test voltages from 10 to 1000 volts. Other voltages below 1000 are easily set.
 Quick charge and discharge for capacitor measurements.

USES: To measure

INSULATION RESISTANCE of cables, transformers, chokes, components, connectors, wiring, terminals, resistors, capacitors, relays, printed circuits, rotating machines, switches, circuit breakers, meters, strain gages, thermocouples, delay lines, slip rings, commutators, heaters, filters, lightning arresters, and other devices.

RESISTANCE of high-valued resistors, resistance films, diodes, transistors, and piezoelectric elements.

VOLTAGE AND TEMPERATURE COEFFICIENTS of resistance.

VOLUME AND SURFACE RESISTIVITY of solids, such as printed-board material, resins, plastics, potting and casting compounds, rubber, refractories, and semi-

conductors; of liquids, such as oils, plasticizers, and solvents; and of sheet materials, including plastics, recording tape, and varnished fabrics.

DESCRIPTION: The circuit is a dc Wheatstone bridge with a high-impedance, high-sensitivity detector. Precision, wire-wound resistors are used for the fixed bridge arm and the lower-valued decade-step arms. Metal-film and carbon-film resistors are used for the higher decade steps, with trimmers for precise adjustment in terms of the wire-wound standards. The balancing arm is a wire-wound variable resistor.

The guard terminal eliminates the effects of stray resistances to ground. For capacitor leakage resistance measurement, charging time is a fraction of a second.

SPECIFICATIONS

Resistance Range: 1 k Ω to 1000 T Ω (10^3 to 10^{15} Ω) in ten ranges.

Accuracy: 10^3 Ω to 10^{10} Ω , $\pm 1\%$. After self-calibration: 10^{10} to 10^{12} Ω , $\pm 1\%$ *; 10^{13} Ω , $\pm 2\%$; 10^{14} Ω , $\pm 10\%$; 10^{15} Ω , \pm one scale division.

$\Delta R\%$ Dial: $\pm 5\%$ range; accurate to $\pm 0.2\%$ or, for small changes, to $\pm 0.1\%$.

Test Voltage: Voltage accuracy is $\pm 3\% \pm 0.5$ V.

Fixed Voltages	10	20	50	100	200	500	1000	V
Minimum Unknown R	1	3	7	20	50	150	500	k Ω

Minimum Test Voltage for 1% Resolution:	Multiplier Setting	Max R_x	Volts
for approx 1-mm meter deflection	100 G or less	10^{11}	10
	100 G	10^{12}	100
	1 T	10^{13}	200

* At high voltages; 1% accuracy is obtainable at 10 V up to 10^{11} Ω ; see above.

Short-Circuit Current: <15 mA, 10–50 V; <10 mA, 100–1000 V.

Power Required: 105 to 125 or 210 to 250 V, 50 to 60 c/s, 13 W.

Mechanical Data: Flip-Tilt Case (see page 258)

Model	Width		Height		Depth		Net Wt		Ship Wt	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Portable*	12 3/4	325	12 1/2	320	7 3/4	200	18	8.5	29	13.5
Rack	19	485	12 1/4	315	5†	130	19	9.0	31	14.5

* Dimensions with case closed and including handle. † Behind panel.

See also *General Radio Experimenter*, July 1964.

Catalog No.	Description	Price
1644-9701	Type 1644-A Megohm Bridge, Portable Model	\$625.00
1644-9820	Type 1644-A Megohm Bridge, Rack Model	625.00

PATENT NOTICE. See Notes 1, 15, and 22, page 11.

NEW

in catalog S





Type 1862-C MEGOHMMETER

FEATURES:

Direct reading and simple to operate.
 Test potentials of 100 volts and 500 volts permit approximate measurement of voltage coefficient.
 Voltage can be removed from *unknown* terminals by setting of either switch to DISCHARGE position, thus permitting connections to be made without danger of shock.
 Panel light indicates when voltage is applied to the terminals.
 Guard and ground terminals provided.

USES: Rugged, versatile, and safe, this megohmmeter rapidly measures wide ranges of resistance at either of two test voltages. The 100-volt level is the EIA standard for measurement of composition, film, and wire-wound resistors above 100 kilohms. The 500-volt level is a standard value in the measurement of the insulation resistance of rotating machinery, transformers, cables, capacitors, appliances, and other electrical equipment.

Regulated power supply and charging circuit permit

rapid and accurate measurement of the leakage resistance of capacitors.

Guard and ground terminals permit measurement of grounded or ungrounded two- or three-terminal resistors.

DESCRIPTION: The megohmmeter consists of a regulated power supply, a complement of resistance standards, and a balanced, dc, vacuum-tube voltmeter with very high input resistance.

SPECIFICATIONS

Resistance Range: 0.5 M Ω to 2 T Ω (5×10^5 to 2×10^{12} Ω) at 500 V; 0.5 M Ω to 0.2 T Ω at 100 V; 6 decade ranges; 90% of meter scale utilized for resistance scales up to 500,000 M Ω ; center-scale values are 1, 10, 100, 1000, 10,000 and 100,000 M Ω for 500-V operation.

Accuracy: $\pm 3\%$ of indication at low-resistance end of each decade to $\pm 12\%$ (accuracy to which scale can be read) at high-resistance end up to 50,000 M Ω ; possible additional $\pm 2\%$ error at top decade. Switch position provided for standardizing calibration at 500 V.

Test Voltage:	Min R	Max R	Max I
100 V \pm 4 V	0.5 M Ω	200 G Ω = 2×10^{11} Ω	\approx 2 mA
500 V \pm 10 V	0.5 M Ω	2 T Ω = 2×10^{12} Ω	\approx 10 mA

Power Required: 105 to 125 or 210 to 250 V, 40 to 60 c/s (operates satisfactorily up to 400 c/s), 25 W.

Accessories Supplied: Spare fuses, 2 color-coded test leads.

Mechanical Data: Flip-Tilt Case (see page 258)

Model	Width		Height		Depth		Net Weight		Shipping Weight	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Portable	8½	210	11½	295	7½	190	9	4.1	12	5.5
Rack	19	485	12¼	315	5*	130	10	4.6	23	10.5

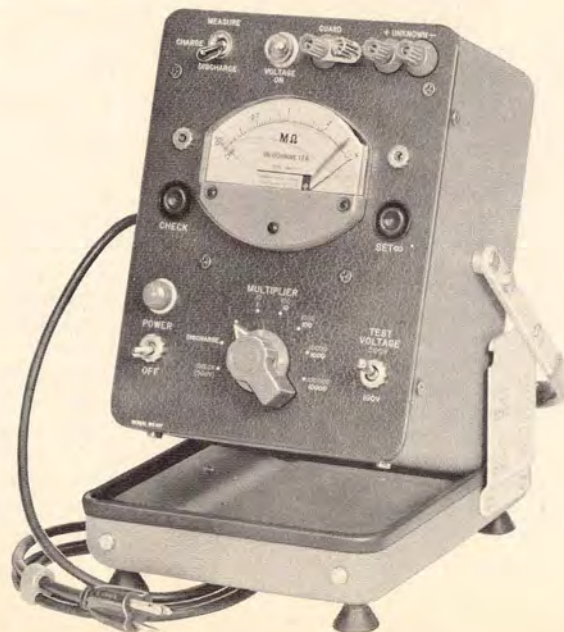
*Behind panel.

For a more detailed description, see *General Radio Experimenter*, July 1963.

Catalog Number	Description	Price
1862-9703	Type 1862-C Megohmmeter, Portable Model	\$310.00
1862-9844	Type 1862-C Megohmmeter, Rack Model	310.00

PATENT NOTICE. See Notes 15 and 22, page 11.

ELECTROMETER: The Type 1230-A Electrometer and DC Amplifier, described on page 174, measures resistances as high as 5×10^{14} ohms as well as very low voltages and currents.



0.5



COAXIAL ELEMENTS



DC TO MICROWAVE

Described on the following 26 pages is one of the most comprehensive lines of coaxial equipment available anywhere. There are two basic classifications: the GR874 series, whose common element is the general-purpose GR874 Coaxial Connector, and the GR900 series, based on the GR900 Precision Coaxial Connector. Each series includes connectors, adaptors, and circuit elements, as well as a slotted line, so that measurement setups can be conveniently assembled.

Both the GR874 and the GR900 Connectors have gained wide popularity, not only as circuit elements but also among instrument manufacturers, who have put the electrical and physical advantages of these connectors to good use on their products.

General Radio entered the coaxial instrument field more than 16 years ago, with the introduction of the GR874 Connector, which offered not only excellent electrical performance but a major convenience feature: any two, although identical, could be mated. The hermaphrodite, quick-connect GR874 was soon joined by a family of circuit elements and adaptors using the new connector. GR874-equipped instruments — notably the slotted line and the admittance meter — were added to solve the special measurement problems

of vhf and uhf. The availability of precise measuring instruments in turn made possible a continuous refinement of the basic connector. A particularly important chapter in the GR874 development was written a few years ago, when a locking version, fully compatible with the nonlocking GR874 and retaining the hermaphrodite feature, was announced.

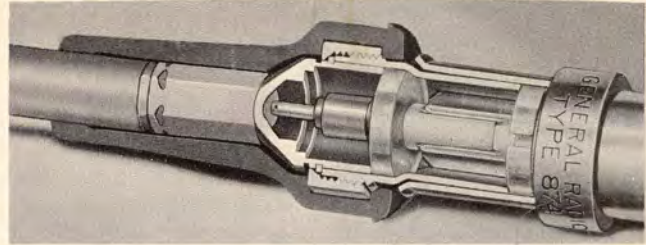
True precision came to coaxial measurements in 1963, in the form of the GR900 Precision Coaxial Connector and associated equipment. Until that breakthrough, the development of precise instruments for coaxial measurements had been retarded for want of a precise connector. The GR900 Connector opened the door to the development of a new, ultraprecise slotted line, new measuring techniques, and new applications for coaxial lines where only waveguide had gone before. Today, the GR900 line includes adaptors, terminations, air-line sections, and other components. Another significant figure has been added to coaxial measurement: Where one formerly spoke of a VSWR of 1.03, one now speaks of a VSWR of, say, 1.034, with confidence in the last figure. In terms of accuracy and resolution gained, the GR900 development must rank as one of the most significant of the past decade.

INDEX

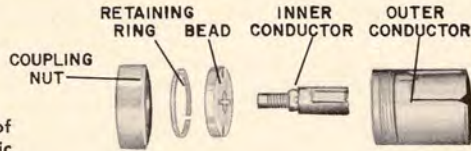
Item	Page		Item	Page		Item	Page	
	GR874 Coaxial Series	GR900 Precision Coaxial Series		GR874 Coaxial Series	GR900 Precision Coaxial Series		GR874 Coaxial Series	GR900 Precision Coaxial Series
Adaptors	80	98	Insertion Unit	92		Series Inductor	91	
Adjustable Lines	90		Kit, Slotted Line	83		Short-Circuit		
Air Lines	90	102	Lines			Terminations	89	99
Attenuators	88		Adjustable	90		Slotted Line	82	100
Balun	94		Constant-Impedance	90	102	Slotted Line Accessories	83	102
Bias Insertion Unit	91		Radiating	92		Smith Charts	84	84
Cable	85		Reference		102	Stand	93	
Cable Connectors	78	97	Rigid	90		Standards, Impedance		102
Capacitor, Coupling	92		Trombone	90		Standard Terminations	89	99
Capacitor, Variable	91		Low-Pass Filters	87		Stubs	91	
Clamps	93		Micrometer Vernier	82		Tee	92	
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Constant-Impedance Line	90		Open-Circuit			Tool Kits	78	97
Coupling Capacitor	92		Terminations	89	99	Trombone Line	90	
Coupling Elements	92		Panel Connectors	78	96, 97	Tube, Outer Conductor		97
Coupling Probe	92		Patch Cords	85		Tuners		102
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Flexible Line	85		Rectifier, Voltmeter	86		Voltmeter Rectifier	86	
Indicator, Voltmeter	86		Rod, Inner Conductor		97			
Inductor, Series	91		Rotary Joint	92				



The GR874 Connector is the keystone of the GR874 line of coaxial equipment, which includes adaptors, stubs, attenuators, filters, patch cords, and many other devices. The GR874 connector also appears on the TYPE 874-LBA Slotted Line, the TYPE 1602-B Admittance Meter, and the TYPE 1607-A Transfer-Function and Immittance Bridge, and throughout the entire GR instrument line wherever a good general-purpose coaxial connector is called for.



Cutaway view of GR874 basic connector mated with GR874 cable connector.



Exploded view of Type 874-B Basic Connector.

The elements of a GR874 Connector, as shown in the exploded view, are an inner conductor, an outer conductor, a supporting polystyrene bead, a phosphor-bronze retaining ring, and a threaded coupling nut. All metal parts are machined and formed to very close tolerances, and all are made of hard-drawn brass, except for the center conductor, which is heat-treated beryllium copper to ensure good gripping capability and long wear. A bright-alloy finish on all surfaces produces high conductivity for low loss and gives long-lasting protection against tarnish.

Inner and outer conductors are similar in principle; each is a tube with four longitudinal slots in one end, with two opposite quadrants displaced inward. When two connectors are joined, the undisplaced quadrants of one overlap the displaced quadrants of the other (see cutaway view).

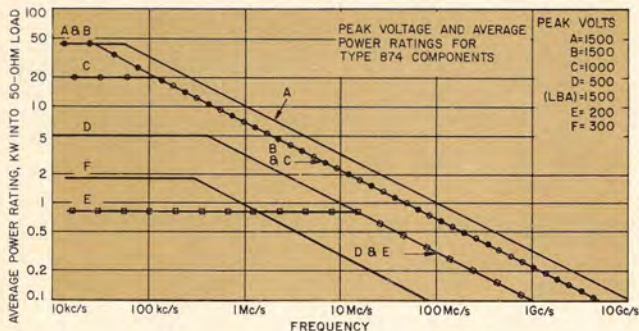
The locking version of the GR874 is fully compatible with

the nonlocking type. Locking connectors, besides furnishing a strong mechanical connection, minimize leakage. Most GR874-equipped instruments use the locking connector. With this panel connector, and particularly with the recessed version, an instrument can, by means of appropriate GR874 Adaptors, be quickly equipped with coaxial connectors of any popular type.

The GR874 Connector is backed up by one of the most complete lines of coaxial components and devices available anywhere. The user of a GR874-equipped laboratory need seldom, if ever, turn to other connector types for a needed element. If he does, he will almost certainly be able to select a GR874 Adaptor for the conversion.

Many GR874 components are now available equipped with locking as well as nonlocking connectors. The locking version in each case is identified by an L in the type designation.

New members of the GR874 line are constantly being developed, so that equipping a laboratory with the GR874 line today will seem an even wiser choice tomorrow.



ELECTRICAL CHARACTERISTICS

The GR874 Connector has the lowest reflection characteristics of any standard, general-purpose, 50-ohm coaxial connector in the dc-to-7-Gc frequency range. Its vswr performance is typically superior to that of the most highly regarded military-type connector in common laboratory use. GR874 cable connectors, in fact, offer vswr performance superior to that of any cable with which they can be used, and therefore add no significant reflections when used in measurement setups.

Power-handling, peak-voltage, leakage, and vswr data are given on the charts on this and the following pages.

PATENT NOTICE. See Note 4, page 11.

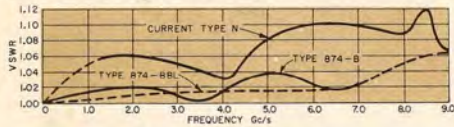
Category	Page	Applicable Type 874 Items	See Curve	Peak Volts
Adaptors	81	-QHJA, -QHPA, -QLJA, -QLPA, -QLTJ, -QLTP, -QU1A, -QU2, -QU3A	A	1500
		-QCP, -QCJA, -QCJL, -QNP, -QNPL; -QNJA, -QNJL, -QSCP, -QSCJ, -QSCJL	C	1000
		-QBJA, -QB JL, -QBPA, -QTNJ, -QTNJL, -QTNP, -QUJ, -QUJL, -QUP	D	500
		-QMDJ, -QMDJL, -QMDP	F	300
Air Lines Adjustable Fixed	90	-LAL, -LK10L, -LK20L	B	1500
		-L10, -L10L, -L20, -L20L, -L30, -L30L	A	1500
Connectors	79	-B, -BBL, -PLT, -PRLT, -PFL	A	1500
		-CA, -CLA, -C8A, -CL8A, -PBA, -PB8A, -PLA, -PL8A, -PRLA, -PRL8A	C	1000
		-C58A, -CL58A, -C62A, -CL62A, -PB58A, -PB62A, -PL58A, -PL62A, -PRL58A, -PRL62A	D	500
		-C174A, -CL174A, -PB174A, -PL174A, -PRL174A	F	300
Elements	92	-EL, -EL-L, -T, -TL	A	1500
		-K, -KL	D	500
Filters	87	-F185L, -F500L, -F1000L, -F2000L, -F4000L	E	200
Patch Cords	85	-R20A, -R20LA	C	1000
		-R22A, -R22LA	D	500
Slotted Line	82	-LBA	D	1500



The GR874 line of coaxial connectors includes 30 different types, as listed in the chart on page 79.

AIR-LINE CONNECTORS

The TYPES 874-B and 874-BBL Basic Connectors are for use on rigid, 50-ohm air lines made from 9/16-inch-ID, 5/8-inch-OD tubing and 0.244-inch-diameter rod. The TYPE 874-BBL is a locking connector specially designed for excellent performance up to 9 Gc/s.



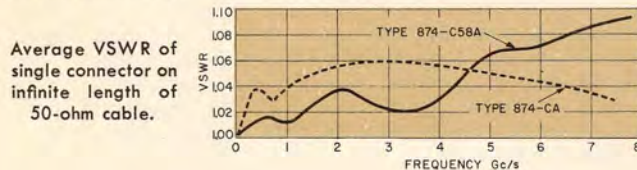
Typical VSWR of pairs of Type 874-B and -BBL Connectors compared with a pair of the latest standard type-N connectors.



CABLE CONNECTORS

The GR874 cable connector is available in 10 types to accommodate five basic cable sizes in both locking and non-locking versions. These connectors fit more than 40 different RG types of coaxial cable, as well as General Radio TYPES 874-A2 and -A3 cable. Each cable connector consists of a basic connector plus inner and outer transition pieces, a soft-copper ferrule, a heat disk, and a flexible cable guard. The cylindrical transition pieces maintain the 50-ohm characteristic impedance of the connector throughout the reduction to the cable diameter. The cable inner conductor is soldered to the inner transition piece, and the cable braid and jacket are crimped to the outer transition by the ferrule. Braid and jacket are thus kept from working loose and causing reflections and leakage.

A Neoprene cable guard serves as a protective handle. Sized to grip the cable securely without compressing it, the cable guard adds to the quick-connect-disconnect convenience of the connector.



Average VSWR of single connector on infinite length of 50-ohm cable.

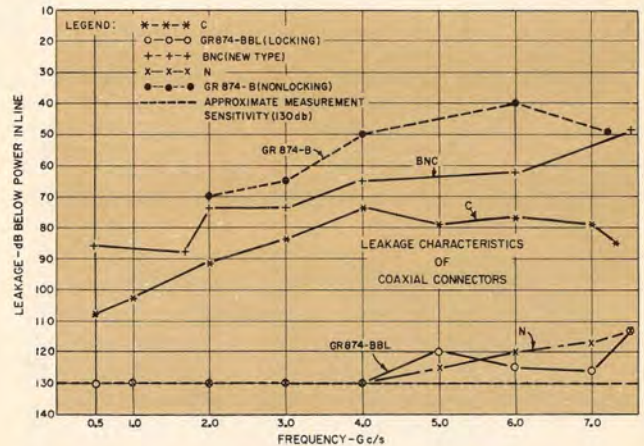
PANEL CONNECTORS



Panel connectors are available for five basic cable sizes (as for cable connectors) and in three configurations: flanged, locking, and locking recessed. The flanged (nonlocking) connector can be mounted on either the front or the back of the panel and is attached by means of four screws. The locking panel connector is also flanged and attached by four screws. The recessed locking connector reduces the protrusion in front of the panel to 1/8 inch to save space and to present a neat appearance.

Locking panel connectors are also available with a solder terminal to accommodate single-wire leads.

The TYPE 874-PFL Panel-Feedthrough Locking Connector is a short section of air line with a locking GR874 connector at each end. It is useful for joining GR874 cable connectors directly through a panel, avoiding awkward patch-cord runs on instrument racks.



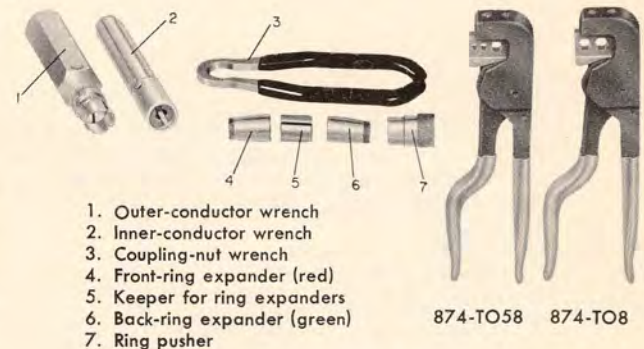
Typical leakage characteristics of GR874 Connectors compared with other types.

TOOLS

Several special tools are available to facilitate assembly of GR874 Connectors — these tools ensure quick assembly, neat, uniform appearance, and best electrical and mechanical performance.

The TYPE 874-TOK Tool Kit consists of an inner-conductor wrench to install both the insulating bead and the inner conductor and an outer-conductor wrench to install the outer conductor and to tighten the coupling nut. The other pieces aid in installation of the retaining ring.

When a GR874 Connector is installed on cable, the ferrule must be crimped to secure the cable to the connector. Pliers can be used to crimp the ferrule, but, for the neatest crimp in the shortest time, use of a TYPE 874-T058 or -T08 Crimping Tool is recommended. Die dimensions for these hexagonal crimping tools are as follows: TYPE 874-T058: 0.215, 0.250, 0.375 inch; TYPE 874-T08: 0.389, 0.411 inch.



1. Outer-conductor wrench
2. Inner-conductor wrench
3. Coupling-nut wrench
4. Front-ring expander (red)
5. Keeper for ring expanders
6. Back-ring expander (green)
7. Ring pusher

874-T058 874-T08




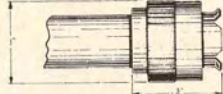



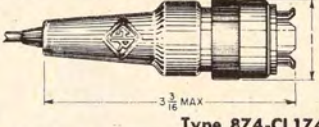

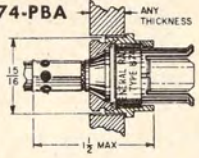
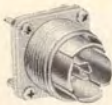
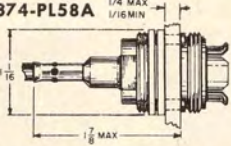
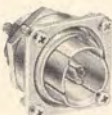
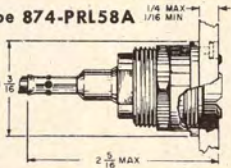

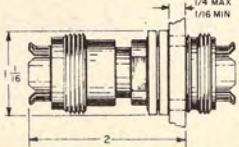
Catalog No.	Description	Net Weight	Price
0874-9902	Type 874-TOK Tool Kit	1 lb (0.5 kg)	\$25.00
0874-9901	Type 874-T058 Crimping Tool	1 3/4 lb (0.8 kg)	85.00
0874-9900	Type 874-T08 Crimping Tool	1 3/4 lb (0.8 kg)	75.00

Use on Cable Connector	Crimping Tool Type
874-CA, CLA, C58A, CL58A, C62A, CL62A, C174A, CL174A, PBA, PLA, PRLA, PB58A, PL58A, PRL58A, PB62A, PL62A, PRL62A, PB174A, PL174A, PRL174A	874-T058
874-C8A, CL8A, PB8A, PRL8A	874-T08

GR874 CONNECTOR SERIES

COAXIAL ELEMENTS



See page 77 for power and voltage ratings		Type	Fits	Catalog Number	Price*
▼ BASIC CONNECTOR — NONLOCKING					
		874-B	50-ohm Rigid Air Line	0874-9400	\$2.25
▼ BASIC CONNECTOR — LOCKING					
		874-BBL	50-ohm Rigid Air Line	0874-9403	3.25
▼ CABLE CONNECTORS — NONLOCKING					
		874-CA	(50-ohm) 874-A2 Cable	0874-9410	3.00
		874-C8A	(50-ohm) RG-8A/U, -9B/U, -10A/U, -87A/U, -116/U, -156/U, -165/U, -166/U, -213/U, -214/U, -215/U, -225/U, -227/U, (non-50-ohm) RG-11A/U, -12A/U, -13A/U, -63B/U, -79B/U, -89/U, -144/U, -146/U, -149/U, -216/U Cables	0874-9412	3.00
	 Type 874-CA	874-C58A	(50-ohm) 874-A3, RG-29/U -55/U (series), -58/U (series), -141A/U, -142A/U, -159/U, -223/U Cables	0874-9414	3.00
		874-C62A	(non-50-ohm) RG-59/U, -62/U (series), -71B/U, -140/U, -210/U Cables	0774-9416	3.00
		874-C174A	(50-ohm) RG-174/U, -188/U, -316/U; (non-50-ohm) RG-161/U, -179/U Cables	0874-9418	4.50
▼ CABLE CONNECTORS — LOCKING					
	 Type 874-CL174A	874-CLA 874-CL8A 874-CL58A 874-CL62A 874-CL174A	Same as Type 874-CA. Same as Type 874-C8A. Same as Type 874-C58A. Same as Type 874-C62A. Same as Type 874-C174A.	0874-9411 0874-9413 0874-9415 0874-9417 0874-9419	4.00 4.00 4.00 4.00 5.50
▼ PANEL CONNECTORS — FLANGED					
	 Type 874-PBA	874-PBA 874-PB8A 874-PB58A 874-PB62A 874-PB174A	Same as Type 874-CA. Same as Type 874-C8A. Same as Type 874-C58A. Same as Type 984-C62A. Same as Type 874-C174A.	0874-9440 0874-9442 0874-9444 0874-9446 0874-9448	4.00 4.00 4.00 4.00 5.00
▼ PANEL CONNECTORS — LOCKING					
	 Type 874-PL58A	874-PLA 874-PL8A 874-PL58A 874-PL62A 874-PLT 874-PL174A	Same as Type 874-CA. Same as Type 874-C8A. Same as Type 874-C58A. Same as Type 874-C62A. Wire Lead. Same as Type 874-C174A.	0874-9441 0874-9443 0874-9445 0874-9447 0974-9459 0874-9449	4.00 4.00 4.00 4.00 4.00 5.00
▼ PANEL CONNECTORS — LOCKING RECESSED					
	 Type 874-PRL58A	874-PRLA 874-PRL8A 874-PRL58A 874-PRL62A 874-PRLT 874-PRL174A	Same as Type 874-CA. Same as Type 874-C8A. Same as Type 874-C58A. Same as Type 874-C62A. Wire Lead. Same as Type 874-C174A.	0874-9461 0874-9463 0874-9465 0874-9467 0874-9479 0874-9469	4.00 4.00 4.00 4.00 4.00 5.00
▼ PANEL CONNECTOR — LOCKING FEEDTHROUGH					
		874-PFL	Mates any pair of GR874 Connectors directly through a panel or wall. Can be mounted as recessed or non-recessed panel locking connector.	0874-9451	9.50

Net weight 1 to 4 ounces, depending upon item.

* For quantities of 1 to 99; prices for larger quantities on request.



GR874 ADAPTORS

Thirty-five different adaptors provide easy conversion from the GR874 Connector to most popular military and commercial coaxial connectors, including high-power TV broadcast types. Many of these adaptors are available in locking as well as nonlocking versions.

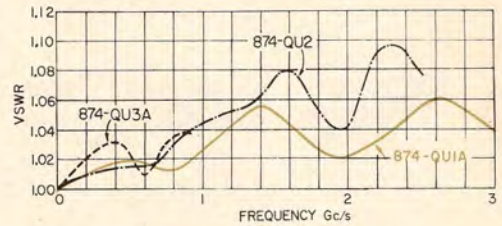
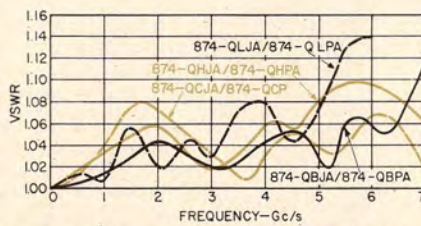
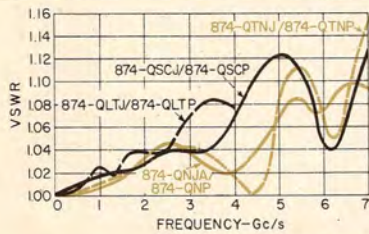
GR874 Adaptors extend the usefulness of GR874 Connectors without sacrificing electrical performance. The vswr of the combination of GR874 Connector and GR874 Adaptor is actually comparable to that of the "other series" connector alone.

Original-equipment manufacturers will recognize the possibilities of these adaptors in combination with the GR874 locking recessed panel connector. An instrument originally equipped with these connectors can, by means of appropriate GR874 Adaptors, be quickly converted

to almost any coaxial connector series, with the resulting panel connector rigidly attached and protruding less than an inch beyond the panel surface.

Because any two GR874 Adaptors mate, a few of them can perform a cross-connection task that would otherwise involve a costly collection of direct adaptors. For instance, interconnection of all possible combinations of types N, C, BNC, TNC, UHF, and Microdot plugs and jacks would require 72 direct adaptors, whereas only 12 GR874 Adaptors are needed to do the same job.

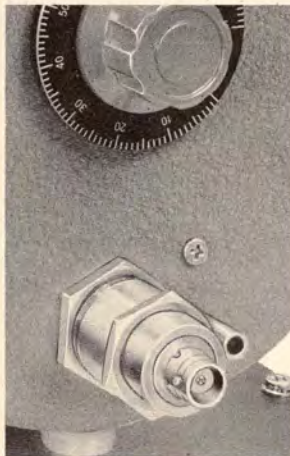
In ordering adaptors by type number, note that the P or J suffix letter identifies the connector on the adaptor, not the connector that the adaptor fits. (For instance, the TYPE 874-QNJ Adaptor contains a type N jack, and therefore fits a type N plug.) An L in the type designation indicates a locking adaptor.



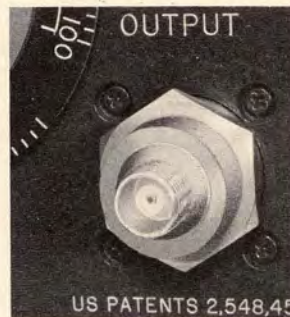
Typical VSWR introduced in line by pairs of GR874 Adaptors plugged together.

**Now —
YOU CAN
CONNECT
GR874-EQUIPPED INSTRUMENTS
TO
MOST OTHER
COAXIAL CONNECTORS**

GR874 ADAPTORS PROVIDE THE LINK



recessed GR874 panel connector adapted to type TNC with Type 874-QTNJL Adaptor



unit-oscillator output connector adapted to type BNC with Type 874-QBJL Adaptor



locking GR874 panel connector converted to type N with Type 874-QNJL Adaptor

GR874 ADAPTORS

COAXIAL ELEMENTS



ADAPTORS TO:	Type		Contains GR874 and ...	Connects GR874 to ...	Net Wt	Catalog Number	Price	
	Nonlocking	Locking						
▼ Type BNC								
	874-QBJA	874-QBJL	BNC Jack	BNC Plug	1 oz (30 g)	0874-9700	\$ 4.75	
	874-QBPA		BNC Jack	BNC Plug	1 1/2 oz (45 g)	0874-9701	5.75	
			BNC Plug	BNC Jack	1 1/2 oz (45 g)	0874-9800	6.50	
▼ Type C								
	874-QCJA	874-QCJL	C Jack	C Plug	1 oz (30 g)	0874-9702	7.50	
	874-QCP		C Jack	C Plug	2 oz (60 g)	0874-9703	8.50	
			C Plug	C Jack	2 oz (60 g)	0874-9802	7.00	
▼ Type HN								
	874-QHJA		HN Jack	HN Plug	1 1/2 oz (45 g)	0874-9704	6.00	
	874-QHPA		HN Plug	HN Jack	2 1/2 oz (75 g)	0874-9804	7.50	
▼ Type LC								
	874-QLJA		LC Jack	LC Plug	5 oz (145 g)	0874-9706	8.00	
	874-QLPA		LC Plug	LC Jack	7 1/2 oz (215 g)	0874-9806	33.00	
▼ Type LT								
	874-QLTJ		LT Jack	LT Plug	4 3/4 oz (135 g)	0874-9708	26.00	
	874-QLTP		LT Plug	LT Jack	7 oz (200 g)	0874-9808	31.00	
▼ Type MICRODOT								
	874-QMDJ	874-QMDJL	Microdot Jack	Microdot Plug	1 oz (30 g)	0874-9720	10.00	
	874-QMDP		Microdot Jack	Microdot Plug	1 1/2 oz (45 g)	0874-9721	11.00	
			Microdot Plug	Microdot Jack	1 oz (30 g)	0874-9820	10.50	
▼ Type N								
	874-QNJA	874-QNJL	N Jack	N Plug	1 1/2 oz (45 g)	0874-9710	5.00	
	874-QNP		N Jack	N Plug	2 oz (60 g)	0874-9711	6.00	
		874-QNPL	N Plug	N Jack	1 3/4 oz (50 g)	0874-9810	5.50	
			N Plug	N Jack	2 1/4 oz (70 g)	0874-9811	6.50	
▼ Type OSM/BRM								
	874-QMMJ	874-QMMJL	OSM/*BRM Jack	OSM/*BRM Plug	1 oz (30 g)	0874-9722	11.00	
	874-QMMP		OSM/BRM Jack	OSM/BRM Plug	1 1/2 oz (45 g)	0874-9723	12.00	
			OSM/BRM Plug	OSM/BRM Jack	1 oz (30 g)	0874-9822	11.00	
			OSM/BRM Plug	OSM/BRM Jack	1 1/2 oz (45 g)	0874-9823	12.00	
▼ Type SC								
	874-QSCJ	874-QSCJL	SC Jack	SC Plug (Sandia)	1 3/8 oz (40 g)	0874-9712	10.00	
	874-QSCP		SC Jack	SC Plug (Sandia)	2 oz (60 g)	0874-9713	11.00	
			SC Plug	SC Jack (Sandia)	1 5/8 oz (50 g)	0874-9812	13.00	
▼ Type TNC								
	874-QTNJ	874-QTNJL	TNC Jack	TNC Plug	1 oz (30 g)	0874-9716	8.50	
	874-QTNP		TNC Jack	TNC Plug	1 1/2 oz (45 g)	0874-9717	9.50	
			TNC Plug	TNC Jack	1 1/4 oz (35 g)	0874-9816	6.50	
▼ Type UHF								
	874-QUJ	874-QUJL	UHF Jack	UHF Plug	1 oz (30 g)	0874-9718	5.50	
	874-QUP		UHF Jack	UHF Plug	2 oz (60 g)	0874-9719	6.50	
			UHF Plug	UHF Jack	1 1/2 oz (45 g)	0874-9818	5.00	
▼ Type 274								
	874-Q2		274 Plug/Jack	274 Plug or Jack	2 oz (60 g)	0874-9870	5.50	
	874-Q9		938 Jack	938 Binding Posts	3 oz (85 g)	0874-9874	6.00	
▼ UHF 50-OHM RIGID LINE								
	874-QU1A			7/8-in, RG-155/U (EIA TR-134)	7 oz (200 g)	0874-9770	35.00	
	874-QU2				1 1/8-in, RG-153/U (EIA TR-134)	1 1/4 lb (0.6 kg)	0874-9772	80.00
	874-QU3A				3 1/8-in, RG-154/U (EIA TR-134)	5 1/4 lb (2.4 kg)	0874-9774	240.00

* Also mates with NPM and STM.

See page 77 for power and voltage ratings



Type 874-LBA SLOTTED LINE

FEATURES:

- High accuracy at a reasonable price.
- Rugged construction for production use.
- Integral probe and crystal.
- Wide frequency range, 300 Mc/s to 5 Gc/s.
- Wide variety of available accessories, including adaptors to other connector series.

One of the most important basic measuring instruments used at uhf and higher frequencies is the slotted line. General Radio offers two models: the general-purpose TYPE 874-LBA and, for measurements requiring accuracies of a few tenths of one percent, the TYPE 900-LB Precision Slotted Line.

The slotted line is used to determine the standing-wave pattern of the electric field in a coaxial transmission line. From a knowledge of the standing-wave pattern, one can determine several characteristics of the circuit connected to the load end of the slotted line. For instance, the degree of mismatch between the load and the transmission line can be calculated from the ratio of the maximum amplitude of the wave to the minimum. This ratio is called the voltage standing-wave ratio, or *v*SWR. The load impedance can be calculated from the standing-wave ratio and the position of a minimum point on the line with respect to the load. The wavelength of the exciting signal can be measured

as the distance between minima, as successive minima or maxima are spaced a half wavelength apart. These capabilities make the slotted line a valuable instrument for measurements on antennas, components, coaxial elements, and networks.

The TYPE 874-LBA Slotted Line is a 50-ohm, air-dielectric, coaxial line whose electric field is sampled by a probe, which projects through a longitudinal slot in the outer conductor. The probe rides on a carriage, which is driven by a pulley-and-cord linkage conveniently operated from one end of the line. Both the position of the probe and the degree of coupling can be precisely set. A crystal rectifier, built into the carriage, can be tuned to the operating frequency by means of an adjustable stub.

A source of about one milliwatt rf power is adequate for most measurements. Suitable generators and detectors are listed on the following page.

SPECIFICATIONS

- Characteristic Impedance:** 50Ω ± 0.5%.
- Probe Travel:** 50 cm. Scale in centimeters; each division is 1 mm.
- Scale Accuracy:** ± (0.1 mm + 0.05%).
- Frequency Range:** 300 Mc/s to 5 Gc/s. At 300 Mc/s, the slotted line covers a half wavelength. Operation below 300 Mc/s is possible with slightly reduced accuracy by use of lengths of TYPE 874 Air Lines (page 90).
- Constancy of Probe Pickup:** ± 1.5%.
- Residual *v*SWR:** Less than 1.025 at 1 Gc/s, 1.04 at 2 Gc/s, 1.055 at 3 Gc/s, 1.07 at 4 Gc/s, 1.1 at 5 Gc/s.
- Accessories Supplied:** Storage box and spare drive cable.
- Accessories Required:** Adjustable Stub (TYPE 874-D20L) for tun-

ing the crystal rectifier when audio-frequency detector or microammeter is used; suitable detector and generator; one each, TYPE 874-R22LA and TYPE 874-R22A Patch Cords, for generator and detector connections.

Accessories Available: A complete slotted-line kit is described on page 83. For measurement of *v*SWR greater than 10, a TYPE 874-LV Micrometer Vernier is recommended. Smith Charts are listed on page 84. Adaptors are listed on page 81. TYPE 900-DP Probe Tuner is described on page 83.

Dimensions: 26 by 4½ by 3½ in (660, 115, 89 mm).

Net Weight: 8½ lb (3.9 kg).

Shipping Weight: 23 lb (10.5 kg).

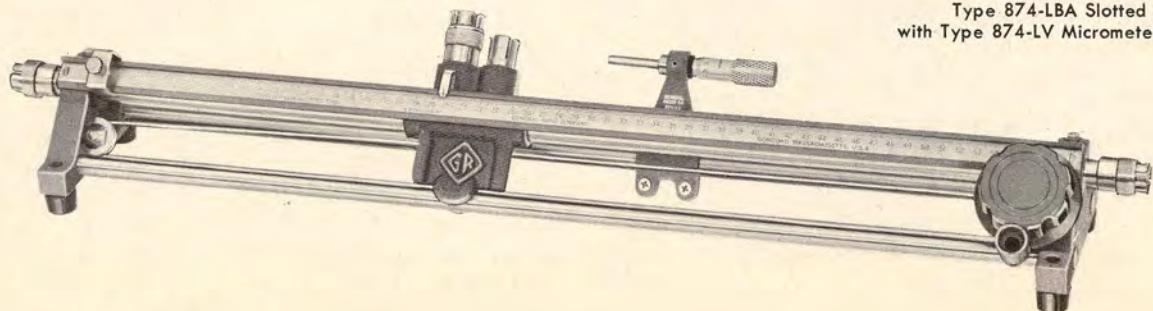
Type 874-LV MICROMETER VERNIER

For precise measurements of large *v*SWR by the width-of-minimum method, and for precise phase measurements. Consists of a micrometer head calibrated in centimeters (calibrated to 0.001 cm), mounted on an arm that can be attached to the rear base rod of the slotted

line. One turn of the micrometer barrel advances the head by 0.5 mm. Maximum range is 2.5 cm. Can be read to ± 0.002 mm.

Net Weight: 8 oz (230 g).

Catalog Number	Description	Price
0874-9650	Type 874-LBA Slotted Line	\$315.00
0874-9652	Type 874-LV Micrometer Vernier	37.50



Type 874-LBA Slotted Line
with Type 874-LV Micrometer Vernier.



Type 900-DP PROBE TUNER

NEW



The precise probe and tuner assembly is available as an optional accessory for the TYPE 874-LBA. It comprises a screw-driven adjustable stub and an adjustable probe, whose depth of penetration is indicated on the control knob. It will tune the probe-crystal diode assembly to resonance at any frequency from 300 Mc/s to 9 Gc/s.

Frequency Range: 0.3 to 9 Gc/s. **Tuning:** Shunt.
Probe Depth Scale: Calibrated in inches (0.001/div).
Stub Tuner: Calibrated in cm.
Dimensions: Length 11 in (280 mm), dia 7/8 in (23 mm), over-all, closed.
Net Weight: 8½ oz (245 g).

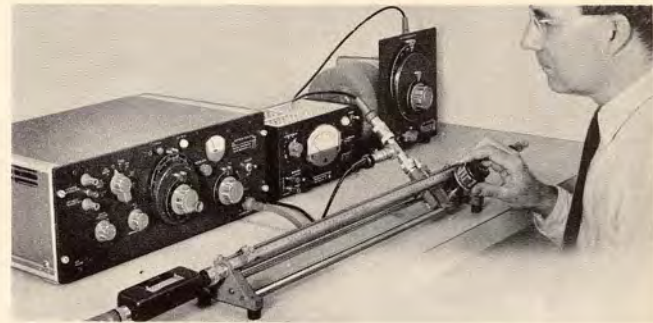
Catalog No.	Description	Price
0900-9654	Type 900-DP Probe Tuner	\$75.00

GENERATORS

Oscillators covering the frequency range of the slotted line are described on pages 139 to 144. They can be square-wave modulated at 1 kc/s with the TYPE 1264-A Modulating Power Supply. For use at higher frequencies, both the TYPE 1220-A Unit Klystron Oscillator and the TYPE 1360-B Microwave Oscillator have internal 1-kc square-wave modulation.

DETECTORS

The simplest suitable detector consists of a microammeter and the slotted line's built-in crystal. Its sensitivity is low. For measurement of vswr between 1 and 5, satisfactory results can be obtained with a 50-microampere meter and oscillator

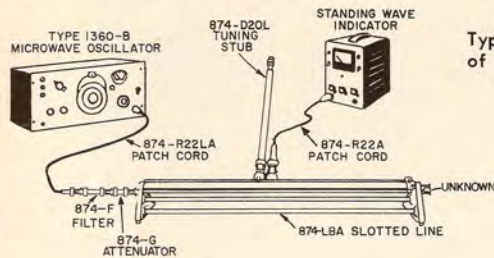


power levels between 100 milliwatts and 20 watts. A TYPE 874-D20L 20-cm Adjustable Stub is required. A meter-sensitivity control, consisting of a 10-kilohm variable shunt resistor, is recommended.

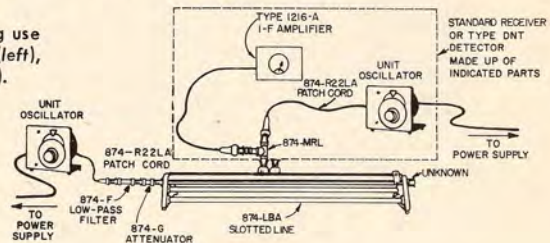
Most popular vswr indicators are satisfactory detectors. The generator must be modulated at 1 kc/s. A TYPE 874-D20L 20-cm Adjustable Stub or a TYPE 900-DP Probe Tuner is required for tuning.

The heterodyne detector is a general-purpose laboratory detector. It is excellent for measurements of nonlinear circuits and of high values of vswr, where a high degree of harmonic rejection is necessary. It is not recommended for vswr's below 1.05. The General Radio TYPE DNT Detectors cover the frequency range from 40 to 2030 Mc/s (up to 5 Gc/s by the use of harmonics). See page 109.

A low-pass coaxial filter should be used to eliminate harmonics of the signal source, and a TYPE 874-G10L Fixed Attenuator to isolate the oscillator from the effects of load changes. See pages 87 and 88.



Typical measurement setups showing use of slotted line, VSWR indicator (left), and heterodyne detector (right).



COAXIAL KITS

Type 874-EKA BASIC SLOTTED-LINE KIT

For impedance and vswr measurements with the slotted line, the coaxial elements listed below are available as the TYPE 874-EKA Basic Slotted-Line Kit. The TYPE 874-LBA Slotted Line is included in the kit, but the generator and detector are not.

Shipping Weight: 38 lb (17.5 kg).

Catalog No.	Description	Price
0874-9521	Type 874-EKA Basic Slotted-Line Kit	\$592.50

KITS FOR CABLE MEASUREMENTS

Various combinations of GR874 coaxial elements can be used very effectively with Unit Instruments and associated equipment to measure attenuation, characteristic impedance, velocity of propagation, and capacitance of both coaxial and twin-conductor cables.

For convenience in ordering, the necessary equipment is offered in assemblies for specific types of measurement. These kits and their use are described in General Radio Reprint E-104, "The Measurement of Cable Characteristics," available on request.

Type	Description	Type	Description	Type	Description
874-A2	Coaxial Cable (25 ft)	874-D50L	Adjustable Stub	874-QNPL	Adaptor, Connects to type N Jack
874-A3	Coaxial Cable (25 ft)	874-LAL	Adjustable Line	874-R22A	Patch Cord
874-BBL	Basic Connector, Locking (2)	874-LBA	Slotted Line	874-R22LA	Patch Cord, Locking
874-B	Basic Connector (2)	874-PL58A	Panel Connector, Locking	874-R34	Patch Cord
874-CA	Cable Connector (2)	874-PRL58A	Panel Connector, Locking, Recessed	874-TL	Tee, Locking
874-C8A	Cable Connector (2)	874-QBJL	Adaptor, Locking, Connects to type BNC Plug	874-W50BL	50-ohm Termination
874-CLA	Cable Connector, Locking (2)	874-QNJL	Adaptor, Locking, Connects to type N Plug	874-WN	Short-Circuit Termination
874-C58A	Cable Connector (2)			874-WO	Open-Circuit Termination
874-CL58A	Cable Connector, Locking (2)			874-TOK	Tool Kit
874-D20L	Adjustable Stub			874-Z	Stand



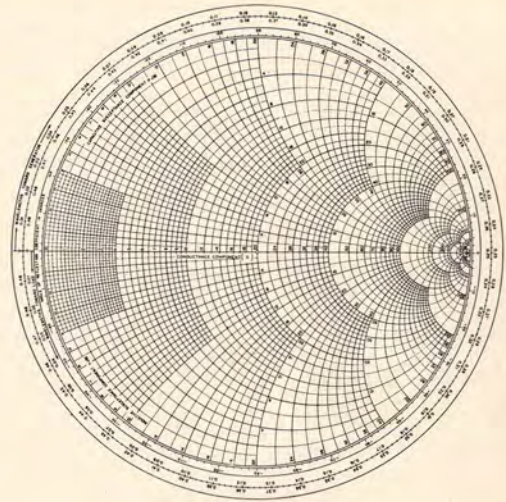
SMITH CHARTS

The Smith Chart facilitates measurements made with slotted lines. It can be used to determine the impedance corresponding to any *v*s*w*r and to convert from impedance to admittance, and vice versa. Five forms of Smith Chart are available. Those with normalized coordinates are for use with lines of any impedance. The 50-ohm characteristic impedance (20-millimho characteristic admittance) is common to all General Radio coaxial equipment. Charts are 8½ by 11 inches.

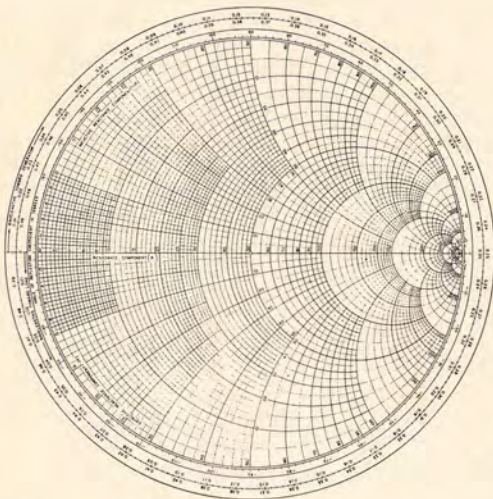
Catalog Number	Description
5301-7568	Type Y Smith Chart (20-mmho admittance coordinates)
5301-7569	Type Z Smith Chart (50-ohm impedance coordinates)
5301-7560	Type N Smith Chart (normalized coordinates)
5301-7561	Type NE Smith Chart (normalized expanded coordinates)
5301-7562	Type HE Smith Chart (normalized highly expanded coordinates)

Price per unit of 50 (minimum quantity sold)

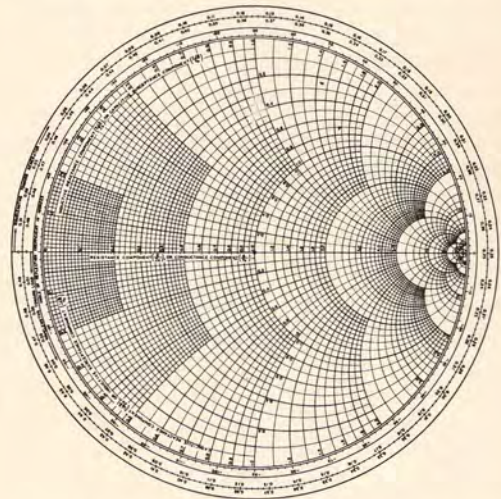
No. of units	1	2-3	4-9	10-19	20 and over
Price	\$2.00	\$1.90	\$1.75	\$1.40	\$1.25



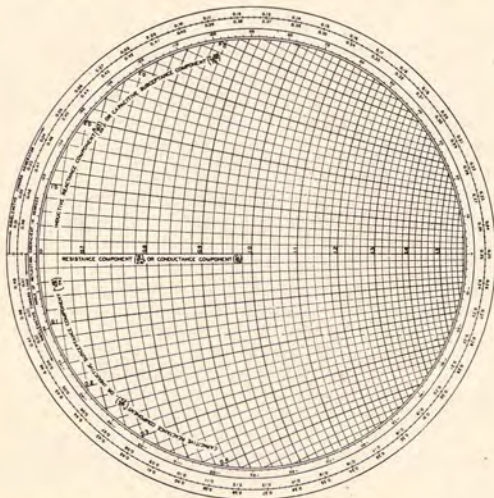
Catalog Number 5301-7568, admittance coordinates.



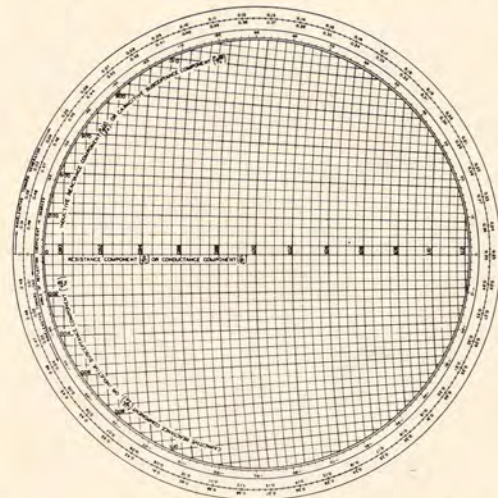
Catalog Number 5301-7569, impedance coordinates.



Catalog Number 5301-7560, normalized coordinates.



Catalog Number 5301-7561, normalized expanded coordinates.



Catalog Number 5301-7562, normalized highly expanded coordinates.



TYPE 874-A2 COAXIAL CABLE

This is a flexible, double-shielded, low-loss coaxial cable, consisting of No. 14 stranded inner conductor separated from the two tinned-copper braids by 0.244-inch-OD polyethylene dielectric and a 0.375-inch-OD, gray, noncontaminating polyvinyl-chloride jacket.

SPECIFICATIONS

Characteristic Impedance: $50\Omega \pm 5\%$.
Nominal Capacitance: 30.8 pF/ft.
Attenuation 2.6 dB/100 ft at 100 Mc/s; 10.5 dB/100 ft at 1 Gc/s.
Propagation Velocity Factor: 66%.
Net Weight: 2¼ lb (1.3 kg) per 25 ft.

Catalog Number	Description	Price
0874-9500	Type 874-A2 Coaxial Cable	\$0.60/ft (0.40/ft in lengths of 25 ft or more)

TYPE 874-A3 COAXIAL CABLE

This cable is more flexible than the TYPE 874-A2, but the losses are somewhat higher. The inner conductor is 19 strands of 0.0071-inch tinned soft-copper wire, separated from the double braid by 0.116-inch-OD polyethylene dielectric. The jacket is 0.206-inch-OD, black, noncontaminating polyvinyl chloride. This cable is recommended for most general-purpose applications.

SPECIFICATIONS

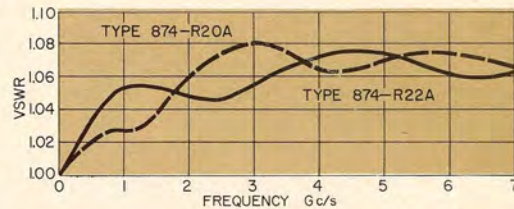
Characteristic Impedance: $50\Omega \pm 5\%$.
Nominal Capacitance: 29 pF/ft.
Attenuation: 5.3 dB/100 ft at 100 Mc/s; 22 dB/100 ft at 1 Gc/s; 45 dB/100 ft at 3 Gc/s.
Propagation Velocity Factor: 66%.
Net Weight: 1 lb (0.5 kg) per 25 ft.

Catalog Number	Description	Price
0874-9501	Type 874-A3 Coaxial Cable	\$0.35/ft (0.20/ft in lengths of 25 ft or more)

PATCH CORDS

The following three-foot coaxial patch cords meet the need for flexible connections in the measurements laboratory. The TYPES 874-R20A and -R22A Patch Cords have very low vswr characteristics (see curves) and are available with either locking or nonlocking GR874 Connectors.

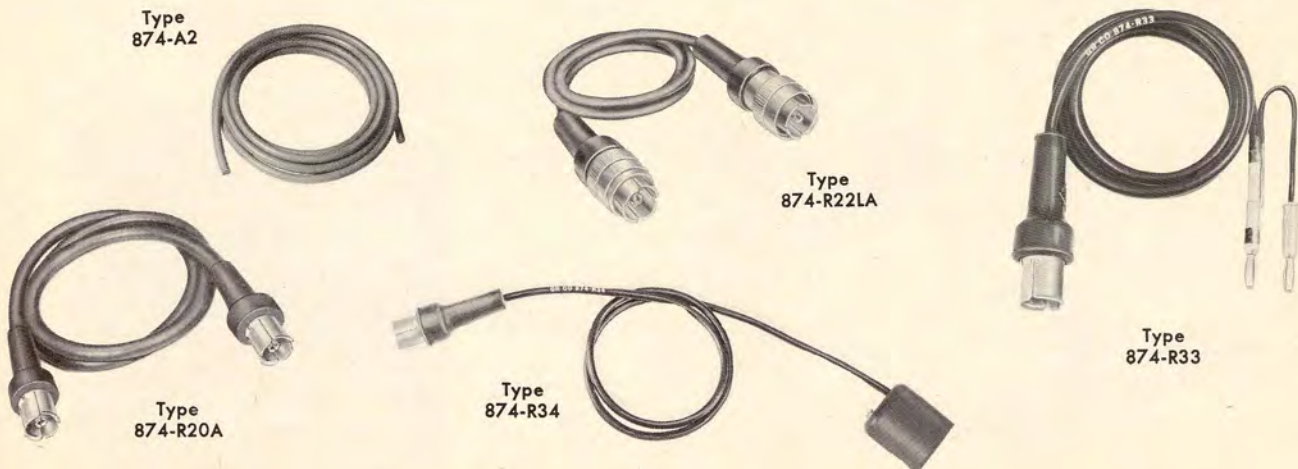
The TYPE 874-R33 Patch Cord terminates in a pair of banana plugs, one connected to the center conductor and the other to the braid through a 5-inch pigtail. These plugs mate directly with TYPE 274 and 938 Jacks, TYPE 938 Binding Posts, and TYPE 838 Alligator Clips (see pages 252, 253, and 256). The TYPE 874-R34



Patch Cord terminates in a TYPE 274-NK Shielded Double Plug (see page 256).

Other patch cords, equipped with General Radio TYPE 274 double plugs, are described on page 257.

Catalog No.	Patch Cord Type	Cable Type	Connectors (see p 79 & 256)	Braid	Length (ft)	Freq Range	Net Weight	Price
0874-9680	874-R20A	874-A2	874-CA	Double	3	1-9 Gc/s	7 oz (200 g)	\$12.50
0874-9681	874-R20LA	874-A2	874-CLA	Double	3	1-9 Gc/s	9 oz (255 g)	14.50
0874-9682	874-R22A	874-A3	874-C58A	Double	3	1-9 Gc/s	4 oz (115 g)	11.50
0874-9683	874-R22LA	874-A3	874-CL58A	Double	3	1-9 Gc/s	6 oz (170 g)	13.50
0874-9690	874-R33	low C, 72Ω coaxial	874-C58A & 274-NO	Single	3	—	2½ oz (75 g)	7.00
0874-9692	874-R34	RG-58C/U	874-C58A & 274-NK	Single	3	—	3½ oz (100 g)	7.00





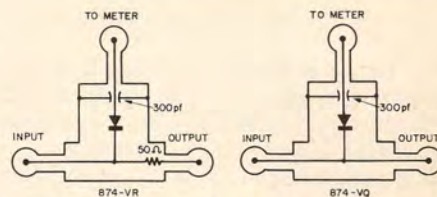
Type 874-VQ VOLTMETER DETECTOR

Used with the TYPE 874-VI Voltmeter Indicator (see below) for voltage measurement, with the TYPE 1232-A Tuned Amplifier and Null Detector (see page 104) as a sensitive (approximately 100 μ V full-scale) detector of modulated signals, or with a microammeter as an rf detector. It introduces no appreciable discontinuity when inserted in a 50-ohm coaxial line. It can be used with the TYPE 874-W50B 50-ohm Termination as a matched detector to terminate a line.

SPECIFICATIONS

Frequency Range (as Matched Detector): 0.5 Mc/s to 2 Gc/s. Usable from 60 c/s to 7 Gc/s.
Maximum Voltage: 2 V.
VSWR: Less than 1.1 at 1 Gc/s, 1.2 at 2 Gc/s.

Schematic diagram of Types 874-VQ and 874-VR.



Bypass Capacitance: Approximately 300 pF.
Crystal: 1N23B.
Dimensions: Length 3 3/4, height 2 1/2 in (96, 64 mm).
Net Weight: TYPE 874-VQ, 5 oz (145 g); TYPE 874-VQL, 6 oz (170 g).

Catalog No.	Description	Price
0874-9940	Type 874-VQ Voltmeter Detector	\$30.00
0874-9941	Type 874-VQL Voltmeter Detector (locking connectors)	32.00

Type 874-VR VOLTMETER RECTIFIER

Used with the TYPE 874-VI Voltmeter Indicator (see below) to measure or to monitor the voltage in coaxial systems. It contains a 50-ohm resistor in series with the output line and thus can be used to measure the voltage behind a 50-ohm impedance. In combination with a signal source and TYPE 874-VI Voltmeter Indicator, this device simulates a 50-ohm generator with a known equivalent open-circuit voltage. It is also a good general-purpose detector for use with a microammeter or, for high sensitivity (100 μ V full scale) for modulated

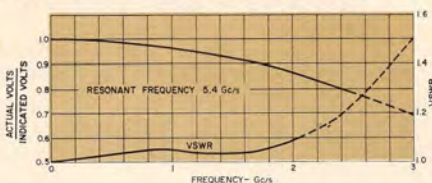
signals, with the TYPE 1232-A Tuned Amplifier and Null Detector. It is used with the TYPE 1263-A Amplitude-Regulating Power Supply, in an oscillator amplitude-leveling system.

SPECIFICATIONS

Frequency Range (as Calibrated Voltmeter): 15 Mc/s to 2.5 Gc/s.
Maximum Voltage: 2 V.
Bypass Capacitance: Approximately 300 pF.
Crystal: 1N23B.
Dimensions: Length 3 3/4, height 2 1/2 in (96, 64 mm).
Net Weight: TYPE 874-VR, 5 oz (145 g); TYPE 874-VRL, 6 oz (170 g).

Catalog No.	Description	Price
0874-9942	Type 874-VR Voltmeter Rectifier	\$30.00
0874-9943	Type 874-VRL Voltmeter Rectifier (locking connectors)	32.00

Typical VSWR for Type 874-VQ and correction factor for Types 874-VQ and 874-VR.



Type 874-VI VOLTMETER INDICATOR

Measures dc output of either TYPE 874-VQ or TYPE 874-VR at any level between 0.1 and 2 volts. A built-in 60-cycle calibration system eliminates errors arising from differences in crystal rectification efficiencies.

SPECIFICATIONS

Range and Accuracy of Calibrating Voltage: 0.1 to 2 V, \pm 0.05 V.
Crystal Current for Full-Scale Indication: 200 μ A.
Power Required: 105 to 125 or 210 to 250 V, 50 to 60 c/s.

Input Resistance: 600 Ω min, 10,000 Ω max.
Accessory Supplied: TYPE CAP-22 Power Cord.
Accessory Required: One TYPE 874-R34 Patch Cord (page 85).
Dimensions: 5 1/2 by 5 1/2 by 4 1/2 in (140, 140, 115 mm), over-all.
Net Weight: 3 lb (1.4 kg).
Shipping Weight: 5 lb (2.3 kg).

Catalog No.	Description	Price
0874-9936	Type 874-VI Voltmeter Indicator	\$110.00

Type 874-VQL



Type 874-VRL



Type 874-VI



Type 874-MR MIXER RECTIFIER

A broadband rf mixer. Used with a TYPE 1216-A Unit I-F Amplifier, it acts as a heterodyne detector with a 30-Mc difference frequency. The output circuit contains a low-pass filter with a cutoff frequency of 40 Mc/s. A 250-ohm series resistor isolates the circuit from the local oscillator.

SPECIFICATIONS

Frequency Range: 40 Mc/s to 5 Gc/s; at lower and higher frequencies with less sensitivity.

Cutoff Frequency of Output Filter: 40 Mc/s.

Maximum Input from Local Oscillator: 2 V.

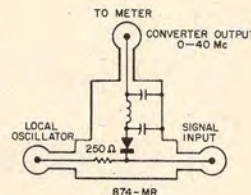
Typical Sensitivity: 5 μ V for discernible deflection on meter of TYPE 1216-A Unit I-F Amplifier or communications receiver S meter.

Crystal Current: 5 mA max, 0.2 mA min.

Output Impedance: Approximately 400 Ω .

Crystal: 1N21B.

Accessories Required: For complete detector assembly, see page 109.



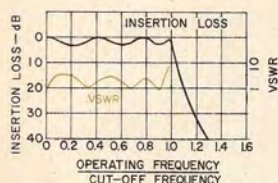
Schematic diagram of Type 874-MR.

Dimensions: Length 3 3/4, height 3 1/2 in (96 by 89 mm).

Net Weight: TYPE 874-MR, 7 oz (200 g); TYPE 874-MRL, 8 oz (230 g).

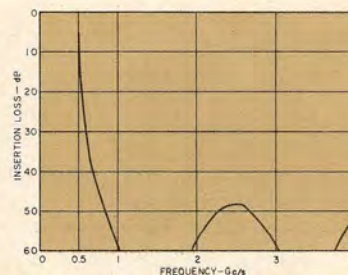
Catalog No.	Description	Price
0874-9944	Type 874-MR Mixer Rectifier	\$32.50
0874-9945	Type 874-MRL Mixer Rectifier (locking connectors)	34.50

Type 874-F LOW-PASS FILTERS



Typical insertion loss and VSWR, Type 874-F Filters.

Recommended for use in immittance- or voltage-measuring systems to reduce harmonics, and especially in systems containing nonlinear elements or sections that might resonate at a harmonic. Also useful in slotted-line measurements. Filters are Tschebyscheff type, which produce a very steep cutoff characteristic at the expense of passband flatness. Spurious responses in the stopband are very small. All filters are equipped with locking GR874 Connectors.

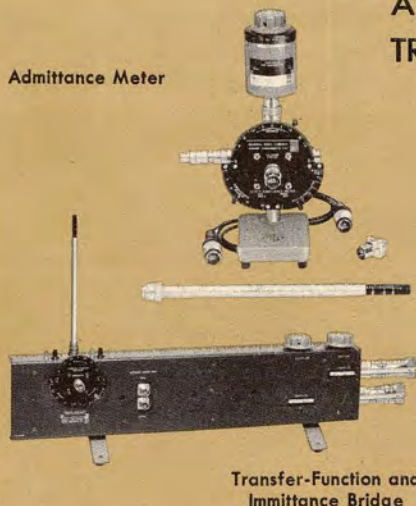


Typical stop-band response of Type 874-F500L Low-Pass Filter.

Catalog No.	Description	Physical Length	Net Weight	Price
0874-9533	Type 874-F185L 185-Mc Low-Pass Filter	17 3/8 in	12 oz (340 g)	\$32.00
0874-9537	Type 874-F500L 500-Mc Low-Pass Filter	10 3/16 in	8 1/2 oz (245 g)	26.00
0874-9541	Type 874-F1000L 1-Gc Low-Pass Filter	7 1/8 in	8 oz (230 g)	24.00
0874-9545	Type 874-F2000L 2-Gc Low-Pass Filter	4 3/8 in	4 1/2 oz (130 g)	24.00
0874-9549	Type 874-F4000L 4-Gc Low-Pass Filter	2 7/8 in	3 oz (85 g)	24.00



ADMITTANCE METER TRANSFER-FUNCTION AND IMMITTANCE BRIDGE



Two important VHF-UHF instruments are the Type 1602-B UHF Admittance Meter (page 54) and the Type 1607-A Transfer-Function and Immittance Bridge (page 56). Both are GR874-equipped, null-type instruments useful up to 1500 megacycles.

The admittance meter is widely used in VSWR and impedance measurements on antennas, transmission lines, and coaxial systems and components. It can be used to adjust a network to a given admittance, to match one network to another, and to match an antenna to a 50-ohm circuit.

The transfer-function and imittance bridge performs all the measurements of the admittance meter and also measures the forward and reverse complex transfer functions of four-terminal networks, both active and passive. This instrument has become a fundamental tool in transistor work, where it is used to measure α , β , and h parameters, and is also used to measure characteristics of tunnel diodes, tubes, and many other networks and components.



Type 874-G FIXED ATTENUATORS

Single-section, T-type resistance pads, for insertion of fixed attenuation in 50-ohm systems and for isolation and matching to 50 ohms over a broad frequency range. Each attenuator consists of one disk and two cylindrical resistors, as shunt and series elements, respectively.

SPECIFICATIONS

Dc Resistance: 50 Ω \pm 1% when terminated in 50 Ω .
VSWR: Less than 1.1 to 1 Gc/s, 1.2 to 3 Gc/s for all units; to

4 Gc/s, less than 1.3 for -G20, 1.35 for -G10, and 1.4 for -G3 and -G6.

Accuracy in 50- Ω System: \pm 1.5% of nominal at dc; \pm 0.2 dB from value indicated on curve to 1 Gc/s; \pm 0.4 dB to 2 Gc/s; \pm 0.6 dB to 4 Gc/s.

Temperature Coefficient: Less than 0.0003 dB/ $^{\circ}$ C/dB.

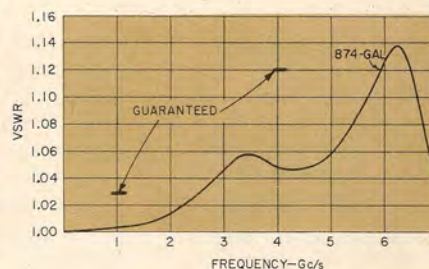
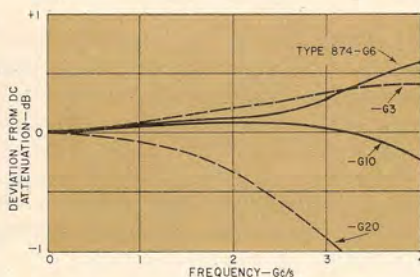
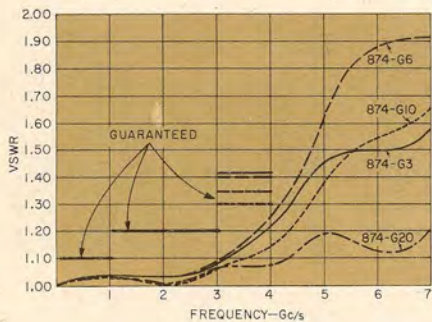
Maximum Power: CW - 1 W; pulse - 2000 W peak, 1 W average.

Physical Length: 3 1/2 in (89 mm), over-all.



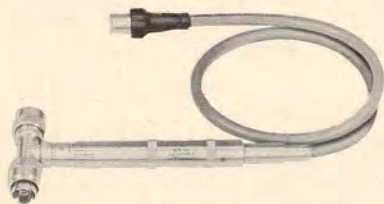
Catalog Number	Description	Net Weight	Price
0874-9564	Type 874-G3 Fixed Attenuator (3 dB)	3 oz (85 g)	\$36.00
0874-9565	Type 874-G3L* Fixed Attenuator (3 dB)	4 oz (115 g)	38.00
0874-9568	Type 874-G6 Fixed Attenuator (6 dB)	3 oz (85 g)	30.00
0874-9569	Type 874-G6L* Fixed Attenuator (6 dB)	4 oz (115 g)	32.00
0874-9570	Type 874-G10 Fixed Attenuator (10 dB)	3 oz (85 g)	30.00
0874-9571	Type 874-G10L* Fixed Attenuator (10 dB)	4 oz (115 g)	32.00
0874-9572	Type 874-G20 Fixed Attenuator (20 dB)	3 oz (85 g)	30.00
0874-9573	Type 874-G20L* Fixed Attenuator (20 dB)	4 oz (115 g)	32.00

* Locking connectors.



(Left) Guaranteed and typical VSWR and (center) correction factor for fixed attenuators. (Right) Guaranteed and typical VSWR introduced in line by Type 874-GAL.

Type 874-GAL ADJUSTABLE ATTENUATOR



A waveguide-below-cutoff type, useful as a calibrated attenuator or as a sampling device. Calibrated in decibels, on a micrometer-type scale. Absolute attenuation

is the sum of insertion loss and scale reading. The main line is a short coaxial section with locking GR874 Connectors, one end for source and the other for load. It introduces minimum discontinuity when inserted in a 50-ohm line. The loop output is brought out through three feet of 50-ohm cable.

Can be used with TYPE 874-VR Voltmeter Rectifier and TYPE 874-VI Voltmeter Indicator (page 86) to convert a Unit Oscillator (pages 139 to 144) into a signal generator.

SPECIFICATIONS

Calibrated Range: 120 dB (relative attenuation) with input line terminated in 50 Ω ; 129 dB with input line terminated in adjustable stub to minimize the electric field at the coupling point (scale reads -9 to 120 dB).

Insertion Loss (from input connector to end of output cable at 1 Gc/s, when signal source impedance is 50 Ω):

With input line terminated in 50 Ω , and scale set at 0 dB, 32 \pm 2 dB; set at -9 dB, 17 \pm 2 dB (settings below 0 are not accurate).

With input line terminated in adjustable stub (which extends the range over which the calibration is accurate to the -9 dB scale setting), 19 \pm 2 dB minimum.

(Insertion loss is approximately inversely proportional to frequency up to 1 Gc/s.)

Insertion Loss Directly Through Tee: Negligible.

Accuracy of Attenuation:

Stub-terminated input, \pm (0.01 times difference in attenuation

reading +0.2) dB, direct-reading.

50- Ω terminated input, \pm (0.015 times difference in attenuation reading + 0.2) dB, when corrected. Correction chart supplied.

VSWR Introduced into Line: Less than 1.03 at 1 Gc/s; less than 1.12 from 1 to 4 Gc/s.

VSWR of Output: Less than 4 at 1 Gc/s; less than 5 from 1 to 4 Gc/s.

Maximum Power: Input power limit inversely proportional to square root of frequency. Power should not exceed 300 W at 1 Gc/s. Output power should not exceed 1/2 W.

Frequency Range: 100 Mc/s to 4 Gc/s.

Net Weight: 1 1/4 lb (0.6 kg).

Catalog No.	Description	Price
0874-9577	Type 874-GAL Adjustable Attenuator	\$82.00



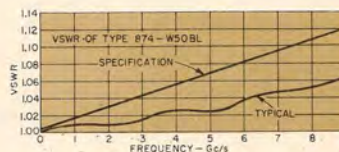
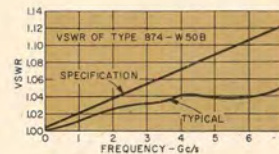
50-OHM TERMINATIONS

Type 874-W50B, -W50BL 50-OHM TERMINATIONS

Each unit comprises a 50-ohm cylindrical resistor mounted in a tapered coaxial holder and is useful for impedance matching, establishment of reference conditions, and as a termination. The TYPE 874-W50BL is equipped with a TYPE 874-BBL Basic Connector and thus offers greater stability and repeatability as well as extended frequency range (to 9 Gc/s) and locking capability.



Type W50B



Type W50BL

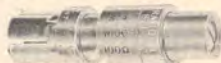


	Type 874-W50B	Type 874-W50BL
Frequency Range:	dc to 7 Gc/s	dc to 9 Gc/s
VSWR:	$<1.005 + 0.017 f_{Gc}$	$<1.005 + 0.013 f_{Gc}$
Dc Resistance:	$50 \Omega \pm 0.5\%$	$50 \Omega \pm 0.5\%$
Maximum Power:	2 W continuous	2 W continuous

Catalog No.	Description	Net Weight	Price
0874-9954	Type 874-W50B 50-ohm Termination	2½ oz (70 g)	\$23.00
0874-9955	Type 874-W50BL 50-ohm Termination, locking	3 oz (85 g)	24.00

COAXIAL STANDARDS — 100 AND 200 OHMS

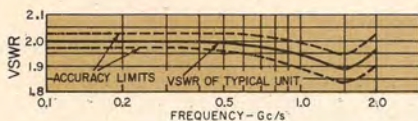
Type 874-W100 100-OHM COAXIAL STANDARD



Produces known resistive termination at specific locations on coaxial lines. Useful for checking accuracy of directional couplers, bridges, and admittance meters. The known location of the purely resistive termination permits the production of many known complex impedances through the addition of sections of TYPE 874-L Air Line (page 90).

Dc Resistance: $100 \Omega \pm 1\%$.

Maximum Power: ¼ W continuous, 150 W peak.



Typical VSWR of (left) Type 874-W100 and (right) Type 874-W200.

Type 874-W200 200-OHM COAXIAL STANDARD

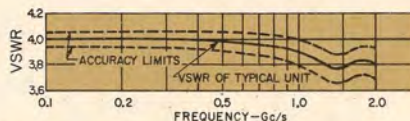


Same as TYPE 874-W100 except standard resistance is 200 ohms.

Dc Resistance: $200 \Omega \pm 1\%$.

Maximum Power: ¼ W continuous, 50 W peak.

Catalog No.	Description	Net Weight	Price
0874-9956	Type 874-W100 100-ohm Coaxial Standard	3 oz (85 g)	\$35.00
0874-9958	Type 874-W200 200-ohm Coaxial Standard	3 oz (85 g)	35.00



SHORT-CIRCUIT TERMINATIONS

Type 874-WN SHORT-CIRCUIT TERMINATION



A fixed short circuit mounted in a connector, for establishing reference conditions on coaxial lines and for use in substitution measurements.

Catalog No.	Description	Net Weight	Price
0874-9970	Type 874-WN Short-Circuit Termination	1 oz (30 g)	\$4.50

Type 874-WN3 SHORT-CIRCUIT TERMINATION



Same as TYPE 874-WN, except that the short circuit is at a point 3 cm (3.2-cm electrical distance) beyond the face of the bead in the GR874 Connector.

Catalog No.	Description	Net Weight	Price
0874-9972	Type 874-WN3 Short-Circuit Termination	1½ oz (45 g)	\$6.50

OPEN-CIRCUIT TERMINATIONS

Type 874-WO OPEN-CIRCUIT TERMINATION



A shielding cap for open-circuited lines, for establishing reference conditions on coaxial lines, and for use in substitution measurements. Produces an open circuit at same point in line that TYPE 874-WN produces a short circuit.

Catalog No.	Description	Net Weight	Price
0874-9980	Type 874-WO Open-Circuit Termination	1 oz (30 g)	\$2.75

Type 874-WO3 OPEN-CIRCUIT TERMINATION



Same as TYPE 874-WO, except that the open circuit is at a point corresponding to that of the short circuit in the TYPE 874-WN3 Short-Circuit Termination.

Catalog No.	Description	Net Weight	Price
0874-9982	Type 874-WO3 Open-Circuit Termination	1½ oz (45 g)	\$5.00



Type 874-L RIGID AIR LINES

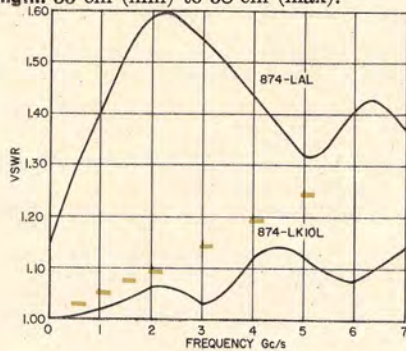
For spacing stubs or other elements of a coaxial system; also useful as time-delay elements and as absolute impedance in time-delay reflectometers. Each air line consists of a length (10, 20, or 30 cm) of 50-ohm, air-dielectric coaxial line with a GR874 Coaxial Connector, either regular or locking, at each end. Locking versions use TYPE 874-BBL Basic Connectors and are thus usable up to 9 Gc/s.

Time Delay: 10 cm, 0.334 ns $\pm 0.7\%$; 20 cm, 0.667 ns $\pm 0.4\%$; 30 cm, 1.001 ns $\pm 0.3\%$.
Characteristic Impedance: 50 Ω $\pm 0.4\%$.

Type 874-LAL ADJUSTABLE LINE

An air-dielectric coaxial line that can be telescoped to change its length. Used in matching networks, as a phase shifter, and as a variable time-delay element. Contacts are made by multiple-spring fingers. Connectors are locking GR874.

Characteristic Impedance: Not constant — approximately 50 Ω when fully collapsed, approximately 57 Ω when fully extended.
Adjustment Range: 25 cm.
Physical Length: 33 cm (min) to 58 cm (max).



Curves shown are typical VSWR; dashed points are specifications.

Type 874-LK CONSTANT-IMPEDANCE ADJUSTABLE LINES

A line stretcher with a very low vswr and a uniform characteristic impedance of 50 ohms. Especially useful for eliminating the usual Smith-chart corrections for length of line between unknown and impedance-measuring device. These lines are useful as impedance-matching transformers and phase-adjustment elements in coaxial systems. Locking GR874 Connectors.

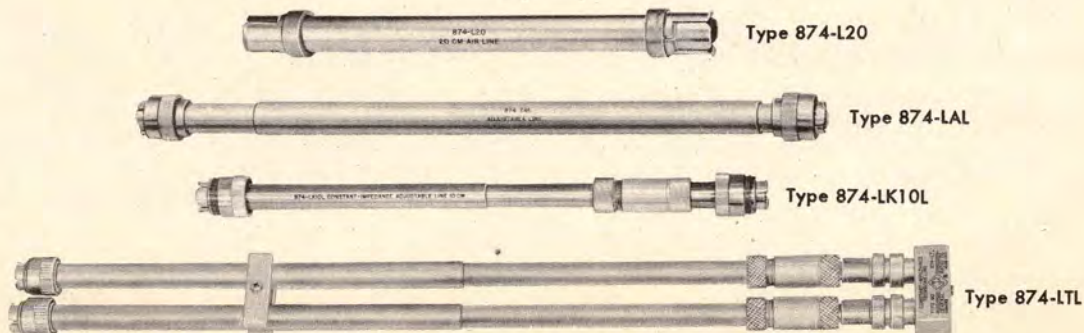
Characteristic Impedance: 50 Ω .
Adjustment Range: TYPE 874-LK10L, 10 cm (half wavelength at 1.5 Gc/s); TYPE 874-LK20L, 22 cm (half wavelength at 680 Mc/s).
Physical Length: TYPE 874-LK10L, 35 cm (min) to 45 cm (max); TYPE 874-LK20L, 58 cm (min) to 80 cm (max).
VSWR: TYPE 874-LK20L, less than 1.03 at 500 Mc/s, less than 1.06 at 1 Gc/s, less than 1.08 at 1.5 Gc/s, less than 1.10 at 2 Gc/s. TYPE 874-LK10L, same as TYPE 874-LK20L to 2 Gc/s, less than 1.15 at 3 Gc/s, less than 1.2 at 4 Gc/s, less than 1.25 at 5 Gc/s.

Type 874-LTL TROMBONE CONSTANT-IMPEDANCE ADJUSTABLE LINE

With this line stretcher, built like a trombone slide, the user can vary the length of a 50-ohm transmission line between two fixed terminals without moving the terminals or using flexible cable. Consists of two TYPE 874-LK20L Adjustable Lines mounted in parallel and joined at one end by a U-shaped section to form a rigid assembly. Can be plugged into two adjacent GR874 Coaxial Connectors or inserted in a line by means of two ells (not included) when installed vertically to save bench space. Low vswr. An excellent phase shifter.

Characteristic Impedance: 50 Ω .
Frequency Range: Dc to 2 Gc/s (TYPE 874-LK10L is recommended above 2 Gc/s).
Adjustment Range: 44 cm (half wave at 340 Mc/s).
Physical Length: 61 cm (min) to 83 cm (max).
Spacing: 1 3/16 inch between centers.
VSWR: Less than 1.10 to 1 Gc/s, and 1.25 to 2 Gc/s.

Catalog Number	Description	Net Weight	Price
0874-9604	Type 874-L10 10-cm Air Line	2 1/2 oz (70 g)	\$ 9.50
0874-9605	Type 874-L10L 10-cm Air Line, locking connectors	3 1/2 oz (98 g)	11.50
0874-9608	Type 874-L20 20-cm Air Line	4 1/2 oz (126 g)	10.50
0874-9609	Type 874-L20L 20-cm Air Line, locking connectors	5 1/2 oz (154 g)	12.50
0874-9612	Type 874-L30 30-cm Air Line	6 1/2 oz (182 g)	11.50
0874-9613	Type 874-L30L 30-cm Air Line, locking connectors	7 1/2 oz (210 g)	13.50
0874-9621	Type 874-LAL Adjustable Line	10 oz (280 g)	27.00
0874-9627	Type 874-LK10L 10-cm Constant-Impedance Adjustable Line	9 oz (255 g)	42.00
0874-9631	Type 874-LK20L 22-cm Constant-Impedance Adjustable Line	15 oz (425 g)	42.00
0874-9645	Type 874-LTL Trombone Constant-Impedance Adjustable Line	2 1/4 lb (1.02 kg)	97.00





Type 874-D20L and -D50L ADJUSTABLE STUBS



For matching or tuning, for use as adjustable short-circuit terminations, and as reactive elements. With an external indicator, the stub can function as a reaction-type wavemeter. Consists of a coaxial line with a sliding short circuit of the multiple-spring-finger type. The 20-centimeter stub is calibrated in electrical length. The 50-centimeter stub is not calibrated but has an adjustable reference marker. Each is equipped with a locking connector.

SPECIFICATIONS

Characteristic Impedance: 50 Ω .
Maximum Travel: TYPE 874-D20L, 20 cm; TYPE 874-D50L, 50 cm.
Physical Length: TYPE 874-D20L, 28 cm (min) to 48 cm (max); TYPE 874-D50L, 58 cm (min) to 109 cm (max).
Net Weight: TYPE 874-D20L, 7 oz (196 g); TYPE 874-D50L, 13 oz (364 g).

Catalog No.	Description	Price
0874-9511	Type 874-D20L 20-cm Adjustable Stub	\$17.50
0874-9513	Type 874-D50L 50-cm Adjustable Stub	21.00

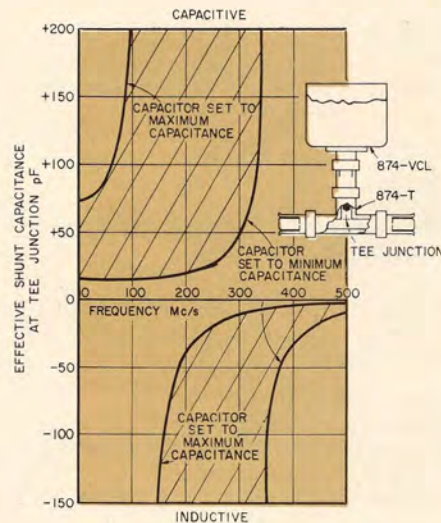


Type 874-VCL VARIABLE CAPACITOR

Tuning element for resonant-line circuits, matching transformers, and baluns at low frequencies where line-type elements are awkward to use. Well shielded, high-temperature polystyrene insulation, precision ball bearings, locking connector.

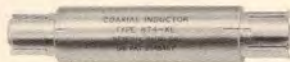
SPECIFICATIONS

Scale: 0 to 100.
Capacitance Range: Low frequencies, 14 to 70 pF at connector, 16.5 to 72.5 pF at T-junction. Linear capacitance variation.
Dimensions: Diameter 2 1/2, height 5 1/4 in (64, 135 mm).
Net Weight: 12 1/2 oz (350 g).



Catalog No.	Description	Price
0874-9931	Type 874-VCL Variable Capacitor	\$70.00

Type 874-XL SERIES INDUCTOR



Used as a general-purpose tuning element in resonant-line circuits, matching transformers, and baluns at low frequencies.

SPECIFICATIONS

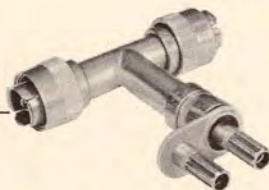
Series Inductance: 0.226 μ H \pm 5% at 1 kc/s.
Net Weight: 3 1/2 oz (98 g).

Catalog No.	Description	Price
0874-9998	Type 874-XL Series Inductor	\$19.00

Type 874-FBL BIAS INSERTION UNIT

NEW

in catalog S



Used in immittance and similar measurements where bias is to be applied to diodes, transistors, and other solid-state devices. It comprises a blocking capacitor in series with the line, an isolating choke, and a low-pass filter.

In slotted-line measurements, it is inserted at the source end of the line and therefore introduces no reflections at the measurement terminals.

SPECIFICATIONS

Current Rating: 2.5 A.
Voltage Rating: 400 V.
VSWR: Typically, less than 1.25 from 300 Mc/s to 5 Gc/s.
Insertion Loss: Typically, less than 0.4 dB from 300 Mc/s to 3 Gc/s, less than 0.8 dB from 3 Gc/s to 5 Gc/s.
Dimensions: 4 3/8 by 3 3/8 in (115, 99 mm). **Weight:** 6 1/2 oz (185 g).

Catalog No.	Description	Price
0874-9759	Type 874-FBL Bias Insertion Unit	\$45.00



DETECTORS



In most types of electrical measurements, a detector is used for aural or visual indication of the desired measurement condition. Such devices as null indicators, demodulators, and voltmeters are usually combined with filters and amplifiers to constitute detectors for specific purposes. Different types of measurement impose different requirements on the detector. Thus, bridge measurements require both selectivity and shielding to reduce extraneous signals and high sensitivity for maximum precision of measurement. For measurement of relative signal levels (gain or loss), a wide linear range is desirable, as well as an accurately calibrated level indication. In demodulators, distortion must be minimized to ensure faithful reproduction of the modulation envelope.

A simple rectifier followed by a meter or earphones can be used to convert an ac signal to dc or to demodulate an rf signal, but such a system has inherently low sensitivity. For higher sensitivity, some form of amplifier is necessary. At audio frequencies, the signal is usually amplified directly and then rectified to operate a meter, although with null detectors, earphones can be used at the user's option. At radio frequencies, a radio receiver, if well shielded, is a satisfactory detector, but a broadband heterodyne detector employing a wide-range local oscillator is usually more flexible in application. Here, the incoming signal is heterodyned with that of a local oscillator to produce the differ-

ence frequency, which is amplified in an intermediate-frequency amplifier.

General Radio offers detectors using all three types of amplifiers — untuned, tunable, and fixed-tuned intermediate frequency.

The Type 1212-A Unit Null Detector is an untuned detector, which covers a wide frequency range and uses limiting amplifiers to produce a nonlinear compression of the meter scale so as to cover a range of at least 100 dB, thus eliminating the need for amplifier gain adjustments during bridge-balancing operations.

For maximum effective sensitivity, one of the accessory filters should be used at the input: the Type 1212-P1, for eliminating pickup at the power-line frequency in measurements above 10 kc/s; or the Type 1212-P2, for maximum sensitivity and selectivity at 1 Mc/s. The Type 1212-P3 RF Mixer is also available for this instrument, extending its frequency coverage to 60 Mc/s or more in conjunction with appropriate local oscillators (see DNT assemblies, page 109).

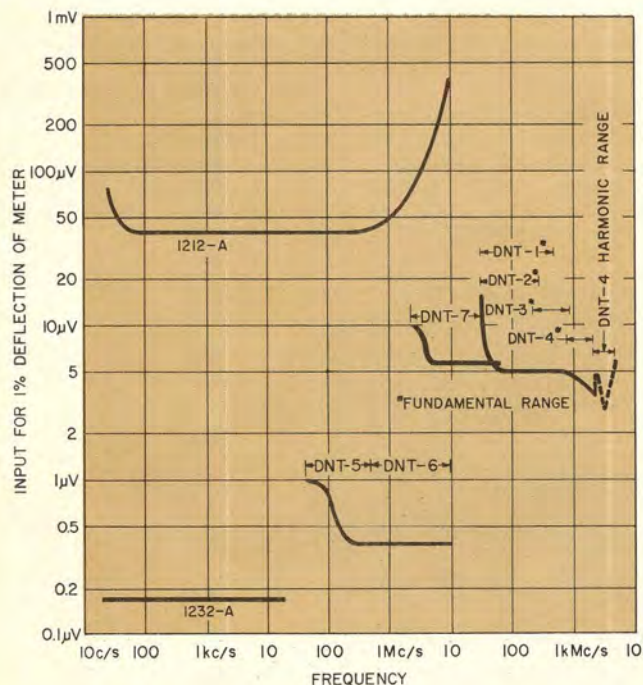
The Type 1232-A Tuned Amplifier and Null Detector is tunable over the audio-frequency range, with two additional fixed frequencies of 50 and 100 kc/s. Its unusually high sensitivity, low noise level, excellent selectivity, and high gain make it suitable for the most exacting bridge-measurement requirements. With the Type 1232-P1 RF Mixer, it can be used as the i-f amplifier in a heterodyne-detector system at frequencies up to 10 Mc/s (see page 109).

For audio-frequency bridge measurements, the Type 1240-A Bridge Oscillator-Detector provides both the bridge power source and the detector in a simple, compact structure.

Complete heterodyne-detector systems, the Types DNT-5, DNT-6, and DNT-7, are available, which use the above amplifiers and mixers.

For very-high and ultra-high frequencies, the Types DNT-1, DNT-2, DNT-3, and DNT-4 Detectors are used. The mixer is the Type 874-MR, and the i-f signal is amplified in the Type 1216-A Unit I-F Amplifier.

Simple rectifiers are often used at the high frequencies. The Type 874-VQ Voltmeter Detector and Type 874-VR Voltmeter Rectifier cover a very wide frequency range, as indicated on the chart. Used with an audio amplifier, such as the Type 1232-A, they are sensitive detectors of modulated signals.



Sensitivity and frequency ranges of various detectors.

OTHER INSTRUMENTS SUITABLE AS DETECTORS

The following general-purpose and special-purpose instruments can also be used in detection systems over their respective frequency ranges.

Type	Name	See Page
1206-B	Unit Amplifier	36
1551-C	Sound-Level Meter	14
1900-A	Wave Analyzer	28

Sensitivity and frequency ranges of various detectors.



Type 1232-A TUNED AMPLIFIER AND NULL DETECTOR

20 c/s TO 20 kc/s; 50 AND 100 kc/s

FEATURES:

- High sensitivity — typically, better than 0.1 microvolt at 1 kc/s. ■ 120-dB gain.
- High selectivity — approximately 5% bandwidth.
- Very low noise level — generally below 0.1 microvolt.
- Continuous (plus range switch) tuning — 20 c/s to 20 kc/s in 3 ranges.
- Spot frequencies at 50 and 100 kc/s.

USES: Bridge detector for audio frequencies.

Extremely sensitive, heterodyne, rf null detector for frequencies up to 10 Mc/s, when used as a 20-kc and 100-kc i-f amplifier with the TYPE 1232-P1 RF Mixer and appropriate local oscillator. See listing of TYPES DNT-5 and DNT-6 Heterodyne Detectors on page 109.

Audio-frequency preamplifier for oscilloscopes, microphones, vibration pickups, and other transducers.

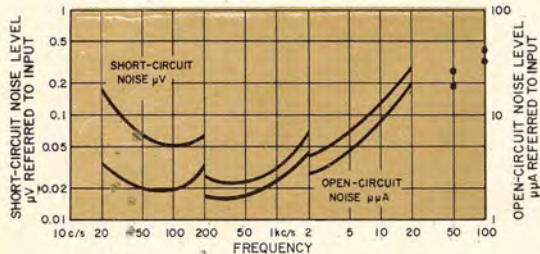
General-purpose, tunable, or broadband audio amplifier (± 3 dB from 20 c/s to 20 kc/s plus spot frequencies at 50 kc/s and 100 kc/s).

Audio wave analyzer (for approximate measurements) with a sensitivity of a fraction of a microvolt.

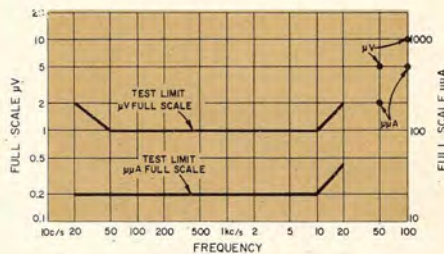
Detector for modulated frequencies from 500 kc/s to 5000 Mc/s, with the TYPE 874-VQ Voltmeter Detector.

DESCRIPTION: This battery-operated, solid-state amplifier consists of a low-noise preamplifier, followed by a frequency selective stage, and an amplifier-compressor stage. Tuning is accomplished by a GR-designed, single-control, rc, bridged-T network in a negative-feedback loop. The compact convertible-bench cabinet has extendible legs to tilt the panel at a convenient viewing angle. Panel extensions are available to adapt the assembly for rack mounting.

SPECIFICATIONS



Typical noise levels as a function of frequency. Minimum input for full-scale meter deflection as a function of frequency, when amplifier is tuned to peak response.



Frequency Response:

Tunable Filters — 20 c/s to 20 kc/s in 3 ranges; between 2% and 6% bandwidth to 15 kc/s; 2nd harmonic at least 34 dB down from peak, 3rd at least 40 dB down; rejection filter on two highest ranges reduces 60-cycle level to at least 60 dB below peak (50 dB at 50 c/s). Dial accuracy is $\pm 3\%$.

50- and 100-kc Filters — 2nd harmonic 44 and 53 dB down, respectively.

Flat Response — ± 3 dB 20 c/s to 100 kc/s.

Sensitivity: See plot. Typically better than 0.1 μ V over most of the frequency range.

Noise Level Referred to Input: See plot. Noise figure at 1 kc/s is less than 2 dB at an optimum source impedance of 27 k Ω .

Noise Level Referred to Output: Less than 5 mV on FLAT filter-frequency position, minimum gain setting, and -20 dB switch position; less than 50 mV in MAX SENS position.

Input Impedance: Approximately 50 k Ω at maximum gain; varies inversely with gain to 1 M Ω at minimum gain.

Maximum Safe Input Voltage: 200 V ac or 400 V dc.

Voltage Gain: 120 dB on the tunable ranges; 100 dB, flat range; 106 dB at 50 kc/s; 100 dB at 100-kc position.

Output: 1 V into 10,000 Ω . Internal impedance is 3000 Ω .

Meter Linearity: DB differences are accurate to $\pm 5\% \pm 0.1$ division for input of less than 0.3 V.

Compression (on LOG position): Reduces full-scale sensitivity by 40 dB. Does not affect bottom 20% of scale.

20-dB Position: Reduces gain by 20 dB in linear mode.

Distortion (in FLAT position): Less than 5% (from meter rectifiers).

Power Supply: 12 V dc, from 9 mercury (M72) cells in series. Estimated battery life is 1500 hours. Optionally, a rechargeable battery (non-mercury) can be supplied on special order.



Terminals: Input, GR874 Coaxial Connector (see pages 78 to 85 for mating connectors, patch cords and adaptors); output, binding posts.

Mechanical Data: Convertible-Bench Cabinet (see page 258)

Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
8	205	6	155	7½	190	5¾	2.7	8	3.7

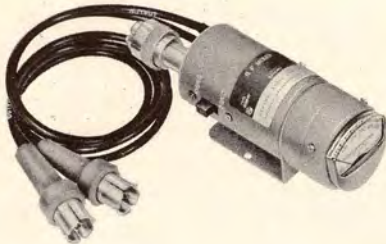
For a more detailed description, see *General Radio Experimenter*, July 1961.

Catalog No.	Description	Price
1232-9701	Type 1232-A Tuned Amplifier and Null Detector	\$360.00
0480-9638	Type 480-P308 Relay-Rack Adaptor Set	7.00

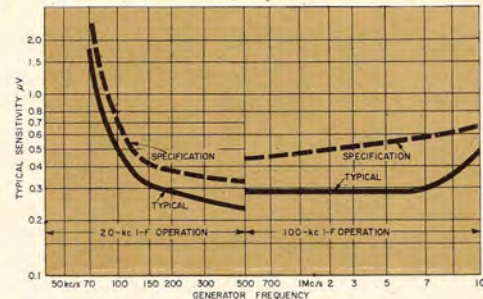
PATENT NOTICE. See Notes 4 and 15, page 11.

Type 1232-P1 RF MIXER

70 kc/s TO 10 Mc/s



Sensitivity (open-circuit voltage from 50-ohm source, equivalent to noise level).



This well-shielded rf mixer, with the TYPE 1232-A Null Detector and a local oscillator, becomes a sensitive heterodyne detector with a high degree of harmonic rejection. When the frequency of the local oscillator is swept, the combination can be used for approximate spectrum analysis with an oscilloscope. It can also be

used as a sensitive level indicator in attenuation measurements. The circuit comprises a semiconductor diode, tuned i-f output transformer, crystal-current meter, and associated components. For complete detector assemblies, including local oscillator, see page 108.

SPECIFICATIONS

Frequency Range: 70 kc/s to 10 Mc/s. (Can be used up to 60 Mc/s, with care in the selection and identification of local-oscillator frequencies.) Recommended local oscillators for the 70-kc to 0.5-Mc and the 0.5- to 10-Mc ranges are TYPE 1210-C and TYPE 1211-C, respectively.

I-F Output Frequencies: Switch-selected, 20 kc/s or 100 kc/s.

Bandwidth: 0.8 kc/s in 20-kc position, 10 kc/s in 100-kc position with a 20-kΩ output load (TYPE 1232-P1 RF Mixer alone).

Sensitivity: See plot.

Input Impedance: Approximately 200 Ω.

Output Impedance: Approximately 20,000 Ω.

Dimensions: Diameter 2¼, length 6¾ in (58, 175 mm).

Net Weight: 1 lb (0.5 kg).

Shipping Weight: 3 lb (1.4 kg).

For a more detailed description, see *General Radio Experimenter*, December 1963.

Catalog No.	Description	Price
1232-9601	Type 1232-P1 RF Mixer	\$105.00

Type 1240-A BRIDGE OSCILLATOR-DETECTOR

The TYPE 1232-A Tuned Amplifier and Null Detector and the TYPE 1311-A Audio Oscillator have been combined in a single, convenient unit for use with audio-frequency bridges and other null-balance devices. This assembly, the TYPE 1240-A Bridge Oscillator-Detector, occupies a minimum of bench space and is provided with removable panel extensions, which adapt it for rack mounting. The combination can also be easily disassembled so that component instruments can be used separately.

The oscillator supplies 11 fixed frequencies from 50 c/s to 10 kc/s. The detector is tunable continuously from 20 c/s to 20 kc/s, with additional spot frequencies of 50 kc/s and 100 kc/s.

Net Weight: 13½ lb (6.5 kg).

Shipping Weight: 28 lb (13 kg).

Catalog No.	Description	Price
1240-9701	Type 1240-A Bridge Oscillator-Detector	\$590.00

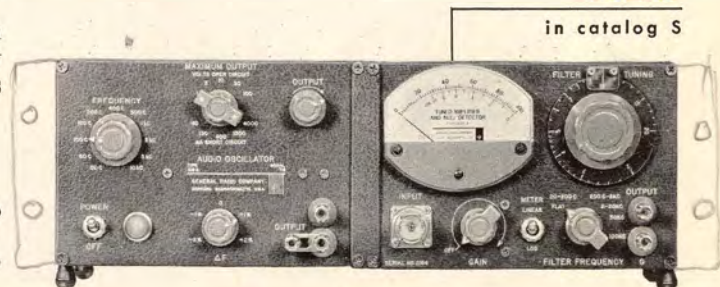
SPECIFICATIONS

Power Required: Null detector, internal battery; oscillator, 105 to 125 or 210 to 250 V, 50 to 400 c/s, 22 W max.

Dimensions: Width 19, height 6, depth 7¾ in (485, 155, 200 mm), over-all, with panel extensions.

NEW

in catalog S





Type 1212-A UNIT NULL DETECTOR

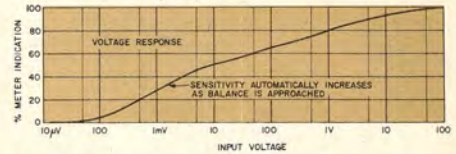
FEATURES:

- 50 c/s to 5 Mc/s. ■ Quasi-logarithmic response.
- On-scale range of approximately 120 dB.
- Meter sensitivity control for setting of voltage range desired.
- Sensitivity increases as balance is approached, thus increasing speed and precision.
- Regulated tube voltages and balanced meter circuit maintain stability.

USES: This unit null detector is an inexpensive, broad-band balance indicator for ac bridge measurements from 50 c/s to 5 Mc/s. With the TYPE 1212-P3 RF Mixer and a local oscillator, its range can be extended to 60 Mc/s as a heterodyne detector. See TYPE DNT-7 Heterodyne Detector, page 109.

DESCRIPTION: The instrument consists of a three-stage, broadband amplifier with series-peaking compensation. Germanium-diode clippers are used between

Meter indication vs input voltage.

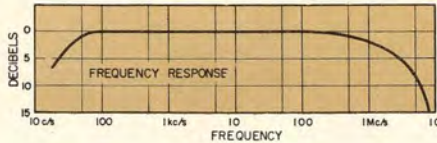


stages to obtain the quasi-logarithmic response. The output meter has a linear scale. Earphone terminals are provided.

SPECIFICATIONS

- Frequency Response:** See plot.
- Sensitivity:** Less than 40 μ V at 1 kc/s for 1% of full scale.
- Power Required:** TYPE 1203-B (or 1203-BQ18) Unit Power Supply (see page 219).
- Hum and Noise Level:** Hum, 20 μ V; broadband noise, 30 μ V.

Frequency response characteristic.



- Input Terminal:** Locking GR874 Coaxial Connector.
- Accessories Supplied:** Power-supply plug.
- Accessories Available:** TYPES 1212-P1 and -P2 Filters, TYPE 1212-P3 RF Mixer (see below); TYPE 874 patch cords for input connection (page 85).

Mechanical Data: Unit-Instrument Cabinet (see page 258)

With Power Supply	Width		Height		Depth		Net Weight		Shipping Weight	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
	15	385	5 3/4	150	6 1/4	160	9 3/4	4.5	13	6

Type 1212-P2 1-Mc FILTER

This shielded, tuned LC filter provides insertion gain at 1 Mc/s and attenuates higher and lower frequencies. Plugs into detector connector.

- Insertion Gain:** Between 22 dB and 32 dB at 1 Mc/s.
- Second-Harmonic Rejection:** At least 39 dB.
- Maximum Input Voltage:** 200 V.
- Terminals:** GR874 Coaxial Connector at each end.
- Dimensions:** Diameter 2, length 5 in (50, 130 mm).
- Net Weight:** 9 oz (0.3 kg). **Shipping Weight:** 1 lb (0.5 kg).

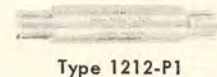
TYPE 1212-P1 HIGH-PASS FILTER

This shielded π C filter provides about 50-dB attenuation at 60 c/s. Plugs into detector input connector.

- Nominal Load Impedance:** 1 M Ω .
- Input Voltage Limit:** 150 V max.
- Terminals:** GR874 Coaxial Connector at each end.
- Dimensions:** Diameter 7/8, length 4 3/4 in (25, 110 mm).
- Net Weight:** 3 oz (0.1 kg).
- Shipping Weight:** 1 lb (0.5 kg).

Catalog No.	Description	Price
1212-9701	Type 1212-A Unit Null Detector	\$195.00
1203-9702	Type 1203-B Unit Power Supply (for 105- to 125-V supply)	55.00
1203-9818	Type 1203-BQ18 Unit Power Supply (for 210- to 250-V supply)	on request
1212-9601	Type 1212-P1 High-Pass Filter	15.00
1212-9602	Type 1212-P2 1-Mc Filter	35.00
0480-9986	Type 480-P4U3 Relay-Rack Adaptor Set	12.00

PATENT NOTICE. See Notes 4 and 15, page 11.



Type 1212-P1



Type 1212-P2

Type 1212-A Unit Null Detector with Type 1203-B Unit Power Supply

Type 1212-P3 RF MIXER



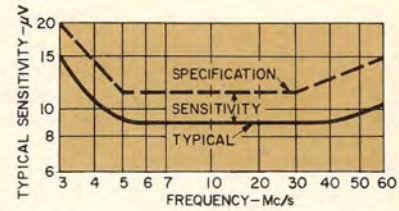
The TYPE 1212-P3 RF Mixer, which is similar to the TYPE 1232-P1, combines with the TYPE 1212-A Unit Null Detector to form a sensitive heterodyne null detector from 3 Mc/s to 60 Mc/s. For a complete detector assembly including local oscillator, see page 109.

This combination may also be used as a receiver or as an approximate spectrum analyzer and sensitive level indicator throughout its frequency range.

SPECIFICATIONS

Frequency Range: 3 Mc/s to 60 Mc/s. (Can be used up to 150 Mc/s if care is taken in the selection and identification of local-oscillator frequency.)

Sensitivity as a function of frequency.



Sensitivity: See plot.

I-F Output Frequency: 1 Mc/s.

Bandwidth: 25 kc/s with TYPE 1212-A Unit Null Detector.

Input Impedance: 200 Ω (approximately).

Output Impedance: 50 kΩ (approximately).

Terminals: GR874 Coaxial Connectors.

Dimensions: Diameter 2 1/4, length 6 3/4 in (58, 175 mm).

Net Weight: 1 lb (0.5 kg).

Shipping Weight: 2 lb (1 kg).

Catalog No.	Description	Price
1212-9603	Type 1212-P3 RF Mixer	\$105.00

PATENT NOTICE. See Note 4, page 11.

Type 1216-A UNIT I-F AMPLIFIER

The basic element of the TYPES DNT-1, -2, -3, and -4 Detectors is the TYPE 1216-A Unit I-F Amplifier. It consists of four tuned i-f amplifier stages, a detector, a video amplifier stage, an accurate rf attenuator, and two power supplies. It is designed to operate from the output of the TYPE 874-MRL Mixer Rectifier.

The automatic volume control, which facilitates bridge balancing and other null-type measurements, can be switched out for voltage-level measurements.

A built-in, precision, step attenuator makes possible

accurate measurements of relative signal levels. The meter is calibrated in dB, as well as in linear units, for convenient interpolation between the 10-dB attenuator steps.

Provision is made for measuring crystal-mixer current. One of the internal power supplies furnishes power for a heterodyning oscillator. See page 108 for complete detector assemblies.

Modulation on the input signal is available at the output terminals.

SPECIFICATIONS

Center Frequency: 30 Mc/s.

Bandwidth: >0.5 Mc/s at 3 dB down; 9.5 Mc/s at 60 dB down.

Sensitivity: From a 400-Ω source, 2-μV input for 1% deflection (above noise); 50-μV input for full-scale deflection. These are open-circuit source voltages.

Noise Figure: Approximately 5 dB.

Attenuator: 0 to 70 dB in 10-dB steps. **Accuracy:** ±(0.3 dB + 1%).

30-Mc Output-Circuit Bandwidth (Modulation): 0.4 Mc/s.

Output Impedance: 600 Ω.

Maximum Output Voltage: 2 V, open circuit.

Terminals: Input, GR874 Connector on 2-ft cable; output, 3/4-in-spaced TYPE 938 Binding Posts.

Power Supply Output: 300 V, dc, at 30 mA; 6.3 V, ac, at 1 A.

Power Required: 105 to 125 or 210 to 250 V, 50 to 60 c/s. Power input, 45 W at full load. Can also be operated at 400 c/s where line

voltage does not drop below 110 (or 220) V.

Accessories Supplied: Spare fuses.

Mechanical Data: Unit-Instrument Cabinet (see page 258)

Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
10 1/4	260	5 3/4	150	6 1/4	160	8 1/4	3.8	10	4.6

Catalog No.	Description	Price
1216-9701	Type 1216-A Unit I-F Amplifier	\$375.00
0480-9985	Type 480-P4U2 Relay-Rack Adaptor Panel (panel, 19 by 7 inches)	11.00

PATENT NOTICE. See Notes 4 and 15, page 11.





Type DNT HETERODYNE DETECTORS

Types DNT-1, -2, -3, AND -4 — 40 Mc/s TO 5 Gc/s

FEATURES:

- Wide frequency ranges. ■ High sensitivity.
- Excellent shielding. ■ AVC for null-detector use.
- Broad bandwidth with good selectivity. ■ Wide-range calibrated attenuator.

USES: This general-purpose, heterodyne detector is a high-sensitivity, high-frequency voltmeter for relative signal levels, a standing-wave indicator, and a null detector.

Its excellent shielding makes it suitable for low-level measurements in the presence of high-level external fields.

GAIN, LOSS, SIGNAL LEVEL

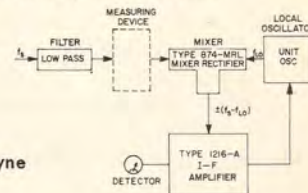
It can be used: to measure insertion loss and attenuation, crosstalk in multiterminal devices such as switches, and antenna gain and radiation patterns; as a field-strength indicator; and as a laboratory high-frequency receiver.

Signal levels can be measured over an 80-dB range, and, with the use of external TYPE 874-G20L Attenuators, 110 dB.

RF VOLTMETER

When standardized at one signal level in terms of a standard-signal generator, the TYPE DNT Detector

Type DNT-3 Heterodyne Detector.



Block diagram of the heterodyne detector.

can be used to measure rf voltage as low as 10 μ V.

DETECTOR

It is the recommended null detector for the TYPE 1602-B UHF Admittance Meter and the TYPE 1607-A Transfer-Function and Immittance Bridge.

As a standing-wave indicator with the TYPE 874-LBA and TYPE 900-LB Slotted Lines ($v_{SWR} > 1.05$), it is particularly useful for measurements on nonlinear elements, where a high degree of harmonic rejection and small applied signal level are required.

DESCRIPTION: Each assembly comprises one TYPE 874-MRL Mixer Rectifier, one TYPE 1216-A Unit I-F Amplifier, one TYPE 874-G10L 10-dB Pad, one TYPE 874-EL-L 90° Ell, plus one unit oscillator and one filter, both depending on the frequency range desired (see price table). For maximum shielding, components are equipped with locking GR874 Coaxial Connectors, which can be used interchangeably with the non-locking type.

The frequency range can be extended through the use of oscillator harmonics, but sensitivity is decreased, and care must be taken to avoid ambiguous beats.

To cover wide frequency ranges, however, it is recommended that one complete DNT detector be ordered, plus the necessary oscillators and filters for the additional frequency ranges desired. For instance, for the range from 40 to 950 Mc/s, one would order a TYPE DNT-2 Detector, plus one TYPE 1209-C Unit Oscillator and one TYPE 874-F1000L Filter.

SPECIFICATIONS

Frequency Range: See sensitivity curves on page 103; also price table.

Sensitivity: Typically 5 μ V; see curves on page 103.

Mixer: TYPE 874-MRL Mixer Rectifier (page 87).

Local Oscillator: See page 140 for specifications.

Input Terminal: Mixer input terminal is a locking GR874 Coaxial Connector. For connection to other coaxial types, see GR874 Coaxial Adaptors, page 81, and the TYPE 874-R22LA Patch Cord (page 85).

Power Required: 105 to 125 or 210 to 250 V, 50 to 60 c/s, 45 W.

Rack-Mount: Relay-rack adaptor panels are available for both oscillator and i-f amplifier. (See pages 107 and 143.)

Weights:	DNT-1, DNT-3	DNT-2	DNT-4
<i>Net</i>	16 lb (7.5 kg)	17 lb (8 kg)	24½ lb (11.5 kg)
<i>Shipping</i>	22 lb (10 kg)	23 lb (10.5 kg)	30 lb (14 kg)

Catalog Number	Type	Frequency Range — Mc/s				Local Oscillator Supplied	Filter Supplied	Price
		Fundamental	2nd Harmonic*	3rd Harmonic*	4th Harmonic*			
1235-9601	Type DNT-1	40†-530	100-1030	165-1530	230-2030	Type 1208-C	874-F500L	\$745.50
1235-9602	Type DNT-2	40†-280	70-530	120-780	170-1030	Type 1215-C	874-F500L	705.50
1235-9603	Type DNT-3	220-950	470-1870	720-2790	970-3710	Type 1209-C	874-F1000L	778.50
1235-9604	Type DNT-4	870-2030	1770-4030	2670-6030	Not recommended	Type 1218-B	874-F2000L	943.50

* For harmonic operation, the appropriate low-pass filter must be used. PATENT NOTICE. See Note 4, page 11.

† 40 Mc/s is the practical low-frequency limit.

Types DNT-5, -6, AND -7 — 70 kc/s TO 50 Mc/s

The TYPES DNT-5 and -6 Heterodyne Detectors use the TYPE 1232-A Tuned Amplifier and Null Detector as the i-f amplifier — TYPE DNT-5 at 20 kc/s and TYPE DNT-6 at 100 kc/s. TYPE DNT-7 uses the TYPE 1212-A Unit Null Detector. All three are well shielded from external fields and are suitable for low-level measurements.

They are excellent detectors for the TYPE 1606-A

and TYPE 916-AL RF Bridges. With the addition of an external calibrated attenuator, such as the TYPE 874-GA (page 88), a substitution method can be used in the several voltage-level measurements listed under DNT-1 to DNT-4 on the preceding page. Sensitivity curves appear on page 103. For detailed specifications, see the listing of the various components, as indicated.

Type DNT-5 HETERODYNE DETECTOR

70 TO 500 kc/s

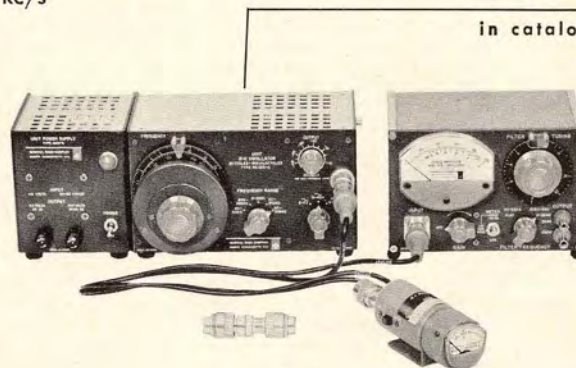
NEW

in catalog S

Complete heterodyne detector consists of:	Page
1 TYPE 1232-A Tuned Amplifier and Null Detector	104
1 TYPE 1210-C Unit R-C Oscillator	134
1 TYPE 1203 Unit Power Supply	219
1 TYPE 1232-P1 RF Mixer	105
1 TYPE 874-G10L Fixed Attenuator	88

Net Weight: 17½ lb (8 kg). Shipping Weight: 24 lb (11 kg).

Catalog No.	Description	Price
1235-9605	Type DNT-5 Heterodyne Detector, for 105-to-125-volt supply	\$737.00
1235-9795	Type DNT-5Q18 Heterodyne Detector, for 195-to-250-volt supply	on request



Type DNT-6 HETERODYNE DETECTOR

500 kc/s TO 10 Mc/s

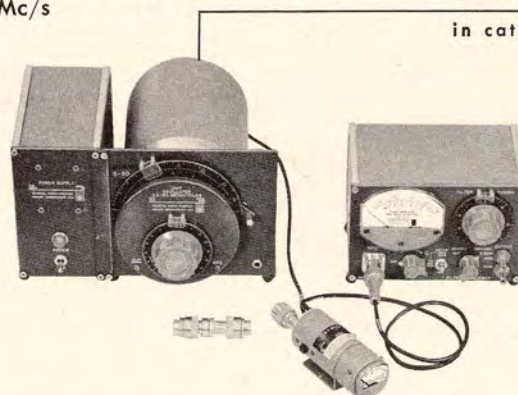
NEW

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Complete heterodyne detector consists of:	Page
1 TYPE 1232-A Tuned Amplifier and Null Detector	104
1 TYPE 1211-C Unit Oscillator	140
1 TYPE 1269-A Unit Power Supply	219
1 TYPE 1232-P1 RF Mixer	105
1 TYPE 874-G10L Fixed Attenuator	88

Net Weight: 24½ lb (11.5 kg). Shipping Weight: 33 lb (15 kg).

Catalog No.	Description	Price
1235-9606	Type DNT-6 Heterodyne Detector, for 105-to-125-, 195-to-235-, or 210-to-250-volt supply	\$912.00



Type DNT-7 HETERODYNE DETECTOR

3 TO 50 Mc/s

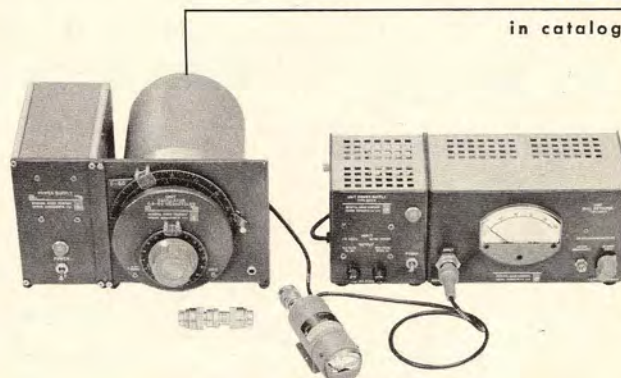
NEW

in catalog S

Complete heterodyne detector consists of:	Page
1 TYPE 1212-A Unit Null Detector	106
1 TYPE 1212-P3 RF Mixer	107
1 TYPE 1211-C Unit Oscillator	140
1 TYPE 1269-A Unit Power Supply	219
1 TYPE 1203 Unit Power Supply	219
1 TYPE 874-G10L Fixed Attenuator	88

Net Weight: 28½ lb (13 kg). Shipping Weight: 39 lb (18 kg).

Catalog No.	Description	Price
1235-9607	Type DNT-7 Heterodyne Detector, for 105-to-125-volt line	\$802.00
1235-9797	Type DNT-7Q18 Heterodyne Detector, for 195-to-250-volt supply	on request



PATENT NOTICE. See Notes 4 and 15, page 11.



FREQUENCY STANDARDS



Time is one of the three fundamental physical dimensions. Since frequency is specified in terms of events per unit time (cycles per second, or Hertz), the production of an accurate frequency is directly related to the establishment of an exact time interval.¹ Although formerly determined by astronomical observations, exact time intervals are now derived from the atomic frequency standard. International agreement has defined the second as 9,192,631,770 cycles of the resonance-frequency transition of the cesium atom under zero-field conditions. This uniform time scale is called Atomic Time (A-1). By definition, this is the fraction $1/31,556,925,975$ of the tropical year 1900. This definition relates time in the atomic scale to the previous most nearly constant time scale, Ephemeris Time, which is based on the orbital period of the earth about the sun (the time between vernal equinoxes). For everyday living, Solar Time, also known as Universal Time (UT-2) or Greenwich Mean Time, which is based on the mean rotational period of the earth, must be used. For example, for navigation and the tracking of artificial satellites with the earth used as a platform, a precise knowledge of the earth's average rotational period is required. Solar time is now defined in terms of atomic time, the rate being for the years 1965-1966 150×10^{-10} lower than A-1 time.

Standard frequencies and time intervals for measurement purposes are usually derived from a secondary frequency standard, such as the quartz-crystal oscillator, which is periodically calibrated in terms of a primary standard by means of standard-frequency or standard-time radio transmissions. Depending upon the accuracy required, local frequency can be established by either frequency or time measurement. All standard frequency and time transmissions in the United States are on the UT-2 time scale except for WWVB on 60 kc/s, which is on the A-1 scale.

Atomic clocks establish a perfectly uniform time. By international agreement, the time intervals broadcast are related to this uniform atomic time with step corrections not exceeding 100 milliseconds to agree with astronomical observations of the earth's rotation. Astronomical time observations are carried out by national observatories throughout the world. Their measurements are made available to users by radio time-signal transmissions and by telegraph in their respective countries. In the United States, the U. S. Naval Radio Observatory transmits radio time signals through the facilities of the U. S. Naval Radio Service. Standard time signals monitored by the Naval Observatory are also broadcast continuously by the standard-frequency transmitters of WWV, operated by the National Bureau of Standards. In Canada, a similar service, broadcast by CHU, is provided by the Dominion Observatory.

The user of a frequency standard equipped with means for measurement of the time of arrival of a radio time signal can then calibrate the standard directly in terms of time. For a precise calibration, the errors of the transmitted time signal must be taken into account. Correction data for this purpose may be obtained from the Superintendent, U. S. Naval Observatory, Washington 25, D. C.

Calibration accuracy using a standard-time transmission depends upon the characteristics of the transmitted signal and of the propagation path. The variations in the time of reception of a high-frequency sky-wave signal from such stations as WWV or CHU are seldom less than 100 microseconds, due to propagation path variations. A low-frequency signal, known to be propagated via a ground-wave, will have variations of less than 2 microseconds over a 1500-mile path.²

CALIBRATION METHODS

The basic methods of intercomparing the frequencies of two sources are the same whether the primary standard is local or remote. The techniques employed will differ because of the propagation characteristics of radio transmissions and noise on the radio signal, which do not exist with local calibration. The principal techniques are: zero-beat — direct phase comparison; direct time comparison; frequency difference measurement — usually digital.

A. ZERO-BEAT TECHNIQUES

The basic method for frequency intercomparison is a direct comparison of the phase difference of two signals nearly equal in frequency. If not nearly equal, they must be nearly harmonically related. A change in relative phase between two signals may be determined by measurement of their beat frequency, by observation of a lissajous figure on an oscilloscope, or by measurement with a voltmeter of their common amplitude.

The precision of the zero-beat method is limited by the ability to detect the zero-beat condition. Suppose, for example, one has a "zero-beat"

detector capable of 1-cycle resolution and it is desired to set two standard frequencies equal to one another as closely as possible. If the two frequencies are 1 Mc/s, then the error will be 1 ppm. Greater resolution can only be attained by multiplication of the two frequencies or by increased resolution of the zero-beat detector. As a practical example of the zero-beat technique, consider the comparison of the 5-Mc carrier of WWV against a local 5-Mc signal. By use of either the receiver S meter or the beat-frequency oscillator, about 1-cycle resolution is available, and the local standard can be set to about 1 part in 10^7 .

VLF phase-tracking receivers take advantage of the more stable propagation characteristics of VLF transmissions.³ Because the frequency is low, a very high degree of phase resolution is required. VLF trackers are capable of resolving 1 beat in about 5 days; this would be about 1×10^{-10} per day on 20 kc/s. If a very narrow bandwidth is used, a phase tracker can extract the desired data under very adverse signal-to-noise ratio conditions.

B. DIRECT TIME INTERCOMPARISON.

Frequency may be established to a high degree of precision by direct comparison of time intervals derived from the frequency to be calibrated and from the standard. The time interval compared is usually one second, derived from the standard to be calibrated by a precision electronic clock such as the GR Type 1123-A Digital Synchronometer. An example of this method is the comparison of locally produced one-second pulses with the one-second timing pulses transmitted by Radio Station WWV. There are two distinct advantages of this method of comparison over others: (1) Individual measurements do not have to have great accuracy since the accuracy

¹ F. D. Lewis, "Frequency and Time Standards," *Proceedings of the IRE*, September 1955, pp 1046-1069.

² Doherty, R. N. et al, "Timing Potentials of Loran-C," *Proceedings of the IRE*, November 1961, p 1659.

³ Pierce, J. A. "The Diurnal Carrier Phase Variation of a 16-kilocycle Transatlantic Signal," *Proceedings of the IRE*, May 1955, p 584.

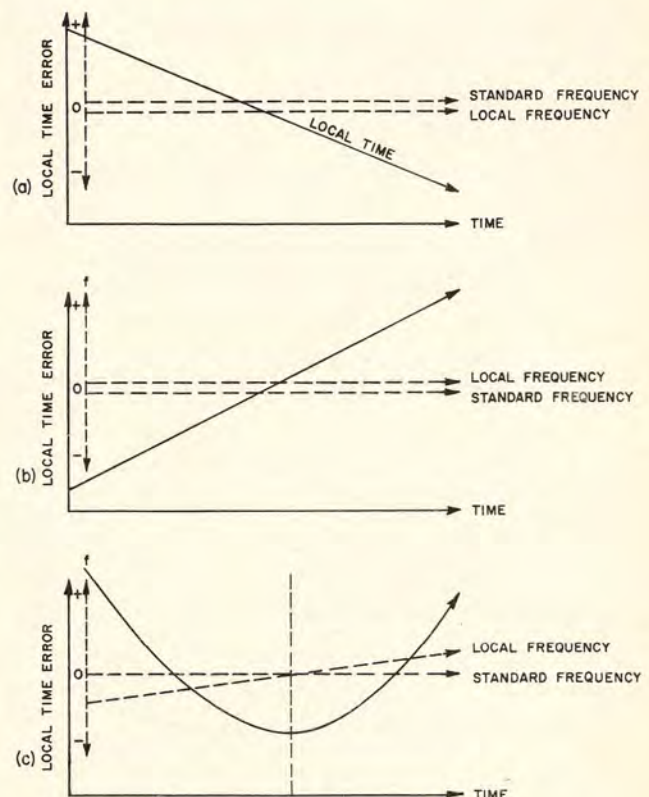


Figure 1.

is increased by taking longer and longer time intervals between measurements. (2) The measurement results in an accurately set local clock. Local time is known to the extent that the propagation time of the radio signal is known.

The basic principle of the measurement lies in the integrating character of the clock. If the frequency driving the clock is low, the time between successive zero crossings of the driving frequency is a little longer than standard, and at each cycle the clock will lose a fixed increment of time. Obviously, the longer the measurement interval, the larger the time error (Figure 1a). The case of a clock driven by too high a frequency is shown in Figure 1b; the clock steadily gains time with respect to standard time.

The assumption of an absolutely constant frequency with a fixed error with respect to the primary standard leading to a linear change in local time is not the situation usually encountered in practice. The local standard will generally have some drift, which will cause the time error to depart from linear as shown in Figure 1. If the drift in frequency is constant with time, for example $f = (f_0 + kt)$, and the initial frequency setting, f_0 , is low, it is obvious that at some future instant of time f will become equal to the standard frequency, and the time intervals will be precisely correct. The curves of time error are now parabolic. Figure 1c shows the shape of time error when the local frequency has a positive drift.

As an example of the use of this method of frequency calibration, assume that in your locality WWV can be received with a reproducibility of one millisecond. (This figure must be established by experiment.) Then, in a one day interval, a change in the local frequency of $10^{-8}/86,400$ or approximately $1:10^8$ can be established.

This method of calibration is limited in accuracy only by one's ability to establish time simultaneously in the measurement. If the local time is, for example, marked by a brief pulse like that produced by a Type 1123-A Digital Synchronometer and a cycle of a burst from a Loran C transmitter can be observed, then time can be compared to a fraction of a microsecond,⁴ and the local frequency can be established to within a few parts in 10^{10} in a time interval of only a few minutes (Figure 2).

C. DIGITAL FREQUENCY MEASUREMENT

The introduction to the section on frequency meters describes the application of digital frequency meters to frequency measurement problems in general. Counters can obviously be used for precision frequency inter-comparison. The accuracy is limited only by the maximum counting time from one source and the maximum counting rate of the counter. Thus, a 10-Mc counter such as the General Radio Type 1153-A with its ten-second time base controlled by the standard can be used to calibrate another frequency source at 10 Mc/s to an accuracy of $1:10^8$. The counter is particularly convenient when the oscillator to be calibrated is not harmonically related to the standard frequency.

THE STANDARD-FREQUENCY LABORATORY

Figure 3 shows equipment that might be encountered in a typical Frequency Standard Laboratory. The requirements of any specific application will dictate how elaborate the system must be. If time information is not required, a master oscillator combined with a VLF Phase Tracker to monitor its performance may suffice as reference frequency source. Alternatively, one can use time signals to monitor the oscillator performance. A cesium beam (primary) standard can be used to check the frequency of a master oscillator but does not provide time calibration, and reference to time signals is still required. In the system shown in Figure 3, the master oscillator is monitored against WWVB by a phase tracker and provides exact reference frequencies while the two other (working standard) oscillators are offset by -150×10^{-10} to provide time signals on the UT-2 scale. A

⁴ D. O. Fisher and R. W. Frank, "A New Approach to Precision Time Measurements," *General Radio Experimenter*, February-March 1965.

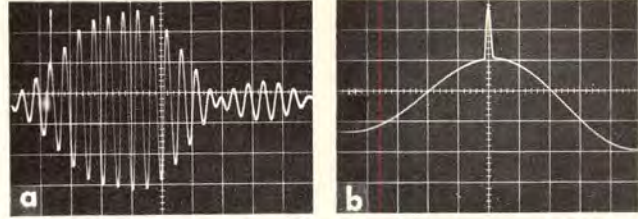


Figure 2. Time comparison of marker pulse and Loran-C 100-kc pulses. a. Sweep rate 20 μs/cm. (Note marker pulse on third cycle.) b. Sweep rate 1 μs/cm, pulse centered.

frequency-intercomparison system permits the working standards to be compared with the reference and plots continuous records of their stability.

Multipliers, dividers, and synthesizers make other frequencies available for distribution for calibration and test purposes. These frequencies can be derived either from the master oscillator on the exact frequencies or from the working standards with -150×10^{-10} offset. Distribution amplifiers provide isolation between the various users.

The frequency comparison system can consist of a 10-Mc counter using the master oscillator as time base. If the other oscillators are measured at 5 Mc/s, a 1000-second gate time in the counter will provide $\pm 2 \times 10^{-10}$ resolution. Higher resolution requires the use of multipliers or error-multipliers. Multiplication to 100 Mc/s and the use of a 100-Mc counter provides a resolution of $\pm 1 \times 10^{-11}$ for a 1000-second count. Error-multipliers can increase the basic resolution up to 1000 times and do not require a 100-Mc counter. In either case, the digital data from the counter can be printed in numerical form or a digital-analog converter can be used for continuous strip-chart recording. The same frequency intercomparison system can also be used to measure the frequencies of oscillators in other locations if the signals are fed through the distribution lines to the frequency standard equipment.

Listed in this section of the catalog are complete frequency and time standards, as well as their component instruments. They include a standard-frequency oscillator of high spectral purity, a frequency divider, and a digital time comparator of high precision with all-solid state circuitry, plus two frequency multipliers, which operate on the locked-oscillator principle.

	Page
Type 1121 Frequency and Time Standards	112
Type 1115-B Standard-Frequency Oscillator	114
Type 1114-A Frequency Divider	115
Type 1123-A Digital Synchronometer	116
Type 1112 Frequency Multipliers	118

FREQUENCY SYNTHESIZERS

A new class of instrument, the frequency synthesizer, is both a frequency standard and a variable-frequency signal source. All output frequencies are synthesized coherently from a single-frequency source, usually a quartz crystal oscillator. In General Radio synthesizers, the output frequency is adjustable in decade steps, plus a continuous control. Modular construction permits synthesizers to be assembled with any desired resolution from 3 to 9 significant figures.

GR synthesizers use a room-temperature quartz-crystal oscillator as the standard source, which can be locked to an external standard, such as the Type 1115-B Standard-Frequency Oscillator, when extreme stability is required. See page 155. FREQUENCY METERS, both digital and analog, are listed on pages 119 to 127.

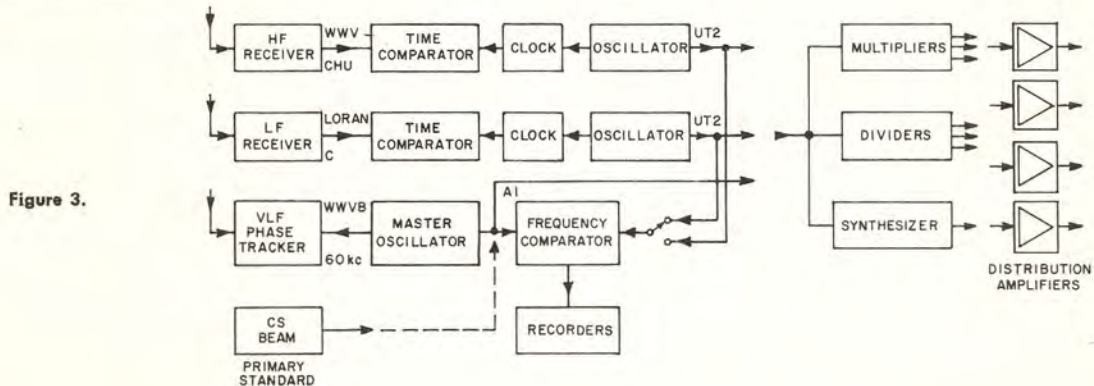


Figure 3.

Type 1121 FREQUENCY AND TIME STANDARDS

FEATURES:

- Excellent long-term and instantaneous stabilities.
- High spectral purity.
- Reliability — 24-hour emergency batteries in crystal oscillator and SYNCHRONOMETER® time comparator.
- Wide range of output frequencies — up to 1000 Mc/s.

These frequency standards will supply standard frequencies for both laboratory measurements and production testing; for standardizing digital counters (either as a source for routine accuracy checks or directly as a counter time base); for measuring received signals in conjunction with frequency meters and other comparison equipment; and for the measurement and standardization of time.

The TYPE 1121 Frequency and Time Standards are combinations of the TYPE 1115-B Standard-Frequency Oscillator, the TYPE 1123-A Digital SYNCHRONOMETER® time comparator and auxiliary equipment, completely assembled in floor-type relay racks with all interconnecting cables. Blank panels are included to fill unused space in the rack. The component instruments are described on pages 114-118.

Each standard is thoroughly tested as an operating system before shipment.

The TYPE 1115-B Standard-Frequency Oscillator operates at 5 Mc/s, uses a fifth-overtone-mode quartz crystal, and furnishes output frequencies of 5 Mc/s, 1 Mc/s, and 100 kc/s.

The TYPE 1123-A Digital SYNCHRONOMETER time comparator integrates the oscillator frequency to

produce precise time-of-day information, permits accurate comparison between the frequency standard and standard-time radio transmissions, and generates timing pulses at 100, 10, and 1 kc/s, 100, 10, 1, and 0.1 c/s.

In the TYPE 1121-AH model, frequencies of 10, 100, and 1000 Mc/s are produced in low-noise phase-locked-oscillator frequency-multiplier units for uhf and microwave applications. The vhf and uhf signals are essentially free from submultiple output frequencies. The spectral purity of the multiplier output frequencies is determined by the fm noise generated in the multipliers (see specification for TYPE 1112 Standard-Frequency Multiplier, page 118). The spectrum of the 5-Mc output of the crystal oscillator is unaffected by the presence of the multipliers.

The TYPE 1121-AL produces low-frequency sine waves of 10 and 1 kc/s, 400, 100, and 60 c/s, and 10-kc square waves from the TYPE 1114-A Frequency Divider.

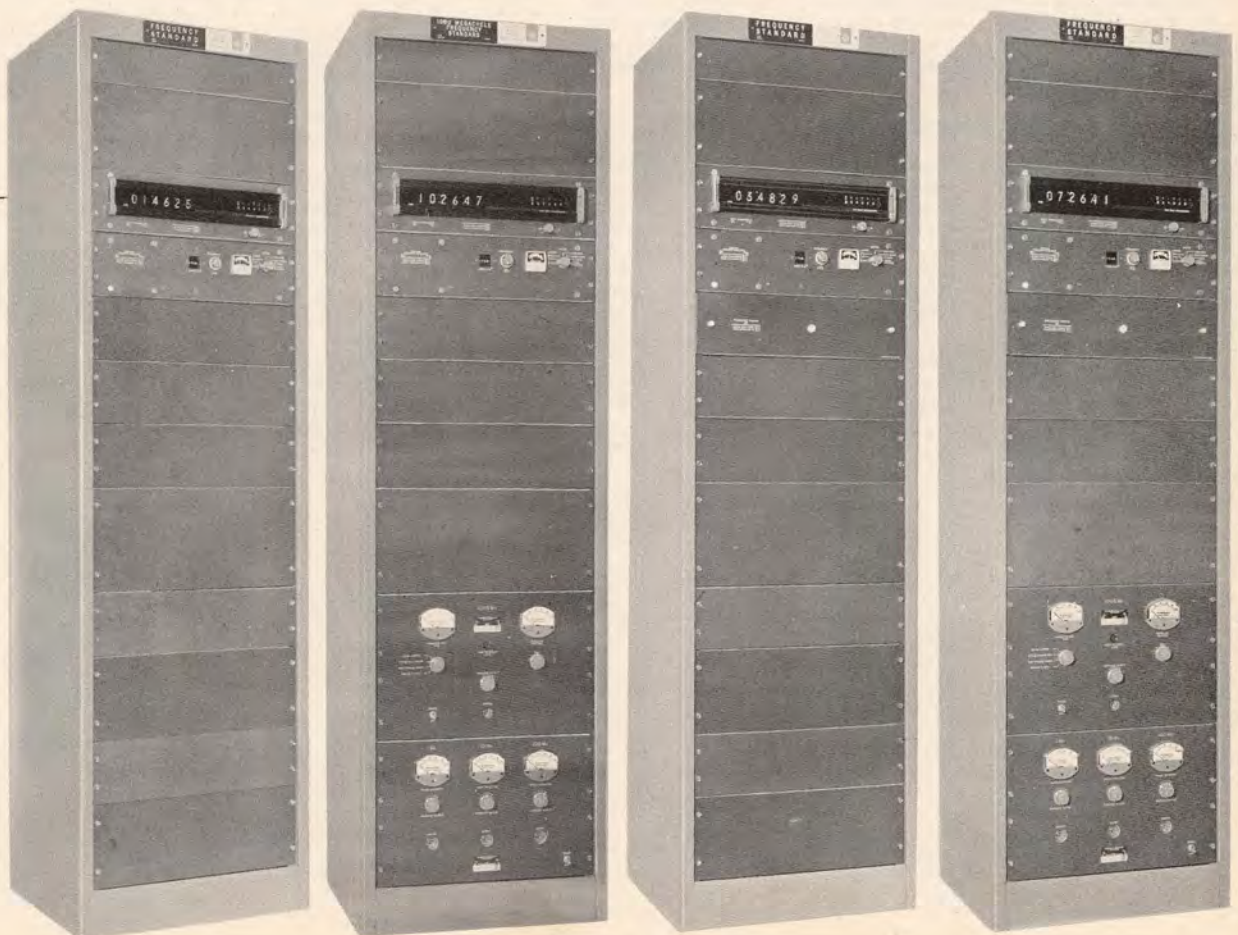
The TYPE 1121-AHL includes all the items of the -AH and -AL models, and its output frequencies extend from 60 c/s to 1000 Mc/s.

TYPE 1121-A

TYPE 1121-AH

TYPE 1121-AL

TYPE 1121-AHL



NEW

in catalog S

Type 1121-A FREQUENCY AND TIME STANDARD

Components:

- TYPE 1115-B Standard-Frequency Oscillator
- TYPE 1123-A Digital SYNCHRONOMETER® time comparator
- Floor-type relay rack
- Blank panels to fill rack
- Connection cables

Output Frequencies: Sine waves, 5, 1 Mc/s, 100 kc/s, plus timing pulses of 100, 10, 1 kc/s, 100, 10, 1, and 0.1 c/s.

Power Required: 40 W at 90 to 130 or 180 to 260 V, 40 to 2000 c/s, or 24 to 32 V dc. Internal nickel-cadmium batteries provide at least 24-hour emergency operation.

Net Weight: 170 lb (78 kg).

Shipping Weight: 350 lb (161 kg).

Type 1121-AH 1000-Mc FREQUENCY AND TIME STANDARD

Components:

- TYPE 1115-B Standard-Frequency Oscillator
- TYPE 1123-A Digital SYNCHRONOMETER® time comparator
- TYPE 1112-A Standard-Frequency Multiplier
- TYPE 1112-B Standard-Frequency Multiplier
- Floor-type relay rack
- Blank panels to fill rack
- Connection cables

Output Frequencies: Sine waves, 1000, 100, 10, 5, 1 Mc/s, 100 kc/s, plus timing pulse of 100, 10, 1 kc/s, 100, 10, 1, and 0.1 c/s.

Power Required: Frequency multipliers 235 W, max, at 105 to 125 or 210 to 250 V, 50 to 60 c/s. Standard-frequency oscillator and SYNCHRONOMETER 40 W at 90 to 130 or 180 to 260 V, 40 to 2000 c/s, or 24 to 32 V dc. Internal nickel-cadmium batteries provide at least 24-hour emergency operation for standard-frequency oscillator and time comparator.

Net Weight: 220 lb (102 kg).

Shipping Weight: 400 lb (184 kg).

Type 1121-AL FREQUENCY AND TIME STANDARD

Components:

- TYPE 1115-B Standard-Frequency Oscillator
- TYPE 1123-A Digital SYNCHRONOMETER® time comparator
- TYPE 1114-A Frequency Divider*
- TYPE 1114-P6, -P7 Plug-In Units
- Floor-type relay rack
- Blank panels to fill rack
- Connection cables

Output Frequencies: Sine waves, 5, 1 Mc/s, 100, 10, 1 kc/s, 100, 400, 60 c/s. Timing pulses of 100, 10, 1 kc/s, 100, 10, 1, and 0.1 c/s.

Power Required: Standard-frequency oscillator and SYNCHRONOMETER, 40 W at 90 to 130 or 180 to 260 V, 40 to 2000 c/s, or 24 to 32 V dc; frequency divider, 7 W, max, at 105 to 125 or 210 to 250 V, 50 to 400 c/s. Internal nickel-cadmium batteries provide at least 24-hour emergency operation for standard-frequency oscillator and time comparator.

Net Weight: 190 lb (87 kg).

Shipping Weight: 360 lb (166 kg).

* The TYPE 1114-P1 and TYPE 1114-P2 Plug-In Units are not included.

Type 1121-AHL 1000-Mc FREQUENCY AND TIME STANDARD

Components:

- TYPE 1115-B Standard-Frequency Oscillator
- TYPE 1123-A Digital SYNCHRONOMETER® time comparator
- TYPE 1112-A Standard-Frequency Multiplier
- TYPE 1112-B Standard-Frequency Multiplier
- TYPE 1114-A Frequency Divider*
- TYPE 1114-P6, -P7 Plug-In Units
- Floor-type relay rack
- Blank panels to fill rack
- Connection cables

Output Frequencies: Sine waves, 1000, 100, 10, 1 Mc/s, 100, 10, 1 kc/s, 100, 400, 60 c/s, and 10-kc square waves. Timing pulses of 100, 10, 1 kc/s, 100, 10, 1, and 0.1 c/s.

Power Required: Standard-frequency oscillator and SYNCHRONOMETER 40 W at 90 to 130 or 180 to 260 V, 40 to 2000 c/s, or 24 to 32 V dc, frequency multipliers, 235 W, max, at 105 to 125 or 210 to 250 V, 50 to 60 c/s; frequency divider, 7 W, max, at 105 to 125 or 210 to 250 V, 50 to 400 c/s. Internal nickel-cadmium batteries provide at least 24-hour emergency operation for standard-frequency oscillator and time comparator.

Net Weight: 230 lb (106 kg).

Shipping Weight: 410 lb (189 kg).

* The TYPE 1114-P1 and TYPE 1114-P2 Plug-In Units are not included.

OTHER COMBINATIONS CAN BE SUPPLIED. SEND US YOUR REQUIREMENTS.

Catalog Number	Description	Price
1121-9701	Type 1121-A Frequency and Time Standard	\$5295.00
1121-9817	Type 1121-AH 1000-Mc Frequency and Time Standard	8110.00
1121-9831	Type 1121-AL Frequency and Time Standard	6300.00
1121-9553	Type 1121-AHL 1000-Mc Frequency and Time Standard	9115.00

PATENT NOTICE. See Note 4, page 11.



FEATURES:

- Exceptional short-term stability, approaching the theoretical maximum.
- Very high spectral purity.
- 35-hour emergency power supply — internal nickel-cadmium battery.
- External supply can be either ac or dc.
- Proportional-control oven. ■ All-solid-state circuitry.
- Output frequencies of 5 Mc/s, 1 Mc/s, and 100 kc/s.
- Meets MIL E16400D specification for vibration and MIL-I-26600 for RFI.
- Voltage control of frequency permits use in phase-locked systems.

USES: This highly stable piezoelectric oscillator is suitable for exacting scientific and military uses — in both laboratories and manufacturing plants and on shipboard — wherever a rugged, high stability standard of frequency is required.

Exceptional spectral purity of the 5-Mc output permits multiplication to microwave frequencies for such applications as microwave spectroscopy and coherent-phase radar. Typical noise pedestal at X band is -80 dB per $\sqrt{c/s}$.

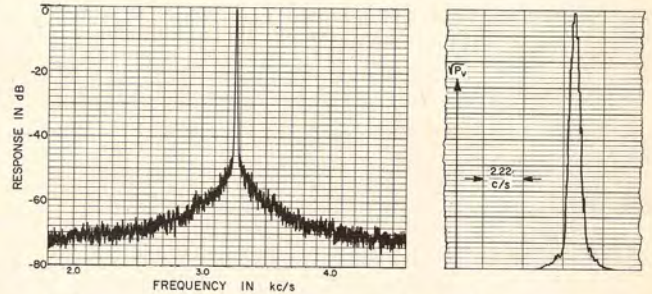
When combined with the TYPE 1123-A Digital SYNCHRONOMETER (as in the TYPE 1121 Frequency Standards), this oscillator becomes a highly accurate time standard, which can be precisely compared with, and transferred to, other clocks, either remote or local.

DESCRIPTION: The quartz crystal is a 5-Mc, 5th-overtone gettered unit. It is mounted in a single stage, proportional-control oven, which also contains the oscillator and AGC circuits. Power consumption of the oven is about 0.6 watt at 25°C ambient. This low power consumption is an important advantage when operation from the internal battery is necessary.

The frequency of the oscillator is adjusted by a panel control, direct reading in parts in 10^{10} , to allow correction of crystal aging.

Plug-in circuit boards provide easy access to the components.

A nickel-cadmium, 4-ampere-hour battery is floated across the dc supply. The cells are of the pressure-



(Left) X-band power spectrum of two Type 1115-B Standard-Frequency Oscillators. Analyzer bandwidth is 10 c/s. (Right) Center portion of spectrum measured with 0.54-cycle bandwidth. Vertical scale is linear ($\sqrt{\text{power}}$).

relief type and cannot explode. In the event of power-line failure, operation for at least 35 hours is ensured at room temperature and over 24 hours at 0°C. An external dc supply of 22 to 35 volts can also be used. If ac power, external dc, and internal battery are connected, the power will be drawn from the source that provides the highest voltage to the regulator circuit. The change-over is made by diodes and is completely continuous.

The battery is recharged by a current-limited voltage source, which maintains the battery at optimum charge conditions. The float, or trickle-charge, voltage is temperature compensated to correct for changes in the emf of the battery over the full temperature range.

SPECIFICATIONS

Output: 5 and 1 Mc/s, 100 kc/s; 1 V, rms, +50 -10% into 50 Ω at each frequency.

Frequency Adjustment: 2700×10^{-10} (1×10^{-10} per dial division).

External Frequency Control: Dc voltage from +0.5 to +12 V can be applied. Range is at least 5×10^{-7} , total.

Frequency Stability:

Temperature Effects: $< \pm 1 \times 10^{-11}$ per degree C between 0°C and 50°C.

Loading of Output: $< \pm 2 \times 10^{-11}$ open circuit to short circuit.

Supply Voltage: $< \pm 1 \times 10^{-11}$ for $\pm 10\%$ ac line-voltage changes.
 $< \pm 2 \times 10^{-11}$ for 22 to 35 V, external dc.

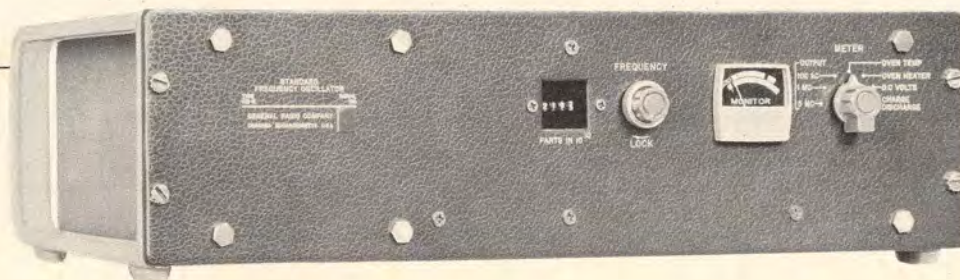
Aging: $< 5 \times 10^{-10}$ per day after 30 days of operation;
 $< 1 \times 10^{-10}$ per day is typical after 1 year.

Short-Term Stability (5 Mc/s): Standard Deviation (σ) is less than stated below (95% confidence):

Averaging Time	Frequency Deviation (σ)	Phase Deviation (Radians)
300 μ s	100×10^{-11}	1×10^{-5}
1 ms	50×10^{-11}	1.5×10^{-5}
10 ms	10×10^{-11}	3×10^{-5}
100 ms	1.5×10^{-11}	4.5×10^{-5}
1 s	1×10^{-11}	3×10^{-4}
10 s	1×10^{-11}	3×10^{-3}

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in catalog S



Spectral Purity: Line width of 5-Mc output multiplied by 2000 times (10 Gc/s or X band) is less than 0.25 c/s.

Noise Pedestal: Less than -145 dB per $\sqrt{c/s}$ at 5 Mc/s.

Power Required (ac or dc):

Ac: 90 to 130 or 180 to 260 V, 40 to 2000 c/s, 8 W at 115 V.
Dc: 22 to 35 V, 4 W at 24 V.

Emergency Power: Internal battery provides 24- to 35-hour operation depending on ambient temperature.

Terminals: Locking GR874, 5 Mc/s, 1 Mc/s, 100 kc/s; type BNC, 1 Mc/s and 100 kc/s for connection to TYPE 1123-A Digital SYNCHRONOMETER.

Mechanical Data: Rack-Bench Cabinet (see page 258)

Model	Width		Height		Depth		Net Weight		Shipping Weight	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Bench	19	485	6	155	14½	370	35	16	52	24
Rack	19	485	5¼	135	14½*	370	35	16	52	24

* Behind panel.

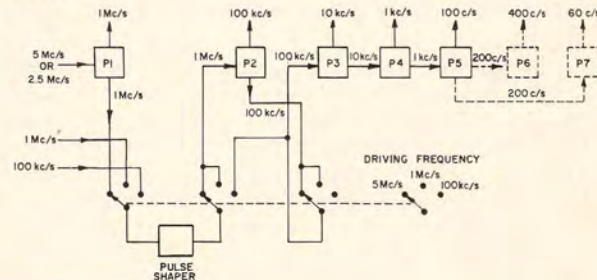
See also *General Radio Experimenter*, June 1964.

Catalog Number	Description	Price
1115-9802	Type 1115-B Standard-Frequency Oscillator, Bench Mount	\$2050.00
1115-9812	Type 1115-B Standard-Frequency Oscillator, Rack Mount	2050.00

Type 1114-A FREQUENCY DIVIDER

FEATURES: ■ Wide range of output frequencies. ■ Fail-safe operation. ■ Very low jitter.

The frequency divider operates from the 5-Mc output of the standard-frequency oscillator to produce output frequencies of 1 Mc/s, 100 kc/s, 10 kc/s, 1 kc/s and 100 c/s; optionally, outputs of 400 c/s and 60 c/s are available. The 5-Mc to 1-Mc divider is a regenerative type; all others are switching types. All circuits are fail-safe. There is no output when the input signal is absent. Output is sine wave, with additional square waves at 10 kc/s and 100 kc/s. All divider units are plug-in modules.



SPECIFICATIONS

Input: 5 Mc/s, 1 Mc/s, 100 kc/s, 50 Ω , 1 V \pm 50%.

Output (with 5-Mc input):

Sine Waves — 1 Mc/s } 1 V { +50% } into 50 Ω
 100 kc/s } { -10% }
 10 kc/s } 1 V { +50% } into 600 Ω
 1 kc/s } { -10% }
 100 c/s }
 *400 c/s } 1 V { +50% } into 600 Ω
 *60 c/s } { -10% }

* Optional accessories.

Square Waves -- 100 kc/s } Approximately 7 V, p-to-p,
 10 kc/s } open circuit

Spurious Signals: Better than 34 dB down.

Jitter: <0.5 ns for 100-cycle output with respect to 5-Mc input.

Optional Frequencies: 400 c/s; 60 c/s. See below.

Power Required: 105 to 130 or 210 to 260 V, 50 to 400 c/s; approximately 7 W.

Mechanical Data: Rack-bench Cabinet (see page 258)

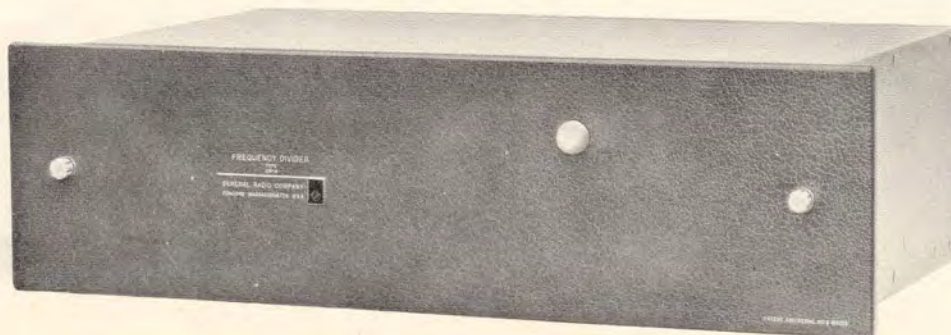
Model	Width		Height		Depth		Net Wt		Ship Wt	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Bench	19	485	5¼	135	11½	295	15	7	22	10
Rack	19	485	5¼	135	11*	280	15	7	22	10

* Behind panel.

See also *General Radio Experimenter*, April 1961.

Catalog Number	Description	Price
1114-9801	Type 1114-A Frequency Divider, Bench Model	\$950.00
1114-9811	Type 1114-A Frequency Divider, Rack Model	950.00
1114-9606	Type 1114-P6 400-cycle Plug-in Unit	115.00
1114-9607	Type 1114-P7 60-cycle Plug-in Unit	130.00

PATENT NOTICE. See Notes 1 and 4, page 11.





Type 1123-A DIGITAL SYNCHRONOMETER

PRECISION, SOLID-STATE, DIGITAL CLOCK

FEATURES:

- All-solid-state logic circuitry — no moving parts.
- Internal nickel-cadmium battery for approximately 24-hour emergency operation.
- Bright, 6-digit indication of hours/minutes/seconds.
- Any digit can be changed manually without disturbance to timing.
- Time comparisons to 20 ns.
- Manual start, fail-safe, regenerative circuits stop clock if input fails for even one cycle.
- BCD 1-2-4-2 (1-2-4-8 optional at extra cost) output data — 10- μ s resolution.
- Low-jitter, standard, timing pulses at 100, 10, and 1 kc/s, 100, 10, 1, and 0.1 c/s.

USES: The TYPE 1123-A Digital SYNCHRONOMETER® time comparator is a solid-state digital clock for the calibration of frequency and time standards. It provides precise time-of-day information, both visually and in BCD (1-2-4-2) form, and permits accurate comparisons between local standards and the transmission of standard time (WWV, Loran C, etc.). The clock can compare its own time with standard time without disturbance of its internal time. Clock's internal time can be automatically synchronized (within 10 μ s) to standard time.

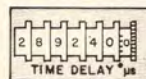
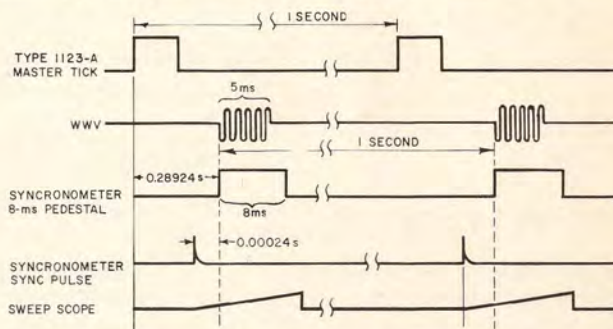
Any number of clocks can be started simultaneously from one location — remote clocks can be started from and synchronized to a local clock (without interruption of local clock). Time can be transferred from one location to another. One sets the clock at the master station and actually carries the standard time to remote locations.

DESCRIPTION: (see diagram on page 117)

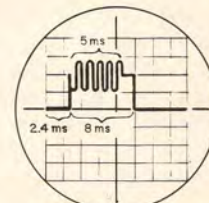
Circuit functions in the SYNCHRONOMETER may be divided into four general parts: starting, timekeeping, synchronizing, and readout.

Starting is accomplished either by a front-panel push-button or by a pulse (from an external source or another SYNCHRONOMETER). With either method any number of clocks can be started simultaneously, and remote units can be started in synchronism with an operating master clock, without disturbance of the master time indication.

Timekeeping A pulse train derived from the 100-kc input is fed through fail-safe, regenerative-gate circuits. The pulses in the train, 10 microseconds apart, are then divided in five anti-time-delay decade dividers to produce a 1-pps master tick. All timekeeping circuits use silicon transistors operated at low-power levels. In the event of power failure, the built-in battery will automatically sustain the timekeeping operation for approximately 24 hours.



TIME DELAY SETTING AT ALIGNMENT



SCOPE FACE AT ALIGNMENT

To determine the precise time relationship of the Digital Synchronometer's master tick to WWV standard timing bursts, both the time transmission and the clock's 8-millisecond pedestal are displayed on a CRO screen. By means of front-panel thumbwheels, successive amounts of delay are introduced until the pedestal is exactly aligned with the WWV bursts. When the delay is determined, the Type 1123-A need only be switched to self-sync operation, and the master tick will be shifted to synchronism with the transmission. The sync pulse retains oscilloscope synchronism and keeps the pedestal in view throughout the operation.

Where the characteristics of the standard-time transmission permit greater resolution than that provided by the 8-ms pedestal, the 0.2- μ s marker can be used. With this marker, time comparisons with a precision of better than ± 20 ns are possible.

Time Comparison and Synchronization The decade dividers of the timekeeping circuits provide, at output jacks, low-jitter, timing pulses at 100 kc/s, 10 kc/s, 1 kc/s, 100 c/s, 10 c/s, 1 c/s, and 0.1 c/s. These signals also operate a five-digit recognition circuit to produce

NEW

in catalog S





Type 1112 STANDARD-FREQUENCY MULTIPLIERS

FEATURES: Provides microwave-range standard frequencies — 250-milliwatt output at 1000 Mc/s. Excellent phase stability. ■ Extremely low noise.

USES: The TYPE 1112 Standard-Frequency Multipliers generate sine-wave signals of 1, 10, 100, and 1000 Mc/s when driven from a 100-kc or 1-Mc source or, when driven from a 1-, 2.5-, or 5-Mc source, outputs of 10, 100, and 1000 Mc/s.

The output provides standard frequencies in the microwave region for precise frequency measurements. The unusually low noise and excellent phase stability of output signals permit intercomparison of lower-frequency, standard-frequency oscillators and comparison of crystal with atomic standards.

DESCRIPTION: The phase stability and low noise of the multiplier outputs result from the use of a narrow-band filter,

which selects only the desired harmonic at each output frequency.

In the TYPE 1112-A Multiplier, the 100-kc input signal is multiplied to 1, 10, and 100 Mc/s. Quartz-crystal filters are used, each in an oscillator circuit whose frequency is phase-locked to the desired harmonic frequency.

In the TYPE 1112-B Multiplier, which operates from a separate 100-Mc output of the TYPE 1112-A, a phase-locked klystron oscillator is used as a selective filter. Phase-modulation noise inherent in klystrons is minimized by negative feedback. The reference standard is the multiplied harmonic of the crystal-controlled 100-Mc driving signal.

SPECIFICATIONS

Type	Input		Residual FM Noise	Locking Range	Output		Open-Circuit Volts
	Freq in Mc/s	Volts			Bandwidth† Decade	Power	
1112-A	0.1	1	$< \pm 1 \times 10^{-9}$	± 15 in 10^6	0.1-1 Mc/s	50	20 mW into 50Ω 4 channels: 1 at 1 Mc/s 1 at 10 Mc/s 2 at 100 Mc/s
	1	1.5			1-10 Mc/s	500	
	2.5	0.4			10-100 Mc/s	5000	
	5	0.4					
1112-B	100	20 mW* (50Ω)	$< \pm 1 \times 10^{-9}$	± 100 kc‡	100 kc/s‡	1000 Mc/s, 250 mW, 50Ω sine wave	> 3

* From TYPE 1112-A. † Expressed as allowable frequency deviation rate. ‡ At input frequency.

Spurious Signals: At least 100 dB below output level.

Terminals: Locking GR874 Coaxial Connectors; adaptors (page 81) are available to all commonly used types.

Accessories Supplied: TYPE 1112-A — TYPE CAP-22 Power Cord, TYPE 874-R22LA Patch Cord, spare fuses; TYPE 1112-B — TYPE CAP-22 Power Cord, two TYPE 874-R22LA Patch Cords, spare fuses.

Power Required: 105 to 125 or 210 to 250 V, 50 to 60 c/s. TYPE 1112-A, 110 W; TYPE 1112-B, 125 W.

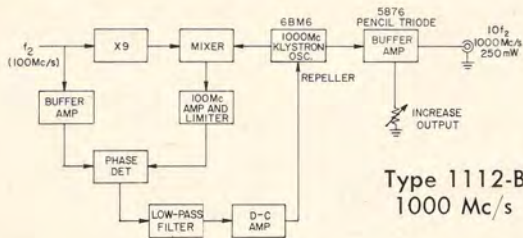
Dimensions: Relay-rack panel, 19 by 12¼ in (485 by 330 mm); depth behind panel, 11 in (280 mm).

Net Weight: TYPE 1112-A, 25 lb (11.5 kg); TYPE 1112-B, 35 lb (16 kg).

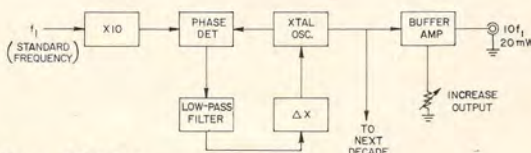
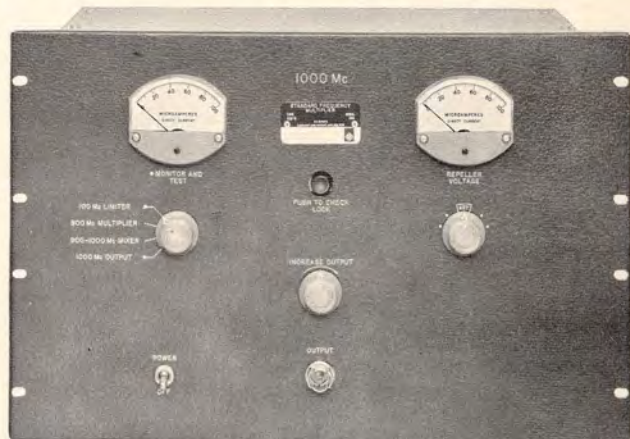
Shipping Weight: TYPE 1112-A, 40 lb (18.5 kg); TYPE 1112-B, 50 lb (23 kg).

Catalog No.	Description	Price
1112-9701	Type 1112-A Standard-Frequency Multiplier	\$1450.00
1112-9702	Type 1112-B Standard-Frequency Multiplier	1360.00

PATENT NOTICE. See Notes 4 and 15, page 11.



Type 1112-B
1000 Mc/s



Type 1112-A
1, 10, 100 Mc/s



An unknown frequency is measured by comparison with a standard frequency. The comparison may be direct, as with a digital frequency meter that includes a quartz-crystal-oscillator time base, or indirect, as with a calibrated, analog-type frequency meter.

The digital frequency meter, or counter, measures frequencies up to about 10 Mc/s directly and economically. The decade scaler is an economical means of extending the range, by direct-counting techniques, upward by a factor of 10. For higher frequencies, say, up to 500 Mc/s, heterodyne converters offer a convenient and accurate means of range extension.

For the measurement of intermittent signals and weak microwave signals, the harmonics of stable, tunable oscillators can be used to transfer the unknown signal to a high-level signal within the range of the measurement system.

Low frequencies, below a few kilocycles per second, can be measured in terms of their periods. The block diagram of Figure 1 illustrates these various techniques.

There are many measurements where the high resolution of the counter is not required, and, for these, the direct-reading analog frequency meter is satisfactory and is less expensive than the digital type.

DIGITAL FREQUENCY METERS

The elements of a digital frequency meter (commonly called a counter) are shown in Figure 2. The reference standard, usually called the time base, is a quartz-crystal oscillator. For period measurement (low frequencies), the counter totals the number of standard pulses from the time base for one or more periods of the unknown frequency. For direct frequency measurement, it counts the number of cycles of the unknown in a standard time interval, usually one second. In either type of measurement, the result is displayed as a series of illuminated digits.

In addition to its basic function of measuring frequency (or period), the counter can also count events (pulses), whether uniform in rate or random, and display the total. It can also be made to measure the ratio between two input frequencies.

General Radio counters use simple, reliable, all-solid-state circuits and are designed for maximum performance at low cost. All models include a precise quartz oscillator as the

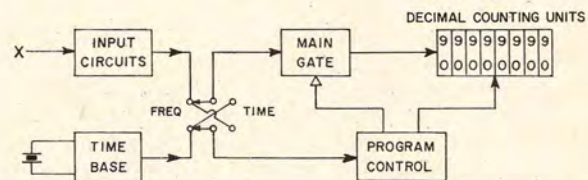


Figure 2. Elementary block diagram of a digital counter.

measurement reference. Input controls are provided to permit reliable counting, regardless of input waveform. The 5-digit readout indicators are bright, incandescent-lamp units designed for maximum legibility and simple bulb replacement. Counting-time controls vary the resolution of the readout over a 1000-to-1 range so that any five digits of interest are displayed — coarse digits for coarse measurements, fine digits for fine measurements.

Four counters are offered by General Radio, differing in frequency range and in the number of measurement capabilities.

TABLE 1 — Basic Frequency Meters

Type	Frequency Range	Use	Page	Price
1150-B	10 c/s to 400 kc/s	Freq, Total	121	\$ 995
1150-BH	10 c/s to 1 Mc/s	Freq, Total	121	1095
1151-A	dc to 400 kc/s	Freq, Period, Ratio, Total	122	1195
1153-A	dc to 10 Mc/s	Freq, Total	123	1495

All models are available with data output (P suffix) for printer or D/A converter at an additional charge of \$55.

RANGE EXTENSION — to 100 Mc/s or 500 Mc/s

Higher frequencies are measured by a combination of the Type 1153-A Digital Frequency Meter and the Type 1156-A Decade Scaler (up to 100 Mc/s) or the Type 1133-A Frequency Converter (up to 500 Mc/s). These extension units have been designed as independent, self-contained instruments based on the "add-a-unit" philosophy pioneered by General Radio. They may be used with other counters or other types of instruments for a variety of measurements.

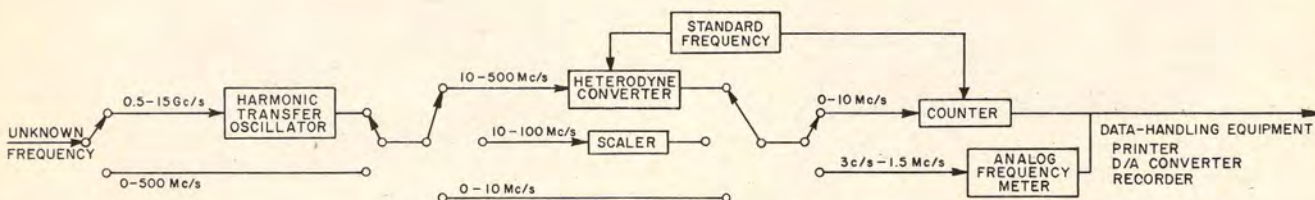


Figure 1. Frequency measurement techniques. Frequencies shown are approximate upper limits for the various systems.

FREQUENCY METERS

Counter-extension unit combinations are available as complete assemblies with all necessary accessories.

TABLE II — Extended-Range Combinations

Type	Frequency Range	Page	Price
1144-A	dc to 100 Mc/s	124	\$1995
1143-A	dc to 500 Mc/s	124	3090

ANALOG FREQUENCY METER

The Type 1142-A Frequency Meter and Discriminator described on page 127 is a pulse-count-discriminator type of frequency meter with an over-all accuracy of 0.2% and a range of 3 c/s to 1.5 Mc/s. With the Type 1156-A Decade Scaler, its range is increased to 15 Mc/s. In addition to its use as a frequency meter, it operates as a highly linear discriminator for measurements of fm deviation, either the wide swings characteristic of fm systems or the very small swings encountered in measurements of incidental fm and of short-term frequency stability of oscillators.

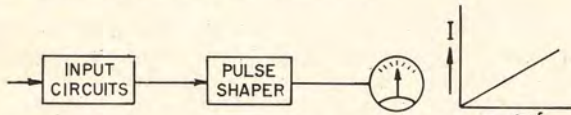
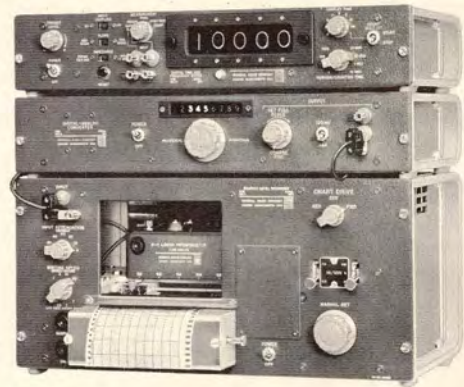


Figure 3. Elementary block diagram of an analog frequency meter.

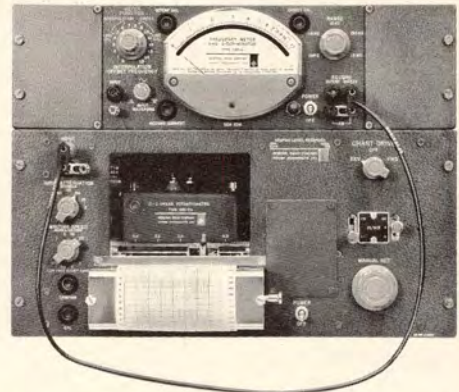
ACCESSORY EQUIPMENT

Data-handling equipment — D/A converter, data printer, and graphic recorder — is available for use with GR digital frequency meters and is described on pages 177 to 183. Combinations of frequency meter and auxiliary equipment can be assembled to meet the user's requirements. Several possibilities are illustrated here.

Each assembly can be supplied with individual units bolted together for bench use, with hardware for rack mount, or mounted in bench-type racks. We shall be glad to quote on combinations to meet your needs.



Recording frequency and period meter. Includes Type 1151-A Digital Time and Frequency Meter and Type 1510-A Digital-to-Graphic Recording Assembly.



Recording frequency meter, 0-1.5 Mc/s. Consists of Type 1142-A Frequency Meter and Discriminator and Type 1521-B Graphic Level Recorder (with linear potentiometer).



500-Mc frequency meter, with printer. Includes Type 1143-A Frequency-Measuring Assembly and Type 1137-A Data Printer.



100-Mc recording frequency meter. Includes Type 1144-A 100-Mc Digital Frequency Meter and Discriminator and Type 1510-A Digital-to-Graphic Recording Assembly.



Type 1150-B, -BH DIGITAL FREQUENCY METERS

10 c/s TO 400 kc/s 10 c/s TO 1 Mc/s

FEATURES:

- Cumulative count or frequency measurements.
- Bright-light, in-line readout.
- High accuracy — stable, temperature-controlled crystal-oscillator time base.

USES: The TYPE 1150 Digital Frequency Meters are basic general-purpose counters for laboratory and industrial use. B models measure to 400 kc/s, BH models to 1 Mc/s. They can be used to calibrate oscillators, to monitor frequencies, and to measure frequencies with high resolution for measurements on precision filters and other frequency-selective devices.

With appropriate transducers, the counters can be used to measure pressure, temperature, strain, weight, production-line output, number of particles in liquids, and other quantities or events that may or may not be periodic. Used with the TYPE 1536-A Photoelectric Pickoff, the counters easily measure high rotational speeds.

DESCRIPTION: These instruments count the number of cycles of the input signal occurring in a precise time interval of 0.01, 0.1, 1, or 10 seconds, established by the quartz-crystal oscillator. The counting circuits are ring-of-ten units.

A triggering level control optimizes input sensitivity for all waveforms and reduces the possibility of erroneous indications from noise or other unwanted signals.

The -BP and -BPH models include data-output provision for use with the TYPE 1137-A Data Printer, the TYPE 1510-A Digital-to-Graphic Recording Assembly, the TYPE 1136-A Digital-to-Analog Converter, and other recording or data-processing equipment.

SPECIFICATIONS

INPUT

Frequency Range	Accuracy	Sensitivity (p-to-p), Impedance
10 c/s to 400 kc/s for Types 1150-B, -BP	±1 count	Better than 1 V at 1 MΩ
10 c/s to 1 Mc/s for Types 1150-BH, -BPH	±time-base stability	and 80 pF; ac coupled. Maximum input: ±300 V.

Self Test: TEST position of measurement switch disconnects input and applies 100 kc/s to check all functions.

Display: 5-digit, in-line readout, incandescent-lamp operated. Display time of 0.16, 0.32, 0.64, 1.28, 2.56, 5.12, 10.24 seconds, or infinity.

Counting Interval: 0.01, 0.1, 1, or 10 seconds, extendible by multiplier switch, or as set manually.

TIME BASE

	Internal Oscillator Stability
100 kc/s, internal or external. Internal oscillator crystal-controlled; adjustment provided, adjusted to within 10 ppm when shipped.	Short term: <0.5 ppm. Cycling: Less than counter resolution. Temp effects: <2.5 ppm, 0 to 50°C ambient rise. Warmup: Within 1 ppm after 15 min. Aging: <1 ppm per week after 4 weeks, decreasing thereafter.

AUXILIARY CONNECTIONS (rear-mounted connectors)

Time-Base Output: 100 kc/s, 20 V, p-to-p, behind 100 kΩ.

External Time-Base Input: 100 kc/s at 1 V, p-to-p, into 1 kΩ.

Auxiliary Connector: Inputs — reset, start-stop. Outputs — carry pulse from last decade, print command, zero-set, 100 kc/s, +20-V test point.

Photoelectric Pickoff Input Connector: 3-terminal telephone jack with +20 V dc and connection to main input.

Data-Output Connector (Types 1150-BP and -BPH only): 10-line decimal for each digit, one wire binary 1 (+14-V level) and nine wires binary 0 (0 to +4-V level), source impedance 2.4 kΩ; +20-V power; and print command pulse.

GENERAL

Power Required: 105 to 125 or 210 to 250 V, 50 to 60 c/s, 45 W.

Accessories Supplied: TYPE CAP-22 Power Cord, eight replacement incandescent lamps, spare fuses.

Accessories Available: TYPE 1536-A Photoelectric Pickoff (page 216). For TYPE 1150-BP and -BPH only — TYPE 1136-A Digital-to-Analog Converter (page 182), TYPE 1137-A Data Printer (page 183), TYPE 1510-A Digital-to-Graphic Recording Assembly (page 182).

MECHANICAL DATA Rack-Bench Cabinet (see page 258)

Model	Width		Height		Depth		Net Wt		Ship Wt	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Bench	19	485	3 7/8	99	12 1/2	320	17 1/2	8	27	12.5
Rack	19	485	3 1/2	90	11 3/8*	298	17 1/2	8	27	12.5

* Behind panel.

For a more detailed description, see *General Radio Experimenter*, August 1964.

Catalog No.	Description	Price
1150-9802	Type 1150-B Digital Frequency Meter, 400 kc/s, Bench Model	\$ 995.00
1150-9812	Type 1150-B Digital Frequency Meter, 400 kc/s, Rack Model	995.00
1150-9909	Type 1150-BP Digital Frequency Meter, 400 kc/s, with data output, Bench Model	1050.00
1150-9910	Type 1150-BP Digital Frequency Meter, 400 kc/s, with data output, Rack Model	1050.00
1150-9505	Type 1150-BH Digital Frequency Meter, 1 Mc/s, Bench Model	1095.00
1150-9515	Type 1150-BH Digital Frequency Meter, 1 Mc/s, Rack Model	1095.00
1150-9563	Type 1150-BPH Digital Frequency Meter, with data output, 1 Mc/s, Bench Model	1150.00
1150-9564	Type 1150-BPH Digital Frequency Meter, with data output, 1 Mc/s, Rack Model	1150.00



NEW MODEL
in catalog S



Type 1151-A DIGITAL TIME AND FREQUENCY METER

DC TO 400 kc/s

FEATURES:

- Cumulative count, frequency, period, or ratio measurements.
- Bright-light, in-line readout.
- High accuracy — temperature-controlled crystal oscillator time base.
- High reliability — ring counters operate with wide range of transistor characteristics.

USES: The TYPE 1151-A is, like the TYPE 1150-B, a general-purpose counter for the laboratory or production line, but with a full complement of input controls and with the program needed for period, multiple-period, and ratio measurements. The ability to make period measurements up to 1000 periods is especially useful for accurate measurement of low frequencies.

DESCRIPTION: The input circuits provide choices between ac or dc coupling, negative- or positive-going slope, and two sensitivities.

For frequency measurement, the main gate is opened and closed by a 100-kc crystal-oscillator signal divided down to 0.1, 1, 10, or 100 c/s.

For period measurement, the main gate is opened and closed by the signal of unknown frequency, and the clock pulses are supplied by the 100-kc crystal oscillator.

For ratio measurement, the counter is programmed as for period measurement, except that the internally generated 100-kc clock signal is replaced by the signal from an input channel. Ratio measurements can be made over the full frequency-resolution range of the counter.

The -AP models include data-output provision for use with the TYPE 1137-A Data Printer, the TYPE 1510-A Digital-to-Graphic Recording Assembly, the TYPE 1136-A Digital-to-Analog Converter, and other recording or data-processing equipment.

SPECIFICATIONS

Measurement	Accuracy		Sensitivity
Frequency: Dc to 400 kc/s	± 1 count ± time-base stability	Counting interval: 0.01, 0.1, 1, or 10s, extendible by multiplier switch, or as set manually.	0.2 V, p-to-p, at 200 kΩ and 40 pF or 1 V at 1 MΩ and 100 pF, switch selected. Maximum input, ± 200 V ac coupled; 500 V dc coupled, at 1 MΩ.
Period: 1, 10, 100, or 1000 periods. Dc to 20 kc/s	± 1 count ± time-base stability ± noise error	Equivalent open-circuit noise: 5 mV, p-to-p, at 1 MΩ, less at 200 kΩ. Counted Frequency: 100 kc/s	
Ratio: B/A, 10 B/A, 100 B/A, or 1000 B/A		Input A: dc to 20 kc/s; Input B: dc to 400 kc/s	Input B: 1 V at 100 kΩ.

Input Trigger: Ac or dc coupled, positive- or negative-going. Trigger level range is adequate to permit triggering on zero crossings of signals twice minimum amplitude and on narrow pulses of either polarity.

Self Test: TEST position of measurement switch disconnects input and applies 100 kc/s to check all functions.

DISPLAY 5-digit, in-line readout, incandescent-lamp operated. Display time of 0.16, 0.32, 0.64, 1.28, 2.56, 5.12, 10.24 seconds, or infinity.

TIME BASE	Internal Oscillator Stability
100 kc/s, internal or external. Internal quartz-crystal oscillator; adjustment provided, adjusted to within 10 ppm when shipped.	Short term: <0.5 ppm. Cycling: Less than counter resolution. Temp effects: <2.5 ppm, 0 to 50°C ambient rise. Warmup: Within 1 ppm after 15 min. Aging: <1 ppm per week after 4 weeks, decreasing thereafter.

AUXILIARY CONNECTIONS (rear-mounted connectors)

Time-Base Output: 100 kc/s, 20 V, p-to-p, behind 100 kΩ.

External Time-Base Input: 100 kc/s at 1 V, p-to-p, into 1 kΩ.

Auxiliary Connector: Inputs — reset, start-stop. Outputs — carry pulse from last decade, print command, zero-set, 100 kc/s, +20-V test point.

Photoelectric Pickoff Input Connector: 3-terminal telephone jack with +20 V dc and connection to main input.

Data-Output Connector (Type 1151-AP only): 10-line decimal for each digit, one wire binary 1 (+14-V level), and nine wires binary 0 (0 to +4-V level), source impedance 2.4 kΩ; +20-V power; and print-command pulse.

GENERAL

Power Required: 105 to 125 or 210 to 250 V, 50 to 60 c/s, 50 W.

Accessories Supplied: TYPE CAP-22 Power Cord, eight replacement incandescent lamps, spare fuses.

Accessories Available: TYPE 1536-A Photoelectric Pickoff (page 216). For TYPE 1151-AP only — TYPE 1136-A Digital-to-Analog Converter (page 182), TYPE 1137-A Data Printer (page 183), TYPE 1510-A Digital-to-Graphic Recording Assembly (page 182).

MECHANICAL DATA Rack-Bench Cabinet (see page 258)

Model	Width		Height		Depth		Net Wt		Ship Wt	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Bench	19	485	3 3/4	99	12 1/2	320	19	9	27	12.5
Rack	19	485	3 1/2	90	11 3/4*	298	19	9	27	12.5

* Behind panel.

See also *General Radio Experimenter*, June 1963.

Catalog No.	Description	Price
1151-9801	Type 1151-A Digital Time and Frequency Meter, Bench Model	\$1195.00
1151-9811	Type 1151-A Digital Time and Frequency Meter, Rack Model	1195.00
1151-9871	Type 1151-AP Digital Time and Frequency Meter, with data output, Bench Model	1250.00
1151-9981	Type 1151-AP Digital Time and Frequency Meter, with data output, Rack Model	1250.00





Type 1153-A DIGITAL FREQUENCY METER

DC TO 10 Mc/s

FEATURES:

- Bright-light, in-line readout with decimal point and spill lamp.
- High sensitivity — 100 millivolts, peak-to-peak.
- Input controls for triggering adjustments.
- All-solid-state circuitry.

USES: The TYPE 1153-A Digital Frequency Meter is a compact, inexpensive laboratory or industrial counter for frequency measurements from dc to 10 Mc/s. With the TYPE 1156-A Decade Scaler, the range is extended to 100 Mc/s, and, with the TYPE 1133-A Frequency Converter, to 500 Mc/s. Assemblies of these instruments are listed on page 124.

The -AP models include data-output provision for use with the TYPE 1137-A Data Printer, the TYPE 1510-A Digital-to-Graphic Recording Assembly, the TYPE 1136-A Digital-to-Analog Converter, and other recording or data-processing equipment.

DESCRIPTION: The TYPE 1153-A Digital Frequency Meter measures frequency by counting the number of

zero-crossings of the input signal during a time interval established by an internal 100-ke time-base. Provision is also made for an external time-base.

The input controls provide a choice of sensitivity, ac or dc coupling, and triggering level and permit operation with input signals as small as 100 millivolts, peak-to-peak.

The readout includes a spill lamp, which provides an indication when the register capacity has been filled. A stable, GT-cut, room-temperature crystal is incorporated in the time-base oscillator. Since the time-base crystal operates at room temperature, there is no frequency shift due to oven cycling. This is most important when the counter is used with the TYPE 1133-A Frequency Converter for measurements up to 500 Mc/s.

SPECIFICATIONS

INPUT

- Frequency:** Dc to 10 Mc/s.
- Accuracy:** ± 1 count \pm time-base stability.
- Sensitivity:** 0.1 V, p-to-p, at 100 k Ω and 50 pF; 1.0 V at 1 M Ω and 20 pF. For narrow pulses, 0.1 V at 100 k Ω and >30-ns duration; 0.2 V at 100 k Ω and >15 ns; 1.0 V at 1 M Ω and >30 ns; 2.0 V at 1 M Ω and >15 ns. Max allowable input is ± 400 V (at 1 M Ω).
- Counting Interval:** 0.01, 0.1, 1, or 10 s, extendible by multiplier switch, or as set manually.
- Input Trigger:** Ac or dc coupled. Trigger level range is ± 1 V at 0.1-V sensitivity, ± 10 V at 1-V sensitivity. Trigger-level drift is typically 0.05 V, p-to-p, at 0.1-V sensitivity, 0.5 V, at 1-V sensitivity, from 0°C to 50°C.
- Self Test:** TEST position of measurement switch disconnects input and applies 100 kc/s to check all functions.
- DISPLAY** 5-digit, in-line readout with decimal point and spill lamp, incandescent-lamp operated. Display time of 0.16, 0.32, 0.64, 1.28, 2.56, 5.12, 10.24 seconds, or infinity.

TIME BASE

100 kc/s, internal or external. Internal frequency derived from 200-ke, GT-cut, room temperature crystal; adjustment provided, adjusted to within 1 ppm when shipped.

Stability

- Cycling:** None
- Temp Effects:** <6 ppm, 0 to 50°C ambient rise; < ± 0.1 ppm per °C, 20° to 30°C ambient rise.
- Aging:** <0.1 ppm per week.

AUXILIARY CONNECTIONS (rear-mounted connectors)

- Time-Base Output:** 100 kc/s, 4 V, p-to-p, behind 2 k Ω .
- External Time-Base Input:** 100 kc/s at 1 V, p-to-p, into 1 k Ω .
- Auxiliary Connector:** Inputs — reset, start-stop. Outputs — carry pulse from last decade, print command, zero set, 100 kc/s, +20-V test point.
- Photoelectric Pickoff Input Connector:** 3-terminal telephone jack with +20 V dc and connection to main input.

Data-Output Connector (Type 1153-AP only): 10-line decimal for each digit — one wire binary 1 (+14-V level) and nine wires binary 0 (0 to +4-V level); source impedance 2.4 k Ω ; +20-V power; ground; and print-command pulse.

GENERAL

- Operating Temp:** 0° to +50°C.
- Power Required:** 105 to 125 or 210 to 250 V, 50 to 60 c/s, 70 W.
- Accessories Supplied:** TYPE CAP-22 Power Cord, 8 replacement incandescent lamps, spare fuses.
- Accessories Available:** TYPE 1536-A Photoelectric Pickoff, TYPE 1133-A Frequency Converter and TYPE 1153-P1 Frequency Multiplier to extend range to 500 Mc/s, TYPE 1156-A Decade Scaler to extend range to 100 Mc/s. For TYPE 1153-AP only — TYPE 1136-A Digital-to-Analog Converter (page 182), TYPE 1137-A Data Printer (page 183), TYPE 1510-A Digital-to-Graphic Recording Assembly (page 182).

MECHANICAL DATA Rack-Bench Cabinet (see page 258)

Model	Width		Height		Depth		Net Wt		Ship Wt	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Bench	19	485	3 $\frac{7}{8}$	99	12 $\frac{1}{2}$	320	20	9.5	28	13
Rack	19	485	3 $\frac{1}{2}$	89	11 $\frac{5}{8}$ *	298	20	9.5	28	13

* Behind panel.

Catalog No.	Description	Price
1153-9801	Type 1153-A Digital Frequency Meter, Bench Model	\$1495.00
1153-9811	Type 1153-A Digital Frequency Meter, Rack Model	1495.00
1153-9871	Type 1153-AP Digital Frequency Meter, with data output, Bench Model	1550.00
1153-9981	Type 1153-AP Digital Frequency Meter, with data output, Rack Model	1550.00
1153-9601	Type 1153-P1 Frequency Multiplier	70.00



NEW

in catalog S



FREQUENCY-MEASURING ASSEMBLIES

These assemblies combine the TYPE 1153 Digital Frequency Meter with range-extension devices to cover wide ranges of frequency. They are shipped completely assembled for bench use and are easy to operate. Hardware for rack mount is supplied. They can also be fur-

nished in bench-type relay racks. Quotations on request. Each assembly is available with or without data-output provision for use with auxiliary equipment such as printers, digital-to-analog converters, and data-processing equipment.

Type 1144-A 100-Mc DIGITAL FREQUENCY METER

DC TO 100 Mc/s

This assembly gives a direct indication of frequency up to 100 Mc/s at low cost and with a minimum of panel space. It consists of the TYPE 1153 Digital Frequency Meter and the TYPE 1156-A Decade Scaler. The scaler divides the input frequency by 10 and provides 100-millivolt, peak-to-peak, sensitivity.

Mechanical Data:

Width		Height		Depth		Net Wt		Ship Wt	
in	mm	in	mm	in	mm	lb	kg	lb	kg
19	485	5 7/8	150	12 1/2	320	46	21	61	28
Catalog No.		Description						Price	

1144-9701	Type 1144-A 100-Mc Digital Frequency Meter	\$1995.00
1144-9829	Type 1144-AP 100-Mc Digital Frequency Meter, with data output	2050.00

PATENT NOTICE. See Note 4, page 11.

NEW

in catalog S



Type 1143-A FREQUENCY-MEASURING ASSEMBLY

DC TO 500 Mc/s

For 500-Mc coverage this assembly combines the TYPE 1153 Digital Frequency Meter and the TYPE 1133-A Frequency Converter. Sensitivity is better than 10 millivolts above 100 kc/s, and signal-to-noise ratio is high. The assembly includes a TYPE 1153-P1 Frequency Multiplier, which converts the 100-ke time-base output of the frequency meter to the 5-Mc reference frequency signal required by the converter. The unknown frequency is the sum of the frequency meter and converter indication. All scales are direct reading.

Mechanical Data:

Width		Height		Depth		Net Wt		Ship Wt	
in	mm	in	mm	in	mm	lb	kg	lb	kg
19	485	11 1/4	290	19	485	54	24.5	84	39
Catalog No.		Description						Price	

1143-9701	Type 1143-A Frequency-Measuring Assembly, dc to 500 Mc/s	\$3090.00
1143-9829	Type 1143-AP Frequency-Measuring Assembly, dc to 500 Mc/s, with data output	3145.00

PATENT NOTICE. See Note 4, page 11.

NEW

in catalog S





Type 1156-A DECADE SCALER

DC TO 100 Mc/s

FEATURES:

- High sensitivity — better than 100 millivolts, peak-to-peak.
- Good input termination; vswr less than 1.1 at 100 Mc/s; reflection less than 10% for 0.4-ns rise-time pulses.
- High output drive — 5 volts, peak-to-peak, open-circuit; 1 volt, peak-to-peak, into 50 ohms.
- Compact — 1 3/4-inch panel height.

USES: The TYPE 1156-A Decade Scaler extends the upper frequency limit of the TYPE 1153-A Digital Frequency Meter to 100 Mc/s, by direct counting. The combination is available as the TYPE 1144-A Frequency-Measurement Assembly, described on page 123. The scaler can also be used with any General Radio counter, counters of other makes, oscilloscope trigger circuits, analog frequency meters, or any instrument requiring 10-to-1 frequency division. Combined with TYPE 1142-A Frequency Meter and Discriminator, it forms a direct-reading analog-type frequency meter capable of measuring frequencies up to 15 Mc/s.

DESCRIPTION: The TYPE 1156-A Decade Scaler is a completely self-contained, 100-Mc, direct-counting frequency divider.

The input circuitry consists of a GR874 locking connector, an attenuator with four 50-ohm positions and one 500-ohm position, and an input amplifier, which provides 100-millivolt sensitivity and also isolates the input from noise generated by the switching circuits. The input amplifier is followed by two Schmitt circuits, a self-clearing ring that scales by five, and a flip-flop that scales by two. This flip-flop drives a high-current Schmitt circuit, which delivers 20-milliampere square waves to a GR874 locking connector.

A level control permits optimum triggering with a variety of inputs including sine waves, pulses, and noisy signals. The input and output connectors can be attached to either the front or the rear of the instrument.

SPECIFICATIONS

	Frequency	Impedance	Remarks
INPUT	Dc to 100 Mc/s	50 or 500 Ω	VSWR: 1.1 max at 100 Mc/s (50 Ω). Reflection: 10% max with 0.4-ns step (50 Ω).
OUTPUT	Dc to 10 Mc/s	250 Ω	Approximately square-wave output, 20 mA; 1 V into 50 Ω, over 5 V open circuit, all p-to-p.

Sensitivity: 0.1, 0.2, 0.5, and 1 V, p-to-p, at 50 Ω; 1 V, p-to-p, at 500 Ω. Maximum input is 20 times sensitivity or 1/2 W, whichever is smaller.

GENERAL

Power Required: 105 to 125 or 210 to 250 V, 50 to 60 c/s, 15 W.

Terminals: GR874 Locking Connectors. For connection to other types of coaxial connectors, use a locking adaptor, which locks securely in place, yet is easily removed. See page 81.

Accessories Supplied: TYPE CAP-22 Power Cord, spare fuses.

Accessories Available: TYPE 874-K Coupling Capacitor for ac coupling to input or output connectors. See page 92.

Mechanical Data: Rack-Bench Cabinet (see page 258)

Model	Width		Height		Depth		Net Weight		Shipping Weight	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Bench	19	485	2 1/8	54	12 1/4	315	10 3/4	4.9	25	11.5
Rack	19	485	1 3/4	45	11 3/8*	288	10 3/4	4.9	25	11.5

* Behind panel.

Catalog Number	Description	Price
1156-9801	Type 1156-A Decade Scaler, Bench Model	\$490.00
1156-9811	Type 1156-A Decade Scaler, Rack Model	490.00

PATENT NOTICE. See Note 4, page 11.

NEW

in catalog 5





Type 1133-A FREQUENCY CONVERTER

100 kc/s TO 500 Mc/s

FEATURES:

- Wide frequency range — 100 kc/s to 500 Mc/s.
- High sensitivity. ■ Tuned amplifier provides selectivity.
- Easy to use; in-line digital readout.

USES: This converter extends the frequency range of the TYPE 1153-A Digital Frequency Meter to 500 Mc/s. It also increases the sensitivity to about 10 millivolts. The converter can be used with other 10-Mc counters if a reference frequency of 5-Mc/s is available or can be derived from the counter. Models for use with other reference frequencies can be supplied on special order.

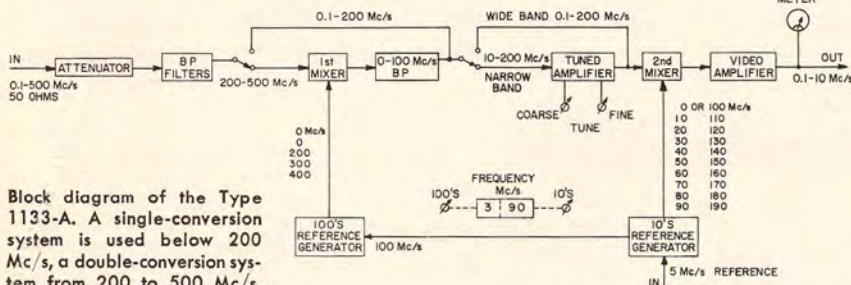
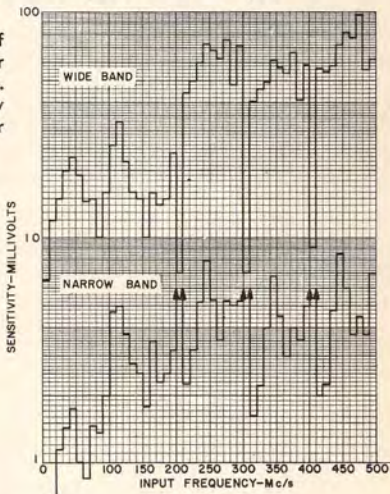
DESCRIPTION: The converter heterodynes the unknown input frequency against a 10-Mc multiple of a standard frequency, derived from the time-base of the counter, and applies the difference frequency to the counter. The unknown frequency is indicated by the sum of the counter display and the in-line readout on the converter.

Use of linear mixing circuits in the converter results in high signal-to-noise ratio under a wide range of

measurement conditions. The tuned amplifier in the converter can be switched in for measurement of low-level or noisy signals, or out for simplified wide-band operation.

The TYPE 1133-A Frequency Converter requires a reference frequency of 5 Mc/s. When the converter is used in the TYPE 1143-A Frequency Measurement Assembly, the 5-Mc reference is supplied by a TYPE 1153-P1 Frequency Multiplier, which multiplies the 100-ke output of the counter to 5 Mc/s. If the counter has a 5-Mc output, the multiplier is not required.

Typical over-all sensitivity of converter and counter for 10.1-Mc counter indication. This is worst case. Sensitivity is better for lower converter output frequencies.



Block diagram of the Type 1133-A. A single-conversion system is used below 200 Mc/s, a double-conversion system from 200 to 500 Mc/s.

SPECIFICATIONS

	Frequency	Impedance	Remarks
INPUT	100 kc/s to 500 Mc/s	50 Ω	Reference frequency required: 5 Mc/s, 15 mV, rms, into 50 Ω.
OUTPUT	100 kc/s to 10.1 Mc/s	100 Ω (approx)	Output amplitude: 0.25 to 1 V (approx). Narrow-band operation provides filtering to reduce noise. Linear mixer preserves signal-to-noise ratio during conversion.

MECHANICAL DATA Rack-Bench Cabinet (see page 258)

Model	Width		Height		Depth		Net Wt		Ship Wt	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Bench	19	485	7½	190	17¾	450	34	15.5	50	23
Rack	19	485	7	180	15*	380	34	15.5	50	23

* Behind panel.

See also *General Radio Experimenter*, May 1961.

Sensitivity (with Type 1153-A Counter): Better than 10 mV on narrow band, better than 100 mV on wide band (see plot).

GENERAL

Power Required: 105 to 125 or 210 to 250 V, 50 to 60 c/s, 70 W.

Accessories Supplied: Two coaxial patch cords for connection to counter; one TYPE CAP-22 Power Cord; spare fuses.

Catalog No.	Description	Price
1133-9801	Type 1133-A Frequency Converter, Bench Model	\$1525.00
1133-9811	Type 1133-A Frequency Converter, Rack Model	1525.00

PATENT NOTICE. See Note 4, page 11.





Type 1142-A FREQUENCY METER AND DISCRIMINATOR

3 c/s TO 1.5 Mc/s

FEATURES:

- 0.2% accuracy
- 20-mV sensitivity
- High resolution through scale expansion.
- Highly linear, low-noise discriminator for fm measurements.

USES: Frequency measurement from 3 c/s to 1.5 Mc/s; to 15 Mc/s with TYPE 1156-A Decade Scaler.

Frequency drift measurements (with TYPE 1521-B Graphic Level Recorder).

Fm deviation (with TYPE 1806-A Electronic Voltmeter).

Fm components (with TYPE 1900-A Wave Analyzer).

The usable frequency range can be extended upwards if the unknown frequency is heterodyned against a stable frequency. This gives a proportionate increase in resolution. At 100 Mc/s, frequency drift and inci-

denital fm can be measured to at least one part in 10⁹.

DESCRIPTION: This instrument is a pulse-count discriminator. The input signal is clipped and amplified. It then triggers a pulse of constant amplitude and duration for each input cycle. The average dc component of the pulse train actuates the meter. With fm input, the time spacing of the pulses varies, producing an ac component that reproduces the modulating frequency and whose amplitude is a measure of the deviation.

SPECIFICATIONS

INPUT

Frequency	Maximum Voltage	Sensitivity (rms), Impedance
3 c/s to 1.5 Mc/s in 5 ranges; full-scale values of 150 c/s to 1.5 Mc/s.	300 V, p-to-p, up to 150 kc/s, 70 V, p-to-p, above 150 kc/s.	20 mV, 20 c/s to 150 kc/s; rising to 200 mV at 3 c/s and 1.5 Mc/s. Up to 5 V for narrow pulses (1 ns). 100-kΩ impedance dropping to minimum of 5 kΩ above 500 kc/s.

INTERPOLATION: A calibrated interpolation feature expands meter scale by a factor of 10 so that 1/10 of any range covers the full scale, providing a readout precision of 0.1%.

ACCURACY 0.2%, nominal. Internal calibration at twice line frequency to standardize output current. Over-all accuracy is the sum of recorder output current accuracy and any of the other errors that are applicable.

Recorder Output Current: Below 15 kc/s, 0.05% of full scale +0.05% of reading; above 15 kc/s, 0.1% of full scale +0.1% of reading.

Meter: Direct reading, 1% of reading above 10% of full scale (0.1% of full scale below 10% of full scale). Interpolating, 0.1% of full scale (range switch setting).

Line-Voltage Effect: ±10% change produces approximately ±0.2% change in reading (±0.5% on 1.5-Mc range).

Warmup Drift: Less than 0.2% of reading after a few minutes, substantially complete within 30 minutes.

Ambient-Temperature Effect: Output current changes less than 0.01%/°C (0.02%/°C on 1.5-Mc range).

DISCRIMINATOR CHARACTERISTICS

Output Voltage: 15 V dc full scale (1.5) on all ranges.

Residual FM Noise: Below 1 Mc/s, more than 100 dB below full output. (With 400-cycle power, 90 dB down.) Narrow-band

residual noise at frequencies other than 60 or 120 c/s is more than 120 dB down from full output.

Linearity: Below 15 kc/s, 0.05% of full scale (15 V) ± 0.05% of output voltage; above 15 kc/s, 0.1% of full scale (15 V) ± 0.1% of output voltage.

RECORDER OUTPUT

Direct: Output current adjustable to drive recorders from 1 mA (2.7 kΩ max) to 5 mA (190 Ω max).

Interpolate: Full scale, 0.64 V behind 4.8 kΩ.

GENERAL

Power Required: 105 to 125 or 210 to 250 V, 50 to 400 c/s, 85 W.

Accessories Supplied: TYPE CAP-22 Power Cord, spare fuses.

Accessories Available: TYPE 1156-A Decade Scaler (page 125); TYPE 480-P312 Relay-Rack Adaptor Set, panel height 5 1/4 in.

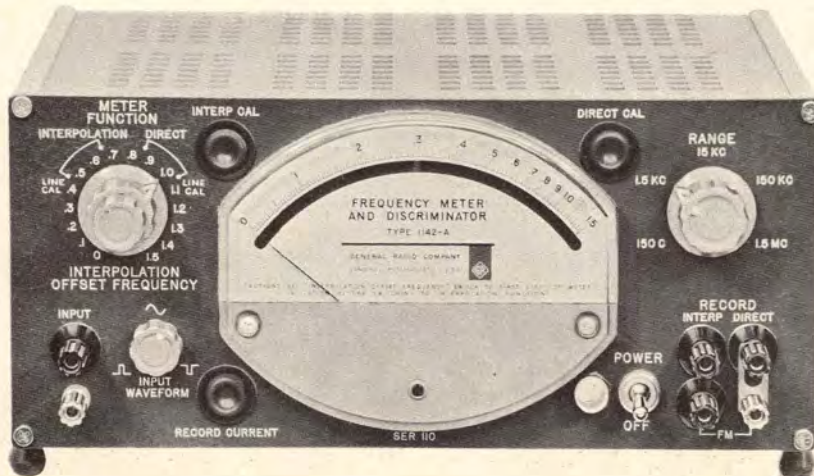
MECHANICAL DATA Convertible-Bench Cabinet (see page 258)

Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
12	305	5 3/4	150	12	305	16	7.5	23	10.5

For a more detailed description, see *General Radio Experimenter*, January 1961.

Catalog No.	Description	Price
1142-9701	Type 1142-A Frequency Meter and Discriminator	\$565.00
0480-9632	Type 480-P312 Relay-Rack Adaptor Set	
		6.50

PATENT NOTICE. See Notes 15 and 16, page 11.





GENERATORS (SIGNAL SOURCES)



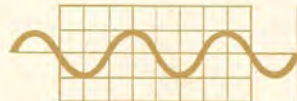
A signal source is essential in any electrical measuring system; it provides the stimulus that creates the response to be measured. This source is usually an oscillator or standard-signal generator of known characteristics, which can be adjusted to establish a known set of conditions. These characteristics comprise the frequency, the output voltage and impedance, the carrier-signal waveform, which may typically be sine-wave, square-wave, pulse or random-noise, and the modulation, which carries the system information through variation of phase, frequency, amplitude, or timing of the carrier waveform.

Signal sources can be classified functionally as to whether the information that they yield is readily usable in frequency-domain or in time-domain analysis. Sine-wave techniques form the basis of power-generation and transmission systems and most communication systems, leading to ready frequency-domain analysis. Many newer developments in information transmission and data handling, however, such as radar systems, digital computers, telemetry, and even the more venerable wire telegraphy, are based upon pulse techniques, which yield most easily to time-domain analysis.

Common to all these systems are ultimate performance limitations determined by system bandwidths and noise. Bandwidth and transient performance are the two sides of a coin; they convert one into the other and can be measured as phenomena in either the frequency or the time domain, at the convenience of the analyst. Noise is most easily measured by comparison with a noise source of known characteristics.

General Radio Company manufactures signal sources in all these categories:

1. **OSCILLATORS**, or sine-wave generators, embracing frequencies from 0.01 c/s to 7 Gc/s, with maximum output levels from a few milliwatts to 200 watts.
2. **STANDARD-SIGNAL GENERATORS** — sine-wave oscillators with accurately calibrated output voltage behind a standard impedance and with calibrated modulation capabilities. For wide-band measurements, a sweep-frequency model, Type 1025-A, provides calibrated sweep bands as well as calibrated output. Mechanical sweep devices are also available for converting conventional signal generators and oscillators to sweep generators.
3. **FREQUENCY SYNTHESIZERS** produce output frequencies continuously adjustable over wide ranges and all coherently derived from a quartz-crystal oscillator. Three basic models are offered, with optional degrees of resolution from one part in 10^3 to one part in 10^6 , with either manual or programmable control.
4. **PULSE GENERATORS** — for time-domain measurements, three high-performance pulse generators are listed, plus a pulse amplifier for higher-power applications, and a tone-burst generator.
5. **RANDOM-NOISE GENERATOR** — produces wide-band noise of uniform spectrum level and approximately Gaussian energy distribution for noise and vibration testing in mechanical systems, noise measurements in communicative circuits, and applications in psychological, probability, and information-theory research.



OSCILLATORS

The variable-frequency, sine-wave oscillator is the basic general-purpose signal source. With it one can make a series of measurements at uniquely specified frequencies, which can be combined to specify performance in the frequency domain. These measurements may be made by manual settings, point by point, or by a frequency swept automatically over the desired range to display the system response on a chart recorder or a cathode-ray oscilloscope.

The oscillators whose characteristics are summarized on the page opposite are of four types: LC, RC, beat-frequency, and klystron.

LC OSCILLATORS At radio frequencies where tuning can be accomplished by air capacitors, the LC circuit is the best and most economical frequency-determining system. The Type 1330-A Bridge Oscillator uses tuned circuits to

cover a frequency range of 10,000:1. The Types 1211, 1208, 1215, 1209, and 1361 Oscillators cover frequencies from 500 kc/s to 960 Mc/s. All of these employ unique tuned circuits, in which the inductance and capacitance are varied simultaneously. Many of them use the General-Radio-developed butterfly circuit,¹ which has no sliding or wiping contacts.

At frequencies above 1,000 Mc/s, circuits with distributed constants are used. The Type 1218-B Unit Oscillator covers a frequency range of 900 to 2,000 Mc/s with ganged transmission lines.

¹ Eduard Karplus, "Wide-Range Tuned Circuits and Oscillators for High Frequencies," *Proceedings of the Institute of Radio Engineers*, July, 1945. Eduard Karplus, "The Butterfly Circuit," *General Radio Experimenter*, October, 1944.

MODULATION

In RC OSCILLATORS the frequency is determined by resistive and capacitive elements.² The RC degenerative circuit, of which the Type 1311-A and the Type 1310-A are examples, is an original, patented, General Radio development. A Wien-bridge network is the tuning element in these two, as well as in the Type 1210-C, a small, versatile instrument, which produces either sine-wave or square-wave output over a wide frequency range. The Type 1305-A, a phase-shift oscillator, generates frequencies as low as 0.01 c/s with single-phase, three-phase, and four-phase output, as well as an output continuously variable in phase over 360°.

The BEAT-FREQUENCY OSCILLATOR was mentioned as early as 1920 by Van der Bijl.³ In this oscillator the output frequency is the difference between the frequencies of a variable-frequency and a fixed-frequency oscillator. Several decades of frequency can be covered in one band with a single control.

The first commercial beat-frequency oscillator was produced by General Radio in the middle 1920's. As the development of components and circuits has progressed, increasingly better models have been developed, culminating in the present Type 1304-B Beat-Frequency Audio Generator, whose logarithmic scale greatly facilitates frequency-response measurements and which can be driven by the Type 1521-B Graphic Level Recorder for automatic plotting.

In KLYSTRON OSCILLATORS, first described by the Varians,⁴ the frequency is determined by a velocity-modulated electron stream, which excites a resonant cavity. The Type 1360-B Microwave Oscillator uses a reflex klystron in a coaxial cavity with a noncontacting plunger to cover frequencies from 1.7 to 4.1 Gc/s. Internal square-wave and frequency modulation are provided.

The Type 1220-A Unit Klystron Oscillator is a klystron power supply that covers frequencies from 2700 to 7425 Mc/s with plug-in klystron tubes, each of which is adjustable over a narrow band of frequencies.

The rf oscillators can all be amplitude modulated with sine waves, and the Type 1218-B, Type 1361-A, and Type 1220-A can be directly square-wave and pulse modulated as well.

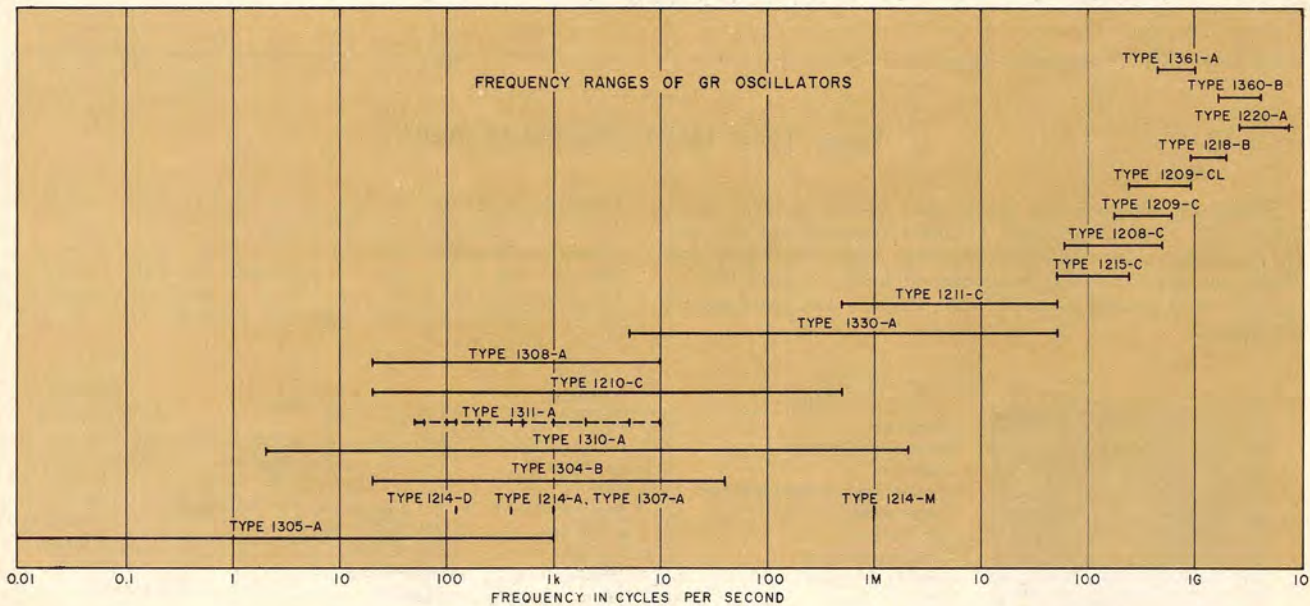
The Unit Oscillators operating above 50 Mc/s can, except for the Type 1208-C, be pulse or square-wave modulated by the Type 1264-A Modulating Power Supply, and can be held to a constant output amplitude with the Type 1263 Amplitude-Regulating Power Supply.

SWEEPING FREQUENCY

Specific provision for automatic display is incorporated in many General Radio sources.⁵ Electronic sweeping systems are particularly suited to microwave sources and are incorporated in the Type 1220-A Unit Klystron Oscillator and the Type 1360-B Microwave Oscillator to cover frequencies from 1.7 Gc/s to 7 Gc/s.

To convert to automatic operation the many existing manually operated devices that have given, and are still giving, good service, the Type 1750-A Sweep Drive provides a mechanical hand that will grasp and rotate knobs and dials of assorted sizes and varieties and provide dc voltages that define their angular positions. The Type 908-P and 908-R Dial Drives perform similar functions for instruments using General Radio Precision Dials.

² First described by Nichols in 1921; see U.S. Patent 1,442,781.
³ H. J. Van der Bijl, "Thermionic Vacuum Tube," McGraw-Hill Book Company, 1920 (first edition), p 377.
⁴ Russell H. and Sigurd F. Varian, "A High-Frequency Oscillator and Amplifier," *Journal of Applied Physics*, May, 1939, p 321.
⁵ See also the Type 1025-A Standard Sweep-Frequency Generator, which has the accurately calibrated output and other features of the standard-signal generator.



OSCILLATORS

Type	Name	Class	Frequency Range	Maximum Output	Open-Circuit Volts	Nominal Load Impedance-ohms	Harmonic Distortion	Power Supply	See Page	
Audio and Sub-Audio Frequency	1305-A	Low-Frequency Oscillator	RC	0.01-1000 c/s	170 mW per phase	10	600	<2%	AC Line	131
	1214-D	Unit Oscillator	Tuned Circuit	120 c/s	400 mW	45	1, 10, 100, 1000	<3%	AC Line	130
	1307-A	Transistor Oscillator	Tuned Circuit	400 and 1000 c/s	6 mW	2	600	<5%	Mercury Cells	21
	1214-A	Unit Oscillator	Tuned Circuit	400 and 1000 c/s	200 mW	60	8000	<3%	AC Line	130
	1304-B	Beat-Frequency Audio Generator	Beat-Frequency	20 c/s-20 kc/s 20-40 kc/s	1 W	50	600	<1%	AC Line	132
	1210-C	Unit RC Oscillator	RC	20 c/s-0.5 Mc/s	80 mW	7 45 30	> 500 > 10,000 > 1000	<1.5% <5% Square Wave	AC Line with Unit Power Supply	134
	1310-A	Oscillator	RC	2 c/s-2 Mc/s	160 mW	20	600	<0.25%	AC Line	135
	1311-A	Audio Oscillator	RC	11 frequencies 50 c/s-10 kc/s	1 W	1, 3, 10, 30, 100	0.1-10,000	<0.5%	AC Line	136
	1308-A	Audio Oscillator and Power Amplifier	RC	20 c/s-10 kc/s	200 W	4, 12.5, 40, 125, 400	0.8, 2.5, 8, 80, 800	1% to 2%	AC Line	137
Medium and High Frequency	1214-M	Unit Oscillator	Tuned Circuit	1 Mc/s	300 mW	7	50	<3.5%	AC Line	130
	1330-A	Bridge Oscillator	Tuned Circuit	60, 400, 1000 c/s 5 kc/s-50 Mc/s	0.75 W 1 W	12 10	50 20-80	<5%	AC Line	138
	1211-C	Unit Oscillator	Tuned Circuit	0.5-5 Mc/s 5-50 Mc/s	1 W 200 mW		50		AC Line with Unit Power Supply	
	1215-C	Unit Oscillator	Semi-Butterfly	50-250 Mc/s	80 mW		50		AC Line with Unit Power Supply	
VHF and UHF	1208-C	Unit Oscillator	Sliding-Contact Tuned Circuit	65-500 Mc/s	100 mW		50		AC Line with Unit Power Supply	139
	1209-CL	Unit Oscillator	Butterfly Tuned Circuit	180-600 Mc/s	300 mW		50		AC Line with Unit Power Supply	to
	1209-C	Unit Oscillator	Butterfly Tuned Circuit	250-920 Mc/s	200 mW		50		AC Line with Unit Power Supply	144
	1361-A	UHF Oscillator	Butterfly Tuned Circuit	450-1050 Mc/s	150 mW		50		AC Line with Unit Power Supply	
	1218-B	Unit Oscillator	Coaxial-Line Tuned Circuit	900-2000 Mc/s	140 mW		50		AC Line with Unit Power Supply	
SHF	1220-A	Unit Klystron Oscillator	Velocity-Modulated	2700-7425 Mc/s	75-100 mW		50		AC Line with Unit Power Supply	146
	1360-B	Microwave Oscillator	Velocity-Modulated	1.7-4.1 Gc/s	100 mW		50		AC Line	145

Type 1214 UNIT OSCILLATORS

These are compact and inexpensive fixed-frequency oscillators. The TYPE 1214-A and -D Unit Oscillators are convenient modulators for the high-frequency Unit Oscillators and power sources for bridge measurements. The output can be isolated from ground for use of the oscillator as a plate-circuit modulator.

Power Required: 105 to 125 V, 50 to 60 c/s, 15 W. Can also operate on frequencies up to 400 c/s.

Accessories Supplied: Spare fuses.

Cabinet: Unit Instrument (see page 258). TYPE 480-P4U1 Relay-Rack Adaptor Panel Set available to mount oscillator (panel 19 by 7 in); catalog number: 0480-9984; price: \$11.00.



Type 1214-A

TYPE	1214-A	1214-D	1214-M
Frequency	400 and 1000 c/s ± 2%	120 c/s ± 5%	1 Mc/s ± 1%
Maximum Output*	200 mW into 8000 Ω	400 mW into 1, 10, 100, 1000 Ω	300 mW into 50 Ω
Distortion	3% into 8000 Ω	3% into matched load	3.5% into 50 Ω
Open-Circuit Output Voltage*	0 to 60 V	45, 13, 4.5, or 1.3 V	0 to 7 V
Dimensions	Panel width 4 3/4, height 5 1/4, depth 6 in (120, 135, 155 mm)		
Net Weight	4 1/2 lb (2.1 kg)	4 1/2 lb (2.1 kg)	2 3/4 lb (1.3 kg)
Shipping Weight	5 lb (2.3 kg)	5 lb (2.3 kg)	4 lb (1.9 kg)
Catalog Number	1214-9701	1214-9704	1214-9713
Price	\$85.00	\$115.00	\$85.00

* Output voltage changes by about 12% per 10% change in line voltage. Power and voltage values given are for 115-V input.



Type 1305-A LOW-FREQUENCY OSCILLATOR

0.01 TO 1000 c/s

FEATURES:

- Frequencies down to 0.01 cycle per second (36 cycles per hour).
- 0 to 360° variable phase output.
- Known output levels over 80-dB range.
- Logarithmic frequency scale.
- Excellent amplitude stability.
- 1-, 2-, 3-, or 4-phase output.

USES: This generator has many uses in the development and testing of servomechanisms, low-frequency amplifiers, recorders, geophysical equipment, medical instruments, analogs of 3-phase power systems, and electrical analogs of mechanical systems. With suitable amplifiers it can serve as a variable-frequency drive for low-power, two-phase or three-phase machines.

In addition to its three-phase output (0°, 120°, 240°), any phase of which can be used singly, an adaptor produces four-phase output at 0°, 90°, 180°, 270° for such applications as circular oscilloscope sweeps and component resolution (with phase detectors).

The variable phase output is useful for measurements of phase with Lissajous-pattern techniques, gain and

phase-shift of four-terminal devices, and transfer characteristics of amplifiers and servomechanisms.

DESCRIPTION: Three independent, RC phase-shift networks, connected as low-pass filters, are used in a direct-coupled, phase-shift oscillator circuit. Miller-effect amplifiers increase the effective size of the polystyrene capacitors for operation at the lowest frequencies. The amplitude regulator provides an extremely high degree of amplitude stability, independent of frequency. Cathode-follower circuits provide low-distortion, low-impedance outputs.

A purely resistive network produces the constant amplitude, variable phase output.

SPECIFICATIONS

FREQUENCY

Range: 0.01 to 1000 c/s in five decade ranges, continuously adjustable with logarithmic dial.

Accuracy: ±2% of reading. Warmup drift less than 1% in first 10 min, less than 0.2% in next hour.

OUTPUT

	Phase Diff	Per Phase (line to neutral) Voltage	Impedance	Notes
Three-Phase	120° ± 2° between adjacent phases.	At least 10 V, rms, open-circuit; constant with frequency to ± 5%. Phase voltages equal within ± 2%.	600 Ω; 75 Ω on DIRECT output.	Max power, 167 mW per phase into 600-Ω wye. Distortion < 2%. On DIRECT output, load impedance should be at least 600 Ω, wye, or 1800 Ω, delta.
Four-Phase	90° ± 3° between adjacent phases.	At least 5 V, rms, open-circuit.	600 Ω	From plug-in adaptor.
Variable-Phase	0° to 360°, accuracy ± 3°.	Approx 0.8 V, rms, open-circuit, constant with frequency to ± 5%.	Variable, 15 kΩ max.	Distortion less than 5%.

GENERAL

Hum: More than 60 dB down, OUTPUT AMPLITUDE control at max.

Output Meter: 6-phase detector minimizes ripple; indication fluctuations +5% to -10% of true rms at lowest output frequencies.

Power Required: 105 to 125 or 210 to 250 V, 50 to 60 c/s, 165 W.

Accessories Supplied: TYPE 1305-P1 Four-Phase Adaptor, TYPE CAP-22 Power Cord, 3 TYPE 274-MB Double Plugs, spare fuses.

Accessories Available: Dial drives (see pages 153 and 154).

MECHANICAL DATA Rack-Bench Cabinet (see page 258)

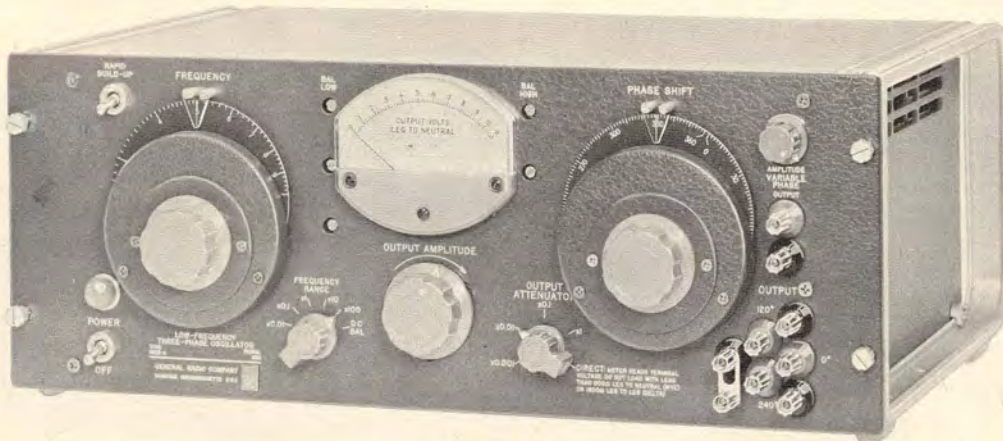
Model	Width		Height		Depth		Net Weight		Shipping Weight	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Bench	19	485	7 3/4	190	15 1/2	395	35	16	43	20
Rack	19	485	7	180	13 1/2*	345	33	15	43	20

* Behind panel.

For a more detailed description, see *General Radio Experimenter*, August-September, 1959.

Catalog No.	Description	Price
1305-9801	Type 1305-A Low-Frequency Oscillator, Bench Model	\$940.00
1305-9811	Type 1305-A Low-Frequency Oscillator, Rack Model	940.00

PATENT NOTICE. See Note 15, page 11.





Type 1304-B BEAT-FREQUENCY AUDIO GENERATOR

20 c/s TO 40 kc/s

FEATURES:

- Covers entire audio range in one sweep of dial.
- Logarithmic frequency scale and linear frequency-increment dial.
- One watt into 600 ohms.
- Output voltage constant with frequency.
- Known output over 80-dB range.
- Low distortion and hum.
- Easily adaptable to automatic audio-frequency testing.

USES: The many features of this generator make it especially well suited for amplitude-frequency tests on audio-frequency equipment — lines, amplifiers, filters, equalizers, transducers, and other networks. It finds constant use in the electronics laboratory as a power source for acoustical tests, as a power source for bridge measurements, and as a modulator for rf signal generators.

Frequency-response characteristics of circuits and devices can be recorded by either the TYPE 1521-B Graphic Level Recorder or by an XY recorder. The graphic level recorder drives the generator dial through a chain-and-gear system, and the response is plotted on chart paper whose frequency scale matches that of the oscillator. For XY plotting, the drive can be the TYPE 908-R96 Dial Drive.

An assembly of generator and graphic level recorder is listed on the next page.

DESCRIPTION: This instrument has a number of unusual design features that contribute to superior performance and ease of operation. Two radio-frequency oscillators, one fixed and one variable, feed a pentagrid

converter through buffer amplifiers. The resulting difference frequency, after passing through a low-pass filter, is amplified in a degenerative amplifier. The output stage of this amplifier is the unique, low-distortion, single-ended, push-pull circuit.*

The oscillator output level is continuously adjustable, and the output can be either balanced or grounded. The unbalanced circuit contains a three-step calibrated attenuator. The output voltmeter is calibrated in dBm and open-circuit output volts.

The frequency dial carries a logarithmic frequency scale for the range 20 c/s to 20 kc/s and is driven by a slow-motion gear-reduction drive, essentially free from backlash.

Rotation is continuous over 360°, to facilitate automatic recording. A cycles-increment dial varies the frequency over a range of ±50 c/s at any setting of the main dial and can be swept by the TYPE 1750-A Sweep Drive.

The 20- to 40-kc range is selected by a single panel switch.

*A. P. G. Peterson and D. B. Sinclair, "A Single-Ended Push-Pull Audio Amplifier," *Proceedings of the IRE*, Vol 40, pp 7-11, January 1952.

SPECIFICATIONS

FREQUENCY

Range: 20 c/s to 40 kc/s in two ranges, 20 c/s to 20 kc/s and 20 kc/s to 40 kc/s.

Controls: Main dial has precision 10:1 reduction gear drive, and can be rotated continuously for automatic drive. Frequency-increment dial is direct drive. Two-position switch changes frequency range.

Calibration: Main scale, logarithmic from 20 c/s to 20 kc/s, 80° per decade. High-range position of switch adds 20 kc/s to main scale calibration. Frequency-increment dial, linear, -50 to +50 c/s.

Accuracy: Main dial, ±(1% + 0.5 c/s) after standardization by zero-beat or line-frequency setting. The 20-kc increment for high range is accurate to ±0.5%. Frequency-increment dial, ±1 c/s.

Stability: At zero beat, drift from a cold start is less than 7 c/s in the first hour and is essentially completed within two hours.

OUTPUT

Voltage: Continuously variable from below 5 mV to 50 V, open circuit. Full-scale, open-circuit output voltages of 50 mV, 500 mV, 5 V, and 50 V.

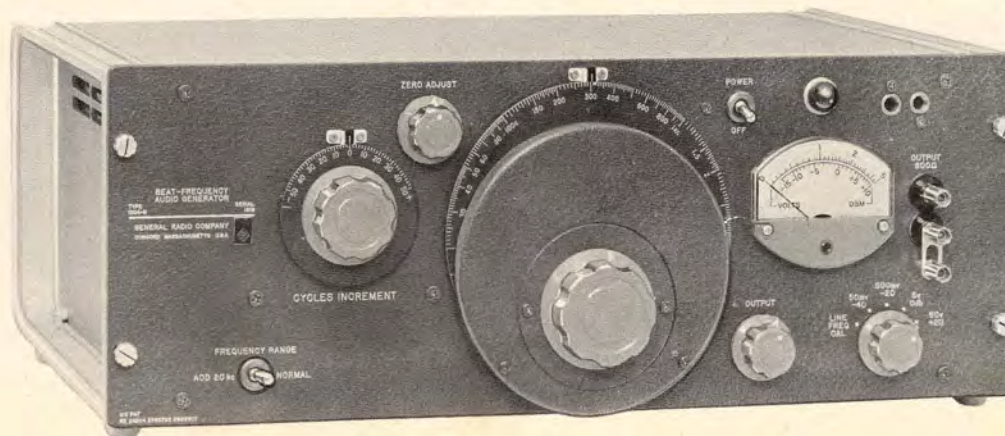
Frequency Characteristic: For a 600-Ω resistive load, NORMAL range, 20 to 20,000 c/s, ±0.25 dB; ADD 20 KC range, 20 to 30 kc/s, ±0.5 dB; 30 to 40 kc/s, ±1.0 dB.

The open-circuit voltage rises at the higher frequencies.

Impedance: 600 Ω, resistive, ±2%. At +20 dBm setting of attenuator, the output may be used either balanced or grounded. With grounded output, the attenuator can be used throughout its entire range.

Power: 1 W, maximum, into a 600-Ω resistive load.

Distortion: Less than 0.25% from 100 to 10,000 c/s. Below 100 c/s, harmonics increase and may reach 0.5% at 50 c/s. Above 10,000 c/s, the harmonic content is less than 1%.



Ac Hum: Less than 0.1% of output voltage for meter readings above 10% of full scale.

Voltmeter: Calibrated in volts output at open circuit, and in dBm. Above 10% of full scale, the calibration is accurate within $\pm 5\%$ of indication.

Attenuator: Used only with single-ended output; has three steps of 20 dB each, accurate to $\pm 1\%$ of the nominal attenuation.

Control: For each step of the attenuator, output voltage can be varied continuously from zero to maximum.

Zero-Beat Indicator: The output voltmeter indicates zero beat.

GENERATOR

Terminals: TYPE 938 Binding Posts and Western Electric double output jack on panel; a four-terminal socket at rear.

Power Required: 105 to 125 or 210 to 250 V, 50 to 60 c/s; approximately 90 W.

Accessories Supplied: TYPE CAP-22 Power Cord, 4-terminal plug, spare fuses.

Accessories Available: Dial Drives (page 154); TYPE 1304-P1 Muting Switch; TYPE 1521-B Graphic Level Recorder (page 178).

MECHANICAL DATA Rack-Bench Cabinet (see page 258)

Model	Width		Height		Depth		Net Weight		Shipping Weight	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Bench	19	485	7½	190	15¼	390	39	18	43	20
Rack	19	485	7	180	13¼*	340	39	18	43	20

* Behind panel.

For a more detailed description, see *General Radio Experimenter*, June 1954.

Catalog Number	Description	Price
1304-9802	Type 1304-B Beat-Frequency Audio Generator, Bench Model	\$850.00
1304-9812	Type 1304-B Beat-Frequency Audio Generator, Rack Model	850.00

PATENT NOTICE. See Notes 5, 9, 14, and 15, page 11.

Type 1350-A GENERATOR-RECORDER ASSEMBLY

This automatic, audio-frequency measuring system combines the TYPE 1304-B Beat-Frequency Audio Generator and TYPE 1521-B Graphic Level Recorder in a single assembly for the automatic plotting of frequency-response data. The recorder is a fully transistorized, single-channel, servo-type with a 40-dB, dynamic range plug-in potentiometer (20-dB, 80-dB, and linear potentiometers are also available).

Constant generator output and uniform recorder response make this an excellent assembly for measuring the response of filters, attenuators, networks, loud-speakers, amplifiers, microphones, transducers, and complete acoustic systems.

The complete assembly includes the following:

TYPE 1304-B Beat-Frequency Audio Generator with accessories, end frames and rack supports.

TYPE 1521-B Graphic Level Recorder (page 178) with accessories (including a 40-dB potentiometer), TYPE 1521-P19 motor, end frames and rack supports.

1521-9427 Chart Paper, 10 rolls

TYPE 274-NP Patch Cord

TYPE 1521-P10B Drive Unit

TYPE 1521-P15 Link Unit

TYPE 1521-P16 Sprocket Kit

TYPE 1560-P95 Adaptor Cable

TYPE 1304-P1 Muting Switch

The blank parts on the chart paper correspond to the length of the blank portion on the generator dial so that many charts can be recorded with complete synchronization of the chart and the dial frequency.

Power Required: 105 to 125 or 210 to 250 V, 60 or 50 c/s (see price list below), 135 W.

Mechanical Data:

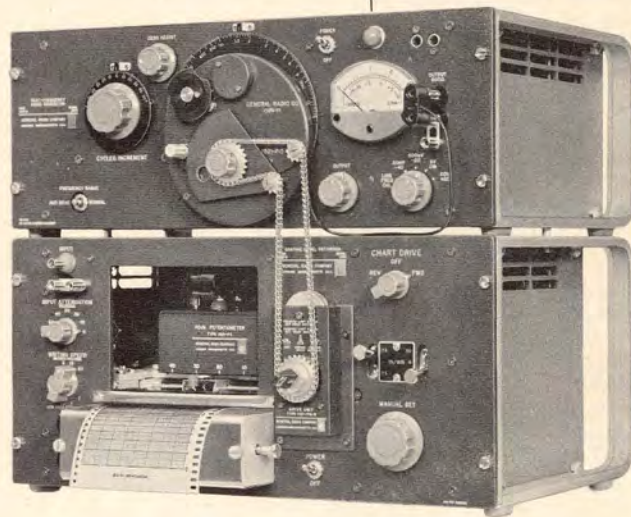
Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
19	485	16½	420	15¼	390	89	41	165	76

For a more detailed description, see *General Radio Experimenter*, September 1964.

Catalog No.	Description	Price
1350-9701	Type 1350-A Generator-Recorder Assembly, for 60-cycle supply	\$2055.00
1350-9494	Type 1350-AQ1 Generator-Recorder Assembly, for 50-cycle supply	on request

NEW

in catalog S



Type 1304-P1 MUTING SWITCH

The muting switch short circuits the generator output during rotation through the blank portion of the dial and thus eliminates any low-frequency signals that might damage the recorder or the device under test when the recorder is swept continuously. The switch can be adjusted to mute the blank portion of the dial plus any range of frequencies from 0 c/s to 1.5 kc/s.

The switch mounts on the main-dial assembly of the generator and connects to the generator output terminals by means of a cable and plug.

Net Weight: 6½ oz (185 g). **Shipping Weight:** 3 lb (1.4 kg).

Catalog No.	Description	Price
1304-9601	Type 1304-P1 Muting Switch	\$37.50



Type 1210-C UNIT R-C OSCILLATOR

SINE AND SQUARE WAVES — 20 c/s TO 0.5 Mc/s

FEATURES:

- Wide frequency range — audio, ultrasonic, and radio frequencies.
- High output voltage, constant with frequency.
- Small — inexpensive — compact and rugged.
- Precision frequency-control dial. ■ Sweepable, with dial drive.

USES: This compact, inexpensive oscillator offers outstanding performance per dollar and per cubic inch of space. It can be used as:

- A sine-wave power source for measurements.
- A square-wave source for network steady-state and transient response measurements.
- A sine- or square-wave modulator for rf generators.
- A square-wave trigger for pulse generators.
- A swept oscillator for displaying amplitude-frequency characteristics (with the TYPE 907-R144 Dial Drive) on a graphic recorder.
- A 3-watt oscillator, when combined with the TYPE 1206-B Unit Amplifier.

DESCRIPTION: An RC network determines the frequency of the oscillator. A fast-response AVC system holds the amplitude of oscillation constant despite changes in frequency or line voltage.

The oscillator has three different outputs that contribute to its versatility and usefulness:

1. A low-impedance, low-voltage, low-distortion output from a cathode-follower amplifier.
2. A high-impedance output from a high-voltage amplifier. Output impedance is independent of attenuator setting.
3. A square-wave output of 30 volts, peak-to-peak, (open-circuit) with $\frac{1}{3}$ - μ s rise time.

SPECIFICATIONS

FREQUENCY

Range: 20–500,000 c/s in five ranges: 20–200, 200–2000, 2000–20,000, 20,000–200,000, and 50,000–500,000 c/s. Dial has two scales and covers each decade in about $4\frac{1}{2}$ turns.

Accuracy: $\pm 3\%$.

Stability: Warmup drift is less than 1%, complete in 1 to 2 hours.

OUTPUT

Control: Logarithmic, calibrated 0 to 50 dB.

Low-Impedance: (for loads of 500 Ω and higher) 0 to 7 V, ± 1 dB up to 200 kc/s, open circuit. Output impedance 50 Ω at full output, 1250 Ω at half output. No-load distortion less than 1%, 200 c/s to 10 kc/s, less than 1.5% at all frequencies. Hum at least 60 dB below output. Attenuator calibration reliable for loads of 12 k Ω and higher.

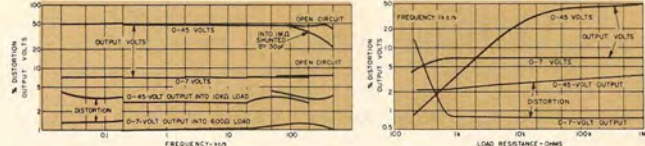
High-Impedance: (for loads of 10 k Ω and higher) 0 to 45 V, ± 1 dB, 200 c/s to 150 kc/s, open circuit. Output impedance 14 k Ω , constant with attenuator setting. No-load distortion less than 5%, 200 c/s to 200 kc/s; reduced under load. Hum at least 50 dB below maximum output.

Square-wave: 0 to 30 V, p-to-p, open circuit. Output impedance 2500 Ω . Rise time about $\frac{1}{3}$ μ s, no load; 0.15 μ s, 1-k Ω load. Overshoot about 1%. Hum at least 60 dB below output.

GENERAL

Power Required: TYPE 1203 Unit Power Supply, 50 to 400 c/s.

Accessories Available: TYPE 1206-B Unit Amplifier for 3-W output, TYPE 907-R144 Dial Drive, adaptor panel for rack mounting.



Typical sine-wave output and harmonic distortion characteristics of the Type 1210-C Unit R-C Oscillator as functions of frequency and load.

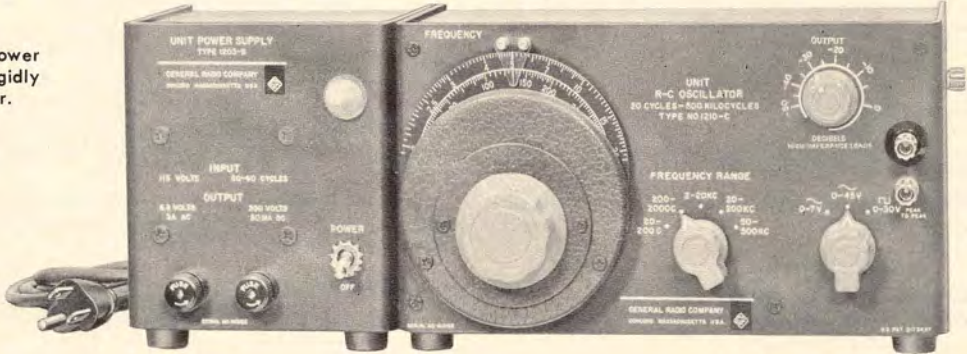
MECHANICAL DATA Unit-Instrument Cabinet (see page 258)

	Width		Height		Depth		Net Wt		Ship Wt	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
With power supply	15	385	5 $\frac{3}{4}$	150	7	180	10 $\frac{1}{2}$	4.8	18	8.3

For a more detailed description, see *General Radio Experimenter*, April 1958.

Catalog No.	Description	Price
1210-9703	Type 1210-C Unit R-C Oscillator	\$185.00
1203-9702	Type 1203-B Unit Power Supply, 105–125 V	55.00
1203-9818	Type 1203-BQ18 Unit Power Supply, 195–250 V	on request
0480-9986	Type 480-P4U3 Relay-Rack Adaptor Panel (panel height, 7 in)	12.00

Oscillator and power supply can be rigidly clamped together.





TYPE 1310-A OSCILLATOR

2 c/s TO 2 Mc/s

FEATURES:

- Very wide frequency range. ■ Low distortion. ■ Constant output.
- Rugged, compact; transistorized circuitry.
- Can be synchronized with external source.

USES: The superior characteristics of this oscillator make it an exceptionally useful laboratory signal source.

Constant output over a very wide frequency range facilitates frequency-response measurements.

High-resolution dial, and exceptional amplitude and frequency stability are important for measurements in filters and narrow-band devices.

Equally useful in 600-ohm and 50-ohm circuits, since distortion is independent of load, even a short circuit.

When phase-locked to a frequency standard, the oscillator can deliver a high-level standard-frequency output with adjustable amplitude and low distortion.

DESCRIPTION: A capacitance-tuned, RC Wien-bridge oscillator drives a low-distortion output amplifier, which isolates the oscillator from the load and delivers a constant voltage behind 600 ohms.

A jack is provided for introduction of a synchronizing signal for phase locking or to furnish a signal, independent of the output attenuator setting, to operate a counter, or to synchronize an oscilloscope or another oscillator.

Seven transistors, one nuvistor, and ingenious design make the Type 1310-A Oscillator not only rugged, reliable, and insensitive to mechanical vibration but also compact and light in weight.

SPECIFICATIONS

FREQUENCY

Range: 2 c/s to 2 Mc/s in 6 decade ranges; continuously adjustable, one-turn, high-resolution dial with 4 1/4:1 drive.

Accuracy: ±2% of reading. **Stability:** Typical warmup drift, under 0.1%; typical drift after warmup, 0.001% short term (1 min), 0.03% long term (12 hr); all at 1 kc/s.

Synchronization: Telephone jack provided for external phase-locking signal. Locking range is about ±3% for 1-V, rms, input reference signal.

OUTPUT

Power: 160 mW into 600 Ω.

Voltage: Over 20 V, open circuit; continuously adjustable attenuator (approximately 50 dB).

Amplitude Stability: Typical drift after warmup, 0.02% short term (1 min), 1.0% long term (12 hr); both at 1 kc/s.

Frequency Characteristic: ±2%, 20 c/s to 200 kc/s, open circuit or 600-Ω resistive load. (See curve.)

Impedance: Approximately 600 Ω.

Distortion: <0.25%, 50 c/s to 50 kc/s, with linear loads; see curve. Hum <0.02% independent of attenuator setting.

Synchronization: High-impedance, constant-amplitude, 1-V, rms, output for use with oscilloscope, counter, or other oscillators.

GENERAL

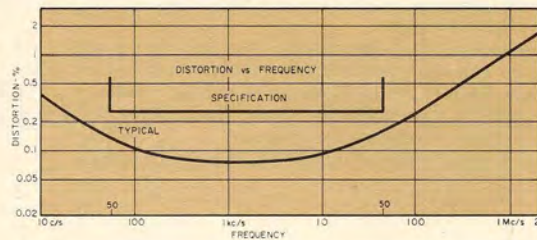
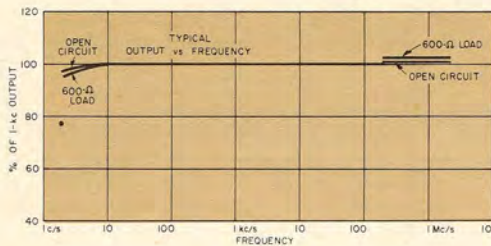
Power Required: 105 to 125, 195 to 235, or 210 to 250 V, 50 to 400 c/s, 12 W.

Accessories Supplied: TYPE CAP-22 Power Cord, spare fuses.

MECHANICAL DATA Convertible-Bench Cabinet (see page 258)

Width		Height		Depth		Net Wt		Ship Wt	
in	mm	in	mm	in	mm	lb	kg	lb	kg
8 1/4	210	6	155	8 1/8	210	7 3/4	3.6	10	4.6

Catalog No.	Description	Price
1310-9701	Type 1310-A Oscillator	\$295.00



1310-A

NEW

in catalog S



Type 1311-A AUDIO OSCILLATOR

FEATURES:

- One-watt output at 11 audio frequencies.
- Low distortion, even on short circuit.
- Drives balanced or grounded circuits.
- Excellent frequency and amplitude stability.
- Can be synchronized with external signal.
- Output up to 4 amperes or 100 volts.
- Low noise.
- All-solid-state circuitry.

USES: The many features and superior performance of this instrument make it well suited for almost any application requiring a high-quality audio oscillator. For bridge measurements, the shielded output-transformer secondary minimizes circulating ground currents and matches loads over a wide impedance range. The frequency can be synchronized with that of an external standard for precise measurement of frequency-sensitive parameters.

Its short-term amplitude stability and frequency stability are advantageous for the calibration of high-speed level recorders and analog-to-digital convertors. Its ability to drive any load impedance with low wave-

form distortion makes it an outstanding general-purpose oscillator.

DESCRIPTION: The frequency is determined by a Wien-bridge network. A multi-stage, Class-B, six-transistor circuit delivers an output of one watt. A tapped output transformer makes available a wide range of voltages and short-circuit currents. Feedback around the whole amplifier makes the distortion practically independent of load impedance, even under short-circuit conditions.

The convertible bench-type cabinet can be easily mounted in a relay rack by means of adaptor panels.

SPECIFICATIONS

FREQUENCY

Range: 11 fixed frequencies, 50, 60, 100, 120, 200, 400, 500, 1000, 2000, 5000, 10,000 c/s. ΔF control provides $\pm 2\%$ adjustment. One other frequency can be added by the installation of two resistors at an unused switch position.

Accuracy: $\pm 1\%$ when ΔF control is at zero.

Frequency Stability: 0.1%, typical, long-term, after warmup.

Synchronization: Telephone jack provided for external synchronizing signal. Locking range is about $\pm 3\%$ for 1-V, rms, reference signal. ΔF control can be used for phase adjustment.

OUTPUT

Power: 1 W into matched load (taps provide at least 0.5 W into any resistive load between 80 Ω and 8 k Ω .)

Voltage: Continuously adjustable from 0 to 1, 3, 10, 30, or 100 V, open circuit.

Current: Continuously adjustable from 0 to 40, 130, 400, 1300, 4000 mA, short circuit (approximately).

Impedance: Between one and two times matched load, depending on control setting. Output circuit is isolated from ground.

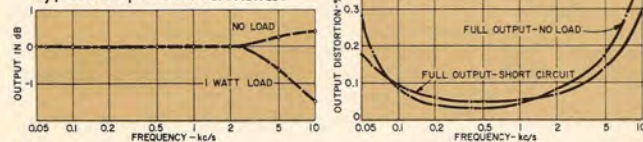
Amplitude Stability: Better than 1% long term, 0.01% short term, typical after warmup.

Synchronization: High-impedance, constant-amplitude, 1-V, rms, output for use with oscilloscope, counter, or other oscillator.

Distortion: Less than 0.5% under any load condition. Typically less than 0.1% over much of range. Oscillator will drive a short circuit without waveform clipping.

Ac Hum: Typically less than 0.003% of output voltage.

Typical output characteristics.



GENERAL

Terminals: TYPE 938 Binding Posts. Separate ground terminal holds shorting link, which can be used to ground adjacent OUTPUT binding post.

Power Required: 105 to 125 or 210 to 250 V, 50 to 400 c/s. 22 W.

Accessories Supplied: TYPE CAP-22 Power Cord, spare fuses.

Accessories Available: Rack-mounting set (panel 5 1/4 in high).

MECHANICAL DATA Convertible-Bench Cabinet (see page 258)

Width		Height		Depth		Net Wt		Ship Wt	
in	mm	in	mm	in	mm	lb	kg	lb	kg
8	205	6	155	7 3/4	200	6	2.8	9	4.1

See also *General Radio Experimenter*, August-September 1962.

Catalog No.	Description	Price
1311-9701	Type 1311-A Audio Oscillator	\$215.00
0480-9638	Type 480-P308 Relay-Rack Adaptor Set	7.00

PATENT NOTICE. See Note 1, page 11.





Type 1308-A AUDIO OSCILLATOR AND POWER AMPLIFIER

200-WATT, VARIABLE-FREQUENCY POWER SUPPLY

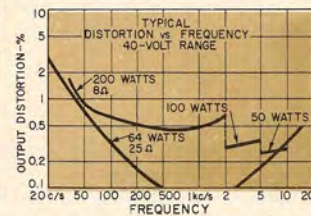
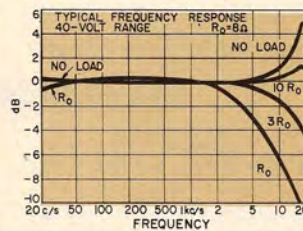
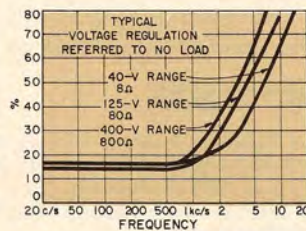
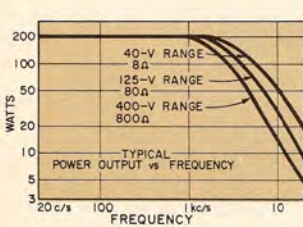
FEATURES:

- Wide frequency range — 20 c/s to 20 kc/s.
- All-solid-state circuitry. ■ Output transformer will pass dc.
- Matches wide range of loads. ■ Delivers up to 5 amperes or 400 volts.
- Power amplifier can be used separately.

USES: The TYPE 1308-A Audio Oscillator and Power Amplifier is an ac power source covering the audio range. It is an excellent power source for the TYPE 1633-A Incremental-Inductance Bridge. Its low dynamic output impedance enhances its usefulness as a power source for testing other devices over a wide range of supply frequencies. This instrument will provide a low-distortion signal (not clipped) to nonlinear loads, such as capacitor-input rectifier systems. It can also be used to drive small shake tables and to isolate sensitive equipment from power-line transients.

This instrument also finds many uses as an audio-frequency power amplifier. When it is used with the TYPE 1396-A Tone-Burst Generator, high-power tone bursts are provided for testing sonar projectors, amplifiers, etc.

DESCRIPTION: This instrument combines a capacitor-tuned, Wien-bridge oscillator, a low-distortion power amplifier, and a tapped output transformer. The output is monitored by an overload circuit, which turns off the output when it exceeds safe limits.



SPECIFICATIONS

FREQUENCY

Range: 20 to 20,000 c/s in 3 decade ranges. **Accuracy:** ±3%.
Stability: Approx 0.1% from no load to full load; short-term, approx 0.03%; warm-up drift at full load, 100 c/s, 1.5%; 1 kc/s and 10 kc/s, 0.03%.

OUTPUT

Power: 200 VA, 50 c/s to 1 kc/s; see curves.
Load Power Factor: (At full ratings) any for continuous operation to 30°C ambient or intermittent operation to 50°C ambient. 0.7 to 1.0 for continuous operation to 50°C ambient.
Overload Protector: Electronic overload circuit trips at about 1½ full-scale current (manual reset); thermal protection on transistor heat sink (automatic reset).
Voltage: 0 to 400 V, rms, in 5 ranges of 0 to 4, 12.5, 40, 125, and 400 V. Regulation (see curves) less than 20%, no load to full load, 20 c/s to 1 kc/s (bandwidth greater than 10 kc/s provides essentially instantaneous regulation).
Output Voltmeter: 0 to 5, 15, 50, 150, 500 V, full scale.
Current: 0 to 5 A, rms, in 6 ranges of 0 to 0.016, 0.05, 0.16, 0.5, 1.6, and 5 A. Ammeter output monitor, 0 to 0.05, 0.16, 0.5, 1.6, and 5 A full scale.
Optimum Load Impedances: 0.8, 2.5, 8, 80, 800 Ω. Operates satisfactorily with higher impedance or nonlinear loads. Output transformer passes dc equal to rated ac. Amplifier output impedance is approximately 0.3, 0.3, 1.6, 19, and 220 ohms, respectively, below 1 kc/s.

Harmonic Distortion: 1%, 100 c/s to 10 kc/s (with linear loads at rated output, see curves); 2%, 50 c/s to 100 c/s, with linear loads. With non-linear loads additional distortion in the load voltage is caused by the voltage drop in the amplifier output impedance.
Hum: 50 dB or more below max output.

AMPLIFIER
Sensitivity: About 2 V for full output. **Input Impedance:** 10 kΩ.

GENERAL
Power Required: 105 to 125 or 210 to 250 V, 50 to 60 c/s, 70 to 500 W depending on load. For 50-cycle supply, maximum output must be reduced slightly.

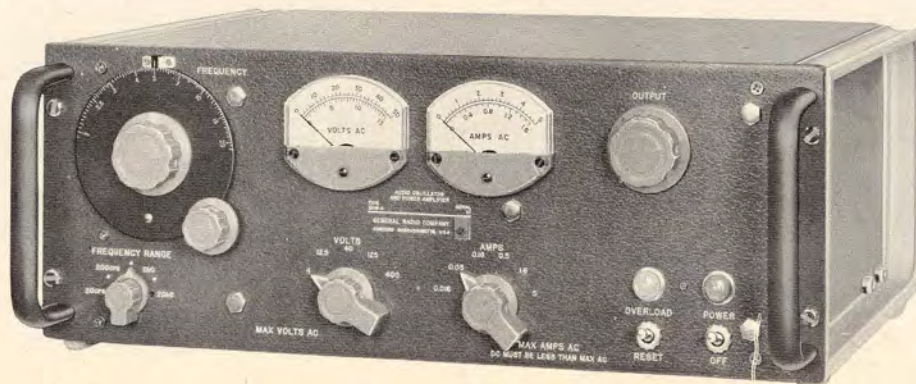
Accessories Supplied: TYPE CAP-22 Power Cord, spare fuses.
MECHANICAL DATA Rack-Bench Cabinet (see page 258)

Model	Width		Height		Depth		Net Wt		Ship Wt	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Bench	19	485	7	180	16¼	414	91	42	145	67
Rack	19	485	7	180	15*	385	91	42	145	67

* Behind panel.
 See also *General Radio Experimenter*, January 1964.

Catalog No.	Description	Price
1308-9801	Type 1308-A Audio Oscillator and Power Amplifier, Bench Model	\$1150.00
1308-9811	Type 1308-A Audio Oscillator and Power Amplifier, Rack Model	1150.00

PATENT NOTICE. See Note 1, page 11.





Type 1330-A BRIDGE OSCILLATOR

400 c/s TO 50 Mc/s

FEATURES:

- Wide frequency range. ■ Good frequency stability.
- Internal modulation available.
- One-watt output over much of the radio-frequency range.
- Excellent shielding.
- Rugged and compact construction.

USES: The TYPE 1330-A Bridge Oscillator is an economical, general-purpose laboratory source of audio and radio frequencies. It covers the major part of the frequency range of the TYPE 1606-A and TYPE 916-AL Radio-Frequency Bridges and the TYPE 716-CS1 Capacitance Bridge. It also supplies 400 and 1000 c/s for bridge measurements. Its power output is adequate for most direct-deflection-type measurements with resonant circuits.

By means of adaptors (page 81) its coaxial output connectors can be made to fit all commonly used types.

DESCRIPTION: The circuit and the mechanical construction are similar to those of the TYPE 1001-A Standard-Signal Generator (page 150), but a higher-power oscillator tube is used, and the aperiodic output stage has been omitted. Tuning capacitor and inductors are ruggedly constructed to assure frequency stability, the oscillator circuits are doubly shielded to minimize stray fields, and a modulating circuit of unusual design provides excellent modulation characteristics over the radio-frequency range.

Modulation is available at two audio frequencies and at two levels, selected by switches.

SPECIFICATIONS

FREQUENCY

Range: 5 kc/s to 50 Mc/s, continuous, plus 1000 c/s, 400 c/s, and the power-line frequency.

Calibration: Direct reading for eight 3:1 ranges. Calibration is logarithmic, and vernier dial indicates increments of 0.1% per division from 5 kc/s to 15 Mc/s.

Accuracy: 400 and 1000 c/s, $\pm 5\%$; frequencies below 150 kc/s, $\pm 3\%$; above 150 kc/s, $\pm 2\%$, all at no load. Frequency shift with 50- Ω load, 5% at low carrier frequencies; less than 1% above 150 kc/s.

OUTPUT

Voltage: Open-circuit audio, 12 V; rf, adjustable, approximately 10 V over the mid-frequency range, less at ends of range.

Power (into 50- Ω load): Audio, approximately $\frac{3}{4}$ W; rf, 1 W, over most of range.

Impedance: Audio jack, 50 Ω ; rf, 20 to 80 Ω , depending upon frequency, when output control is at maximum setting.

GENERAL

Distortion: Rf, with maximum output into 50 Ω , about 3.5%, except at the lower frequencies, where it reaches 7%. Audio, 5%.

Leakage: Stray fields are less than 50 μ V/m at 2 ft from the oscillator.

Modulation: Internal only, at 400 and 1000 c/s, 25% and 50%.

Envelope Distortion: Less than 6% at 50% modulation; less than 4% at 25% modulation.

Power Required: 105 to 125 or 210 to 250 V, 50 to 60 c/s; 30 W, approximately.

Terminals: GR874 Coaxial Connectors, locking. For connection to type N, BNC, TNC, SC, or C connector, use a locking adaptor (page 81), which locks securely in place yet is easily removed.

Accessories Supplied: TYPE 874-R22LA Coaxial Cable, TYPE 874-Q2 Adaptor, TYPE TO-44 Adjustment Tool (mounted on rf shield cover), TYPE CAP-22 Power Cord, and spare fuses.

MECHANICAL DATA Lab-Bench Cabinet (see page 58)

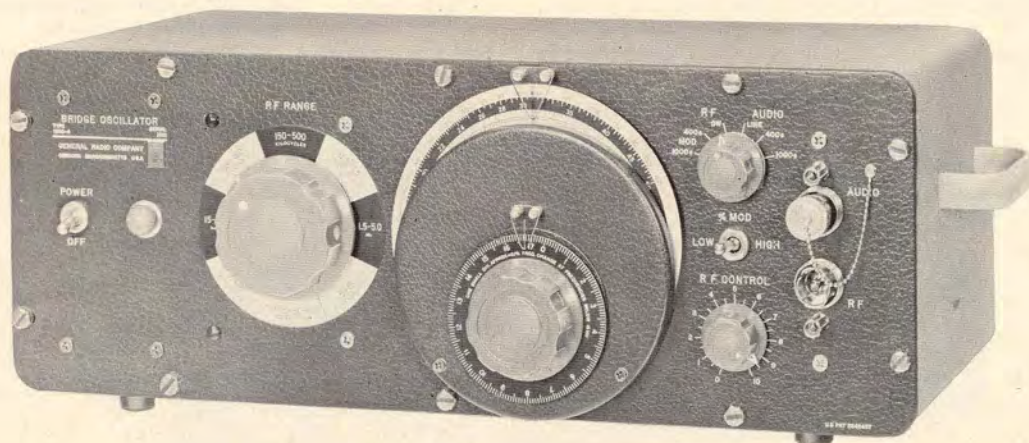
Cabinet can be removed for rack mounting (panel 19 by 7 in).

Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
21 $\frac{3}{4}$	555	7 $\frac{1}{2}$	190	11 $\frac{1}{4}$	285	37 $\frac{1}{2}$	17	50	23

For a more detailed description, see *General Radio Experimenter*, December 1950.

Catalog Number	Description	Price
1330-9701	Type 1330-A Bridge Oscillator	\$735.00

PATENT NOTICE. See Note 4, page 11.





HIGH-FREQUENCY OSCILLATORS

0.5 TO 2000 Mc/s

These compact, low-priced oscillators provide continuous coverage from 500 kc/s to 2000 Mc/s with single-dial control and output in the order of several hundred milliwatts. A complete listing of their characteristics will be found on pages 140 and 141. Additional coverage to 7425 Mc/s is provided by a group of microwave oscillators (see pages 145 and 146). In conjunction with one of the companion group of power supplies (see page 142), any oscillator becomes a complete signal source with characteristics adapted to the customer's application. By appropriate choice of power

supply, the oscillator can deliver (1) maximum power, (2) optimum frequency stability with minimum residual fm and a-m, (3) pulse and square-wave modulated output, (4) amplitude-regulated output for sweeping applications, or (5) can be incorporated into a heterodyne detector system (see page 109). Power supplies and oscillators are designed for semi-permanent attachment for bench use or relay-rack mounting. Accessories suitable for use with these oscillators are listed on page 143.

GENERAL SPECIFICATIONS

for 500-kc — 2000-Mc Oscillators

Frequency Control: Gear-driven precision dials.

Output Power: Output power obtainable with TYPES 1203 or 1269, and 1201, 1264, or 1267 Power Supplies is shown in the figure accompanying the description of each oscillator. With TYPE 1216-A Unit I-F Amplifier, multiply the power shown for the TYPE 1203 or 1269 by about 0.4.

With the TYPE 1263-B Amplitude-Regulating Power Supply, the maximum useful power output is 20 milliwatts. The available power is adequate for practically all laboratory measurements with bridges, slotted lines, admittance and transfer-function meters, tuned circuits, etc.

Output System: A short coaxial line brings the output from an adjustable coupling loop (in the TYPE 1211-C, from a fixed loop and potentiometer) to a locking GR874 Coaxial Connector. The output connector is located at the rear of the oscillator except on the TYPE 1361-A, which has it on the front panel. Maximum power can be delivered to load impedances normally encountered in coaxial systems. Adaptors are available to convert the GR874 Connector to any other common type (see page 81). These adaptors lock securely in place, yet are easily removed.

Power Supply: The external power supply should be chosen from the group listed in the Summary of Power-Supply Characteristics, page 142. Operation from 400-cycle lines is permissible with many of these power supplies with all oscillators except the TYPE 1208-C.

Modulation: For amplitude modulation over the audio range, a modulating voltage is imposed on the plate supply. A jack is provided for this purpose. The audio source must be capable of carrying the dc plate current of the oscillator. The inexpensive TYPE 1214 fixed-frequency oscillators are recommended as modulators. For 30% a-m, incidental fm in this system is of the order of 0.01% at the lower part of the tuning range, and increases to about 0.05% at the high-frequency end. Approximately 40 volts across 8000 ohms is adequate to produce 30% modulation.

Square-wave or pulse modulation can be obtained on all oscillators, except the TYPE 1211-C and TYPE 1208-C, by use of

the TYPE 1264-A Modulating Power Supply. All oscillators except the TYPE 1208-C can be square-wave modulated at 1 kc/s supplied by the TYPE 1263-B Amplitude-Regulating Power Supply.

Sweep Applications: Mechanical sweep at speeds suitable for oscilloscopic display can be obtained by use of the TYPE 1750-A Sweep Drive with the TYPES 1209-C, 1209-CL, 1211-C, 1215-C and 1361-A. The TYPES 1208-C and 1218-B are not recommended for this service because of the sliding contacts in their tuned circuits.

Slower mechanical sweep for use with XY recorders is possible with the TYPE 907-R144 or 908-R96 Dial Drives. The TYPE 1218-B is not recommended for use with these drives, but the TYPE 1208-C can be driven intermittently for short periods.

The TYPE 1263-B Amplitude-Regulating Power Supply is recommended to hold the oscillator output constant as the frequency is varied, particularly when mechanical sweep is employed. It can be used with all oscillators except TYPE 1208-C.

Mounting:

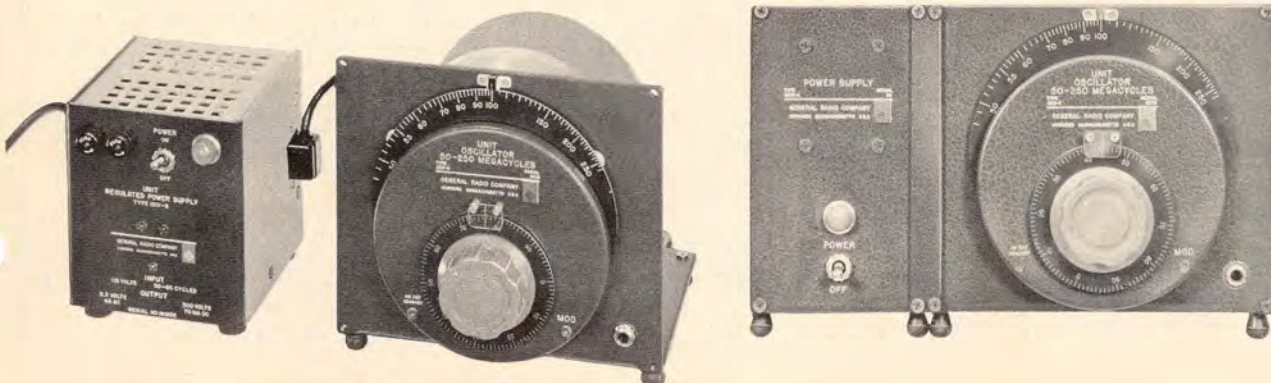
Bench Use — Any of the oscillators can be used on the bench with any of the recommended power supplies; interconnecting cables are supplied. All oscillators and all power supplies, except the TYPES 1203 and 1201, are 7 inches high and can be attached to each other with the hardware supplied to form a rigid assembly.

Relay-Rack Use — Any oscillator except the TYPE 1218-B can be relay-rack mounted together with a TYPE 1263, 1264, 1267, or 1269 Power Supply in 7 inches of rack height. The TYPE 1218-B requires 7 inches of rack height when mounted with a TYPE 1267 or 1269 Power Supply, or 14 inches of rack height when used with TYPE 1263 or 1264 Power Supply. Accessories required for rack mounting are listed on page 143. When the TYPE 1201 or TYPE 1203 Power Supply is used, separate rack-adaptor panels are necessary. For complete assemblies of oscillator and power supply for either rack mount or bench mount, see page 144.

See pages 140, 141, and 144 for individual listings

Oscillator with Unit-type power supply (Type 1201 or Type 1203).

Oscillator with Type 1269 or Type 1267 Power Supply. Oscillator with Type 1264 Power Supply is shown on page 144.



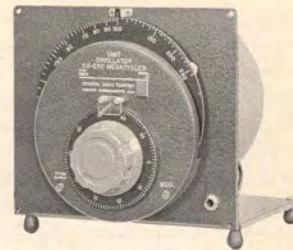
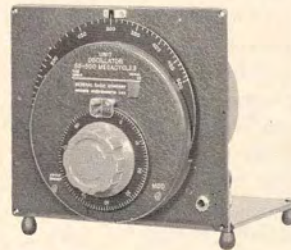
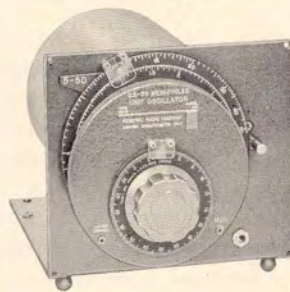


HF, VHF, UHF OSCILLATORS

Supplied with each oscillator, except as noted under "Remarks":

Type 874-R22LA Patch Cord

Telephone Plug



<i>Catalog Number</i>	1211-9703	1208-9703	1215-9703
	Type 1211-C Unit Oscillator	Type 1208-C Unit Oscillator	Type 1215-C Unit Oscillator
<i>Frequency</i>	0.5 to 50 Mc/s	65 to 500 Mc/s	50 to 250 Mc/s
<i>Tuned Circuit</i>	Variable L and C	Variable L and C	Semi-Butterfly
<i>Calibration Accuracy</i>	±2%	±2%	±1%
<i>Warmup Frequency Drift (typical)</i>	0.4%	0.5%	0.2%
<i>Power Output into 50 ohms using Power Supply:</i> —Type 1203 or 1269 ---Type 1201, 1264 or 1267. (See also page 142)			
<i>Cabinet¹ (see page 258)</i>	Unit	Unit	Unit
<i>Panel Dimensions</i>	8 × 7 in (180, 205 mm)	8 × 7 in (180, 205 mm)	8 × 7 in (180, 205 mm)
<i>Depth Behind Panel</i>	9¾ in (250 mm)	7¾ in (190 mm)	7½ in (190 mm)
<i>Net Weight</i>	11½ pounds (5.5 kg)	6 pounds (2.8 kg)	7¼ pounds (3.3 kg)
<i>Shipping Weight</i>	19 pounds (9 kg)	9 pounds (4.1 kg)	10 pounds (4.6 kg)
<i>Price</i>	\$340.00	\$265.00	\$225.00

ACCESSORIES AVAILABLE

<i>Modulating Power Supply</i> See pages 142 and 221.	No	No	Yes ²
<i>Amplitude-Regulating Power Supply</i> See pages 143 and 220.	Yes	No	Yes
<i>Dial Drives (page 154)</i>	Types 908-P1, -P2, -R96	Types 908-P1, -R96	Types 908-P1, -P2, -R96
<i>Sweep Drive (page 153)</i>	Yes	Not recommended	Yes
<i>Remarks</i>	Type 874-Q2 Adaptor supplied	Sliding Contact	No Sliding Contact

¹ Relay-rack mount, see page 144.

² Requires Adaptor Cable, TYPE 1264-P1 (see page 151).



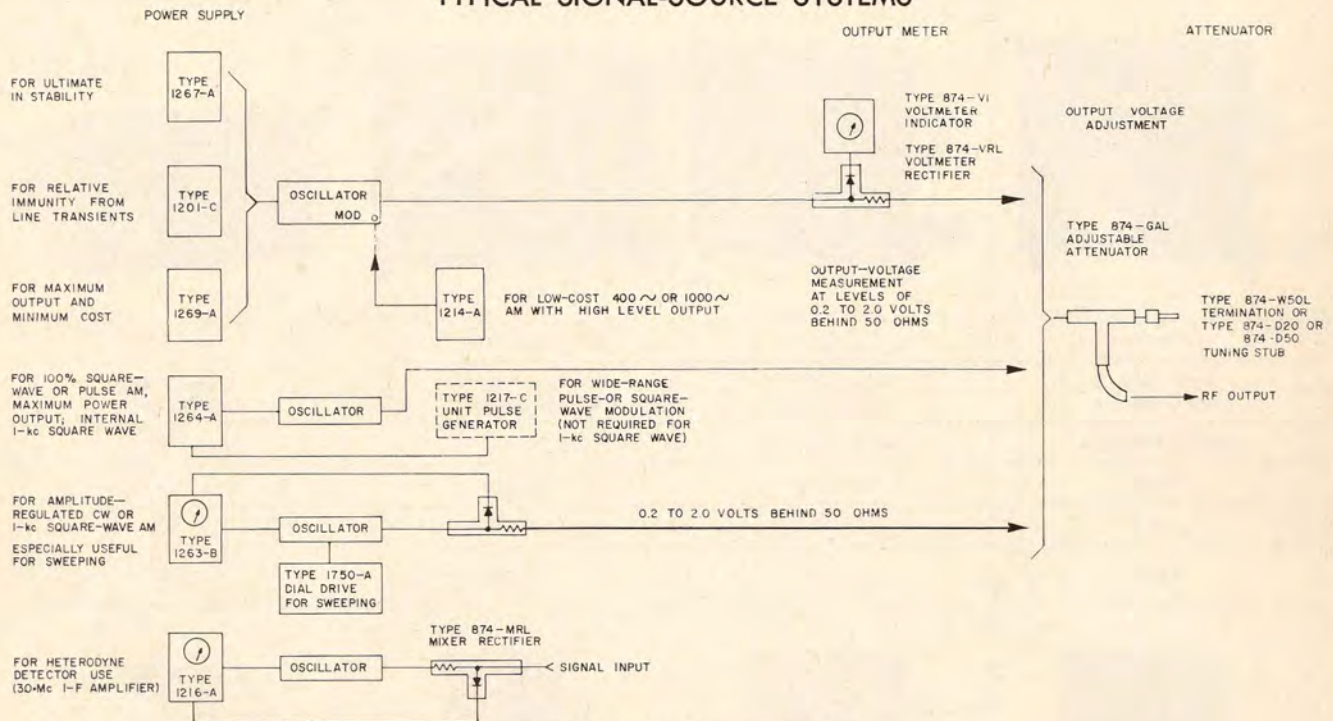
1209-9933	1209-9703	1361-9701	1218-9702
Type 1209-CL Unit Oscillator	Type 1209-C Unit Oscillator	Type 1361-A UHF Oscillator	Type 1218-B Unit Oscillator
180 to 600 Mc/s	250 to 960 Mc/s	450 to 1050 Mc/s	900 to 2000 Mc/s
Butterfly	Butterfly	Butterfly	Adjustable Lines
±1%	±1%	±1%	±1%
0.2%	0.2%	0.2%	0.1%
Unit	Unit	Convertible Bench	Unit
8 × 7 in (180, 205 mm)	8 × 7 in (180, 205 mm)	8 × 7 in (180, 205 mm)	12 × 7 in (305, 205 mm)
7 3/8 in (190 mm)	7 3/8 in (190 mm)	8 1/4 in (210 mm)	7 1/2 in (190 mm)
6 pounds (2.8 kg)	6 pounds (2.8 kg)	7 pounds (3.2 kg)	15 pounds (7 kg)
9 pounds (4.1 kg)	9 pounds (4.1 kg)	11 pounds (5 kg)	26 pounds (12 kg)
\$300.00	\$300.00	\$300.00	\$465.00
ACCESSORIES AVAILABLE			
Yes ²	Yes ²	Yes	Yes
Yes	Yes	Yes	Yes
Types 908-P1, -P2, -R96	Types 908-P1, -P2, -R96	Types 908-P1, -P2, 907-R144	Not recommended
Yes	Yes	Yes	No
No Sliding Contact	No Sliding Contact	Logarithmic frequency scale. Low external field. Calibrated attenuator. No sliding contact.	Sliding Contacts. Fine frequency control. Low external field.

See page 139 for general specifications

combinations of Oscillators and Power Supplies.



TYPICAL SIGNAL-SOURCE SYSTEMS



OSCILLATOR POWER SUPPLIES

Power-supply characteristics are frequently a determining factor in the performance of an oscillator. For such applications as parametric-amplifier pumps, oscillators must be stable against all power-line variations and free of modulation from power-supply ripple. For these extreme requirements, both plate and heater supplies should be regulated, well-filtered dc, as in the TYPE 1267 Power Supply.

Where relative freedom from line transients is required without ultimate reduction in longer term drifts and hum modulation, regulated plate supply is desirable, but unregulated ac may be used for the heater supply. This need is met by the TYPE 1201 Power Supply.

For many noncritical applications, unregulated dc plate and ac heater supplies are entirely adequate and represent considerable

economy. The TYPE 1269-A and TYPE 1203 Power Supplies are of this type.

Other applications require power supplies in which the plate-supply voltage is controllable to modulate or to regulate the oscillator output. The TYPE 1264-A Modulating Power Supply provides 100% amplitude modulation at high level by square waves or pulses as well as cw operation. The TYPE 1263-B Amplitude-Regulating Power Supply includes a feedback loop to maintain constant oscillator output as the oscillator frequency is varied. Constant output not only speeds and simplifies measurements where the oscillator is tuned manually but is essential when making sweep measurements. The TYPE 1263-B Amplitude-Regulating Power Supply has an internal 1-kc oscillator for modulation.

SUMMARY OF OSCILLATOR POWER-SUPPLY CHARACTERISTICS

Type	Applications	Input Line 50 to 60 c/s	Dc Plate Supply	Heater Supply	Panel Width	Page Ref	Price
1267-A ¹	Ultimate stability for CW	105 to 125 V	300 V @ 70 mA, regulated	6.3 V dc @ 1 A, reg	4"	219	\$170.00
1267-AQ18 ¹		195 to 250 V					on request
1201-C ¹	Relative freedom from line transients	105 to 125 V	300 V @ 70 mA, regulated	6.3 V ac @ 4 A	*	219	95.00
1201-CQ18 ¹		195 to 250 V					on request
1269-A ¹	Maximum output and low cost	105 to 125 V or 195 to 250 V	380 V open circuit; 300 V @ 50 mA	6.3 V ac @ 3 A	4"	219	75.00
1203-B		105 to 125 V					55.00
1203-BQ18	Maximum output and minimum cost	195 to 250 V			*	219	on request
1264-A ^{1,2,3}	100% square wave and pulse a-m	105 to 125 V or 210 to 250 V	200 to 300 V @ 50 mA, reg	6.3 V ac @ 2.1 A	8"	221	285.00
1263-B ²	Amplitude-regulated CW or 1-kc square-wave output		0 to 300 V @ 30 mA	6.3 V dc @ 0.5 A	8"	220	425.00
1216-A ¹	Heterodyne detector		300 V @ 30 mA	6.3 V ac @ 1 A	*	107	375.00

* Unit-Instrument Cabinet; see page referenced.

¹ May be operated from 400-cycle supply, except with TYPE 1208-C Unit Oscillator.

² Not for use with TYPE 1208-C Unit Oscillator.

³ Requires TYPE 1264-P1 Adaptor Cable when used with TYPES 1215-C, 1209-CL, and 1209-C Unit Oscillators (see pages 140 and 141). Not recommended for use with TYPE 1211-C.

For complete combinations of Oscillator and Power Supply, see page 144.









RF OSCILLATOR ACCESSORIES

RACK-ADAPTOR SETS For mounting Oscillators and Power Supplies in a 19-inch rack

These adaptor sets include the necessary flanges and hardware for combining oscillator and power supply into a rigid assembly and for extending the panel width

to rack size. A coaxial cable with panel connector is supplied for mounting on the right-hand adaptor panel to provide alternate front or rear output connections.*

Oscillator Type	Adaptor Set for Oscillator only	Adaptor Set for Oscillator and either Type 1267 or Type 1269-A Power Supply	Adaptor Set for Oscillator and either Type 1263-B or Type 1264-A Power Supply
1211-C 1215-C 1208-C 1209-C 1209-CL 1361-A	 Catalog No. 0480-9608 Type 480-P408 Price: \$8.00	 Catalog No. 0481-9642 Type 481-P412 Price: \$20.00	 Catalog No. 0481-9646 Type 481-P416 Price: \$21.00
1218-B	 Catalog No. 0481-9642 Type 481-P412 Price: \$20.00	 Catalog No. 0481-9646 Type 481-P416 Price: \$21.00	 Catalog No. 0482-9642 Type 482-P412† Price: \$24.00

* Not supplied with TYPE 480-P408. † Consists of one set for oscillator and one set for power supply.

DIAL DRIVES Descriptions and specifications will be found on pages 153 and 154.

Type	Name	Primary Characteristics
908-P1	Synchronous Dial Drive	will drive TYPES 1330-A, 1211-C, 1215-C, 1208-C, 1209-CL, 1209-C, 1361-A, 1360-B.
908-P2	Synchronous Dial Drive	will drive TYPES 1211-C, 1330-A, 1215-C, 1209-CL, -C, 1361-A, 1360-B.
907-R144	Dial Drive	144° per minute; 20-kΩ potentiometer; use with TYPE 1361-A, 1360-B.
908-R96	Dial Drive	96° per minute; 20-kΩ potentiometer; use with TYPES 1211-C, 1215-C, 1208-C, 1209-CL, 1209-C, 1330-A.
1750-A	Sweep Drive	Sweep speed: 0.5-5 c/s; sweep arc: 30-300°; sweep voltage output to oscilloscope: 2.5 V, peak-to-peak. Will drive any GR oscillator or signal generator.

COAXIAL ELEMENTS

Name	Type Number	Page Ref
Adaptors, coaxial connector to type N, BNC, TNC, SC, C, or UHF connector	874-Q	81
Attenuator, adjustable	874-GA	88
Attenuator, fixed pads	874-G	88
Coaxial Cables	874-A2, A3	85
Detector, voltmeter (crystal)	874-VQ	86
Balun	874-UBL	94
Filters	874-F	87
Lines, air, fixed	874-L	90
Mixer Rectifier (crystal)	874-MR	87
Stub, adjustable (tuning)	874-D	91
Terminations	874-W	89
Line Stretchers	874-LT	90
Voltmeter	874-VI	86
Patch Cords	874-R	85

For complete combinations of Oscillator and Power Supply for both bench and rack mount, see page 144.

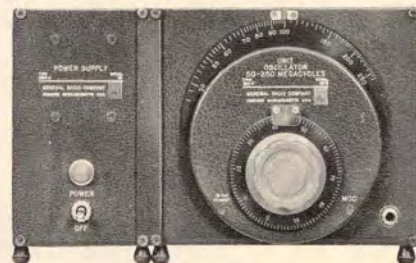


OSCILLATOR-POWER-SUPPLY COMBINATIONS

FREQUENCY RANGE AND (OSCILLATOR TYPE) ↓	PERFORMANCE →		Ultimate cw stability; very low residual fm			Stable cw; 100% square-wave & pulse modulation; internal 1-kc square-wave	Amplitude-leveled output behind 50-Ω source impedance; metered output level; 1-kc square-wave modulation, or cw
	(POWER SUPPLY TYPE)		(1269-A)	(1267-A)	(1267-AQ18)	(1264-A)	(1263-B)
	INPUT LINE VOLTAGE		105 to 125 V or 195 to 250 V	105 to 125 V	195 to 250 V	105 to 125 V or 210 to 250 V	105 to 125 V or 210 to 250 V
500 kc/s-50 Mc/s (Type 1211-C)	Bench Mount	Catalog No. Type Price	1211-9439 1211-C9 \$415.00	1211-9437 1211-C7 \$510.00	1211-9438 1211-C7Q18 on request	Not Available	1211-9433 1211-C3 \$765.00
	Rack Mount	Catalog No. Type Price	1211-9579 1211-C9R \$435.00	1211-9577 1211-C7R \$530.00	1211-9578 1211-C7RQ18 on request		1211-9573 1211-C3R \$786.00
50-250 Mc/s (Type 1215-C)	Bench Mount	Catalog No. Type Price	1215-9439 1215-C9 \$300.00	1215-9437 1215-C7 \$395.00	1215-9438 1215-C7Q18 on request	1215-9434 1215-C4 \$525.00	1215-9433 1215-C3 \$650.00
	Rack Mount	Catalog No. Type Price	1215-9579 1215-C9R \$320.00	1215-9577 1215-C7R \$415.00	1215-9578 1215-C7RQ18 on request	1215-9574 1215-C4R \$546.00	1215-9573 1215-C3R \$671.00
65-500 Mc/s (Type 1208-C)	Bench Mount	Catalog No. Type Price	1208-9439 1208-C9 \$340.00	1208-9437 1208-C7 \$435.00	1208-9438 1208-C7Q18 on request	Not Available	Not Available
	Rack Mount	Catalog No. Type Price	1208-9579 1208-C9R \$360.00	1208-9577 1208-C7R \$455.00	1208-9578 1208-C7RQ18 on request		Available	Available
180-600 Mc/s (Type 1209-CL)	Bench Mount	Catalog No. Type Price	1209-9539 1209-CL9 \$375.00	1209-9537 1209-CL7 \$470.00	1209-9538 1209-CL7Q18 on request	1209-9534 1209-CL4 \$600.00	1209-9533 1209-CL3 \$725.00
	Rack Mount	Catalog No. Type Price	1209-9589 1209-CL9R \$395.00	1209-9587 1209-CL7R \$490.00	1209-9588 1209-CL7RQ18 on request	1209-9584 1209-CL4R \$621.00	1209-9583 1209-CL3R \$746.00
250-960 Mc/s (Type 1209-C)	Bench Mount	Catalog No. Type Price	1209-9439 1209-C9 \$375.00	1209-9437 1209-C7 \$470.00	1209-9438 1209-C7Q18 on request	1209-9434 1209-C4 \$600.00	1209-9433 1209-C3 \$725.00
	Rack Mount	Catalog No. Type Price	1209-9579 1209-C9R \$395.00	1209-9577 1209-C7R \$490.00	1209-9578 1209-C7RQ18 on request	1209-9574 1209-C4R \$621.00	1209-9573 1209-C3R \$746.00
450-1050 Mc/s (Type 1361-A)	Bench Mount	Catalog No. Type Price	1361-9419 1361-A9 \$375.00	1361-9417 1361-A7 \$470.00	1361-9418 1361-A7Q18 on request	1361-9414 1361-A4 \$585.00	1361-9413 1361-A3 \$725.00
	Rack Mount	Catalog No. Type Price	1361-9509 1361-A9R \$395.00	1361-9507 1361-A7R \$490.00	1361-9508 1361-A7RQ18 on request	1361-9504 1361-A4R \$606.00	1361-9503 1361-A3R \$746.00
900-2000 Mc/s (Type 1218-B)	Bench Mount	Catalog No. Type Price	1218-9429 1218-B9 \$540.00	1218-9427 1218-B7 \$635.00	1218-9428 1218-B7Q18 on request	1218-9424 1218-B4 \$750.00	1218-9423 1218-B3 \$890.00
	Rack Mount	Catalog No. Type Price	1218-9549 1218-B9R \$561.00	1218-9547 1218-B7R \$656.00	1218-9548 1218-B7RQ18 on request	1218-9544 1218-B4R \$774.00	1218-9543 1218-B3R \$914.00



Type 1209-C4R



Type 1215-C9



Type 1360-B MICROWAVE OSCILLATOR

FEATURES:

Excellent frequency stability.

At least 50-milliwatt output over most of range — typically 100 milliwatt or more.

Output monitor permits maximum output setting for any frequency and load.

Internal linear sweep over 1- to 3-Mc bands; sync pulses also provided.

DB scale on attenuator, particularly useful at low output levels.

Modulation — internal 1-ke square wave; external fm, pulse, or square wave.

USES: The many modulation capabilities of this oscillator make it a most useful power source for microwave measurements. It is a suitable driver for slotted lines and a stable local oscillator for heterodyne detectors.

DESCRIPTION: The oscillator is a reflex klystron in a coaxial cavity with a non-contacting plunger. The two frequency ranges, 1.7 to 2.8 Gc/s and 2.6 to 4.1 Gc/s, are selected automatically by the main frequency dial.

The scales are in different colors; a pilot light indicates the scale in use.

The output is adjustable and monitored against overcoupling.

Cathode, repeller, and bias voltages are well regulated, and the klystron heater supply is dc. Tube replacements, including the klystron, require no tools. Long-life Teflon* bearings are used for the plunger.

* Registered trademark of the E. I. duPont de Nemours and Company.

SPECIFICATIONS

FREQUENCY

Range: 1.7 to 4.1 Gc/s in two ranges, 1.7 to 2.8 Gc/s, covered in 5½ turns of tuning control, and 2.6 to 4.1 Gc/s, covered in 9 turns; 100-division interpolation scale.

Fine Frequency Control (ΔF): Order of 1 Mc/s, but not functioning for square-wave modulation.

Accuracy: ±1%.

Stability: Warmup drift under laboratory conditions is approximately 0.15% during the first hour, total drift approximately 0.25%. After warmup, average frequency observed in a 1-second measurement interval is stable within approximately 5 ppm over a 10-minute period.

Residual FM: Approximately 0.5 ppm in the lower frequency range and 0.2 ppm in the higher. Dominant frequencies are 60 and 120 c/s (with 60-cycle line frequency.)

OUTPUT

Power: At least 20 mW from 1.7 to 2.1 Gc/s; at least 50 mW from 2.1 to 4.1 Gc/s. Individual instruments may vary 2:1 from typical curve.

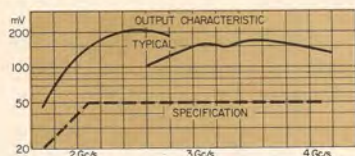
Attenuator: Relative calibration only.

Terminal: GR874 Coaxial Connector, recessed, locking. For connection to type N, BNC, TNC, SC, or C connector, use a locking adaptor (page 81), which locks securely in place, yet is easily removed. Panel connector is recessed, and adaptor projects only about an inch from panel.

INTERNAL MODULATION

Narrow-Band Sweep: At least 0 to 1 Mc/s at either 1 kc/s or line-frequency rate. Maximum sweep width up to 3 Mc/s depends on carrier frequency. Negative pulse for oscilloscope synchronization provided.

Square-Wave: 1 kc/s, adjustable approximately ±5%.



Output-power characteristic.

EXTERNAL MODULATION

FM: Sensitivity approximately 0.2 Mc/s per V, input impedance, 400 kΩ and 70 pF (ac only).

Square-Wave: 50 c/s to 200 kc/s, 12 V, rms, sine wave or 20 V p-to-p, square wave; 20% minimum duty cycle from external source. Input impedance greater than 100 kΩ.

Pulse: Rise and fall times approximately 0.2 μs, minimum length approximately 0.5 μs. Input impedance 100 kΩ; driving-pulse amplitude, 20 V, p-to-p; maximum duty cycle 20%.

GENERAL

Power Required: 105 to 125 or 210 to 250 V, 50 to 60 c/s, 85 W. Instrument will operate satisfactorily (except for line-frequency sweep) at power-line frequencies up to 400 c/s.

Accessories Supplied: TYPE 874-R22LA Patch Cord, TYPE CAP-22 Power Cord, spare fuses.

MECHANICAL DATA Rack-Bench Cabinet (see page 258)

Model	Width		Height		Depth		Net Weight		Shipping Weight	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Bench	19	485	7½	195	15½	395	38	17.5	75	35
Rack	19	485	7	180	13*	330	38	17.5	75	35

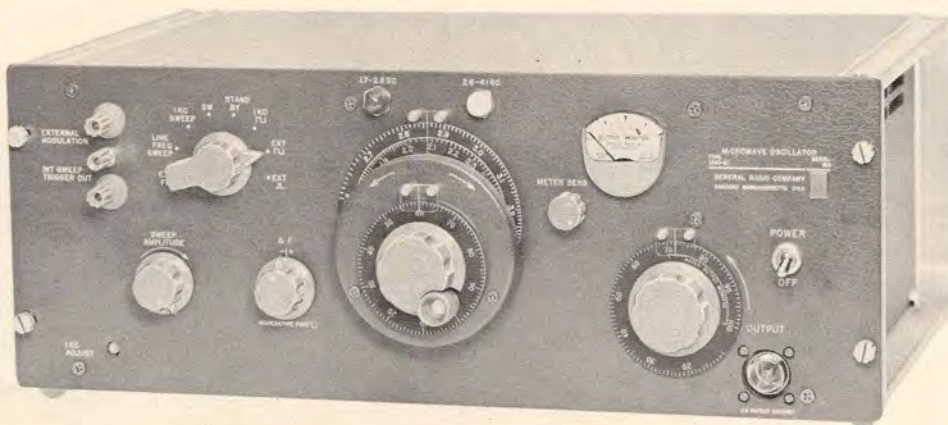
* Behind panel

For a more detailed description, see *General Radio Experimenter*, February 1962 and August 1964.

Catalog No.	Description	Price
1360-9802	Type 1360-B Microwave Oscillator, Bench Model	\$1175.00
1360-9812	Type 1360-B Microwave Oscillator, Rack Model	1175.00

PATENT NOTICE. See Note 4, page 11.

1.7 TO
4.1 Gc/s



NEW MODEL
in catalog S



Type 1220-A UNIT KLYSTRON OSCILLATOR

2700 TO 7425 Mc/s

FEATURES:

- Versatile, microwave power source.
- Wide range of frequencies and modulation capabilities.
- Small — compact — inexpensive.

USES: The Unit Klystron Oscillator generates fixed frequencies between 2700 and 7425 Mc/s which can be swept and can be amplitude modulated by either square waves or pulses, with low incidental fm.

Because of its relatively high output, low cost, small size, and rugged construction, it is equally useful in the laboratory, on the production line, and in classroom demonstrations. It is an excellent source for slotted-line measurements of impedance and vswr, measurements of bandwidth, and attenuation measurements on cables, lines, and pads.

DESCRIPTION: This instrument includes an adjustable, regulated source of repeller voltage, a Schmitt squaring circuit, a 1000-cycle rc oscillator, and a socket for a reflex klystron tube.

Eight plug-in klystrons cover the frequency range. The oscillator is listed with each single klystron; additional klystrons can be ordered as desired.

The frequency range listed for each klystron can be covered by screw adjustment at the rear of the instrument.

SPECIFICATIONS

Frequency Range: Depends on klystron type (see table below); frequency range of any unit can be changed to that of any other by the insertion of the appropriate klystron.

Amplitude Modulation:

Internal: 1-kc square wave, adjustable ± 15 c/s.

External: Square wave — 50 c/s to 200 kc/s; sine or square-wave modulating signal of at least 15 volts, rms, required — TYPE 1210-C Unit R-C Oscillator recommended.

Pulse: 1- to 10,000- μ s duration, less than 0.2- μ s rise and fall times, 50-cycle to 200-kc repetition rate; at least 20-V peak pulse voltage required — TYPE 1217-C Unit Pulse Generator recommended.

Frequency Modulation: At least 15-Mc excursion with less than 3-dB change in output at 60 c/s and rms-input of the order of 10 V.

Output Terminal: Locking GR874 Coaxial Connector. This instrument can be equipped with type N, BNC, TNC, SC, or C connectors through the use of locking adaptors, listed on page 81.

Power Required: TYPE 1201-C (or -CQ18) Unit Power Supply as shown below is required. Ac line connection to the oscillator chassis is made through this power supply. Normal power-line frequency is 50 to 60 c/s, but can be 400 c/s, provided that the line voltage is between 115 and 125 (230 and 250) V.

Accessories Recommended: Fixed attenuator pad for isolating oscillator from load (page 88); TYPE 874-VQ or -VR for facilitating tuning adjustments (page 86).

Mechanical Data: Unit-Instrument Cabinet (see page 258)

With power supply	Width		Height		Depth		Net Weight		Shipping Weight	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
	15	380	5 3/4	145	6 1/4	160	12	5.5	16	7.5

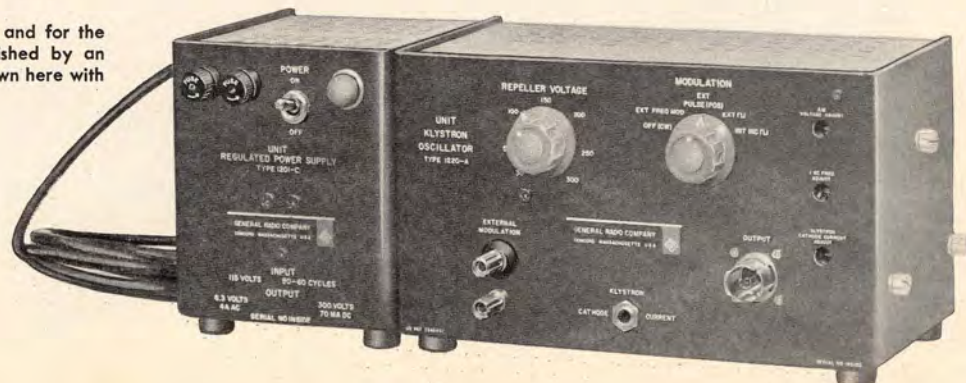
For a more detailed description, see *General Radio Experimenter*, March 1957.

Catalog Number	Description	Nominal Output in mW	Price	Tube only Type	Catalog Number	Price	
Klystron Oscillator with Klystron, for							
1220-9411	Type 1220-A1	2700-2960 Mc/s,	100	\$385.00	726-C	1220-9601	\$ 65.00
1220-9412	Type 1220-A2	2950-3275 Mc/s	90	408.25	6043	1220-9602	88.25
1220-9413	Type 1220-A3	3400-3960 Mc/s	90	415.00	2K29	1220-9603	95.00
1220-9414	Type 1220-A4	3840-4460 Mc/s	75	422.50	2K56	1220-9604	102.50
1220-9415	Type 1220-A5	4240-4910 Mc/s	100	415.00	2K22	1220-9605	95.00
1220-9416	Type 1220-A6	5100-5900 Mc/s	80	412.00	6115	1220-9606	92.00
1220-9417	Type 1220-A7	5925-6450 Mc/s	100	388.00	QK404	1220-9607	68.00
1220-9418	Type 1220-A8	6200-7425 Mc/s	90	388.00	5976	1220-9608	68.00
1220-9701	Type 1220-A Klystron Oscillator (without Tube)			320.00			
1201-9703	Type 1201-C Unit Regulated Power Supply (105 to 125 V)			95.00			
1201-9824	Type 1201-CQ18 Unit Regulated Power Supply (210 to 250 V)			on request			
0480-9986	Type 480-P4U3 Relay-Rack Adaptor Panel (holds both oscillator and power supply)			12.00			

All klystron tubes except the 6043 are designed for relatively infrequent tuning. With most of the klystrons listed, tuning can be accomplished without removal of shield.

PATENT NOTICE. See Note 4, page 11.

Power for the klystron cathode and for the internal 1-kc modulator is furnished by an external Unit Power Supply, shown here with the oscillator.





STANDARD-SIGNAL GENERATORS



A standard-signal generator is a source of alternating-current energy of accurately known characteristics. The carrier, or center, frequency is indicated by a dial setting, the output voltage by a meter reading and associated attenuator setting, and the modulation by a meter reading set by appropriate control knobs. Common types of modulation signals are sine-wave, square-wave, and pulse; the output signal may be either frequency- or amplitude-modulated by these signals. When the frequency-modulation system produces a considerable excursion in frequency at a relatively low cyclical rate, the instrument is known as a sweep-frequency generator and is particularly useful for automatic data display. Standard-signal generators are used for testing radio receivers, as voltage standards over the range from a few microvolts to about a volt, and generally as power sources in measurement of gain, bandwidth, signal-to-noise ratio, standing-wave ratio, and other circuit properties.

For use as a standard-signal generator, the oscillator must be stable, have reasonably constant output over any one frequency range, have good waveform, and have no appreciable hum or noise modulation. Careful over-all shielding of the generator is essential in order to minimize stray fields.

The elements of an amplitude-modulated standard-signal generator are shown in Figure 1. An amplifier may be added readily at lower frequencies, as shown in Figure 2, to isolate the oscillator from the load and to minimize the incidental frequency modulation that usually results from amplitude modulation. The elements of a standard sweep-frequency generator are shown in Figure 3.

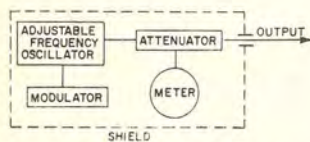


Figure 1. Elements of a standard-signal generator.

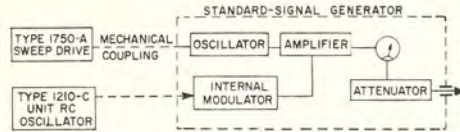


Figure 2. Modulation (and sweep) methods.

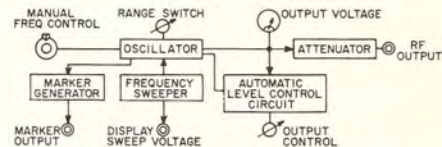


Figure 3. Elements of a standard sweep-frequency generator.

Amplitude-Modulated Signal Generators

The three General Radio amplitude-modulated standard-signal generators are general-purpose, wide-tuning-range instruments covering the range from 5 kc/s to 940 Mc/s. Amplitude modulation is provided from an internal, fixed-frequency, sine-wave generator or from an external audio-frequency source. This provision is omitted for sweep-frequency generators. Amplitude modulation is generally accompanied by incidental frequency modulation. This can be minimized by an amplifier, as mentioned above.

Sweep-Frequency Generators

The Type 1025-A Standard Sweep-Frequency Generator covers the range from 700 kc/s to 230 Mc/s in ten octave bands and has in addition bandspread ranges at 450 kc/s and 10.7 Mc/s. This instrument employs a rotating tuning capacitor to bring the precision and stability of conventional, manually tuned signal generators to the field of sweep measurement. It sweeps 20 times per second over complete octave ranges and is fast enough to eliminate flicker. This generator includes a very effective automatic level control so that the full advantage may be taken of the use of sweep techniques.

Sweep-Frequency Operation of Conventional Signal Generators

Conventional manual signal generators can also be swept over limited ranges through the use of the Type 1750-A Sweep Drive, which can impart reciprocating rotation up to 300 degrees at rates of 1 to 5 c/s to the tuning control (see Figure 2). The corresponding frequency variation is listed in the specifications for the individual instruments.

STANDARD-SIGNAL GENERATORS

Type	Frequency Range	Open-Circuit Voltage	Output Impedance	Modulation %	Page
1001-A	5 kc/s-50 Mc/s	0.1 μ V-200 mV	10 Ω , 50 Ω	0-80%	150
1021-AV	40-250 Mc/s	0.5 μ V-1 V	50 Ω	0-50%	151
1021-AU	250-940 Mc/s	0.5 μ V-1 V	50 Ω	0-50%	151

STANDARD SWEEP-FREQUENCY GENERATOR

1025-A	0.7 to 230 Mc/s 0.45 and 10.7 Mc/s	0.3 μ V-1 V	50 Ω	Sweep, all bands	148
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ACCESSORIES

1000-P4	Dummy Antenna				152
1000-P5	VHF Transformer (50 ohms grounded to 300 ohms balanced)				152
1000-P10	Test Loop				152



Type 1025-A STANDARD SWEEP-FREQUENCY GENERATOR

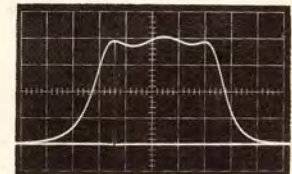
FEATURES:

- Wide frequency range, plus bandspread ranges for 450 kc/s and 10.7 Mc/s.
- Rf output from 1 μ V to 1 V, accurately calibrated.
- Quiet, reliable motor-driven sweep provides drift-free display.
- Display can cover any portion of selected frequency range from 1/10 to full range.
- Single, continuously variable marker is accurately calibrated in both frequency and amplitude — does not interfere with displayed response.
- Converts easily from sweep to true cw operation.
- Separate high-level output to operate a counter without disturbance to cw output.
- Low leakage makes possible accurate measurements at low signal levels.

USES: The standard sweep-frequency generator is an accurately calibrated source for sweep-frequency measurements on tuned circuits, filters, i-f amplifiers, and other networks. Amplitude and frequency data can be taken directly from the oscilloscope display by use of the calibrated marker. The instrument can be easily switched to cw operation, so that the response can be displayed point-by-point without changes in the test setup.

DESCRIPTION: This instrument combines the characteristics of the standard-signal generator and the swept oscillator.

The frequency of the sinusoidal output is varied smoothly and continuously over a frequency band in repetitive cycles by a motor-driven tuning capacitor. Thus, the amplitude response of a network or device as a function of frequency can be displayed automatically on an oscilloscope. A synchronously varying horizontal deflection voltage is provided. The large dial indicates the frequency of a manually positioned marker on the display. The amplitude of the marker



Marker is accurately calibrated in frequency and amplitude.

is adjustable and is monitored by a panel meter, thus providing frequency and amplitude calibration of the displayed response.

The frequency range is covered in 10, step-switched, octave bands plus 2 bandspread ranges.

The entire selected range is swept, but, by means of EXPAND DISPLAY and DISPLAY START controls, as little as one-tenth of any range can be set to occupy the full width of the oscilloscope screen.

Manual and slow-speed (with auxiliary dial drive) operation is also possible, for xy recording and point-by-point measurements. A detector probe is supplied, but the dc output of devices with built-in detectors can also be utilized.

SPECIFICATIONS

FREQUENCY

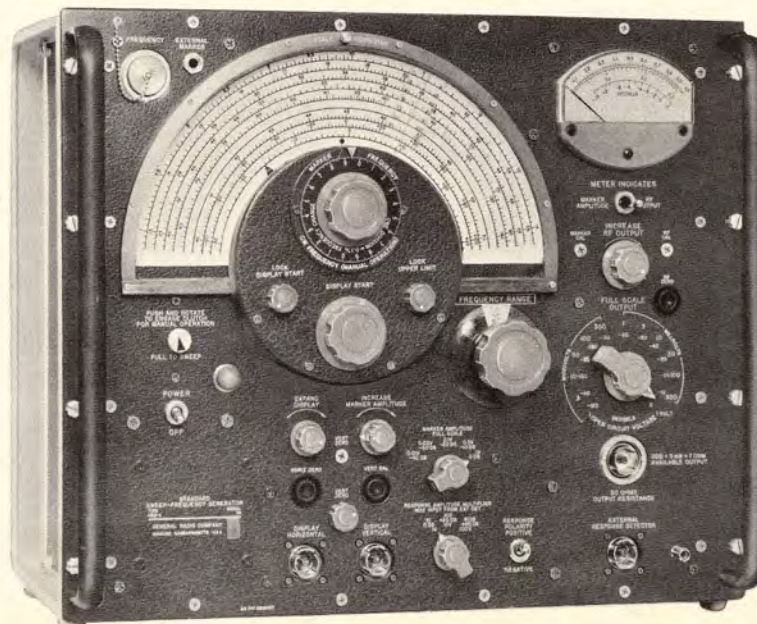
Range: 0.7 to 230 Mc/s in 10 ranges (0.7 to 1.4, 1.3 to 2.6, 2.4 to 4.8, 4 to 8, 7 to 14, 13 to 26, 24 to 48, 40 to 80, 65 to 140, and 100 to 230 Mc/s) and bandspread ranges of 400 to 500 kc/s and 10.7 \pm 0.3 Mc/s.

Alternate range* sectors can be substituted in the range-selector turret. Those presently available are: 0.4 to 0.8 Mc/s, 2 \pm 0.1 Mc/s, 2.8 \pm 0.1 Mc/s, 4 to 5 Mc/s, 5 \pm 0.3 Mc/s,

16 \pm 0.3 Mc/s, 19 \pm 1 Mc/s, and 40 to 50 Mc/s. Special bandspread ranges* can be provided as follows:

Specified Center Frequency	Bandwidth
Between 0.4 and 0.5 Mc/s	\pm 0.01 Mc/s
0.45 and 1.6 Mc/s	\pm 0.03 Mc/s
1.4 and 5 Mc/s	\pm 0.1 Mc/s
4.5 and 16 Mc/s	\pm 0.3 Mc/s

* Prices on request.



Control: 11-in semicircular dial, logarithmic scales for octave bands up to 80 Mc/s, quasi-logarithmic between 65 and 230 Mc/s, essentially linear for all bandspread ranges. One division on the slow-motion dial represents approximately 0.1% frequency difference on the octave frequency bands.

Calibration Accuracy: ± 0.5% of reading at output voltages less than 0.3 V when scale corrector is set to bring dial to index line. Frequency changes up to ± 0.5% can be caused by load changes at output voltages over 0.3V. With an external frequency meter, scale corrector can be used to bring dial into agreement, for frequency resolution within ± 0.1%.

Drift: 0.3%, or less, for 3 h after 1-h warmup.

Sweeping Rate: 20 times per second, 22.2 ms from low- to high-frequency end; output blanked for return sweep.

Sawtooth Sweep Voltage: 100 V, p-to-p, max; amplitude and starting point in frequency band both adjustable.

Marker: 3 mV to 1 V, adjustable, internally generated, half-sinusoidal waveform, at any frequency within sweep range; response amplitude multiplier effectively extends range up to 100 V; amplitude is indicated to an accuracy of ± 10%.

External Marker Input Voltage: 1 V, p-to-p, into 50 kΩ. Birdie-type markers can be applied, which are controlled in amplitude and added to the response displayed.

RF OUTPUT

Voltage: 0.3 μV to 1 V (-123 to 7 dBm power) behind 50 Ω, adjustable.

Accuracy: ± 14% of reading, over-all, up to 100 Mc/s; harmonics may add additional ± 3% error above 100 Mc/s. Over-all accuracy is sum of voltmeter error of ± 2% of reading + 2% of full scale and attenuator error of 1% per step up to a maximum of 6%.

Stability: Output constant within ± 1% (0.1 dB) up to 100 Mc/s, ± 3% (0.25 dB) up to 230 Mc/s. Output variations due to band switching and line-voltage changes will not exceed ± 3% (0.25 dB) max. TYPE 874-R22LA Patch Cord reduces output 5% (0.4 dB) at 230 Mc/s.

Effective Generator Impedance: 50 Ω resistive, VSWR less than 1.01 at panel jack; less than 1.1 at output of TYPE 874-R22LA Patch Cord, over the frequency range of the active generator.

Leakage: External rf field produces negligible interference with measurements down to lowest output levels.

RESPONSE AMPLIFIER

Input Voltage: 1, 10, or 100 V, max, as selected by response-amplifier switch. Noise level (with 100-kΩ source) varies with multiplier-switch setting — 1 mV max, p-to-p, at ×1 (1V), 10 mV at ×10 (10 V), and 100 mV at ×100 (100 V), referred to input.

Input Impedance: 1 MΩ parallel with 30 to 45 pF.

Gain: Approximate dc amplification between external response input connector and vertical display output connector varies with multiplier-switch setting — ×8 (18 dB) at ×1, ×0.8 at ×10, ×0.08 at ×100.

Bandwidth: 10 kc/s or greater; sufficient to pass all details of any response that can be resolved at maximum sweep rate.

Polarity: Switch provided to give positive display output voltage with either positive or negative inputs from external response detector.

OTHER OUTPUT VOLTAGES

Display, Vertical: Up to + 8 V into 100-kΩ load, consisting of marker plus response to be displayed.

Display, Horizontal: Up to + 100 V dc or sawtooth peak into 100-kΩ load.

Frequency Output Voltage: 0.1 to 0.3 V into 50 Ω for operating external frequency counter or external marker generator.

GENERAL

Power Required: 105 to 125 or 210 to 250 V, 60 c/s, 145 W. 50-cycle model available.

Terminals: GR874 Coaxial Connector, recessed, locking, except EXTERNAL MARKER input connector, which is a standard telephone jack. For connection to type N, BNC, TNC, SC, C, or UHF connector, use a locking adaptor (page 81), which locks securely in place, yet is easily removed. Panel connector is recessed, and adaptor projects only about an inch from panel. See also page 80.

Accessories Supplied: TYPE 1025-P1 Detector Probe, 2 TYPE 874-R22A Patch Cords, TYPE 874-R22LA Patch Cord, 3 TYPE 874-R33 Patch Cords, 2 TYPE 874-C58A Cable Connectors, 6 TYPE 838-B Alligator Clips, TYPE CAP-22 Power Cord, phone plug, spare fuses.

Accessories Available: TYPE 874-VQ Voltmeter Detector, TYPE 874-WM 50-ohm Termination, TYPE 908-P3 Synchronous Dial Drive. Dial drive provides 125° per min dial speed (at 60 c/s), manually reversible, for slow-speed XY recording. It is powered by a 50- to 60-cycle synchronous motor and is installed in place of the frequency control knob.

MECHANICAL DATA Rack-Bench Cabinet (see page 258)

Model	Width		Height		Depth		Net Weight		Shipping Weight	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Bench	19	485	16	410	13¾	350	73	34	152	70
Rack	19	485	15¾	400	11½*	290	73	34	152	70

* Behind panel

For a more detailed description, see *General Radio Experimenter*, January 1963. "Sweep-Frequency Measurement Techniques" (General Radio Reprint A-109) is also available, free on request.

TYPE 1025-P1 DETECTOR PROBE
(supplied with instrument)

Frequency: 0.4 to 250 Mc/s, flat within 5% (0.4 dB).

Fall Time: 150 μs, or less, sufficiently short to follow all details of any response that can be resolved at maximum sweep rate of generator.

RF Voltage: 3 V, rms

Input Impedance: 25 kΩ in parallel with 1.5 pF up to 10 Mc/s, decreases to 6 kΩ at 250 Mc/s.

Transfer Characteristic: Positive polarity; dc output voltage equals rms rf voltage above 0.5-V input; essentially square-law characteristic below 50 mV input.

Catalog Number	Description	Price
1025-9801	Type 1025-A Standard Sweep-Frequency Generator (for 60-cycle supply), Bench Model	\$3250.00
1025-9811	Type 1025-A Standard Sweep-Frequency Generator (for 60-cycle supply), Rack Model	3250.00
1025-9495	Type 1025-AQ1 Standard Sweep-Frequency Generator (for 50-cycle supply), Bench Model	on request
1025-9496	Type 1025-AQ1 Standard Sweep-Frequency Generator (for 50-cycle supply), Rack Model	on request
0908-9603	Type 908-P3 Synchronous Dial Drive	40.00

PATENT NOTICE. See Note 4, page 11.



Type 1001-A STANDARD-SIGNAL GENERATOR

FEATURES:

- Low cost. ■ Small, light, and sturdy — the result of design and construction simplicity.
- Excellent frequency stability — both short-term and long-term.
- Very low residual output and stray field.
- Frequency relatively unaffected by load or attenuator setting.
- Output amplifier avoids sideband clipping and isolates oscillator from load.
- Output can be matched into a 50-ohm system.

USES: The TYPE 1001-A Standard-Signal Generator is a laboratory instrument for use in determining the performance of receivers and other equipment at ultrasonic and radio frequencies. Its sturdy construction and simplicity of operation make it suitable for production testing. Because of its small size, light weight, and low power consumption, it can be adapted for use in field-strength measurements.

The frequency can be swept by the TYPE 1750-A Sweep Drive.

DESCRIPTION: The oscillator frequency varies logarithmically with dial rotation, so that the precision of frequency setting is constant; the vernier dial is calibrated directly in percentage frequency increments.

SPECIFICATIONS

CARRIER FREQUENCY

Range: 5 kc/s to 50 Mc/s in 8 ranges of 5 to 15 kc/s, 15 to 50 kc/s, 50 to 150 kc/s, 150 to 500 kc/s, 0.5 to 1.5 Mc/s, 1.5 to 5 Mc/s, 5 to 15 Mc/s, and 15 to 50 Mc/s. Logarithmic scale up to 15 Mc/s, departs slightly from logarithmic at higher frequencies. Vernier-dial frequency increment is 0.1% per dial division up to 15 Mc/s.

Accuracy: $\pm 1\%$ of reading.

Stability: Warmup drift is of the order of 0.25%. Half the maximum drift is reached in approximately $1\frac{1}{2}$ hours.

Sweep: Maximum range with TYPE 1750-A Sweep Drive is 14%.

Distortion and Noise Level:

Envelope Distortion: Less than 8% at 80% amplitude modulation.

Carrier Noise Level: Corresponds to about 0.1% modulation.

Carrier Distortion: Of the order of 7% on all except 5 to 15 kc/s range, where it may increase to approximately 15%.

Leakage: Stray fields at 1 Mc/s are less than one microvolt per meter two feet from the generator.

Amplitude Modulation: 0 to 80%, continuously variable, indicated on the panel meter to $\pm 10\%$ of reading with possible additional error of 2% modulation.

Internal modulation frequency, 400 c/s $\pm 5\%$.

External modulation characteristic, 20 c/s to 15 kc/s, flat within ± 1 dB; 12 V into 4 k Ω required for 80% modulation.

Incidental Frequency Modulation: 30 to 300 ppm at 80% amplitude

A buffer amplifier between the oscillator and the low-impedance output circuits can be amplitude modulated from zero to 80%. Loose coupling between the oscillator and the amplifier minimizes incidental frequency modulation. The output circuit is coupled to the amplifier through a high-pass filter, to reduce modulation-frequency voltages in the output.

The output voltage is determined by a carrier-level control and two output controls. The carrier-level control adjusts the plate-supply voltage of the oscillator, and the output controls set the attenuation of a continuously adjustable, L-network attenuator, and a decade step attenuator.

A 400-cycle RC oscillator supplies internal modulation voltage. The panel meter can be switched to monitor either carrier-level input to the attenuator or modulation percentage.

modulation, over all ranges except 15 to 50 Mc/s where it may be 3 times as great; approximately proportional to modulation percentage at low modulation percentages.

OUTPUT

Output	Voltage	Impedance
2 VOLTS Terminal	2 V, open circuit, up to at least 15 Mc/s, with output meter set to reference mark. Accuracy: $\pm 3\%$ at mid-frequencies.	300 Ω
ATTEN Terminal	0.1 μ V to 200 mV, open circuit; 0.05 μ V to 100 mV with output cable terminated at both ends; continuously variable. Accuracy: $\pm(6\% + 0.1 \mu$ V), 150 kc/s to 10 Mc/s with output dial near full scale or 1/10 full scale (error may be 4% greater with output dial set to mid-scale region); $\pm(10\% + 0.3 \mu$ V) above 10 Mc/s with output dial near full scale (error may be 10% larger or smaller at other output dial settings).	10 Ω ; 50 Ω when series unit is used; 50 Ω at highest output position of attenuator; 25 Ω at end of terminated cable.

GENERAL

Power Required: 105 to 125, 195 to 235, or 210 to 250 V, 40 to 60 c/s, 65 W; 115 to 125 V up to 400 c/s.

Terminals: GR874 Coaxial Connectors, recessed, locking. For



5 kc/s TO 50 Mc/s

connection to type N, BNC, TNC, SC, C, or UHF connector, use a locking adaptor (page 81), which locks securely in place, yet is easily removed. Panel connector is recessed, and adaptor projects only about an inch from panel.

Accessories Supplied: TYPE 874-R22LA Coaxial Cable, TYPE 1000-P1 50-Ohm Termination Unit, TYPE 1000-P2 40-Ohm Series Unit, TYPE 874-Q2 Adaptor, TYPE TO-44 Adjustment Tool (stored in cabinet), TYPE 274-MB Plug, TYPE CAP-22 Power Cord, spare fuses.

Accessories Available: TYPE 1000-P4 Standard Dummy Antenna,

the TYPE 1000-P10 Test Loop, TYPE 1750-A Sweep Drive. (Pages 152 and 153.)

MECHANICAL DATA Lab-Bench Cabinet (see page 258)

Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
20¼	515	13¾	350	11	280	54	25	67	31

See also *General Radio Experimenter*, September 1949.

Catalog Number	Description	Price
1001-9701	Type 1001-A Standard-Signal Generator	\$995.00

PATENT NOTICE. See Note 4, page 11.

Type 1021 STANDARD-SIGNAL GENERATOR

FEATURES:

- Simplicity; reliability; low cost. ■ Ease of operation.
- Wide frequency coverage in single dial range. ■ Good frequency stability.
- Accurately known output voltage, frequency, and impedance.
- Auxiliary calibration in dB below one milliwatt.
- High output. ■ Excellent shielding.

USES: These reliable vhf and uhf generators can be used to determine radio receiver and amplifier characteristics in the engineering laboratory and in production, as well as to supply power at very-high and ultra-high frequencies for bridges, slotted lines, and other measuring devices.

The frequency can be swept by the TYPE 1750-A Sweep Drive.

DESCRIPTION: Each TYPE 1021 Standard-Signal Generator is made up of two units mounted in a single cabinet. One unit consists of the power supply, modulator, and metering

system; the other is one of the readily interchangeable carrier oscillators.

Individual tuning units can be furnished for use with one common power supply and cabinet assembly. Power supply and cabinet assembly can also be purchased separately.

The frequency-determining elements are butterfly circuits. A mutual-inductance-type attenuator, with a dial calibrated in both open-circuit voltage and dB below one milliwatt, is used. Provision is made for external and 1000-cycle, sine-wave, internal amplitude modulation.

SPECIFICATIONS

Type	Frequency Range	Accuracy	Sweep Range (with Type 1750-A)
1021-AV	40 to 250 Mc/s in two bands — 40 to 50 Mc/s, 50 to 250 Mc/s	±1% of reading. Approx 8 turns of 100-division slow- motion dial cover range of main dial.	Approx 4% at 40 Mc/s, 9% at 50 Mc/s and 20% at 250 Mc/s
1021-AU	250 to 940 Mc/s in one band		Approx 5% at low end of range and 15% at high end.

OUTPUT

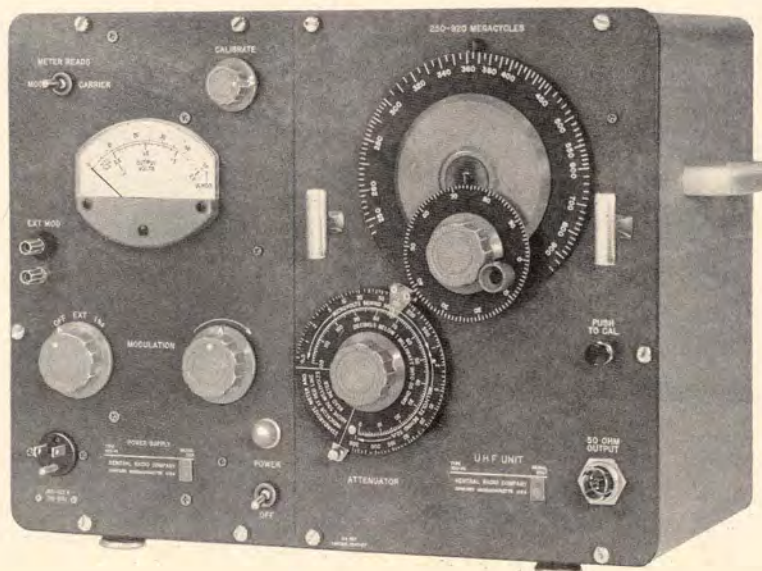
Power: 0 to 126 dB below 1 mW into 50 Ω, directly calibrated.

Voltage: 0.5 μV to 1 V behind 50 Ω, continuously variable.

Voltage Accuracy: ±2 dB over-all; voltmeter calibration, ±1 dB between 0.5 and 1.0 V; attenuator calibration, ±0.5 dB between 1 μV and 0.1 V and ±1 dB between 0.1 V and 0.5 V.

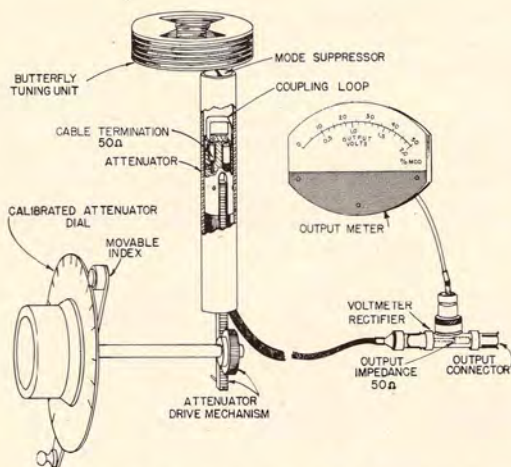
Impedance: 50 Ω ± 10%, following output meter.

Amplitude Modulation: 0 to 50%. Internal, 1000 c/s ± 5%. External, 30 c/s to 15 kc/s, flat within ±3 dB; 18 V into 100 kΩ for 50% modulation. TYPE 1310-A Oscillator is recommended.



40 TO 250 Mc/s
AND 250 TO 940 Mc/s

STANDARD-SIGNAL GENERATORS



Functional diagram of output system.

The output voltmeter is connected across the output of the attenuator. The accuracy of the output voltage at the reference point is determined by the voltmeter alone and is unaffected by the length of cable between the pickup loop in the attenuator and the point where the voltage is measured. Open-circuit output voltages between 0.5 and 2 volts are indicated by the meter; the output impedance is 50 ohms. For lower voltages, the output is first set to 0.5 volt, and the movable attenuator index is set to the 0.5-volt point on the attenuator dial. Voltages are then indicated by the attenuator dial, as long as the load is unchanged.

Incidental FM at 50% Amplitude Modulation (approximate):

TYPE 1021-AV, 100 ppm up to 100 Mc/s; 500 ppm up to 250 Mc/s.

TYPE 1021-AU, 100 ppm up to 400 Mc/s; 1000 ppm up to 920 Mc/s.

Distortion and Noise Level:

Envelope Distortion: Approximately 5% at 50% modulation.

Carrier Noise Level: Corresponds to about 0.2% modulation.

Leakage: Stray fields and residual output voltage are sufficiently low for measurements on receivers of 1- μ V sensitivity.

GENERAL

Power Required: 105 to 125 or 210 to 250 V, 50 to 60 c/s, 50 W; 110 to 125 or 220 to 250 V, 400 c/s.

Terminal: GR874 Coaxial Connector. This instrument can be equipped with type N, BNC, TNC, SC, C, or UHF connector through the use of locking adaptors, listed on page 81.

Accessories Supplied: TYPE 874-R22LA Patch Cord, TYPE CAP-22 Power Cord, spare fuses.

Accessories Available: GR874 Coaxial Elements, TYPE 1750-A Sweep Drive, TYPE 1000-P5 VHF Transformer.

MECHANICAL DATA Lab-Bench Cabinet (see page 258)

Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
20¼	515	13½	345	11	280	37½	17.5	50	23

See also *General Radio Experimenter*, March 1950.

Catalog Number	Description	Price
1021-9827	Type 1021-AV VHF Standard-Signal Generator, 40 to 250 Mc/s	\$795.00
1021-9939	Type 1021-AU UHF Standard-Signal Generator, 250 to 940 Mc/s	795.00
1021-9602	Type 1021-P2 UHF Oscillator Unit* only, 250 to 940 Mc/s	475.00
1021-9920	Type 1021-P3B VHF Oscillator Unit* only, 40 to 250 Mc/s	475.00
1021-9601	Type 1021-P1 Power Supply (includes modulator unit and cabinet)	320.00

* Less power supply unit and cabinet. Can replace oscillator unit in signal generator listed above, to provide additional frequency range.

PATENT NOTICE. See Notes 4 and 10, page 11.

Type 1000-P4 DUMMY ANTENNA

Connected to the terminated output of a 50-ohm generator, this dummy antenna provides the output characteristics specified by the IRE (IEEE) in "Standards on Radio Receivers, Methods of Testing Amplitude-Modulation Broadcast Receivers," 1948.

Dimensions: Diameter 7/8, length 4 3/8 in (23, 115 mm).

Net Weight: 3¼ oz (0.1 kg). **Shipping Weight:** 1 lb (0.5 kg).

Type 1000-P10 TEST LOOP

For testing radio receivers with loop antennas by the preferred method of the 1948 "Standards on Radio Receivers, Methods of Testing Amplitude-Modulation Broadcast Receivers," published by the IRE (IEEE). The 3-turn loop is enclosed in aluminum tubing for electrostatic shielding. The field strength in volts per meter, 19 inches from the loop, is one-tenth the generator output in volts, with a 50-ohm generator.

Frequency: 3 Mc/s, max.

Accuracy: $\pm 10\%$ ($\pm 5\%$ is typical); with TYPE 1001-A Standard-Signal Generator, $\pm 15\%$ ($\pm 10\%$ is typical).

Dimensions: Width 11¾, height 16½, depth 3½ in (300, 420, 89 mm), over-all.

Net Weight: 4½ lb (2.1 kg). **Shipping Weight:** 6 lb (2.8 kg).

Catalog Number	Description	Price
1000-9604	Type 1000-P4 Dummy Antenna	\$16.00
1000-9605	Type 1000-P5 VHF Transformer	27.50
1000-9610	Type 1000-P10 Test Loop	50.00

TYPE 1000-P5 VHF TRANSFORMER

50 TO 220 Mc/s

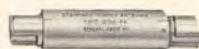
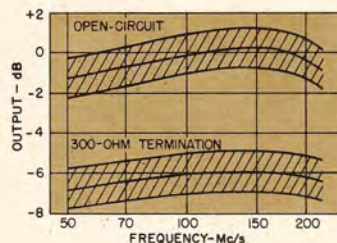
The TYPE 1000-P5 VHF Transformer plugs into a 50-ohm standard-signal generator to produce an equal, balanced, open-circuit voltage behind a 300-ohm balanced impedance for measurements of fm and TV receivers.

One terminal fits the Alden HA902P Connector for standard 300-ohm line, the other a GR874 Coaxial Connector.

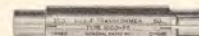
Dimensions: Diameter 7/8, length 4 3/8 in (23, 115 mm).

Net Weight: 3½ oz (0.1 kg). **Shipping Weight:** 1 lb (0.5 kg).

See also *General Radio Experimenter*, November 1949.



Type 1000-P4



Type 1000-P5





Type 1750-A SWEEP DRIVE

MECHANICAL HAND FOR AUTOMATIC SWEEPING

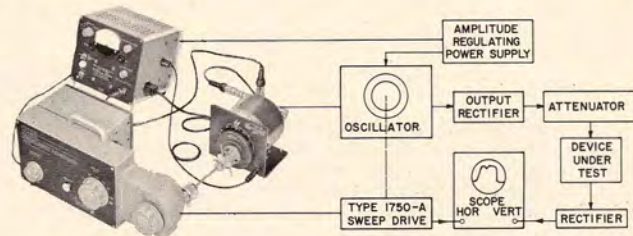
FEATURES:

- Provides narrow- and wide-range automatic data display.
- Converts mechanically tunable oscillators or generators to swept-signal sources.
- Attaches easily to most knobs, dials or shafts.
- Sweeps any arc from 30° to 300° at rates up to 5 per second.

USES: The TYPE 1750-A Sweep Drive adapts manually operated equipment to sweep operation. It can be used in the display of electrical quantities as a function of the shaft angle of the device being swept and can be adjusted to sweep, in reciprocating motion, any arc from 30 to 300 degrees, at rates up to 5 per second. In conjunction with GR Unit Oscillators, it makes available an extremely versatile system of swept signal sources covering a frequency span from 20 c/s to 2000 Mc/s. For constant output over the entire frequency range of any one of the Unit Oscillators, the TYPE 1263-B Amplitude-Regulating Power Supply is used. See pages 139 and 221.

DESCRIPTION: The output shaft is driven through an adjustable rack and a differential. Sweep frequency, arc, and center position are all adjustable while the drive is in motion. An adjustable limit switch can be set to stop the drive when predetermined limits of motion of the driven shaft are exceeded.

An oscilloscope-deflection-voltage circuit provides horizontal deflection that is proportional to shaft angle. A blanking circuit is included to eliminate the oscilloscope return trace and to produce a base line. At low sweep rates, memory or storage oscilloscopes are desirable.



A constant-amplitude sweeping system consisting of a Type 1750-A Sweep Drive, a Unit Oscillator, an amplitude-regulating power supply, and GR874 coaxial accessories.

SPECIFICATIONS

Output Shaft

Center Position: Adjustable over 9-turn range.

Sweep Arc: Adjustable 30 to 300 degrees.

Sweep Rate: Adjustable 0.5 to 5 per second. Moment of inertia of driven device determines upper limit.

Torque: 24 ounce-inches, max. Will drive TYPES 1209-C, 1209-CL, 1211-C, 1215-C Unit Oscillators, TYPE 1361-A UHF Oscillator, TYPE 1360-B Microwave Oscillator, TYPE 1304-B Beat-Frequency Audio Generator, TYPE 1308-A Audio Oscillator and Power Amplifier, TYPES 1305-A, 1310-A, and 1330-A Oscillators, TYPE 1564-A Sound and Vibration Analyzer, TYPES 1001-A and 1021-A Standard-Signal Generators.

Height of Shaft: Adjustable, 2½ to 4⅞ in over bench.

Flexible Coupling: 5¼ in long. Couples to ¼- and ⅝-in shafts; knobs and dials 1 to 4 in in diameter.

Limit Switch: Adjustable within 9 turns.

Sweep Voltage: 2.5 V, peak-to-peak, ungrounded.

Blanking: Shorting contact closed during clockwise rotation of driven shaft, ungrounded.

Power Required: 105 to 125 volts, 50 to 60 c/s, 60 W. On 400-cycle supply, maximum sweep speed is reduced 25%. A 210- to 250-volt model, TYPE 1750-AQ18, is also available.

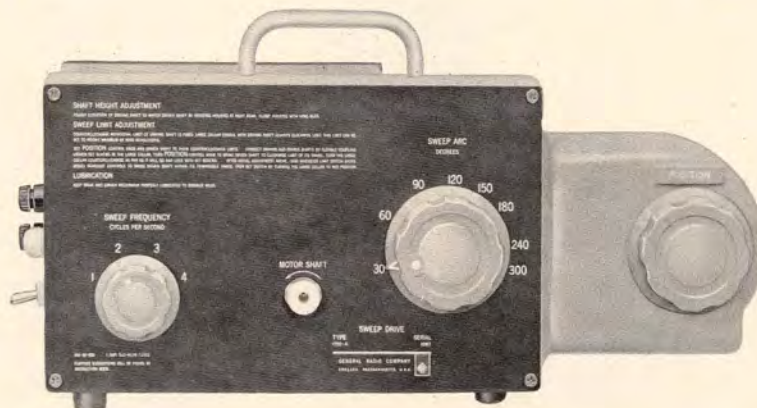
Accessories Supplied: Couplings, lubricant, spare fuses.

Mechanical Data:

Width		Height		Depth		Net Wt		Ship Wt	
in	mm	in	mm	in	mm	lb	kg	lb	kg
17½	445	9	230	8¼	210	22½	10.5	33	15

For a more detailed description, see *General Radio Experimenter*, April 1955. For a discussion of sweep measurements, ask for a copy of "Sweep-Frequency Measurement Techniques" (Reprint A-109), free on request.

Catalog No.	Description	Price
1750-9701	Type 1750-A Sweep Drive, for 115-volt Model	\$595.00 on request
1750-9911	Type 1750-AQ18 Sweep Drive, for 230-volt Model	





Type 907, 908 DIAL DRIVES

FEATURES:

- Inexpensive mechanical sweep device.
- Attaches directly on oscillator dial.
- R-models furnish a horizontal deflection voltage.
- Convenient sweep means for use with storage scopes.

DESCRIPTION: These dial drives are an inexpensive means for adapting manually operated equipment to sweep operation. They can be installed directly in place of the vernier knob on TYPE 908 Dials and on the TYPE 907 dials used on GR high-frequency Unit Oscillators.

Each drive is powered by a synchronous motor. When the drive encounters a mechanical stop, the TYPE 908-P3 stops; the others reverse automatically. Adjustable stops that clamp on the dial are furnished; power switch and power cord are included.



Type 907-R144 Dial Drive installed on the Type 1304-B Beat-Frequency Audio Generator.

SPECIFICATIONS

Power Required: 105 to 125 V, 50 to 60 c/s, 3 W. For 210- to 250-volt supply, an external 2:1 step-down transformer must be used. On 50-cycle lines, dial speeds are reduced 20%.

TYPE 908-P SYNCHRONOUS DIAL DRIVES: Can be used on all TYPE 907 and 908 Precision Dials. The synchronous-motor drive supplies the equivalent of a horizontal time calibration.

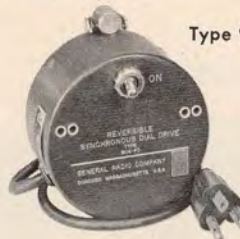
TYPE 907-R and 908-R DIAL DRIVES supply a sweep voltage proportional to angle of rotation. One knob engages the motor, the other permits manual setting at any point and direct manual drive. A dc voltage, applied to an internal 20-kΩ potentiometer (10 mA, max), permits use with a wide range of dc output levels. Binding posts for the position-signal output are provided.

Drive Type	908-P1		908-P2		908-P3	908-R96		907-R144
Dial Type	907	908	907	908		908		907
*Dial Speed °/min	144	96	1080	720	135	96		144
Resolution						0.2°		0.4°
Recommended Display	Graphic Recorder		Oscilloscope		XY Recorder	XY Recorder		XY Recorder
Will Drive These Instruments	1208-C, 1209-C, 1209-CL, 1211-C, 1215-C, 1330-A, 1304-B, 1210-C, 1360-B, 1361-A		1209-C, 1209-CL, 1211-C, 1215-C, 1304-B, 1360-B, 1361-A		1025-A	1208-C, 1209-C, 1209-CL, 1211-C, 1215-C, 1304-B, 1305-A, 1330-A		1210-C, 1564-A, 1360-B, 1361-A
Dimensions	Depth 3, dia 3 5/8 in (76, 92 mm)					Depth 3 7/8, dia 5 7/8 in (100, 150 mm)		Depth 3 7/8, dia 4 in (100, 105 mm)
Net Weight	1 1/4 lb (0.6 kg)					2 lb (0.9 kg)		1 3/4 lb (0.8 kg)
Shipping Weight	3 lb (1.4 kg)					3 lb (1.4 kg)		3 lb (1.4 kg)
Catalog Number	0908-9601		0908-9602		0908-9603	0908-9859		0907-9885
Price	\$40.00		\$40.00		\$40.00	\$85.00		\$75.00

* For 60-cycle power. With 50-cycle power, dial speeds are reduced 20%.



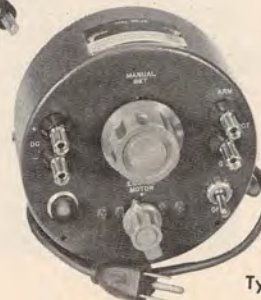
Type 908-P1



Type 908-P2



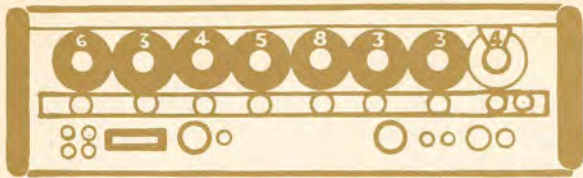
Type 908-P3



Type 908-R96



Type 907-R144



FREQUENCY SYNTHESIZERS



Appearing for the first time in this catalog are three new precision frequency sources, the Types 1161-A, 1162-A, and 1163-A Coherent Decade Frequency Synthesizers. They deliver 2 volts at accurately known, stable, sine-wave frequencies, selectable on a decimal-digit basis, from 0 c/s* to a maximum of 0.1, 1, or 12 Mc/s. Any chosen output frequency is coherently derived from a single, internal, quartz-crystal oscillator.

The output frequency is synthesized directly by repetitive arithmetic manipulations of frequency in a series of identical modules.

All three synthesizers are equipped for direct, front-panel, digit selection, and each is available in 20 models. Choice of model depends upon the user's requirements for resolution, versatility, and remote programming.

* 30 c/s for TYPE 1163-A.

COHERENT DECADE FREQUENCY SYNTHESIZERS

NEW

in catalog 5

FEATURES:

- Sine-wave outputs of quartz-crystal frequency stability.
- Settable to any frequency within the specified ranges.
- Resolution to at least 9 significant figures — bright, in-line digital frequency display.
- Frequency-adjustable, digit-by-digit or continuously.
- Low cost — 60 models to meet exact needs for frequency range and resolution.
- Programmable/manual or manual only.
- All-solid-state; plug-in modules for system expansion and ease of maintenance.
- Internally calibratable electronic sweep.
- Ac or battery power.

USES: The Coherent Decade Frequency Synthesizer is an excellent source of accurately known, stable, sine-wave signals for precise measurements. No external frequency counter is needed.

GR synthesizers are well suited for repeatable, high-precision, frequency-response measurements on amplifiers, filters, transducers, and similar electronic devices, by either point-by-point or sweep techniques. Models equipped with a Continuously Adjustable Decade can furnish swept-frequency output signals over frequency bands selectable in width from hundreds of kilocycles per second to a fraction of a millicycle per second. Precise frequency markers can also be derived with the help of simple external circuits.

GR frequency synthesizers are also stable, operational signal sources for sophisticated radar, telemetry, single-sideband communications, and data-handling systems.

Large illuminated digits on the decade controls eliminate errors in reading and ensure precise frequency

adjustment and accurate resettability in production-line applications.

Programmed adjustment is available to speed repetitive testing, to ensure exact frequency reproduction, and to allow for remote operation.

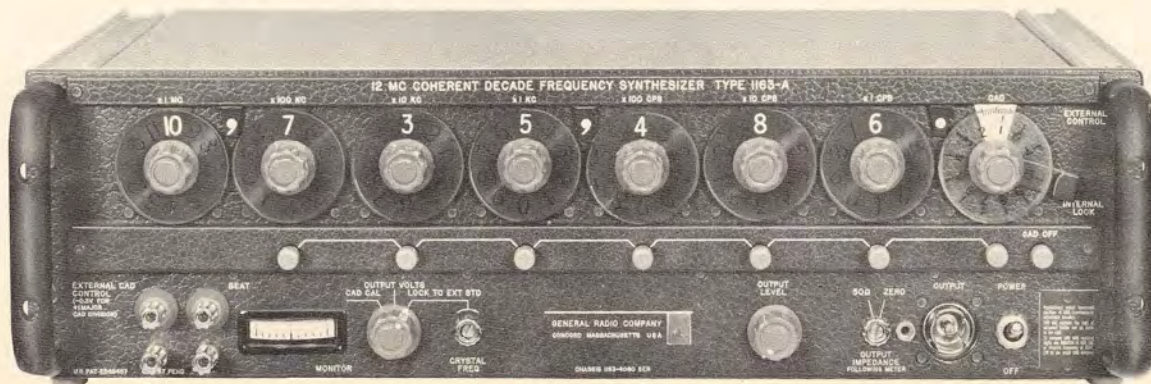
DESCRIPTION:

MODULAR CONSTRUCTION

The new synthesizer designs are based on identical, iterative circuits in the frequency-derivation chain. These compact, all-solid-state instruments are made up of interchangeable, plug-in modules. This results in minimum cost to the user, inasmuch as he can buy originally only the resolution that he needs. Yet, he can always easily add modules for increased resolution.

These modules combine in several ways to form a large variety of synthesizer models, with differing numbers of digits. Models may have simple manual control only, or manual control combined with remote-programming capability.

A minimal system consists of a relay-rack-width chassis into which are plugged power-supply, frequency-source, and output-mixer modules, plus three step-



1163-A

FREQUENCY SYNTHESIZERS



For extremely exacting frequency requirements, the internal crystal oscillator can be conveniently phase-locked to an external standard. With the Type 1115-B Standard-Frequency Oscillator (page 114), the synthesizer yields a full range of frequency outputs that vary typically less than 5 parts in 10^{10} per day.

decade digit modules. Each chassis contains all necessary switching, wiring, and connectors and requires no alteration for expansion, even to change from manual to programmable operation. Additional modules plug into the instrument in minutes.

QUARTZ-CRYSTAL FREQUENCY SOURCE

All frequencies are synthesized, coherently, from a primary oscillator employing a hermetically sealed AT-cut crystal, without oven. Temperature coefficient is low in the normal operating range. In the many applications where extreme precision is not required, substantial savings in cost, space, and weight are achieved.

When maximum stability is required, the oscillator can readily be phase-locked to any external standard frequency of 100 kc/s, 1 Mc/s, 2.5 Mc/s, or 5 Mc/s. The Type 1115-B Standard-Frequency Oscillator is recommended.

STEP-DECADE MODULES

The basic building block of the new synthesizers is a step decade called the Digital Insertion Unit, DI for short. Up to seven of these can be combined to produce a decade-frequency synthesizer with in-line, digital readout. The signal flows through the train of DI units from right to left. Each DI divides by ten the frequency of the signal received from the unit to its right and inserts its own digit information at the head of the train of numbers created by previous synthesis.

CONTINUOUSLY ADJUSTABLE DECADE MODULE

A second type of module, a Continuously Adjustable Decade (CAD), is recommended for initial inclusion in any of the synthesizers but, alternatively, can be added later. With this unit the output frequency can be continuously adjusted, and any portion of the frequency range can be electronically swept. The CAD also adds at least 2 digits of resolution (3 digits if it is set by comparison with digit dials) beyond the last of the digitally stepped dials.

Frequency Search

The CAD can functionally replace one or more of the DI units. For example, if the push-button switch beneath a $\times 10$ CPS decade is operated, the CAD replaces that decade and all decades to the right. The

CAD thus automatically controls the synthesizer output frequency through a 100-cycle range in the frequency region selected by the dials to the left of the button. This process can be used to replace any number of DI step decades for continuous manual frequency search over a wide or a narrow range.

Sweeping

The CAD frequency can also be swept, through a range at least as great as the range of manual control, by an external voltage introduced at front-panel jacks. The sweep range of the synthesizer output can be made very small, if the CAD is substituted for a decade at the far right, or progressively larger, as step decades toward the left are replaced. The CAD can generate precision frequency markers with a minimum of external equipment. A marker at center frequency, as displayed on all the digit dials, plus side markers, at any chosen spacing about center, can easily be formed.

Increased Resolution

The CAD can also be used to extend the number of significant figures in the readout. It can add two places by direct dial reading. Or, the CAD can be calibrated in terms of a selected series of step decades (by observation of a zero-beat on a front-panel monitor meter) and then switched back to the end position to add three or more significant figures to the readout. The known digital setting of the step decades is transferred to the CAD in this operation.

Precise frequency offsets from the digit-dial reading can be produced by a similar technique. The Type 1142-A Frequency Meter (page 127) can be used to present a highly magnified indication of the departure of the actual output frequency from that set on the digit dials, as the CAD is varied.

PROGRAMMABLE STEP-DECADE MODULE

Programmable versions of the synthesizer offer, at the operator's choice, direct manual frequency selection by the local knobs, remote programming, or a mixture of the two. In the RDI-1 programmable decades, digits are selected by internal switching circuits, actuated by simple, external circuit closure, in either a biquinary or 10-line code.

RANGE AND RESOLUTION OPTIONS

Type Number Suffix*	Calibrated Digits		0-100 kc/s Type 1161	0-1 Mc/s Type 1162	30 c/s-12 Mc/s Type 1163†
	Decades Only	Decades Plus CAD**	Smallest Step (Step Decades Only)	Smallest Step (Step Decades Only)	Smallest Step (Step Decades Only)
-A(R)7C	7	9	0.01 c/s	0.1 c/s	1 c/s
-A(R)6C	6	8	0.1 c/s	1.0 c/s	10 c/s
-A(R)5C	5	7	1.0 c/s	10 c/s	100 c/s
-A(R)4C	4	6	10 c/s	100 c/s	1 kc/s
-A(R)3C	3	5	100 c/s	1 kc/s	10 kc/s
-A(R)7	7		0.01 c/s	0.1 c/s	1 c/s
-A(R)6	6		0.1 c/s	1.0 c/s	10 c/s
-A(R)5	5		1.0 c/s	10 c/s	100 c/s
-A(R)4	4		10 c/s	100 c/s	1 kc/s
-A(R)3	3		100 c/s	1 kc/s	10 kc/s

* Letter R, when present, denotes a programmable model.

** Direct reading (without calibration check of CAD). If CAD is calibrated in terms of step decades, at least one more significant figure can be added.

† First decade not programmable.

GENERAL CHARACTERISTICS

In these synthesizers the simplicity and resettability of step adjustment can be combined with the ease of search and comparison characteristic of continuous adjustment.

In addition, on CAD-equipped models a rapid self-check of the synthesizer operation is made with front-panel controls and indicators.

Operation of the synthesizers is simple and straightforward. The frequency determined by the step-decade rotary switches is displayed in line, in high-contrast characters, with comma and decimal point. The digits are rear-lighted in active decades and darkened (but still readable) in decades replaced by the CAD. In

programmable models, control is transferred from the local dial to the remote-control circuit (connected to the rear of any RDI-1) when the dial is set in its "R" position. The CAD dial is illuminated when that module is in use and dark when it is not in circuit.

When not active, both the DI units and the CAD are in a stand-by state and ready for instant use. The CAD dial is a continuous rotary type with 120 fiducial marks (-1.0 to +11.0).

Several auxiliary frequency outputs are available at rear-apron connectors (see specifications); one important application of these is to phase-lock multiple-synthesizer installations.

The level of the output signal is continuously adjustable and indicated on the panel meter.

SPECIFICATIONS

	Type 1161-A	Type 1162-A	Type 1163-A
Frequency Range:	0-100 kc/s	0-1 Mc/s	30 c/s-12 Mc/s
Smallest Digital Step:	0.01 c/s	0.1 c/s	1 c/s
Smallest Direct-Calibrated CAD Increments (A7C-models only):	0.0001 c/s	0.001 c/s	0.01 c/s
Max Bandwidth Controllable by CAD:	100 kc/s	1 Mc/s	1 Mc/s
RDI-1 Units may be used in:	All digit positions		All except 1-Mc step position
Spurious Frequency Outputs: Harmonic (at max output):	< -40 dB	< -40 dB	< -34 dB
Nonharmonic:	< -80 dB	< -60 dB	< -60 dB
Output:	Coupling switch at AC: Adjustable, 0 to 2 V, rms; metered at output receptacle (internal impedance = 7 Ω; min load impedance for full power = 50 Ω).		Output impedance switch at 50 Ω: 0 to 2 V, rms; metered; behind 50 Ω.
	Coupling switch at DC: Adjustable, 0 to 0.8 V, rms; not metered. (Source impedance variable up to about 4 kΩ with level setting.)		Output impedance switch at 0: 0 to 2 V, rms; metered at output receptacle after low impedance.
Output Frequency Characteristic:	±1 dB max, 50 c/s to max frequency (across 50-Ω or higher load, ac-coupled). ±0.2 dB max, 0 to 10 kc/s (dc-coupled).		±1.5 dB max, 50 c/s to 12 Mc/s; 50-Ω load.

AVAILABLE AUXILIARY OUTPUTS (rear of instruments)

Primary Outputs, All Three Types: 100 kc/s and 5 Mc/s (0.5 V, rms, min, across 50 Ω).

Secondary Outputs: 0.1 V, min, across 1 kΩ.

All Three Types	Type 1162-A	Type 1163-A
1.0 Mc/s	50 Mc/s	39 to 50 Mc/s
5/5.1 Mc/s	50/51 Mc/s	(1-Mc steps);
42 Mc/s		50/51 Mc/s
+18 V dc (test point or limited-current source)		

FOR ALL THREE TYPES

Operating Temperature Range: 0 to 50°C.

Internal Frequency Standard: Room-temperature, quartz-crystal oscillator. Temperature coefficient of frequency is typically less than $2 \times 10^{-7}/^{\circ}\text{C}$ from 20°C to 50°C. A front-panel frequency adjustment is provided. Crystal can easily be phase-locked to an external standard.

Lock Signal Input from external standard (if used): 0.25 V, rms, to 5 V, rms, 5 Mc/s, or any submultiple down to 100 kc/s. Input impedance is approximately 1 kΩ for low-level signals; drops to approximately 50 Ω effective at high level.

Power Required: 105 to 125, 195 to 235, or 210 to 250 V, 50 to 400 c/s, 55 W; or 20 to 28 V dc, 1.8 A.

Accessories Supplied: TYPE 874-R22LA Coaxial Patch Cord, Bridging Unit (maintenance substitute for DI), Panel Insert for use with Bridging Unit, TYPE CAP-22 3-wire power cord, spare dial lamps and fuses.

Terminals: Locking GR874 coaxial, TYPE 938 Binding Post, and miniature coaxial.

Cabinet: Rack-bench; end frames for bench mount and fittings for rack mount are included.

Mechanical Data: Rack-Bench Cabinet (see page 258)

Model	Width		Height		Depth		Net Weight		Shipping Weight	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Bench	19	485	5¼	135	15½	395	38	17.5	45	20.5
Rack	19	485	5¼	135	13*	330	38	17.5	45	20.5

* Behind panel.

See also *General Radio Experimenter*, September 1964.

PATENT NOTICE. See Notes 4 and 8, page 11.

STANDARD MODELS

Type 1161-A

0-100 kc/s



Type 1161-A7C

MANUAL OPERATION				REMOTE/MANUAL OPERATION			
Catalog No.	Type	Units Included*	Price	Catalog No.	Type	Units Included*	Price
1161-9597	1161-A7C	7 DI Units + CAD	\$5460.00	1161-9527	1161-AR7C	7 RDI Units + CAD	\$6055.00
1161-9596	1161-A6C	6 DI Units + CAD	5020.00	1161-9526	1161-AR6C	6 RDI Units + CAD	5530.00
1161-9595	1161-A5C	5 DI Units + CAD	4580.00	1161-9525	1161-AR5C	5 RDI Units + CAD	5005.00
1161-9594	1161-A4C	4 DI Units + CAD	4140.00	1161-9524	1161-AR4C	4 RDI Units + CAD	4480.00
1161-9593	1161-A3C	3 DI Units + CAD	3700.00	1161-9523	1161-AR3C	3 RDI Units + CAD	3955.00
1161-9417	1161-A7	7 DI Units	4960.00	1161-9507	1161-AR7	7 RDI Units	5555.00
1161-9416	1161-A6	6 DI Units	4520.00	1161-9506	1161-AR6	6 RDI Units	5030.00
1161-9415	1161-A5	5 DI Units	4080.00	1161-9505	1161-AR5	5 RDI Units	4505.00
1161-9414	1161-A4	4 DI Units	3640.00	1161-9504	1161-AR4	4 RDI Units	3980.00
1161-9413	1161-A3	3 DI Units	3200.00	1161-9503	1161-AR3	3 RDI Units	3455.00

Type 1162-A

0-1 Mc/s



Type 1162-A4C

1162-9597	1162-A7C	7 DI Units + CAD	\$5600.00	1162-9527	1162-AR7C	7 RDI Units + CAD	\$6195.00
1162-9596	1162-A6C	6 DI Units + CAD	5160.00	1162-9526	1162-AR6C	6 RDI Units + CAD	5670.00
1162-9595	1162-A5C	5 DI Units + CAD	4720.00	1162-9525	1162-AR5C	5 RDI Units + CAD	5145.00
1162-9594	1162-A4C	4 DI Units + CAD	4280.00	1162-9524	1162-AR4C	4 RDI Units + CAD	4620.00
1162-9593	1162-A3C	3 DI Units + CAD	3840.00	1162-9523	1162-AR3C	3 RDI Units + CAD	4095.00
1162-9417	1162-A7	7 DI Units	5100.00	1162-9507	1162-AR7	7 RDI Units	5695.00
1162-9416	1162-A6	6 DI Units	4660.00	1162-9506	1162-AR6	6 RDI Units	5170.00
1162-9415	1162-A5	5 DI Units	4220.00	1162-9505	1162-AR5	5 RDI Units	4645.00
1162-9414	1162-A4	4 DI Units	3780.00	1162-9504	1162-AR4	4 RDI Units	4120.00
1162-9413	1162-A3	3 DI Units	3340.00	1162-9503	1162-AR3	3 RDI Units	3595.00

Type 1163-A

30 c/s-12 Mc/s

AVAILABLE 4th QUARTER 1965



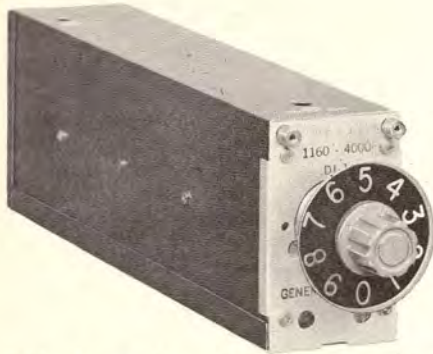
Type 1163-A7C

1163-9597	1163-A7C	7 DI Units + CAD	\$5600.00	1163-9527	1163-AR7C	1 DI + 6 RDI Units + CAD	\$6110.00
1163-9596	1163-A6C	6 DI Units + CAD	5160.00	1163-9526	1163-AR6C	1 DI + 5 RDI Units + CAD	5585.00
1163-9595	1163-A5C	5 DI Units + CAD	4720.00	1163-9525	1163-AR5C	1 DI + 4 RDI Units + CAD	5060.00
1163-9594	1163-A4C	4 DI Units + CAD	4280.00	1163-9524	1163-AR4C	1 DI + 3 RDI Units + CAD	4535.00
1163-9593	1163-A3C	3 DI Units + CAD	3840.00	1163-9523	1163-AR3C	1 DI + 2 RDI Units + CAD	4010.00
1163-9417	1163-A7	7 DI Units	5100.00	1163-9507	1163-AR7	1 DI + 6 RDI Units	5610.00
1163-9416	1163-A6	6 DI Units	4660.00	1163-9506	1163-AR6	1 DI + 5 RDI Units	5085.00
1163-9415	1163-A5	5 DI Units	4220.00	1163-9505	1163-AR5	1 DI + 4 RDI Units	4560.00
1163-9414	1163-A4	4 DI Units	3780.00	1163-9504	1163-AR4	1 DI + 3 RDI Units	4035.00
1163-9413	1163-A3	3 DI Units	3340.00	1163-9503	1163-AR3	1 DI + 2 RDI Units	3510.00

* All DI units are TYPE 1160-DI-1, except in the TYPE 1163-A, which always contains one TYPE 1160-DI-4 unit (non-programmable) in the X1MC station. All RDI units are TYPE 1160-RDI-1.

SYNTHESIZER MODULES

MANUAL STEP-DECADE MODULE



Sold only as replacements or to fill out partially equipped synthesizers.

Digit-Insertion Units, TYPE 1160-DI-1, are available singly or in multiples, to expand the resolution capability of less-than-fully equipped synthesizers, or as spares. The modules are complete and ready to plug in. The change takes only minutes and requires no special tools. The DI-1 module functions identically in any step-decade station of *any* synthesizer, except for the $\times 1\text{MC}$ station on the TYPE 1163-A.

A plug-in bridging unit, which completes the signal path in the empty decade station, must first be removed. All ancillary controls are preinstalled for every station, even in minimally equipped synthesizers.

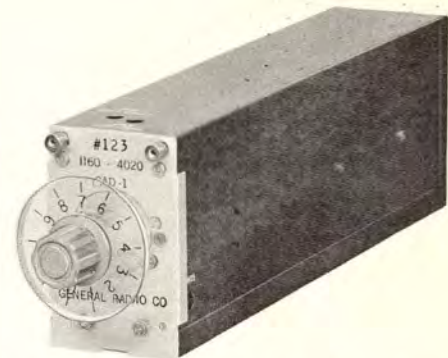
Net Weight: 1½ lb (0.7 kg).

Catalog No.	Description	Price
1160-9439	Type 1160-DI-1 Digit-Insertion Unit (Manual control)	\$450.00

CONTINUOUSLY ADJUSTABLE DECADE MODULE

The TYPE 1160-CAD-1 Continuously Adjustable Decade module is available to add increased versatility and extended resolution to *any* synthesizer purchased without this decade. The CAD adds two calibrated digits to the readout directly and three or more if it is first calibrated against the step decades. It can convert any step decade (and all to its right) to continuously adjustable operation at the push of a button. The capability of instantaneous self-check is another advantage furnished a synthesizer to which the CAD is added. The module is complete and ready to plug into the decade station at the right-hand end of any of the synthesizers. The change takes only minutes and requires no special tools.

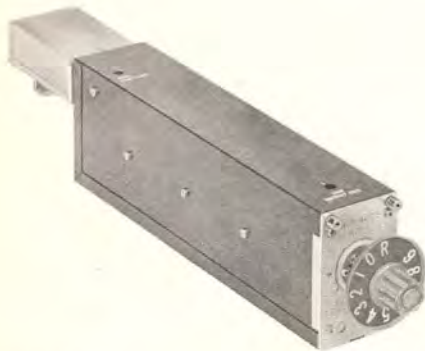
Net Weight: 1¾ lb (0.8 kg).



Sold only as replacements or to fill out partially equipped synthesizers.

Catalog No.	Description	Price
1160-9432	Type 1160-CAD-1 Continuously Adjustable Decade, including Calibrating Mixer Unit	\$510.00

PROGRAMMABLE STEP-DECADE MODULE



Sold only as replacements or to fill out partially equipped synthesizers.

The TYPE 1160-RDI-1 Digit-Insertion Unit (remote or manual control) is offered singly or in multiples, to permit programmed frequency selection in the step decades of *any* of the synthesizers, except in the $\times 1\text{MC}$ decade of the TYPE 1163-A. It can fill out partially complete programmable synthesizers or convert manual instruments, partially or fully, to programmed operation. The modules are complete and ready to plug in. The change takes only minutes and requires no special tools. A 12-pin filter-plug at the rear can be cabled to either a biquinary or 10-line coded programmer for fast, automatic operation. Control-cable filtering circuits are included in the plug.

For local-control override of any decade, the operator has merely to turn the dial from the program position, "R," to the desired digit.

For 10-line operation, each digit is remotely selected by the connection of the corresponding line to "common". Biquinary operation permits duplication of the digit-circuit closures for digits 0-4 and 5-9, with choice provided by a high-low circuit closure.

Except for the programmed-operation capability, the module is identical to the DI-1 module.

Net Weight: 1½ lb (0.7 kg).

Catalog No.	Description	Price
1160-9479	Type 1160-RDI-1 Digit-Insertion Unit (Remote or manual control), including Filter Plug	\$535.00

HOOK-UP CABLE FOR RDI-1

A special, 12-conductor, shielded cable is recommended for connection of the 12-pin filter-plug to remote equipment. One 50-foot roll of cable is furnished with each synthesizer containing an RDI-1 unit but is not supplied with an individually purchased RDI-1. Additional 50-foot lengths can be ordered.

Net Weight: 2½ lb (1.2 kg).

Catalog No.	Description	Price
1160-9650	Hook-up Cable for RDI-1, 50 feet	\$15.00



PULSE GENERATORS



Much of today's electronic engineering effort is devoted to the development of circuits and systems operating in the time domain. Switching, pulse, and digital circuits predominate in modern computing, navigation, and data-communication systems. In the laboratory, the oscilloscope as the detector and the pulse generator as the signal source replace the voltmeter and sinusoidal oscillator of yesterday.

A pulse generator is, in essence, a highly versatile and controllable switch. Two parameters of interest, and which must be controlled, are the pulse repetition frequency, or switching rate, and the pulse duration, or length of time the switch is closed (or open). The rise time, or speed of switching, is also an important parameter. In addition to the characteristics of the switch, specific applications will require particular characteristics for the energy source switched. The output impedance, open-circuit voltage, and available current must all be known and specified to fit a given pulse generator to a specific application.

Computational and data rates rise as rapidly as device development will permit. Pulse repetition rates can now range from nearly dc to over 100 Mc/s, and durations from seconds to less than 1 nanosecond. For computation and data-transmission systems, most of the applications can be served by relatively low power outputs, while radar and certain magnetic data-storage systems may require pulses of extremely high energy. It appears that a pulse generator that will meet all requirements, even in the laboratory, is out of the question.

The series of pulse generators offered in this catalog are pulse-signal sources of as general a type as economics will permit. The Type 1217-C produces pulses ranging from 0.1 μ s to 1 s over a repetition rate range from dc to 2 Mc/s. It, like all the General Radio pulse-generator line, contains an internal prf oscillator with continuous range from 3 c/s to 1.2 Mc/s. Both pulse polarities are simultaneously available, and output circuits are dc coupled, an absolutely necessary characteristic when pulses of long duration must be produced. This high level of performance is achieved at nominal cost because the output power level is low. The

Type 1397-A Pulse Amplifier can be used to translate this performance to 1-ampere output levels.

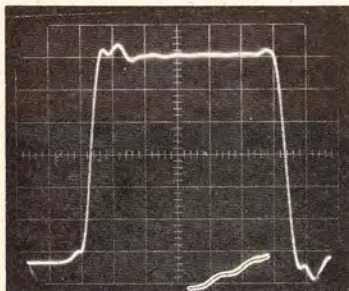
The Type 1398-A Pulse Generator is very similar in electrical characteristics to the Type 1217-C but produces faster pulses (5-ns rise time) at high current (60 mA).

For the utmost in flexibility we offer the Type 1395-A Modular Pulse Generator. This hybrid system has duration ranges, rise times, and prf ranges similar to the Type 1217-C but permits, in one package, interconnection of various modules to produce a pulse generator of almost infinite variety. An input circuit module either serves as a prf oscillator or processes an external driving signal from dc to 2 Mc/s to produce a standardized system-synchronizing pulse. A second module produces pulses or delayed 0.1- μ s synchronizing pulses in the range from 0.1 to 1 s with rise times of 15 ns. A single input module and three pulse/delay modules will form an excellent double-pulse generator, while 5 pulse/delay modules will provide a triple-pulse. A third module, timed from a pulse/delay module, will produce pulses with linear and independently variable rise and fall times over a range from 0.1 μ s to 1 s. A fourth module produces up to 16-bit pulse words. A power amplifier with up to 0.4-ampere output at limited duty-ratio is the fifth module.

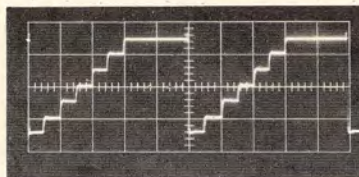
The Type 1396-A Tone-Burst Generator, a new type of pulse instrument, operates as a coherent gate for an externally introduced signal. It has many applications in sonar, the design and test of amplifiers, transducers, filters, meters, as well as in acoustical measurements.

PULSE GENERATORS

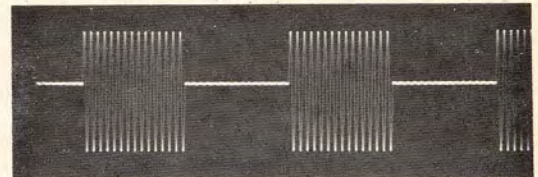
Type	Name	Remarks	Page
1217-C	Unit Pulse Generator	Low cost — high performance	164
1398-A	Pulse Generator	60-mA pulse output	166
1395-A	Modular Pulse Generator	Generates complex pulse waveforms — ultimate in flexibility	161
1397-A	Pulse Amplifier	1-A output pulses into 50 Ω	165
1396-A	Tone-Burst Generator	Coherent gate — adjustable on and off intervals	167



0.12- μ s pulse from Type 1217-C Unit Pulse Generator.



Staircase waveform generated by Type 1395-A Modular Pulse Generator.



Tone-burst pattern from Type 1396-A Tone-Burst Generator. Input, 3 kc/s; 16 cycles on; 16 cycles off.

Type 1395-A MODULAR PULSE GENERATOR



FEATURES:

- Generates wide variety of complex pulse waveforms.
- Five different modules available.
- Total of seven modules can be used at one time in variety of combinations.
- Designed for maximum flexibility, convenience, and economy.

USES: This instrument is used principally as a means for simulating the signals commonly associated with radar, telemetry, and moderate-speed digital-data handling. By selecting the appropriate number and types of plug-in modules, a user actually builds his own special-purpose instrument. Some typical applications for this generator include:

- Generation of staircase or ramp waveforms for testing analog-to-digital converters and allied equipment.
- Generation of pulse bursts for radar video-circuit testing and simulation.
- Generation of waveforms suitable for testing or simulating pulse-duration modulation in telemetry circuits.
- Physiological and geophysical tests using the low prf's and long time delays and pulse durations available.
- Synthesis of special pulses used as sync signals, such as pedestals, doublets, etc.

DESCRIPTION: The main frame of the TYPE 1395-A Modular Pulse Generator contains the power supply to operate the

seven modules that the main frame can accommodate, two ADDER busses with their corresponding output controls and jacks, and a bias control (labeled PULSE DC COMPONENT) for varying the level of the output-pulse base line. Through suitable programming of the individual module-selector switches, positive, negative, or simultaneous positive and negative outputs representing the "sum" of the waveforms generated by the respective modules are available at the ADDER output jacks. The output level at each of these jacks is adjustable by a 100-ohm potentiometer.

Five types of modules are available plus a skeleton-frame module in which the user can install his own circuitry. The five modules can be used in any combination up to a total of seven, of which only one may be a Power Amplifier and a maximum of three may be Pulse Shapers. To satisfy power-supply limitations, Pulse Shaper Units fit only in the three right-hand slots and the Power Amplifier only in the farthest right-hand slot.

SPECIFICATIONS

MAIN FRAME

ADDER Output Level: 0 to 1 V or more, depending on number of modules used (continuously adjustable).

ADDER Output Impedance: 100 Ω or less (100-Ω pot).

PULSE DC COMPONENT Range: 0 to +20 V (continuously adjustable).

Power Required: 105 to 125 V, 195 to 235 V, or 210 to 250 V, 50 to 60 c/s; approximately 250 W, depending on quantity and type of plug-ins.

Accessories Supplied: TYPE CAP-22 Power Cord; spare fuses; six patch cords — one each TYPES 274-LMB and 274-LMR, two

each TYPES 274-LSB and 274-LSR; four blank cover panels; one 14-conductor module extension cable.

Accessories Available: All modules in the TYPE 1395 series, TYPE 1217-P2 Single-Pulse Trigger (see page 164).

Mechanical Data: Rack-Bench Cabinet (see page 258)

Model	Width		Height		Depth		Net Wt*		Ship Wt*	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Bench	19	485	9 1/8	230	14 1/2	370	29	13.2	42	19.5
Rack	19	485	8 3/4	220	13 1/4 †	340	27	12.3	42	19.5

* Without modules. † Behind panel.

TYPE 1395-P1 PRF UNIT



This module generates the pulses that trigger the Pulse/Delay Units and provides the synchronization necessary for synthesizing complex waveforms. The maximum repetition rate is 1.2 Mc/s when generated internally, and at least 2 Mc/s with external drive. The PRF Unit acts as a synchronous divider when a signal of higher frequency is applied to the LOCK SIG jack, and a stable division of up to about 20:1 is possible. When a positive pulse is applied to the GATE IN jack, the PRF Unit is disabled for the duration of the pulse. Varying the time of occurrence and duration of this gating pulse, which can be generated by other modules, controls when and how long the PRF Unit is operative.

SPECIFICATIONS

PULSE REPETITION FREQUENCY

Internally Generated: 2.5 c/s to 1.2 Mc/s with 12-position switch and uncalibrated ΔF control.

Externally Controlled: After adjustment for maximum sensitivity, sine-wave input of 0.5 V, rms, required for prf from dc to 0.5 Mc/s, rising to 1.5 V, rms, at 2 Mc/s. Input impedance at 0.5 V is approx 100 kΩ shunted by 50 pF. Non-sinusoidal signal requires a negative-going step of 1 V.

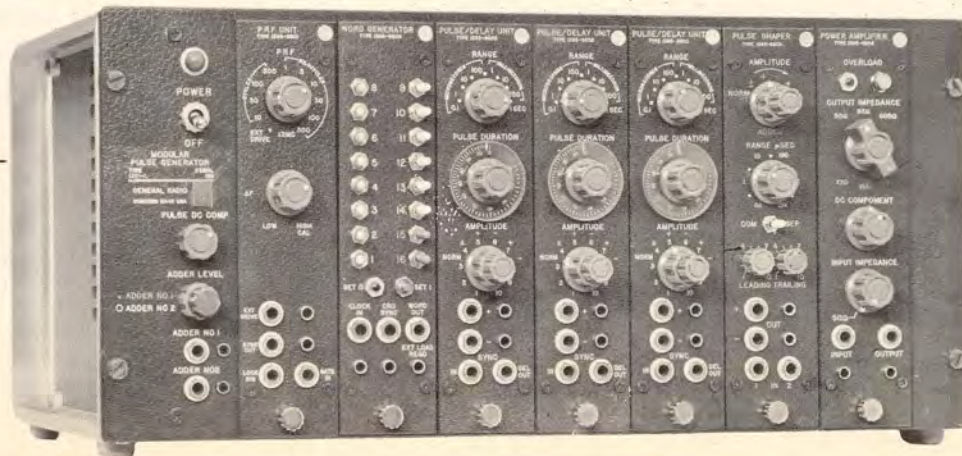
INPUT AND OUTPUT SIGNALS

Sync Out Pulses: At least 10 V, positive, with duration between 75 and 150 ns (nominally 100 ns); rise time approx 25 ns and output impedance approx 35 Ω.

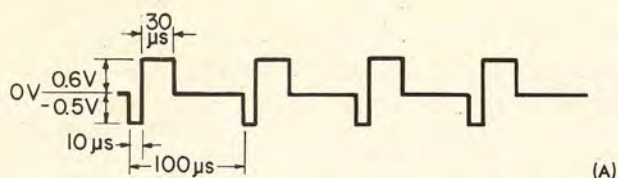
Lock Signal: PRF Unit operating at 1 kc/s can be locked to a frequency of 10 kc/s by 10-V positive pulses with 100-ns duration or with a sine wave of 7 V, rms. Required positive-pulse

NEW

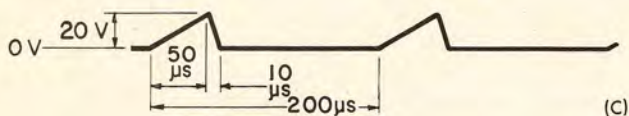
in catalog S



PULSE GENERATORS

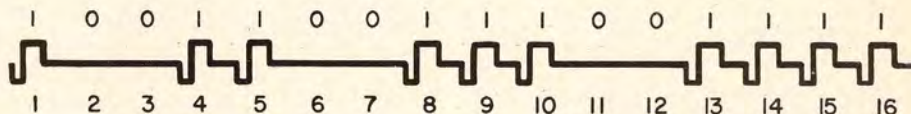


Waveform that appears at the ADDER No. 1 terminal with one PRF Unit driving two Pulse/Delay Units at 10 kc/s. Amplitudes and durations of positive and negative pulses can be independently adjusted.



One PRF Unit, one Pulse/Delay Unit, and one Pulse Shaper are used to form this train of triangular waveforms. The PRF Unit is set for 5 kc/s. The positive-going ramp rises linearly to 20 V in 50 μ s while the negative-going ramp falls to zero in 10 μ s. Rise and fall times are independently variable.

Pattern produced when a word generator is connected between PRF Unit and the first Pulse/Delay Unit in (A), above, with switches set as shown.



amplitude increases to about 12 V to lock the 1 kc/s to a frequency of 2 kc/s.

Gate Input: A potential more positive than -1 V at this terminal stops the generation of SYNC OUT pulses.

Stability: Prf jitter is 0.05% when the PRF Unit is operated from the power supply in the TYPE 1395-A main frame.

GENERAL

Power Consumption: +150 V at 25 mA; -150 V at 5 mA; +15 V at 5 mA; 6.3 V, 60 c/s, 1 A. Power supplied by frame.

Accessories Supplied: Six patch cords — one each TYPES 274-LMB and 274-LMR, two each TYPES 274-LSB and 274-LSR; two insulated plugs, one each TYPES 274-DB1 and 274-DB2.

Accessories Available: TYPE 1217-P2 Single-Pulse Trigger, other TYPE 1395 modules.

Net Weight: 1½ lb (0.7 kg).

Shipping Weight: 4½ lb (2.1 kg).



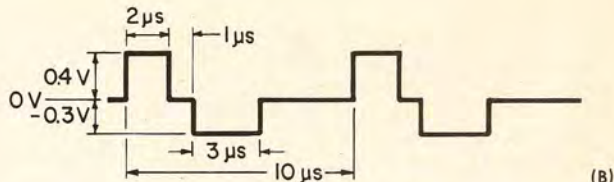
TYPE 1395-P2 PULSE/DELAY UNIT

Each Pulse/Delay Unit receives its input signal from a PRF Unit or other external source. The output pulses are then adjusted for the desired amplitude, polarity, duration, and delay time by the front-panel controls. If further shaping is required, the pulses are fed into a Pulse Shaper module. If they are to be combined with other pulses, they are fed to the ADDER busses on the Type 1395-A main frame. Alternatively the output can be applied directly to the circuit under test through the front-panel jacks. Maximum output current is 20 milliamperes, and the dc reference level of the output pulse can be varied by the PULSE DC COMPONENT control on the main frame.

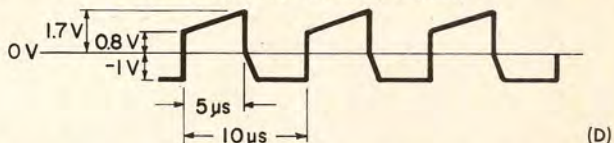
SPECIFICATIONS

Pulse and Delay Durations: 100 ns to 1 s, accurate to $\pm 5\%$ of reading or $\pm 2\%$ of full scale, or ± 35 ns, whichever is greater.

Pulse Repetition Frequency: Determined by input sync signal — range dc to 2.4 Mc/s. Input signals can be randomly spaced if separated by at least 400 ns.



Pulse train produced by one PRF Unit and three Pulse/Delay Units operating at 100 kc/s. The amplitude and duration of the positive pulse are controlled by one Pulse/Delay Unit whose delayed output triggers a second Pulse/Delay Unit. This second unit provides the delay between the positive and negative pulses, and its delayed output triggers the third unit to produce the negative pulse.



This train of ramp pulses is produced with one PRF Unit, one Pulse/Delay Unit, and one Pulse Shaper. Prf is 100 kc/s, and the zero-volt level is adjusted by the main chassis PULSE DC COMPONENT control.

Rise and Fall Times: Less than 15 ns with 50- Ω load. On high-voltage output (20 V into 1 k Ω), transitions are typically 80 ns + 2 ns/pF of load capacitance.

Output Voltage: ± 20 V pulses into 1-k Ω internal load impedance (± 1 V into 50- Ω load).

Input Sync Requirements: Positive-going pulse, 10 to 20 V, with 75- to 150-ns duration.

Delayed Output: Positive pulse of at least 10-V amplitude and 75- to 150-ns duration. Output impedance approx 125 Ω . Time between SYNC IN and DEL OUT pulses set by PULSE DURATION control.

Stability: Pulse-duration jitter is 0.05% when Pulse/Delay Unit is operated in the TYPE 1395-A main frame.

Power Consumption: +150 V at 15 mA; -150 V at 30 mA; 6.3 V, 60 c/s, 0.7 A; 6.3 V, 60 c/s, 1.3 A; +15 V at 5 mA; 0 to +20 V, variable, at 25 mA. Power supplied by frame.

Accessories Supplied: Five patch cords — two each TYPES 274-LSB and 274-LSR, one TYPE 274-LMR; two insulated plugs, one each TYPES 274-DB1 and 274-DB2.

Net Weight: 1¾ lb (0.8 kg).

Shipping Weight: 4¾ lb (2.2 kg).

TYPE 1395-P3 PULSE SHAPER

This unit produces pulses with straight-line leading and trailing edges whose rise and fall times can be adjusted individually by separate controls or simultaneously by a single control. The leading edge starts with the pulse that is applied to the IN 1 jack; the trailing edge starts with the pulse that is applied to the IN 2 jack. Therefore, the output-pulse duration is always greater than the time interval between input pulses. If input pulses are applied only to the IN 1 jack, the leading edge of the output pulse starts with the first input pulse and the trailing edge starts with the second pulse. Both positive and negative output pulses are produced, and the dc reference level can be varied by the PULSE DC COMPONENT control on the main frame. The output can be switched to the ADDER busses.



SPECIFICATIONS

INPUT PULSES: 10 V to 20 V in amplitude and 75 ns minimum duration.

OUTPUT PULSES

Duration: Time between pulses at IN 1 and IN 2 plus duration of trailing edge.

Rise and Fall Times: 100 ns to 10 ms in five decade ranges, $\pm 10\%$ of full scale, from the 0 to 100% points. Rise and fall times can be adjusted, independently by separate controls or simultaneously by a single control, within the same decade range. To obtain times less than a few hundred nanoseconds, output must be terminated in 50 to 100 Ω .

Linearity: A leading or trailing edge voltage $e(t)$ making a transition of E volts in time T will not at any time t depart from the equation $e = \frac{Et}{T}$ ($0 \leq t \leq T$) by more than 0.1 E (typically better than 0.05 E). The fastest transitions will not yield this performance unless outputs are terminated in 50 to 100 Ω .

Voltage: ± 20 -V pulses into 1-k Ω internal load impedance (± 1 V into 50- Ω load).

GENERAL

Power Consumption: +150 V at 45 mA; -150 V at 55 mA; 6.3 V, 60 c/s, 0.15 A; 6.3 V, 60 c/s, 0.6 A; 0 to +20 V, variable, at 30 mA. Power supplied by frame.

Accessories Supplied: Five patch cords — two each TYPES 274-LSB and 274-LSR, one TYPE 274-LMR; two insulated plugs, one each TYPES 274-DB1 and 274-DB2.

Net Weight: 1 $\frac{3}{4}$ lb (0.8 kg). **Shipping Weight:** 4 $\frac{3}{4}$ lb (2.2 kg).



TYPE 1395-P4 POWER AMPLIFIER

This amplifier is designed primarily for pulse amplification in applications where extremely fast rise time is not necessary. It delivers a 20-volt, minimum, pulse of either polarity into a 50-ohm load, and can amplify the signals from the ADDER busses or the output of any TYPE 1395 module. As a sine-wave amplifier it is useful for frequencies in the audio range and up to 1.5 Mc/s, or 5 Mc/s, depending upon the termination. Output power as a sine-wave amplifier is approximately two watts, and distortion is 5% or less. It is a suitable coupling element between the outputs of the various pulse-forming modules and the most commonly encountered impedances used in radar, video, and telephone practice.

SPECIFICATIONS

Output Impedances: 50, 93, and 600 Ω , all $\pm 10\%$.

Gains: 20, 20, and 26 dB, respectively, at the above impedances and with matched loads, all ± 2 dB.

Pulse Output Voltage: ± 20 V pulses into 50- Ω load with 10% duty cycle. Larger duty cycles may be used at lower output levels.

Rise and Fall Times: Less than 60 ns on all transitions with a 50- Ω load and selector switch set for 50- Ω impedance.

Sine-Wave Amplifier: Power output into 50- and 93- Ω loads is at least 2.5 W (3% distortion typical); into 600- Ω load, at least 1.5 W (distortion, 1.5% typical).

Frequency Response: Down less than 3 dB at 20 c/s and 5 Mc/s with 50- and 93- Ω loads; 20 c/s and 1.5 Mc/s with 600- Ω load.

Dc Level: Dc baseline of pulses and centerline of sine waves can be moved at least ± 1.5 V dc with 50- Ω loads, and more with higher impedance loads.

Input Impedance: Adjustable from 50 to 1050 Ω , shunted by approx 45 pF.

Power Consumption: +150 V at 150 mA, max; -150 V at 150 mA, max; 6.3 V, 60 c/s, 2.2 A; 6.3 V, 60 c/s, 1.9 A. Power supplied by frame.

Accessories Supplied: Four patch cords — one each TYPES 274-LMB, 274-LMR, 274-LSB, and 274-LSR; two insulated plugs, one each TYPES 274-DB1 and 274-DB2.

Net Weight: 2 lb (1 kg).

Shipping Weight: 5 lb (2.3 kg).

TYPE 1395-P6 WORD GENERATOR

This module produces a pattern of 16 binary digits (BITS) in accordance with the settings of the switches on the module front panel. As many as seven Word Generators can be connected in cascade, utilizing the full capacity of the TYPE 1395-A main frame, to provide an 112-bit capability in one binary word. Rear-panel switching provides conversion of the 16-bit-per-generator capacity to 14-bit capacity. Numerous options are provided by the interconnection of two or more Word Generators in cascade, or by a change in the internal wiring of a Word Generator with a patch cord.

The output pulses are trigger signals designed to operate other TYPE 1395 modules. In addition, each Word Generator provides a sync pulse coincident with the time when an output pulse would occur from switch #1, whether or not that switch is actually engaged.



SPECIFICATIONS

INPUT

Pulse Repetition Frequency: Dc to 2.5 Mc/s, externally controlled by TYPE 1395-P1 PRF Unit (or similar unit).

Trigger-Pulse Requirements: 10- to 20-V positive-going pulses of 75- to 150-ns duration. Square waves can be used above 10 kc/s; sine waves, above 500 kc/s.

Impedance: 400 to 600 Ω , depending upon trigger amplitude.

OUTPUTS

Oscilloscope Sync: Rectangular pulse of 2-V min amplitude and duration equal to period of driving-signal prf. Occurs approx 50 ns before the switch #1 output pulse, whether or not the switch is on.

Word Out: 10- to 20-V positive-going pulses of 75- to 150-ns duration. Output impedance approx 150 Ω , but termination in 500 to 1000 Ω is recommended.

Pattern: Set by front-panel switches. Choice of 16-bit or 14-bit capacity by rear-panel switch. One can achieve capacities other than 14 and 16 by modification of internal wiring. Interconnection of up to seven units provided by the TYPE 1395-A main frame.

GENERAL

Power Consumption: +15 V at 5 mA; 6.3 V, 60 c/s, 0.8 A. Power supplied by frame.

Accessories Supplied: Five patch cords — one each TYPES 274-LSB, 274-LSR, 274-LMB, 274-LMR, and 274-LLR; two insulated plugs, one each TYPES 274-DB1 and 274-DB2.

Net Weight: 2 $\frac{1}{2}$ lb (1.2 kg). **Shipping Weight:** 5 $\frac{1}{2}$ lb (2.5 kg).

TYPE 1395-P7 SKELETON FRAME

A blank module suitable for mounting the components of a user-designed circuit.

Net Weight: $\frac{1}{2}$ lb (0.3 kg). **Shipping Weight:** 3 $\frac{1}{2}$ lb (1.6 kg).

Dimensions: Width 2 $\frac{1}{8}$, height 8 $\frac{1}{2}$, depth 5 in (55, 220, 130 mm), over-all.

Catalog No.	Description	Price
1395-9801	Type 1395-A Modular Pulse Generator, Bench Model	\$500.00
1395-9811	Type 1395-A Modular Pulse Generator, Rack Model	500.00
1395-9601	Type 1395-P1 PRF Unit	150.00
1395-9602	Type 1395-P2 Pulse/Delay Unit	165.00
1395-9603	Type 1395-P3 Shaper Unit	375.00
1395-9604	Type 1395-P4 Power Amplifier	250.00
1395-9606	Type 1395-P6 Word Generator	400.00
1395-9607	Type 1395-P7 Skeleton Frame	12.00



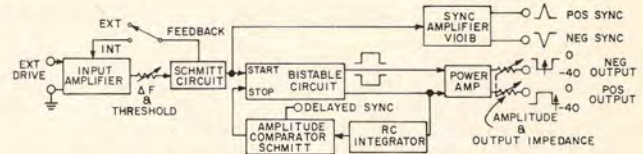
Type 1217-C UNIT PULSE GENERATOR

FEATURES:

- Fast rise and fall time — less than 10 ns.
- Duration adjustment over more than seven decades, 0.1 μ s to 1.1 s.
- Repetition rate from 2.5 c/s to 1.2 Mc/s, continuous, internal.
- 40-volt output pulses of either polarity simultaneously available.

USES: This simple, reliable pulse generator has many applications in the laboratory and on the test bench. Its wide ranges of pulse-duration and repetition rate and its excellent output characteristics fit it for any application where an oscilloscope can be used as an indicator. Applications range from high-speed computing circuits through radar to geophysical and physiological pulse simulation. It is an excellent, low-cost instrument for the student laboratory.

DESCRIPTION: Circuit functions are shown in the block diagram. The input circuits can be switched to act either as an aperiodic amplifier with adjustable sensitivity or as a stable prf oscillator. The pulse-timing circuits consist of a transistor bistable circuit, an RC



Block diagram of the circuit system.

integrator, and a Schmitt amplitude comparator. The bistable circuit switches a pair of pentode tubes in the output circuit. The pentode output stage is direct coupled to the output terminals so that the pulse dc component is retained. Efficient circuit design has resulted in a 40-mA output with only 60-mA total plate input.

SPECIFICATIONS

PULSE REPETITION FREQUENCY

Internally Generated: 2.5 c/s to 1.2 Mc/s, with calibrated points in a 1-3 sequence from 10 c/s to 300 kc/s, and 1.2 Mc/s, all $\pm 5\%$. Continuous coverage with an uncalibrated control.

Externally Controlled: Aperiodic, dc to 2.4 Mc/s with 1 V, rms, input (0.5 V at 1 Mc/s and lower); input impedance at 0.5 V, rms, approximately 100 k Ω shunted by 50 pF. Output pulse is started by negative-going input transition.

OUTPUT-PULSE CHARACTERISTICS

Duration: 100 ns to 1 s in 7 decade ranges, $\pm 5\%$ of reading or $\pm 2\%$ of full scale or ± 35 ns, whichever is greater.

Rise and Fall Times: Less than 10 ns into 50 or 100 Ω ; typically 60 ns + 2 ns/pF external load capacitance into 1 k Ω (40 V).

Voltage: Positive and negative 40-mA current pulses available simultaneously. Dc coupled, dc component negative with respect to ground. 40 V, peak, into 1-k Ω internal load impedance for both negative and positive pulses. Output control marked in approximate output impedance.

Overshoot: Overshoot and noise in pulse, less than 10% of amplitude with correct termination. **Ramp-off:** Less than 1%.

Synchronizing Pulses:

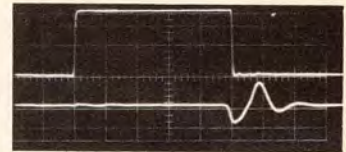
Pre-pulse: Positive and negative 8-V pulses of 150-ns duration. If positive sync terminal is shorted, negative pulse can be increased to 50 V. Sync-pulse source impedance:

positive — approx 300 Ω ; negative — approx 1 k Ω .

Delayed Sync Pulse: Consists of a negative-going transition of approximately 5 V and 100-ns duration coincident with the late edge of the main pulse. Duration control reads time between prepulse and delayed sync pulse. This negative transition is immediately followed by a positive transition of approximately 5 V and 150 ns to reset the input circuits of a following pulse generator. (See oscillogram).

Stability: Prf and pulse-duration jitter are dependent on power-

1- μ s pulse into 50 ohms with delayed sync pulse.



supply ripple and regulation. With TYPE 1201 Power Supply external-drive terminals short-circuited, prf jitter and pulse-duration jitter are each 0.01%. With TYPE 1203 Power Supply, they are 0.05% and 0.03%, respectively. (Jitter figures may vary somewhat with range switch settings, magnetic fields, etc.)

GENERAL

Power Required: TYPE 1203 or TYPE 1201 Unit Power Supply is recommended.

Accessories Available: TYPE 1217-P2 Single-Pulse Trigger, rack-adaptor panel for both generator and power supply (19 by 7 in).

MECHANICAL DATA Unit-Instrument Cabinet (see page 258)

With power supply	Width		Height		Depth		Net Wt		Ship Wt	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
	15	385	5 3/4	150	6 1/2	165	9 1/2	4.4	12	5.5

See also *General Radio Experimenter*, December 1964.

Catalog No.	Description	Price
1217-9703	Type 1217-C Unit Pulse Generator	\$275.00
1217-9602	Type 1217-P2 Single-Pulse Trigger	25.00
1203-9702	Type 1203-B Unit Power Supply (for 115-volt supply)	55.00
1203-9818	Type 1203-BQ18 Unit Power Supply (for 230-volt supply)	on request
0480-9986	Type 480-P4U3 Relay-Rack Adaptor Panel	12.00

NEW MODEL

in catalog S



Single-pulse trigger

Unit pulse generator with power supply.



Type 1397-A PULSE AMPLIFIER

1.2-AMPERE OUTPUT, PEAK-TO-PEAK

FEATURES:

- 60 volts, positive or negative, into 50 ohms, direct-coupled.
- Rise and fall times less than 50 nanoseconds or continuously adjustable from 0.1 to 100 microseconds.
- Operates as substantially linear amplifier or as pulse shaper.
- Automatic overload protection.

USES: The TYPE 1397-A Pulse Amplifier can be used with any pulse generator capable of supplying negative input pulses, particularly the TYPES 1217-B and -C and the TYPE 1398-A Pulse Generators.

Such combinations are excellent for testing radar circuits, which often require pulses up to 50 volts into 50 ohms, with transitions less than 50 nanoseconds and repetition rates up to one megacycle per second. The high output is also valuable for testing switching arrays and the thin-film or core memories used in computers. The variable-transition-time feature provides a rapid means for determination of the rise-time ranges over which these devices will operate.

Additional uses include the testing of inductors, semi-conductors, and other components. The linearly increasing output current is especially useful for testing pulse transformers.

DESCRIPTION: The TYPE 1397-A Pulse Amplifier has two

modes of operation: normal and variable transition time. In the normal mode, the input pulses are fed directly to the output amplifier. This mode provides the fastest rise and fall times, typically 30 ns. In the variable transition-time mode, exponential transitions are obtained by applying the input pulses to an RC network that slows the leading and trailing edges. Linear transitions are obtained by applying a higher-level input pulse to overdrive the RC network. The output of the RC network is followed by a diode circuit, which provides the linear transitions. Transition times are continuously adjustable from approximately 0.1 to 100 μ s.

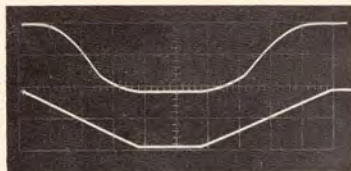
The output amplifier consists of three parallel-connected pentodes. In the POSITIVE position of the PULSE POLARITY switch, the pentodes operate as cathode followers to produce a ground-based, positive pulse into an internal shunt of 50 ohms or infinity. In the NEGATIVE position, the pentodes operate as inverters and produce ground-based, negative pulses into an internal shunt of 50 ohms, 100 ohms, or infinity.

SPECIFICATIONS

Mode	Input Impedance	Drive Required	Rise and Fall Times	Output (ground reference; dc coupled)
NORMAL	100 Ω or 100 k Ω shunted by approx 50 pF, switch selected	-2 V, p-to-p, minimum	< 50 ns (typically 30 ns) with input rise and fall times of < 20 ns	Rampoff: Approx 20% with 5-ms pulse duration Amplitude: 1.2 A, p-to-p, max (60 V into 50 Ω). 1 A, p-to-p, with 10% duty ratio. Automatic overload protector with manual reset.
VARIABLE Linear	30 k Ω , approx	-30 V, p-to-p, approx, minimum	0.1 to 100 μ s, approx, linear, continuously adjustable	Amplitude Variation: $\pm 10\%$ for duty ratio changes from minimum to 10%. With $\pm 10\%$ line-voltage changes, positive output variation is $\pm 10\%$, negative output is $\pm 5\%$.
Exponential	100 Ω	-2 to -4 V, p-to-p, approx	0.1 to 100 μ s, approx, exponential, continuously adjustable	Internal Shunt: Positive output, 50 Ω or open circuit; negative output, 50, 100 Ω , or open circuit.

TRANSFER CHARACTERISTICS: Operation approximates linear amplifier in normal mode.

Transfer Function:



Negative output (top) resulting from 2-V, linearly rising input; (bottom) in normal, 100- Ω , input mode.

Transconductance: 0.5 \cup (2 V in produces 1 A out).

Inherent Delay: < 50 ns between input pulse and output pulse.

Max Duty Ratio: 10%.

GENERAL

Power Required: 105 to 125, 195 to 235, or 210 to 250 V, 50 to 60 c/s, 100 W.

Terminals: Input, TYPE 938 Binding Posts; output, GR874 recessed, locking connector.

Accessories Supplied: TYPE CAP-22 Power Cord, spare fuses.

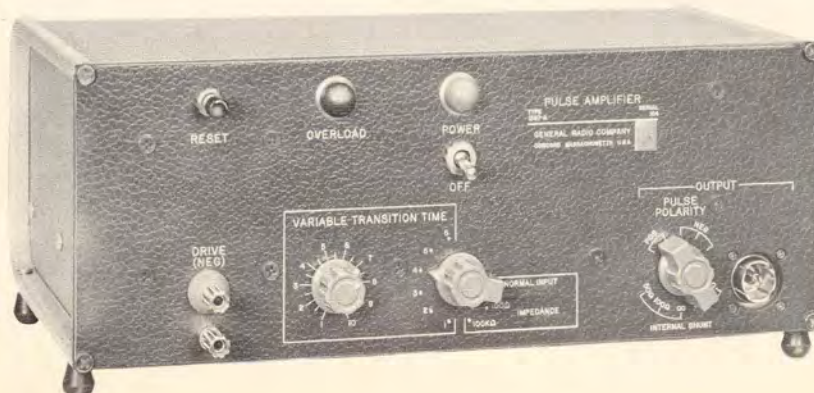
Accessories Available: Relay-rack adaptor set, panel 19 by 5 1/4 in (485, 135 mm), depth behind panel 9 in (230 mm).

Mechanical Data: Convertible-Bench Cabinet (see page 258)

Width		Height		Depth		Net Wt		Ship Wt	
in	mm	in	mm	in	mm	lb	kg	lb	kg
14	355	5 7/8	150	10 1/4	260	18	8.5	24	11

Catalog No.	Description	Price
1397-9701	Type 1397-A Pulse Amplifier	\$495.00
0480-9634	Type 480-P314 Relay-Rack Adaptor Set	6.00

AVAILABLE 4TH QUARTER 1965



NEW

in catalog S



Type 1398-A PULSE GENERATOR

FEATURES:

- Rise and fall times less than 5 ns.
- 60-mA positive and negative current pulses available simultaneously.
- Pulse duration adjustable from 0.1 μ s to 1.1 s.
- Repetition rate from 2.5 c/s to 1.2 Mc/s, continuous, internal.
- Self-contained power supply.

DESCRIPTION: The TYPE 1398-A Pulse Generator is basically a TYPE 1217-C Unit Pulse Generator (see page 164) with a self-contained power supply, higher output, and improved output-pulse characteristics. Rise

and fall times are less than 5 nanoseconds, one-half those of the TYPE 1217-C. Power output has been increased to provide positive and negative 60-mA current pulses, producing 60-V pulses across the 1-k Ω internal load impedance.

SPECIFICATIONS

PULSE REPETITION FREQUENCY

Internally Generated: 2.5 c/s to 1.2 Mc/s, with calibrated points in a 1-3 sequence from 10 c/s to 300 kc/s, and 1.2 Mc/s, all $\pm 5\%$. Continuous coverage with an uncalibrated control.

Externally Controlled: Aperiodic, dc to 2.4 Mc/s with 1-V, rms, input (0.5 V at 1 Mc/s and lower); input impedance at 0.5 V, rms, approximately 100 k Ω shunted by 50 pF. Output pulse is started by negative-going input transition.

OUTPUT-PULSE CHARACTERISTICS

Duration: 100 ns to 1 s in 7 decade ranges, $\pm 5\%$ of reading or $\pm 2\%$ of full scale or ± 35 ns, whichever is greater.

Rise and Fall Times: Less than 5 ns into 50 or 100 Ω ; typically 60 ns + 2 ns/pF external load capacitance into 1 k Ω (60 V).

Voltage: Positive and negative 60-mA current pulses available simultaneously. Dc coupled, dc component negative with respect to ground. 60 V, peak, into 1-k Ω internal load impedance for both negative and positive pulses. Output control marked in approximate output impedance.

Overshoot: Overshoot and noise in pulse, less than 10% of amplitude with correct termination.

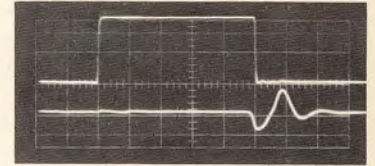
Ramp-off: Less than 1%.

Synchronizing Pulses:

Prepulse: Positive and negative 8-V, approx, pulses of 150-ns duration. If positive sync terminal is shorted, negative pulse can be increased to 100 V. **Sync-pulse source impedance:**

- positive — approx 300 Ω ;
- negative — approx 1 k Ω .

1- μ s pulse into 50 ohms with delayed sync pulse.



Delay-Sync Pulse: Consists of a negative-going transition of approximately 5 V and 100-ns duration, coincident with the late edge of the main pulse. Duration control reads time between prepulse and delayed sync pulse. This negative transition is immediately followed by a positive transition of approximately 5 V and 150 ns to reset the input circuits of a following pulse generator. (See oscillogram.)

Stability: With external-drive terminals short-circuited, prf jitter and pulse-duration jitter are each 0.04%. (Jitter figures may vary somewhat with range switch settings, magnetic fields, etc.)

Power Required: 105 to 125, 195 to 235, or 210 to 250 V, 50 to 60 c/s, 90 W.

Accessories Available: TYPE 1217-P2 Single-Pulse Trigger (see page 164), rack-adaptor panel.

MECHANICAL DATA Convertible-Bench Cabinet (see page 258)

Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
12	305	5 1/4	135	8 1/4	210	14 1/2	7.0	18	8.5

AVAILABLE 4th QUARTER 1965

Catalog Number	Description	Price
1398-9701	Type 1398-A Pulse Generator	\$535.00
0480-9632	Type 480-P312 Relay-Rack Adaptor Panel	6.50

NEW

in catalog S





Type 1396-A TONE-BURST GENERATOR

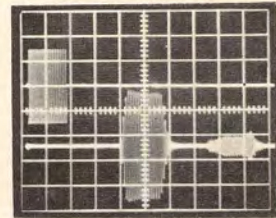
FEATURES:

Functions as a phase-coherent gate for any input waveform. Alternately passes and blocks a selected number of cycles of any input frequency from dc to 500 kc/s.
 Number of cycles in each burst and interval between bursts are individually adjustable.
 Starting and stopping point of the burst is adjustable.

USES: The TYPE 1396-A Tone-Burst Generator is the first commercial instrument of its kind; it provides an instrumentation bridge for the gap between continuous-wave testing and step-function, or pulse, testing. It is ideally suited for applications such as the test and calibration of sonar transducers and amplifiers, the measurement of distortion and transient response of amplifiers and loudspeakers, and routine testing of filters and ac meters. Still other uses are found in the measurement of room acoustics and automatic-gain-control circuits, in the synthesis of time ticks on standard-time radio transmissions, and in psychoacoustic instrumentation.

DESCRIPTION: A binary scaler is used to establish both the number of cycles in a burst and the time duration between bursts. Separate front-panel controls select the number of cycles of the timing-input signal during which the gate will be opened and closed. Additional features of the Tone-Burst Generator are a switch that holds the gate open for preliminary

Typical waveform produced by the Type 1396-A/Type 1308-A combination with a 15-kc signal turned on for 16 cycles and off for one-half second. Upper trace shows input to sonar projector; lower trace shows output from projector and subsequent echo return from wall of test tank.



alignment of external equipment (if necessary); trigger controls, which allow control of the relative phase of the gate and input signal; the ability to use separate input signals for the gate timing and gated signals; and a timed mode for extremely long periods between bursts.

The Tone-Burst Generator is also useful with pulse and aperiodic signals. If pulses are applied to its input, the TYPE 1396-A performs as a word generator or a frequency divider.

SPECIFICATIONS

SIGNAL INPUT (signal to be gated)

Frequency Range: dc to 500 kc/s.

Maximum Voltage Level: ± 7 V (5 V, rms).

Input Impedance: Approximately 10 k Ω .

TIMING SIGNAL (signal that controls gate timing)

Frequency Range: dc to 500 kc/s.

Maximum Voltage Level: ± 10 V.

Minimum Voltage Level: 1 V, p-to-p.

Input Impedance: Approximately 7 k Ω .

Triggering: Slope selectable, trigger level adjustable from -7 to $+7$ V.

GATE TIMING: Gate-open and -closed intervals can be independently set to 2, 4, 8, 16, 32, 64, or 128 cycles (periods) of timing signal. By means of a MINUS ONE switch, intervals can be set to 1, 3, 7, 15, 31, 63, or 127 cycles. The gate-closed intervals can also be timed in increments of one period of timing signal from 1 ms to 10 s. Fixed timing errors are less than 0.5 μ s.

GATED SIGNAL OUTPUT

Gate-Open Output: Maximum signal level is ± 7 V. Total distortion is less than -60 dB (compared to maximum level) at 1 kc/s and 10 kc/s.

Gate-Closed Output: Less than 140 mV, p-to-p, (-40 dB) with maximum signal input.

Pedestal Output (dc potential difference between open- and closed-gate output): Can be nulled from front panel. Less than 50-mV change with line voltage.

Switching Transients: Less than 140 mV, p-to-p, (-40 dB compared to maximum signal input), with 120-pF load.

Output Impedance: 600 Ω .

Gating Voltage Output (signal for triggering oscilloscope): Rectangular waveform of approximately $+12$ V at 10-k Ω source when the gate is closed and approximately -12 V at 20 k Ω when the gate is open.

GENERAL

Ambient Operating Temperature: 0 to 50°C (32° to 122°F).

Power Required: 105 to 125, 195 to 235, or 210 to 250 V, 50 to 400 c/s, 15 W, approximately.

Accessories Supplied: TYPE CAP-22 Power Cord.

Accessories Required: External source for any desired frequency range between 0 and 500 kc/s.

Accessories Available: Relay-rack adaptor set (panel height 5 $\frac{1}{4}$ in).

MECHANICAL DATA Convertible-Bench Cabinet (see page 258)

Width		Height		Depth		Net Wt		Ship Wt	
in	mm	in	mm	in	mm	lb	kg	lb	kg
8	205	5 $\frac{7}{8}$	150	7 $\frac{1}{2}$	195	6 $\frac{1}{2}$	3	9	4.1

See also *General Radio Experimenter*, May 1964.

Catalog No.	Description	Price
1396-9701	Type 1396-A Tone-Burst Generator	\$490.00
0480-9638	Type 480-P308 Relay-Rack Adaptor Set	7.00



NEW

in catalog 5



VARIABLE DELAY LINES

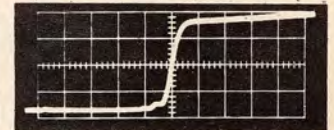
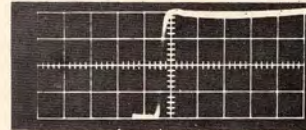
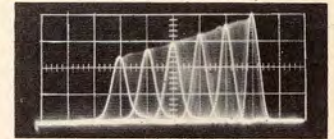
Type 314-S86 VARIABLE DELAY LINE 0 TO 0.5 μ s

This variable delay line finds general application as a wide-band phase-shifting device, particularly when it is desired to delay a wide-band signal without the introduction of phase distortion.

Good transient response is obtained by a skewed-turn method of delay equalization. The "baseline ripple," caused by variation in characteristic impedance along the line, has been reduced to 5% or less of the signal amplitude. End reflections have been minimized by the use of tapered capacitance elements at the ends of the winding. Materials are chosen for reliable operation under varying conditions of temperature and humidity.

There is no "ringing" or overshoot, and the delay is constant over a wide frequency range.

Oscillogram showing pulse shape and amplitude as delay setting is varied. Tektronix 541 Oscilloscope, 53K/54K Pre-Amplifiers; sweep, 0.1 μ s/cm.



Step response of 0.5- μ s, 200- Ω variable delay line with skewed winding; (left) step input, (right) step output at 0.5- μ s delay. Scope photos taken on Tektronix 541 Oscilloscope, 0.1- μ s/cm sweep.

SPECIFICATIONS

- Delay Range:** 0 to 0.5 μ s ($\pm 10\%$).
- Characteristic Impedance:** 200 Ω , $\pm 15\%$ up to 4.5 Mc/s.
- Dc Resistance:** Not over 20 Ω .
- Delay vs Frequency (with respect to delay at 1 Mc/s):** $\pm 1\%$ at 10 Mc/s; $\pm 2\%$ at 15 Mc/s; $\pm 4\%$ at 20 Mc/s measured at maximum delay.
- Amplitude Response vs Frequency:** Loss at max delay, 9% (0.8 dB) at dc; 30% (3 dB) at 6 Mc/s; 60% (8 dB) at 10 Mc/s; 90% (20 dB) at 25 Mc/s.
- Pulse and Step Response:** See accompanying oscillograms.
- Resolution:** 1 ns.
- Voltage Rating:** 1500 V, peak, winding to ground.

- Dimensions:** Diameter, including terminals, 3 $\frac{1}{4}$ in (83 mm); depth 1 $\frac{1}{2}$ in (39 mm), exclusive of shaft; shaft diameter $\frac{3}{8}$ in (10 mm); shaft extends beyond body $\frac{3}{4}$ in (20 mm). Knob is furnished.
- Net Weight:** 6 oz (0.2 kg).
- Shipping Weight:** 1 lb (0.5 kg).

See also *General Radio Experimenter*, October 1956.

Catalog No.	Description	Price
0314-9917	Type 314-S86 Variable Delay Line	\$60.00

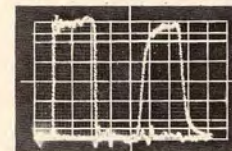
PATENT NOTICE. See Note 20, page 11.

Type 301-S104 VARIABLE DELAY LINE

0 TO 25 ns

The TYPE 301-S104 Variable Delay Line is a small distributed-winding unit with a sliding tap for adjustment of delay. Precious-metal wire is used in the winding to ensure reliable contact. Capacitive coupling between the terminals is minimized by shielding.

Applications for this line will be found in such fields as computers, nuclear physics, radar, and any place where an adjustable, linear phase shifter or wide-band, pulse-delay network is useful.



Photograph taken from the screen of a Lumatron 112 oscilloscope. The sweep speed is 5 ns/cm. The photograph shows two sweeps superposed, the first with the delay line set for minimum delay, and the second trace with the line set for maximum delay. Delay, rise time, baseline ripple, and pulse distortion can be measured from the photograph. Attenuation may differ slightly among units.

SPECIFICATIONS

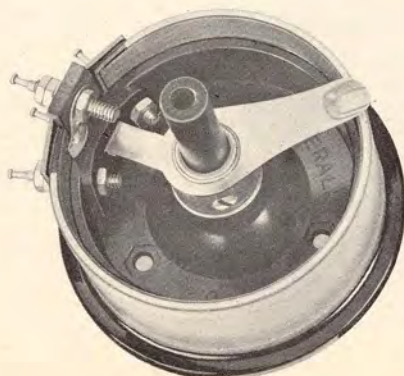
- Delay Range:** 0 (approximately) to 25 ns ($\pm 10\%$).
- Resolution:** 0.06 ns.
- Characteristic Impedance:** 190 Ω $\pm 15\%$.
- Pulse Rise Time:** 2.4 ns (approx) at maximum delay.
- Dc Resistance:** 5.5 Ω ($\pm 20\%$).
- Voltage Rating:** 1500 V, peak, winding to ground.
- Dimensions:** Diameter, including terminals, 2 in (51 mm); thickness, exclusive of shaft, 15/16 in (24 mm); shaft diameter, $\frac{1}{4}$ in

- (7 mm); shaft extension beyond body $\frac{3}{4}$ in (20 mm).
- Net Weight:** 1 $\frac{1}{2}$ oz (43 g).
- Shipping Weight:** 1 lb (0.5 kg).

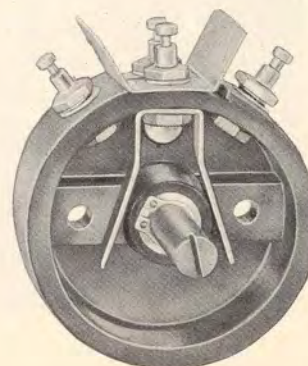
See also *General Radio Experimenter*, October 1961.

Catalog No.	Description	Price
0301-9489	Type 301-S104 Variable Delay Line	\$48.00

TYPE 314-S86



TYPE 301-S104



NOISE GENERATOR



Electrical noise is, by definition, an unwanted disturbance, and its reduction in communication circuits is a constant aim of the electronics engineer. When supplied by a properly controlled generator, however, noise becomes a remarkably useful test signal, which has, for many measurements, properties that are more useful than those of a single-frequency signal.

Broad-band electrical noise is often called random noise, because it has a random, or Gaussian, distribution of amplitudes as a function of time. When used as a test signal, it

also usually has a uniform spectrum level over its specified frequency range. The random-noise signal, embracing a wide range of frequencies and having a randomly varying instantaneous amplitude, closely approximates the signals normally encountered in many electronic circuits and particularly in busy communication systems. The General Radio Type 1390-B Random-Noise Generator provides a high level of random electrical noise at its output terminals, and its many possible uses make it an indispensable item in the equipment of the modern electronics laboratory.

Type 1390-B RANDOM-NOISE GENERATOR

5 c/s TO 5 Mc/s

FEATURES:

Wide frequency range — 5 c/s to 5 Mc/s. ■ Uniform spectrum level over audio range. Output variable from 30 microvolts to 3 volts. ■ Built-in attenuator. Low hum level by use of dc heater supply. ■ Low external noise field. Regulated heater for gas tube stabilizes output level.

USES: This instrument generates wide-band noise of uniform spectrum level, particularly useful for noise and vibration testing in electrical and mechanical systems. Some of its many uses are:

AS A BROAD-BAND SIGNAL SOURCE FOR

- intermodulation and cross-talk tests.
- simulation of telephone-line noise.
- measurements on servo amplifiers.
- noise interference tests on radar.
- determining meter response characteristics.
- setting transmission levels in communication circuits.
- frequency-response measurements. When the random-noise generator is used for frequency-response measurements, either the TYPE 1900-A Wave Analyzer or the TYPE 1564-A Sound and Vibration Analyzer is a satisfactory narrow-band detector. The one-third-octave band of the latter permits measurements to very low frequencies. With the TYPE 1521-B Graphic Level Recorder, continuous records of level vs frequency can be plotted from the output of the analyzer.

AS A SIGNAL SOURCE FOR MEASUREMENTS OF

- reverberation. The TYPE 1900-A Wave Analyzer and the TYPE 1564-A Sound and Vibration Analyzer

can be used with this generator to produce narrow bands of noise for acoustical measurements.

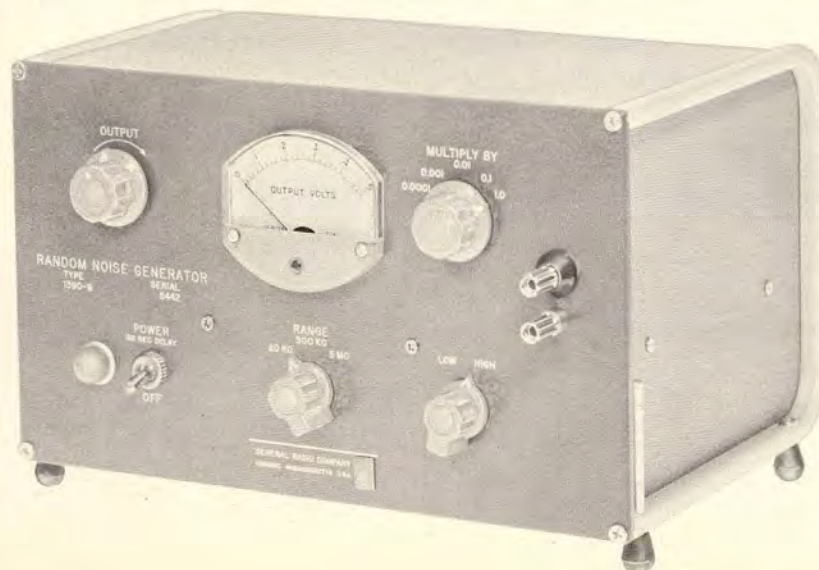
- sound attenuation of ducts, walls, panels, or floors.
- acoustical properties of materials.
- room acoustics.
- and for classroom or laboratory demonstrations.

WITH A SUITABLE POWER AMPLIFIER

- to drive a loudspeaker to produce high-level acoustic noise for fatigue testing of structures or components.
- to drive a vibration shaker for structural tests of components or assemblies.

DESCRIPTION: A gas-discharge tube, with a transverse magnetic field applied, is used as a noise source in this instrument. The noise output of the tube is amplified in a two-stage amplifier. Between the two stages, the noise spectrum is shaped with low-pass filters to provide ranges to 20 kc/s, to 500 kc/s, and to 5 Mc/s.

The output system consists of a continuous attenuator control followed by a 4-step attenuator of 20 dB per step. Metered levels from over 3 volts to below 30 microvolts are conveniently obtained. When the attenuator is used, the output impedance remains essentially constant as the output level is adjusted.



NOISE GENERATOR

SPECIFICATIONS

Frequency Range: 5 c/s to 5 Mc/s.

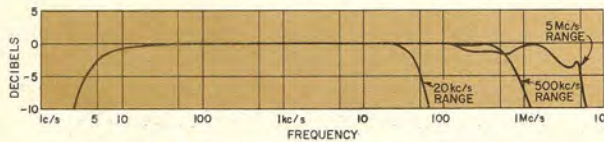
Output Voltage: Maximum open-circuit output is at least 3 V for 20-kc range, 2 V for 500-kc range, and 1 V for 5-Mc range.

Output Impedance: Source impedance for maximum output is approximately 900 Ω . Output is taken from a 2500- Ω potentiometer. Source impedance for attenuated output is 200 Ω . One output terminal is grounded.

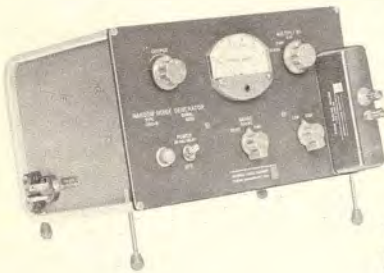
Range	Typical Spectrum Level (with 1-V, rms, output)	Spectrum Level Uniformity*
20 kc/s	5 mV for 1-cycle band	within ± 1 dB, 20 c/s to 20 kc/s
500 kc/s	1.2 mV for 1-cycle band	within ± 3 dB, 20 c/s to 500 kc/s
5 Mc/s	0.6 mV for 1-cycle band	within ± 3 dB, 20 c/s to 500 kc/s; within ± 8 dB, 500 kc/s to 5 Mc/s

*Noise energy also present beyond these limits. Level is down 3 dB at 5 c/s. See plot.

Waveform: Noise source has good normal, or Gaussian, distribution of amplitudes for ranges of the frequency spectrum that are



Typical spectrum-level characteristics.



View of the noise generator with pink-noise filter plugged into the output terminals.

Type 1390-P2 PINK-NOISE FILTER

narrow compared to the band selected. Over wide ranges the distribution is less symmetrical because of dissymmetry introduced by the gas tube. Some clipping occurs on the 500-kc and 5-Mc ranges.

Voltmeter: Rectifier-type averaging meter measures output. It is calibrated to read rms value of noise.

Attenuator: Multiplying factors of 1.0, 0.1, 0.01, 0.001, and 0.0001. Accurate to $\pm 3\%$ to 100 kc/s, within $\pm 10\%$ to 5 Mc/s.

Power Required: 105 to 125 or 210 to 250 V, 50 to 400 c/s, 50 W.

Accessories Supplied: TYPE CAP-22 Power Cord, spare fuses.

Accessories Available: Rack-adaptor panel (panel height 7 in.).

Mechanical Data: Convertible-Bench Cabinet (see page 258)

Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
12 3/4	325	7 1/2	190	9 3/4	250	12	5.5	16	7.5

For additional information, ask for General Radio Reprint E-110.

Catalog No.	Description	Price
1390-9702	Type 1390-B Random-Noise Generator	\$295.00
0480-9642	Type 480-P412 Relay-Rack Adaptor Set	7.00

PATENT NOTICE. See Note 15, page 11.

SPECIFICATIONS

Frequency Response: Sloping -3 dB per octave from 20 c/s to 20 kc/s, -6 dB per octave above 20 kc/s. Output voltage is approximately -5 dB with respect to the input voltage at 20 c/s and -35 dB at 20 kc/s. It lies within 1 dB of the straight line connecting these two points on a graph of output in decibels vs log frequency.

Over-all Output Level: When the filter is used with the random-noise generator set for the 20-kc range, the output voltage of the filter is approximately 30 dB below its input, and the voltage level in each one-third-octave band is approximately 17 dB below that. Thus, when the output meter of the generator indicates 3 V, the output of the filter is approximately 0.1 V, and the level in each one-third-octave band is approximately 15 mV.

Input Impedance: The filter should be driven from a source whose impedance is 1 k Ω or less. Input impedance is variable from 6.5 k Ω + load resistance at zero frequency to 6.7 k Ω at high frequencies.

Output Impedance: The filter should not be operated into a load of less than 20 k Ω . Internal output impedance is variable from 6.5 k Ω + source resistance at low frequencies to approximately 200 Ω at high frequencies.

Input Voltage: 15 V, rms, max.

Terminals: Input terminals are recessed banana pins on 3/4-in spacing at rear of unit. Output terminals are jack-top binding posts with 3/4-in spacing.

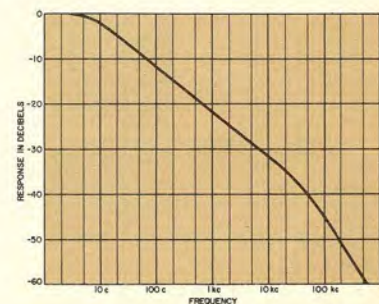
Dimensions: Width 1 3/8, height 5, depth 2 7/8 in (35, 127, 73 mm), over-all.

Net Weight: 6 oz (0.2 kg).

Shipping Weight: 4 lb (1.9 kg).

Catalog No.	Description	Price
1390-9602	Type 1390-P2 Pink-Noise Filter	\$45.00

Response-frequency characteristic of the pink-noise filter.





METERS



Described in this section are a vacuum-tube voltmeter usable up into the gigacycle range, measuring also dc volts and resistance; an electrometer instrument measuring dc millivolts, femtoamperes, and teraohms; and a new output power meter for audio frequencies. The ranges of these instruments, collectively, cover most of the magnitudes usually encountered in the electronics laboratory.

VOLTMETER

The high-vacuum rectifier was first used as a voltmeter to measure power-system voltages.¹ The combination of rectifier and degenerative dc amplifier was introduced by General Radio in 1937.² The modern descendant of that pioneer instrument is the Type 1806-A Electronic Voltmeter, which surpasses in frequency range and accuracy the best of previously available types. It has also many other features that contribute to operating convenience and over-all utility — high input impedance, logarithmic meter scale, excellent zero stability, and a small high-frequency probe with a variety of connector accessories.

ELECTROMETER

The Type 1230-A Electrometer and DC Amplifier is a high-stability, direct-coupled amplifier, which can be used not only for direct-reading measurements of small voltages and currents and high resistances but also for amplifying weak currents and voltages to operate recorders, relays, and other equipment.

Electronic Voltmeter, Rack Model



OUTPUT POWER METER

The output power meter, an original General Radio development,³ is now available for use over wider ranges than ever before. This indispensable laboratory and test-bench device measures power into an adjustable resistive load and thus can determine both the maximum power output and the internal impedance of oscillators and amplifiers.

¹ C. H. Sharp and C. D. Doyle, "Crest Voltmeters," *Trans. AIEE*, Vol 35, February, 1916, pp 99-107.

² W. N. Tuttle, "TYPE 726-A Vacuum-Tube Voltmeter," *General Radio Experimenter*, May, 1937.

³ "A Direct-Reading Meter for Power and Impedance Measurements," *General Radio Experimenter*, November, 1932.

Output Power Meter



Electronic Voltmeter, Portable Model



Electrometer



IN THIS SECTION

Type	Name	Quantity Measured	Range of Measurement	Nominal Frequency Range	Basic Accuracy	Remarks	Page
1806-A, -AR	Electronic Voltmeter	Ac Voltage	0.1 to 1500 V	20 c/s to 1.5 Gc/s	± 2% of indication	2 models, portable and rack	172
		Dc Voltage	0.005 to 1500 V	dc	± 2% of indication		
		Resistance	0.2 Ω to 10 ⁹ Ω		± 5% of indication		
1230-A, -AE	Electrometer and DC Amplifier	Voltage	0.5 mV to 10 V	dc	± 2% of full scale	Also a sensitive amplifier	174
		Current	5 × 10 ⁻¹⁵ A to ± 10 ⁻⁸ A		± 3% of full scale		
		Resistance	3 × 10 ⁵ Ω to 5 × 10 ¹⁴ Ω		± 3% at full scale		
1840-A	Output Power Meter	Power	0.1 mW to 20 W	20 c/s to 20 kc/s	± 0.5 dB at mid-range		176
Impedance	0.6 Ω to 32 kΩ	± 6% at mid-range					

IN OTHER SECTIONS

1932-A	Distortion and Noise Meter	Distortion	0.1% to 30%	50 c/s to 18 kc/s, (harmonics and noise to 55 kc/s)	± 5% of full scale	Excellent for signal-to-noise ratio measurement	35
		Noise Level	-10 to -80 dB				
1900-A	Wave Analyzer	Voltage	30 μV to 300 V	20 c/s to 54 kc/s	± (3% + 2% of full scale + 3 μV)	3, 10, and 50-cycle bandwidths	28
1564-A	Sound and Vibration Analyzer	Voltage	0.1 mV to 30 V	2.5 c/s to 25 kc/s	± 5% of full scale		30
1862-C	Megohmmeter	Resistance	5 × 10 ⁵ to 2 × 10 ¹² Ω	dc	3% to 12%	500 V and 100 V	75
546-C	Microvolter	Voltage	0.5 μV to 1 V	20 c/s to 20 kc/s	± (3% + 0.5 μV)	For use with oscillator as a calibrated source	38
				up to 100 kc/s	± 5% above 0.1 V		
874-VR 874-VI	Voltmeter Rectifier Voltmeter Indicator	Voltage	0.1 to 2 V	15 Mc/s to 2.5 Gc/s	± 0.05 V	Substitution measurement	86



Type 1806-A ELECTRONIC VOLTMETER

FEATURES:

- Measures ac and dc voltages, and resistance.
- High accuracy: $\pm 2\%$ of indicated value over most of the range.
- Wide frequency range — up to 1500 Mc/s.
- Measures up to 1500 volts in only four ranges, each with a 10-to-1 span.
- A single scale for all voltages, except the lowest ac range.
- Small ac probe for easy connection to small components.
- Meter has taut-band suspension.
- An internal socket and reel store the probe and its cable.

USES: This versatile instrument is indispensable in the modern electronics laboratory. It will measure dc voltage from millivolts to 1500 volts; with "open-grid" impedance, up to 150 volts. It will measure ac voltage from 0.1 to 1500 volts. A small probe allows convenient connection to circuit points for high-frequency measurements up to 150 volts, or up to 1500 volts with the new TYPE 1806-P2 Range Multiplier. The probe can be used with the TYPE 1806-P1 Tee Connector to measure voltage on a closed coaxial system at frequencies up to 1500 Mc/s. As an ohmmeter, the TYPE 1806-A will measure resistance from 0.2 ohm to 1000 megohms.

DESCRIPTION: The heart of this instrument is a new, highly stable, tube-and-transistor, dc amplifier. Its

balanced circuit and regulated heater voltages provide zero stability. Calibration stability is excellent because there is so much feedback that changes in tube transconductance or transistor current gain have negligible effect. For measurement of ac voltages, a ceramic thermionic diode with extremely short electron transit time is used in a small, convenient probe with a variety of connector accessories.

The small physical size and close electrode spacing of the diode give it a high resonant frequency and low transit time, both of which contribute to the excellent high-frequency performance.

This instrument is available in both a portable bench model and a relay-rack model. The panel of the portable model can be adjusted to any desired angle for convenient viewing.

SPECIFICATIONS

DC VOLTMETER

Voltage Range: Four ranges, 1.5, 15, 150, and 1500 V, full scale, positive or negative. Minimum reading is 0.005 V.

Input Resistance: 100 M Ω , $\pm 5\%$; also "open grid" on all but the 1500-V range. Grid current is less than 10^{-10} A.

Accuracy: $\pm 2\%$ of indicated value from one-tenth of full scale to full scale; $\pm 0.2\%$ of full scale from one-tenth of full scale to zero. Scale is logarithmic from one-tenth of full scale to full scale, permitting constant-percentage readability over that range.

AC VOLTMETER

Voltage Range: Four ranges, 1.5, 15, 150, and 1500 V, full scale. Minimum reading on most sensitive range is 0.1 V.

Input Impedance: Probe, approximately 25 M Ω in parallel with 2 pF; with TYPE 1806-P2 Range Multiplier, 2500 M Ω in parallel with 2 pF; at binding post on panel, 25 M Ω in parallel with 30 pF.

Accuracy: At 400 c/s, $\pm 2\%$ of indicated value from 1.5 V to 1500 V; $\pm 3\%$ of indicated value from 0.1 V to 1.5 V.

Waveform Error: On the higher ac-voltage ranges, the instrument operates as a peak voltmeter, calibrated to read rms values of a sine wave or 0.707 of the peak value of a complex wave. On distorted waveforms the percentage deviation of the reading from the rms value may be as large as the percentage of harmonics present. On the lowest range the instrument approaches rms operation.



Portable model, Type 1806-A.

Frequency Characteristic: Low-frequency roll-off is less than 3% at 20 c/s. Above 150 V with internal voltage divider, there is an additional error of not more than $\pm 2\%$ for frequencies below 500 kc/s.

Probe resonant frequency is above 3000 Mc/s. Above several hundred megacycles per second, probe should be used in a 50- Ω coaxial system with the TYPE 1806-P1 Tee Connector. Low-frequency roll-off is then less than 3% at 1 kc/s. At high frequencies and low voltages, the error is a function of input voltage level, owing to transit-time effects, as shown in the accompanying plot. Total error is less than ± 3 dB below 1500 Mc/s.

Low-frequency roll-off of the combined voltmeter and multiplier is less than 3% at 10 kc/s. At high frequencies, the multiplier does not affect the over-all voltmeter response.

OHMMETER

Range: 0.2 Ω to 1000 M Ω in four ranges with center scale values of 10 Ω , 1 k Ω , 100 k Ω , and 10 M Ω .

Test Voltage: The dc test voltage is positive and never exceeds 1.5 V. The maximum current (which is delivered to a short circuit on the lowest resistance range) is approximately 43 mA. The maximum available power from the ohmmeter circuit is 16 mW.

Accuracy: $\pm 5\%$ of indicated value from 1 to 10 on scale, approaching $\pm 10\%$ of indicated value at 100 on scale.

GENERAL

Power Required: 105 to 125 or 210 to 250 V, 50 to 400 c/s, 20 W approximately. The case is grounded by the third wire in the power cord. The voltmeter circuit can be disconnected from the case and operated as much as 300 V dc off ground. The low input terminal remains by-passed to the case.

Type 1806-P1 TEE CONNECTOR

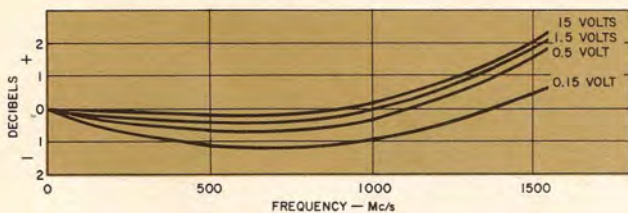
A necessary attachment to the ac probe to realize the full 1500-Mc frequency range of the voltmeter. Screws onto the probe in place of the probe tip.

VSWR: The vswr of the tee connector and probe is less than 1.1 below 1000 Mc/s.

Connectors: Locking GR874 Connectors are used. Adaptors to other coaxial systems are available (see page 81).

Dimensions: 4 by 1 by 1 $\frac{1}{8}$ in (102, 25, 28 mm).

Net Weight: 3 $\frac{1}{2}$ oz (100 g). **Shipping Weight:** 1 lb (0.5 kg).



Rack model, Type 1806-AR.

Probe Storage: A socket and reel store both probe and cable.

Accessories Supplied: Spare fuses, CAP-22 Power Cord (on rack model only), an assortment of probe tips for various types of connections.

MECHANICAL DATA Flip-Tilt Case (see page 258)

Model	Width		Height		Depth		Net Weight		Shipping Weight	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Portable	7 $\frac{1}{2}$	190	8 $\frac{1}{2}$	220	11 $\frac{1}{2}$	295	10	4.6	13	6
Rack	19	485	5 $\frac{1}{4}$	135	9 $\frac{1}{4}$ *	235	10	4.6	17	8

* Behind panel.

For a more detailed description, see *General Radio Experimenter*, July 1963.

Type 1806-P2 10:1 RANGE MULTIPLIER

This is a capacitive voltage divider, which screws onto the ac probe in place of the probe tip. It permits direct use of the probe to 1500 volts ac, and the voltage applied to the probe is one-tenth of that applied to the multiplier.

Multiplication Ratio: 10:1 $\pm 5\%$. An adjustment is provided for matching the multiplier to the voltmeter within $\pm 2\%$.

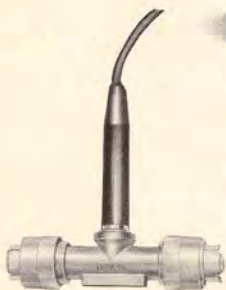
Input Impedance: Equivalent input resistance of the probe-multiplier combination is 100 times that of the probe alone. Equivalent parallel capacitance is approx 2 pF.

Dimensions: $\frac{5}{8}$ in dia by 1 $\frac{1}{4}$ in long (16, 32 mm).

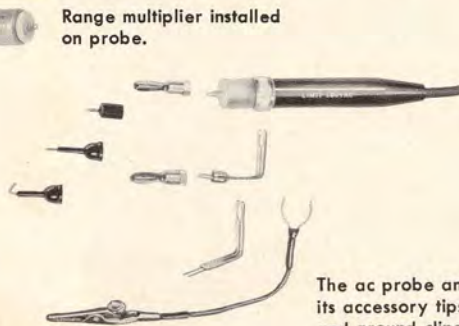
Net Weight: $\frac{1}{2}$ oz (15 g). **Shipping Weight:** 3 oz (85 g).

Typical high-frequency response characteristics of the probe and tee connector operating in a 50-ohm system.

Catalog Number	Description	Price
1806-9701	Type 1806-A Electronic Voltmeter, Portable Model	\$490.00
1806-9811	Type 1806-AR Electronic Voltmeter, Rack Model	490.00
1806-9601	Type 1806-P1 Tee Connector	35.00
1806-9602	Type 1806-P2 10:1 Range Multiplier	20.00



Type 1806-P1

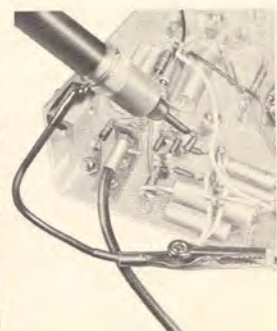


Range multiplier installed on probe.

The ac probe and its accessory tips and ground clips.



Various methods of using the ac probe with different combinations of the tips and ground clips supplied.





Type 1230-A ELECTROMETER AND DC AMPLIFIER

FEATURES:

- Extremely high input resistance, even in humid environment.
- High sensitivity and excellent stability.
- Shielded input circuits and component shield permit shielding to be extended to the unit under test.
- Guard terminals — the low-potential input terminal can be grounded or floating.
- Large meter with two voltage scales and two resistance scales.
- Output terminals for connecting an external meter, oscilloscope, or recorder.
- Amplifies weak de voltages for recording and control.

USES: The Electrometer and DC Amplifier has a wide variety of applications in physics, chemistry, engineering, and industry. Typical uses include the measurement of

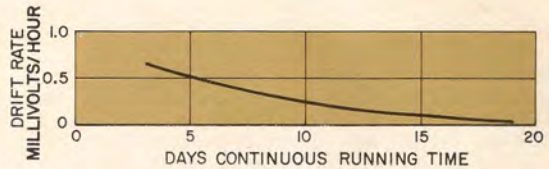
Currents: Ionization currents, photo currents, grid currents in electron tubes, leakage currents in semiconductors and insulators, and time-current curves of capacitors during charge and discharge.

Voltages: Piezoelectric potentials, bioelectric potentials, contact potentials, electrostatic-field potentials, and PH indications.

Resistances: Back resistance of silicon-junction diodes, insulation resistance of electrical equipment, and voltage coefficient of resistance.

DESCRIPTION: The Electrometer and DC Amplifier is basically a millivoltmeter with a three-stage, direct-coupled amplifier that acts as a highly degenerated cathode follower with high over-all transconductance. It measures *voltage* (0.5 millivolt to 10 volts) directly; *current* (5×10^{-15} to 10^{-3} amperes) in terms of the voltage drop across a standard resistor; and *resistance* (3×10^5 to 5×10^{14} ohms) directly.

To achieve a high degree of stability, all power-supply voltages are regulated, and all components are carefully selected and pre-aged. Chassis and subassemblies are



Typical drift after tubes are changed.

shockmounted. See graph for typical drift characteristics.

For high input resistance, unaffected by humidity, the input grid lead of the electrometer tube is enclosed in silicone-treated glass. The input-resistance selector has switch contacts that are mounted on individual Teflon* bushings set in a metal base that connects to a guard point.

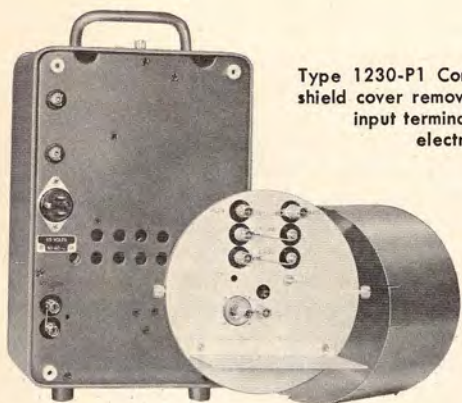
A completely shielded chamber, the TYPE 1230-P1 Component Shield, is available as an accessory within which the components to be measured can be conveniently connected.

The Esterline-Angus (or equivalent) 5-milliamperere graphic recorder is recommended. The TYPE 1230-AE model has a matching Esterline-Angus case. More sensitive recorders, such as the TYPE 1521 Graphic Level Recorder, can be shunted for 5-milliamperere operation.

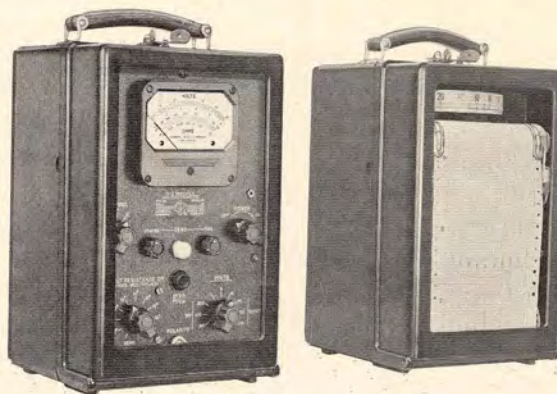
* Registered trademark of the E. I. duPont de Nemours and Company.

FOR VOLTAGE, CURRENT, AND RESISTANCE MEASUREMENTS





Type 1230-P1 Component Shield (with shield cover removed) plugged into the input terminal at the rear of the electrometer.



Type 1230-AE Electrometer and DC Amplifier with a recorder.

SPECIFICATIONS

RANGES OF MEASUREMENT

Voltage: ± 30 , 100, and 300 mV, ± 1 , 3, and 10 V, dc, full scale.

Current: ± 1 mA (10^{-3} A) dc, full scale, to ± 300 fA (3×10^{-13} A) full scale.

Resistance: Direct reading from 300 k Ω to 10 MM Ω (10^{13} Ω) full scale (5×10^{14} Ω at smallest meter division). There are 16 ranges, two per decade. Voltage across the unknown resistance is 9.1 V.

Extensions of Range: With batteries, or other suitable external supply, the resistance range can be extended, the voltage across the unknown can be increased, and the voltage coefficient of resistors can be measured.

With a 300-V battery, the highest resistance range is 10^{15} Ω full scale (6×10^{16} Ω at the smallest meter division). The full battery voltage appears across the unknown resistance. The maximum permissible voltage is 600 V if the external supply is grounded; somewhat greater if ungrounded.

ACCURACY

Voltage: $\pm 2\%$ of full scale on the five highest ranges, $\pm 4\%$ of full scale on the 30-mV range.

Current: $\pm 3\%$ of full scale from 10^{-3} to 10^{-9} A, $\pm 10\%$ of full scale from 3×10^{-10} to 3×10^{-13} A.

Resistance: $\pm 3\%$ from 3×10^5 to 10^{10} Ω at full scale (low-resistance end), $\pm 8\%$ from 3×10^{10} to 10^{13} Ω .

Resistance Standards: 10^4 , 10^5 , 10^6 , 10^7 , 10^8 , 10^9 , 10^{10} , and 10^{11} Ω . The switch also includes zero and infinity positions. The 10^4 - and 10^5 - Ω resistors are wire wound and are accurate to $\pm 0.25\%$. The 10^6 -, 10^7 -, and 10^8 - Ω resistors are of deposited-carbon construction and are accurate to $\pm 1\%$. The 10^9 -, 10^{10} -, and 10^{11} - Ω resistors are carbon, have been treated to prevent adverse humidity effects, and are accurate to $\pm 5\%$. A switch position permits quick checking of the higher-resistance standards in terms of the wire-wound units.

INPUT

Resistance: The input resistance is determined by the setting of the resistance standards switch. In the infinity position, it is approximately 10^{14} Ω .

Capacitance: Less than 35 pF.

Terminals: The input is connected through a GR874 coaxial terminal assembly at the rear of the instrument. In addition, there are

three low terminals to provide versatility in guard and ground connections, as required, for example, in three-terminal network measurements. These are low-thermal-emf binding posts.

Switch: A panel switch permits disconnection of the unknown without transient electrical disturbances in either the unknown or the measuring circuit.

Insulation: Entirely Teflon or silicone-treated glass.

OUTPUT

Indication: Voltage, current, and resistance are indicated on a panel meter.

Recorder: Terminals are available for connecting a recorder (such as the Esterline-Angus 5-mA or 1-mA graphic recorder).

AMPLIFIER CHARACTERISTICS

Maximum Transconductance: 167 m Ω (for 30-mV input, the output current is 5 mA).

Output Load: Maximum allowable recorder resistance is 1500 Ω .

Drift: Less than 2 mV per hour after one-hour warmup.

FREQUENCY CHARACTERISTICS

With a 1500- Ω load at the output terminals, the frequency characteristic is flat within 5% from zero to 10, 30, 100, 300, 1000, and 3000 c/s at the 30-, 100-, 300-mV, 1-, 3-, and 10-V ranges, respectively.

GENERAL

Humidity, Line-Voltage Effects: Negligible.

Accessories Supplied: One adaptor to GR874 Connector, one panel-adaptor assembly, one TYPE 274-SB Plug, TYPE CAP-22 Power Cord, and spare fuses.

Accessories Available: TYPE 1230-P1 Component Shield, TYPE 1521-B Graphic Level Recorder.

Power Required: 105 to 125, 195 to 235, or 210 to 250 V, 50 to 60 c/s, approximately 45 W. Instruments will operate satisfactorily on power-supply frequencies up to 400 c/s.

MECHANICAL DATA Lab-Bench Cabinet (see page 258)

Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
7 $\frac{7}{8}$	195	13 $\frac{1}{4}$	340	9	230	15 $\frac{1}{4}$	7	24	11

Catalog Number	Description	Price
1230-9701	Type 1230-A Electrometer and DC Amplifier	\$460.00
1230-9816	Type 1230-AE Electrometer and DC Amplifier (in Esterline-Angus Case)	540.00
1230-9601	Type 1230-P1 Component Shield	40.00

PATENT NOTICE. See Notes 4 and 15, page 11.



Type 1840-A OUTPUT POWER METER

FEATURES:

- Wide frequency response — 20 c/s to 20 kc/s.
- Rms indication — reads rms with harmonics up to 20%.
- 48 different impedances — 0.6 ohm to 30 kilohms.
- Measures power from 0.1 milliwatt to 20 watts.

USES: The TYPE 1840-A Output Power Meter measures audio-frequency power into any desired load. Its important uses include the measurement of:

Power output of oscillators, amplifiers, preamplifiers, transformers, transducers, and low-frequency lines.

Output impedance, by adjustment of the load seen by the device under test to yield maximum power indication on the meter.

Frequency-response characteristics of amplifiers, transformers, and other audio-frequency devices.

DESCRIPTION: This instrument is basically a multi-tapped audio-frequency transformer with a fixed secondary load. Its two front-panel load switches connect eight identical primary windings and six secondary taps in various combinations to provide a total of 48 different primary impedances.

The use of grain-oriented silicon steel in a laminated core yields a 20-watt rating with a relatively small core. The range can be extended to 200 watts for any particular impedance with the addition of a simple T-network attenuator. Details are given in the instruction book.

SPECIFICATIONS

RANGES

Power: 0.1 mW to 20 W, except as noted on the accompanying derating curves and table. Auxiliary dB scale reads from -15 to +43 dB re 1 mW.

Impedance Setting of Type 1840-A						
Ohms	0.6	0.8	1	1.25	1.6	2
	2.5	3.12	4	5	6.4	8
	10	12.5	16	20	25	32
	40	50	64	80	100	128
Kilohms	0.15	0.2	0.25	0.312	0.4	0.5
	0.6	0.8	1	1.25	1.6	2
	2.5	3.12	4	5	6.4	8
	10	12.5	16	20	25	32
	A	B	C	D	E	F

(Refer to curves at right)

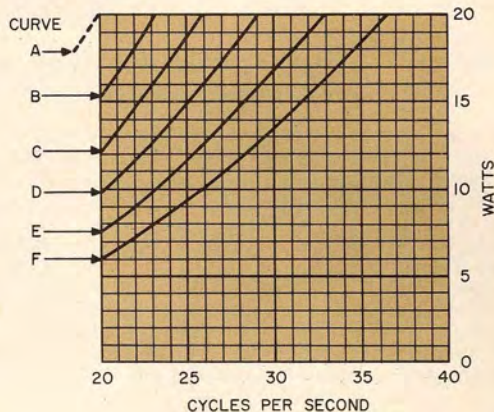
Impedance: 0.6 Ω to 32 kΩ in two ranges; yielding 48 individual impedances spaced approximately $\sqrt{2}$ apart.

ACCURACY

Power: At 1 kc/s, ±0.3 dB; from 50 to 6000 c/s, ±0.5 dB; from 30 to 10,000 c/s, ±1 dB; at 20 c/s, -1.5 dB max, -1 dB average; at 20,000 c/s, -5 dB max, ±1.5 dB average.

Impedance: At 1 kc/s, ±6% max, -0.5% average; from 70 to 5000 c/s, ±7% for values below 10,000 Ω (7% from 70 to 2500 c/s for 10,000 Ω and above); at 20 c/s, -15% max, -8% average; at 20,000 c/s, ±50% max, ±12% average.

Waveform Error: Meter will indicate true rms with as much as 20% second and third harmonics present in the input signal.

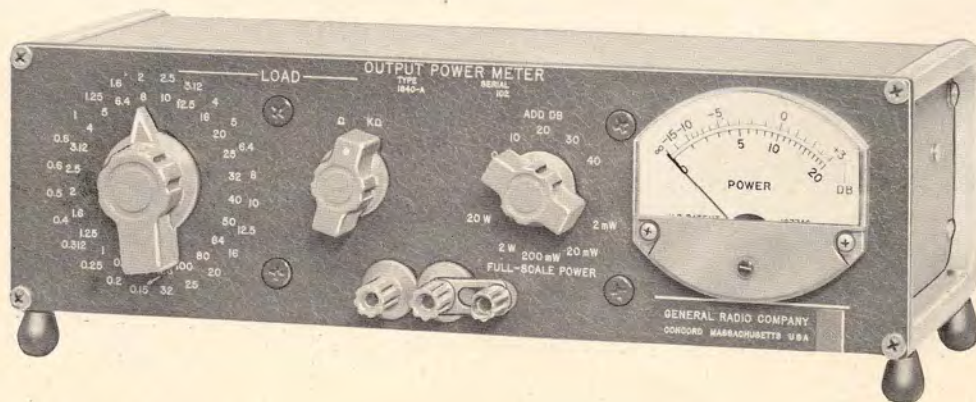


Derating vs impedance setting and frequency.

MECHANICAL DATA Convertible-Bench Cabinet (see page 258)

Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
12	305	4	105	8	205	10¾	4.9	17	8

Catalog Number	Description	Price
1840-9701	Type 1840-A Output Power Meter	\$240.00
0480-9622	Type 480-P212 Relay-Rack Adaptor Set (panel height, 3½ in)	6.00



Dc Recording: 3 dB down at 8 c/s (peak-to-peak amplitude less than 25% of full scale).

Potentiometer Linearity:

20-, 40-, 80-dB Potentiometers: ±1% of full-scale dB value plus a frequency error of 0.5 dB at 100 kc/s and 1.5 dB at 200 kc/s.

Linear Potentiometer: ±1% of full scale.

Resolution: ±0.25% of full scale.

Maximum Input Voltage: 100 V ac.

Input Attenuator: 60 dB in 10-dB steps.

Input Impedance: 10,000 Ω for ac level recording; 1000 Ω for dc recording.

Maximum Sensitivity: 1 mV at 0 dB for level recording; 0.8 or 1 V full-scale for dc recording.

Paper Speeds:

High-speed motor (normally supplied): Paper speeds of 2.5, 7.5, 25, 75 in/min. Used for high-speed-transient measurements and with TYPE 1304 Beat-Frequency Audio Generator.

Medium-speed motor (supplied on request): Paper speeds of 0.5, 1.5, 5, 15 in/min. Used with analyzers and in level-vs-time plots.

Low-speed motor (supplied on request): Paper speeds of 2.5, 7.5, 25, 75 in/h. Used for level-vs-time measurements from 1 to 24 h.

External Dc Reference: An external dc reference voltage of from 0.5 to 1.5 V can be applied internally to correct for variations of up to 3 to 1 in the signal source of the system under test.

Detector Response: Rms within 0.25 dB for multiple sine waves, square waves, or noise. Detector operating level is 1 V.

Chart Paper: 4-inch recording width on 5-inch paper. All rolls are 100 feet long. See full list of charts below.

Accessories Supplied: 40-dB potentiometer, 2 pens, 2-ounce bottle of red ink, 2-ounce bottle of green ink, bottle of potentiometer cleaner, 1 roll of No. 1521-9428 paper, droppers for filling pens, Type CAP-22 Power Cord, spare fuses, adaptor cable for connection to devices having telephone jacks.

Accessories Available: Potentiometers, charts, ink, high-, medium- and slow-speed motors, drive and link units, as listed in price table.

Power Required: 105 to 125 or 210 to 250 V, 50 or 60 c/s, 35 W.

Mechanical Data: Rack-Bench Cabinet (see page 258)

Model	Width		Height		Depth		Net Weight		Shipping Weight	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Bench	19	485	9	230	13½	350	50	23	62	29
Rack	19	485	8¾	225	11¼*	290	50	23	62	29

* Behind panel.

See also *General Radio Experimenter*, September 1964.

Catalog No.	Mounting	Supply Frequency	Paper Speed	Price
1521-9812	Type 1521-B Rack	60 c/s	2.5-75 in/min	\$995.00
1521-9802	Type 1521-B Bench	60 c/s	2.5-75 in/min	995.00
1521-9507	Type 1521-BQ1 Rack	50 c/s	2.5-75 in/min	on request
1521-9506	Type 1521-BQ1 Bench	50 c/s	2.5-75 in/min	on request

PATENT NOTICE. See Notes 1 and 18, page 11.

OPTIONAL MOTORS†

Catalog No.	Description	Price
1521-9619	Type 1521-P19 High-Speed Motor (60 c/s) for paper speeds of 2.5-75 in/min (normally supplied in recorder)††	\$59.00
1521-9921	Type 1521-P21B High-Speed Motor (50 c/s) for paper speeds of 2.5-75 in/min††	on request
1521-9623	Type 1521-P23 Medium-Speed Motor (60 c/s) for paper speeds of 0.5-15 in/min	59.00
1521-9624	Type 1521-P24 Medium-Speed Motor (50 c/s) for paper speeds of 0.5-15 in/min	on request
1521-9513	Type 1521-P20B Low-Speed Motor (60 c/s) for paper speeds of 2.5-75 in/h	59.00
1521-9622	Type 1521-P22 Low-Speed Motor (50 c/s) for paper speeds of 2.5-75 in/h	on request

† Recorder can be supplied with low-speed or medium-speed motor installed, at same price as with standard motor.
 †† Not for use with TYPE 1900-A and TYPE 1564-A Analyzers. Use -P23, -P24.

CHART PAPERS

Catalog No.	Calibration		Chart Length (in)		Associated Instrument	Price
	Horizontal	Vertical (Div)	Calibrated	Blank		
1521-9427	20 c/s-20 kc/s, log	80	9	4½	1304-B Generator	\$2.75
1521-9464	0-10 kc/s, linear	40	20	0	1900-A Analyzer	2.75
1521-9465	0-50 kc/s, linear	40	16	0	1900-A Analyzer	2.75
1521-9493	2.5-25 normalized, log	40	7½	1½	1564-A Analyzer	2.75
1521-9469	2.5-25 normalized, log	40	5	1	1564-A Analyzer	2.75
1521-9463	2.5 c/s-25 kc/s, log	40	18	3	1554-A Analyzer	2.75
1521-9429	25-7500 c/s, log	40	12½	1	760-B Analyzer	2.75
1521-9428	Continuous ¼-in div	40	continuous		1134-A, 1136-A D/A Converters	2.75
1521-9466	Continuous ⅝-in div	50	continuous			2.75

POTENTIOMETERS

Catalog No.	Description	Price
1521-9601	Type 1521-P1 20-dB Potentiometer	\$ 55.00
1521-9602	Type 1521-P2 40-dB Potentiometer§	70.00
1521-9603	Type 1521-P3 80-dB Potentiometer	155.00
1521-9604	Type 1521-P4 Linear Potentiometer (for dc)	55.00

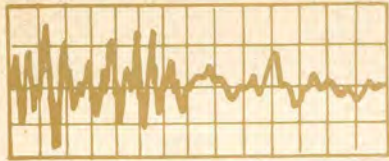
§ Normally supplied with the recorder.

PEN AND INK

Catalog No.	Description	Price
1521-9992	Red Ink, 16-oz bottle	\$ 5.50
1521-9993	Green Ink, 16-oz bottle	5.50
1521-9349	Replacement Pen	3.50

DRIVE AND LINK UNITS FOR COUPLING TO GENERATOR AND ANALYZERS

Catalog No.	Description	Price
1521-9467	Type 1521-P10B Drive Unit to operate any link unit	\$72.00
1521-9615	Type 1521-P15 Link Unit for coupling to Type 1304-B Beat-Frequency Audio Generator or to Type 1554-A or Type 1564-A Sound and Vibration Analyzer	26.00
1521-9616	Type 1521-P16 Sprocket Kit for above link unit. These sprockets offer a choice of the following scale factors (ratio of dB/inch vertical scale to decades/inch on horizontal scale): 20, 25, 45, and 50 dB/decade.	15.00
1900-9601	Type 1900-P1 Link Unit for coupling to Type 1900-A Wave Analyzer	35.00



RECORDERS, PRINTERS CONVERTERS

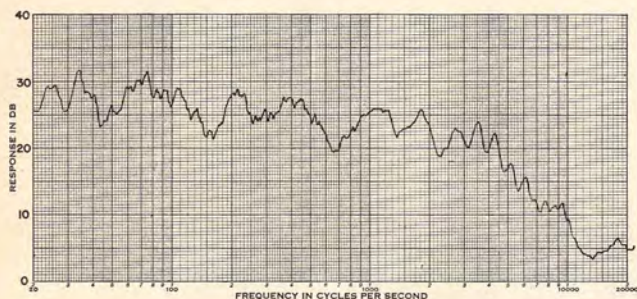


The automatic recording of data has replaced manual methods wherever measurement is continuous or a long series of measurements is made. The analog recorder (also called "graphic" or "strip-chart") produces a permanent record of a voltage or current that is an analog of the quantity under observation. The record is usually in ink, on a moving strip of paper, whose motion is either a function of time or of an independent variable in the measurement program.

The digital recorders or printers, operating from binary-coded data, furnish a numerical record on paper tape. Digital data can be transformed into analog data by a digital-to-analog converter. Listed in this section are two graphic recorders, a printer, a digital-to-analog converter, and a combination converter and recorder.

GRAPHIC LEVEL RECORDER

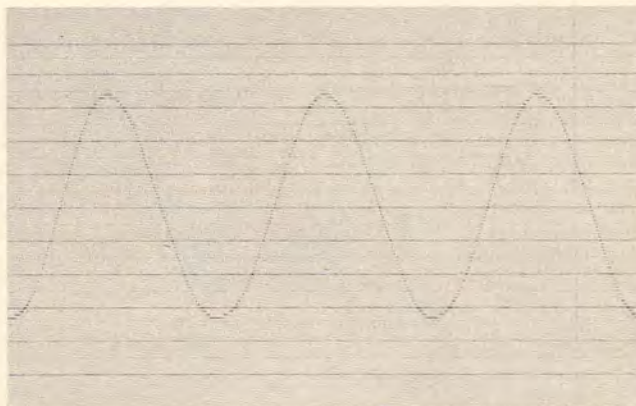
The Type 1521-B Graphic Level Recorder is a servo-type device, producing an ink record on moving paper. It plots linearly in decibels the rms level of ac voltage up to 200 kc/s. Interchangeable potentiometers give full-scale values of 20, 40, and 80 dB, as well as a linear dc range. This recorder can plot the output level of electrical and electro-acoustic devices as a function of time. It is available in combination with wave analyzers for automatic plotting of frequency spectra, with the beat-frequency audio-generator for automatic frequency-response plotting, and with a d/a converter for the analog recording of digital data.



Response of a public address system as plotted automatically by the Type 1521-B Graphic Level Recorder.

SAMPLING RECORDER

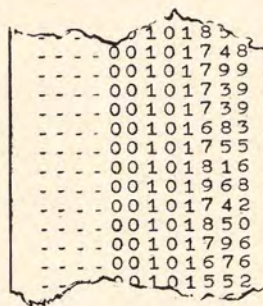
The Type 1520-A Sampling Recorder uses 117 fixed pens, spaced along the vertical scale of a moving chart paper, each of which prints a dot whenever the voltage level of the input function, which is scanned at a 3-kc rate, equals the level of an internally generated linear ramp voltage. Such a system has no frequency response limitation for the recording of transients except that which is imposed by the sampling rate.



Trace of a one-cycle-per-second sine wave as plotted on the Type 1520-A Sampling Recorder.

DATA PRINTER

The Type 1137-A Data Printer operates from BCD input data and prints a permanent numerical record. Models are available with plug-in code modules to accept data from General Radio frequency counters and from the Type 1680-A Automatic Capacitance Bridge Assembly. The printer can also be used with digital devices of other manufacture.



Sample of digital record produced by the Type 1137-A Data Printer.

DIGITAL-TO-ANALOG CONVERTER

The Type 1136-A Digital-to-Analog Converter transforms BCD data to an analog voltage, which can be fed into the Type 1521-B Graphic Level Recorder, the Type 1520-A Sampling Recorder, or other strip-chart recorder to produce a chart record in analog form. The converter and graphic level recorder are available in combination as the Type 1510-A Digital-to-Graphic Recording Assembly.

Type	Name	Page
1521-B	Graphic Level Recorder	178
1520-A	Sampling Recorder	180
1137-A	Data Printer	183
1136-A	Digital-to-Analog Converter	182
1510-A	Digital-to-Graphic Recording Assembly	182



Type 1521-B GRAPHIC LEVEL RECORDER

FEATURES:

- Plots rms level of ac voltage, 7 c/s to 200 kc/s. ■ Completely transistorized.
- Fast writing speed with optimum ballistics. ■ Wide range of paper speeds.
- Calibrated in absolute level. ■ Interchangeable logarithmic potentiometers.
- Mechanical coupling available for driving oscillator or analyzer.
- Simple to operate — three basic controls. ■ Easily converted to dc linear recorder.

USES: The TYPE 1521-B Graphic Level Recorder has a wide variety of uses in physical science and engineering. It produces permanent ink records of the response of electrical or electro-acoustical devices and systems as a function of time or frequency. Owing to the high stability of its reference voltage and amplifier gain, it can be calibrated and used as a recorder of absolute level.

AMPLITUDE-FREQUENCY PLOTTING. The paper drive can be coupled by means of drive and link units to the frequency-control shaft of an oscillator or analyzer for completely automatic recording. The combination of recorder and audio generator (see TYPE 1350-A Generator-Recorder Assembly, page 133) produces records having a true logarithmic frequency scale and is ideal for plotting frequency characteristics of analyzers, recording systems, networks, filters, and equalizers, as well as of loudspeakers, microphones, vibration pickups, and other transducers.

ACOUSTICAL MEASUREMENTS. The combination of recorder and analyzer (see TYPE 1910-A Recording Wave Analyzer, page 29, and TYPE 1911-A Recording Sound and Vibration Analyzer, page 31) makes possible automatic analysis of sound spectra and response measurements on devices excited by white noise.

With a sound-level meter (pages 14-16), the recorder can plot sound levels over a wide dynamic range as a function of time. The writing speed is sufficiently high for the measurement of reverberation time and other transient phenomena.

The wide range of paper speed facilitates long-period studies of the noise produced by traffic and machinery, as well as of short-duration transients.

DESCRIPTION: The TYPE 1521-B Graphic Level Recorder is a completely transistorized, single-channel, servo-type recorder. It produces a strip-chart record with ink on white paper, suitable for reproduction. The pen is attached to a coil, which moves linearly over a 4-inch distance in a uniform magnetic field. A contact attached to the coil rides on a straight potentiometer, which is the balancing element for the servo. The position of the contact is determined by the input signal, and the exponential potentiometer characteristic produces a linear dB scale.

The ac voltage at the potentiometer contact is amplified and then rectified in an rms detector.

The difference between the detector output and a one-volt reference is amplified and used to position the coil, which carries the potentiometer contact and pen. A velocity-feedback coil mounted on the drive-coil frame provides appropriate damping. The response is, for all commonly encountered wave-forms, very close to true rms.

The frequency response can be extended downward to 7 c/s at the slower writing speeds. Writing speeds and low-frequency cutoff are selected by a single switch.

Changes of range are easily accomplished by use of a 20-dB or an 80-dB potentiometer in place of the standard 40-dB unit. With the 80-dB unit, the maximum writing speed is 300 dB/second. The slow writing speeds filter out abrupt level variations, yielding a smoothed plot without loss of accuracy.

For dc recording, a linear potentiometer provides a balancing voltage in series with the input voltage, and the combined voltage is balanced against the 1-volt reference.

SPECIFICATIONS

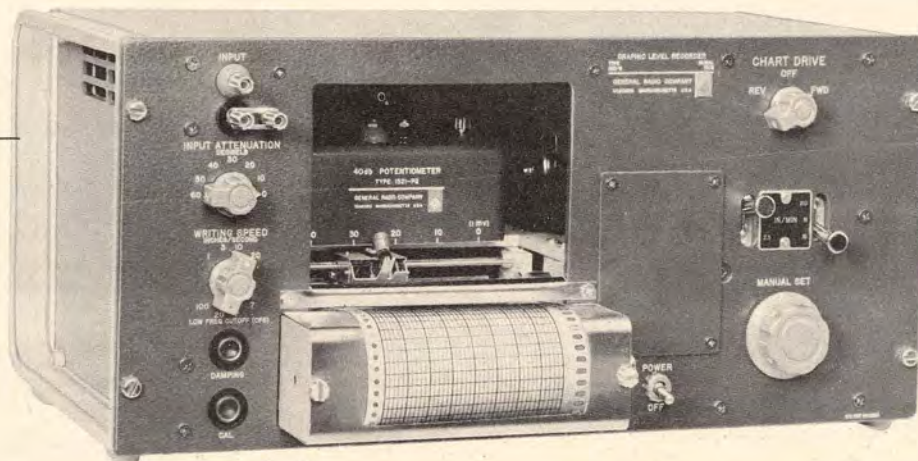
Recording Range: As supplied, 40 dB full-scale; 20-dB and 80-dB ranges are also available. For dc recording, 0.8 to 1 V (0.8 to 1.0 mA) full-scale, with zero position adjustable over full scale.

Frequency Response and Writing Speed:

Level Recording: High-frequency response ± 2 dB to 200 kc/s. Low-frequency sine-wave response depends on writing speed, as shown in following table:

Writing Speed (approx) in/s with 0.1-inch overshoot	Low-Frequency Cutoff c/s (less than 1 dB down)
20	100
10	20
3	7 (3 dB down at 4.5 c/s)
1	7 (3 dB down at 4.5 c/s)

NEW MODEL
in catalog S





Type 1520-A SAMPLING RECORDER

FEATURES:

- Fast transient response — no waveform distortion.
- Quantized record — 3-kc sampling rate.
- No moving pen — 101 fixed styli.
- Prints its own coordinates, as well as voltage range and time scale.
- Resolution 1% of full scale.
- Two independent input channels, each with nine linear and two logarithmic ranges, calibrated.
- Uses inexpensive electro-sensitive paper.

USES: This unique recorder can be used for most of the purposes for which a moving-pen or moving-mirror recorder is used. For the recording of transients, it is usually superior to those types. There is no amplitude or phase distortion of high-speed transients. The practical response limitation is imposed, not by frequency, but by the sampling rate and the paper speed. An input waveform can be satisfactorily reproduced if 3000 samples per second will yield sufficient information and if a chart speed of 10 inches per second will yield sufficient horizontal resolution.

DESCRIPTION: The sampling recorder operates on entirely different principles from those of the well-known moving-coil or moving-mirror devices. Instead of a moving pen, it has 101 fixed styli, spaced at equal intervals along the vertical scale of the chart paper.

The input voltage is measured 3000 times per second. The stylus corresponding to the level of each measured voltage is energized, and a point is plotted. There are 100 discrete levels, each corresponding to one stylus position. The quantization is accomplished by means of an amplitude comparator and a voltage ramp — a linear ramp for linear scales, an exponential ramp for logarithmic scales. A complete scan-print cycle takes about 150 μ s for each channel, or about 300 μ s for both. The sampling time is thus about 300 μ s, corresponding to a 3-kc sampling rate for each channel, with the two channels sampled alternately. With the same input applied to both channels in parallel, the sampling rate is doubled.

Since the voltage-level information in the input signal is converted into the timing of a pulse, the only frequency limitations are those set by paper speed and sampling rate.

For the recording of sine-waves and other simple periodic waveforms, paper speed is the frequency limiting factor, since it determines the horizontal resolution. At maximum speed (10 inches/second), one cycle of a 50-cycle sine wave occupies 1/5 inch on the horizontal scale. On the other hand, a single step function, which, in conventional recorders, requires a wide frequency band and high paper speed even to approximate faithful reproduction, is accurately reproduced by the Sampling Recorder with little or no motion of the paper. As can be seen from the sample charts reproduced here, the record consists of a series of dots. It is the spacing of individual dots that determines the vertical resolution. A vertical rise time as short as 300 microseconds can be accurately determined from the chart, since at least two dots will be printed during the rise. There can be no amplitude or phase distortion of high-speed transients — no lagging response, overshoot, ringing, or other common distortions introduced by a moving-coil system. There is no amplitude “shrinkage” with increasing frequency (“velocity saturation”) or roll off, and the full width of the chart paper can always be used, if desired.

The charts illustrate the differences in response between the Sampling Recorder and the moving-pen type on a composite pulse.

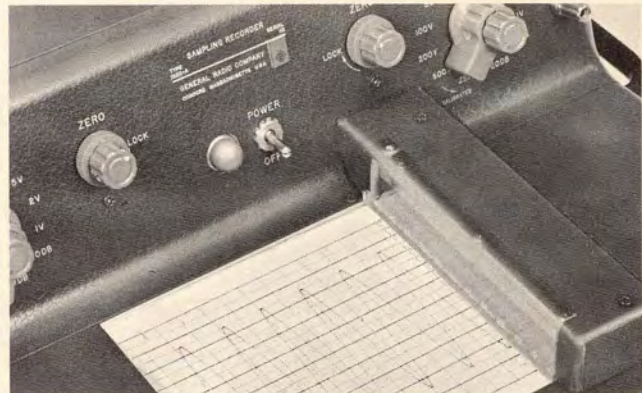
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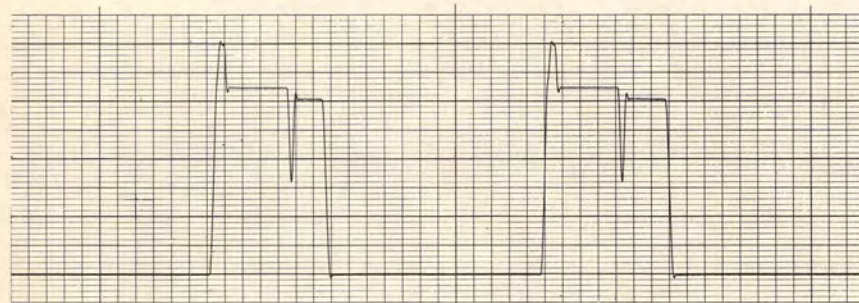
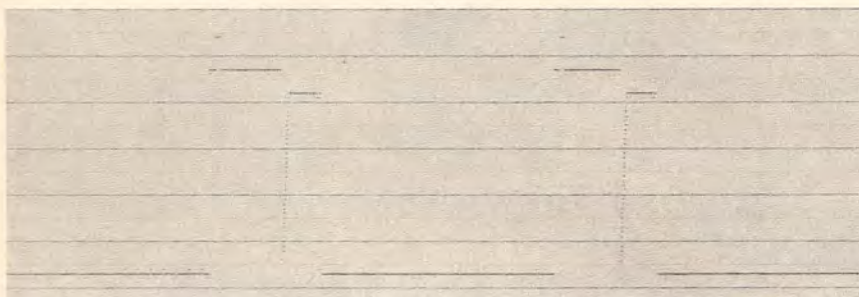


The recorder prints its own coordinates simultaneously with the recording of the input signals. These consist of eleven dark and ten lighter horizontal lines marking intervals of 10% and 5% of full scale, which can easily be read to the nearest percent of full scale. Vertical lines are printed every half inch or every centimeter of paper motion, dependent upon the setting of the paper drive clutch. This system for printing graph paper during recording gives the following advantages:

- a) Only one type of paper must be stocked for all recording uses — a plain, inexpensive paper.
- b) Any dimensional changes of the paper with age or humidity have no effect whatever on accuracy of recording, since the graph paper is printed by the same styli that print the recorded variable.



Close-up view of the 101-styli enclosed in a transparent plastic housing.



Recording of a composite pulse as plotted on (above, left) the Type 1520-A Sampling Recorder and (below, left) a fast pen-type recorder. Note that the pen recorder cannot follow the rapid step changes and shows overshoot, while the sampling recorder shows neither of these defects. The composite pulse consists of a 0.1-second pulse, with a 10-millisecond pulse superposed 10 milliseconds after the leading edge (pulses have 20-nanosecond rise and fall times), followed immediately by a 0.05-second pulse with a 20-millisecond linear rise and 20-nanosecond fall time.

SPECIFICATIONS

Number of Input Channels: 2.
Number of Styli: 117, 101 over 5-inch recording.
Calibrated Voltage Ranges: 1 V to 500 V, full scale, in 1, 2, 5 steps for each channel.
Uncalibrated Voltage Ranges: Any value from 0.3 V to 350 V, full scale, for each channel.
Event Marking: External contact closure or dc voltage actuates one stylus along the lower chart-paper margin to mark the chart in accordance with an external event or condition related to the other signals being recorded.
Logarithmic Ranges: 20 dB and 50 dB, full scale, for each channel.
Resolution: 1% of full scale.
Over-all Accuracy: ±1%.
Sampling Rate: Approximately 3 kc/s for each channel; 6 kc/s if both channels are in parallel.

Time Scales: 10 min, 1 min, 10 s, 1 s, or 0.1 s per centimeter or per inch.
Scale Factors: Full-scale voltage setting and values of time scale are automatically printed along the upper and lower margins of the paper.
Chart Width: 5-inch recording on 6-inch paper.
Paper Type: Electric-writing paper.
Power Required: 105 to 125, 195 to 235, or 210 to 250 V, 50 or 60 c/s, 300 W.
Accessories Supplied: CAP-22 Power Cord, spare fuses, one roll chart paper, and hardware for rack mount.
Dimensions: Bench, width (including handles), 21 in, height 8¾ in, depth 22 in (540, 225, 560 mm), over-all; rack, width 19 in, depth behind panel 11 in, projection in front of panel, 11 in (485, 280, 280 mm).
Net Weight: Approximately 45 lb (20.5 kg).

AVAILABLE 4th QUARTER 1965

Catalog Number	Description	Price
1520-9701	Type 1520-A Sampling Recorder, for 60-cycle supply	\$2950.00
1520-9494	Type 1520-AQ1 Sampling Recorder, for 50-cycle supply	on request
1520-9301	Chart Paper, 200-foot roll	6.00



Type 1136-A DIGITAL-TO-ANALOG CONVERTER

WITH HIGH-SPEED STORAGE SYSTEM

FEATURES:

- Excellent stability and linearity. ■ Self-contained data storage.
- Versatile — accepts 1-2-4-2, 1-2-2-4, or (with modification) 1-2-4-8 coding.
- 1-mA or 100-mV output. ■ All-solid-state circuitry.
- High conversion rate — up to 10,000 conversions per second.

USES: The TYPE 1136-A Digital-to-Analog Converter translates the data output from a digital instrument into a dc voltage or current for analog recording.

DESCRIPTION: The converter selects any three consecutive, or the last two, columns from an input of up to nine columns.

A command pulse from the data source transfers the input data into the storage circuits of the converter. Jam transfer into storage is used so that the analog output changes only when the input data changes (no zero-set between transfers). Storage circuits in the converter permit use with intermittent as well as continuous BCD inputs.

SPECIFICATIONS

Data Input: BCD weighted 1-2-4-2 or 1-2-2-4. Minor modification adapts for 1-2-4-8 input. Binary 1 at least 6 V positive with respect to binary 0. Input impedance 50 kΩ. Binary 0 can be offset from ground by ±150 V.

Conversion Rate: Up to 10,000 conversions per second (controlled by digital-measuring instrument).

Over-all Accuracy: ±0.1% of full scale ± 0.0001% × conversion rate in pps (includes repeatability, long-term stability, linearity, ±10% line variation, and ±15°C ambient-temperature variations around normal 25°C).

Storage Transfer: 50-μs transfer time.

Storage-Command Pulse: Amplitude, 6 V min; duration, 5 μs min; leading-edge slope, 6 V/μs min; polarity, + or - controlled by rear-mounted switch; ac coupled.

Output: 15 to 18 V behind 15 kΩ, or 100 mV with 100-Ω source impedance. Negative side grounded if binary 0 of input not more than 20 V from ground. Output floating if offset voltage is larger than 20 V.

Load: 2 kΩ max for 1-mA output. 1 kΩ min for 100-mV output.

Linearity: ±0.05% of full scale.

Stability: ±0.02% for ±10% line voltage; ±0.003% of fs/°C.

Accessories Supplied: TYPE CAP-22 Power Cord, spare fuses, input cable for connection to the digital instrument.

Power Required: 105 to 125 or 210 to 250 V, 50 to 400 c/s, 7 W.

Mechanical Data: Rack-Bench Cabinet (see page 258)

Model	Width		Height		Depth		Net Wt		Ship Wt	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Bench	19	485	4	105	12	305	13	6	21	10
Rack	19	485	3½	89	11*	280	13	6	21	10

* Behind panel.

See also *General Radio Experimenter*, December 1963.

Type 1510-A DIGITAL-TO-GRAPHIC RECORDING ASSEMBLY

This convenient assembly of the TYPE 1136-A Digital-to-Analog Converter and the TYPE 1521-B Graphic Level Recorder will operate from the output of General Radio digital instruments to produce a strip-chart record that is the analog of the digital data as a function of time. It is equally usable with other digital equipment that is coded for 1-2-4-2,

1-2-2-4, or 1-2-4-8 output.

Shipped assembled, as shown, with 10 rolls of chart paper and input cable. Rack-mount hardware also supplied.

See specifications for TYPE 1136-A Digital-to-Analog Converter (above) and TYPE 1521-B Graphic Level Recorder (page 178).

Catalog No.	Description	Use*	Price
1136-9401	Type 1136-A Digital-to-Analog Converter, Bench Model	For use with Types 1143-AP, 1144-AP, 1150-BP, -BPH, 1151-AP, 1153-AP	\$ 810.00
1136-9501	Type 1136-A Digital-to-Analog Converter, Rack Model		
1136-9402	Type 1136-A Digital-to-Analog Converter, Bench Model	For use with Type 1680-A	680.00
1136-9502	Type 1136-A Digital-to-Analog Converter, Rack Model		
1510-9401	Type 1510-A Digital-to-Graphic Recording Assembly (60-cycle operation)	For use with Types 1143-AP, 1144-AP, 1150-BP, -BPH, 1151-AP, 1153-AP	1855.00 on request
1510-9571	Type 1510-AQ1 Digital-to-Graphic Recording Assembly (50-cycle operation)		
1510-9402	Type 1510-A Digital-to-Graphic Recording Assembly (60-cycle operation)	For use with Type 1680-A	1725.00 on request
1510-9572	Type 1510-AQ1 Digital-to-Graphic Recording Assembly (50-cycle operation)		

* Converters and cables for use with other digital instruments are available on special order. Write for information.

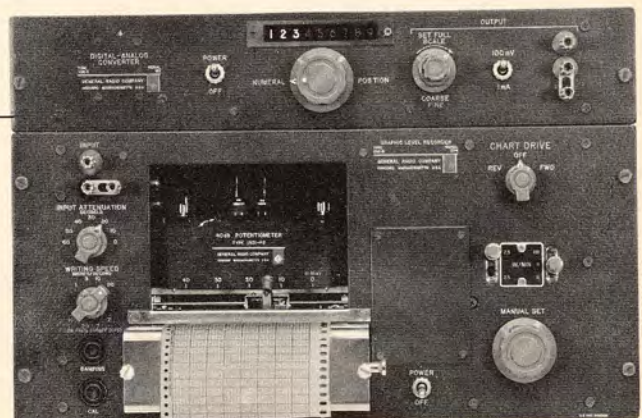
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TYPE 1136-A



TYPE 1510-A





Type 1137-A DATA PRINTER

FOR USE WITH GENERAL RADIO DIGITAL INSTRUMENTS

FEATURES:

- Prints from 4-line BCD or 10-line code inputs.
- Precise, compact, economical; all-solid-state circuitry.
- Convenient — standard 2¼-inch tape is easy to read and easy to write on.
- Reliable — time-proven printing mechanism designed for continuous-duty operation with minimum of maintenance.

USES: The printer provides a precise, compact, and economical means of converting decimal-coded information into permanent, printed form.

It is equipped with plug-in code modules, which accept 10-line data or 4-line 1-2-2-4, 1-2-4-8, or 1-2-4-2 BCD inputs. A two-color ribbon can be electrically or manually controlled to print red or black on standard 2¼-inch paper.

DESCRIPTION: The printing mechanism is a reliable 10-key tabulator with stop-pawls and electromagnets. The use of

solid-state circuits and the absence of power-consuming keyboard actuators keep power requirements to a minimum. By fast, parallel entry of four-line BCD or 10-line inputs, the printer can operate at a rate of three prints per second, with up to 12 digits per print.

The capacity of the printer is 12 columns, not all of which are used for data from the associated GR instruments. Additional plug-in modules and accessory cable are available for printing other data. Both portable and rack models are listed.

SPECIFICATIONS

- Capacity:** 12 columns.
- Digits:** 0 through 9 or blank (column suppression).
- Printing Rate:** 3 lines per second maximum.
- Accuracy:** Identical to input.
- Input:**

Logic Levels	Source Resistance	Binary 0	Binary 1
(with respect to reference):	100 kΩ	-8 to -50 V	0 to +50 V
	2 MΩ	-12 to -50 V	0 to +50 V

Code: 10-line code (one wire is binary 1, eight wires binary 0) or four-line BCD (1-2-2-4, 1-2-4-8, or 1-2-4-2) input, depending on modules used.

Resistance: Approximately 10 MΩ for minus input, 200 kΩ for plus input.

Internal Ground: Isolated from chassis. May be biased to ±100 V.

Color-Control:

Manual: Two-position lever selects red or black print-out.
Remote: Red, binary 1 or open circuit; black, binary 0. Input resistance approximately 2 MΩ.

Column Suppression: Single line grounded for each column suppressed (3 mA max, +10 V open circuit).

Print Command: Change from binary 1 to binary 0. Binary 0, 100 ms minimum after print command; binary 1, 15 ms minimum before next print command. Source resistance 1 MΩ max.

Inhibit Reset Output: Occurs within 50 ms after print command; 200 ms max duration.

Printing Ribbon: 7/16-in two-color adding-machine ribbon.

Paper: Standard 2¼-in roll tape.

Power Required: 105 to 125 or 210 to 250 V, 50 to 60 c/s, 45 W.

Accessories Supplied: Cable assembly for connection to counter, spare fuses.

Accessories Available: Additional plug-in code modules and accessory cables. Printer will handle up to 12 columns. With Catalog Numbers 1137-9743 and 1137-9744, 6 modules are supplied; cable furnished with printer will handle up to 11 columns (5 additional modules); for 12 columns order Catalog Number 1137-9607 Cable. With Catalog Numbers 1137-9735 and 1137-

9736, 5 modules are supplied; cable furnished will handle 5 columns; for 6 to 12 columns, order Catalog Number 1137-9607 Cable, as well as additional modules needed.

Mechanical Data:

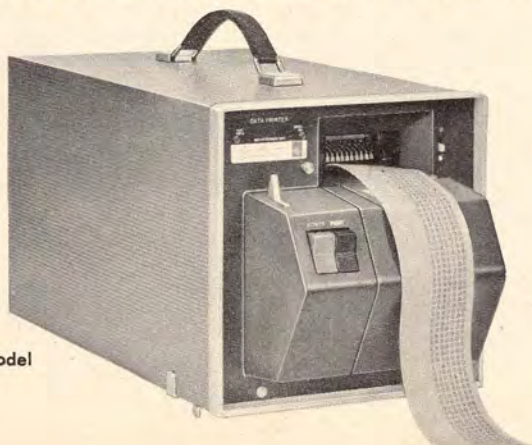
Model	Width		Height		Depth		Net Weight		Shipping Weight	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Portable	8¾	225	9	230	21	540	35	16	45	20.5
Rack	19	485	8¾	225	17½*	445	45	20.5	55	25

* Behind panel.

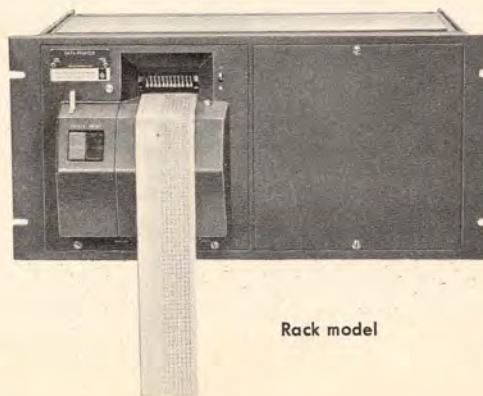
See also *General Radio Experimenter*, June 1963.

Catalog No.	Description	Use†	Price
1137-9735	Type 1137-A Data Printer, 5-column, 10-line decimal, Portable Model	For use with Types 1143-AP, 1144-AP, 1150-BP, 1150-BPH, 1151-AP, 1153-AP	\$1500.00
1137-9736	Type 1137-A Data Printer, 5-column, 10-line decimal, Rack Model		1550.00
1137-9743	Type 1137-A Data Printer, 6-column BCD, Portable Model	For use with Types 1123-A, 1680-A	1515.00
1137-9744	Type 1137-A Data Printer, 6-column BCD, Rack Model		1565.00
1137-9604	Plug-In Code Module, 4-line BCD	Extends number of columns up to a maximum of 12	65.00 (each)
1137-9605	Plug-In Code Module, 10-line decimal		75.00 (each)
1137-9607	Accessory Cable		35.00

† Connectors and cables for use with other digital instruments are available on special order. Write for information.



Portable model



Rack model



STANDARD CAPACITORS



Choice of Capacitor Type

A properly designed air capacitor approaches the ideal standard reactance in that it has very low loss and very small changes with time, frequency, and environment. Capacitance changes with changes in atmospheric pressure (about 18 ppm per inch Hg) and in relative humidity (about 2 ppm per % RH) can be eliminated by hermetic sealing of the capacitor. Changes with temperature can be reduced to a few ppm per °C by the use of low-temperature-coefficient materials in the capacitor. The maximum capacitance for an air-dielectric unit of practical size is of the order of 1000 pF. (See Types 1404, 1401, 1403.)

For higher capacitance, solid dielectrics are used. The preferred dielectric for standard capacitors is high-quality mica, because of its dimensional stability, low loss, and high dielectric strength. The temperature coefficient of a mica capacitor is of the order of +35 ppm per °C. At dc or extremely low frequencies the mica dielectric has the disadvantage of relatively large change of capacitance with frequency. (See Types 1409, 1423.)

Polystyrene has a dielectric constant and dissipation factor very nearly constant with frequency, so that the capacitance change from dc to 1 kc/s is a small fraction of a percent. The temperature coefficient of a polystyrene capacitor is, however, of the order of -140 ppm per °C. (See Type 1424-A.)

Two-Terminal and Three-Terminal Connections

Most capacitors can be represented by the three capacitances shown in Figure 1: the direct capacitance, C_{HL} , capacitance between the plates of the capacitor and the two terminal capacitances, C_{HG} and C_{LG} , which are capacitances from the corresponding terminals and plates to the capacitor case, surrounding objects, and to ground (to which the case is connected either conductively or by its relatively high capacitance to ground).

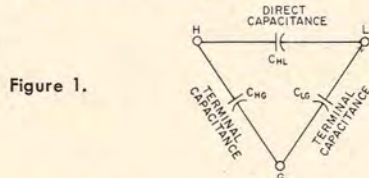


Figure 1.

In the two-terminal connection, the capacitor has the L and G terminals connected together, i.e., the L terminal is connected to the case. The terminal capacitance, C_{LG} , is thus shorted, and the total capacitance is the sum of C_{HL} and C_{HG} . Since one component of the terminal capacitance C_{HG} is the capacitance between the H terminal and surrounding objects, the total capacitance can be changed by changes in the environment, particularly by the introduction of connecting wires.

The uncertainties in the calibrated value of a two-terminal capacitor can be of the order of tenths of a picofarad if the geometry, not only of the capacitor plates but of the environment and of the connections, is not defined and specified with sufficient precision. For capacitors of 100 pF and more,

the capacitance is usually adequately defined for an accuracy of a few hundredths percent if the terminals and method of connection used for calibration are specified. For smaller capacitances or for higher accuracy, the two-terminal capacitor is seldom practical and the three-terminal arrangement is preferred.*

A three-terminal capacitor has connected to the G terminal a shield that completely surrounds at least one of the terminals (H), its connecting wires, and its plates except for the area that produces the desired direct capacitance to the other terminal (L). Changes in the environment and the connections can vary the terminal capacitances, C_{HG} and C_{LG} , but the direct capacitance C_{HL} is determined only by the internal geometry.

This direct capacitance can be calibrated by three-terminal measurement methods, which use guard circuits or transformer-ratio-arm bridges to exclude the terminal capacitances.

The direct capacitance can be made as small as desired, since the shield between terminals can be complete except for a suitably small aperture. The losses in the direct capacitance can also be made very low because the dielectric losses in the insulating materials can be made a part of the terminal impedances. When the three-terminal capacitor is connected as a two-terminal, the two-terminal capacitance will exceed the calibrated three-terminal value (C_{HL}) by at least the terminal capacitance C_{HG} .

Frequency Characteristics

Although the characteristics of the high-quality capacitors used as standards closely approach those of the ideal capacitor, to obtain high accuracy the small deviations from ideal performance must be examined and evaluated. The residual parameters that cause such deviations are shown in the lumped-constant, two-terminal equivalent circuit of Figure 2. R represents the metallic resistance in the leads, supports and plates; L , the series inductance of the leads and plates; C , the capacitance between the plates; C_k the capacitance of the supporting structure. The conductance, G , represents the dielectric losses in the supporting insulators, the losses in the air or solid dielectric between capacitor plates, and the dc leakage conductance.

The effective terminal capacitance C_e of the capacitor becomes greater than the electrostatic or zero-frequency capacitance C_0 as the frequency increases because of the inductance L . When the frequency, f , is well below the resonance frequency f_r (defined by $\omega_r^2 LC_0 = 1$), the fractional increase in capacitance is approximately

$$\frac{\Delta C}{C_0} \approx \omega^2 LC_0 = \left(\frac{f}{f_r}\right)^2 \quad (1)$$

* John F. Hersh, "A Close Look at Connection Errors in Capacitance Measurements," *General Radio Experimenter*, July 1959.

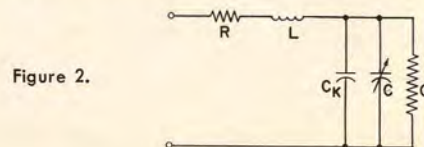


Figure 2.

This change in capacitance with frequency for the capacitors described on the following pages is given either as a plot on logarithmic co-ordinates of the percent increase, $\Delta C/C$, versus frequency or as a tabulation of the values of L or f_r . Since the inductance is largely concentrated in the leads and supports, it is nearly independent of the setting of a variable capacitor. With this information, the increase in capacitance at, for example, a frequency of 1 Mc/s can be computed from the calibrated value at 1 kc/s with high accuracy. For small increases, the accuracy may be greater than that of a measurement at 1 Mc/s because of the difficulties in determining the measurement errors produced by residuals in the connecting leads outside the capacitor.

The three-terminal capacitor has a similar increase in capacitance produced by inductance. The lowest resonance is determined not solely by the calibrated direct capacitance but also by the terminal capacitances, which may be much larger than the direct capacitances (see equivalent circuit of Type 1403 Capacitors, page 190).

When the capacitor has a solid dielectric, such as mica, there is another source of capacitance change with frequency. The capacitance increases at low frequencies as the result of dielectric absorption caused by interfacial polarization in the dielectric. The change in capacitance with frequency of a 1000-pF capacitor with mica dielectric is shown in Figure 3. The dotted line slanting downward to the right represents the change in the dielectric constant of mica resulting from interfacial polarization; that slanting upward to the right shows the change in effective capacitance resulting from series inductance. The magnitude of the change at low frequencies depends upon the dielectric material and is, for example, much smaller for polystyrene than for mica.

Dissipation Factor

The dissipation factor of a capacitor (defined on page 41) is determined by the losses represented in Figure 2 by R and G . The resistance R is not usually significant until the frequency is high enough for the skin effect to be essentially complete. At such frequencies the resistance varies as the square root of frequency and may be expressed as $R_1\sqrt{f}$, where R_1 is the resistance at one Mc/s and f is the frequency in Mc/s. The total dissipation factor at high frequencies is then

$$D = \frac{G}{\omega C} + R_1\sqrt{f}\omega C \quad (2)$$

At low frequencies only the losses represented by G are important. The leakage conductance component is negligible at frequencies above a few cycles per second and is important only when the capacitor is used at dc for charge storage. The dominant components at audio frequencies are the dielectric losses in the insulating structure and in the dielectric material between the plates,

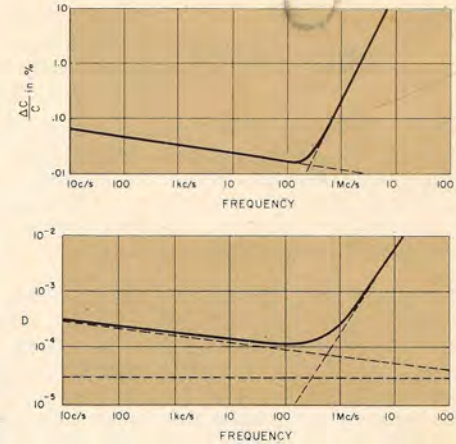


Figure 3. Variation with frequency of capacitance and dissipation factor for a mica capacitor.

In the air capacitor the losses in the air dielectric and on the plate surfaces are negligible under conditions of moderate humidity and temperature. The loss is, therefore, largely in the insulating supports. When good-quality, low-loss materials, such as quartz, ceramics, and polystyrene, are used for insulation, the conductance varies approximately linearly with frequency and the dissipation factor, D_k , of the supports is nearly constant with frequency. The total low-frequency dissipation factor of an air capacitor whose equivalent circuit is that of Figure 2 may be expressed as

$$D = \frac{G}{\omega(C + C_k)} = \frac{D_k C_k}{C + C_k} \quad (3)$$

When the capacitance C is variable, this D is then inversely proportional to the total terminal capacitance. Since the quantity $D_k C_k$ is nearly independent of both frequency and capacitance setting, it is a convenient figure of merit for a variable capacitor.

In a capacitor with a solid dielectric the dominant component of the conductance G is the loss in the dielectric, which varies with frequency. The resulting variation of D with frequency, shown for a mica capacitor in Figure 3, is the sum of three principal components: a constant dissipation factor caused by residual polarizations; a loss produced by interfacial polarizations, which decreases with frequency; and an ohmic loss in the leads and plates, which results in a D proportional to the $3/2$ power of frequency. The total dissipation factor has a minimum value at a frequency that varies inversely with capacitance and which ranges from 1 kc/s to 1 Mc/s for capacitance values from 1 μ F to 100 pF.

The capacitors described in these pages include air-dielectric reference standards, both fixed and variable, both fixed and decade mica-dielectric, and other decades with polystyrene, mica, and paper dielectric.

Type	Name	Capacitance	Page
1422	Precision Capacitor (2- and 3-terminal, variable)	8 models, 1.1 to 1150 pF, full scale	186
1401	Standard Air Capacitor (2-terminal, fixed)	100, 200, 500, 1000 pF	191
1403	Standard Air Capacitor (3-terminal, fixed)	0.01, 0.1, 1, 10, 100, 1000 pF	190
1404	Reference Standard Capacitor (3-terminal, fixed)	1000 pF	188
1409	Standard Capacitor (Fixed, mica)	0.001 to 1 μ F in 10 models	192
1423	Standard Decade Capacitor (mica)	100 pF to 1.111 μ F	189
1424-A	Standard Polystyrene Decade Capacitor (Single decade)	0 to 10 μ F	194
1424-M	Decade Capacitor (Single decade, paper)	0 to 10 μ F	194
1425-A	100- μ F Polystyrene Dielectric Decade Capacitor (Single decade)	0 to 100 μ F	194
1412-BC	Decade Capacitor (2- and 3-terminal)	0 to 1 μ F	195
1419	Decade Capacitor (3- and 4-dial boxes)	0 to 1 μ F	196
980	Decade Capacitor Unit	0.001, 0.01, 0.1, and 1 μ F, full scale	196
505	Capacitor (Fixed, mica)	100 pF to 0.5 μ F in 12 models	193
1429	Fuel-Gage Tester	20 to 6220 pF	191



Type 1422 PRECISION CAPACITOR

FEATURES:

- High stability.
- High accuracy.
- Low backlash.
- High precision of setting — one part in 25,000 of full scale; total scale length is 20 feet.
- Low temperature coefficient of capacitance.
- Low dielectric losses.
- Large transparent knob skirt to facilitate fine setting.

USES: The TYPE 1422 Precision Capacitor is a stable and precise variable air capacitor intended for use as a continuously adjustable standard of capacitance.

One of its most important applications is in ac bridge measurements, either as a built-in standard or as an external standard for substitution measurements.

DESCRIPTION: The capacitor assembly is mounted in a cast frame, which gives the unit rigidity. The frame, spacers, stator rods, and rotor shaft are made of selected alloys of aluminum, which combine the high mechanical strength of brass with the low weight of aluminum. The plates of most models are also of aluminum, so that all parts have the same temperature coefficient of linear expansion.

A worm drive is used to obtain high precision of setting. To avoid eccentricity, the shaft and the worm are accurately machined as one piece. The worm and worm wheel are also lapped into each other to improve smoothness. The dial end of the worm shaft runs in a self-aligning ball bearing, while the other end is supported by an adjustable spring mounting, which gives positive longitudinal anchoring to the worm shaft through the use of a pair of sealed, self-lubricating, preloaded ball bearings. Similar pairs of preloaded ball bearings provide positive and invariant axial location for the main or rotor shaft. Electrical connection to the rotor is made by means of a silver-alloy brush bearing on a silver-overlay drum to assure a low-noise electrical contact.

Stator insulation in all models is a cross-linked thermo-

setting modified polystyrene having very low dielectric losses and very high insulation resistance. Rotor insulation, where used (TYPES 1422-CB, -CL, and -N), is grade L-4 steatite, silicone treated.

TYPE 1422-D is a two-section, two-terminal capacitor, direct reading in total capacitance at the terminals.

TYPE 1422-N is similar to the TYPE 1422-D high-capacitance section but is designed for use at higher frequencies. To minimize residual inductance and resistance, the connections are made through ribbon leads to the center of the stator and to the center of the rotor through silver-alloy brushes bearing on a silver-overlay disk.

TYPES 1422-MD and -ME are two-section, two-terminal capacitors with scales reading the capacitance removed, i.e., the capacitance is maximum at the zero reading. This scale is particularly convenient for substitution measurements.

TYPES 1422-CB, -CC, -CL, and -CD are three-terminal capacitors with shielded coaxial terminals for use in three-terminal measurements. The calibrated direct capacitance is independent of terminal capacitances to ground, and losses are very low. The TYPE 1422-CL has approximately the same maximum capacitance as the -CC model, but constant and much lower terminal capacitances, so that it can be used in measurement circuits where high capacitance to ground can not be tolerated. This low value of stray capacitance, however, is achieved at the expense of minimum calibrated capacitance, which is 10 pF for the -CL model, as contrasted to 5 pF for the -CC model.

SPECIFICATIONS

Initial Accuracy: See table. The errors tabulated are possible errors, i.e., the sum of error contributions from setting, adjustment, calibration, interpolation, and standards. When the capacitor is in its normal position with the panel horizontal, the actual errors are almost always smaller. The accuracy is improved when the readings are corrected using the 12 calibrated values of capacitance given on the correction chart on the capacitor panel and interpolating linearly between calibrated points. Better accuracy can be obtained from a precision calibration of approximately 100 points on the capacitor dial, which permits correction for slight residual eccentricities of the worm drive and requires interpolation over only short intervals. This precision calibration is available for all models at an extra charge. Models so calibrated are listed with the additional suffix letter, P, in the type number. A plastic-enclosed certificate of calibration is supplied, giving corrections to one more figure than the tabulated accuracy.

Stability: The capacitance change with time is less than 1 scale division (0.02% of full scale) per year. The long-term accuracy can be estimated from the stability and the initial accuracy specifications.

Calibration: The measured values are obtained by comparison at 1 kc/s, to a precision better than $\pm(0.01\% + 0.00001 \text{ pF})$, with working standards whose absolute values are known to an accuracy typically $\pm 0.01\%$, determined and maintained in terms of reference standards periodically certified by the National Bureau of Standards.

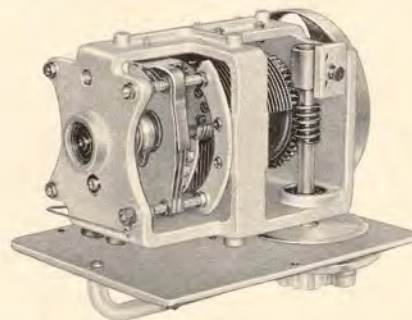
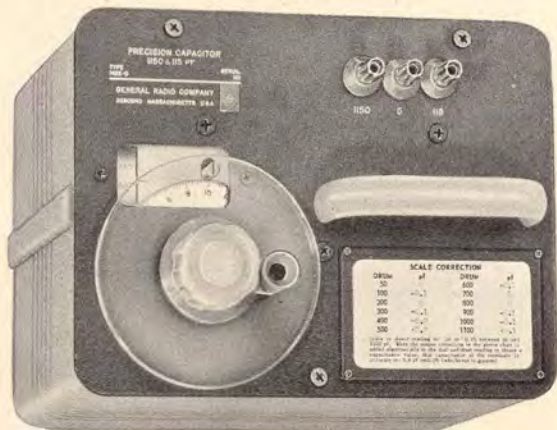
The indicated value of total capacitance of a two-terminal capacitor is the capacitance added when the TYPE 1422 Capacitor is plugged into a TYPE 874-Q9 Adaptor. The uncertainty of this method of connection is approximately $\pm 0.03 \text{ pF}$.*

Resolution: The dial can easily be read and set to 1/5 of a small division.

The backlash is less than 1/5 small division, corresponding to 0.004% of full-scale value. If the desired setting is always approached in the direction of increasing scale reading, no error from this cause will result.

Temperature Coefficient: Approximately $+20 \text{ ppm}/^\circ\text{C}$, for small temperature changes.

* John F. Hersh, "A Close Look at Connection Errors in Capacitance Measurements," *General Radio Experimenter*, July 1959.



Panel and interior views of Type 1422-D Precision Capacitor.

Residual Parameters: See table. The series resistance varies as the square root of the frequency above 100 kc/s. Its effect is negligible below this frequency.

Frequency Characteristic: See plots above, for two-terminal models. The resonance frequency for the -CB and -CC models is approximately 20 Mc/s; for the -CD model, 60 Mc/s for each section; -CL, 40 Mc/s.

Dissipation Factor: The losses in the two-terminal capacitors are primarily in the stator supports, which are of low-loss polystyrene ($DC = 0.01 \times 10^{-12}$).

The very small dissipation factor of the direct capacitance of the three-terminal capacitors is difficult to measure and is estimated to be not greater than 20×10^{-6} for -CB and -CL, and 10×10^{-6} for -CC and -CD.

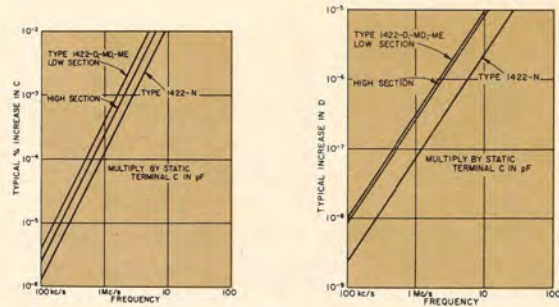
Insulation Resistance: Under standard conditions (23°C, less than 50% RH), greater than 10^{12} ohms.

Maximum Voltage: All models, 1000 V, peak.

Terminals: Jack-top binding posts are provided on 2-terminal models; standard 3/4-inch spacing is used. The rotor terminal is connected to the panel and shield. Locking GR874 Coaxial Connectors are used on three-terminal models.

Accessories Required: For connection to 3-terminal models, 2 GR874 Patch Cords (page 85) or equivalent.

Accessories Available: TYPE 874-Q9 Adaptor (see Calibration, above), for terminal units.



Variation with frequency of effective capacitance and dissipation factor per pF of capacitance for two-terminal Type 1422 Precision Capacitors.

Cabinet: Lab bench (see page 258).

Dimensions: Width 9 1/2, height 7, depth 8 1/2 inches (245, 180, 220 mm), over-all.

Net Weight: 10 1/2 to 12 1/2 lb (4.8 to 5.7 kg), depending upon model.

Shipping Weight: All models, 15 lb (7 kg).

TYPE 1422		Two-Terminal							Three-Terminal					
		-D	-N	-MD	-ME	-CB	-CC	-CL	-CD	CE				
CAPACITANCE RANGE, pF	Min	100	35	100	0	0	0	0	50	5	10	0.5	0.05	
	Max	1150	115	1150	1050	105	105	10.5	1100	110	110	11	1.1	
SCALE, pF/Division:		0.2	0.02	0.2	0.2	0.02	0.02	0.002	0.2	0.02	0.02	0.002	0.0002	
INITIAL ACCURACY: ± Picofarads listed below.														
Direct-Reading (Adjustment):														
Total Capacitance		0.6*	0.1*	0.6*	Differences from Zero				0.6	0.15	0.1	0.04	0.008	
Capacitance Difference		1.2	0.2	1.2	1	0.2	0.2	0.05	1.2	0.3	0.2	0.08	0.016	
With Corrections from Calibration Chart (supplied):														
Total Capacitance		0.3*	0.04*	0.3*					0.3	0.04	0.04	0.01	0.002	
Capacitance Difference†		0.6	0.08	0.6	0.6	0.08	0.08	0.02	0.6	0.08	0.08	0.02	0.004	
With Corrections from Precision Calibration (extra charge):														
Total Capacitance		0.1*	0.01*	0.1*					0.1	0.01	0.01	0.001	0.0002	
Capacitance Difference†		0.2	0.02	0.2	0.2	0.02	0.02	0.004	0.2	0.02	0.02	0.002	0.0004	
RESIDUALS (typical values):														
Series Inductance, μH		0.06	0.10	0.032	0.06	0.10	0.06	0.10	0.14	0.17	0.13	0.17	0.17	
Series Resistance, ohms at 1 Mc/s		0.04	0.05	0.012	0.04	0.05	0.04	0.05	0.1		0.1			
Terminal Capacitance, pF:		high terminal to case						min scale		36	850	34	98	25
								max scale		35	560	33	74	23
		low terminal to case						min scale		58	920	58	117	115
								max scale		53	600	55	92	93
Capacitance at Zero Scale Setting, pF:				1140	135	145	35							

* Total capacitance is the capacitance added when the capacitor is plugged into a TYPE 874-Q9 Adaptor. † Divide error by 2 when one setting is made at a calibrated point.

Catalog Number	Description	Price
1422-9704	Type 1422-D Precision Capacitor	\$350.00
1422-9904	Type 1422-DP Precision Capacitor (with precision calibration)	440.00
1422-9854	Type 1422-MD Precision Capacitor	350.00
1422-9913	Type 1422-MDP Precision Capacitor (with precision calibration)	440.00
1422-9855	Type 1422-ME Precision Capacitor	350.00
1422-9955	Type 1422-MEP Precision Capacitor (with precision calibration)	440.00
1422-9714	Type 1422-N Precision Capacitor	340.00
1422-9880	Type 1422-NP Precision Capacitor (with precision calibration)	390.00
1422-9916	Type 1422-CB Precision Capacitor	340.00
1422-9902	Type 1422-CBP Precision Capacitor (with precision calibration)	390.00
1422-9809	Type 1422-CC Precision Capacitor	340.00
1422-9903	Type 1422-CCP Precision Capacitor (with precision calibration)	390.00
1422-9933	Type 1422-CL Precision Capacitor	340.00
1422-9508	Type 1422-CLP Precision Capacitor (with precision calibration)	390.00
1422-9823	Type 1422-CD Precision Capacitor	310.00
1422-9925	Type 1422-CDP Precision Capacitor (with precision calibration)	400.00
0874-9874	Type 874-Q9 Adaptor	6.00



Type 1404 REFERENCE STANDARD CAPACITOR

3-TERMINAL — HERMETICALLY SEALED — GAS-FILLED

FEATURES:

- Excellent stability — better than 20 parts per million per year.
- Accurate adjustment — within ± 5 parts per million of nominal value.
- Low temperature coefficient.
- Hermetically sealed, with dry-nitrogen dielectric.
- Inner sealed container easily adaptable to oil immersion.
- Capacitance to ground less than 50 pF from either terminal.
- Can be easily used as a dissipation-factor standard.

USES: These capacitors have been designed as primary reference standards of capacitance with which working standards can be compared. The TYPE 1615-A Capacitance Bridge (page 58) is particularly well suited for this purpose and can be conveniently used to calibrate accurately a wide range of working standards in terms of a TYPE 1404 Reference Standard Capacitor. A single 1000- or 100-picofarad standard is also the only standard necessary to calibrate the bridge itself.

In combination with an accurately known external resistor, this capacitor becomes a standard of dissipation factor.

DESCRIPTION: All critical parts of the plate assembly are made of Invar for stability and low temperature

coefficient. After heat cycling and adjustment, the assembly is mounted in a heavy brass container, which, after evacuation, is filled with dry nitrogen under pressure slightly above atmospheric and sealed. The container is mounted on an aluminum panel and protected by an outer aluminum case. Each capacitor is subjected to a series of temperature cycles to determine hysteresis and temperature coefficients and to stabilize the capacitance.

Two locking GR874 Coaxial Connectors are used as terminals. The outer shell of one is connected to the case, but the outer shell of the other is left unconnected to permit the capacitor to be used with an external resistor as a dissipation-factor standard.

SPECIFICATIONS

Calibration: A certificate of calibration is supplied with each capacitor, giving the measured direct capacitance at 1 kc/s and at $23^\circ \pm 1^\circ\text{C}$. The measured value is obtained by a comparison to a precision better than ± 1 ppm with working standards whose absolute values are known to an accuracy of ± 20 ppm, determined and maintained in terms of reference standards periodically measured by the National Bureau of Standards.

Adjustment Accuracy: The capacitance is adjusted before calibration with an accuracy of ± 5 ppm to a capacitance about 5 ppm above the nominal value relative to the capacitance unit maintained by the General Radio reference standards.

Stability: Long-term drift is less than 20 parts per million per year. Maximum change with orientation is 10 ppm and is completely reversible.

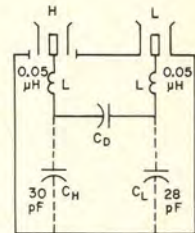
Temperature Coefficient of Capacitance: 2 ± 2 ppm/ $^\circ\text{C}$ from -20°C to $+65^\circ\text{C}$. A measured value with an accuracy of ± 1 ppm/ $^\circ\text{C}$ is given on the certificate.

Temperature Cycling: For temperature cycling over range from -20°C to $+65^\circ\text{C}$, hysteresis (retraceable) is less than 20 ppm at 23°C .

Dissipation Factor: Less than 10^{-5} at 1 kc/s.

Residual Impedances: See equivalent circuit for typical values of internal series inductances and terminal capacitances.

Equivalent circuit showing direct capacitance, C_d , and average values of residual inductance, L , and terminal capacitances, C_a and C_b . $C_d = 1000$ pF for Type 1404-A. $C_d = 100$ pF for Type 1404-B.



Maximum Voltage: 750 volts.

Terminals: Two locking GR874 Coaxial Connectors; easily convertible to other types of connectors by attachment of locking adaptors. Outer shell of one connector is ungrounded to permit capacitor to be used with external resistor as a dissipation-factor standard.

Accessories Required: For connection to TYPE 1615-A Capacitance Bridge, 2 TYPE 874-R20A or TYPE 874-R22LA Patch Cords.

Mechanical Data:

Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
6 3/4	175	6 5/8	170	8	205	8 1/2	3.9	14	6.5

For a more detailed description, see *General Radio Experimenter*, August 1963.

Catalog No.	Description	Price
1404-9701	Type 1404-A Reference Standard Capacitor, 1000 pF	\$225.00
1404-9702	Type 1404-B Reference Standard Capacitor, 100 pF	\$225.00

PATENT NOTICE. See Note 4, page 11.



STANDARD CAPACITORS

Type 1423-A PRECISION DECADE CAPACITOR



100 pF TO 1.111 μ F

FEATURES:

- Direct-reading accuracy $\pm(0.05\% + 0.05 \text{ pF})$.
- Long-term stability $\pm(0.01\% + 0.05 \text{ pF})$ per year.
- Easily readjusted in terms of reference standards.
- Accurate for either two- or three-terminal use.

USES: This capacitor is a very useful and versatile tool for calibration laboratories and for production-line measurements. Any value of capacitance between 100 pF and 1.111 μ F, in steps of 100 pF, can be set on the four decades and will be known to an accuracy of 0.05%. Thus a bridge can be standardized quickly to an accuracy exceeded only by that of individually certified laboratory standards of the highest available quality such as the TYPE 1404-A Reference Standard Capacitor.

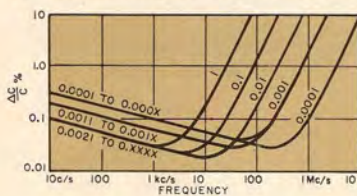
In conjunction with a limit bridge, such as the TYPE 1605-A Impedance Comparator, production-line measurements of arbitrary values of capacitance (such as EIA preferred values) can be made rapidly and accurately, with a minimum of setup time.

DESCRIPTION: This is a doubly shielded decade capacitor consisting of four decades of high-quality silvered-

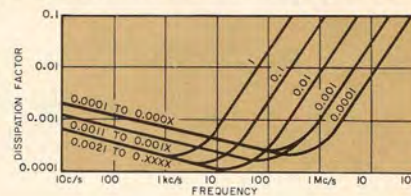
mica capacitors similar to those used in the TYPE 1409 Standard Capacitors. It is housed in a standard relay-rack-type cabinet with aluminum end frames for bench use. A new, in-line readout displays the selected value in large, bold numbers for maximum readability.

The decade switches and associated capacitors are mounted in an insulated metal compartment, which in turn is mounted in a complete metal cabinet. This double-shielded construction ensures that capacitance at the terminals is the same for either the three-terminal or the two-terminal method of connection (except for a constant difference of about one picofarad). This external capacitance can be included in the two-terminal calibration by the adjustment of a single trimmer.

The terminal capacitance values are adjusted precisely to nominal value by independent means and can subsequently be readjusted at calibration intervals, if necessary, without disturbance of the main capacitors.



(Left) Change in capacitance as a function of frequency. These changes are referred to the values that the capacitors would have if there were neither interfacial polarization nor series inductance. The 1-kc value on the plot should be used as a basis of reference in estimating frequency errors.



(Right) Dissipation factor as a function of frequency.

SPECIFICATIONS

Nominal Values: 100 pF to 1.111 μ F in steps of 100 pF.

Accuracy: $\pm(0.05\% + 0.05\text{pF})$ at 1 kc/s, calibrated in the three-terminal connection. Two-terminal connection (capacitor inserted into TYPE 874-Q9 Adaptor) adds about 1.3 pF reading.

Certificate: A certificate is supplied certifying that each component capacitor was adjusted by comparison, to a precision better than $\pm 0.01\%$, with working standards whose absolute values are known to an accuracy typically $\pm 0.01\%$, determined and maintained in terms of reference standards periodically certified by the National Bureau of Standards.

Frequency: Adjusted at 1 kc/s. The behavior of each individual capacitor is similar to that of a TYPE 505 Capacitor.

Dissipation Factor: Not greater than 0.001, 0.0005, and 0.0003 for capacitances of 100 to 1000 pF, 1100 to 2000 pF, and 2100 pF to 1.1110 μ F, respectively.

Temperature Coefficient of Capacitance: Approximately +35 ppm per degree between 10° and 50°C.

Insulation Resistance: Greater than 50 G Ω to 0.1 μ F and greater than 5 G Ω from 0.1 μ F to 1.111 μ F.

Maximum Voltage: 500 V peak, up to 10 kc/s.

Accessories Supplied: Two TYPE 874-Q9 Adaptors.

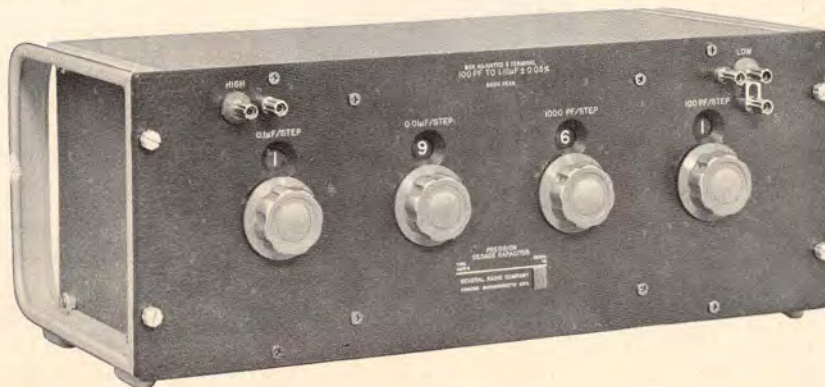
Cabinet: Rack-bench; rack model supplied without metal supports.

Mechanical Data: Rack-Bench Cabinet (see page 258).

Model	Width		Height		Depth		Net Weight		Shipping Weight	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Bench	19	485	7¼	185	10½	270	26	12.0	39	18
Rack	19	485	7	180	8½*	220	26	12.0	39	18

* Behind panel.

Catalog No.	Description	Price
1423-9801	Type 1423-A Precision Decade Capacitor, Bench Model	\$695.00
1423-9811	Type 1423-A Precision Decade Capacitor, Rack Model	695.00





STANDARD CAPACITORS

Type 1403 STANDARD AIR CAPACITOR (Three-Terminal)

USES: For measurement at 100 pF and below, a three-terminal connection increases the accuracy by eliminating the uncertainty in the measurement introduced by the capacitances between the capacitor terminals and ground. The TYPE 1403 Standard Air Capacitors are stable, three-terminal standards in decimal values from 0.001 to 1000 pF. Their terminals are arranged to plug directly into the UNKNOWN terminals of the TYPE 1615-A Capacitance Bridge.

DESCRIPTION: The three largest sizes are similar in construction to the TYPE 1401. The smaller capacitance units are made up of two plates, with a grounded plate between them; an aperture in the grounded plate determines the magnitude of the direct capacitance. Dielectric losses are not detectable; there is no solid dielectric in the direct-capacitance field. All have shielded terminals, both of which are insulated from the case.

SPECIFICATIONS

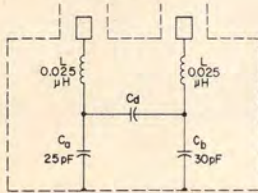
Calibration: A certificate of calibration is supplied with each unit giving the measured capacitance at 1 kc/s and at a specified temperature. The measured value is the direct capacitance between shielded terminals when the capacitor has at least one lead completely shielded and its case connected to a guard point. This value is obtained by comparison, to a precision better than $\pm(0.01\% + 0.00001 \text{ pF})$, with working standards whose absolute values are known to an accuracy typically $\pm 0.01\%$, determined and maintained in terms of reference standards periodically certified by the National Bureau of Standards.

Stability: Capacitance change is less than 0.05% per year.

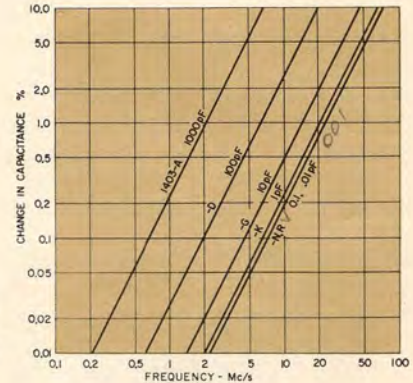
Residual Impedances: See equivalent circuit and plot.

Temperature Coefficient of Direct Capacitance: Typically 20 to 40 ppm per degree between 20° and 70°C. The larger coefficients apply to the smaller capacitance values.

Terminals: GR874 Coaxial Connectors, which provide complete shielding of the leads.



Equivalent circuit showing direct capacitance, C_d , and typical values of residual inductance, L , and terminal capacitances, C_a and C_b .



Change (percent) in effective direct capacitance, with frequency, produced by residual inductance.

Mounting: Aluminum panel and cylindrical case.

Accessories Supplied: Two TYPE 874-C58A Cable Connectors.

Dimensions: Diameter $3\frac{1}{16}$ in (78 mm), height $4\frac{7}{8}$ in (125 mm), over-all.

Net Weight: 1 lb (0.5 kg). **Shipping Weight:** 4 lb (1.9 kg).

Catalog Number	Type	Nominal Capacitance	Adjustment Accuracy	Peak Volts	Dissipation Factor	Price
1403-9701	Type 1403-A	1000 pF	0.1%	700	20×10^{-6}	\$80.00
1403-9704	Type 1403-D	100 pF	0.1%	1500	20×10^{-6}	65.00
1403-9707	Type 1403-G	10 pF	0.1%	1500	30×10^{-6}	55.00
1403-9711	Type 1403-K	1.0 pF	0.1%	1500	20×10^{-6}	45.00
1403-9714	Type 1403-N	0.1 pF	0.1%	1500	20×10^{-6}	45.00
1403-9718	Type 1403-R	0.01 pF	0.3%	1500	20×10^{-6}	45.00
1403-9722	Type 1403-V	0.001 pF	1.0%	1500	20×10^{-6}	45.00

PATENT NOTICE. See Note 4, page 11.



Type 1401 STANDARD AIR CAPACITOR (Two-Terminal)

STANDARD CAPACITORS



FEATURES:

- High accuracy and stability.
- Low losses.
- Low temperature coefficient.
- Convenient size.

USES: The TYPE 1401 Standard Air Capacitors are accurate and stable two-terminal capacitors for laboratory use as reference or working standards. They supplement the TYPE 1409 series of fixed mica capacitors by providing standards of lower loss and lower capacitance.

DESCRIPTION: The aluminum plate assemblies are supported by a mounting plate attached to an aluminum casting. This casting, together with the cylindrical aluminum case, provides a dust-free enclosure and a complete shield. The low, or ground, terminal of the capacitor is connected to this shield. Three supporting rods are used for each of the plate assemblies, ensuring a high degree of rigidity and stability, and all plates, rods, and spacers are aluminum, to minimize thermal stresses. Terminals are insulated by polystyrene bushings and spaced to plug directly into General Radio binding posts, such as the UNKNOWN terminals of the TYPE 716-C Capacitance Bridge.



SPECIFICATIONS

Calibration: A certificate of calibration is supplied with each unit, giving the measured capacitance at 1 kc/s and at a specified temperature. The measured capacitance is the capacitance added when the standard is plugged directly into General Radio binding

posts. This value is obtained by comparison, to a precision better than $\pm 0.01\%$, with working standards whose absolute values are known to an accuracy typically $\pm 0.01\%$, determined and maintained in terms of reference standards periodically certified by the National Bureau of Standards.

Stability: Capacitance change is less than 0.05% per year.

Residual Impedances: The series inductance of all units is approximately 0.05 μ H. See plot.

The metallic resistance of all units is approximately 0.027 Ω at 1 Mc/s. The series resistance varies as the square root of frequency above about 100 kc/s.

Temperature Coefficient of Capacitance: Typically 10 to 20 ppm/ $^{\circ}$ C between 20 $^{\circ}$ and 70 $^{\circ}$ C.

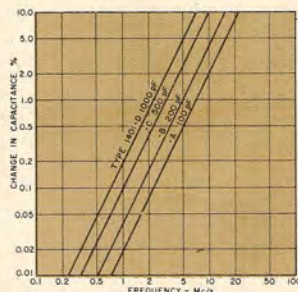
Terminals: TYPE 274 Plugs, spaced $\frac{3}{4}$ inch on centers, to plug into TYPE 938 Binding Posts.

Mounting: Aluminum panel and cylindrical case.

Dimensions: Dia $\frac{3}{16}$ in (78 mm), height $4\frac{7}{8}$ in (125 mm), over-all.

Net Weight: 1 $\frac{1}{8}$ lb (0.6 kg). **Shipping Weight:** 4 lb (1.9 kg).

Change (percent) in effective terminal capacitance, with frequency, produced by residual inductance.



Catalog No.		Insertion Capacitance	Initial Accuracy	Peak Volts	Dissipation Factor	Price
1401-9701	Type 1401-A	100 pF	0.2%	1500	100×10^{-6}	\$50.00
1401-9702	Type 1401-B	200 pF	0.15%	1200	50×10^{-6}	54.00
1401-9703	Type 1401-C	500 pF	0.12%	900	20×10^{-6}	57.00
1401-9704	Type 1401-D	1000 pF	0.1%	700	20×10^{-6}	65.00

Type 1429-A FUEL-GAGE TESTER

The TYPE 1429-A Fuel-Gage Tester is an adjustable standard capacitor for testing and calibrating modern capacitance-type fuel-gage systems in both reciprocating-engine and jet-engine planes.

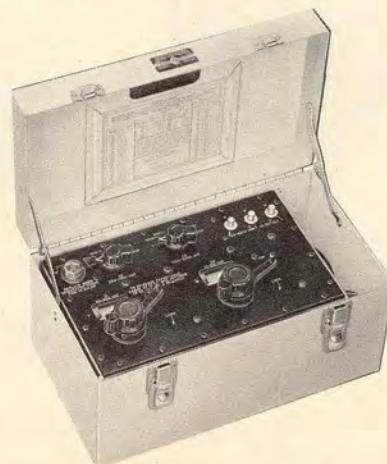
DESCRIPTION: This tester fulfills the same function as the military MD-1 Tester but has smaller dimensions and lower weight. External connections are made through keyed coaxial connectors. Cables and adaptors as required by specification MIL-T-8579 (USAF) are supplied.

All capacitors and a renewable desiccant cartridge are mounted on an aluminum panel and enclosed in a moisture-sealed aluminum cabinet. The latter is shock-mounted in an aluminum transit case with a compartment to hold nine connecting cables and three tee adaptors.

Dimensions: Width 17 $\frac{1}{2}$, height 10 $\frac{1}{2}$, depth 10 $\frac{1}{2}$ in (445, 270, 270 mm), over-all.

Net Weight: 29 lb (13.5 kg). **Shipping Weight:** 34 lb (15.5 kg).

Catalog No.	Description	Price
1429-9701	Type 1429-A Fuel-Gage Tester	\$975.00



ASK FOR COMPLETE SPECIFICATIONS



Type 1409 STANDARD CAPACITOR

FEATURES:

- Stable within $\pm 0.01\%$ per year.
- Calibrated for both two-terminal and three-terminal connections.
- Plug-in terminals permit several units to be stacked one upon the other without leads.

USES: The TYPE 1409 Standard Capacitors are fixed mica capacitors of very high stability for use as two- or three-terminal reference or working standards in the laboratory.

Typical capacitors, observed over more than eight years, have shown random fluctuations of less than $\pm 0.01\%$ in measured capacitance with no evidence of systematic drift.

DESCRIPTION: These capacitor units consist of a silvered-mica and foil pile, spring-held in a heavy metal

clamping structure for mechanical stability. The units are selected for low dissipation factor and are stabilized by heat cycling. They are housed, with silica gel to provide continuous desiccation, in cast aluminum cases, sealed with high-temperature potting wax. A well is provided in the wall of the case for the insertion of a dial-type thermometer. Three jack-top binding posts are provided on the top of the case and removable plugs on the bottom, for convenient parallel connection without error.

SPECIFICATIONS

Accuracy: Within $\pm 0.05\%$ of the nominal capacitance value (two-terminal) marked on the case. Accuracy is guaranteed for two years under the terms of our standard warranty if the capacitor has not been damaged by excessive current or voltage.

Calibration: A certificate of calibration is supplied with each unit, giving both two- and three-terminal measured capacitances at 1 kc/s and at a specified temperature. The measured value is the capacitance added when the standard is plugged directly into General Radio binding posts. This value is obtained by comparison, to a precision better than $\pm 0.01\%$, with working standards whose absolute values are known to an accuracy typically $\pm 0.01\%$, determined and maintained in terms of reference standards periodically certified by the National Bureau of Standards.

Stability: Capacitance change is less than 0.01% per year.

Temperature Coefficient of Capacitance: $+35 \pm 10$ ppm per degree between 10° and 70°C.

Dissipation Factor: Less than 0.0003 at 1 kc/s and 23°C (see curves, next page). Measured dissipation factor at 1000 c/s is

stated in the certificate to an accuracy of ± 0.00005 .

Frequency Characteristics: See typical curves on page 193. Values of series inductance and series resistance at 1 Mc/s are given in the table. This resistance varies as the square root of the frequency for frequencies above 100 kc/s.

Approximate Terminal Capacitance: From H terminal to case (G), 12 to 50 pF. From L terminal (outside foils of capacitor) to case, 300 to 1300 pF.

Leakage Resistance: 5000 ohm-farads or 100 GΩ, whichever is the lesser.

Maximum Voltage: 500 V, peak, below the limiting frequencies tabulated below. At high frequencies the allowable voltage is inversely proportional to frequency, approximately. These limits correspond to a temperature rise of 40°C for power dissipations of 5, 6, and 7.5 W for the small, medium, and large cases, respectively.

Dimensions: Small case, 3¼ by 4 by 2 in (85, 105, 50 mm); medium case, 3¼ by 4 by 2 11/16 in (85, 105, 70 mm); large case, 3¼ by 5½ by 2 11/16 in (85, 145, 70 mm) over-all.

Catalog Number		Nominal Capacitance μF	Maximum Peak Volts	Frequency Limit for Max Volts	Series Inductance μH	Resistance in Ohms at 1 Mc/s	Net Weight	Shipping Weight	Price
1409-9706	Type 1409-F	0.001	500	4.7 Mc/s	0.050	0.02	1 ¼ lb (0.6 kg)	4 lb (1.9 kg)	\$ 32.00
1409-9707	Type 1409-G	0.002	500	2.7 Mc/s	0.050	0.02	1 ¼ lb (0.6 kg)	4 lb (1.9 kg)	32.00
1409-9711	Type 1409-K	0.005	500	1.3 Mc/s	0.050	0.02	1 ¼ lb (0.6 kg)	4 lb (1.9 kg)	34.00
1409-9712	Type 1409-L	0.01	500	750 kc/s	0.050	0.02	1 ¼ lb (0.6 kg)	4 lb (1.9 kg)	34.00
1409-9713	Type 1409-M	0.02	500	430 kc/s	0.050	0.02	1 ¼ lb (0.6 kg)	4 lb (1.9 kg)	36.00
1409-9718	Type 1409-R	0.05	500	210 kc/s	0.055	0.02	1 ¼ lb (0.6 kg)	4 lb (1.9 kg)	39.00
1409-9720	Type 1409-T	0.1	500	120 kc/s	0.055	0.02	1 ¼ lb (0.6 kg)	4 lb (1.9 kg)	42.00
1409-9721	Type 1409-U	0.2	500	70 kc/s	0.055	0.02	1 ¼ lb (0.6 kg)	4 lb (1.9 kg)	55.00
1409-9724	Type 1409-X*	0.5	500	35 kc/s	0.055	0.02	1 ¾ lb (0.8 kg)	4 ½ lb (2.1 kg)	105.00
1409-9725	Type 1409-Y†	1.0	500	17 kc/s	0.070 0.055	0.03	2 ½ lb (1.1 kg)	5 lb (2.3 kg)	175.00

* Mounted in medium case. † Mounted in large case.



Type 1409-T



Type 1409-X



Type 1409-Y



Type 505 CAPACITOR

FEATURES:

- Small, convenient, stable, and accurate.
- Low-loss phenolic case to minimize dielectric loss and leakage conductance.
- Low temperature coefficient of capacitance.

USES: The TYPE 505 Capacitors are stable, low-loss mica capacitors for use as high-quality circuit elements and as secondary standards where the higher accuracy, complete shielding, and lower loss of the TYPE 1409 Standard Capacitors are not required.

DESCRIPTION: The TYPE 505 unit uses the same silvered-mica and foil pile used in the TYPE 1409 and has almost equally high stability. Each unit is sealed with wax in a low-loss phenolic case. Silica gel is included for continuous desiccation, and granulated polyethylene is provided to absorb shock.

SPECIFICATIONS

Accuracy: At 1 kc/s, $\pm 0.5\%$ or ± 3 pF, whichever is the larger.

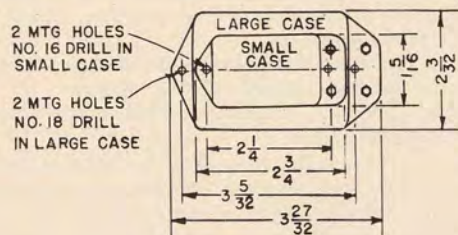
Temperature Coefficient: Approximately +35 ppm per degree between 10° and 50°C. Calibration is made at 23°C, at a frequency of 1 kc/s.

Dissipation Factor: 0.0003 for 1000 pF and higher; 500 pF, 0.00035; 200 pF, 0.0004; 100 pF, 0.0006.

Frequency Characteristics: Similar to those for TYPE 1409. Series inductance is approximately 0.055 μ H for units in small case and 0.085 μ H for large case. Series resistance at 1 Mc/s is approximately 0.03 Ω for small case and 0.05 Ω for large case, varying as square root of frequency above 100 kc/s.

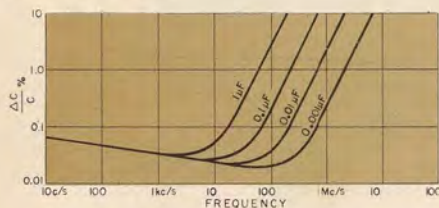
Leakage Resistance: Greater than 100 G Ω when measured at 500 V except for the TYPES 505-T, 505-U, and 505-X, for which it is greater than 50, 25, and 10 G Ω , respectively.

Maximum Voltage: See table. At higher frequencies, the allowable voltage decreases and is inversely proportional to the square root of the frequency. These limits correspond to a temperature rise of 40°C for a power dissipation of 1 W for the small case and 2.5 W for the large case.

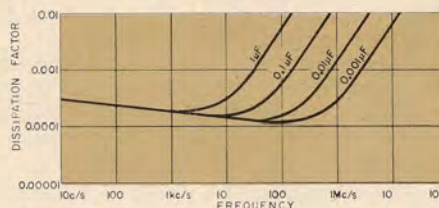


Terminals: Two screw terminals spaced $\frac{3}{4}$ inch apart, with two removable plug bottoms, TYPE 274-P. High terminal (inside foil) is marked H.

Dimensions: See sketch; dimensions shown are in inches. Over-all height, $1\frac{5}{8}$ inches for large case, 1 inch for small case, exclusive of plugs. To convert inches to mm, multiply by 25.4.

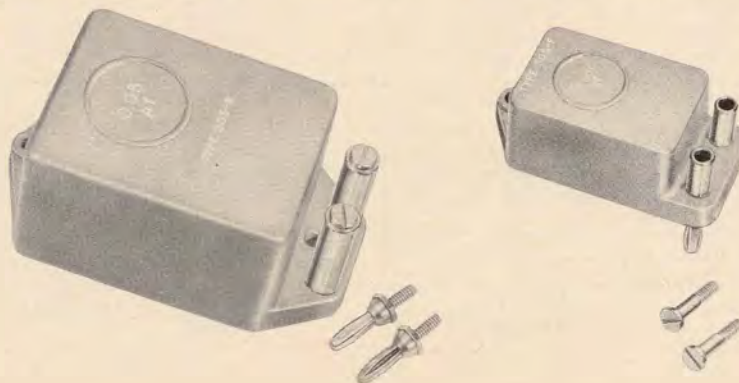


(Left) Change in capacitance as a function of frequency for typical Type 1409 and Type 505 Capacitors. The 1-kc value on the plot should be used as a basis of reference in estimating frequency errors. (Right) Dissipation factor as a function of frequency.



Catalog No.	Type	Capacitance	Maximum Peak Volts	Frequency Limit For Max Volts	Net Weight	Shipping Weight	Price
0505-9701	Type 505-A	100 pF	700	10 Mc/s	4 oz (115 g)	8 oz (230 g)	\$10.00
0505-9702	Type 505-B	200 pF	700	6 Mc/s	4 oz (115 g)	8 oz (230 g)	7.50
0505-9705	Type 505-E	500 pF	500	4 Mc/s	4 oz (115 g)	8 oz (230 g)	7.50
0505-9706	Type 505-F	0.001 μ F	500	2.3 Mc/s	4 oz (115 g)	8 oz (230 g)	7.50
0505-9707	Type 505-G	0.002 μ F	500	1.3 Mc/s	5 oz (145 g)	8 oz (230 g)	7.50
0505-9711	Type 505-K	0.005 μ F	500	630 kc/s	5 oz (145 g)	8 oz (230 g)	7.50
0505-9712	Type 505-L	0.01 μ F	500	360 kc/s	5 oz (145 g)	8 oz (230 g)	9.00
0505-9713	Type 505-M	0.02 μ F	500	210 kc/s	6 oz (170 g)	8 oz (230 g)	11.50
0505-9718	Type *505-R	0.05 μ F	500	100 kc/s	11 oz (315 g)	1 lb (0.5 kg)	18.00
0505-9720	Type *505-T	0.1 μ F	500	50 kc/s	12 oz (340 g)	1 lb (0.5 kg)	22.00
0505-9721	Type *505-U	0.2 μ F	500	20 kc/s	13 oz (370 g)	1 lb (0.5 kg)	35.00
0505-9724	Type *505-X	0.5 μ F	500	10 kc/s	15 oz (425 g)	1 1/4 lb (0.6 kg)	75.00

*Mounted in large case.





TYPE 1424-A STANDARD POLYSTYRENE-DECADE DIELECTRIC CAPACITOR — 10 μF
 TYPE 1425-A STANDARD POLYSTYRENE-DECADE DIELECTRIC CAPACITOR — 100 μF
 TYPE 1424-M DECADE CAPACITOR — 10 μF , PAPER DIELECTRIC

These single-decade capacitors find many uses as standards and circuit elements where high values of capacitance are required.

TYPE 1424-A — 20 polystyrene capacitors, paired to give 10 1- μF units, are housed in two hermetically sealed, non-ferrous metal cases with Teflon*-insulated high terminals, the cases being the common (LOW) terminal. The aluminum outer cabinet and panel are insulated from both capacitor terminals, so that either two- or three-terminal connections can be used.

Residual series inductance and resistance have been minimized by the use of current-sheet conductors, ribbon leads, and multiple switch contacts.

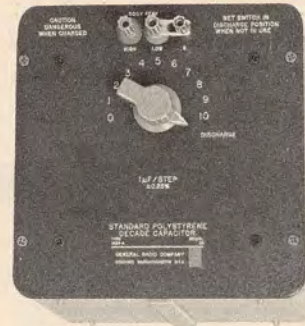
A discharge position is provided on the switch to minimize the danger of electrical shock to the operator. To avoid damage to the capacitor, charging current is also limited by the switching arrangement.

TYPE 1424-M — This capacitor is a 1-microfarad-per-step decade, which has less rigorous performance specifications than the TYPE 1424-A and a correspondingly lower price. Sealed foil-paper capacitors of non-inductive extended-foil construction are used with a viscous impregnant to improve stability.

TYPE 1425-A — Contains 100 capacitors of 1 μF , combined in tens. The configuration and dimensions of binding posts, bus, studs, and current-sheet connectors are arranged to minimize residuals. Switching resistance is kept low through the use of tapered plug connectors, rather than rotary switches. Binding posts have large contact areas and are easily tightened by hand to minimize contact resistance.

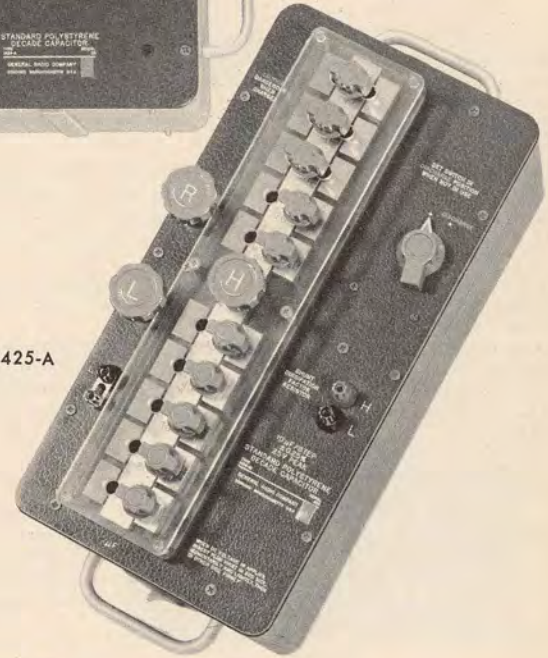
This capacitor is an excellent reference standard for checking the calibration of bridges for the measurement of electrolytic capacitors. To obtain the high dissipation factors needed for that purpose, a decade or other resistor can be connected in parallel or series with the capacitor.

* Registered trademark of E. I. duPont de Nemours and Company.



Type 1424-A. Type 1424-M is similar in appearance.

Type 1425-A



SPECIFICATIONS

Accuracy: The accuracy stated in the table below is guaranteed for two years under the terms of our standard warranty, if the capacitor has not been damaged by excessive current or voltage.

Certificate: For TYPES 1424-A and 1425-A, a certificate is supplied giving measured values obtained by comparison, to a precision better than $\pm 0.01\%$, with working standards whose absolute values are known to an accuracy better than $\pm 0.05\%$, deter-

mined and maintained in terms of reference standards periodically measured by the National Bureau of Standards.

For TYPE 1424-M, a certificate is supplied, certifying the accuracy of adjustment in terms of reference standards, periodically measured by the National Bureau of Standards.

Frequency Characteristic: Calibration and adjustment is made at 1 kc/s. Plots of typical change in capacitance and dissipation factor with frequency are given in the calibration certificate.

Type	1424-A	1425-A	1424-M
Total Capacitance	10 μF	100 μF	10 μF
Capacitance per Step	1 μF	10 μF	1 μF
Dielectric	Polystyrene	Polystyrene	Paper
Adjustment Accuracy at 1 kc/s	$\pm 0.25\%$	$\pm 0.25\%$	$\pm 1\%$
Stability	$\pm 0.05\%$ /year	$\pm 0.05\%$ /year	$\pm 0.35\%$ /year
Dissipation Factor at 1 kc/s	< 0.0003	< 0.0004	< 0.005
Insulation Resistance	$> 10^6 \Omega\text{F}$	$> 10^6 \Omega\text{F}$	$> 10^4 \Omega\text{F}$
Voltage Recovery*	$< 0.1\%$	$< 0.1\%$	$< 5\%$
Temp Coefficient of Capacitance (typical) ppm/ $^{\circ}\text{C}$	-140	-140	+180
Max Operating Temperature $^{\circ}\text{C}$	65	65	90
Max Safe Voltage	500 V, peak, below 10 kc/s	25 V, peak, below 10 kc/s	500 V, peak, up to 2 kc/s
Dimensions Width, height, depth, inches (mm)	9 $\frac{1}{2}$, 7 $\frac{3}{4}$, 8 (245, 195, 205)	9 $\frac{3}{8}$, 19 $\frac{1}{8}$, 8 $\frac{1}{8}$ (240, 485, 205)	9 $\frac{1}{2}$, 6, 8 (245, 150, 205)
Net Weight lb (kg)	16 $\frac{1}{2}$ (7.5)	46 $\frac{1}{2}$ (21.5)	7 $\frac{3}{4}$ (3.6)
Shipping Weight lb (kg)	19 (9)	67 (31)	11 (5)
Catalog Number	1424-9701	1425-9701	1424-9713
Price	\$325.00	\$1400.00	\$195.00

* Dielectric absorption.

Type 1412-BC DECADE CAPACITOR

50 pF TO 1.11115 μ F

FEATURES:

Variable air capacitor provides continuous capacitance adjustment between polystyrene decade steps.

Capacitance is the same (within about 1 pF) for both 2-terminal and 3-terminal connections.

Available for either lab-bench or relay-rack mounting.

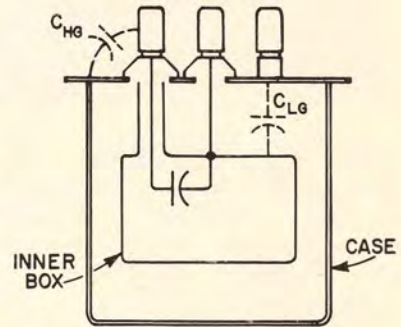
In-line readout with large white numerals against a dark background.

High insulation resistance, low dielectric absorption, and low losses.

USES: The wide capacitance range and high resolution of this decade capacitance box make it exceptionally useful in both laboratory and test shop. Owing to its fine adjustment of capacitance, it is a convenient variable capacitor to use with the TYPE 1605-A Impedance Comparator. The polystyrene dielectric used in the decade steps is necessary for applications requiring low dielectric absorption and constancy of both capacitance and dissipation factor with frequency.

DESCRIPTION: Four decades of polystyrene capacitors and a variable air capacitor are used, mounted in a double-shield box. The double shielding provides 2-terminal and 3-terminal capacitances that are the same except for the capacitance between the terminals. The variable air capacitor with a linear ΔC of 100 pF and a

The double shielding used in the Type 1412-BC Decade Capacitor keeps C_{HG} very small. This capacitance is the difference between the 3-terminal and 2-terminal capacitance of the box; C_{LG} is approximately 125 pF.



resolution of better than 1 pF provides continuous adjustment between the 100-pF steps of the smallest decade. Brackets are provided for rack mounting.

SPECIFICATIONS

Capacitance: 50 pF to 1.11115 μ F in steps of 100 pF with a 0- to 100-pF variable air capacitor providing continuous adjustment to better than 1 pF between steps. Capacitance for 2- and 3-terminal connection differs by about 1 pF.

Dielectric: Polystyrene for decade steps.

Accuracy: $\pm(1.0\% + 5 \text{ pF})$ at 1 kc/s.

Temperature Coefficient: $-140 \text{ ppm}/^\circ\text{C}$ (nominal).

Frequency Characteristics: Dc Cap/1-kc Cap < 1.001 . At higher frequencies the increase is approximately $\Delta C/C = (f/f_r)^2$. The resonant frequency, f_r , varies from over 400 kc/s for a capacitance of 1 μ F to about 27 Mc/s for a capacitance of 150 pF when connections are made to the front terminals. f_r is about 300 kc/s and 70 Mc/s for rear connections and the same capacitances.

Maximum Operating Temperature: 65°C.

Dielectric Absorption (Voltage Recovery): 0.1% maximum.

Dissipation Factor: 150 to 1000 pF, 0.001, max at 1 kc/s; over 1000 pF, 0.0002, max, at 1 kc/s.

Insulation Resistance: 10^{12} ohms, minimum, after 2 minutes at 500 V dc.

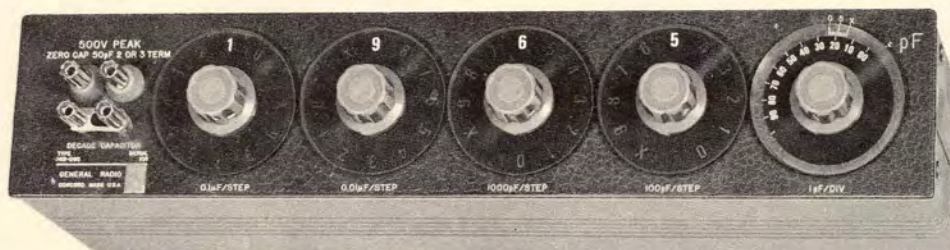
Maximum Voltage: 500 V peak up to 35 kc/s.

Terminals: Four TYPE 938 Binding Posts with grounding link are provided on the panel. Two of the binding posts are connected to the case and located for convenient use with patch cords in 3-terminal applications. Access is also provided to rear terminals for relay-rack applications.

Mechanical Data: Lab-Bench Cabinet (see page 258)

Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
17 $\frac{5}{16}$	440	3 $\frac{1}{2}$	89	6	155	8 $\frac{1}{2}$	3.9	10	4.6

Catalog Number	Description	Price
1412-9410	Type 1412-BC Decade Capacitor	\$170.00



NEW

in catalog S

SPECIFICATIONS

DECADE CAPACITOR UNITS		Dielectric				Polystyrene			Silvered Mica — GR Type 505			Paper	Silvered Mica (Molded)	
TYPE NUMBER		980-A	980-B	980-C	980-D	980-F	980-G	980-H	980-L	980-M	980-N			
Maximum Capacitance (μF)		1.0	0.1	0.01	0.001	1.0	0.1	0.01	1.0	0.1	0.01			
Capacitance per Step (μF)		0.1	0.01	0.001	0.0001	0.1	0.01	0.001	0.1	0.01	0.001			
Zero Capacitance	2-terminal connection	Approximately 11 pF												
	3-terminal connection	5 pF												
Accuracy ¹	2-terminal connection ²	±1%			±(1% +2 pF)	±0.5%			±1.5%	±1%				
	3-terminal connection	±1%	±1%	±1.5%	±1% - (2% +4 pF)	±0.5%	±0.5%	±1%	±1.5%	±1%	±1%			
Dissipation Factor		<0.0002				<0.0003			<0.005	<0.001				
Insulation Resistance at 100 V, 25°C, 50% RH (ohms)		10 ¹²				5 × 10 ⁹	25 × 10 ⁹	25 × 10 ⁹	10 ¹⁰	10 ⁹	10 ⁹			
Temperature Coefficient of Capacitance (ppm/°C)		-140 nominal				+35 ± 10			+180 nominal	EIA Characteristic C				
Max Voltage ³ (dc or peak)		500				500			500	500				
Frequency Limit for Maximum Voltage ³		35 kc/s	125 kc/s	800 kc/s	5 Mc/s	10 kc/s	100 kc/s	600 kc/s	1 kc/s	50 kc/s	400 kc/s			
Maximum Operating Temperature (C)		65				90			90	90	90			
Voltage Recovery ⁴		<0.1%				<3%			<5%	—				
Terminals		Bus wire				Flexible leads								
Mounting Hardware Supplied		Knob, dial plate, switch stops, and machine screws												
Width, height, depth behind panel — inches (multiply by 25.4 for mm)		3 7/8, 3 3/8, 3 1/8	2 3/4, 3 3/8, 3 1/8			4 7/8, 4 1/4, 4 1/8	4 1/4, 4, 4 1/8	3 5/8, 3 3/8, 4 1/8	2 3/4, 3 1/4, 3 1/2					
Net Weight — lb (kg)		2 1/8 (1)				3 3/4 (1.7)	2 (0.9)	1 5/8 (0.8)	1 5/8 (0.8)	1 1/2 (0.7)	1 1/2 (0.7)			
Shipping Weight — lb (kg)		6 (2.8)				8 (3.7)	6 (2.8)	6 (2.8)	6 (2.8)	6 (2.8)	6 (2.8)			
Catalog Number		0980-9701	0980-9702	0980-9703	0980-9704	0980-9706	0980-9707	0980-9708	0980-9712	0980-9713	0980-9714			
Price		\$66.00	\$45.00	\$45.00	\$50.00	\$200.00	\$77.00	\$52.00	\$49.00	\$57.00	\$35.00			

DECADE CAPACITORS		1419-A		1419-B		1419-K		1419-M	
TYPE NUMBER		1419-A		1419-B		1419-K		1419-M	
Type 980 Decades Used		A, B, C		A, B, C, D		F, G, H		L, M, N	
Maximum Capacitance of Box (μF)		1.110		1.1110		1.110		1.110	
In Steps of (μF)		0.001		0.0001		0.001		0.001	
Zero Capacitance	2-terminal connection	37 pF		50 pF		41 pF		35 pF	
	3-terminal connection	15 pF		20 pF		13 pF		16 pF	
Frequency Characteristic		Similar to those for the Type 980 Decade Capacitor Units, modified by the additional inductance and resistance at the box terminals and wiring.							
Dc Cap/1-kc Cap		<1.001				Typically 1.03			
Cabinet		Lab-bench (see page 258)							
Over-all Dimensions — in (mm)		13, 4 5/16, 5 (330, 110, 130)		16 5/16, 4 5/16, 5 (415, 110, 130)		14 1/8, 5 1/2, 6 (359, 140, 153)		14 1/8, 5 1/2, 6 (359, 140, 153)	
Net Weight — lb (kg)		8 3/8 (3.8)		10 1/2 (4.8)		11 1/4 (5.5)		6 1/4 (2.9)	
Shipping Weight — lb (kg)		10 (4.6)		11 (5)		18 (8.5)		8 (3.7)	
Catalog Number		1419-9701		1419-9702		1419-9711		1419-9713	
Price		\$180.00		\$230.00		\$360.00		\$170.00	

¹ Capacitance increments from zero position are within this percentage of the indicated value for any setting at 1 kc/s.
² Units are checked with switch mechanism high, electrically, and the common lead and case grounded.
³ At frequencies above the indicated maximum, the allowable voltage decreases and is (approximately) inversely proportional to frequency. These limits correspond to a temperature of 40°C.
⁴ Final % of original charging voltage after a charging period of one hour and a 10-second discharge through a resistance equal to one ohm per volt of charging.

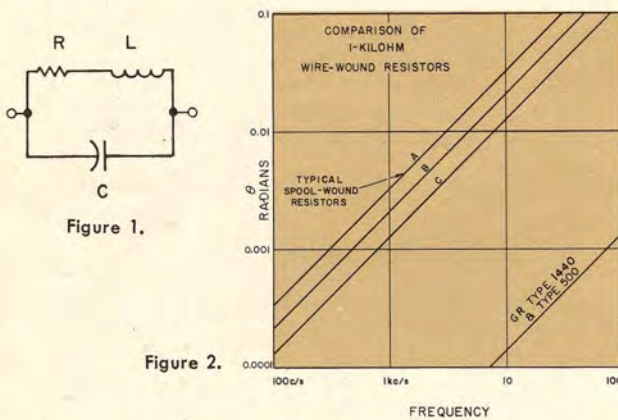
Decade Resistors and Decade Inductors are described on pages 203 and 208, respectively.



STANDARD RESISTORS



Because of its accuracy of adjustment, long-term stability, low- and uniform-temperature coefficient, and relative immunity to ambient humidity conditions, the wire-wound resistor is the most suitable type for use as a laboratory standard at audio and low radio frequencies, as well as at dc. In the resistance range from a fraction of an ohm to over one megohm, such resistors have been developed to a high state of refinement through improvements in design and manufacturing techniques.



The effective parallel admittance is given by:

$$Y = G + jB = \frac{1}{R_p} + \frac{1}{jX_p} = \frac{\frac{1}{R} + j\omega \left[C - \frac{L}{R^2} \left(1 - \frac{\omega^2}{\omega_r^2} \right) \right]}{1 + \left(\frac{\omega L}{R} \right)^2}$$

At low frequencies where terms in ω^2 are negligible, the resistor may be represented by a two-element network consisting of the dc resistance, R , in series with an inductance equal to $L - R^2C$ or in parallel with a capacitance equal to $C - L/R^2$. Because of the presence of the R^2 term in the equivalent reactive parameters, shunt capacitance is the dominating residual for high values of resistance, while for low values the series inductance invariably predominates. Generally, individual wire-wound resistors above a few kilohms are capacitive, while decades are capacitive at somewhat lower values.

In the simplified circuit above, the effective parallel resistance of a high-valued resistor in which shunt capacitance dominates would be independent of frequency. Actually, other effects may cause the parallel resistance to decrease with frequency. For example, dielectric losses in the shunt capacitance, C , of Figure 1 are equivalent to a resistance

$$R_d = \frac{1}{D\omega C}$$

(where D is the dissipation factor of the distributed capacitance), which decreases with frequency and causes the effective parallel resistance to decrease rapidly beyond a certain frequency. In addition, distributed capacitance along the winding causes a similar rapid decrease in resistance even if its dielectric loss is negligible. The equations above indicate that the effective series resistance of low-valued resistors would be independent of frequency up to quite high frequencies. In practice, if the residual inductance and capacitance are kept small, skin effect becomes the main cause for departure from the low-frequency value of these resistors.

General Radio wire-wound resistance elements are designed to minimize inductance in low-resistance values and to minimize capacitance for high values of resistance. All units up through 200 ohms utilize an Ayrton-Perry winding, in which each resistor consists of two windings in opposite directions, such that their magnetic fields are opposed and largely

Resistors designed for ac use differ from those intended for use only at dc in that low series reactance and constancy of resistance as frequency is varied are important design objectives. The residual capacitance and inductance become increasingly important as the frequency is raised, acting to change the terminal resistance from its low-frequency value.

For frequencies where the resistance and its associated residual reactances behave as lumped parameters, the equivalent circuit of a resistor can be represented as shown in Figure 1. L is the equivalent inductance in series with the resistance, and C is the equivalent capacitance across the terminals of the resistor.

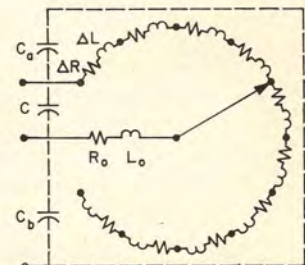
It is necessary to differentiate clearly between the concepts of equivalent series and equivalent parallel circuits. The two-terminal circuit of Figure 1 can be described as an impedance $R_s + jX_s$ or as an admittance $G + jB = \frac{1}{R_p} + \frac{1}{jX_p}$, wherein the parameters are a function of frequency. This distinction between series and parallel components is more than a mathematical exercise — the use to which the resistor is to be put will frequently determine which component is of principal interest.

The expression for the effective series impedance is:

$$Z_s = R_s + jX_s = \frac{R + j\omega \left[L \left(1 - \frac{\omega^2}{\omega_r^2} \right) - R^2C \right]}{\left(1 - \frac{\omega^2}{\omega_r^2} \right)^2 + (\omega RC)^2}$$

where $\omega_r = \frac{1}{\sqrt{LC}}$ and $\frac{\omega^2}{\omega_r^2} = \omega^2 LC$.

Figure 3. Equivalent circuit of a resistance decade, showing location and nature of residual impedances.



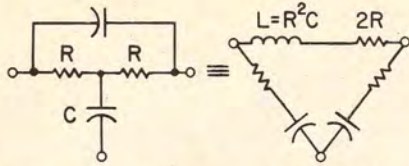


Figure 4. Equivalent wye and delta networks for a resistor with capacitance to shield. The presence of the capacitance, C , gives the resistor an apparent inductive component, $L = R^2C$.

cancel. For very low-valued units, the residual inductance of such a winding is of the order of 1% of that of a corresponding single winding.

Elements having 500-ohm resistance or higher are unifilar-wound on flat rectangular "cards," and have inherently less inductance than so-called "noninductive" spool-wound types because of the low cross-sectional area of the winding (refer to Figure 2). The capacitance of a card-type resistor is also much lower than that of a spool type because the turns of wire are not piled up but are evenly wound in one layer.

These wire-wound resistors exhibit a negligible frequency error in resistance up to about 500 kc/s for values up to 500 ohms, and only moderate errors at 1Mc/s.

In decade boxes, the residual impedances of the switches, wiring, and cabinet are added to those of the resistors themselves. The equivalent circuit is then that of Figure 3, which represents a single Type 510 decade. For multiple-decade boxes, the series inductances are additive, but the capacitance is approximately that across the highest valued decade used (see specifications for each type).

The effect of the residual reactance depends greatly upon the way the resistor is connected in the circuit. For example, parallel capacitance can often be compensated for when the resistor is connected in parallel with a capacitor. For high-valued resistors, the upper frequency limit for a given error is some ten times higher in the effective parallel resistance than it is for the series connection.

General Radio decade boxes have a separate terminal for the case. With a three-terminal connection, the capacitance is reduced because capacitance from the resistor terminals to the case (C_a and C_b in Figure 3) are guarded and do not shunt the resistance. Moreover, this direct impedance can appear slightly inductive due to distributed capacitance

from resistor to case, as explained by the wye-delta transformation of Figure 4.

The resistance material used for most General Radio units is Evanohm,* an alloy with excellent stability, very low and constant temperature coefficient, low thermal emf with copper, and high tensile strength. It is relatively insensitive to humidity and strain. For resistance units of less than 5 ohms, the older, well-known manganin alloy is used because its lower resistivity allows wire dimensions that are easier to work with and to adjust.

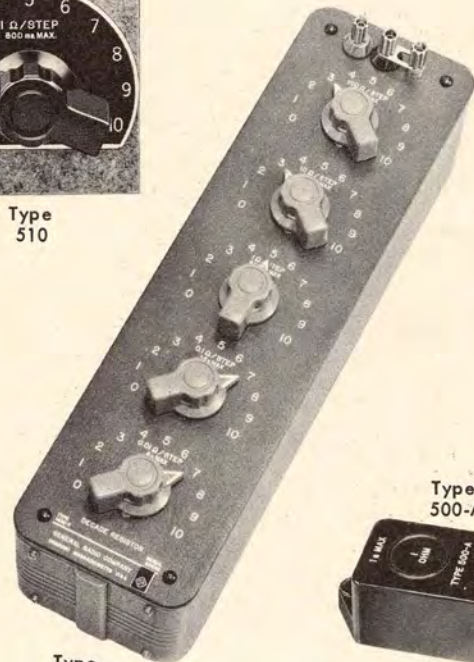
* Registered trademark of the Wilbur B. Driver Company.



Type 510



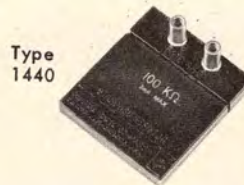
Type 510



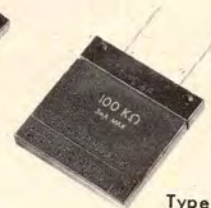
Type 1432



Type 500-A



Type 1440



Type 1441

Type	Name	Use	Page
1440	Standard Resistor	Laboratory standard	200
1441	Standard Resistor	Precision component	200
500	Resistor	Utility standard	201
1434	Decade Resistor	Resistance box, small, compact	202
1432	Decade Resistor	Resistance box, highest accuracy	203
510	Decade Resistance Unit	Circuit component	203



Types 1440 and 1441 STANDARD RESISTORS

- FEATURES:** ■ Excellent long-time stability. ■ High accuracy.
 ■ Low thermal emf to copper.

USES: These extremely stable standard resistors are designed in two styles:

TYPE 1440, a laboratory or production standard for calibrating resistance bridges and for substitution measurements.

TYPE 1441, which can be built into precision measuring equipment. It is recommended as a component in test instruments or in production equipment that requires resistors of high accuracy and stability.

DESCRIPTION: These standards are card-type, wire-wound resistors, carefully wound and adjusted. Low-temperature-coefficient Evanohm* wire is used for values above 10 ohms, manganin for the lower-resistance units. All units are heat cycled to reduce strains and are

repeatedly checked to eliminate any that show abnormal behavior. They are encased in sealed, oil-filled, diallyl-phthalate boxes to promote long-term stability and to provide mechanical protection.

The **TYPE 1440** resistors have low-thermal-emf binding posts and removable banana plugs to provide the four terminals necessary for accurate measurements at low values of resistance. A label on the reverse side lists initial calibration and date, space for future calibration data, and serial number.

The **TYPE 1441** resistors have heavy wire leads, holes for horizontal mounting, and hardware for vertical mounting.

* Registered trademark of the Wilbur B. Driver Company.

SPECIFICATIONS

Accuracy: $\pm 0.01\%$ for all units except those of 1 Ω , which are $\pm 0.02\%$. This accuracy is guaranteed for our standard warranty period of two years, unless the resistor has been damaged by excessive current. Measurements on the low-value **TYPE 1440** units should be made with a four terminal connection and on the **TYPE 1441**'s at $\frac{1}{2}$ inch from the case. All measurements at 23°C.

Calibration Accuracy: **TYPE 1440** Resistors are calibrated by comparison, to a precision of ± 20 ppm, with working standards whose absolute values are known typically to ± 10 ppm as determined and measured in terms of reference standards periodically measured by the National Bureau of Standards. The measured deviation from nominal value, at 23°C and 0.01 watt, is entered on the label on the reverse side of the resistor.

Stability: ± 30 ppm per year.

Temperature Coefficient (Max): ± 10 ppm/°C for resistances above 10 Ω ; ± 20 ppm/°C for 10 Ω and below.

Power Rating: 1 W. The corresponding current is indicated on the resistor and in the table below. This dissipation will cause a

temperature rise of approximately 25°C and a resulting temporary resistance change due to the temperature coefficient. If this rating is exceeded, permanent changes may result.

Residual Impedances: Approximate shunt capacitance (2-terminal measurement), **TYPE 1440**, 2.5 pF; **TYPE 1441**, 1.5 pF; less for 3-terminal measurement. Typical series inductance, see table.

Approximate Frequency Characteristic: See table.

Terminals: **TYPE 1440** — gold-plated jack-top copper binding posts ($\frac{3}{4}$ -in spacing) with banana plugs that are removable and can be replaced by 6-32 screws for installation of soldering lugs. **TYPE 1441** — #16 tinned copper wire. See sketch.

Mechanical Data:

Type	Dimensions*	Net Wt†	Ship Wt†
1440	2¼, 2½, ¾ in (58, 64, 10 mm)	2 oz (60 g)	10 oz (0.3 kg)
1441	2¼, 2⅝, ¾ in (58, 59, 10 mm)	1½ oz (45 g)	10 oz (0.3 kg)

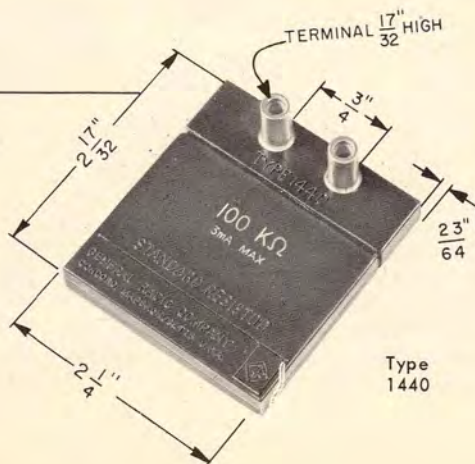
* Less terminals. † Approximate.

Resistance	Max Current	Typical Inductance	Approx Frequency for 0.1% Resistance Change		Type 1440 Standard Catalog Number	Resistor Price	Type 1441 Standard Catalog Number	Resistor Price
			Series R	Parallel R				
1 Ω	1.0 A	0.12 μ H	300 kc/s	30 kc/s	1440-9601	\$10.50	1441-9601	\$ 6.50
10 Ω	310 mA	0.13 μ H	1 Mc/s	300 kc/s	1440-9611	10.50	1441-9611	6.50
100 Ω	100 mA	0.20 μ H	3 Mc/s	1 Mc/s	1440-9621	10.50	1441-9621	6.50
1 k Ω	30 mA	2.5 μ H	2 Mc/s	1 Mc/s	1440-9631	10.50	1441-9631	6.50
10 k Ω	10 mA		200 kc/s	1 Mc/s	1440-9641	10.50	1441-9641	6.50
100 k Ω	3 mA		20 kc/s	100 kc/s	1440-9651	12.50	1441-9651	8.50
1 M Ω	1 mA		2 kc/s	10 kc/s	1440-9661	21.50	1441-9661	17.50

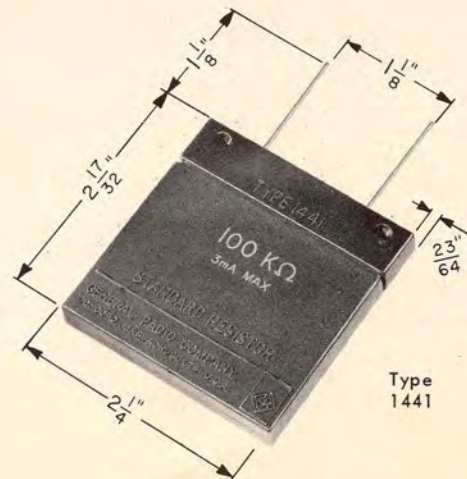
When ordering, please specify catalog number, type number and name, resistance value, and price. Any other resistance value between 0.1 Ω and 1 M Ω can be supplied. Please ask for a quotation.

NEW

in catalog S



Type 1440



Type 1441



Type 500 RESISTORS

FEATURES:

- Convenient and accurate.
- Excellent high-frequency characteristics.
- Low temperature coefficient of resistance.
- Standard plug-in terminals.

USES: The TYPE 500 Resistors are particularly recommended as resistance standards for use in impedance bridges and as secondary standards for laboratory use. The plug-type terminals make them readily interchangeable in experimental equipment. Screw terminals are also supplied for more permanent installations.

DESCRIPTION: This resistor is an accurately adjusted resistance unit wax-sealed in a phenolic case to exclude moisture and to provide protection from mechanical damage. The resistance units are similar in construction to those used in the TYPE 510 Decade-Resistance Units (page 204).

SPECIFICATIONS

Accuracy: See table below. This accuracy is guaranteed for our standard warranty period of two years, unless the resistor has been damaged by excessive current.

Frequency Characteristics: Similar to those of the TYPE 510 Decade-Resistance Units for resistance values up to 600 Ω ; somewhat better for higher resistances, because of the relatively small shunt capacitance of an isolated resistor.

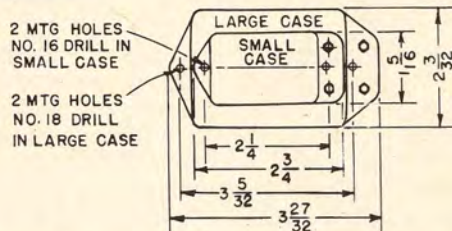
Maximum Power and Current: One watt for a temperature rise of 40°C. The corresponding current is given in the table below and is engraved on each unit.

Temperature Coefficient: Less than ± 20 ppm per degree C at normal room temperature.

Type of Winding: Less than 500 Ω , Ayrton-Perry; 500 Ω and higher, unifilar on thin mica cards. TYPES 500-Y, Z, and ZZ are made up of multiple mica cards in series.

Terminals: Both terminal screws and plugs are supplied. Each terminal stud is recessed as a jack to accommodate a plug. Standard $\frac{3}{4}$ -in spacing is used. High terminal is marked H.

Mounting: Black molded phenolic case is used for all units having a resistance of less than 1000 Ω . For units having a resistance value



of 1000 Ω or higher, a low-loss mica-filled phenolic case is used. Both types are sealed with a high-melting-point wax. TYPES 500-A through -V are in small case; TYPES 500-W, -X, -Y and -Z in large case.

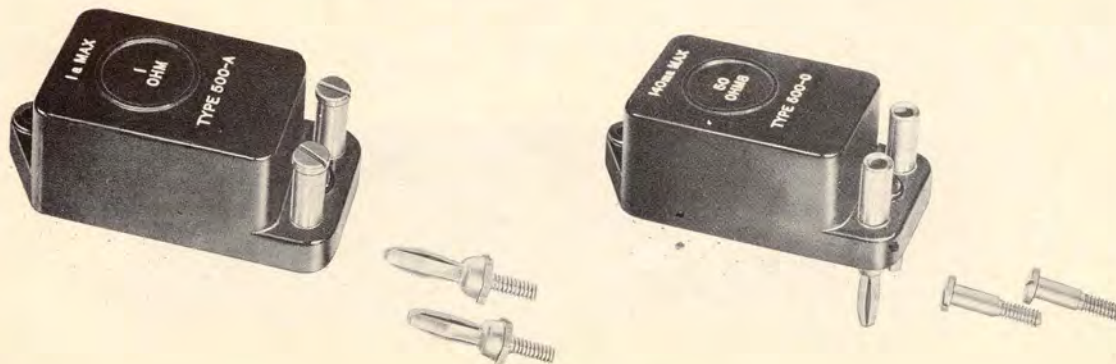
Dimensions: See sketch, dimensions are in inches. Over-all height, $1\frac{5}{8}$ in for large case, 1 in for small case, exclusive of plugs. To convert inches to mm, multiply by 25.4.

Net Weight: 2 oz (60 g).

Shipping Weight: 8 oz (230 g).

Catalog No.	Type	Resistance in Ohms	Accuracy	Maximum Current	Price
0500-9701	Type 500-A	1	0.1%	1.0 A	\$ 6.00
0500-9702	Type 500-B	10	0.05%	310 mA	6.00
0500-9711	Type 500-K	20	0.05%	220 mA	6.00
0500-9703	Type 500-C	50	0.035%	140 mA	6.00
0500-9704	Type 500-D	100	0.025%	100 mA	6.00
0500-9705	Type 500-E	200	0.025%	70 mA	6.00
0500-9706	Type 500-F	500	0.025%	45 mA	6.00
0500-9707	Type 500-G	600	0.025%	40 mA	6.00
0500-9708	Type 500-H	1000	0.025%	30 mA	6.00
0500-9712	Type 500-L	2000	0.025%	22 mA	6.00
0500-9713	Type 500-M	5000	0.025%	14 mA	6.00
0500-9710	Type 500-J	10,000	0.025%	10 mA	6.00
0500-9718	Type 500-R	20,000	0.025%	7 mA	6.00
0500-9720	Type 500-T	50,000	0.025%	4.5 mA	6.00
0500-9721	Type 500-U	100,000	0.025%	3 mA	6.00
0500-9722	Type 500-V	200,000	0.025%	2.2 mA	7.50
0500-9723	Type 500-W	500,000	0.025%	1.4 mA	11.00
0500-9724	Type 500-X	1 Megohm	0.025%	1.0 mA	16.00
0500-9725	Type 500-Y	2 Megohms	0.025%	1.1 mA	28.00
0500-9726	Type 500-Z	5 Megohms	0.025%	0.7 mA	62.00
0500-9504	Type 500-ZZ	10 Megohms	0.025%	0.5 mA	95.00

POTENTIOMETERS: General Radio 970-series potentiometers are listed on page 250.





Type 1434 DECADE RESISTOR

FEATURES:

- High accuracy at low cost.
- Low temperature coefficient.
- Accurate increments as well as accurate total value.
- Excellent stability.

USES: These laboratory-quality, budget-priced decade boxes are designed for maximum usefulness and economy in laboratory measurement, testing, and development work. Their accuracy is adequate for all but the most exacting applications, their small size and clear readout should be particularly useful in experimental setups using small, modern components, and their moderate price will be welcomed by the educational laboratory.

DESCRIPTION: High-quality, wire-wound resistors are used in these decades. The low price is made possible by the use of only six resistors per decade instead of ten. These are combined by switching in such a way that there are no discontinuities, that is, the resistance increases stepwise just as if ten resistors were used. The switches have multiple, solid-silver-alloy contacts for low resistance and long life.

The TYPES 1434-M, -N, and -P contain five step decades of resistance in a small cabinet. The TYPE 1434-QC, a "best buy," has four step decades plus a rheostat to provide 1-ohm resolution in a 1-megohm box. The larger, seven-decade, TYPE 1434-G box is easily converted into a 3½-inch relay-rack unit by the addition of angle brackets and dress strips, which are furnished. This box has lug terminals available at the rear, as well as at panel binding posts.

Resistors are of low temperature-coefficient Evanohm* wire, except the 1-ohm/step decade, which uses manganin wire and the 0.1-ohm/step decade, which uses manganin ribbon. The resistors of the 100-ohm/step, 10-ohm/step, and 1-ohm/step decades are Ayrton-Perry wound to minimize inductance.

*Registered trademark of the Wilbur B. Driver Company.

SPECIFICATIONS

Long-Term Accuracy: See Table I. Our general two-year warranty applies to these tolerances unless the resistor is damaged by excessive current. Tolerance shown applies to both resistance increments and total resistance after correction for zero resistance.

Zero Resistance: Approximately 2 mΩ per dial at low frequencies except for the TYPE 1434-QC for which it is approximately 20 mΩ.

Maximum Current: See table; these values also appear on the panel of each decade box. When this maximum current is passed through a decade, the temporary change in value will be less than the accuracy specification. Currents appreciably higher than this will cause permanent changes.

Temperature Coefficient: Less than ±10 ppm/°C at room temperature, except for the low-valued units where the 0.4%/°C temperature coefficient of the zero resistance must be added.

Frequency Characteristics: Generally similar to those of the TYPE 1432 Decades.

Switches: Multiple, solid-silver-alloy switches are used to obtain low and stable zero resistance.

Terminals: Jack-top binding posts (TYPE 938-A) on standard ¾" spacing. A shield terminal is also provided. The TYPE 1434-G has lug connections accessible from the rear.

Mounting: All types except the TYPE 1434-G are in small cabinets for bench use. The TYPE 1434-G is also designed for bench use but, with the addition of mounting hardware, becomes a 3½-in high, 19-in relay-rack unit.

TABLE I

Total Resistance of Decade	Resistance Per Step	Accuracy*	Maximum Current
1 Ω	0.1 Ω	±2.0%	1 A
10 Ω	1.0 Ω	±0.25%	0.3 A
100 Ω	10 Ω	±0.07%	160 mA
1 kΩ	100 Ω	±0.05%	50 mA
10 kΩ	1 kΩ	±0.05%	16 mA
100 kΩ	10 kΩ	±0.05%	5 mA
1 MΩ	100 kΩ	±0.05%	1.6 mA
100-Ω Rheostat**	1 Ω/div	±1 Ω	200 mA

* At low currents and low frequencies.

** Used in TYPE 1434-QC.

Mechanical Data:

Models	Width		Height		Depth		Net Weight		Shipping Weight	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
M,N,P,QC	11 1/8	298	2 3/4	70	4 1/4	110	3	1.4	4	1.9
G (bench)	17 3/8	442	3 1/2	89	5	130	6	2.8	7	3.2
G (rack)	19	485	3 1/2	89	3 1/2*	89	6	2.8	7	3.2

* Behind panel.

Catalog Number	Description	Total Resistance	Resistance Per Step	Number of Decades	Price
1434-9714	Type 1434-N Decade Resistor	11,111	0.1 Ω	5	\$ 99.00
1434-9713	Type 1434-M Decade Resistor	111,110	1.0 Ω	5	109.00
1434-9716	Type 1434-P Decade Resistor	1,111,100	10 Ω	5	113.00
1434-9576	Type 1434-QC Decade Resistor	1,111,105	1 Ω/div	4 + rheostat	101.00
1434-9707	Type 1434-G Decade Resistor	1,111,111	0.1 Ω	7	155.00

NEW

in catalog S





Type 1432 DECADE RESISTOR

Type 510 DECADE-RESISTANCE UNIT

FEATURES:

- ±0.025% accuracy. ■ Low thermal emf to copper.
- Low zero resistance. ■ Low temperature coefficient of resistance.
- Resistance increments, as well as total value, are always correctly indicated.
- Good frequency characteristics. ■ Residual reactances are small and known.
- Excellent stability. ■ Unaffected by high humidity.

USES: The TYPE 1432 Decade Resistors are primarily intended for precision measurement applications where their excellent accuracy, stability, and low zero resistance are important. They are convenient resistance standards for checking the accuracy of resistance measuring devices and are used as components in dc and audio-frequency impedance bridges. Many of the models can be used up into the radio frequency range. While they are also useful as substitution boxes for optimizing electronic circuitry, the less expensive TYPE 1434 Decade Resistors are recommended for such less exacting applications.

The individual decades (TYPE 510 Decade-Resistance Units) are available for applications requiring only one decade or as components to be built into experimental equipment, production test equipment, or commercial instruments.

DESCRIPTION: Each TYPE 510 Decade-Resistance Unit is enclosed in an aluminum shield, and a knob and etched-metal dial plate are supplied. The switch assem-

blies, less resistors, are also available as the TYPE 510-P4 and -P4L Switches.

The TYPE 1432 Decade Resistor is an assembly of TYPE 510 Decade-Resistance Units in a single cabinet. Mechanical as well as electrical shielding of the units and switch contacts is provided by the attractive aluminum cabinet and panel. The resistance elements have no electrical connection to the cabinet and panel, for which a separate shield terminal is provided.

Each decade has eleven contact studs and ten resistors in series. All the contact studs in the lower-valued decades have a silver overlay to ensure stability of resistance, and all the decades have a silver contact on the zero setting to give low and constant zero resistance.

Winding methods are chosen to reduce the effects of residual reactances. The 1-, 10-, and 100-ohm steps use winding techniques that minimize inductance. The 0.01- and 0.1-ohm steps are straight wire and hairpin-shaped ribbon respectively, and the high valued units are straight wound on mica forms.

SPECIFICATIONS

Long-Term Accuracy: ±0.025% for resistance settings on decades above 100 Ω per step. For lower resistance settings, see table. Our general two-year warranty applies to these tolerances unless the unit is damaged by excessive current. Tolerance shown applies to both resistance increments and total resistance after correction for zero resistance.

Maximum Current: The maximum current for each decade is given in the table below and also appears on the panel of each decade box and on the dial plate of each decade resistance unit.

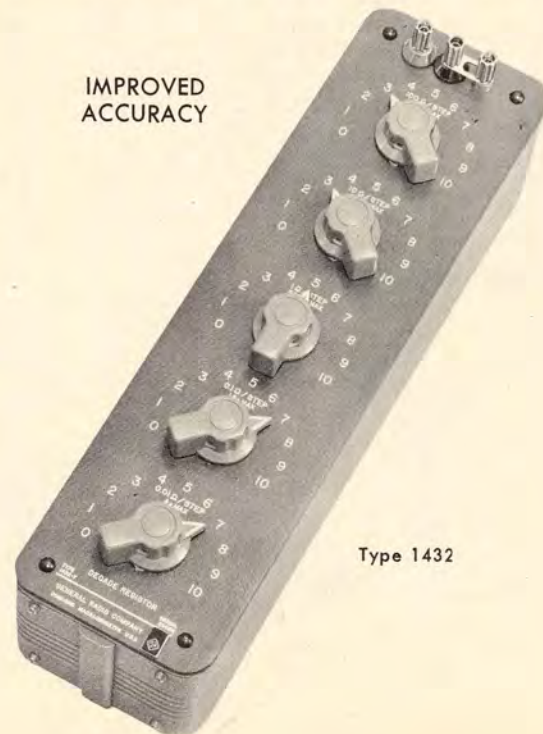
Frequency Characteristic: The accompanying plot shows the maximum percentage change in effective series resistance, as a function of frequency for the individual decade units. For low-resistance decades the error is due almost entirely to skin effect and is independent of switch setting, while for the high-resistance units the error is due almost entirely to the shunt capacitance and its losses and is approximately proportional to the square of the resistance setting.

The high-resistance decades (TYPES 510-E, -F, -G, and -H) are very commonly used as parallel resistance elements in resonant circuits, in which the shunt capacitance of the decades becomes part of the tuning capacitance. The parallel resistance changes by only a fraction (between a tenth and a hundredth) of the series-resistance change, depending on frequency and the insulating material in the switch.

Characteristics of the TYPE 1432 Decade Resistors are similar to those of the individual TYPE 510 units, modified by the increased series inductance, L_s , and shunt capacitance, C_s , due to the wiring and the presence of more than one decade in the assembly. At total resistance settings of approximately 1000 ohms or less, the frequency characteristics of any of these decade resistors are substantially the same as those shown for the TYPE 510 units. At higher settings, shunt capacitance becomes the controlling factor, and the effective value of this capacitance depends upon the settings of the individual decades.



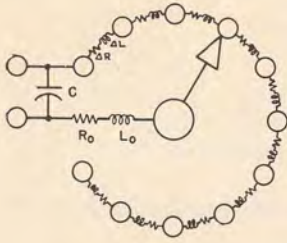
Type 510



Type 1432

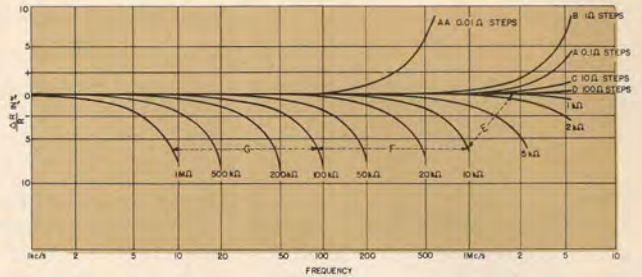
IMPROVED
ACCURACY

STANDARD RESISTORS



(Left) Equivalent circuit of a resistance decade, showing location and nature of residual impedances.

(Right) Maximum percentage change in series resistance as a function of frequency for Type 510 Decade-Resistance Units.



Typical Values of R_0 , L_0 , and C for the Decade Resistors:

Zero Resistance (R_0): 0.001 Ω per dial at dc; 0.04 Ω per dial at 1 Mc/s; proportional to square root of frequency at all frequencies above 100 kc/s.

Zero Inductance (L_0): 0.1 μ H per dial.

Effective Shunt Capacitance (C): This value is determined largely by the highest decade in use. With the low terminal connected to shield, a value of 15 to 10 pF per decade may be assumed, counting decades down from the highest. Thus, if the third decade from the top is the highest resistance decade in circuit (i.e., not set at zero), the shunting terminal capacitance is 45 to 30 pF. If the highest decade in the assembly is in use, the effective capacitance is 15 to 10 pF, regardless of the settings of the lower-resistance decades.

Temperature Coefficient of Resistance: Less than ± 10 ppm per degree C for values above 100 Ω and ± 20 ppm per degree C for 100 Ω and below, at room temperatures. For the TYPE 1432 Decade Resistors, the box wiring will increase the over-all temperature coefficient of the 0.1- and 0.01- Ω decades.

Switches: Quadruple-leaf brushes bear on lubricated contact studs of $\frac{3}{8}$ -in diameter in such a manner as to avoid cutting but yet give a good wiping action. A cam-type detent is provided. There are eleven contact points (0 to 10 inclusive). The switch resistance

is less than 0.0005 Ω . The effective capacitance is of the order of 5 pF, with a dissipation factor of 0.06 at 1 kc/s for the standard cellulose-filled molded phenolic switch form and 0.01 on the mica-filled phenolic form used in the TYPE 510-G and 510-H units.

Maximum Voltage to Case: 2000 V peak.

Terminals: For TYPE 1432, low-thermal-emf jack-top binding posts on standard $\frac{3}{4}$ -in spacing. Shield terminal is provided. TYPE 510 units have soldering lugs.

Mounting: TYPE 1432, lab-bench cabinet (see page 258); TYPE 510, complete with dial plate, knob, template, and mounting screws.

Mechanical Data:

Type 1432	Width		Height		Length		Net Wt		Ship Wt	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
4-Dial	4 $\frac{5}{16}$	110	4 $\frac{3}{4}$	125	13	330	5 $\frac{1}{4}$	2.4	6	2.8
5-Dial	4 $\frac{5}{16}$	110	4 $\frac{3}{4}$	125	15 $\frac{3}{4}$	400	6 $\frac{1}{4}$	2.9	7	3.2
6-Dial	4 $\frac{5}{16}$	110	4 $\frac{3}{4}$	125	18 $\frac{1}{4}$	465	7 $\frac{1}{2}$	3.5	9	4.1
Type 510	Diameter		Depth Behind Panel		oz	kg	lb	kg		
	3 $\frac{1}{16}$	78	3 $\frac{5}{16}$	85	11	0.4	2	1		

DECADE RESISTORS

Catalog Number		Total Ohms	Multiple of	No. of Dials	Type 510 Decades Used	Price
1432-9721	Type 1432-U	111.1	0.01 ohm	4	AA, A, B, C	\$ 98.00
1432-9711	Type 1432-K	1111	0.1	4	A, B, C, D	102.00
1432-9710	Type 1432-J	11,110	1	4	B, C, D, E	110.00
1432-9712	Type 1432-L	111,100	10	4	C, D, E, F	116.00
1432-9717	Type 1432-Q	1,111,000	100	4	D, E, F, G	127.00
1432-9720	Type 1432-T	1111.1	0.01	5	AA, A, B, C, D	124.00
1432-9714	Type 1432-N	11,111	0.1	5	A, B, C, D, E	128.00
1423-9713	Type 1432-M	111,110	1	5	B, C, D, E, F	139.00
1432-9716	Type 1432-P	1,111,100	10	5	C, D, E, F, G	154.00
1432-9725	Type 1432-Y	11,111,000	100	5	D, E, F, G, H	229.00
1432-9724	Type 1432-X	111,111	0.1	6	A, B, C, D, E, F	165.00
1432-9726	Type 1432-Z	11,111,100	10	6	C, D, E, F, G, H	262.00
1432-9702	Type 1432-B	1,111,110	1	6	B, C, D, E, F, G	185.00
1432-9723	Type 1432-W	11,111.1	0.01	6	AA, A, B, C, D, E	158.00

DECADE-RESISTANCE UNITS

Catalog Number		Total Resistance Ohms	Resistance Per Step (ΔR) Ohms	Accuracy of Resistance Increments	Maximum Current 40° C Rise	Power Per Step Watts	ΔL μ H	C^{**} pF	L_0 μ H	Price
0510-9806	Type 510-AA	0.1	0.01	$\pm 2\%$	4 A	0.16	0.01	7.7-4.5	0.023	\$19.50
0510-9701	Type 510-A	1	0.1	$\pm 0.5\%$	1.6 A	0.25	0.014	7.7-4.5	0.023	15.00
0510-9702	Type 510-B	10	1	$\pm 0.15\%$	800 mA	0.6	0.056	7.7-4.5	0.023	21.50
0510-9703	Type 510-C	100	10	$\pm 0.05\%$	250 mA	0.6	0.11	7.7-4.5	0.023	23.50
0510-9704	Type 510-D	1000	100	$\pm 0.025\%$	80 mA	0.6	0.29	7.7-4.5	0.023	24.00
0510-9705	Type 510-E	10,000	1000	$\pm 0.025\%$	23 mA	0.5	3.3	7.7-4.5	0.023	24.00
0510-9706	Type 510-F	100,000	10,000	$\pm 0.025\%$	7 mA	0.5	9.5	7.7-4.5	0.023	27.00
0510-9707	Type 510-G	1,000,000	100,000	$\pm 0.025\%$	2.3 mA	0.5	—	7.7-4.5	0.023	35.00
0510-9708	Type 510-H	10,000,000	1,000,000	$\pm 0.025\%$	0.7* mA	0.5	—	13.5-5.0	0.023	98.00
0510-9604	Type 510-P4	Switch only	(Black Phenolic Frame)							11.00
0510-9511	Type 510-P4L	Switch only	(Low-Loss Phenolic Frame)							12.00

* Or a maximum of 4000 V, peak.

** The larger capacitance occurs at the lowest setting of the decade. The values given are for units without the shield cans in place. With the shield cans in place, the shunt capacitance is from 10 to 20 pF greater than indicated here, depending on whether the shield is tied to the switch or to the zero end of the decade.



STANDARD INDUCTORS



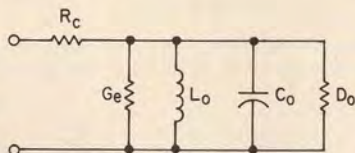
An inductor used as a standard should have the smallest possible changes with time, frequency, current, temperature, external fields, or environment. The residual impedances should be as low as possible. For best accuracy, the connections to the inductor must not affect the calibrated value.

Construction: For minimum generation of, or pickup from, external magnetic fields, the toroidal inductor is preferable to the solenoid. The symmetry of the toroid contributes both to stability and to a constant temperature coefficient.

An air core in the inductor results in the highest stability and a negligible variation of inductance with current, but at the expense of a relatively low Q . Because stability is the prime requirement in a laboratory standard, the Type 1482 Standard Inductors have air cores.

For a given volume, a larger inductance and Q can be obtained from a core of the high-permeability ferromagnetic materials, often termed "iron," although they usually are special alloys. Since the permeability of the material can change with age and particularly with current, the iron-core inductor is inherently less stable than the air-core type. Good stability can still be realized in iron-core inductors by proper design and choice of core materials, as in the Type 940 Decade Inductors.

Figure 1. Equivalent circuit of an air-core inductor. R_c is the series resistance, G_e is the conductance due to eddy-current loss, and D_o is the dissipation factor of the distributed capacitance.



Inductance Changes: The inductance depends not only upon the geometry and the permeability of the core, but upon the residual impedances, which are shown in the equivalent circuit of Figure 1. The largest changes of inductance with frequency are produced by the effective shunt capacitance, C_o , of the winding and the terminals. When the frequency, f , is well below the resonance frequency, f_r , the fractional increase in inductance is approximately

$$\frac{\Delta L}{L_o} \approx \omega^2 L_o C_o = \left(\frac{f}{f_r}\right)^2, \quad (1)$$

where L_o is the zero-frequency inductance.

There is also a decrease in L with increasing frequency, produced by eddy currents in the winding and in ferromagnetic cores; this change can be kept relatively small by the use of stranded wire (litzendraht) and of powdered core materials.

There is practically no change in inductance with current when the core is air, but ferromagnetic core materials have a permeability that changes with magnetizing force, and the change is usually appreciable. The curves shown on page 209 for the Type 940 Inductors are typical. The inductance increases linearly over a small region near zero current, then rises rapidly to a maximum followed by a sudden decrease as saturation is approached. To make these curves independent of the inductance magnitude, the current has been normalized to a value, I_1 , which is that current which produces a specified fractional increase in inductance at a specified permeability.

Q Changes: The storage factor, $Q = \omega L/R$, of an inductor is simply proportional to frequency when L and R are constant. But, as noted above, L can vary with frequency, and the losses are also functions of frequency. The components of loss are best described in terms of dissipation factor, $D = 1/Q$, since the total D is the sum of the component D 's and these can be plotted as straight lines in logarithmic co-ordinates, as shown in Figure 2.

$$D \approx \frac{1}{1 - \left(\frac{f}{f_r}\right)^2} \left[\frac{R_c}{\omega L_o} + G_e \omega L_o + \left(\frac{f}{f_r}\right)^2 D_o \right] \quad (2)$$

Reso- nance Factor	Ohmic Loss, D_c	Eddy- Current Loss, D_e	Dielec- tric Loss, D_d
--------------------------	-------------------------	---------------------------------	--------------------------------

The higher permeability of an iron core makes possible lower values of D_e and D_c , while f_r is slightly reduced and D_o is not changed. The core adds three more components to the dissipation factor: one from eddy currents in the core, proportional to frequency, another from hysteresis loss in the core, independent of frequency, and a third from residual losses in the core, constant with frequency and relatively small. The effects of these losses are shown in the plots of Q versus frequency for Type 940 Decade Inductors.

Calibration: The calibrated inductance of a standard inductor is the change in the measured inductance of a circuit when a portion of that circuit is removed and replaced by the inductor. This measured inductance includes small and variable mutual inductances between the inductor and the rest of the circuit, which are negligible when the calibrated inductance is larger than, say, 100 microhenrys, but which can introduce accuracy-limiting uncertainties into the calibration of smaller inductances. These uncertainties can be reduced to less than one nanohenry to permit accurate calibrations down to one microhenry, if the mutual components are made a definite part of the calibrated inductance. One method of achieving this, used in the Type 1482 Standard Inductors of 200 microhenrys and less, is to provide, on the inductor, a switching link, which connects either the inductor coil or a short circuit through internal leads to the external connection terminals. The calibrated inductance, which is the measured difference at the connection terminals when the switch is moved from coil to short, is to a high degree independent of the external connections or environment.*

Since the inductance usually varies with frequency, an accurate calibration requires that the frequency be specified. When, as in inductors with iron cores, the inductance also varies with current, the calibration must also specify a corresponding current or voltage. Since the frequency or current at which the inductor will be used is not usually known, a convenient reference level is zero frequency and zero current (initial permeability). For example, each Type 940 Decade Inductor is measured at a frequency considerably lower than its resonance frequency, and the measured value is corrected for the increase of L with frequency to obtain the value as frequency approaches zero; measurements are made at two currents within the linear range (less than I_1), and the measured values are extrapolated to obtain the inductance at zero current and initial permeability of the core material.

The inductors described in this section are intended for use in standards and measurement laboratories. They include highly stable air-core reference standards, continuously variable (variometer) types, and decade assemblies of fixed-value units with ferromagnetic cores.

*John F. Hersh, "Connection Errors in Inductance Measurement," *General Radio Experimenter*, 34, 10, October, 1960.

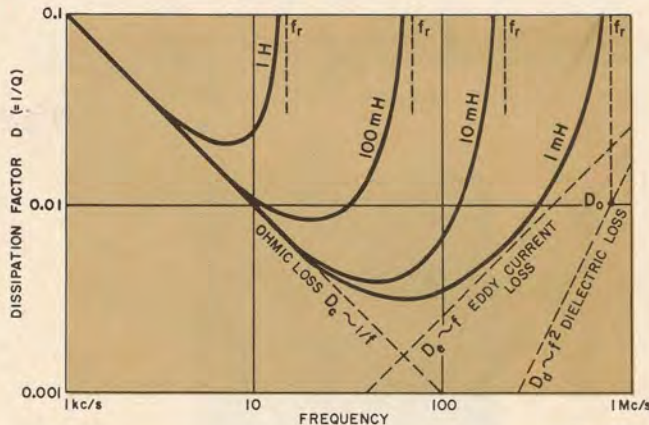


Figure 2. Dissipation-factor variation with frequency in typical air-core Type 1482 Standard Inductors.



STROBOSCOPES



THE STROBOSCOPE AT WORK....

THE ELECTRONIC STROBOSCOPE

The electronic stroboscope is a bright-light source with an oscillator and triggering circuits that turn the light on and off at accurately known flashing rates. The flashing light of the stroboscope, when used to illuminate a cyclically moving object, can produce the optical illusion of stopping or slowing down the motion. Motion is "stopped" when the flashing rate of the stroboscope and the cyclic rate of the object being observed are the same; from this principle stems the stroboscope's well known value as a tachometer. Motion is "slowed" when the flashing rate is offset slightly from the cyclic rate of the object. The apparent slow motion, moreover, is an exact replica of the actual high-speed motion, and the stroboscope is thus an important tool in motion and fluid-flow analysis.

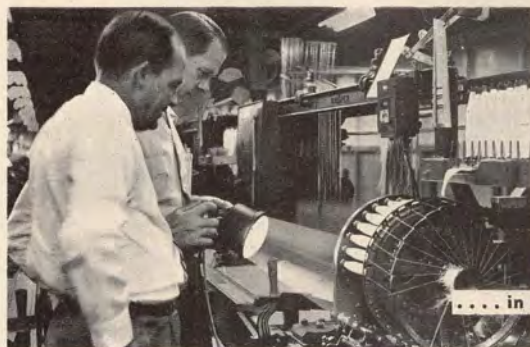
The short flash of a stroboscope offers the photographer a means of reducing exposure time to about a millionth of a second, and so the stroboscope has become standard equipment in the field of ultra-high-speed photography. This subject, of increasing interest to scientists and engineers as well as to photographers, is covered fully in the *Handbook of High-Speed Photography*, available free on request.

THE GENERAL RADIO LINE OF STROBOSCOPES

General Radio's stroboscopic instruments are the result of over 30 years of continuous development engineering in this area. A major step forward in this program was the development, a few years ago, of the Type 1531-A STROBOTAC® electronic stroboscope, which is much faster, much brighter, and yet smaller than earlier models. Thousands of these instruments are now in use in schoolrooms, research laboratories, printing plants, textile mills, chemical plants, and in virtually every type of manufacturing activity. The Type 1531-A remains an outstanding stroboscope at a low price.

Another milestone in stroboscopy is the announcement, in this catalog, of the Type 1538-A STROBOTAC® electronic stroboscope. With a flashing-rate range of up to 150,000 flashes per minute, the Type 1538-A will easily keep pace with the fastest machines known. With battery or ac-line operation, the new stroboscope goes wherever the action is. And with an accessory plug-in storage capacitor, this stroboscope can produce single, short flashes of light at an intensity of 44 million beam candles (at a distance of one meter). Any one of these features — speed, battery operation, intensity — alone would make the new STROBOTAC noteworthy. Together they put it in a class by itself.

Another new member of our line of stroboscopes is the Type 1539-A Stroboslave, a stroboscopic light source that requires external control of its flashing rate. The Stroboslave, whose light output is the same as that of the Type 1531-A STROBOTAC stroboscope, was designed specifically for the many applications where motion study or photog-



... in the textile plant



... at the printing press



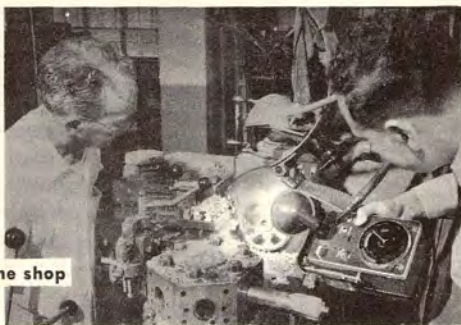
... in the air-moving industry



... in the medical research lab



... in the photographer's studio



... in the machine shop



... in the environmental test lab



... in the classroom

raphy, rather than speed measurement, is required. Because of its compact size, it can easily be built into machines and systems requiring continuous stroboscopic light.

The Type 1532-D Strobolum is an excellent auxiliary source of flashes ten times as bright as those from the STROBOTAC. Like the Stroboslave, it requires external control of flashing rate.

STROBOSCOPE ACCESSORIES

The usefulness of a stroboscope can be multiplied many fold by a small additional investment in accessories. The Type 1536-A or Type 1537-A Photoelectric Pickoff, for example, can synchronize the stroboscope flash with almost any kind of motion, without physical connection to the object being observed. A mechanical contactor, the Type 1535-B, is also available. The addition of a Type 1531-P2 Flash Delay further extends the usefulness of the stroboscope by permitting observation of aperiodic repetitive motion at any point in its cycle. An inexpensive set of nylon disks (Type 1531-P3 Surface-Speed Wheel) converts linear speed (as, for instance, of belts, rollers, etc) into rpm for tachometric measurement with the stroboscope.

STROBOSCOPE APPLICATIONS

The applications for the stroboscope are beyond enumeration. Wherever motion is too fast for the human eye, there is a place for a stroboscope. Here are just a few of the ways in which stroboscopes are paying for themselves many times over:

Stroboscopes are widely used by educators to demonstrate certain laws of physics, such as the relation between frequency and wavelength, the finite velocity of light, the effects of combining colors, the properties of standing waves, the laws of gravity, the principle of stroboscopy itself, etc.

Stroboscopes are used to calibrate mechanical tachometers.

Stroboscopes are used in the development of loudspeakers and of other audio devices.

Stroboscopes are used to check registration on fast-moving printing presses.

Stroboscopes are used to measure the amount of slip between two shafts, between motor and belt, etc.

Stroboscopes are used throughout the textile industry to help design, monitor, and trouble-shoot looms, knitting machines, spinning frames, etc.

A stroboscope, combined with simple accessories, can be used to measure torque, belt tension, and horsepower.

Stroboscopes are used to study the effects of cavitation on turbine blades and on other hydraulic equipment.

Stroboscopes are used in high-speed motion-picture, as well as still, photography.

Stroboscopes are used in the design, production-line checkout, and servicing of electric motors, appliances, and virtually all kinds of production, handling, and packaging machinery.

Stroboscopes are used to help design and trouble-shoot data-processing equipment, such as sorters, punches, etc.

A stroboscope is a versatile instrument, made even more versatile by the ingenious user. Few industries can afford to be without it.



Type 1531-A STROBOTAC® ELECTRONIC STROBOSCOPE

FEATURES:

- High-intensity flash — up to 18 million beam candles (peak) for a single flash.
- High flashing rates up to 25,000 per minute — speed measurements to 250,000 rpm.
- Short flash duration — “stops” rapid motion and permits ultra-high-speed photography.
- High accuracy — rpm measurements can be made to $\pm 1\%$.
- Convenience — small Flip-Tilt case and swivel-mounted lamp.
- Simplicity — dials are easy to set and easy to read.

USES: The STROBOTAC® electronic stroboscope is a small portable flashing-light source used to measure the speed of fast-moving devices or to produce the optical effect of stopping or slowing down high-speed motion for observation. A few of this instrument's many uses are:

- Observation and speed measurement of gears, cams, linkages, shuttles, spindles, motor rotors, and any other elements having repetitive motion.
- Observation of vibrating members, fuel-nozzle spray patterns, and vibrations of components under test in wind tunnels.
- High-speed photography of repetitive or non-repetitive motion (see photos on page 210).

DESCRIPTION: The STROBOTAC electronic stroboscope includes a strobotron lamp and reflector assembly, an electronic pulse generator that controls the flashing rate, and a line-operated power supply.

The flashing-rate range of 110 to 25,000 flashes per minute is divided into three direct-reading ranges; to

avoid reading errors, only the particular range in use is illuminated. The rpm control is concentric with the range selector, and its large diameter provides precise control of the flashing rate. The flash lamp can be triggered externally to “stop” motion for photography. The combination of the TYPE 1531-P2 Flash Delay and the TYPE 1536-A Photoelectric Pickoff can be used as an external triggering source, which also provides an adjustable delay of the stroboscope flash with respect to the triggering pulse from the photoelectric pickoff. The TYPE 1535-B Contactor can also be used for triggering. These accessory instruments are described on page 216.

A built-in calibration system uses the power-line frequency for quick, easy check and readjustment of the flashing-rate calibration.

The strobotron flash lamp and reflector assembly pivots in a plane perpendicular to the panel and swivels 360 degrees on its own axis. The case is equipped with a $\frac{1}{4}$ x 20 socket for mounting the instrument on a tripod.

SPECIFICATIONS

Flashing-Rate Range: 110 to 25,000 flashes per minute in three direct-reading ranges: 110 to 690, 670 to 4170, and 4000 to 25,000. Speeds up to 250,000 rpm can be measured.

Accuracy: $\pm 1\%$ of dial reading after calibration on middle range.

Calibration: Two panel adjustments permit calibration against power-line frequency.

Flash Duration: Approximately 0.8, 1.2, and 3 μ s for high-, medium-, and low-speed ranges, respectively, measured at $\frac{1}{2}$ peak intensity.

Peak Light Intensity: Typical on high-, medium-, and low-speed ranges, respectively, 0.6, 3.5, and 11 million beam candles (6×10^5 , 3.5×10^6 , and 11×10^6 lux at 1 meter distance at the center of the beam); for single flash, 18 million beam candles (18×10^6 lux at 1 meter distance at the center of the beam).

Reflector Beam Angle: 10° at half-intensity points.

Output Trigger: 600- to 800-V negative pulse available at panel jack.

External Triggering: The flash can be triggered by the opening of a mechanical contactor or by a 6-V, peak-to-peak, signal (2-V, rms, sine-wave signal down to 5 c/s).

Power Required: 105 to 125 or 210 to 250 V, 50 to 400 c/s. Maximum power input is 35 W.

Accessories Supplied: Adjustable neck strap, plug to fit input and output jacks, spare fuses.

Accessories Available: TYPE 1531-P2 Flash Delay and TYPE 1536-A Photoelectric Pickoff (page 216), TYPE 1539-A Stroboslave with TYPE 1531-P4 Trigger Cable (page 214), and TYPE 1532-D Strobolume with TYPE 1532-P3 Trigger Cable (page 215).

Mechanical Data: Flip-Tilt Case (see page 258)

Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
10 $\frac{1}{2}$ †	270	6 $\frac{5}{8}$	170	6 $\frac{1}{4}$	160	7 $\frac{1}{4}$	3.3	9	4.1

† Includes handle.

This instrument is listed by the CSA Testing Laboratories as approved.

See also *General Radio Experimenter*, September 1960.

Catalog No.	Description	Price
1531-9701	Type 1531-A Strobotac® electronic stroboscope	\$290.00
1531-9601	Type 1531-P1 Replacement Strobotron Lamp	15.00

PATENT NOTICE. See Notes 6 and 22, page 11.



Type 1538-A STROBOTAC® ELECTRONIC STROBOSCOPE

STROBOSCOPES



FEATURES:

- High flashing rates — up to 150,000 flashes per minute, direct reading.
- Operates from either power line or rechargeable batteries.
- Accessory extension lamp operates up to 6 feet from STROBOTAC.
- Accessory energy-storage capacitor for very short single flashes.
- Can be externally triggered by a contact closure or by photoelectric pickoff.

USES: This newest addition to the GR line of stroboscopic equipment is a more versatile instrument than the TYPE 1531-A STROBOTAC® electronic stroboscope. In addition to providing a much higher maximum flashing rate, the TYPE 1538-A also incorporates many features and user conveniences. It can be operated from a power line, or, if there is no power outlet nearby, from the rechargeable battery pack. The accessory extension lamp is useful in illuminating hard-to-reach areas.

This new stroboscope is ideally suited for photographic applications requiring a high light intensity. With the TYPE 1538-P4 Energy-Storage Capacitor, it is possible to produce very short flashes of light of 44 million beam candles at one meter distance.

DESCRIPTION: The circuitry and mechanical design of the TYPE 1538-A STROBOTAC electronic stroboscope are similar to those used in the TYPE 1531-A. The flashing rate is controlled by an internal calibrated generator and is adjustable from 110 to 150,000 flashes per minute. This over-all range is divided into four direct-reading ranges on the large, illuminated range-control knob. To avoid reading errors, only the range in use is

illuminated. A large-diameter flashing-rate control, concentric with the range knob, provides precise setting of the flashing rate.

The flash can be triggered externally by a simple contact closure across the input terminals, by a positive pulse, or by a sine wave. With a photoelectric pickoff (page 216), the flash can be triggered by pulses that are synchronized with a mechanical motion. The TYPE 1537-A Photoelectric Pickoff contains a light-activated switch, with no light source, which connects directly to the STROBOTAC. The TYPE 1536-A Photoelectric Pickoff contains a similar device but also includes a light source, for which power is supplied by the TYPE 1531-P2 Flash Delay (page 216). With this combination, an adjustable delay is introduced between the time a selected point on a moving object passes the pickoff and the time at which the STROBOTAC flashes. Three-way synchronization of the camera shutter, the mechanical motion, and the STROBOTAC firing is a very useful feature of this Pickoff/Flash Delay combination. Both the STROBOTAC and the TYPE 1538-P4 Energy-Storage Capacitor are equipped with sockets for attaching the two together and for tripod mounting.

SPECIFICATIONS

Flashing-Rate Range: 110 to 150,000 flashes per minute in four direct-reading ranges: 110 to 690, 670 to 4170, 4000 to 25,000, and 24,000 to 150,000 rpm. Speeds to 1 million rpm can be measured.

Accuracy: $\pm 1\%$ on all ranges after calibration on 670- to 4170-rpm range against 50- or 60-cycle line frequency.

Flash Duration: Approximately 0.5, 0.8, 1.2, and 3 μ s for high-to-low speed ranges, respectively, measured at $\frac{1}{2}$ peak intensity; for single flashes with TYPE 1538-P4 Energy-Storage Capacitor, 8 μ s.

Peak Light Intensity: Typically 0.16, 1, 5, and 15 million beam candles (0.16, 1, 5, and 15×10^6 lux measured at 1 meter distance at the beam candle center) for high-to-low speed ranges, respectively; 44 million beam candles at 1 meter for single flash, with TYPE 1538-P4 Energy-Storage Capacitor.

Reflector Beam Angle: 10° at half intensity points.

Output Trigger: Greater than 7 V positive pulse behind 300 Ω .

External Triggering: Either a switch closure across the input jack terminals, a 1-V (peak) positive pulse, or a 0.35 V (rms) sine wave.

Power Required: 100 to 125 or 195 to 250 V, 50 to 400 c/s, 15 W (max) or 20 to 30 V dc, 12 W (max).

Accessories Supplied: Adjustable neck strap, phone plug for input and output jacks, spare fuses.

Accessories Available: TYPE 1538-P2 Extension Lamp, TYPE 1538-P3 Battery and Charger, TYPE 1538-P4 Energy-Storage Capacitor, TYPE 1531-P2 Flash Delay, TYPES 1536-A Photoelectric Pickoff (for use with Flash Delay), TYPE 1537-A Photoelectric Pickoff, and TYPE 1539-A Stroboslave.

Mechanical Data: Flip-Tilt Case (see page 258)

Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
10 $\frac{3}{8}$ †	270	6 $\frac{5}{8}$	170	6 $\frac{1}{2}$	160	7 $\frac{1}{4}$	3.3	10	4.6

† Includes handle.

TYPE 1538-A STROBOTAC® AND ACCESSORIES

NEW

in catalog S



Catalog No.	Description	Price
1538-9701	Type 1538-A Strobotac® electronic stroboscope	\$465.00
1538-9601	Type 1538-P1 Replacement Strobosatron Lamp	15.00
1538-9602	Type 1538-P2 Extension Lamp	55.00
1538-9603	Type 1538-P3 Battery and Charger	225.00
1538-9604	Type 1538-P4 Energy-Storage Capacitor	75.00



Type 1539-A STROBOSLAVE

FEATURES:

- Low cost.
- Small size and light weight.
- Light source on flexible cable for convenient positioning.
- Same light output as TYPE 1531-A STROBOTAC® electronic stroboscope.
- Can be triggered by several methods.

USES: The TYPE 1539-A Stroboslave is a stroboscopic light source that satisfies the basic requirements for motion studies and high-speed photography. It is suitable for all stroboscope applications except tachometry. More than one Stroboslave can be used where there is a need for multiple light sources. When the reflector is removed from the end of the extension cord, the strobotron lamp assembly can be inserted through a hole as small as one inch, making it possible to observe objects in otherwise inaccessible areas.

DESCRIPTION: The Stroboslave is a miniature electronic stroboscope without an internal oscillator for setting the flashing rate; hence, its inability to function as a tachometer. It will operate directly from a switch closure, a TYPE 1537-A Photoelectric Pickoff, a TYPE 1531-P2 Flash Delay (with a TYPE 1536-A Photoelectric Pickoff), or an electrical positive pulse of at least 2 volts peak. In addition, it will operate directly from the output of the TYPE 1538-A STROBOTAC or



Lamp, at end of five-foot cable, can be held in hand as shown here or attached to case as shown below, left.

from the TYPE 1531-A STROBOTAC through a TYPE 1531-P4 Trigger Cable.

The Stroboslave produces the same light output as the TYPE 1531-A STROBOTAC and operates over the same three basic ranges from 0 to 25,000 flashes per minute. The strobotron lamp and reflector are connected to the unit by a five-foot flexible cable so that the light can be positioned close to the subject to be observed.

SPECIFICATIONS

Flashing-Rate Ranges: 0 to 700, 0 to 4200, 0 to 25,000 flashes per min on high-, medium-, and low-intensity ranges, respectively.

Flash Duration: Approx 0.8, 1.2, and 3 μ s, measured at $\frac{1}{3}$ peak intensity, for the low-, medium-, and high-intensity ranges, respectively.

Peak Light Intensity: Typically 0.6, 3.5, and 11 million beam candles (0.6, 3.5, and 11×10^6 lux measured at 1-m distance at the beam center), for low-, medium-, and high-intensity ranges, respectively. For single flash, 18 million beam candles at 1 meter.

Reflector Beam Angle: 10° at half-intensity points.

External Triggering: Either a switch closure across the input jack terminals or a 2-V (peak) positive pulse.

Power Required: 100 to 125 or 195 to 250 V, 50 to 400 c/s, 16 W (max) at 115 V.

Accessories Supplied: Phone plug for input, mounting bracket.

Accessories Available: TYPE 1537-A Photoelectric Pickoff, TYPE 1531-P2 Flash Delay (with a TYPE 1536-A Photoelectric Pickoff), TYPE 1535-B Contactor. (See pages 216 and 217.)

Mechanical Data:

Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
2½	64	8¾	215	4¾	105	2¾	1.3	8	3.7

Catalog No.	Description	Price
1539-9701	Type 1539-A Stroboslave	\$165.00
1531-9604	Type 1531-P4 Trigger Cable (for use with Type 1531-A Strobotac)	15.00

NEW

in catalog S



Tripod socket is provided on Stroboslave case.



Type 1532-D STROBOLUME

FEATURES:

- High-intensity short flash. ■ Wide beam angle.
- Operates from TYPE 1531-A STROBOTAC® electronic stroboscope or TYPE 1535-B Contactor.
- Compact, lightweight assembly.
- Lamp assembly is removable, with 14-foot extension cable.
- Lamp housing has socket with standard tripod thread.
- Long-life sealed-beam lamp.

USES: The Strobolume produces a brilliant white light flash useful for studying motions of machines operating at relatively low speeds. At low flashing rates the Strobolume's light is of a higher intensity than that of the TYPE 1531-A STROBOTAC electronic stroboscope.

The Strobolume can be triggered by a spring-loaded toggle switch on the control panel, by an external contactor such as the TYPE 1535-B, or by the electronic stroboscope. It is a useful light source for single- and multiple-flash photography, when the motion of the sub-

ject is too fast to be stopped by conventional strobe lights.

DESCRIPTION: The Strobolume consists of a high-voltage transformer and rectifiers, a capacitor that is charged to about 2500 volts from the rectifiers, and a lamp through which the capacitor is discharged to produce the flash. The discharge is initiated by a special strobotron tripped by an external impulse. Two ranges of intensity and flashing rate are provided.

SPECIFICATIONS

Flashing Speed Range:

High Intensity: Up to 60 flashes per minute continuous, up to 1200 per minute intermittent.

Low Intensity: Up to 3000 flashes per minute continuous.

Peak Light Intensity: 10 million beam candles (10⁷ lux measured at 1 meter distance at the center of the beam) from single flash to 60 flashes per minute; 0.14 million beam candles (1.4 × 10⁶ lux at 1 meter distance at the center of the beam) at 3000 flashes per minute.

Flash Duration: Approximately 30 μs at high intensity, 10 μs at low intensity.

Beam Width: 45° at half-intensity points.

Guide Number: The guide number (distance in feet times aperture) for high intensity is approximately 25 with film speed of 100 (ASA).

Flashing Control: TYPE 1535-B Contactor, or TYPE 1531-A STROBOTAC electronic stroboscope with TYPE 1532-P3 Trigger Cable.

Accessories Supplied: TYPE CAP-22 Power Cord, Contactor Cable Assembly, and plug for connection to contactor.

Accessories Required: None if lamp is to be flashed manually by pushbutton. For stroboscopic work a TYPE 1535-B Contactor, or a TYPE 1531-A STROBOTAC electronic stroboscope with TYPE 1532-P3 Trigger Cable, is needed. For use with older TYPE 631-BL STROBOTAC, a TYPE 1532-P2B Transformer Cable is required.

Cabinet: Metal case. Lamp assembly is removable. Storage space for lamp cable is provided in case. Lamp housing has 1/4-20 threaded socket for tripod.

Power Required: 105 to 125 V, 50 to 60 c/s; 230-V model, TYPE 1532-DQ18, is available. Power consumption on high intensity is 105 W at 60 flashes per minute, 500 W at 1200 flashes per minute; at low intensity, 120 W at 3000 flashes per minute.

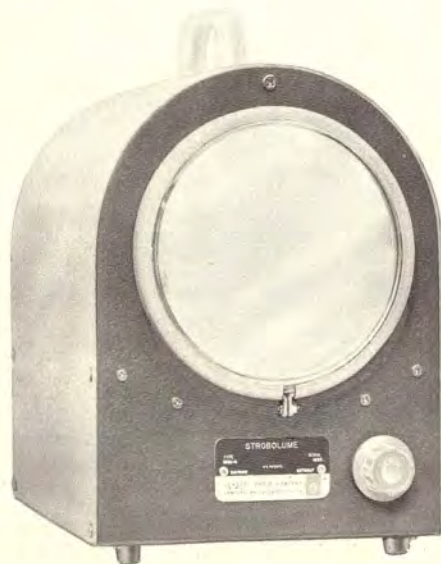
Mechanical Data:

Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
7 1/2	190	11 1/2	295	13	330	18 1/2	8.5	26	12

See also *General Radio Experimenter*, May 1949 and September 1960.

Catalog No.	Description	Price
1532-9704	Type 1532-D Strobolume (for 105-to-125-V supply)	\$375.00
1532-9825	Type 1532-DQ18 Strobolume (for 210-to-250-V supply)	on request
1532-9601	Type 1532-P1 Replacement Lamp	25.00
1532-9941	Type 1532-P2B Transformer Cable	17.00
1532-9603	Type 1532-P3 Trigger Cable	15.00

PATENT NOTICE. See Note 6, page 11.



HIGH-INTENSITY STROBOSCOPE

Type 1531-P2 FLASH DELAY

USES: The combination of flash delay, photoelectric pickoff, and electronic stroboscope is used for visual analysis over a complete cycle of repetitive motion whose period is not constant. In addition, these instruments can be used to provide precise synchronization of camera shutter, stroboscopic flash, and subject for high-speed photographs previously almost impossible to take because of variations in subject speed.

DESCRIPTION: The TYPE 1531-P2 Flash Delay, when used with an external triggering device such as the TYPE 1536-A Photoelectric Pickoff, will provide a continuously adjustable time delay between the triggering pulse and the light flash. The external triggering device may be an oscillator, photocell, or other transducer. A jack is provided for camera shutter synchronization in single-flash photography.

SPECIFICATIONS

Time-Delay Range: Approximately 100 μ s to 0.8 s in three ranges.
Output Pulse: Better than 13 V available for triggering the TYPES 1531-A and 1538-A STROBOTAC® electronic stroboscopes and the TYPE 1539-A Stroboslave.
Sensitivity: As little as 0.3-V input will produce sufficient output to trigger the stroboscope.
Inputs: Phone jack for triggering; jack for camera synchronization.
Accessories Available: TYPE 1536-A Photoelectric Pickoff.
Power Required: 105 to 125 or 210 to 250 V, 50 to 400 c/s, 5 W with TYPE 1536-A connected.
Mounting: Aluminum case with bracket, which clips directly onto the STROBOTAC electronic stroboscope.



Mechanical Data:

Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
5 7/8	135	3 7/8	80	3 3/4	96	2	1	5	2.3

See also *General Radio Experimenter*, August 1963.

Catalog No.	Description	Price
1531-9602	Type 1531-P2 Flash Delay	\$175.00

Type 1536-A PHOTOELECTRIC PICKOFF

- Small size.
- Maneuverable double-jointed linkage.
- Firm mounting with C-clamp or magnet.
- High pulse rate — speeds up to 150,000 rpm.

USES: The TYPE 1536-A Photoelectric Pickoff is powered by the TYPE 1531-P2 Flash Delay, the TYPE 1150-B Digital Frequency Meter, or the TYPE 1151-A Digital Time and Frequency Meter. It produces a voltage pulse whenever its photocell senses a difference in reflected light. If a piece of reflective tape is attached to a moving object, the pickoff will produce a positive pulse whenever the tape passes by the pickoff. When used in combination with the TYPE 1531-P2 Flash Delay and a STROBOTAC® electronic stroboscope or the Stroboslave, the photoelectric pickoff will flash the stroboscope in synchronism with a rotating object but

at a time, determined by the flash-delay setting, after the synchronizing pulse from the photocell. This permits all phases of the motion to be studied. For photography, the camera shutter, the motion of the subject, and the STROBOTAC firing can all be synchronized.

For precise measurement of speed, the pulse from the photoelectric pickoff will operate the TYPES 1150-B and 1151-A Digital Frequency Meters. In combination with the TYPE 1531-P2 Flash Delay, the pickoff also permits continuous measurement or recording of speed with the TYPE 1142-A Frequency Meter and Discriminator.

DESCRIPTION: This photoelectric pickoff contains a light source, a concentrating lens, a photocell, an output cable, and an adjustable mounting system. Light from the internal lamp is reflected from a rotating object back to the photocell.

SPECIFICATIONS

Maximum Pulse Rate: Approximately 2500 pulses/s as limited by the 200- μ s time constant of the photocell and cable combination.
Power Required: 20 to 28 V dc, 40 mA. Power is supplied by the TYPE 1531-P2 Flash Delay or the TYPE 1150-B (or TYPE 1151-A) Digital Frequency Meter.
Accessories Supplied: 10-ft roll of 3/8-in black tape; 10-ft roll of 3/8-in silver tape; carrying case.
Mounting: C-clamp (capacity 1 1/8 in, flat or round) or 1 1/2-in magnet, both supplied.

Dimensions: Pickoff head, 1 1/16-in dia, 2 in long. Linkage consists of two 3/16-in diameter stainless-steel rods, 6 and 6 1/4 in long, and adjustable connecting clamp. Cable is 8 ft long, terminated in phone plug.

Net Weight: 1 1/4 lb (0.6 kg). **Shipping Weight:** 4 lb (1.9 kg).

See also *General Radio Experimenter*, October 1962.

Catalog No.	Description	Price
1536-9701	Type 1536-A Photoelectric Pickoff	\$75.00

Type 1537-A PHOTOELECTRIC PICKOFF

The TYPE 1537-A Photoelectric Pickoff differs from the TYPE 1536-A in that no light source is included. The photosensitive element is a silicon light-activated switch. This pickoff will trigger directly the TYPE 1538-A STROBOTAC and the TYPE 1539-A Stroboslave.

SPECIFICATIONS

Operating Rate: Greater than 2500 pulses/s.
Power Required: 3 to 25 V dc; 0 to 100 μ A depending on operating rate. Power is supplied by instrument with which it is used.
Accessories Supplied: 10-ft roll of $\frac{3}{8}$ -in black tape, 10-ft roll of $\frac{3}{8}$ -in silver tape, carrying case.
Mounting: C-clamp (capacity $1\frac{1}{16}$ in, flat or round) or $1\frac{1}{2}$ -in magnet, both supplied.
Dimensions: Same as TYPE 1536-A Photoelectric Pickoff.
Net Weight: $1\frac{1}{2}$ lb (0.7 kg). **Shipping Weight:** $4\frac{1}{2}$ lb (2.1 kg).

Catalog No.	Description	Price
1537-9701	Type 1537-A Photoelectric Pickoff	\$55.00

NEW

in catalog 5



Type 1535-B CONTACTOR



- Easily attached to or removed from machine in motion.
- Mounted permanently on machine.
- Ball bearings are used on rotating parts.
- Flexible drive coupling shaft can be bent through 90° angle for work in crowded locations.

USES: The TYPE 1535-B Contactor permits synchronization of a stroboscope with a rotating shaft, so that motion can be observed as a function of shaft angle. With the aid of the contactor, the stroboscope can be used in the observation of machines with varying speed.

DESCRIPTION: The electrical contact system consists of a rotating cam and a low-inertia breaker arm. The phasing control permits adjustment of the contact position with respect to the rotating shaft. The coupling system uses a powerful magnet with a centering device to ensure positive drive from a centered steel or iron shaft. Auxiliary devices are supplied for permanent coupling or for use as nonmagnetic shafts.

SPECIFICATIONS

Speed Range: 0 to 1000 rpm.
Contacts per Revolution: One.
Range of Phase Adjustment: 360°; scale graduated in 5-degree intervals.
Range of Height Adjustment: 6 in to 4 ft.
Diameter of Base: 18 in.
Accessories Supplied: Hex wrench and auxiliary coupling devices.
Net Weight: 20 lb (9.5 kg). **Shipping Weight:** 28 lb (13 kg).

Catalog No.	Description	Price
1535-9702	Type 1535-B Contactor	\$185.00



Type 1531-P3 SURFACE-SPEED WHEEL

USES: The TYPE 1531-P3 is used with the TYPES 1531-A and 1538-A STROBOTAC® electronic stroboscopes to make accurate measurements of the linear surface speed of belts, pulleys, wheels, drums, rollers, etc.

DESCRIPTION: Two black nylon wheels of different diameters are mounted on the ends of a sectioned steel rod. The selected wheel is held against the moving object and observed with the stroboscope to determine directly the surface speed.

SPECIFICATIONS

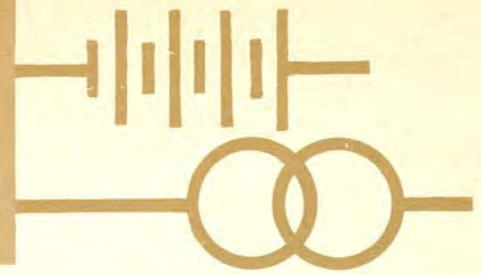
Speed Range: 10 to 2500 ft/min with small wheel and 50 to 12,500 ft/min with large wheel.
Dimensions: Wheels are 0.764 and 1.910 in dia, respectively. Three-section shaft totals 20 in in length.
Net Weight: 8 oz (0.3 kg). **Shipping Weight:** 2 lb (1 kg).

See also *General Radio Experimenter*, August 1963.

Catalog No.	Description	Price
1531-9603	Type 1531-P3 Surface-Speed Wheel	\$15.00



POWER SUPPLIES



Although most General Radio instruments have their own self-contained power supplies, some have been designed for use with separate power supplies for versatility and economy. These power supplies are described in this section.

GENERAL PURPOSE: The Type 1205-B Adjustable Regulated Power Supply is a general-purpose instrument with a regulated output adjustable from 0 to 300 volts at a maximum current of 200 milliamperes.

FOR UNIT INSTRUMENTS: The general-purpose Type 1203 Unit Power Supply or the Type 1201 Unit Regulated Power Supply can be used with any of the Unit Instruments and are recommended for the rectangular-case Unit Instruments, Type 1206-B Unit Amplifier, Type 1210-C Unit R-C Oscillator, Type 1212-A Unit Null Detector, Type 1217-C Unit Pulse Generator, and Type 1220-A Unit Klystron Oscillator.

FOR HIGH-FREQUENCY OSCILLATORS: With the rf, vhf, and uhf oscillators described on pages 129 to 146 one of the

following four power supplies is recommended:

Type 1263-B Amplitude Regulating Power Supply for CW or 1-kc square-wave modulated output at a fixed level adjustable between 0.1 and 2.0 volts behind 50 ohms.

Type 1264-A Modulating Power Supply for CW, 1-kc square-wave modulated, or pulse-modulated output adjustable over a wide range.

Type 1267-A Regulated Power Supply for CW operation with highest stability.

Type 1269-A Power Supply for CW operation with highest output at low cost.

FOR THE TYPE 1633-A INCREMENTAL-INDUCTANCE BRIDGE: The Type 1265-A Adjustable DC Power Supply and the Type 1266-A Adjustable AC Power Supply have been designed primarily for use with the Type 1633-A Incremental-Inductance Bridge.

Type 1205-B ADJUSTABLE REGULATED POWER SUPPLY

GENERAL-PURPOSE POWER SUPPLY

FEATURES:

- Adjustable output voltage from 0 to 300 volts dc.
- Excellent regulation down to zero output.
- Low hum level.
- Small size — over-all volume is less than 1/4 cubic foot.
- High power output — 120 watts.

DESCRIPTION: The TYPE 1205-B Adjustable Regulated Power Supply combines the features of a fast-acting series regulator, which provides a low output impedance over a wide bandwidth, and a high-efficiency controlled rectifier, which limits the range of voltage drop across the regulator. Thus the regulator always operates at the optimum point, and the power dissipation is held to a minimum value for all output and line voltage values.

In addition to the 0- to 300-volt regulated dc output, the instrument provides a -150-volt regulated dc bias voltage and two unregulated ac outputs.

The output voltages are available at panel binding posts and at a multipoint connector in the side of the cabinet. Both the dc output voltage and the output current are indicated on a panel meter.

SPECIFICATIONS

Dc Output

Voltage: 0 to 300 V continuously adjustable, at 200 mA max.

Regulation: No load to full load, 0.1 V; ± 0.75 -V change for $\pm 10\%$ change in line voltage.

Bias Output

Voltage: -150 V dc fixed, at 5 mA max.

Regulation: No load to full load, 0.5 V; 2-V max change for $\pm 10\%$ change in line voltage.

Unregulated Ac Voltage: 2 circuits, each 6.3 V nominal, at 5 A, can be connected in series or parallel.

Meter Accuracy: Voltage, 2%; current, 5%.

120-cycle Ripple: Less than 1 mV.

Internal Impedance: Approximately $0.3 \Omega + 2 \mu\text{H}$ shunted by $4 \mu\text{F}$.

Power Required: 105 to 125 V, 60 c/s; 250 W at full load.

Accessories Supplied: Adaptor plug, spare fuses.

Mechanical Data: Unit-Instrument Cabinet (see page 258)

Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
9 1/2	245	5 1/4	135	8 1/4	210	15	7	26	12

Catalog No.	Description	Price
1205-9702	Type 1205-B Adjustable Regulated Power Supply	\$365.00
0480-9985	Type 480-P4U2 Relay-Rack Adaptor Panel	11.00



PATENT NOTICE. See Notes 15 and 21, page 11.



POWER SUPPLIES

TYPE 1203 UNIT POWER SUPPLY

Type 1201 UNIT REGULATED POWER SUPPLY

These two supplies have been designed to provide plate and heater power for Unit Instruments. The TYPE 1203 is a general-purpose, unregulated, 300-volt dc and 6.3-volt ac supply, while the TYPE 1201 has a regulated plate voltage supply to minimize the effects of line-voltage fluctuations on oscillator amplitude and frequency, amplifier hum level, or pulse-generator jitter. Both supplies are primarily for bench use but can be rack-mounted with other Unit Instruments.

Type 1269-A POWER SUPPLY

Type 1267 REGULATED POWER SUPPLY

These two supplies have been designed primarily for use with the Unit RF Oscillators where the power supply and the oscillator are to be bolted together or mounted in a relay rack. The TYPE 1269-A is a general-purpose, unregulated 300-volt dc and 6.3-volt ac supply. In the TYPE 1267, both heater and plate supplies are regulated to provide complete freedom from line-voltage variations and minimum residual modulation and frequency drift.

SPECIFICATIONS

		TYPE 1203-B	TYPE 1203-BQ18	TYPE 1201-C	TYPE 1201-CQ18
Output	Dc	At nominal input line voltage, 300 V \pm 5% at 50 mA; approx 410 V at no load; 50 mA, max.		300 V, regulated to \pm 0.25% for line and load changes; 70 mA, max.	
	Ripple	Less than 80 mV, rms, at full load		Less than 1 mV, rms, at full load	
	Low Voltage	6.3 V ac, unregulated, at 3 A		6.3 V ac, unregulated; 4 A max	
Input	V	105 to 125	195 to 235 or 210 to 250	105 to 125	195 to 235 or 210 to 250
	c/s	50 to 60 or 400*		50 to 60 or 400*	
	W	50		90	
Connectors		Permanently attached 3-wire line cord, 4-terminal output socket			
Accessories Supplied		Mating plug for output, spare fuses			
Unit-Instrument Cabinet (see page 258)	Dimensions	Width 5, height 5 $\frac{3}{4}$, depth 6 $\frac{1}{4}$ inches (130, 150, 160 mm), over-all			
	Weight	Net, 5 lb (2.3 kg); shipping, 6 lb (2.8 kg)		Net, 6 lb (2.8 kg); shipping, 7 lb (3.2 kg)	
Catalog Number		1203-9702	1203-9818	1201-9703	1201-9824
Price		\$55.00	on request	\$95.00	on request
TYPE 1269-A					
Output	Dc	At nominal input line voltage, 300 V \pm 5% at 50 mA; approx 410 V at no load; 50 mA, max.		300 V, 70 mA max; can be disconnected by standby switch. Regulation, \pm 0.25% for line and load changes.	
	Ripple	Less than 80 mV, rms, at full load		Less than 1 mV, rms, at full load	
	Low Voltage	6.3 V ac, unregulated, at 3 A		6.3 V dc at 1 A; regulation, \pm 0.25% for line voltage changes. Output resistance 35 m Ω , approx.	
Input	V	105 to 125, 195 to 235, or 210 to 250		105 to 125	195 to 235 or 210 to 250
	c/s	50 to 60 or 400*		50 to 60 or 400*	
	W	50		90	
Connectors		Permanently attached 3-wire line cord, 4-terminal output socket		4-terminal output socket	
Accessories Supplied		Mating plug for output, spare fuses		3-wire line cord, mating plug for output, spare fuses	
Convertible-Bench Cabinet (see page 258)	Dimensions	Width 4 $\frac{1}{4}$, height 7 $\frac{3}{8}$, depth 9 $\frac{1}{4}$ (110, 195, 235 mm), over-all			
	Weight	Net, 5 $\frac{3}{4}$ lb (2.7 kg); shipping, 8 lb (3.7 kg)		Net, 7 $\frac{3}{4}$ lb (3.6 kg); shipping, 10 lb (4.6 kg)	
Catalog Number		1269-9701		1267-9701	1267-9911
Price		\$75.00		\$170.00	on request

* At 400 c/s, minimum input line-voltage requirements are increased 5%.



TYPE 1203-B



TYPE 1201-C



TYPE 1269-A



TYPE 1267-A



Type 1263-B AMPLITUDE-REGULATING POWER SUPPLY

FOR USE WITH GR HIGH-FREQUENCY OSCILLATORS

FEATURES:

- Levels oscillator output within 0.5 dB.
- Provides internal 1-kc square-wave modulation.
- Meter indicates rms oscillator output voltage.

USES: The TYPE 1263-B Amplitude-Regulating Power Supply automatically maintains the output of General Radio vhf and uhf oscillators (page 139) at a preset value in spite of incidental amplitude variations that may occur both with supply-voltage variations and with changes in oscillator frequency.

Its very-high-speed response is particularly useful when the oscillator dial is mechanically driven by a TYPE 1750-A Sweep Drive.

This power supply will modulate a Unit Oscillator with 1-kc square waves, thus eliminating incidental frequency modulation and permitting the use of an untuned detector with a sensitive audio amplifier. Regulation of average output level is maintained in

this mode of operation so that swept measurements at very low rf detector levels can be made.

DESCRIPTION: The dc potential developed by the oscillator output rectifier (TYPE 874-VRL) is compared with an adjustable dc reference in a feedback system. A rapid correction is applied to the plate current to hold the oscillator output to a preset level. Rf blanking can be accomplished by external shorting of the reference potential.

For 1-kc modulation, the voltage regulated is the average value of the square-wave envelope. An external synchronous detector can be gated from a voltage provided, to maintain a high signal-to-noise ratio in low-level measurements.

SPECIFICATIONS

Rf Output Voltage: 0.2 to 2.0 V behind 50 Ω for any recommended oscillator (see below). With 1-kc square-wave modulation, 0.2 to 1.0 V (average value of rms carrier level) behind 50 Ω .

Rf Output Regulation: Below 500 Mc/s, rf output of recommended Unit Oscillators is held to within $\pm 5\%$ including the effects of harmonics. This regulation can be attained up to 2000 Mc/s if proper low-pass rf filters (see page 87) are used and a correction applied for the rectifier frequency characteristic.

Modulation:

Frequency: 1-kc square-wave, adjustable $\pm 5\%$, stable within 5 c/s over the rated range of line voltage.

Duty Ratio: 0.5 to 0.53, adjustable to compensate for oscillator-starting delay.

Rise and Decay Times: 50 μ s each.

Overshoot: None. **Ramp-off:** Less than 0.5%.

Gate Voltage: Synchronized with "off" interval of modulation, exceeds 1 V into the recommended load of 30 k Ω shunted by 300 pF. Rise and decay times are less than 50 μ s. Gate output during "on" interval of modulation is less than 0.01 V.

Plate Supply Output: 0 to 300 V at 30 mA.

Heater Supply Output: 6 V $\pm 10\%$ at 0.5 A, 5.4 V $\pm 10\%$ at 0.7 A.

Response Time: For a 2-to-1 step variation in oscillator output, correction is completed within 0.5 ms with cw operation, 50 ms with 1-kc modulation. Recovery time after blanking is less than 2 ms with cw operation, 200 ms with 1-kc square-wave modulation.

Hum and Noise: Peak residual hum and noise modulation, less than $\pm 0.3\%$ on cw, $\pm 3\%$ with 1-kc square-wave modulation.

Output Voltmeter: With 1-kc square-wave modulation, meter reads average value of rms carrier level. Internal standardizing circuit is provided. Accuracy after standardization is better than

$\pm 10\%$ of indication when a correction is applied for rectifier characteristic at extremely high frequencies.

Power Required: 105 to 125 or 210 to 250 V, 50 to 60 c/s, 55 W.

Accessories Supplied: TYPE 874-VRL Voltmeter Rectifier, TYPE 874-R22LA Patch Cord for connecting output rectifier, and TYPE CAP-22 Power Cord, connector cable for modulation jack on oscillator, spare fuses.

Accessories Required: TYPE 874-T Tee for monitoring oscilloscope connection in sweeping applications.

Recommended Oscillators (page 140): TYPE 1215-C (50 to 250 Mc/s), TYPE 1209-CL (180 to 600 Mc/s), TYPE 1209-C (250 to 920 Mc/s), TYPE 1361-A (450 to 1050 Mc/s), TYPE 1218-B (900 to 2000 Mc/s); for cw operation only, TYPE 1211-C (0.5 to 50 Mc/s). See page 144 for complete oscillator-power supply combinations.

Accessories Available: The TYPE 1750-A Sweep Drive (page 153) for automatic operation; coaxial accessories (pages 76 to 94). Panel adaptor plate sets for 19-in relay-rack mounting, panel height 7 in (see page 143).

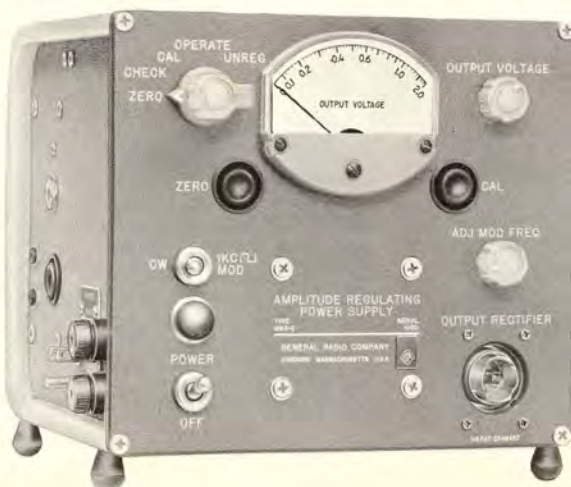
Mechanical Data: Convertible-Bench Cabinet (see page 258)

Width		Height		Depth		Net Wt		Ship Wt	
in	mm	in	mm	in	mm	lb	kg	lb	kg
8	205	7	180	9 1/4	235	14 1/2	7	18	8.5

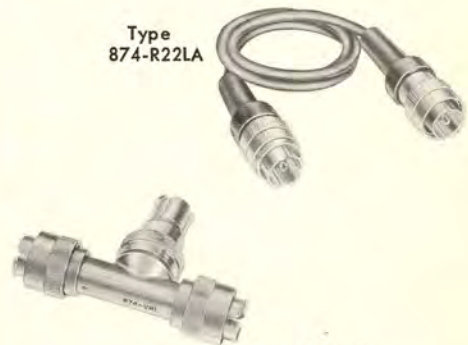
See also *General Radio Experimenter*, September 1961.

Catalog No.	Description	Price
1263-9702	Type 1263-B Amplitude-Regulating Power Supply	\$425.00

PATENT NOTICE. See Notes 4 and 15, page 11.



Type 874-R22LA



Type 874-VRL

Rectifier and patch cord are included



Type 1264-A MODULATING POWER SUPPLY

FOR USE WITH GR HIGH-FREQUENCY OSCILLATORS

FEATURES:

Clean, stable, high-level output pulses. ■ Stable internal 1-ke square-wave generator. Synchronization to wide range of input signals. With an external pulse source, repetition rates from 20 c/s to 100 kc/s are available. Adjustable well-regulated dc output for cw operation. Standby switch position cuts off oscillator output while keeping heater on.

USES: The TYPE 1264-A Modulating Power Supply produces 100% pulse and square-wave modulation of vhf and uhf Unit Oscillators, TYPES 1361-A, 1209-C, 1209-CL, 1215-C, and 1218-B. In addition, it can be used as an adjustable regulated supply for the oscillator plate and as a source of unregulated heater power.

It is available in combination with the above oscillators, as listed on page 144.

DESCRIPTION: The TYPE 1264-A comprises an electronically regulated, adjustable-output, high-voltage, dc supply; a dc-coupled, series-type power modulator driven by a Schmitt trigger circuit; and a 1-ke multivibrator. A switch permits selection of cw, standby (only heaters energized), 1-ke square-wave modulated (internally generated), or externally modulated opera-

tion. Independent panel controls vary the regulated supply voltage for cw operation and the modulator amplitude for square-wave and pulse operation. Controls are also provided to adjust the frequency of the internal 1-ke multivibrator and the duty ratio to produce a true square wave.

The input trigger circuit accepts single or multiple positive pulses, which are reproduced at the modulator output. It also accepts square waves at rates up to 100 kc/s, or sine waves up to 50 kc/s, from any 20-volt source such as the TYPE 1217-C Unit Pulse Generator or the TYPE 1210-C Unit R-C Oscillator and produces square waves at the modulator output. No adjustment of triggering is necessary. The stable 1-ke multivibrator provides ideal square-wave modulation for use with sharply selective amplifiers following the signal detector.

SPECIFICATIONS

Regulated Dc Output (Unmodulated)

Output: Adjustable from 200 to 300 V; 50 mA, max.

Stability: Output voltage at any rated load will change less than 0.5 V for $\pm 10\%$ line-voltage change.

Ripple: Less than 1 mV, rms, with B- grounded; less than 5 mV, rms, with B+ grounded.

Heater Power Output (Unregulated): 6.3 V ac; 2.1 A, max.

Square-Wave Output (Internally Generated)

Amplitude: Adjustable from approximately 160 to 210 V.

Frequency: Adjustable from 850 to 1150 c/s.

Stability: Frequency will change less than 0.5% for $\pm 10\%$ line-voltage change.

Duty Ratio: 0.5, adjustable $\pm 5\%$.

Square-Wave Output (from External Sine-Wave Generator)

Amplitude: Adjustable from approximately 160 to 210 V.

Driver Requirements: 20 to 50 V, rms, 20 to 50,000 c/s.

Pulse Output (Externally Generated)

Amplitude: Adjustable from approximately 160 to 210 V.

Duration (between half-amplitude points): 1.5 μ s to square waves, duration determined by external generator.

Rise and Decay Times (between 10% and 90% of maximum amplitude): Less than 1.5 μ s when driving a load capacitance of 300 pF in shunt with a resistance of 15,000 Ω or less.

Ramp-off: None.

Driver Requirements: +20 to +50 volts peak, positive polarity, 20 to 100,000 pulses per second.

Power Required: 105 to 125 or 210 to 250 V, 50 to 1000 c/s, 85 W.

Accessories Supplied: TYPE CAP-22 Power Cord, connector plug.

Recommended Oscillators: TYPE 1361-A (450 to 1050 Mc/s); TYPES 1215-C (50 to 250 Mc/s), 1209-C (250 to 920 Mc/s), 1209-CL (180 to 600 Mc/s), and 1218-B (900 to 2000 Mc/s) (pages 139 to 144). An adaptor cable (see below) is required for all except TYPES 1218-B and 1361-A.

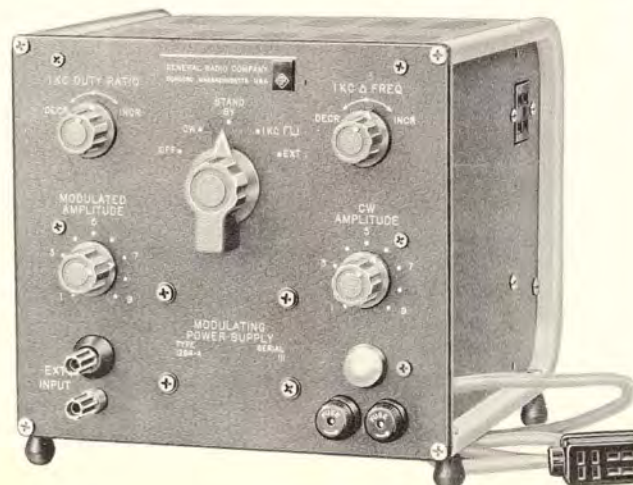
Accessories Available: TYPE 1264-P1 Adaptor Cable to connect to TYPES 1209-C, 1209-CL, and 1215-C Unit Oscillators. Panel-adaptor plate sets for 19-in relay-rack-mounting, panel height 7 in (see page 143).

Mechanical Data: Convertible-Bench Cabinet (see page 258)

Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
8	205	7	180	9¼	235	12	5.5	15	7

See also *General Radio Experimenter*, March 1961.

Catalog No.	Description	Price
1264-9701	Type 1264-A Modulating Power Supply	\$285.00
1264-9601	Type 1264-P1 Adaptor Cable	15.00





Type 1265-A ADJUSTABLE DC POWER SUPPLY

FEATURES:

- Continuously adjustable metered outputs up to 400 volts or 5 amperes.
- Low-impedance output circuit will pass high ac current.
- Current-regulated or voltage-regulated source.

USES: The TYPE 1265-A Adjustable DC Power Supply supplies dc bias for the TYPE 1633-A Incremental-Inductance Bridge. Its characteristics include wide ranges of current and voltage, a passive low-impedance output circuit that will pass high alternating currents, and a choice of voltage or current regulation.

DESCRIPTION: The instrument has four voltage ranges and four current ranges and will deliver its maximum rated power

of 200 watts to 8, 80, or 800 ohms. Ranges are interconnected to prevent overloading. Damage from overloads is prevented by an electronic overload circuit.

The output voltage (or current) is sampled, amplified, and used to control the conduction angle of two power-transistor, controlled rectifiers. These rectifiers control the current into the output transformer whose several taps provide a choice of output voltages. The selected voltage is rectified and then filtered by passive components.

SPECIFICATIONS

Full-Scale Output Ranges: 12.5, 40, 125, 400 V, dc; 0.16, 0.5, 1.6, 5 A, dc; in any combination up to 200 W.

Meters: Voltage and current; ranges switch with output ranges.

Overload Protection: Overload circuit trips at approximately 1½ times full-scale current.

Regulation (Voltage or Current): 0.2% for 10% line-voltage change; 1% for 100% load change.

Speed of Response: Approximately 0.1 second.

Hum Level (rms): Approximately 70 dB below full-scale dc output (55 dB on 5-A ranges).

Power Required: 105 to 125 or 210 to 250 V, 50 to 60 c/s, 380 W at rated load. (Specify if for 50 c/s.)

Accessories Supplied: TYPE CAP-22 Power Cord, spare fuses.

Mechanical Data: Rack-Bench Cabinet (see page 258)

Model	Width		Height		Depth		Net Wt		Ship Wt	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Bench	19	485	7½	190	17¼	440	70	32	124	57
Rack	19	485	7	180	15*	385	70	32	124	57

* Behind panel.

See also *General Radio Experimenter*, May 1962.

Catalog Number	Description	Price
1265-9801	Type 1265-A Adjustable DC Power Supply, Bench Model	\$1050.00
1265-9811	Type 1265-A Adjustable DC Power Supply, Rack Model	1050.00

PATENT NOTICE. See Notes 1 and 15, page 11.

Type 1266-A ADJUSTABLE AC POWER SOURCE

FEATURES:

- Continuously adjustable metered output up to 1250 volts or 5 amperes.
- Will tolerate dc current equivalent to maximum ac current in each range.

USES: The TYPE 1266-A Adjustable AC Power Source is compatible with the TYPE 1265-A Adjustable DC Power Supply to produce high-power composite waveforms for the TYPE 1633-A Incremental-Inductance Bridge.

DESCRIPTION: There are six voltage ranges and five current ranges. These are selected by rotary panel switches, which

are mechanically interlocked to prevent any combination that might exceed the 200 voltampere capacity of the supply. Voltage, in each range, is continuously adjustable from zero to the maximum value selected, by means of a VARIAC® adjustable autotransformer. An automatic trip circuit, with manual reset, protects against unintentional overload.

SPECIFICATIONS

Frequency: Power-line frequency.

Full-Scale Output Ranges: 4, 12.5, 40, 125, 400, 1250 V, rms; 0.05, 0.16, 0.5, 1.6, 5 A; in any combination up to 200 VA. Dc currents up to the rated ac current may be superimposed on output from external source. Maximum voltage derated 20% at 50 c/s.

Meters: Voltage and current; ranges switch with output ranges.

Overload Protection: Overload circuit trips at approximately 1½ times full scale of current meters; can be reset by panel switch.

Power Required: 105 to 125 or 210 to 250 V, 50 to 60 c/s, 230 VA.

Accessories Supplied: TYPE CAP-22 Power Cord and spare fuses.

Mechanical Data: Rack-Bench Cabinet (see page 258)

Model	Width		Height		Depth		Net Wt		Ship Wt	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Bench	19	485	7½	190	17¼	440	46	21	83	38
Rack	19	485	7	180	15*	385	46	21	83	38

* Behind panel.

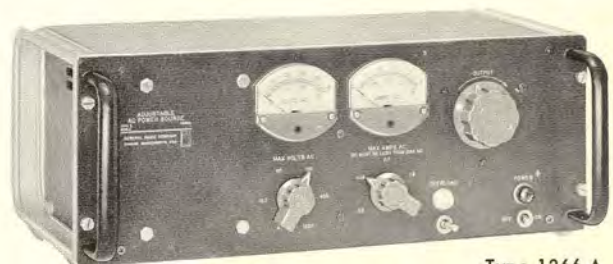
See also *General Radio Experimenter*, May 1962.

Catalog Number	Description	Price
1266-9801	Type 1266-A Adjustable AC Power Supply, Bench Model	\$360.00
1266-9811	Type 1266-A Adjustable AC Power Supply, Rack Model	360.00

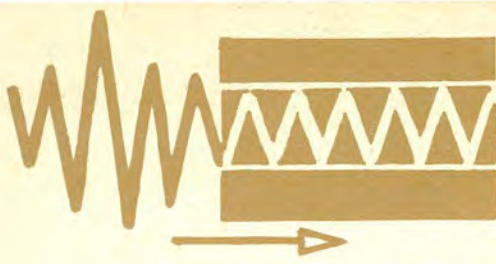
PATENT NOTICE. See Note 15, page 11.



Type 1265-A



Type 1266-A



VARIAC[®] voltage regulators



General Radio Variac[®] automatic voltage regulators have many advantages for both laboratory and industrial use in any application where controlled line voltage is needed.

Variac regulators

Regulate to 0.25%.

Are not load sensitive; they work equally well on all loads from open circuit to maximum rating for continuous service.

Up to 10 times rating for transients.

Introduce no distortion.

Have no power-factor restrictions.

Have high response speed — comparable with magnetic types.

Use all-solid-state control circuits.

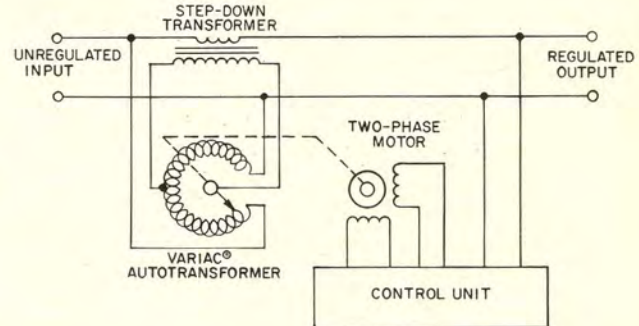
Are available in many models, differing in power rating, correction range voltage, frequency, and packaging.

PRINCIPLE OF OPERATION

The regulator comprises a motor-driven Variac[®] adjustable autotransformer, an auxiliary step-down transformer, and a solid-state control unit, which automatically positions the autotransformer to hold the output voltage constant.

The rms output voltage is converted to a dc signal, which is compared to a reference voltage. The resultant error signal controls a servo motor, providing a true proportional-control system, rather than an on-off circuit. The loop phase and amplitude characteristics are shaped to provide optimum closed-loop transient response. The accompanying oscillograms illustrate a typical response to a 2% step change in line voltage. The traces are greatly expanded and show only the ac voltage peaks.

The use of a true proportional control system provides not only fast correction but also smooth control of voltage, completely free of the voltage jumps introduced by the more

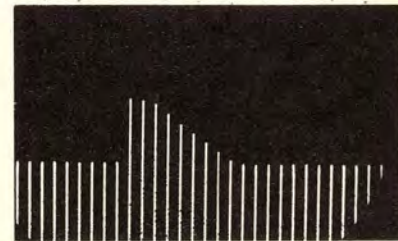
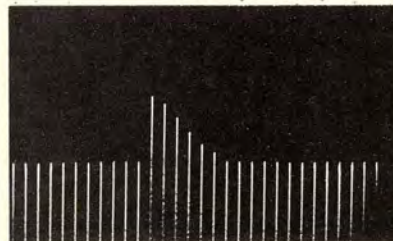
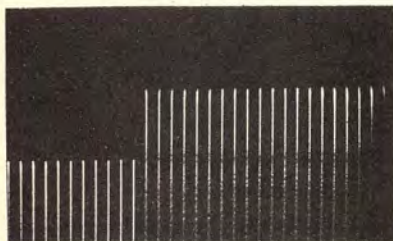


Elementary schematic diagram of General Radio's voltage regulators.

usual on-off control system. The absence of relays provides long trouble-free life, and tolerance of 1000% transient overloads is made possible by the Duratrak[®] commutator surface of the Variac autotransformer, a General Radio development described on page 230.

Three basic models are available: Type 1571, a militarized version, and Types 1581 and 1582, which differ primarily in power rating, for general use. Ratings, closeness of regulation, correction range, and response speed are interdependent; ratings listed below are for 115-volt nominal input, 90 to 110% regulation range, and 0.25% regulation accuracy. For complete detailed listings, see the following pages.

Type	Load Rating KVA	Line Frequency c/s	Page
1581	5.8	50 to 60, 400	224
1582	9.8	50 to 60, 400	224
1571	5.8	50 to 60, 400	226



Oscillograms of line-voltage peaks show response speed of Variac[®] automatic voltage regulators: left, 2% step change in line voltage; center and right, resulting output transients for Type 1581 and Type 1582 Regulators, respectively.



FEATURES:

- All-solid-state circuits.
- High response speed comparable with magnetic regulators.
- No distortion added.
- High accuracy.
- No power-factor restrictions.
- Tolerates transient overloads up to ten times rated.
- Large power-handling capacity.
- Output voltage independent of load.

USES: The TYPES 1581-A and 1582-A VARIAC® automatic voltage regulators automatically compensate for ac line-voltage fluctuations to provide a reliable constant-voltage source over a specified correction range. These units combine high accuracy with large capacity, making them suitable for both laboratory use and industrial installations. Typical uses include the regulation of line voltage for computers, measurement systems, transmitter supplies, and carefully controlled industrial processes.

These regulators operate on the principle described on page 223. They are supplied in four different mounting styles: bench, rack, wall, or without case.

Power output of the standard models ranges from 2 to 20 kVA, depending upon the model selected.

Several models are available in each of the 115-, 230-, and 460-volt classifications to accommodate a wide variety of requirements concerning output current, frequency, correction range, and mounting or cabinet arrangement.

Any of the 60-cycle models can be connected for 50- to 60-cycle operation by a connection change on the VARIAC autotransformer. This will affect the correction ranges, as indicated on the chart on page 225.

The TYPE 1571-A, military version of the TYPE 1581-A, is described on page 226. In addition to the standard and military models listed in this catalog, special models are available for other current ratings and correction ranges. Tell us your requirements.

SPECIFICATIONS

Frequency: 60-cycle models operate from 57 to 63 c/s but can be modified by a connection change to operate from 48 to 63 c/s (50 to 60, nominal); 400-cycle models operate from 350 to 450 c/s.
Response: Rms. **Distortion:** None added. **Efficiency:** > 98%.

Power Required: TYPE 1581-A — no load, 25 W; full load, 115 W. TYPE 1582-A — no load, 45 W; full load, 120 W.

Ambient Temperature: Operating, -20° to +52°C; in storage, -54° to 85°C.

Mechanical Data:

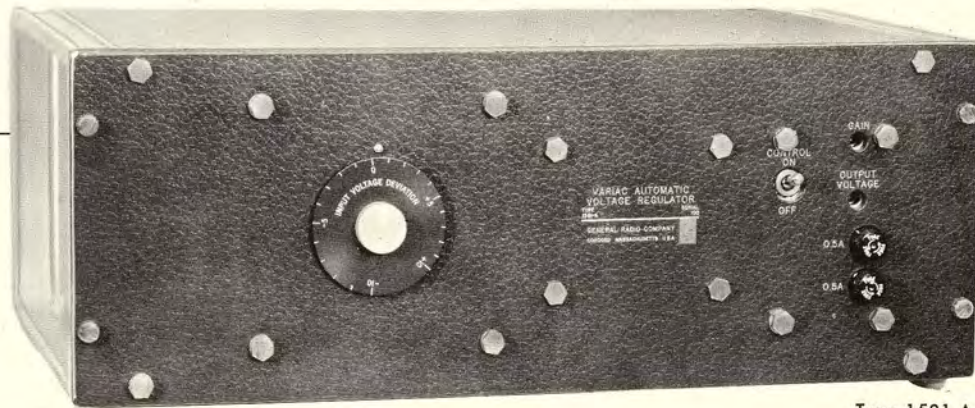
	TYPE 1581									
	Width		Height		Depth		Net Wt		Ship Wt	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Without case	19	485	7	180	10½	270	41½	19	92	42
Bench	19	485	7¾	190	12	305	51	23.5	100	46
Rack	19	485	7	180	11¾*	300	51	23.5	100	46
Wall	19½	495	8½	210	11¼	290	54	24.5	104	48

* Behind panel.

	TYPE 1582									
	Width		Height		Depth		Net Wt		Ship Wt	
	in	mm	in	mm	in	mm	lb	kg	lb	kg
Without case	19	485	7	180	14¼	365	61	28	110	50
Bench	19	485	7¾	190	16	410	71	33	121	55
Rack	19	485	7	180	15¾*	400	71	33	121	55
Wall	19½	495	8½	210	14¾	375	77	35	126	58

* Behind panel.

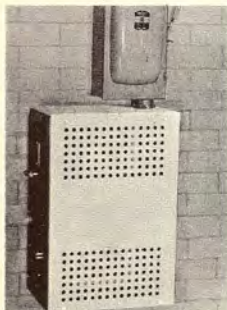
NEW
in catalog S



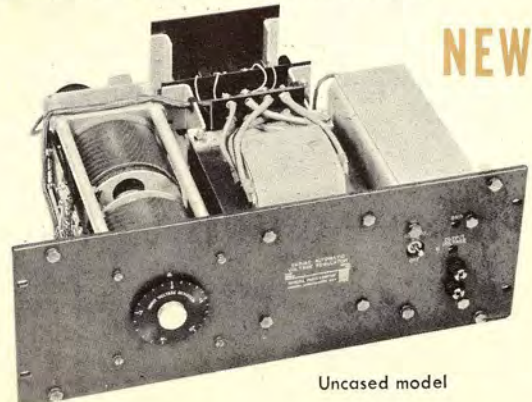
Type 1581-A,
bench model

Output Voltage	Correction Range* %	Output Current (A)	KVA	Max Response Speed (V/s)	Accuracy (% of output V)	Mounting or Style	400 c/s			60 c/s*		
							Type Number	Catalog Number	Price	Type Number	Catalog Number	Price
115 V Adjustable ±10%	90 to 110	50	5.8	40	0.25	No cabinet	1581-ALJ	1581-9551	\$540.00	1581-AL	1581-9831	\$495.00
						Bench	1581-ALMJ	1581-9552	575.00	1581-ALM	1581-9964	530.00
						Rack	1581-ALRJ	1581-9554	575.00	1581-ALR	1581-9974	530.00
						Wall	1581-ALWJ	1581-9555	560.00	1581-ALW	1581-9980	515.00
	85	9.8	20	0.25	No cabinet	1582-ALJ	1582-9551	600.00	1582-AL	1582-9831	555.00	
					Bench	1582-ALMJ	1582-9552	635.00	1582-ALM	1582-9964	590.00	
					Rack	1582-ALRJ	1582-9554	635.00	1582-ALR	1582-9974	590.00	
					Wall	1582-ALWJ	1582-9555	620.00	1582-ALW	1582-9980	575.00	
	82 to 124	25	2.9	80	0.5	No cabinet	1581-AL2J	1581-9556	540.00	1581-AL2	1581-9898	495.00
						Bench	1581-ALM2J	1581-9557	575.00	1581-ALM2	1581-9901	530.00
						Rack	1581-ALR2J	1581-9558	575.00	1581-ALR2	1581-9923	530.00
						Wall	1581-ALW2J	1581-9559	560.00	1581-ALW2	1581-9924	515.00
42.5	4.9	40	0.5	No cabinet	1582-AL2J	1582-9556	600.00	1582-AL2	1582-9898	555.00		
				Bench	1582-ALM2J	1582-9557	635.00	1582-ALM2	1582-9901	590.00		
				Rack	1582-ALR2J	1582-9558	635.00	1582-ALR2	1582-9923	590.00		
				Wall	1582-ALW2J	1582-9559	620.00	1582-ALW2	1582-9924	575.00		
230 V Adjustable ±10%	95 to 105	40	9.2	40	0.25	No cabinet	1581-AH5J	1581-9530	540.00	1581-AH5	1581-9516	495.00
						Bench	1581-AHM5J	1581-9531	575.00	1581-AHM5	1581-9517	530.00
						Rack	1581-AHR5J	1581-9532	575.00	1581-AHR5	1581-9518	530.00
						Wall	1581-AHW5J	1581-9533	560.00	1581-AHW5	1581-9521	515.00
	85	19.7	20	0.25	No cabinet	1582-AH5J	1582-9530	600.00	1582-AH5	1582-9516	555.00	
					Bench	1582-AHM5J	1582-9531	635.00	1582-AHM5	1582-9517	590.00	
					Rack	1582-AHR5J	1582-9532	635.00	1582-AHR5	1582-9518	590.00	
					Wall	1582-AHW5J	1582-9533	620.00	1582-AHW5	1582-9521	575.00	
	90 to 110	20	4.6	80	0.25	No cabinet	1581-AHJ	1581-9522	540.00	1581-AH	1581-9817	495.00
						Bench	1581-AHMJ	1581-9523	575.00	1581-AHM	1581-9951	530.00
						Rack	1581-AHRJ	1581-9524	575.00	1581-AHR	1581-9961	530.00
						Wall	1581-AHWJ	1581-9525	560.00	1581-AHW	1581-9971	515.00
42.5	9.8	40	0.25	No cabinet	1582-AHJ	1582-9522	600.00	1582-AH	1582-9817	555.00		
				Bench	1582-AHMJ	1582-9523	635.00	1582-AHM	1582-9951	590.00		
				Rack	1582-AHRJ	1582-9524	635.00	1582-AHR	1582-9961	590.00		
				Wall	1582-AHWJ	1582-9525	620.00	1582-AHW	1582-9971	575.00		
82 to 124	10	2.3	160	0.5	No cabinet	1581-AH2J	1581-9526	540.00	1581-AH2	1581-9770	495.00	
					Bench	1581-AHM2J	1581-9527	575.00	1581-AHM2	1581-9771	530.00	
					Rack	1581-AHR2J	1581-9528	575.00	1581-AHR2	1581-9772	530.00	
					Wall	1581-AHW2J	1581-9529	560.00	1581-AHW2	1581-9773	515.00	
21.3	4.9	80	0.5	No cabinet	1582-AH2J	1582-9526	600.00	1582-AH2	1582-9770	555.00		
				Bench	1582-AHM2J	1582-9527	635.00	1582-AHM2	1582-9771	590.00		
				Rack	1582-AHR2J	1582-9528	635.00	1582-AHR2	1582-9772	590.00		
				Wall	1582-AHW2J	1582-9529	620.00	1582-AHW2	1582-9773	575.00		
460 V Adjustable ±10%	95 to 105	34	15.6	40	0.25	No cabinet	1582-AK5J	1582-9546	600.00	1582-AK5	1582-9535	555.00
						Bench	1582-AKM5J	1582-9547	635.00	1582-AKM5	1582-9536	590.00
						Rack	1582-AKR5J	1582-9548	635.00	1582-AKR5	1582-9537	590.00
						Wall	1582-AKW5J	1582-9549	620.00	1582-AKW5	1582-9538	575.00
	90 to 110	17	7.8	80	0.25	No cabinet	1582-AKJ	1582-9541	600.00	1582-AK	1582-9819	555.00
						Bench	1582-AKMJ	1582-9542	635.00	1582-AKM	1582-9534	590.00
						Rack	1582-AKRJ	1582-9544	635.00	1582-AKR	1582-9426	590.00
						Wall	1582-AKWJ	1582-9545	620.00	1582-AKW	1582-9821	575.00
	82 to 124	8.5	3.9	160	0.5	No cabinet	1582-AK2J	1582-9395	600.00	1582-AK2	1582-9391	555.00
						Bench	1582-AKM2J	1582-9396	635.00	1582-AKM2	1582-9392	590.00
						Rack	1582-AKR2J	1582-9397	635.00	1582-AKR2	1582-9393	590.00
						Wall	1582-AKW2J	1582-9398	620.00	1582-AKW2	1582-9394	575.00

* Ranges listed are for 57- to 63-cycle operation; for 48- to 63-cycle operation, corresponding correction ranges are 95 to 105%, 91 to 109%, and 84 to 119%.



View of wall-mounted regulator. This model is used to regulate line voltages in the General Radio development and testing laboratories.



NEW

Type 1582-A Available 4th quarter 1965

Uncased model



Type 1571-A VARIAC® AUTOMATIC VOLTAGE REGULATOR

FEATURES:

- Designed to MIL-E-4158B and MIL-E-16400C.
- All-solid-state control circuits.
- High response speed — comparable with that of magnetic regulators.
- No distortion added by regulator.
- High accuracy.
- No power-factor restrictions.
- Tolerates transient overloads up to 10 times rating.
- High power-handling capacity.
- Output voltage independent of load.

The TYPE 1571-A VARIAC® automatic voltage regulator is a militarized version of the TYPE 1581-A described on pages 224 and 225. It is designed to meet the requirements of military specifications MIL-E-4158B and MIL-E-16400C. These models are particularly useful where mechanical shock or vibration is en-

countered. Models are available for use on both 115- and 230-volt ac lines, 400 c/s or 60 c/s (50 to 60 c/s by a change in connection on the autotransformer), and with various output currents and correction ranges. All units are designed for relay-rack mounting.

SPECIFICATIONS

Output Voltage: Adjustable over a range of $\pm 10\%$ from a base value of 115 V (for TYPE 1571-AL) or 230 V (for TYPE 1571-AH), set by a front-panel screwdriver adjustment.

Frequency: 60-cycle models operate from 57 to 63 c/s but can be modified by connection change to operate from 48 to 63 c/s; 400-cycle models operate from 350 to 450 c/s.

Power Required: No load, 25 W; full load, 115 W.

Ambient Temperature: Operating, -29° to $+52^{\circ}\text{C}$; in storage, -54° to 85°C .

Mechanical Data:

Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
19	485	7	180	12*	305	52½	24.5	103	47

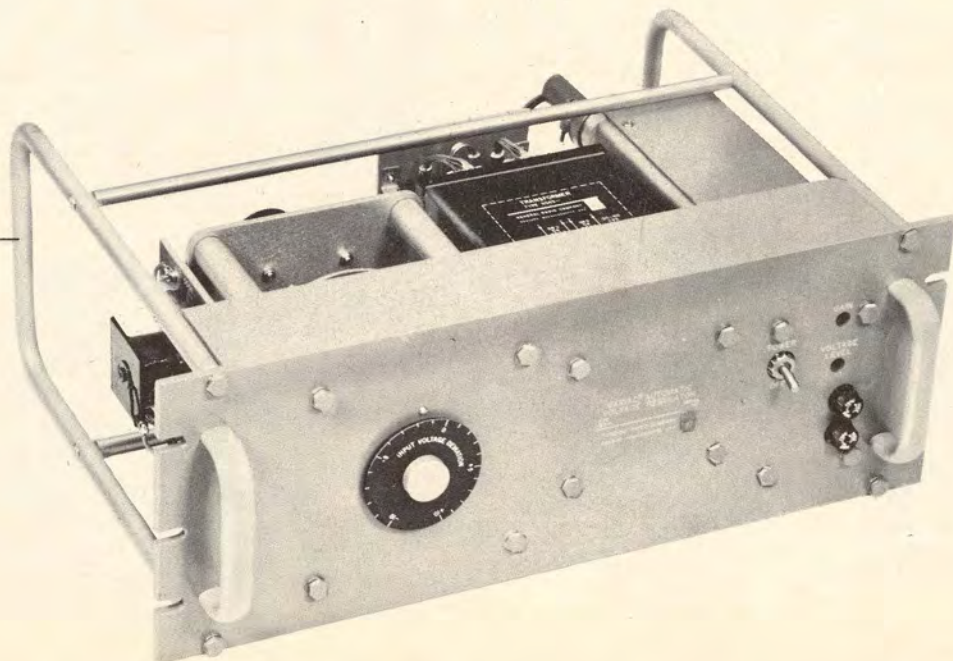
* Behind panel.

Output Voltage	Correction Range* %	Output Current (A)	KVA	Max Response Speed (V/s)	Accuracy (% of output V)	Mounting	400 c/s			60 c/s*		
							Type Number	Catalog Number	Price	Type Number	Catalog Number	Price
115 V Adjustable $\pm 10\%$	90 to 110	50	5.8	40	0.25	Rack	1571-ALJ	1571-9551	\$695.00	1571-AL	1571-9831	\$650.00
	82 to 124	25	2.9	80	0.5	Rack	1571-AL2J	1571-9556	695.00	1571-AL2	1571-9898	650.00
230 V Adjustable $\pm 10\%$	95 to 105	40	9.2	40	0.25	Rack	1571-AH5J	1571-9530	695.00	1571-AH5	1571-9516	650.00
	90 to 110	20	4.6	80	0.25	Rack	1571-AHJ	1571-9522	695.00	1571-AH	1571-9817	650.00
	82 to 124	10	2.3	160	0.5	Rack	1571-AH2J	1571-9526	695.00	1571-AH2	1571-9770	650.00

* Ranges given are for 57- to 63-cycle operation. For 48- to 63-cycle operation, corresponding correction ranges are 95 to 105%, 91 to 109%, and 84 to 119%.

NEW

in catalog S





VARIAC® speed controls



FOR OPERATING DC MOTORS FROM AC LINES

Refer to pages 228 and 229 for specifications and prices.

FEATURES:

- Smooth speed control — 10:1 for most applications; up to 100:1 or more with light loads.
- Full torque at any speed.
- Instant starting; quick reversing.
- Smooth controlled starting for delicate loads; fast high-torque starting for heavy loads.
- Dynamic braking in all models 1/6 hp and higher, to bring the armature to a quick stop.
- Economical, easy to install, require minimum of maintenance.

VARIAC® speed controls are compact, high-performance motor speed controls, designed to operate dc shunt, compound, or series motors from an ac line. The motors are operated with constant field excitation and adjustable armature voltage. A VARIAC® autotransformer, in the input to the armature-supply rectifier, provides smooth continuous adjustment of the armature voltage (and hence of the speed) from rated value down to zero. Regulation is 15 to 30 percent at base speed. A choke in the armature circuit minimizes ac ripple, thus eliminating the need to derate the motor. A resistor, connected across the armature when the switch is in the stop position, provides dynamic braking except on 1/15-hp models.

These controls are completely solid state (no electron tubes are used).

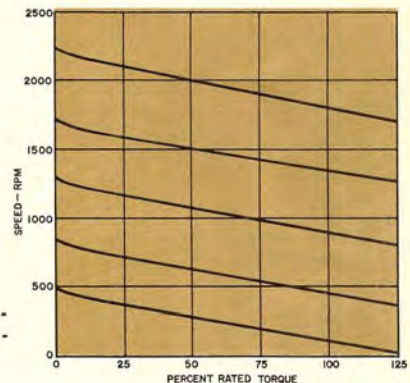
The basic circuit is shown in the diagram. Long-life selenium rectifiers are employed in both armature and field circuits. These are self-protecting against transient voltage surges. Armature overload protection is accomplished with slow-blow fuses in the 1/15- and 1/6-hp models, and with magnetic circuit breakers in the 1/3- and 3/4-hp models.

Curves of the speed-torque characteristics for a typical installation are shown in the diagram.

The VARIAC speed control is available in any of four power ratings: 1/15, 1/6, 1/3, or 3/4 horsepower. Each rating may be had in either of two models. The cabinet model is complete with all necessary switches and pro-

TECTIVE DEVICES. The basic model (identified by the suffix "W" in the type number) is electrically identical with the corresponding cabinet model, but it contains only the essential components, including the VARIAC autotransformer mounted separately. No switches or overload protectors are supplied with the basic models. A switch or drum control is available as a separate item (see below).

The table on the following pages gives the specifications and prices for both the cabinet and the basic models.



Speed-torque characteristics of a typical motor-and-speed-control installation.

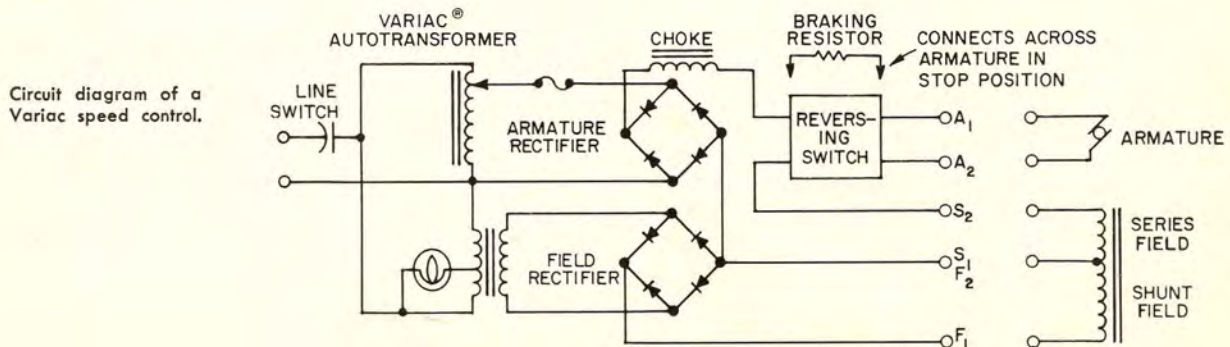
SWITCH AND CONTROLLER

for Use with 1/6-HP, 1/3-HP, and 3/4-HP Basic (W) Models

The TYPE 1702-P3 appliance-type switch, supplied with the cabinet models, is available for the W models as a separate item. This switch is designed to break the ac and dc circuits simultaneously and handle reversing and dynamic braking. The escutcheon plate (supplied) is engraved FORWARD, STOP, and REVERSE.

A drum-type Controller, TYPE 1705-P1, is also available separately for use with the basic models in machine-shop production work.

For prices of the switch and controller, see page 228.



Circuit diagram of a Variac speed control.

VARIAC[®] MOTOR SPEED CONTROLS

These speed controls are simple and rugged and have good regulation. They have given excellent performance in many types of industrial applications and are particularly well suited for use in the shop and the laboratory. See page 227 for general description and circuit.



Type 1701-AK
Cabinet Model
Two speed ranges

1/15 hp and less
for shunt motors



Type 1701-AKW
Basic Model

1/15 hp and less for
series or universal motors



Type 1701-AU
Available only
in cabinet model

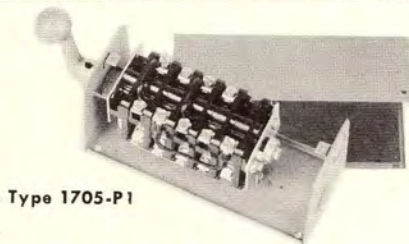
Field and armature leads must be separate to provide constant field excitation

Ac Input	Power supply	Volts	115	115
	single phase	Full-load amperes	1.5	1.5
	Line voltage limits	at 60 cycles	105—125	105—125
		at 50 cycles	105—120	105—120
	Input power, watts	Full load	175	175
Stand-by		None	None	
Dc Output	Armature	Amperes	0.8	0.8
		Volts	0—115	0—115
	Field	Amperes	0.2	1.25 or 1.0
		Volts	115 or 38	10 or 16
	Speed range		0 to rated or 0 to 2 × rated	0 to rated or 0 to 2 × rated
Model		Cabinet	Basic	Cabinet
Dimensions (inches)	Cabinet (w × h × d)	5 7/8 × 6 3/4 × 3 3/4	6 1/8 × 9 × 2 3/4	5 7/8 × 6 3/4 × 3 3/4
	Variac (w × h × d)	in cabinet	3 1/4 × 3 11/16 × 4 3/8	in cabinet
Weight (pounds)	Net	6	5 3/4	6
	Shipping	11	11	11
Catalog Number		1701-9819	1701-9821	1701-9939
Prices net FOB factory	1-4	\$95.00	\$72.00	\$95.00
	5-19	93.00	68.50	93.00
	20 and up	91.00	65.50	91.00

RECOMMENDED MOTORS FOR USE WITH ABOVE VARIAC[®] MOTOR SPEED CONTROLS

Motors not sold separately

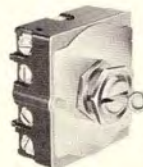
Motor ratings: open, drip proof, electrically reversible, 40° C rise continuous, horizontal, rigid base. Any motor within control ratings can be used.	Shunt	Series or Universal
Catalog Number	1701-9621	1701-9604
Type Number	MOD-21	MOD-4
Horsepower	1/15	1/15
Speed RPM	1725	8800
Frame Size	68	NSE-12
Leads (brought out separately)	4	4
Bearings	Ball	Sleeve
Weight	Net — 6 1/2 lb Shipping — 14 lb	Net — 3 1/2 lb Shipping — 6 lb
Price	\$38.00	\$21.50



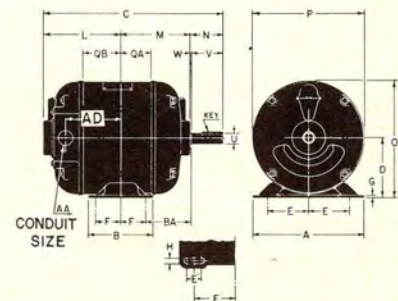
Type 1705-P1

Type 1702-P3 three-position Switch for use with Types 1700-CW, 1702-BW, and 1703-BW.

Type 1705-P1 drum-type Controller, especially suitable for machine-shop production work. For descriptions, refer to page 227.









Type 1702-P3



Catalog No.	Description	Price
1702-9603	Type 1702-P3 Switch	\$11.00
1705-9601	Type 1705-P1 Controller	30.00

VARIAC® SPEED CONTROLS SPECIFICATIONS AND PRICES

For description of these models, refer to page 227

1/12 to 1/6 hp		1/4 and 1/3 hp		1/2 and 3/4 hp	
					
Type 1703-A Cabinet Model	Type 1703-BW Basic Model	Type 1700-B Cabinet Model	Type 1700-CW Basic Model	Type 1702-A Cabinet Model	Type 1702-BW Basic Model
115		115		115	
2.2		5		10	
105—125		105—125		105—125	
105—125		on Special Order only		on Special Order only	
325		560		1150	
30		38		65	
1.5		3.0		6.5	
0—115		0—115		0—115	
0.2		0.4		0.4	
115 or 66 or 48		115 or 75		115 or 75	
0 to rated or	0 to 1.25 × rated	0 to rated or	0 to 1.15 × rated	0 to rated or	0 to 1.15 × rated
Cabinet	Basic	Cabinet	Basic	Cabinet	Basic
7 1/8 × 7 3/4 × 4 3/4	6 7/8 × 10 1/8 × 3 1/2	12 7/8 × 9 1/8 × 4 5/8	12 1/2 × 9 3/16 × 4 7/8	13 1/2 × 14 7/8 × 5 1/8	15 3/16 × 10 11/16 × 5 13/16
in cabinet	3 1/4 × 3 11/16 × 4 3/8	in cabinet	4 1/2 × 4 15/16 × 5 1/2	in cabinet	5 3/4 × 6 1/4 × 5
9	8	23 1/2	23 1/2	41	38 3/4
11	15	30	40	49	51
1703-9701	1703-9826	1700-9702	1700-9828	1702-9701	1702-9826
\$110.00	\$90.00	\$180.00	\$155.00	\$255.00	\$215.00
107.00	87.50	176.00	151.50	245.00	206.00
104.00	85.00	172.00	148.00	235.00	197.00

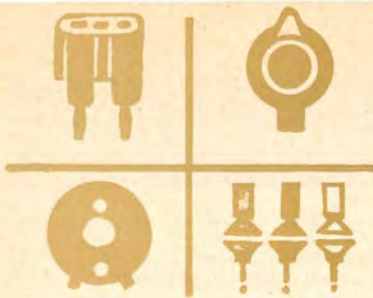
RECOMMENDED MOTORS FOR USE WITH ABOVE VARIAC® MOTOR SPEED CONTROLS

Motors not sold separately

Compound with separate series - field leads		Compound with interpoles		Compound with interpoles	
1703-9611		1700-9603		1702-9625	
MOD-11		MOD-3		MOD-25	
1/6		1/3		3/4	
1725		1725		1725	
G-56		G-56		J-56	
6		6		6	
Ball		Ball		Ball	
Net — 30 lb	Shipping — 35 lb	Net — 33 lb	Shipping — 37 lb	Net — 45 lb	Shipping — 49 lb
\$62.00		\$76.00		\$115.00	

DIMENSIONS OF MOTORS USED WITH VARIAC® MOTOR SPEED CONTROLS

Catalog Number	Frame Size															U		KEY						
		A	B	C	D	E	E'	F	G	H	L	M	N	O	P	Min	Max	Sq	Lgt	V	W	AA	AD	BA
5760-9603	G-56	6 5/8	4 1/8	10 3/4	3 1/2	2 7/16	5/8	1 1/2	1/4	1 1/2	4 13/32	4 13/32	1 15/16	6 31/32	6 15/16	.6245	.6250	3/16	1/4	1 7/8	1/16	1/2	3 3/32	2 3/4
5760-9604	NSE-12	3 9/16	2 1/4	5 11/16	2	1 15/32	7/16	5/8	..	1/4	2 3/8	2 3/8	1 5/16	3 21/32	3 21/64	.3119	.3122	..	..	..	..	..	..	1 3/4
5760-9611	G-56	6 5/8	3 7/8	10 3/4	3 1/2	2 7/16	7/8	1 1/2	1/4	1 1/2	4 13/32	4 13/32	1 15/16	6 31/32	6 15/16	.6245	.6250	3/16	1/4	1 7/8	1/16	1/2	3 5/16	2 3/4
5760-9621	68	4	5	7 3/4	2 1/16	1 19/32	9/32	1 19/32	1/8	9/32	3 7/16	3 3/8	1 5/16	3 31/32	4 1/4	.3120	.3125	..	..	..	..	..	..	1 1/4
5760-9625	J-56	6 5/8	4 1/8	12 1/2	3 1/2	2 7/16	5/8	1 1/2	1/4	1 1/2	6 1/4	4 1/4	1 15/16	6 31/32	6 15/16	.6245	.6250	3/16	1/4	..	..	1/2	5	2 3/4



PARTS & ACCESSORIES



The General Radio Company has developed and is constantly improving a comprehensive line of parts for use in its laboratory and industrial instruments. Among the design objectives are maximum reliability, long life, convenience, attractive appearance, and known electrical characteristics. All General Radio parts are painstakingly designed, use high-quality materials, and are produced by methods that yield reasonable prices. One important design consideration is to produce integrated groups of basic elements that fit together electrically and have a unity of appearance.

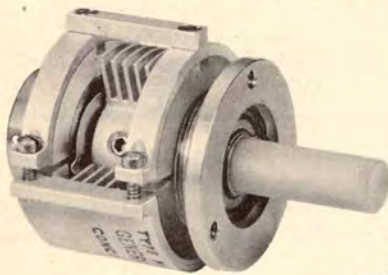
Described in this section are capacitors, potentiometers, transformers, knobs, dials, binding posts, plugs and jacks,

and patch cords. Two groups are new in this catalog: copper binding posts, fabricated from copper to minimize thermal emf to copper wires; and new single- and double-plug patch cords.

Additional parts will be found in other sections of this catalog. Decade capacitors, resistors, and inductors are listed in the section on standards, pages 184-209, variable delay lines on page 168, and coaxial connectors and parts on pages 76-102.

These are high-quality parts, designed for instrument use and fabricated from materials with superior electrical and mechanical properties.

Type 1420 VARIABLE AIR CAPACITORS



These capacitors were developed especially for use in laboratory instruments. The stator and insulated rotor are each machined from solid, shaped aluminum extrusions of identical alloy. Features include low dielectric losses, low inductance and resistance, good linearity, high mechanical and thermal stability, and sealed, long-life ball bearings.

SPECIFICATIONS

Capacitance Range: See table. The data in the table are for the capacitor used as a two-terminal device, with rotor grounded. If the stator is grounded, maximum and minimum capacitance values will be decreased by about 1 pF. The rotor-to-ground capacitance is about 1 pF. The stator-to-ground capacitance is about 1.5 pF.

Linearity: The variation of capacitance with angle of rotation is guaranteed linear within $\pm 0.3\%$ of full scale. The angular range of linear variation is 160° .

Typical independent linearity is better than $\pm 0.2\%$.

Dielectric Losses: For the grounded-rotor connection, the dielectric losses correspond to a *DC* product of less than 0.01×10^{-12} . The rotor-to-ground capacitance has a *DC* product of 0.1×10^{-12} . This loss component is in parallel with the main capacitance only for the grounded-stator connection.

Inductance: Approximately $0.006 \mu\text{H}$.

Insulation Resistance: Greater than $10^{11} \Omega$ under standard ASTM laboratory conditions (23°C , $50\% \text{RH}$).

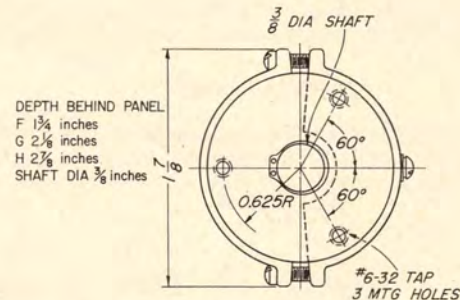
Temperature Coefficient of Capacitance: Approximately $+0.003\%$ per degree C.

Maximum Voltage: 700 V peak.

Torque: 2 ounce-inches maximum with shaft vertical.

Dimensions: See sketch below. To convert inches to mm, multiply by 25.4. Where dimensions are critical, write for a copy of the latest drawings.

Shock and Vibration: Will pass shock and vibration tests of MIL-T-945-A.



Catalog Number	Description	Nominal Range		Range for Linear Variation	Net Weight		Shipping Weight		Price
		Max	Min		oz	g	lb	kg	
1420-9706	Type 1420-F Variable Air Capacitor	70 pF	13 pF	54 ± 5 pF	4	110	1	0.5	\$30.00
1420-9707	Type 1420-G Variable Air Capacitor	130 pF	14 pF	108 ± 5 pF	4½	125	1	0.5	32.00
1420-9708	Type 1420-H Variable Air Capacitor	250 pF	16 pF	216 ± 5 pF	5½	155	1	0.5	33.00

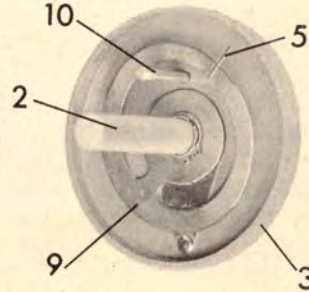
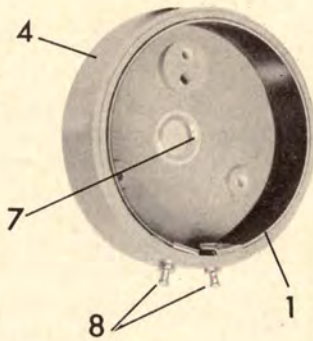
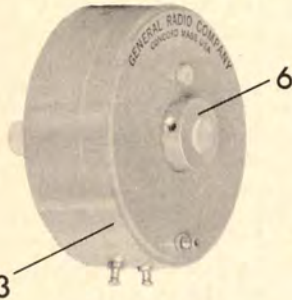


970-SERIES POTENTIOMETERS

USES: These potentiometers are moderately priced controls with high-quality performance. They can be used at dc, throughout the audio- and ultrasonic-frequency ranges, and, in many applications, at low radio frequencies.

**HIGH LEAKAGE RESISTANCE
LOW CAPACITANCE TO GROUND**

- 2 Glass-reinforced-polyester shaft
- 3 New diallyl-phthalate dust-proof cover
- 4 New diallyl-phthalate body



HIGH RESOLUTION
5 Small-diameter brush of precious-metal alloy

LOW NOISE

- 1 Firm clean track
- 5 Precious metal contact
- 9 Uniform contact pressure

HIGH RELIABILITY

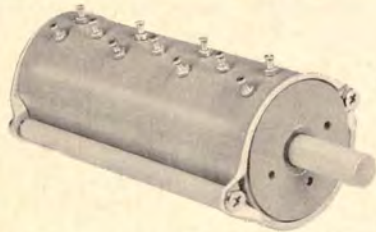
- 8 Turret terminals are both riveted to end of clamps and soldered to ends of winding and to silver-plated, spring-bronze contact take-off in cover so that none of the fixed internal connections depends on pressure alone.
- 9 Brush arm and spring are combined into a single stamping of spring-temper phosphor-bronze.
- 10 Screw that holds cover to base passes through a horseshoe-shaped slot in brush arm to serve as a rotational stop that exerts no force on brush.

**SIMPLE MECHANICAL ADJUSTMENT
EXCELLENT MECHANICAL STABILITY
EXCELLENT REPEATABILITY**

- 6 Projecting hub permits adjustment of shaft with respect to contact brush while case is closed. Hub rotates in a recessed brass insert molded into cover to form a metal-to-metal bearing close to plane of brush.
- 7 A second bearing is provided by a nylon-graphite insert to guide shaft into base.

**EXCELLENT LINEARITY
LOW TEMPERATURE COEFFICIENT
LOW INDUCTANCE**

- 1 Low, uniformly wound, temperature-coefficient resistance element on a thin, phenolic-laminate mandrel firmly cemented into body molding.



GANGING

When ganged, the 970-Series Potentiometers retain their low-capacitance characteristics. Units are designed to be nested with molded spacing rings, stacked on a long shaft, and held together with thin metal clamping rings and tie rods. This assembly allows units to be set in any desired phase relationship. Inquiries are welcomed on a special-design basis.

SPECIAL TYPES

Units in the 970 design can be made on special order with: 360° mechanical rotation, taps as close as 1/4 inch apart along the entire winding, resistance other than listed values, equiv-

alent noise resistance lower than standard, resistance tapers, resistance tolerance, and linearity tolerances better than standard. For applications requiring maximum shaft rigidity, shafts of metal-cored phenolic or of metal can be supplied.

KNOBS

Recommended knobs are described on page 254.

DIAL PLATES






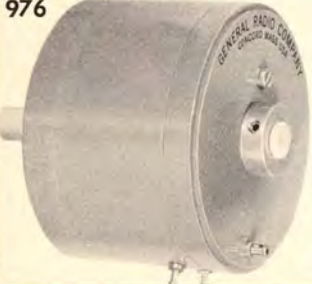
The TYPE 970-P1 (below) is a 2-inch dial plate for use with the TYPES 971, 972, 973, and 974 with a pointer-type knob. Scale covers 315°. The TYPE 970-P2 is a 2 3/4-inch reversible dial plate for use with the TYPES 975 and 976 with a pointer-type knob or attached to a knob. Scale covers 320°.



Type	Catalog Number	Price
970-P1	0970-9601	\$0.55
970-P2	0970-9602	0.55

Type	Effective Electrical Rotation	Total Mechanical Rotation	Standard Resistance Tolerance	Average Torque oz/in	Independent Linearity %	Power Rating at 0°C ambient temp*	
						Mounted on Alum Panel	Suspended in Air
971	315° ± 5°	330° ± 5°	± 5%	1 3/4	± 2	5.6	3.5
972	315° ± 5°	330° ± 5°	± 5%	1 3/4	± 2	7.8	5.8
973	320° ± 5°	330° ± 5°	± 5%	2 1/2	± 1	8.4	5.9
974	320° ± 5°	330° ± 5°	± 5%	2 1/2	± 1	12.0	9.4
975	320° ± 2°	330° ± 5°	± 2%	4	± 0.5	13.4	10.7
976	320° ± 2°	330° ± 5°	± 2%	4	± 0.5	19.0	16.8

* Power rating in watts decreases linearly with rising ambient temperature to zero at 100°C.

970-SERIES POTENTIOMETERS	All dimensions in inches			Type	Nominal Resist- ance Ohms	Temperature Coefficient of Resistance %	Resolution %	Catalog Number	Price				
	Approx Weight	Knobs	Dial Plate										
	½ oz	KNS-6 KNSP-6	970-P1	971-B	2	±0.07	<1	971-9702	\$ 5.25				
				971-C	5	±0.07	<1	971-9703	5.25				
				971-D	10	±0.002	<1	971-9704	5.25				
				971-E	20	±0.002	<1	971-9705	5.25				
				971-F	50	±0.002	<0.5	971-9706	5.25				
				971-G	100	±0.002	<0.5	971-9707	5.25				
				971-H	200	±0.002	<0.5	971-9708	5.25				
				971-J	500	±0.002	<0.5	971-9710	5.25				
				971-K	1000	±0.002	<0.5	971-9711	5.25				
				971-L	2000	±0.002	<0.5	971-9712	5.25				
				971-M	5000	±0.002	<0.2	971-9713	5.25				
				971-N	10,000	±0.002	<0.2	971-9714	5.25				
				971-P	20,000	±0.002	<0.2	971-9716	5.25				
					¾ oz	KNS-6 KNSP-6	970-P1	972-F	50	±0.002	<1	972-9706	5.75
972-G	100	±0.002	<0.5					972-9707	5.75				
972-H	200	±0.002	<0.5					972-9708	5.75				
972-J	500	±0.002	<0.5					972-9710	5.75				
972-K	1000	±0.002	<0.5					972-9711	5.75				
972-L	2000	±0.002	<0.5					972-9712	5.75				
972-M	5000	±0.002	<0.5					972-9713	5.75				
972-N	10,000	±0.002	<0.2					972-9714	5.75				
972-P	20,000	±0.002	<0.2					972-9716	5.75				
972-Q	50,000	±0.002	<0.2					972-9717	5.75				
	1 oz	KNS-6 KNSP-6	970-P1					973-C	5	±0.07	<0.5	973-9703	6.25
								973-D	10	±0.07	<0.5	973-9704	6.25
								973-E	20	±0.002	<0.5	973-9705	6.25
								973-F	50	±0.002	<0.5	973-9706	6.25
				973-G	100	±0.002	<0.5	973-9707	6.25				
				973-H	200	±0.002	<0.5	973-9708	6.25				
				973-J	500	±0.002	<0.2	973-9710	6.25				
				973-K	1000	±0.002	<0.2	973-9711	6.25				
				973-L	2000	±0.002	<0.2	973-9712	6.25				
				973-M	5000	±0.002	<0.2	973-9713	6.25				
				973-N	10,000	±0.002	<0.1	973-9714	6.25				
				973-P	20,000	±0.002	<0.1	973-9716	6.25				
				973-Q	50,000	±0.002	<0.1	973-9717	6.25				
					1 ¼ oz	KNS-6 KNSP-6	970-P1	974-D	10	±0.07	<0.5	974-9704	6.75
974-E	20	±0.07	<0.5					974-9705	6.75				
974-F	50	±0.002	<0.5					974-9706	6.75				
974-G	100	±0.002	<0.5					974-9707	6.75				
974-H	200	±0.002	<0.5					974-9708	6.75				
974-J	500	±0.002	<0.5					974-9710	6.75				
974-K	1000	±0.002	<0.2					974-9711	6.75				
974-L	2000	±0.002	<0.2					974-9712	6.75				
974-M	5000	±0.002	<0.2					974-9713	6.75				
974-N	10,000	±0.002	<0.2					974-9714	6.75				
974-P	20,000	±0.002	<0.1					974-9716	6.75				
974-Q	50,000	±0.002	<0.1					974-9717	6.75				
974-R	100,000	±0.002	<0.1					974-9718	8.00				
	3 oz	KNS-8 KNSP-8	970-P2					975-J	500	±0.002	<0.2	975-9710	7.25
				975-K	1000	±0.002	<0.2	975-9711	7.25				
				975-L	2000	±0.002	<0.2	975-9712	7.25				
				975-M	5000	±0.002	<0.2	975-9713	7.25				
				975-N	10,000	±0.002	<0.1	975-9714	7.25				
				975-P	20,000	±0.002	<0.1	975-9716	7.25				
				975-Q	50,000	±0.002	<0.05	975-9717	8.25				
				975-R	100,000	±0.002	<0.05	975-9718	8.25				
					4 oz	KNS-8 KNSP-8	970-P2	976-K	1000	±0.002	<0.2	976-9711	8.25
								976-L	2000	±0.002	<0.2	976-9712	8.25
976-M	5000	±0.002	<0.2					976-9713	8.25				
976-N	10,000	±0.002	<0.2					976-9714	9.00				
976-P	20,000	±0.002	<0.1					976-9716	9.00				
976-Q	50,000	±0.002	<0.1					976-9717	10.00				
976-R	100,000	±0.002	<0.05					976-9718	10.00				
976-T	200,000	±0.002	<0.05					976-9720	10.00				

Type 907 GEAR-DRIVE PRECISION DIALS

These 4-inch diameter precision dials have aluminum dial plates with black enamel finish. Scales are individually engraved on an automatic, self-indexing engraving machine. The fine, radial, accurately located lines divide the complete circumference into 360 divisions numbered from 0 to 360.

Settings can be consistently duplicated to one-fifth of a division, allowing a precision of resetting of better than 0.06% of full scale. Parallax is eliminated by the use of an indicator that always remains flush with the surface of the dial and, at the same time, through the flexibility of its mounting, absorbs any slight eccentricities of the main shaft.

The ring gear and drive pinion are precision-cut gears, spring-pressed to eliminate any backlash. The drive ratio is 10:1, and it is possible to use a calibrated vernier or increment dial on the pinion shaft if desired. The drive pinion is held in a stainless-steel collet, which runs in a phosphor-bronze bushing. The collet allows the drive to be adjusted for any panel thickness up to 5/16 inch.

The main dials are set permanently and securely to their shafts through the use of two setscrews 90° apart; this procedure eliminates any dial backlash that might otherwise occur.



(Left) Front-of-panel-mounting Type 907-WA. (Right) Rear-of-panel-mounting Type 907-WB. Maximum panel thickness 5/16 in (8mm).



The dial hubs are bored to receive a 3/8-inch shaft, but a bushing is furnished for use with 1/4-inch shafts.

The dial indicator, knob, and all necessary mounting parts are supplied, as are complete drilling and mounting instructions. Motor drives are described on page 154.

Total Panel Area: 4 by 5 in (105, 130 mm).

Net Weight: 11 oz (0.4 kg). **Shipping Weight:** 3 lb (1.4 kg).

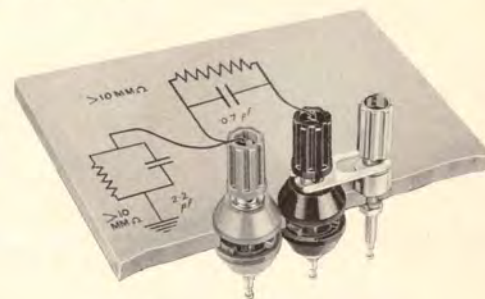
Catalog No.	Description	Price
0907-9857	Type 907-WA Precision Dial	\$12.00
0907-9863	Type 907-WB Precision Dial	12.00

Type 938 BINDING POSTS

The excellent electrical properties and ingenious mechanical design of the TYPE 938 Binding Posts provide all the properties needed for modern electronic instruments. Two styles are available: nickel-plated brass for economy, and gold-plated copper for high conductivity and low thermal emf with connection to copper wires. Both styles are available with either metal or insulated tops designed for easy hand tightening. On the copper binding posts, 3/8-inch, 12-point wrenches can be used. The styrene insulation has high insulation resistance and low dissipation factor and is available either red or black for color coding.

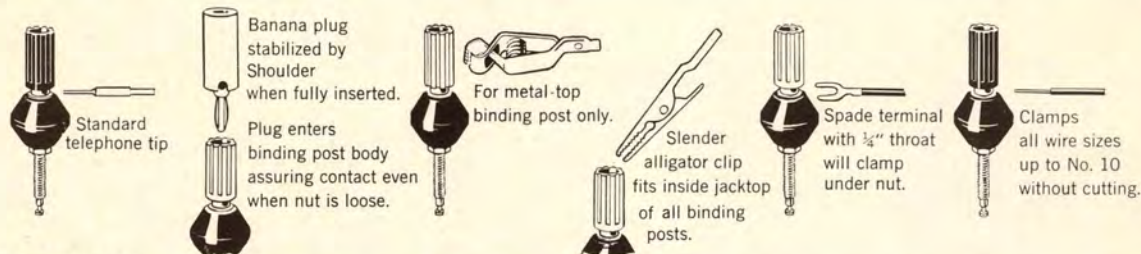
These binding posts can be mounted on metal or insulating panels of a thickness from zero to 5/16 inch. Mechanical details and methods of connection are shown below.

The binding post has the same height above panel as the nonlocking GRS74 Coaxial Connector (see page 79), whose center contact will take a Type 274 Plug, so that a grounded binding post can be mounted adjacent to the coaxial connector to fit a TYPE 274-MB Double Plug.

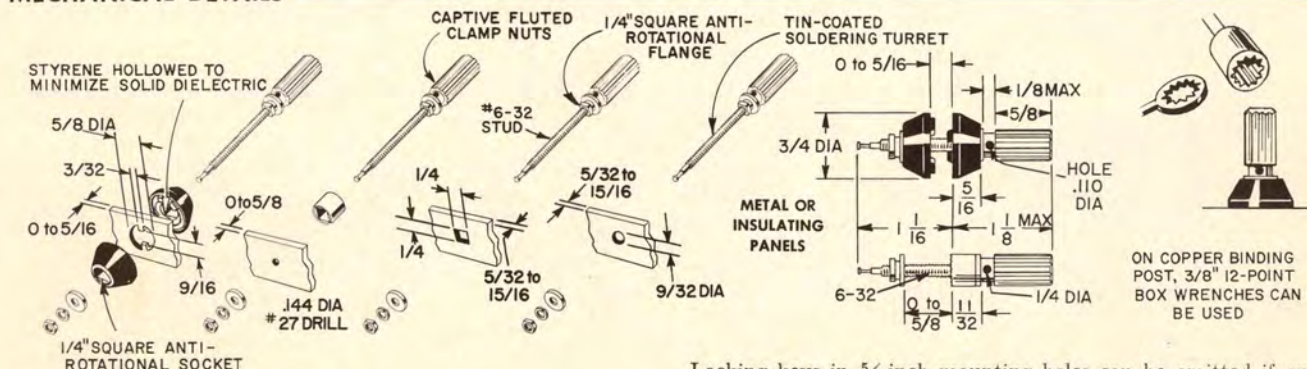


Rating: 30 A peak, 4 kV peak.
Breakdown: 10 kV peak.
Dissipation Factor: <0.0005 at 1 kc/s.

METHODS OF CONNECTION



MECHANICAL DETAILS



Locking keys in 5/8-inch mounting holes can be omitted if only moderate resistance to rotation is needed.

To convert inches to mm, multiply by 25.4.

TYPE 938 BINDING POSTS	Type	<input type="checkbox"/> brass, nickel plated <input type="checkbox"/> copper, gold plated	Net Weight for 10		Catalog Number	Unit Price* in Lots of			
			oz	g		10† to 99	100 to 999	1000 to 1999	2000 up
			BINDING POSTS						
	938-A	Metal-Top Binding Post, brass	4	115	0938-9701	\$0.40	\$0.29	\$0.27	\$0.25
	938-C	Black-Top Binding Post, brass	3	85	0938-9703	0.55	0.40	0.38	0.35
	938-D	Red-Top Binding Post, brass	3	85	0938-9704	0.55	0.40	0.38	0.35
	938-G	Metal-Top Binding Post, copper	5½	158	0938-9707	0.90	0.80	0.75	0.75
	938-H	Black-Top Binding Post, copper	4	115	0938-9708	0.80	0.71	0.67	0.67
	938-K	Red-Top Binding Post, copper	4	115	0938-9711	0.80	0.71	0.67	0.67
INSULATORS									
	938-BB	Black Insulators, pair	1	30	0938-9808	0.20	0.12	0.11	0.10
	938-BR	Red Insulators, pair	1	30	0938-9812	0.20	0.12	0.11	0.10
	938-YB	Double Insulators. Interlocking bosses permit mounting on very thin panels	2	60	0938-9873	0.30	0.18	0.16	0.15
ACCESSORIES									
	938-F	Spacer, brass. Square anti-rotational socket and anti-rotational teeth	1	30	0938-9706	0.12	0.09	0.09	0.09
	938-FG	Spacer, copper. Square anti-rotational socket and anti-rotational teeth	1	30	0938-9830	0.20	0.18	0.17	0.17
	938-L	Shorting Link, brass. For two binding posts mounted on ¾-in centers	1	30	0938-9712	0.10	0.09	0.09	0.09
	938-LG	Shorting Link, copper. For two binding posts mounted on ¾-in centers	1	30	0938-9503	0.25	0.22	0.20	0.20
	838-B	Alligator Clip. 15-A peak rating. Fits inside jack top of all binding posts	2	60	0838-9702	0.20	0.19	0.17	0.17
ASSEMBLIES									
	938-P	Metal Top/Spacers, brass. Assembly of 938-A, 938-F	5	145	0938-9716	0.52	0.38	0.36	0.34
	938-W	Metal Top/Black Insulators, brass. Assembly of 938-A, 938-BB	5	145	0938-9723	0.60	0.41	0.38	0.35
	938-R	Metal Top/Red Insulators, brass. Assembly of 938-A, 938-BR	5	145	0938-9718	0.60	0.41	0.38	0.35
	938-WB	Black Top/Black Insulators, brass. Assembly of 938-C, 938-BB	4	115	0938-9863	0.75	0.52	0.49	0.45
	938-WR	Red Top/Red Insulators, brass. Assembly of 938-D, 938-BR	4	115	0938-9864	0.75	0.52	0.49	0.45
	938-GM	Metal Top/Spacers, copper. Assembly of 938-G, 938-FG	6½	183	0938-9834	1.10	0.98	0.92	0.92
	938-GB	Metal Top/Black Insulators, copper. Assembly of 938-G, 938-BB	6½	183	0938-9832	1.10	0.92	0.86	0.86
	938-GR	Metal Top/Red Insulators, copper. Assembly of 938-G, 938-BR	6½	183	0938-9835	1.10	0.92	0.86	0.86
	938-HB	Black Top/Black Insulators, copper. Assembly of 938-H, 938-BB	5	145	0938-9434	1.00	0.83	0.78	0.78
	938-KR	Red Top/Red Insulators, copper. Assembly of 938-K, 938-BR	5	145	0938-9838	1.00	0.83	0.78	0.78

* Net Prices. No further quantity discounts.

† Minimum quantity sold.

Prices for binding-post assemblies are for shipment unassembled. When assembly and/or individual packaging before shipment is required, add 10¢ per binding post for assembly, 8¢ for packaging.



Type KN FLUTED KNOBS

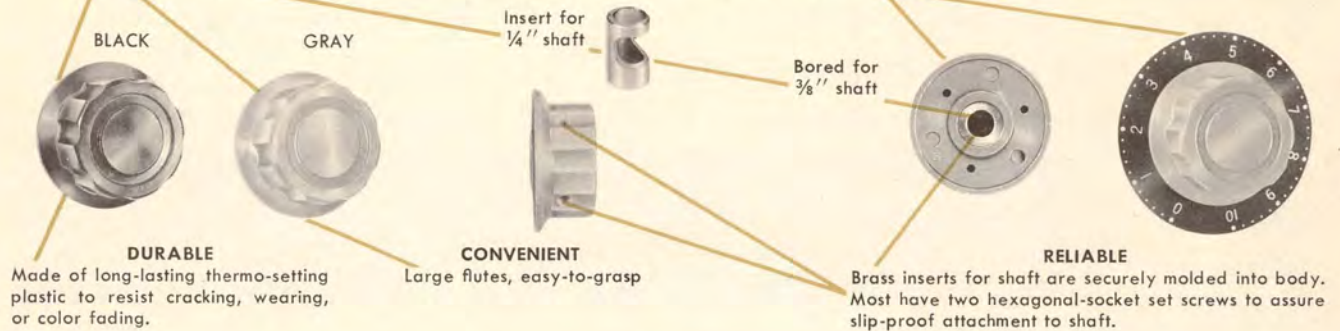
Four styles. Skirtless KNU style can be used for coaxial knob arrangements.

VERSATILE

Most come in two colors to distinguish control functions or to match various panel colors.

All but smallest fit either 1/4" or 3/8" shafts.

Large knobs have molded holes, which can be drilled deeper to allow a dial plate to be attached (see page 250).



DURABLE
Made of long-lasting thermo-setting plastic to resist cracking, wearing, or color fading.

CONVENIENT
Large flutes, easy-to-grasp

RELIABLE
Brass inserts for shaft are securely molded into body. Most have two hexagonal-socket set screws to assure slip-proof attachment to shaft.

	Catalog Number	Type	Dimensions				Shaft Size	Set Screws	Net Weight for five		Unit Price† in Lots of						
			Skirt Diameter		Over-all Depth				oz	g	**5 to 19	20 to 99	100 to 499	500 to 1999	2000 up		
			in	mm	in	mm											
	5500-9601	KNB-1	1 5/16	24	3/4	20	Bored for 3/8" (10 mm), bushing furnished to adapt to 1/4" (7 mm)	1	3 3/4	108	\$0.90	\$0.85	\$0.79	\$0.74	\$0.68		
	5505-9601	KNB-1GY	1 5/16	24	3/4	20			3 3/4	108	1.00	0.95	0.88	0.81	0.75		
	5500-9602	KNB-2	1 5/16	34	3/4	20		2, 90° apart	6	170	0.95	0.90	0.84	0.78	0.72		
	5505-9602	KNB-2GY	1 5/16	34	3/4	20			6	170	1.05	0.99	0.92	0.85	0.79		
	5505-9603	KNB-3GY no white dot	1 5/16	24	3/4	20	1	3	85	1.05	0.99	0.92	0.85	0.79			
	5505-9503	KNB-3DGY	1 5/16	24	3/4	20		3	85	1.10	1.04	0.97	0.90	0.83			
	5525-9601	KNS-1GY	1 5/16	24	3/4	20	1/4" (7 mm)	2, 90° apart	6	170	0.80	0.75	0.70	0.65	0.60		
	5520-9606	KNS-6	1 5/16	34	3/4	20	Bored for 3/8" (10 mm), bushing furnished to adapt to 1/4" (7 mm)	2, 135° apart	5 1/2	183	0.80	0.75	0.70	0.65	0.60		
	5525-9606	KNS-6GY	1 5/16	34	3/4	20		2, 90° apart	5 1/2	183	0.90	0.85	0.79	0.74	0.68		
	5520-9608	*KNS-8	1 15/16	50	3 1/16	21			8	230	0.90	0.85	0.79	0.74	0.68		
	5525-9608	*KNS-8GY	1 15/16	50	13/16	21			8	230	1.10	1.04	0.97	0.90	0.83		
	5520-9610	*KNS-10	2 3/8	61	29/32	23.5			12 1/2	353	1.30	1.23	1.15	1.06	0.98		
	5525-9610	*KNS-10GY	2 3/8	61	29/32	23.5			12 1/2	353	1.50	1.42	1.32	1.22	1.13		
	5520-9612	*KNS-12	2 7/8	73	1	26			17	485	1.40	1.32	1.23	1.14	1.05		
	5525-9612	*KNS-12GY	2 7/8	73	1	26			17	485	1.70	1.61	1.50	1.38	1.28		
		5530-9601	KNSP-1	1 5/16	24	3/4			20	1/4" (7 mm)	2, 90° apart	6	170	0.70	0.66	0.62	0.57	0.53
5535-9601		KNSP-1GY	1 5/16	24	3/4	20			Bored for 3/8" (10 mm), bushing furnished to adapt to 1/4" (7 mm)	2, 135° apart	6	170	0.80	0.75	0.70	0.65	0.60
5530-9606		KNSP-6	1 5/16	34	3/4	20	5 1/2	183			0.80	0.75	0.70	0.65	0.60		
5535-9606		KNSP-6GY	1 5/16	34	3/4	20	5 1/2	183		0.90	0.85	0.79	0.74	0.68			
5530-9608		*KNSP-8	1 15/16	50	13/16	21	8	230		0.90	0.85	0.79	0.74	0.68			
5535-9608		*KNSP-8GY	1 15/16	50	13/16	21	8	230		1.10	1.04	0.97	0.90	0.83			
5530-9610		*KNSP-10	2 3/8	61	29/32	23.5	12 1/2	353		1.30	1.23	1.15	1.06	0.98			
5535-9610		*KNSP-10GY	2 3/8	61	29/32	23.5	12 1/2	353		1.50	1.42	1.32	1.22	1.13			
5530-9612		*KNSP-12	2 7/8	73	1	26	17	485		1.40	1.32	1.23	1.14	1.05			
5535-9612		KNSP-12GY	2 7/8	73	1	26	17	485		1.70	1.61	1.50	1.38	1.28			
	5545-9611	KNU-11GY no skirt, dia 3/4" (20 mm)			1/2	13	1/4" (7 mm)	1		2	60	0.75	0.71	0.66	0.62	0.57	
	5545-9614	KNU-14GY no skirt, dia 9/16" (15 mm)			1/2	13	1/8" (4 mm)		1	30	0.75	0.71	0.66	0.62	0.57		

□ black knobs ■ gray knobs * Accept dial plate (see page 250). ** Minimum quantity sold. † Net prices. No further quantity discounts.



Type 578 SHIELDED TRANSFORMER

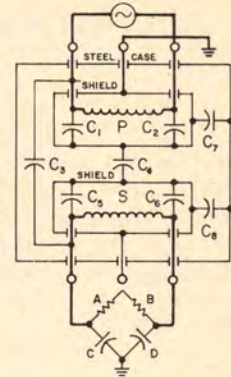
FOR BRIDGE ISOLATION



This transformer is used in direct-reading ac bridges to isolate the bridge circuit from changes in electrostatic potential in the generator (or detector) circuit and to reduce the effect of the capacitance of the external circuit to ground. It can also be used to isolate any measuring circuit from the generator or detector or to produce a balanced output from a grounded generator.

Three shields are used, one around each winding and a third to bring the core laminations to the potential of the case.

Grounded bridge supplied through a double-shielded transformer. When case is grounded, the capacitance placed across each capacitance arm is 40 pF. Note that the winding shield on the bridge side is not grounded but is floating.



SPECIFICATIONS

Turns Ratio: 4 to 1 or 1 to 4.

Ranges: See price table.

Nominal Capacitances: See drawing.

C_1, C_2, C_5, C_6each 200 pF C_4 30 pF
 C_3 0.3 pF C_7, C_8each 70 pF

Winding Inductance: Turns squared (see table) multiplied by 3.5×10^{-6} H, approx.

Dc Resistance (in ohms): 30 times inductance in henrys, approx.

Voltage Limits: The high-impedance winding of TYPES 578-A or -B may be connected directly across a 115-V, 50- to 60-cycle line if the impedance connected to the other winding equals or exceeds

the lowest value given under "low impedance" in the table below. The TYPE 578-B may be used at 25 c/s under the same conditions.

For TYPES 578-A or -B, the low-impedance winding may be connected directly to a 115-V, 50- to 60-cycle line provided that the resistance across the high-impedance winding exceeds 10,000 Ω . The TYPE 578-B may be used at 25 c/s under the same conditions.

Insulation: The insulation from winding to winding and from windings to case will withstand 1000 V, peak.

Dimensions: Base, $3\frac{1}{8} \times 2\frac{1}{16}$ in (80, 70 mm); height, $4\frac{1}{8}$ in (105 mm).

Net Weight: $2\frac{1}{2}$ lb (1.2 kg). **Shipping Weight:** 4 lb (1.9 kg).

Catalog Number	Description	Turns	Frequency Range*	Impedance Range*		Price
				Low-Impedance Winding	High-Impedance Winding	
0578-9701	Type 578-A Shielded Transformer	600:2400	50 c/s — 10 kc/s	50 Ω —5 k Ω	1 k Ω —100 k Ω	\$35.00
0578-9702	Type 578-B Shielded Transformer	1000:4000	20 c/s — 5 kc/s	60 Ω —6 k Ω	1.2 k Ω —120 k Ω	35.00
0578-9703	Type 578-C Shielded Transformer	60:240	2 kc/s—500 kc/s	20 Ω —2 k Ω	0.4 k Ω —40 k Ω	35.00

* These ranges are for transmission within 6 dB. At extremes of both impedance and frequency ranges, the transmission may be down by 12 dB.

Type 941-A TOROIDAL TRANSFORMER

FOR IMPEDANCE MATCHING OR BRIDGING

This transformer is for impedance matching or bridging in low-level, 600-ohm communications circuits. It has highly astatic windings and tight coupling. The toroidal core is a spiral of high-permeability-alloy tape. Identical pairs of windings on each half of the toroid minimize pickup and induction field, while close coupling between inner and outer windings keeps leakage reactance low and extends high-frequency response.

SPECIFICATIONS

Frequency and Impedance Ranges:

Terminating Impedances	Frequency for 1-DB Drop	Flat Insertion Loss Less Than
600 Ω	9600 Ω	80 c/s—100 kc/s
600 Ω	2400 Ω	20 c/s—135 kc/s
600 Ω	2400 Ω	80 c/s—340 kc/s
600 Ω	600 Ω	20 c/s—200 kc/s
150 Ω	600 Ω	5 c/s— 50 kc/s
150 Ω	600 Ω	20 c/s—200 kc/s
37.5 Ω	600 Ω	5 c/s— 50 kc/s

Zero-Signal Inductance: Inner windings, in series, at least 5 H; outer windings, in series, at least 20 H.

Operating Level and Distortion:

Watts	DBM	Rms Distortion, 60 c/s
1.26	31	<1%
1	30	<0.5%
0.5	27	<0.2%
0.032	15	<0.1%

Voltage Matching: Inner windings, 0.015% or better; outer windings, 0.08% or better.

Resistance: Inner windings, in series, 9 Ω ; outer windings, in series, 34 Ω (approximately).

Dimensions: Aluminum case, $3\frac{5}{8}$ by $3\frac{1}{8}$ by $1\frac{5}{8}$ in (95, 80, 40 mm). Mounting blocks project $\frac{3}{32}$ inch beyond case in $3\frac{1}{8}$ -inch dimension. Mounting holes are $3\frac{3}{8}$ inches on centers and are drilled for clearance with 10-32 machine screws.

Net Weight: $13\frac{3}{8}$ oz (0.4 kg).

Shipping Weight: 2 lb (1 kg).


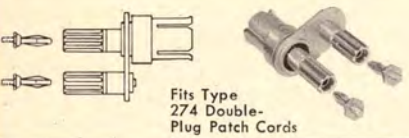


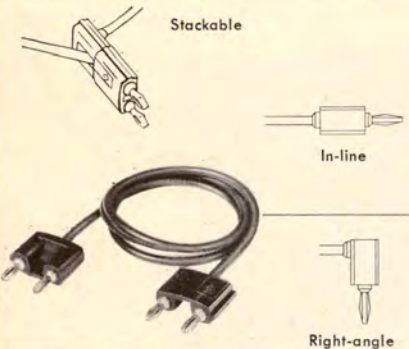

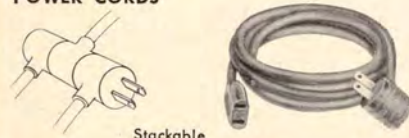



Catalog Number	Description	Price
0941-9701	Type 941-A Toroidal Transformer	\$55.00

PARTS & ACCESSORIES

JACKS AND PLUGS	Dimensions in Inches	Catalog Number	Unit Price† in Lots of								
			each	5 to 9	10 to 19	20 to 99	100 to 199	200 to 999	1000 to 1999	2000 up	
<p>The Type 938 Jacks also fit Type 274 Plugs. The Type 938-J Jack has a longer shank than the Type 274 Jack. The Type 938-X Jack Assembly consists of the Type 938-J Jack and Type 938-B Insulators (page 252).</p>	<p>JACKS</p>	<p>TYPE 938-J JACK. Fits Type 274 Plugs, has long unthreaded shank that makes it suitable for mounting in Type 938-BB and Type 938-BR Insulators or Type 938-F Spacers (page 252). Net Weight for 10: 3 oz (85 g).</p>	0938-9710	—	—	0.32	0.32	0.27	0.27	0.25	0.22
		<p>TYPE 938-XB JACK ASSEMBLY, black. Net Weight for 10: 4 oz (115 g).</p>	0938-9868	—	—	0.52	0.52	0.39	0.39	0.36	0.32
		<p>TYPE 938-XR JACK ASSEMBLY, red. Net Weight for 10: 4 oz (115 g).</p>	0938-9869	—	—	0.52	0.52	0.39	0.39	0.36	0.32
<p>The Type 274 Jacks and Plugs, originated by General Radio in 1924, are widely used in electronics and communications laboratories for connecting equipment in temporary or semi-permanent setups and for connecting plug-in elements. All Type 274 Jacks and Plugs are rated at 15 amperes. Plugs have nickel-plated brass studs and beryllium copper springs. Jacks are nickel-plated brass. These plugs and jacks are designed for positive and reliable contact, typically 1 milliohm. The plug seats firmly in the jack so that the plug springs are not depended upon for mechanical stability.</p>		<p>TYPE 274-J JACK. Rated at 15 A, nickel-plated brass, fits Type 274 Plugs. Net Weight for 20: 3 oz (85 g).</p>	0274-9710	—	—	—	0.10	0.09	0.09	0.08	0.07
	<p>PLUGS</p>	<p>TYPE 274-P PLUG. Rated at 15 A, nickel-plated brass stud and beryllium copper springs, fits Type 274 and Type 938 Jacks. Net Weight for 20: 2 oz (60 g).</p>	0274-9716	—	—	—	0.13	0.11	0.11	0.10	0.09
		<p>TYPE 274-U PLUG. Rated at 15 A, nickel-plated brass stud and beryllium copper springs, fits Type 274 and Type 938 Jacks. Net Weight for 10: 3 oz (85 g).</p>	0274-9721	—	—	0.20	0.20	0.18	0.18	0.17	0.16
		<p>TYPE 274-SB SHORT-CIRCUIT PLUG. Consists of two Type 274-U plugs connected with metal links, fits Type 274 and Type 938 Jacks. Net Weight each: 1 oz (30 g).</p>	0274-9887	0.95	—	—	—	—	—	—	—
<p>The Type 274-DB Insulated Single Plug is a styrene-insulated plug with a jack top. A set-screw clamp is provided on the plug end.</p>		<p>TYPE 274-DB1 INSULATED SINGLE PLUG, black. Net Weight for 5: 2 oz (60 g).</p>	0274-9454	—	0.50	0.43	0.43	0.40	0.36	0.34	0.34
		<p>TYPE 274-DB2 INSULATED SINGLE PLUG: red. Net Weight for 5: 2 oz (60 g).</p>	0274-9455	—	0.50	0.43	0.43	0.40	0.36	0.34	0.34
<p>Rating: 15 A, peak; 4 kV, peak. Breakdown: 23 kV, peak. Dissipation Factor: < 0.0005 at 1 kc/s.</p>		<p>TYPE 274-MB INSULATED DOUBLE PLUG. Molded styrene double-plug assembly, which fits Type 938 Binding Posts or Type 274 Jacks on standard 3/4-inch spacing. Jack top permits stacking for multiple connections. A cross hole through the center provides strain relief for attached cables up to 0.2-inch diameter. The plug is completely insulated. Net Weight for 5: 3 oz (85 g).</p>	0274-9875	—	0.65	0.57	0.57	0.54	0.49	0.47	0.47
	<p>Rating: 15 A, peak; 1.2 kV, peak. Breakdown: 3.4 kV, peak. Dissipation Factor: < 0.0005 at 1 kc/s.</p>	<p>TYPE 274-NK SHIELDED DOUBLE PLUG. Double plug in an aluminum case with ceramic insulation for completely shielded connections to Type 938 Binding Posts. Strain relief for 0.2 and 0.25 inch OD is provided. This plug terminates the Type 274-NL Patch Cord (page 257) and Type 874-R34 Patch Cord (page 85). Net Weight each: 2 oz (60 g).</p>	0274-9877	1.35	—	—	—	—	—	—	—

† Net prices. No further quantity discounts.

ADAPTORS AND CORDS	Type	Length		Net Weight		Catalog Number	Price
		in	mm	oz	g		
ADAPTORS  <p>Fits standard 3/4-inch-spaced binding posts</p>	274-QBJ Adaptor	—	—	2	60	0274-9884	\$2.50
 <p>Fits Type 274 Double-Plug Patch Cords</p>	874-Q2 Adaptor	—	—	2	60	0874-9870	5.50
 <p>Fits standard 3/4-inch-spaced binding posts</p>	874-Q9 Adaptor	—	—	2	60	0874-9874	6.00
PATCH CORDS  <p>Stackable. Accepts Type 838-B Alligator Clip</p>	274-LLB Single-Plug Patch Cord, black 274-LLR Single-Plug Patch Cord, red 274-LMB Single-Plug Patch Cord, black 274-LMR Single-Plug Patch Cord, red 274-LSB Single-Plug Patch Cord, black 274-LSR Single-Plug Patch Cord, red	36 36 18 18 9 9	920 920 460 460 230 230	1 1/2 1 1/2 1 1 1 1	45 45 30 30 30 30	0274-9468 0274-9492 0274-9847 0274-9848 0274-9849 0274-9850	1.25 1.25 1.25 1.25 1.25 1.25
 <p>Stackable</p> <p>In-line</p> <p>Right-angle</p>	274-NQ Double-Plug Patch Cord, in-line cord 274-NQM Double-Plug Patch Cord, in-line cord 274-NQS Double-Plug Patch Cord, in-line cord 274-NP Double-Plug Patch Cord, right-angle cord 274-NPM Double-Plug Patch Cord, right-angle cord 274-NPS Double-Plug Patch Cord, right-angle cord	36 24 12 36 24 12	920 610 305 920 610 305	3 2 1 1/2 3 2 1 1/2	85 60 45 85 60 45	0274-9860 0274-9896 0274-9861 0274-9880 0274-9892 0274-9852	3.50 3.50 3.50 3.50 3.50 3.50
 <p>Fits standard 3/4-inch-spaced binding posts</p>	274-NL Shielded Double-Plug Patch Cord 274-NLM Shielded Double-Plug Patch Cord 274-NLS Shielded Double-Plug Patch Cord	36 24 12	920 610 305	4 3 2 1/2	115 85 75	0274-9883 0274-9882 0274-9862	4.50 4.50 4.50
POWER CORDS  <p>Stackable</p>	CAP-35 2-Wire Power Cord	7	2.14	7	200	4200-9635	1.75
 <p>Stackable</p>	CAP-22 3-Wire Power Cord	7	2.14	9	255	4200-9622	2.50



CABINETS



General Radio instrument cabinets are rugged, attractive, and versatile. Heavy-gauge aluminum and tough wrinkle finishes combine to keep GR instruments operating and looking like new through many years of hard service.

We use five basic cabinet types: (1) rack-bench cabinets, with standard rack-width panels and optional bench or rack-mounting accessories, (2) Flip-Tilt cases, for portable instruments, (3) convertible-bench cabinets, for smaller laboratory instruments, (4) Unit cabinets, for the GR line of Unit Instruments and power supplies, and (5) lab-bench cabinets, for laboratory standards, decade boxes, and similar instruments.



For bench use, the rack-bench cabinet is equipped with aluminum end frames.

RACK-BENCH CABINETS

A rack-bench cabinet consists of three major parts: a heavy-gauge aluminum cabinet comprising the top, bottom, sides, and rear of the instrument; a rack-width (19-inch) front panel, permanently attached to the instrument chassis; and either aluminum end frames, if the instrument is to be used on the bench, or two supports for rack mounting. The instrument is shipped with either type of mounting, as ordered. Subsequent conversion is, however, quite simple.

In bench models, the end frames serve several purposes. They allow instruments to be neatly stacked and bolted together. They also serve as supporting feet, carrying handles, and protective bumpers.

In relay-rack models, the front panel and the two supports are attached by screws to the front of the relay rack, and the supports to the cabinet. The cabinet acts as a drawer slide, and the resulting installation offers easy accessibility to the interior of the instrument. The panel and chassis may be withdrawn from the front of the rack, with the cabinet left stationary. Or the cabinet may be removed from the rear of the rack, with panel and chassis left stationary.

On certain instruments usually permanently installed in relay racks, supports and end frames are omitted.

FLIP-TILT CASES

General Radio's exclusive Flip-Tilt case includes three main parts: the instrument cabinet, a captive cover, and a carrying-handle and lever assembly. When the instrument is



Flip-Tilt case in one of its many operating positions. Rubber gasket provides friction to allow almost any tilt angle.

Locked fully open, instrument is ready for either operation or transit.



Locked closed, with accessories and instruction manual inside, the instrument is well protected against damage.

Another of the many faces of the versatile Flip-Tilt, which here has traded cover and handle for a rack adaptor panel.



closed for storage or transit, the cover is locked in place over the front panel by means of slide-buttons and latches on the carrying handle. To open the cabinet, the user slides the buttons out of the latches and pushes down on the carrying handle. The lever action of the handle raises the cabinet from the cover. The cabinet is then easily flipped into position for operation. The operating position may be fully open and locked squarely in the cover or tilted at almost any angle. A rubber seal around the edge of the cover provides friction to hold the cabinet in the tilted position. When the instrument is closed, the same gasket provides a tight seal for the enclosure. Accessories and instruction manual are conveniently stored in the Flip-Tilt cover.

Certain Flip-Tilt instruments are also available in standard relay-rack cabinets; most other Flip-Tilt instruments are available adapted for rack mounting. In such adaptations, the Flip-Tilt case (minus cover and handle) is neatly and securely mounted in a relay-rack adaptor panel.



Convertible-bench instruments with meters tilt on extendible legs for easy viewing of front panel. Panel extensions are used for rack mount.

CONVERTIBLE-BENCH CABINETS

Small and medium-sized instruments commonly used on the bench are housed in GR's unique convertible-bench cabinet, designed primarily for the bench but offering quick relay-rack adaptability.

The convertible-bench cabinet is made of sturdy aluminum finished in GR medium gray wrinkle. The U-shaped dust cover can be easily slipped off after removal of quick-action clamp fasteners. Instruments with panel meters can be tilted to the most convenient angle by means of extendible front legs.

Conversion for relay-rack mounting is easy: matching panel extensions are simply attached by means of screws to the instrument panel and to the relay rack.

LAB-BENCH AND UNIT CABINETS

Lab-bench cabinets are simple enclosures used primarily for laboratory standards and decade boxes. Two U-shaped pieces of $\frac{1}{8}$ -inch extruded aluminum are strip-locked together to form the sides, and an aluminum bottom plate and



Two aluminum extrusions are strip-locked together to form the sides, heavy aluminum panel and bottom plate are added, and this precision capacitor is given the excellent shielding and trim appearance of the lab-bench cabinet.

$\frac{3}{16}$ -inch aluminum panel complete the enclosure. The result is a cabinet well shielded, structurally solid, and efficiently manufactured.

The Unit cabinet, used for general-purpose power supplies and other basic instruments, consists of two U-shaped aluminum pieces — one forming panel and sides and the other making up top, bottom, and rear of the instrument. The latter piece is a perforated dust cover that is easily withdrawn for access to the instrument chassis.

Unit Instruments are specially designed for use with each other, and mating connectors permit the neat, compact assembly of power supply and driven instrument. Adaptor panels are available for rack-mounting Unit Instruments.

OTHER CABINETS

While most General Radio instruments are housed in the five cabinets described above, several other types of mounting are used to serve the special demands of various instruments. These range from the pocket-sized cases used for certain portable sound-measuring instruments to the specialized structures of a slotted line or an admittance meter.

Accessory mounting hardware, such as end frames, relay-rack supports, and relay-rack adaptor panels, may be ordered separately by those customers wishing to convert from one type of mounting to another. Many of these accessories are listed along with the related instruments. Further information on such hardware, dimensions, etc., is available on request.



This Unit Instrument and power supply make a neat combination, with no wasted space. Chassis-mounted multipoint power connectors mate, and locking strips are supplied to make the union permanent, if desired.

REACTANCE CHART

Always use corresponding scales

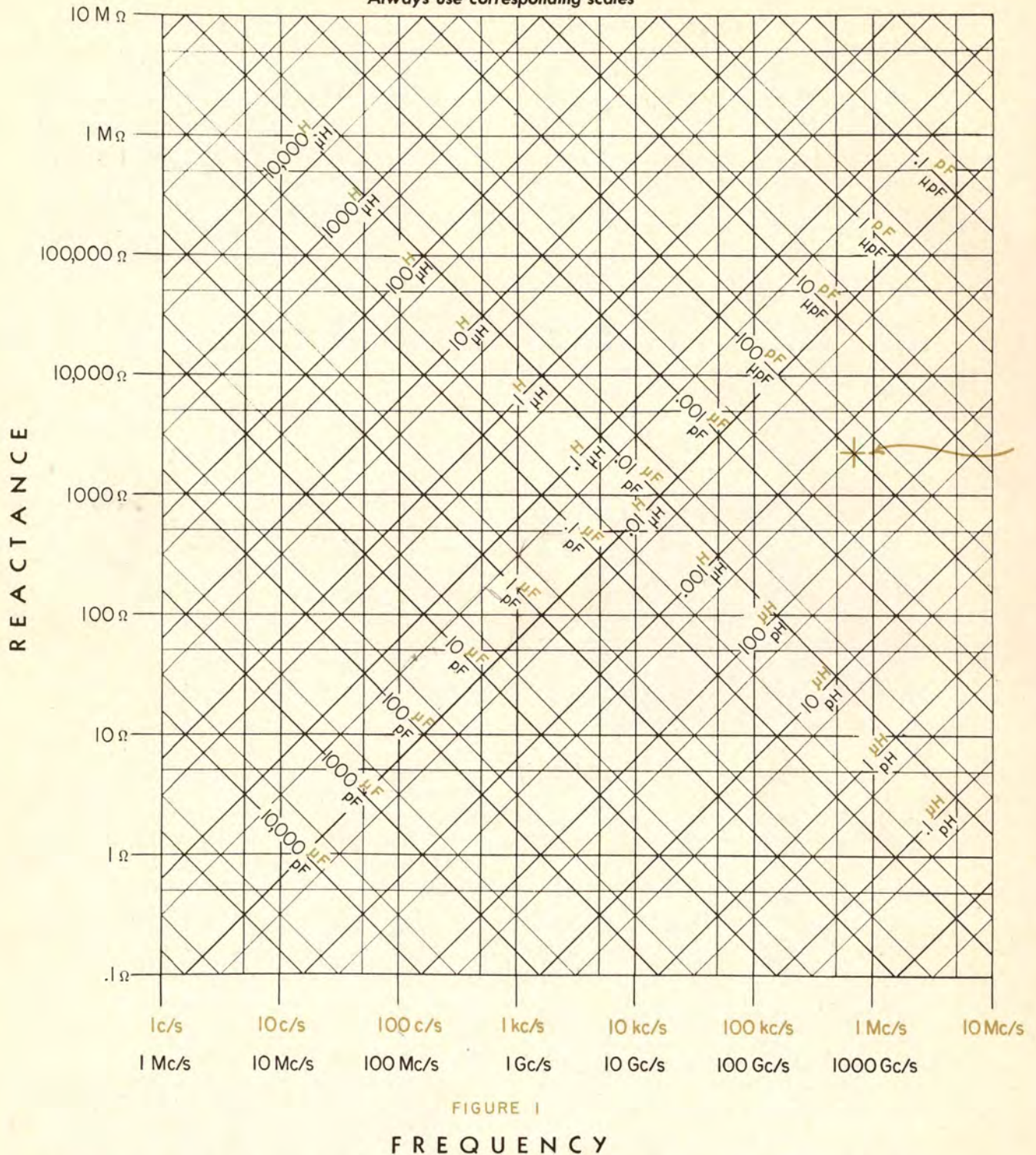


FIGURE 1

FREQUENCY

Figure 1 is the complete chart, used for rough calculations. Figure 2, which is a single decade of Figure 1 enlarged approximately 7 times, is used where two or three significant figures are to be determined.

TO FIND REACTANCE Enter the charts vertically from the bottom (FREQUENCY) and along the lines slanting upward to the left (CAPACITANCE) or to the right

(INDUCTANCE). Corresponding scales (gold or black) must be used throughout. Project horizontally to the left from the intersection and read REACTANCE.

TO FIND RESONANT FREQUENCY Enter the slanting lines for the given inductance and capacitance. Project downward and read resonant frequency from the bottom scale. Corresponding scales (gold or black) must be used throughout.

REACTANCE CHART

Always obtain approximate value from Figure 1 before using Figure 2

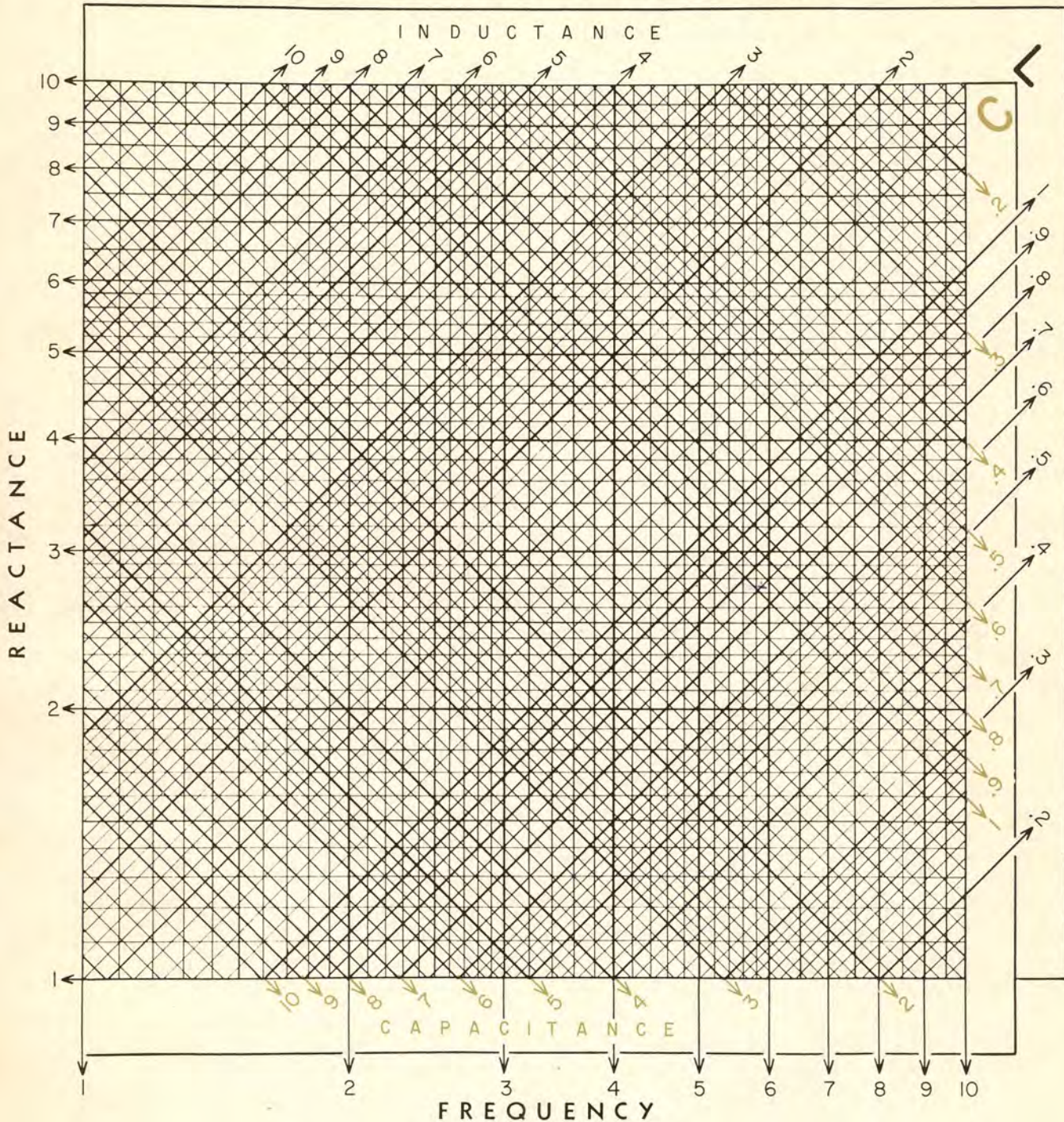


FIGURE 2

Example: The point indicated in Figure 1 corresponds to a frequency of about 700 kc/s and an inductance of 500 μ H, or a capacitance of 100 pF, giving in either case a reactance of about 2000 ohms. The resonant frequency of a circuit containing these values of inductance and capacitance is, of course, 700 kc/s, approximately.

USE OF FIGURE 2 Figure 2 gives additional precision but does not place the decimal point, which must be located from a preliminary entry on Figure 1. Since the

chart necessarily requires two logarithmic decades for inductance and capacitance for every single decade of frequency and reactance, unless the correct decade for *L* and *C* is chosen, the calculated values of reactance and frequency will be in error by a factor of 3.16. In Figure 2, the capacitance scale is gold; inductance scale is black.

Example: (Continued) The reactance corresponding to 500 μ H or 100 pF is 2230 ohms at 712 kc/s, their resonant frequency.



DECIBEL CONVERSION TABLES

In communications systems the ratio between any two amounts of electric or acoustic power is usually expressed in units on a logarithmic scale. The *decibel* (1/10th of the *bel*) on the briggsian or base-10 scale and the *neper* on the napierian or base-*e* scale are in almost universal use for this purpose.

Since voltage and current are related to power by impedance, both the *decibel* and the *neper* can be used to express voltage and current ratios, if care is taken to account for the impedances associated with them. In a similar manner the corresponding acoustical quantities can be compared.

From Table I and Table II on the following pages conversions can be made in either direction between the number of *decibels* and the corresponding power, voltage, and current ratios. Both tables can also be used for *nepers* by application of a conversion factor.

Decibel — The number of decibels N_{dB} corresponding to the ratio between two amounts of power P_1 and P_2 is

$$N_{dB} = 10 \log_{10} \frac{P_1}{P_2}$$

When two voltages E_1 and E_2 or two currents I_1 and I_2 operate in identical impedances,

$$N_{dB} = 20 \log_{10} \frac{E_1}{E_2} \quad \text{and} \quad N_{dB} = 20 \log_{10} \frac{I_1}{I_2}$$

If E_1 and E_2 or I_1 and I_2 operate in unequal impedances,

$$N_{dB} = 20 \log_{10} \frac{E_1}{E_2} + 10 \log_{10} \frac{Z_2}{Z_1} + 10 \log_{10} \frac{k_1}{k_2}$$

$$\text{and } N_{dB} = 20 \log_{10} \frac{I_1}{I_2} + 10 \log_{10} \frac{Z_1}{Z_2} + 10 \log_{10} \frac{k_1}{k_2},$$

where Z_1 and Z_2 are the absolute magnitudes of the corresponding impedances and k_1 and k_2 are the values of power factor for the impedances. E_1 , E_2 , I_1 , and I_2 are also the absolute magnitudes of the corresponding quantities. Note that Table I and Table II can be used to evaluate the impedance and power factor terms, since both are similar to the expression for power ratio.

Neper — The number of nepers N_{nep} corresponding to a power ratio $\frac{P_1}{P_2}$ is

$$N_{nep} = \frac{1}{2} \log_e \frac{P_1}{P_2}$$

For voltage ratios $\frac{E_1}{E_2}$ or current ratios $\frac{I_1}{I_2}$ working in identical impedances,

$$N_{nep} = \log_e \frac{E_1}{E_2} \quad \text{and} \quad N_{nep} = \log_e \frac{I_1}{I_2}$$

Relations Between Decibels and Nepers

Multiply decibels by 0.1151 to find nepers
Multiply nepers by 8.686 to find decibels

TO FIND VALUES OUTSIDE THE RANGE OF CONVERSION TABLES

Table I: Decibels to Voltage and Power Ratios

Number of decibels positive (+): Subtract +20 decibels successively from the given number of decibels until the remainder falls within range of Table I. *To find the voltage ratio*, multiply the corresponding value from the right-hand voltage-ratio column by 10 for each time you subtracted 20 dB. *To find the power ratio*, multiply the corresponding value from the right-hand power-ratio column by 100 for each time you subtracted 20 dB.

Example — Given: 49.2 dB

$$49.2 \text{ dB} - 20 \text{ dB} - 20 \text{ dB} = 9.2 \text{ dB}$$

$$\text{Voltage ratio: } 9.2 \text{ dB} \rightarrow 2.884$$

$$2.884 \times 10 \times 10 = 288.4$$

$$\text{Power ratio: } 9.2 \text{ dB} \rightarrow 8.318$$

$$8.318 \times 100 \times 100 = 83180$$

Number of decibels negative (-): Add +20 decibels successively to the given number of decibels until the sum falls within the range of Table I. *For the voltage ratio*, divide the value from the left-hand voltage-ratio column by 10 for each time you added 20 dB. *For the power ratio*, divide the value from the left-hand power-ratio column by 100 for each time you added 20 dB.

Example — Given: -49.2 dB

$$-49.2 \text{ dB} + 20 \text{ dB} + 20 \text{ dB} = -9.2 \text{ dB}$$

$$\text{Voltage ratio: } -9.2 \text{ dB} \rightarrow 0.3467$$

$$0.3467 \times 1/10 \times 1/10 = 0.003467$$

$$\text{Power ratio: } -9.2 \text{ dB} \rightarrow 0.1202$$

$$0.1202 \times 1/100 \times 1/100 = 0.0001202$$

Table II: Voltage Ratios to Decibels

For ratios smaller than those in table — Multiply the given ratio by 10 successively until the product can be found in the table. From the number of decibels thus found, subtract +20 decibels for each time you multiplied by 10.

Example — Given: Voltage ratio = 0.0131

$$0.0131 \times 10 \times 10 = 1.31$$

$$\text{From Table II, } 1.31 \rightarrow 2.345 \text{ dB}$$

$$2.345 \text{ dB} - 20 \text{ dB} - 20 \text{ dB} = -37.655 \text{ dB}$$

For ratios greater than those in table — Divide the given ratio by 10 successively until the remainder can be found in the table. To the number of decibels thus found, add +20 dB for each time you divided by 10.

Example — Given: Voltage ratio = 712

$$712 \times 1/10 \times 1/10 = 7.12$$

$$\text{From Table II, } 7.12 \rightarrow 17.050 \text{ dB}$$

$$17.050 \text{ dB} + 20 \text{ dB} + 20 \text{ dB} = 57.050 \text{ dB}$$

TABLE I

GIVEN: Decibels

TO FIND: Power and $\left\{ \begin{matrix} \text{Voltage} \\ \text{Current} \end{matrix} \right\}$ Ratios

TO ACCOUNT FOR THE SIGN OF THE DECIBEL

For positive (+) values of the decibel — Both voltage and power ratios are greater than unity. Use the two right-hand columns.

For negative (-) values of the decibel — Both voltage and power ratios are less than unity. Use the two left-hand columns.

Example — Given: ± 9.1 dB; Find:

	Power Ratio	Voltage Ratio
+9.1 dB	8.128	2.851
-9.1 dB	0.1230	0.3508

← -dB+ →					← -dB+ →				
Voltage Ratio	Power Ratio	dB	Voltage Ratio	Power Ratio	Voltage Ratio	Power Ratio	dB	Voltage Ratio	Power Ratio
1.0000	1.0000	0	1.000	1.000	.5623	.3162	5.0	1.778	3.162
.9886	.9772	.1	1.012	1.023	.5559	.3090	5.1	1.799	3.236
.9772	.9550	.2	1.023	1.047	.5495	.3020	5.2	1.820	3.311
.9661	.9333	.3	1.035	1.072	.5433	.2951	5.3	1.841	3.388
.9550	.9120	.4	1.047	1.096	.5370	.2884	5.4	1.862	3.467
.9441	.8913	.5	1.059	1.122	.5309	.2818	5.5	1.884	3.548
.9333	.8710	.6	1.072	1.148	.5248	.2754	5.6	1.905	3.631
.9226	.8511	.7	1.084	1.175	.5188	.2692	5.7	1.928	3.715
.9120	.8318	.8	1.096	1.202	.5129	.2630	5.8	1.950	3.802
.9016	.8128	.9	1.109	1.230	.5070	.2570	5.9	1.972	3.890
.8913	.7943	1.0	1.122	1.259	.5012	.2512	6.0	1.995	3.981
.8810	.7762	1.1	1.135	1.288	.4955	.2455	6.1	2.018	4.074
.8710	.7586	1.2	1.148	1.318	.4898	.2399	6.2	2.042	4.169
.8610	.7413	1.3	1.161	1.349	.4842	.2344	6.3	2.065	4.266
.8511	.7244	1.4	1.175	1.380	.4786	.2291	6.4	2.089	4.365
.8414	.7079	1.5	1.189	1.413	.4732	.2239	6.5	2.113	4.467
.8318	.6918	1.6	1.202	1.445	.4677	.2188	6.6	2.138	4.571
.8222	.6761	1.7	1.216	1.479	.4624	.2138	6.7	2.163	4.677
.8128	.6607	1.8	1.230	1.514	.4571	.2089	6.8	2.188	4.786
.8035	.6457	1.9	1.245	1.549	.4519	.2042	6.9	2.213	4.898
.7943	.6310	2.0	1.259	1.585	.4467	.1995	7.0	2.239	5.012
.7852	.6166	2.1	1.274	1.622	.4416	.1950	7.1	2.265	5.129
.7762	.6026	2.2	1.288	1.660	.4365	.1905	7.2	2.291	5.248
.7674	.5888	2.3	1.303	1.698	.4315	.1862	7.3	2.317	5.370
.7586	.5754	2.4	1.318	1.738	.4266	.1820	7.4	2.344	5.495
.7499	.5623	2.5	1.334	1.778	.4217	.1778	7.5	2.371	5.623
.7413	.5495	2.6	1.349	1.820	.4169	.1738	7.6	2.399	5.754
.7328	.5370	2.7	1.365	1.862	.4121	.1698	7.7	2.427	5.888
.7244	.5248	2.8	1.380	1.905	.4074	.1660	7.8	2.455	6.026
.7161	.5129	2.9	1.396	1.950	.4027	.1622	7.9	2.483	6.166
.7079	.5012	3.0	1.413	1.995	.3981	.1585	8.0	2.512	6.310
.6998	.4898	3.1	1.429	2.042	.3936	.1549	8.1	2.541	6.457
.6918	.4786	3.2	1.445	2.089	.3890	.1514	8.2	2.570	6.607
.6839	.4677	3.3	1.462	2.138	.3846	.1479	8.3	2.600	6.761
.6761	.4571	3.4	1.479	2.188	.3802	.1445	8.4	2.630	6.918
.6683	.4467	3.5	1.496	2.239	.3758	.1413	8.5	2.661	7.079
.6607	.4365	3.6	1.514	2.291	.3715	.1380	8.6	2.692	7.244
.6531	.4266	3.7	1.531	2.344	.3673	.1349	8.7	2.723	7.413
.6457	.4169	3.8	1.549	2.399	.3631	.1318	8.8	2.754	7.586
.6383	.4074	3.9	1.567	2.455	.3589	.1288	8.9	2.786	7.762
.6310	.3981	4.0	1.585	2.512	.3548	.1259	9.0	2.818	7.943
.6237	.3890	4.1	1.603	2.570	.3508	.1230	9.1	2.851	8.128
.6166	.3802	4.2	1.622	2.630	.3467	.1202	9.2	2.884	8.318
.6095	.3715	4.3	1.641	2.692	.3428	.1175	9.3	2.917	8.511
.6026	.3631	4.4	1.660	2.754	.3388	.1148	9.4	2.951	8.710
.5957	.3548	4.5	1.679	2.818	.3350	.1122	9.5	2.985	8.913
.5888	.3467	4.6	1.698	2.884	.3311	.1096	9.6	3.020	9.120
.5821	.3388	4.7	1.718	2.951	.3273	.1072	9.7	3.055	9.333
.5754	.3311	4.8	1.738	3.020	.3236	.1047	9.8	3.090	9.550
.5689	.3236	4.9	1.758	3.090	.3199	.1023	9.9	3.126	9.772

TABLE I (continued)

← -dB+ →					← -dB+ →				
Voltage Ratio	Power Ratio	dB	Voltage Ratio	Power Ratio	Voltage Ratio	Power Ratio	dB	Voltage Ratio	Power Ratio
.3162	.1000	10.0	3.162	10.000	.1585	.02512	16.0	6.310	39.81
.3126	.09772	10.1	3.199	10.23	.1567	.02455	16.1	6.383	40.74
.3090	.09550	10.2	3.236	10.47	.1549	.02399	16.2	6.457	41.69
.3055	.09333	10.3	3.273	10.72	.1531	.02344	16.3	6.531	42.66
.3020	.09120	10.4	3.311	10.96	.1514	.02291	16.4	6.607	43.65
.2985	.08913	10.5	3.350	11.22	.1496	.02239	16.5	6.683	44.67
.2951	.08710	10.6	3.388	11.48	.1479	.02188	16.6	6.761	45.71
.2917	.08511	10.7	3.428	11.75	.1462	.02138	16.7	6.839	46.77
.2884	.08318	10.8	3.467	12.02	.1445	.02089	16.8	6.918	47.86
.2851	.08128	10.9	3.508	12.30	.1429	.02042	16.9	6.998	48.98
.2818	.07943	11.0	3.548	12.59	.1413	.01995	17.0	7.079	50.12
.2786	.07762	11.1	3.589	12.88	.1396	.01950	17.1	7.161	51.29
.2754	.07586	11.2	3.631	13.18	.1380	.01905	17.2	7.244	52.48
.2723	.07413	11.3	3.673	13.49	.1365	.01862	17.3	7.328	53.70
.2692	.07244	11.4	3.715	13.80	.1349	.01820	17.4	7.413	54.95
.2661	.07079	11.5	3.758	14.13	.1334	.01778	17.5	7.499	56.23
.2630	.06918	11.6	3.802	14.45	.1318	.01738	17.6	7.586	57.54
.2600	.06761	11.7	3.846	14.79	.1303	.01698	17.7	7.674	58.88
.2570	.06607	11.8	3.890	15.14	.1288	.01660	17.8	7.762	60.26
.2541	.06457	11.9	3.936	15.49	.1274	.01622	17.9	7.852	61.66
.2512	.06310	12.0	3.981	15.85	.1259	.01585	18.0	7.943	63.10
.2483	.06166	12.1	4.027	16.22	.1245	.01549	18.1	8.035	64.57
.2455	.06026	12.2	4.074	16.60	.1230	.01514	18.2	8.128	66.07
.2427	.05888	12.3	4.121	16.98	.1216	.01479	18.3	8.222	67.61
.2399	.05754	12.4	4.169	17.38	.1202	.01445	18.4	8.318	69.18
.2371	.05623	12.5	4.217	17.78	.1189	.01413	18.5	8.414	70.79
.2344	.05495	12.6	4.266	18.20	.1175	.01380	18.6	8.511	72.44
.2317	.05370	12.7	4.315	18.62	.1161	.01349	18.7	8.610	74.13
.2291	.05248	12.8	4.365	19.05	.1148	.01318	18.8	8.710	75.86
.2265	.05129	12.9	4.416	19.50	.1135	.01288	18.9	8.811	77.62
.2239	.05012	13.0	4.467	19.95	.1122	.01259	19.0	8.913	79.43
.2213	.04898	13.1	4.519	20.42	.1109	.01230	19.1	9.016	81.28
.2188	.04786	13.2	4.571	20.89	.1096	.01202	19.2	9.120	83.18
.2163	.04677	13.3	4.624	21.38	.1084	.01175	19.3	9.226	85.11
.2138	.04571	13.4	4.677	21.88	.1072	.01148	19.4	9.333	87.10
.2113	.04467	13.5	4.732	22.39	.1059	.01122	19.5	9.441	89.13
.2089	.04365	13.6	4.786	22.91	.1047	.01096	19.6	9.550	91.20
.2065	.04266	13.7	4.842	23.44	.1035	.01072	19.7	9.661	93.33
.2042	.04169	13.8	4.898	23.99	.1023	.01047	19.8	9.772	95.50
.2018	.04074	13.9	4.955	24.55	.1012	.01023	19.9	9.886	97.72
.1995	.03981	14.0	5.012	25.12	.1000	.01000	20.0	10.000	100.00
.1972	.03890	14.1	5.070	25.70					
.1950	.03802	14.2	5.129	26.30					
.1928	.03715	14.3	5.188	26.92					
.1905	.03631	14.4	5.248	27.54					
.1884	.03548	14.5	5.309	28.18					
.1862	.03467	14.6	5.370	28.84					
.1841	.03388	14.7	5.433	29.51					
.1820	.03311	14.8	5.495	30.20					
.1799	.03236	14.9	5.559	30.90					
.1778	.03162	15.0	5.623	31.62					
.1758	.03090	15.1	5.689	32.36					
.1738	.03020	15.2	5.754	33.11					
.1718	.02951	15.3	5.821	33.88					
.1698	.02884	15.4	5.888	34.67					
.1679	.02818	15.5	5.957	35.48					
.1660	.02754	15.6	6.026	36.31					
.1641	.02692	15.7	6.095	37.15					
.1622	.02630	15.8	6.166	38.02					
.1603	.02570	15.9	6.237	38.90					

← -dB+ →				
Voltage Ratio	Power Ratio	dB	Voltage Ratio	Power Ratio
3.162×10^{-1}	10^{-1}	10	3.162	10
10^{-1}	10^{-2}	20	10	10^2
3.162×10^{-2}	10^{-3}	30	3.162×10	10^3
10^{-2}	10^{-4}	40	10^2	10^4
3.162×10^{-3}	10^{-5}	50	3.162×10^2	10^5
10^{-3}	10^{-6}	60	10^3	10^6
3.162×10^{-4}	10^{-7}	70	3.162×10^3	10^7
10^{-4}	10^{-8}	80	10^4	10^8
3.162×10^{-5}	10^{-9}	90	3.162×10^4	10^9
10^{-5}	10^{-10}	100	10^5	10^{10}

To find decibel values outside the range of this table, see page 262.

TABLE II

GIVEN: $\left\{ \begin{array}{l} \text{Voltage} \\ \text{Current} \end{array} \right\}$ Ratio

TO FIND: Decibels

POWER RATIOS

To find the number of decibels corresponding to a given power ratio — Assume the given power ratio to be a voltage ratio and find the corresponding number of decibels from the table. The desired result is exactly one-half of the number of decibels thus found.

Example — Given: a power ratio of 3.41.

Find: 3.41 in the table:

3.41 \rightarrow 10.655 dB (voltage)

10.655 dB $\times \frac{1}{2}$ = 5.328 dB (power)

Voltage Ratio	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
1.0	.000	.086	.172	.257	.341	.424	.506	.588	.668	.749
1.1	.828	.906	.984	1.062	1.138	1.214	1.289	1.364	1.438	1.511
1.2	1.584	1.656	1.727	1.798	1.868	1.938	2.007	2.076	2.144	2.212
1.3	2.279	2.345	2.411	2.477	2.542	2.607	2.671	2.734	2.798	2.860
1.4	2.923	2.984	3.046	3.107	3.167	3.227	3.287	3.346	3.405	3.464
1.5	3.522	3.580	3.637	3.694	3.750	3.807	3.862	3.918	3.973	4.028
1.6	4.082	4.137	4.190	4.244	4.297	4.350	4.402	4.454	4.506	4.558
1.7	4.609	4.660	4.711	4.761	4.811	4.861	4.910	4.959	5.008	5.057
1.8	5.105	5.154	5.201	5.249	5.296	5.343	5.390	5.437	5.483	5.529
1.9	5.575	5.621	5.666	5.711	5.756	5.801	5.845	5.889	5.933	5.977
2.0	6.021	6.064	6.107	6.150	6.193	6.235	6.277	6.319	6.361	6.403
2.1	6.444	6.486	6.527	6.568	6.608	6.649	6.689	6.729	6.769	6.809
2.2	6.848	6.888	6.927	6.966	7.008	7.044	7.082	7.121	7.159	7.197
2.3	7.235	7.272	7.310	7.347	7.384	7.421	7.458	7.495	7.532	7.568
2.4	7.604	7.640	7.676	7.712	7.748	7.783	7.819	7.854	7.889	7.924
2.5	7.959	7.993	8.028	8.062	8.097	8.131	8.165	8.199	8.232	8.266
2.6	8.299	8.333	8.366	8.399	8.432	8.465	8.498	8.530	8.563	8.595
2.7	8.627	8.659	8.691	8.723	8.755	8.787	8.818	8.850	8.881	8.912
2.8	8.943	8.974	9.005	9.036	9.066	9.097	9.127	9.158	9.188	9.218
2.9	9.248	9.278	9.308	9.337	9.367	9.396	9.426	9.455	9.484	9.513
3.0	9.542	9.571	9.600	9.629	9.657	9.686	9.714	9.743	9.771	9.799
3.1	9.827	9.855	9.883	9.911	9.939	9.966	9.994	10.021	10.049	10.076
3.2	10.103	10.130	10.157	10.184	10.211	10.238	10.264	10.291	10.317	10.344
3.3	10.370	10.397	10.423	10.449	10.475	10.501	10.527	10.553	10.578	10.604
3.4	10.630	10.655	10.681	10.706	10.731	10.756	10.782	10.807	10.832	10.857
3.5	10.881	10.906	10.931	10.955	10.980	11.005	11.029	11.053	11.078	11.102
3.6	11.126	11.150	11.174	11.198	11.222	11.246	11.270	11.293	11.317	11.341
3.7	11.364	11.387	11.411	11.434	11.457	11.481	11.504	11.527	11.550	11.573
3.8	11.596	11.618	11.641	11.664	11.687	11.709	11.732	11.754	11.777	11.799
3.9	11.821	11.844	11.866	11.888	11.910	11.932	11.954	11.976	11.998	12.019
4.0	12.041	12.063	12.085	12.106	12.128	12.149	12.171	12.192	12.213	12.234
4.1	12.256	12.277	12.298	12.319	12.340	12.361	12.382	12.403	12.424	12.444
4.2	12.465	12.486	12.506	12.527	12.547	12.568	12.588	12.609	12.629	12.649
4.3	12.669	12.690	12.710	12.730	12.750	12.770	12.790	12.810	12.829	12.849
4.4	12.869	12.889	12.908	12.928	12.948	12.967	12.987	13.006	13.026	13.045
4.5	13.064	13.084	13.103	13.122	13.141	13.160	13.179	13.198	13.217	13.236
4.6	13.255	13.274	13.293	13.312	13.330	13.349	13.368	13.386	13.405	13.423
4.7	13.442	13.460	13.479	13.497	13.516	13.534	13.552	13.570	13.589	13.607
4.8	13.625	13.643	13.661	13.679	13.697	13.715	13.733	13.751	13.768	13.786
4.9	13.804	13.822	13.839	13.857	13.875	13.892	13.910	13.927	13.945	13.962
5.0	13.979	13.997	14.014	14.031	14.049	14.066	14.083	14.100	14.117	14.134
5.1	14.151	14.168	14.185	14.202	14.219	14.236	14.253	14.270	14.287	14.303
5.2	14.320	14.337	14.353	14.370	14.387	14.403	14.420	14.436	14.453	14.469
5.3	14.486	14.502	14.518	14.535	14.551	14.567	14.583	14.599	14.616	14.632
5.4	14.648	14.664	14.680	14.696	14.712	14.728	14.744	14.760	14.776	14.791
5.5	14.807	14.823	14.839	14.855	14.870	14.886	14.902	14.917	14.933	14.948
5.6	14.964	14.979	14.995	15.010	15.026	15.041	15.056	15.072	15.087	15.102
5.7	15.117	15.133	15.148	15.163	15.178	15.193	15.208	15.224	15.239	15.254
5.8	15.269	15.284	15.298	15.313	15.328	15.343	15.358	15.373	15.388	15.402
5.9	15.417	15.432	15.446	15.461	15.476	15.490	15.505	15.519	15.534	15.549

TABLE II (continued)

Voltage Ratio	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
6.0	15.563	15.577	15.592	15.606	15.621	15.635	15.649	15.664	15.678	15.692
6.1	15.707	15.721	15.735	15.749	15.763	15.778	15.792	15.806	15.820	15.834
6.2	15.848	15.862	15.876	15.890	15.904	15.918	15.931	15.945	15.959	15.973
6.3	15.987	16.001	16.014	16.028	16.042	16.055	16.069	16.083	16.096	16.110
6.4	16.124	16.137	16.151	16.164	16.178	16.191	16.205	16.218	16.232	16.245
6.5	16.258	16.272	16.285	16.298	16.312	16.325	16.338	16.351	16.365	16.378
6.6	16.391	16.404	16.417	16.430	16.443	16.456	16.469	16.483	16.496	16.509
6.7	16.521	16.534	16.547	16.560	16.573	16.586	16.599	16.612	16.625	16.637
6.8	16.650	16.663	16.676	16.688	16.701	16.714	16.726	16.739	16.752	16.764
6.9	16.777	16.790	16.802	16.815	16.827	16.840	16.852	16.865	16.877	16.890
7.0	16.902	16.914	16.927	16.939	16.951	16.964	16.976	16.988	17.001	17.013
7.1	17.025	17.037	17.050	17.062	17.074	17.086	17.098	17.110	17.122	17.135
7.2	17.147	17.159	17.171	17.183	17.195	17.207	17.219	17.231	17.243	17.255
7.3	17.266	17.278	17.290	17.302	17.314	17.326	17.338	17.349	17.361	17.373
7.4	17.385	17.396	17.408	17.420	17.431	17.443	17.455	17.466	17.478	17.490
7.5	17.501	17.513	17.524	17.536	17.547	17.559	17.570	17.582	17.593	17.605
7.6	17.616	17.628	17.639	17.650	17.662	17.673	17.685	17.696	17.707	17.719
7.7	17.730	17.741	17.752	17.764	17.775	17.786	17.797	17.808	17.820	17.831
7.8	17.842	17.853	17.864	17.875	17.886	17.897	17.908	17.919	17.931	17.942
7.9	17.953	17.964	17.975	17.985	17.996	18.007	18.018	18.029	18.040	18.051
8.0	18.062	18.073	18.083	18.094	18.105	18.116	18.127	18.137	18.148	18.159
8.1	18.170	18.180	18.191	18.202	18.212	18.223	18.234	18.244	18.255	18.266
8.2	18.276	18.287	18.297	18.308	18.319	18.329	18.340	18.350	18.361	18.371
8.3	18.382	18.392	18.402	18.413	18.423	18.434	18.444	18.455	18.465	18.475
8.4	18.486	18.496	18.506	18.517	18.527	18.537	18.547	18.558	18.568	18.578
8.5	18.588	18.599	18.609	18.619	18.629	18.639	18.649	18.660	18.670	18.680
8.6	18.690	18.700	18.710	18.720	18.730	18.740	18.750	18.760	18.770	18.780
8.7	18.790	18.800	18.810	18.820	18.830	18.840	18.850	18.860	18.870	18.880
8.8	18.890	18.900	18.909	18.919	18.929	18.939	18.949	18.958	18.968	18.978
8.9	18.988	18.998	19.007	19.017	19.027	19.036	19.046	19.056	19.066	19.075
9.0	19.085	19.094	19.104	19.114	19.123	19.133	19.143	19.152	19.162	19.171
9.1	19.181	19.190	19.200	19.209	19.219	19.228	19.238	19.247	19.257	19.266
9.2	19.276	19.285	19.295	19.304	19.313	19.323	19.332	19.342	19.351	19.360
9.3	19.370	19.379	19.388	19.398	19.407	19.416	19.426	19.435	19.444	19.453
9.4	19.463	19.472	19.481	19.490	19.499	19.509	19.518	19.527	19.536	19.545
9.5	19.554	19.564	19.573	19.582	19.591	19.600	19.609	19.618	19.627	19.636
9.6	19.645	19.654	19.664	19.673	19.682	19.691	19.700	19.709	19.718	19.726
9.7	19.735	19.744	19.753	19.762	19.771	19.780	19.789	19.798	19.807	19.816
9.8	19.825	19.833	19.842	19.851	19.860	19.869	19.878	19.886	19.895	19.904
9.9	19.913	19.921	19.930	19.939	19.948	19.956	19.965	19.974	19.983	19.991

Voltage Ratio	0	1	2	3	4	5	6	7	8	9
10	20.000	20.828	21.584	22.279	22.923	23.522	24.082	24.609	25.105	25.575
20	26.021	26.444	26.848	27.235	27.604	27.959	28.299	28.627	28.943	29.248
30	29.542	29.827	30.103	30.370	30.630	30.881	31.126	31.364	31.596	31.821
40	32.041	32.256	32.465	32.669	32.869	33.064	33.255	33.442	33.625	33.804
50	33.979	34.151	34.320	34.486	34.648	34.807	34.964	35.117	35.269	35.417
60	35.563	35.707	35.848	35.987	36.124	36.258	36.391	36.521	36.650	36.777
70	36.902	37.025	37.147	37.266	37.385	37.501	37.616	37.730	37.842	37.953
80	38.062	38.170	38.276	38.382	38.486	38.588	38.690	38.790	38.890	38.988
90	39.085	39.181	39.276	39.370	39.463	39.554	39.645	39.735	39.825	39.913
100	40.000	—	—	—	—	—	—	—	—	—

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