INSTRUCTION MANUAL

MODELS 150A, 150AR

MICROVOLT-AMMETERS

WARRANTY

We warrant each of our products to be free from defects in material and workmanship. Our obligation under this warranty is to repair or replace any instrument or part thereof (except tubes and batteries) which, within a year after shipment, proves defective upon examination.

To exercise this warranty, contact your Keithley field engineering representative. You will be given assistance and shipping instructions.

REPAIRS AND RECALIBRATION

Keithley Instruments and its international distributors maintain complete repair facilities.

To insure prompt repair or recalibration service, please contact your Keithley field representative before returning the instrument.

Estimates for repairs, normal recalibrations, and calibrations traceable to the National Bureau of Standards are available upon request.

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* Change Notice

* Yellow Change Notice sheet is included only for instrument modifications affecting the Instruction Manual.

SECTION I - INTRODUCTION

The Model 150A Microvolt-Ammeter is a stable, versatile instrument for measuring extremely low level DC signals. It functions as a voltmeter from one microvolt to one volt full scale, and as an ammeter from one milliampere to one hundred micro-microamperes full scale. It also operates as a DC amplifier with gains up to ten million for driving recorders.

The very low noise level of the Model 150A, together with its long term stability make it ideal for many measurements requiring extreme power sensitivity.

Typical applications include measuring the output from strain gages, thermopiles, thermocouples, bolometers, phototubes, ionization chambers, scintillation counters, and barrier layer cells. Other applications are found in cell studies, measurement of electrochemical potentials, electrolytic corrosion studies, molecular weight analysis and Hall effect studies.

In addition to its use as a direct indicator of minute potentials and currents, the Model 150A may also be used as a null detector in Wheatstone or Mueller bridges, or with an external voltage source as a meg-megohmmeter.

An important feature of the instrument is zero suppression up to 100 times full scale, in place of the usual more limited meter zero. This permits measurements of small signals in the presence of large thermal EMF's or other masking DC signals.

SECTION II - SPECIFICATIONS

VOLTMETER SPECIFICATIONS

RANGES: Thirteen overlapping ranges in 1x and 3x steps from one microvolt to one volt full scale on a zero-center meter.

ZERO ACCURACY: 2% of full scale on all ranges.

STABILITY: After one hour, $\pm$0.1 microvolt $\pm 2 \times 10^{-5}$ R microvolt drift per day, where R is the source resistance in ohms.

NOISE: With the input shorted, less than 0.03 microvolt peak-to-peak (0.006 microvolt rms). At various source resistances, the noise peak-to-peak in microvolts is given by $E = 6.5 \times 10^{-4} (R + 2000)^{\frac{1}{2}}$, since the input resistance is added to R, the source resistance.

INPUT RESISTANCE: Tabulated below; if input shunting resistors are requested, the input resistance is 100 kilohms on MICROVOLT ranges and one megohm on MILLIVOLT ranges. Maximum source resistances specified on the 1- and 3-microvolt ranges also hold with shunting input resistors.

RANGE	Input Resistance	Max. Source Resistance
1 microvolt	1 megohm	10 kilohms
3 microvolts	3 megohms	30 kilohms
10 microvolts	10 megohms	100 kilohms
30 microvolts	30 megohms	300 kilohms
100 microvolts and above	90 megohms	1 megohm

RESPONSE SPEED (10% to 90% of final value): Depends on source resistance. With maximum specified source resistance, less than one second on all ranges except the 1-microvolt range, where it is within two seconds.

With source resistance less than 10% of the maximum, response is within 0.5 second, except on the 1-microvolt range, where it is within one second.

VOLTAGE ZERO SUPPRESS: Ranges of 10, 100, 1000 and 10,000 microvolts; and 0.1, 1, 10 and 100 millivolts, corresponding to the MICROVOLTS and MILLIVOLTS positions on the FUNCTION switch. Accuracy of the buckout ranges is about 20% and stability is such that 100 times full scale may be suppressed.

AMMETER SPECIFICATIONS

RANGES: Fifteen overlapping ranges in 1x and 3x steps from 0.1 milli-microampere (10^{-10} ampere) to 1000 microamperes (10^{-3} ampere) on a zero-center meter.

STABILITY: After one hour, $\pm 2 \times 10^{-11}$ ampere per day.

NOISE: Less than 2 x 10^{-12} ampere peak-to-peak.

ACCURACY: Within 3% of full scale on all ranges.

VOLTAGE DROP: 100 microvolts on the MILLI-MICROAMPERES ranges, one millivolt on the MICROAMPERES ranges.

INPUT RESISTANCE: On the MICROAMPERES ranges the input resistance is equal to 10^{-3} divided by the range in amperes. On the MILLI-MICROAMPERES ranges it is equal to 10^{-4} divided by the range in amperes.

RESPONSE SPEED: One second maximum, except on the 0.1-milli-microampere range, where it is two seconds maximum.

CURRENT ZERO SUPPRESS: Up to 100 full scales on any range. Accuracy and stability are the same as for the voltage zero suppress.

GENERAL SPECIFICATIONS

OUTPUT: $\pm$10 volts at five milliamperes for full-scale deflection on any range. Gain of dc amplifier is from 10 to 10^7.

OUTPUT RESISTANCE: Less than 10 ohms within the amplifier passband.

60 CPS REJECTION: Greater than 50:1.

INPUT ISOLATION: Negative terminal may be grounded or floating up to $\pm$400 volts with respect to the case. A link is provided for grounding the negative terminal to the case.

CONNECTORS: Input: Special receptacle.
Rear Output: Amphenol 80PC2F receptacle.
Front Output (Model 150AR): Binding posts.

TUBE COMPLEMENT: Two EF86, one 0A2, one 12AT7, two 12AX7, one 12B4A, one 5651, one 6CM6, one 6084.

POWER: 105-125 volts or 210-250 volts, 50 watts, 60 cps. 50-cps models on special order.

ACCESSORIES SUPPLIED: Model 1501 Low Thermal Test Leads; a length of low-thermal solder; mating output plug.

ACCESSORIES AVAILABLE: Model 1502 Low Thermal Connector Pair.

DIMENSIONS: Model 150A: 11-1/8 inches high x 7$\frac{1}{4}$ inches wide x 13$\frac{1}{4}$ inches deep.
Model 150AR: 7 inches high x 19 inches wide x 13 inches deep.

NET WEIGHT: Model 150A: 20 pounds.
Model 150AR: 22 pounds.

SECTION III - OPERATION

A. OPERATING CONTROLS

The controls of the Model 150A are simple and conveniently placed. Their functions are as follows:

ON switch is located to the right of the panel meter.

FUNCTION switch selects the function which is to be used: MILLI-VOLTS, MICROVOLTS, MICROAMPERES or MILLI-MICROAMPERES.

RANGE switch selects the full scale multiplier of the function selected by the FUNCTION switch. Note that the .3 and .1 positions are to be used for CURRENT measurements only.

ZERO SUPPRESS controls consist of the zero RANGE switch, which selects the coarse range of suppressing voltage in discreet steps and the zero SET potentiometer, which gives continuously variable fine control, including settings through zero.

B. PRELIMINARY SET-UP

Connect the instrument to the power line. Unless otherwise marked the unit may be used on 117 volt, 60 cps line. To convert to 220-volt operation, refer to the MAINTENANCE section. A three-wire line cord is furnished, which grounds the cabinet. If a three-wire receptacle is not available, use the two-pin adapter furnished, and ground the third lead to an external ground.

Set controls as follows:

FUNCTION: MILLIVOLTS

RANGE: 1000

ZERO SUPPRESS: OFF

Input: Short the input leads together.

C. GENERAL PRECAUTIONS

1. Source Resistance - In SECTION II - SPECIFICATIONS under INPUT RESISTANCE, the maximum source resistance for use with each voltage range is specified. Reasonable operation is possible with source resistance up to ten times greater than those specified; however, the measurement will suffer from a considerable decrease in speed of response, and measuring accuracy. If the instrument is left completely open-circuited, the meter will generally drift off scale on any voltage range. On current ranges this does not happen because of the input shunting resistors.

2. Shielding - Since the instrument operates with a modulator frequency of 120 cps, it is not generally sensitive to 60 cps pickup unless it is large enough to overload the amplifier. The pickup may be a source of difficulty when using the amplifier with high impedances on the more sensitive voltage ranges and on the two or three most sensitive current ranges. In these cases it is desirable to shield the leads and the sources as completely as possible. In some cases a simple low-pass filter at the input to eliminate frequencies of about 1 cps and above will be helpful. No use is made of an input filter in this instrument, since any input series impedance due to the filter will increase the input noise and the thermal drift. When operating above ground, the case of the instrument must be grounded.

3. Thermal EMF - Extreme precautions have been taken in the input circuit to minimize thermal EMF's so that the residual EMF is less than 0.6 microvolt. The material used in the input circuit is pure copper. Any other metal will generate a thermocouple potential. Lead solder is particularly troublesome. Where thermal EMF's are a problem, soldering should be done with the cadmium-tin solder supplied with the instrument.

4. Input Noise: The noise at the input is a function of input resistance and is approximately given by

$$E = 1.29 \times 10^{-10} (R+2000)^{\frac{1}{2}}$$

where E is the rms noise, and R is the source resistance. It is assumed that the bandwidth of the instrument is about 1 cps and the temperature is 80°F. If noise is observed, calculate the theoretical noise and compare results. Also bear in mind that only wire-wound resistors approach the ideal resistor. However, if Evanohm or manganin resistors are used, a considerable thermal EMF of the resistor material against copper will be observed.

5. Checking the Zero Point - At low levels, spurious EMF's may be generated simply by contact between the input leads and the terminals under test. If possible, always leave the instrument connected and adjust the zero after establishing a zero reference in the apparatus under test. For example, in bridge measurements, disconnect the bridge exciting voltage; or with a phototube, shield the tube from light.

6. Overloads - The current applied to the input circuit should be less than one milliampere dc steady state, 10 milliamperes dc short-term. When the FUNCTION switch is on the MILLIVOLTS position, the off-scale impedance can be as low as 10 kilohms. On the MICROVOLTS position, it may approach 10 ohms.

D. MEASURING VOLTAGE

1. Direct Voltage Measurements - Place the FUNCTION switch at MILLIVOLTS or MICROVOLTS as necessary for the measurement to be taken. Then turn the RANGE switch to more sensitive ranges until the meter gives a usable deflection.

2. Measuring Voltage Variations - Set the FUNCTION switch and RANGE switch to obtain the best deflection of the meter. Use the ZERO SUPPRESS controls as described in IV-D to increase the sensitivity of the meter. Then small changes in a relatively large steady signal may be displayed with a large scale deflection.

3. Measuring Differential Voltages - When measurements are to be made in a circuit where the LOW connection is above ground potential, remove the DISCONNECT LINK from one of its posts. This disconnects the instrument circuit ground from chassis ground. DO NOT attempt to make such measurements where the low side of the circuit being measured is more than 400 volts above external ground potential.

If a recorder is being used with the instrument in this arrangement, the recorder ground must not be connected to the output ground of the instrument, since the low side of the output would no longer be grounded.

E. MEASURING CURRENT

Direct Current Reading - Turn the FUNCTION switch to MICROAMPERES or MILLI-MICROAMPERES, and the RANGE to 1000. Connect the instrument to the current source and set the RANGE to the range which gives the best deflection of the meter.

Measuring Current Variations - Proceed as above for direct current readings, and then use the ZERO SUPPRESS and SET as described under IV-D.

F. OTHER APPLICATIONS

1. Null Indicator - The Model 510A makes an extremely sensitive null indicator which may be used in a Wheatstone or Mueller Bridge.

In a Wheatstone Bridge, the Model 150A is connected between the two resistor arms. With the FUNCTION on MILLIVOLTS, and the RANGE on 1000, the bridge can be adjusted to give a zero reading on the meter. The instrument can then be set on more sensitive ranges for finer adjustments of the bridge.*

*If the bridge is arranged so that one terminal of the detector is grounded, the Model 150A may be used as described in E. If the detector must be used floating, remove the DISCONNECT LINK at the rear and observe the same precautions as in D.3.for measuring differential voltages.

2. Megohmmeter - The Model 510A may be used to measure resistances, utilizing an external voltage source and measuring the current which flows in the unknown.

SECTION IV - CIRCUIT DESCRIPTION

The Model 150A is basically a narrow-band chopper amplifier employing negative feedback to stabilize the gain and increase the input impedance.

A. Input Circuit

Zero Stability: The effect of thermal emf's generated in the input circuitry is reduced to nearly the vanishing point by the use of only copper or silver materials in the input circuit. All solder joints are made with a low thermal cadmium-tin solder. The chopper and chopper transformer employ copper leads. All switching in the input circuit is accomplished with a solid copper switch. Critical resistors in the input circuit are wound of copper wire. The input connector has solid copper spring-loaded contacts.

The input voltage is applied to the moving arm of a 120-cps mechanical chopper. The feedback voltage is connected to the primary center tap of the input transformer. Thus, the difference voltage is applied first across one half of the primary and then, with phase reversal, to the other half. This full wave error signal is stepped up 16 to 1 by the input transformer and applied to the grid of V1, a 6084 low-noise pentode.

B. AC Amplifier

In parallel with the plate load resistor of V1 is a relatively high Q, 120 cps resonant circuit which narrows the bandwidth and reduces spurious signals.

V2 and V3, EF86 pentodes, further amplify the chopped error signal which is then demodulated synchronously by selenium diodes D101 and D102.

To obtain the 120 cps demodulator driving signal, use is made of the ripple frequency from a bridge rectifier circuit operating from the line voltage. The ripple is connected to the primary of the demodulator driver transformer.

C. DC Amplifier

The demodulated signal is applied to the grid of V4. V4, V5, and V6 form the dc amplifier and output cathode follower which add further forward gain to the system and supply output power. Feedback around V4, V5 and V6 multiplies the effective capacitance of demodulator filter capacitor C113 by about 1000. This yields the large equivalent capacitance necessary to smooth the demodulated error signal. Because of the feedback, spurious noise in the dc stages outside the pass band of the whole amplifier are effectively degenerated.

D. Zero Suppression

A low-current ±10 volt supply is derived from the main dc supply using 10-volt zener diodes. Potentiometer R174 may be set at any voltage from -10 to +10 volts, this voltage being applied through appropriate dropping resistors to the feedback point to achieve zero suppression. The potentiometer is the front panel control marked SET, while switch S3, which determines the portion fed back, is labeled RANGE.

E. Other Controls

Three controls are set at the factory and should require only infrequent attention by the user.

R118 is an internal control marked DC AMP BAL. It is used to zero the DC amplifier, i.e., to set the output voltage to zero when the demodulator output is zero. This is not very critical since any unbalance will simply be fed back to the input to produce a small error signal to correct itself. R127 is marked METER CAL. This is the variable portion of the meter multiplier resistance to allow for meter-to-meter sensitivity differneces.

R177, marked CURRENT BALANCE, may be set at some voltage which will cause a current to flow through R175 to the chopper arm. This current is used to compensate for a small generated "chopper current" which would otherwise flow in the input circuit. This "chopper current" differs from chopper to chopper, but is fairly stable for long periods of time. Its effect on any current range could be removed with the ZERO SUPPRESS controls, but the Current Balance method used here gives an effective zero input current for all ranges.

F. Power Supply

A standard half-wave rectifier followed by an R-C filter is used to supply unregulated B+ and B- to the output cathode follower.

The unregulated B- is regulated to -150 volts in V7, OA2, and is used for the negative returns for the dc amplifier.

Unregulated B+ is fed to the plate of V8, 12B4A, the series tube in a 225-volt electronic regulator. The output voltage from this regulator is divided by R510 and R511 and compared to reference tube V9, a 5651. The difference signal is amplified by cascade amplifier V10, a 12AX7, and applied to the grid-cathode circuit of the series tube. This regulated 225 volts supplies B+ directly to the dc amplifier, through a decoupling filter (R176, C110) to the second and third ac amplifier stages, and through another decoupling filter (R103, C104) to the first ac amplifier stage.

Regulated B+ and B- also supply currents to the 10 volt zener diodes which are used for zero suppression. This gives two-stage regulation for these very critical voltages.

The first two ac amplifier filaments and the first dc amplifier filaments are driven by a bridge-rectified 6-volt d.c. supply. The R-C filter, R512, C507, and C508, insure low ripple.

SECTION V - MAINTENANCE

Except for occasional tube or chopper replacement, very little maintenance is required by the Models 150A and 150AR. Components are operated well below rating and solid-state devices are employed where possible to achieve long, trouble-free service.

Certain portions of the input circuit are wired using copper wire and special cadmium-tin solder. These special joints are painted red. If, for any reason, these joints must be unsoldered or re-soldered, USE ONLY CADMIUM-TIN SOLDER AND A COPPER-TIPPED SOLDERING IRON WHICH HAS NEVER BEEN USED WITH ORDINARY LEAD-TIN SOLDER. A small spool of cadmium-tin solder is supplied with each instrument.

What may seem to be circuit failure in the Micro Volt-Ammeter is quite often found to be an unusual condition in the entire test set-up. Therefore, before trouble-shooting the instrument, check to see whether it operates correctly with:

1. All other circuitry disconnected.
2. Input shorted (with copper leads).
3. Power line voltage and frequency correct.

If the difficulty persists, the following systematic procedure may be employed to determine the fault.

TROUBLE-SHOOTING

Reference is made to the Schematic Diagram, 12188D, and the Voltage-Resistance Diagram enclosed at the rear of the manual.

To begin trouble-shooting, short the input terminals, strap chassis ground to LO with the link provided (Model 150AR only), and switch RANGE to OFF. A zero offset of a few tenths of a microvolt is normal. On current functions with the input terminals open but shielded, it should be possible to set zero current with the CURRENT BALANCE control.

EXCESSIVE OUTPUT NOISE (INPUT TERMINALS SHORTED)

Short the input grid of the dc amplifier, pin 7 of V4, to ground. If this stops the noise, it is being generated in the ac amplifier. Unfortunately, because of the very low signal levels involved, noise in the ac amplifier is difficult to trace by other than the substitution method. Most logical noise sources are V1 or the chopper. To replace the chopper, unplug the cap at the top, and unscrew the three thumb-screw nuts which clamp the chopper leads. Unscrew the four chopper mounting screws and lift out the chopper. When inserting the new chopper, make sure that the chopper leads are pressed against the copper terminals and that the insulating washers are between the leads and the thumb-screw nuts. Observe wiring so as to rewire exactly the same as the original.

If the noise persists after shorting the dc amplifier input, the noise is being generated in the dc amplifier or power supply. A stage-by-stage search should reveal the source.

OUTPUT NOT ZERO (INPUT TERMINALS SHORTED)

Be sure that **RANGE is set to OFF. Short the dc amplifier input grid,** pin 7 of V4, to ground. Use the DC AMP BAL control to set the output to zero. If this cannot be done, the dc amplifier or power supply are at fault. If it can be set to zero, the trouble may be in the ac amplifier or demodulator circuit.

a. Power Supply - B+ should be about +225 on pin 1 of V8, and B- should be -150 on pins 2, 4 or 7 of V7. If V7 is not firing, correct the fault in the unregulated B-. If +225 is not present, check for unregulated B+ (about 340 volts) at the plate pin 9 of V8. If the unregulated B+ is all right, check the tube pin voltages of V8, V9, and V10 to locate the faulty tube or part.

b. AC Amplifier - Remove the output tube (V6) and clip pin 1 of the output connector to ground. Place the FUNCTION switch on MILLIVOLTS, and turn the **SET and RANGE controls full** clockwise. This puts a large dc error signal across the chopper and input transformer. Use an oscilloscope to check for the presence of 120 cps at the primary of the input transformers (the two outside terminals on the chopper terminal block). Absence of signal means chopper failure (or much less likely, shorted input transformer). Listen for audible chopper action and check chopper drive, if necessary.

If the 120 cps signal is present, check stage-by-stage throughout the ac amplifier, reducing the input signal as desired by backing off the **RANGE and/or SET controls, until the failure is** discovered.

d. Demodulator Circuit - Check for presence of about 80 volts rms at the secondary of the demodulator transformer (at the ends of R113 and R114).

The tests outlined above will not suffice to pin-point every fault which may exist. They should, however, lead to the correction of common failures. In the event that troubles cannot be corrected by these means, or the user finds it more expedient, the unit may be returned to the factory for repair and recalibration at a nominal cost.

220-VOLT OPERATION

For 220-volt operation the power transformer primary connections must be changed. The jumpers connecting black and black-white together and blue and blue-white should be removed. The blue and black-white leads should be tied together. **Replace the 1.5 ampere fuse (Keithley part FU-8) with a 0.75 ampere fuse (Keithley part FU-14).**

SECTION 6. REPLACEABLE PARTS

6-1. REPLACEABLE PARTS LIST. The Replaceable Parts List describes the components of the Models 150A and 150AR Microvolt-Ammeters and their accessories. The List gives the circuit designation, the part description, a suggested manufacturer, the manufacturer's part number and the Keithley Part Number. The name and address of the manufacturers listed in the "Mfg. Code" column are contained in Table 2.

6-2. HOW TO ORDER PARTS.

a. For parts orders, include the instrument's model and serial number, the Keithley Part Number, the circuit designation and a description of the part. All structural parts and those parts coded for Keithley manufacture (80164) must be ordered from Keithley Instruments, Inc. In ordering a part not listed in the Replaceable Parts List, completely describe the part, its function and its location.

b. Order parts through your nearest Keithley distributor or the Sales Service Department, Keithley Instruments, Inc.

amp	ampere	Ω	ohm
CbVar	Carbon Variable	PMC	Paper, metal cased
CerD	Ceramic, Disc	Poly	Polystyrene
Comp	Composition	p	pico (10^{-12})
DCb	Deposited Carbon	Spec	Special
ETB	Electrolytic, tubular	μ	micro (10^{-6})
f	farad	v	volt
		Var	Variable
k	kilo (10^{3})		
		w	watt
M or meg	mega (10^{6}) or megohms	WW	Wirewound
m	milli (10^{-3})	WWVar	Wirewound Variable
Mfg.	Manufacturer		
MtF	Metal Film		
Mil. No.	Military Type Number		
My	Mylar		

TABLE 1. Abbreviations and Symbols.

MODELS 150A, 150AR REPLACEABLE PARTS LIST

(Refer to Schematic Diagram 12188D for circuit designations.)

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.
C101	*.047-.33 µf	200 v	My	00656	V84C-V161	C29-*
C102	4.7 µf	10 v	ETB	05397	K4R7-J10S	C71-4.7M
C103	.1 µf	200 v	PMC	00656	P82-Z	C18-.1M
C104	20 µf	450 v	ETB	56289	TVA1709	C8-20L
C105	.1 µf	400 v	My	00656	V84C-V161	C30-.1M
C106 (60 cps)	.0082 µf	100 v	Poly	84171	PE	C45-.0082M
C106 (50 cps)	.0122 µf	100 v	Poly	84171	PE	C45-.0122M
C107	4.7 µf	10 v	ETB	05397	K4R7-J10S	C71-4.7M
C108	.01 µf	600 v	CerD	72982	811Z5V103P	C22-.01M
C109	.1 µf	200 v	PMC	00656	P82-Z	C18-.1M
C110	20 µf	450 v	ETB	56289	TVA-1709	C8-20L
C111	4.7 µf	10 v	ETB	05397	K4R7-J10S	C71-4.7M
C112	.1 µf	400 v	My	00656	V84C-V161	C30-.1M
C113	.333 µf	200 v	My	00656	V84C-V161	C29-.333M
C114	.001 µf	600 v	CerD	72982	801Z5V102P	C22-.001M
C115	.0047 µf	600 v	CerD	72982	811Z5V472P	C22-.0047M
C116	.001 µf	600 v	CerD	72982	801Z5V102P	C22-.001M
C117 (50 cps)	.0047 µf	600 v	CerD	72982	811Z5V472P	C22-.0047M
C501	20 µf	600 v	ETB	00656	PRS-1890	C35-20M
C502	20 µf	450 v	ETB	56289	TVA1709	C8-20L
C503	20 µf	600 v	ETB	00656	PRS-1890	C35-20M
C504	.01 µf	600 v	CerD	72982	811Z5V103P	C22-.01M
C505	20 µf	450 v	ETB	56289	TVA1709	C8-20L
C506	*0.5 µf	600 v	My	14655	PM-65P	C92-0.5M
C507	1000 µf	12 v	ETB	83125	TD1000-15	C11-1000M
C508	1000 µf	12 v	ETB	83125	TD1000-15	C11-1000M
C509	.1 µf	400 v	My	14655	PM-65P	C30-.1M

DIODES

Circuit Desig.	Type	Number	Mfg. Code	Keithley Part No.
D101	Selenium	5U1	81483	RF-15
D102	Selenium	5U1	81483	RF-15
D103	Zener	1N713	12954	DZ-22
D104	Zener	1N713	12954	DZ-22
D105	Selenium	PT065	81483	RF-18

*Nominal value, factory selected.

DIODES (Cont'd)

Circuit Desig.	Type	Number	Mfg. Code	Keithley Part No.
D106	Selenium	PT065	81483	RF-18
D107	Selenium	PT065	81483	RF-18
D108	Selenium	PT065	81483	RF-18
D109	Selenium	PT065	81483	RF-18
D110	Selenium	PT065	81483	RF-18
D111	Selenium Bridge	C1B	81483	RF-7

MISCELLANEOUS PARTS

Circuit Desig.	Description	Mfg. Code	Keithley Part No.
F1 (117 v)	Fuse, 1.5 amp, 3 AG	75915	FU-8
F1 (234 v)	Fuse, 0.75 amp, 3 AG	75915	FU-14
---	Fuse Holder (Mfg. No. 34201)	75914	FH-3
G1 (60 cps)	Chopper	80164	CV-2
G1 (50 cps)	Chopper	80164	CV-3
J1	Receptacle Assembly, Input	80164	12450B
---	Plug, Special, Mate of J1	80164	13011B
J2	Receptacle, Microphone, OUTPUT (Mfg. No. 80PC2F)	02660	CS-32
---	Plug, Microphone, Mate of J2 (Mfg. No. 80MC2M)	02660	CS-33
--(r)	Binding Post OUTPUT (Mfg. No. DF21RC)	58474	BP-11R
--(r)	Binding Post, LO (Mfg. No. DF21BC)	58474	BP-11B
--(r)	Binding Post, G (Mfg. No. DF21BC)	58474	BP-11B
--(r)	Shorting Link (Mfg. No. 938-L)	24655	BP-6
L1	Choke, 200 hy	80164	CH-1
M	Meter	80164	ME-14
---	Meter Lamp (Mfg. No. 323)	08804	PL-1
P1	Power Cord, 6 feet (Mfg. No. 4638-13)	82879	CO-2
---	Cable Clamp	80164	CC-7
S1	Rotary Switch less components, FUNCTION	80164	SW-56A

(r) Used only on Model 150AR.

MISCELLANEOUS PARTS (Cont'd)

Circuit Desig.	Description	Mfg. Code	Keithley Part No.
---	Rotary Switch with components, FUNCTION	80164	12914B
---	Skirted Knob, Function Switch	80164	KN-11
S2	Rotary Switch less components, RANGE	80164	SW-54
---	Rotary Switch with components, Range	80164	12310B
---	Skirted Knob, Range Switch	80164	KN-10
S3	Rotary Switch less components, ZERO SUPPRESS Range	80164	SW-58
---	Rotary Switch with components, Zero Suppress, Range	80164	12311B
---	Skirted Knob, Zero Suppress Range Switch	80164	KN-10
---	Skirted Knob, Zero Suppress Set Potentiometer	80164	KN-17
S4	Toggle Switch, DPDT, ON (Mfg. No. 20905-FR)	04009	SW-14
T1	Power Transformer	80164	TR-27
T2	Demodulator Transformer	80164	TR-26
T3	Input Transformer	80164	TR-28

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.
R101	33 kΩ	10%, 1/2 w	Comp	01121	EB	R1-33K
R102	2 MΩ	1%, 1 w	MtF	75042	MEF	R44-2M
R103	47 kΩ	10%, 1/2 w	Comp	01121	EB	R1-47K
R104	1 MΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-1M
R105	3.3 MΩ	10%, 1/2 w	Comp	01121	EB	R1-3.3M
R106	1 MΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-1M
R107	22 kΩ	10%, 1/2 w	Comp	01121	EB	R1-22K
R108	3.3 MΩ	10%, 1/2 w	Comp	01121	EB	R1-3.3M
R109	1 MΩ	10%, 1/2 w	Comp	01121	EB	R1-1M
R110	22 kΩ	10%, 1/2 w	Comp	01121	EB	R1-22K
R111	1 MΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-1M
R112	*200 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-200K
R113	100 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-100K
R114	100 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-100K
R115	1.2 MΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-1.2M
R116	470 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-470K
R117	333 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-333K
R118	500 kΩ	10%, 2 w	CbVar	01121	J53034	RP5-500K
R119	680 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-680K
R120	3.3 MΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-3.3M

*Nominal value, factory selected.

RESISTORS (Cont'd)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.
R121	2.2 MΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-2.2M
R122	62 kΩ	1%, 1 w	DCb	91637	DCF-1	R13-62K
R123	100 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-100K
R124	1 MΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-1M
R125	1 MΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-1M
R126	30 kΩ	5%, 10 w	WW	63743	10F	R5-30K
R127	10 kΩ	10%, 2 w	WWVar	71450	WP10K	RP9-10K
R128	95.3 kΩ	1%, 1 w	MtF	75042	CEC	R94-95.3K
R129	Not Used					
R130	Not Used					
R131	Not Used					
R132	Not Used					
R133	*220 kΩ	10%, 1/2 w	Comp	01121	EB	R1-220K
R134	**10 Ω	1%	WWSpec	80164		R18-18-10
R135	**10 kΩ	1%	WWSpec	80164		R18-18-10K
R136	1.11 kΩ	1%, 1/2 w	DCbSpec	80164		R38-1.11K
R137	100 kΩ	1%, 1/2 w	DCbSpec	80164		R38-100K
R138	10 kΩ	5%,	WWSpec	80164		R18-19-10K
R139	Not Used					
R140	10 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-10K
R141	3.33 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-3.33K
R142	1 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-1K
R143	333 Ω	1%, 1/2 w	WW	01686	7020	R48-333
R144	100 Ω	1%, 1/2 w	WW	01686	7020	R48-100
R145	33.3 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-33.3
R146	10 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-10
R147	*3.33Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-3.33
R148	*1.0 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-1.0
R149	1 MΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-1M
R150	333 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-333K
R151	100 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-100K
R152	33.3 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-33.3K
R153	500 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-500
R154	500 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-500
R155	10 MΩ	1%, 1 w	DCb	91637	DCF-1	R13-10M
R156	3.3 MΩ	10%, 1/2 w	Comp	01121	EB	R1-3.3M
R157	1 MΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-1M
R158	333 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-333K
R159	99 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-99K
R160	32.3 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-32.3K

*Nominal value, factory selected.
**Resistors R134 and R135 are matched to 1/2%. Order only as a pair.

RESISTORS (Cont'd)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.
R161	9 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-9K
R162	100 kΩ	10%, 1/2 w	Comp	01121	EB	R1-100K
R163	390 kΩ	10%, 1/2 w	Comp	01121	EB	R1-390K
R164	100 kΩ	10%, 1/2 w	Comp	01121	EB	R1-100K
R165	47 kΩ	10%, 1/2 w	Comp	01121	EB	R1-47K
R166	15 kΩ	10%, 1/2 w	Comp	01121	EB	R1-15K
R167	4.7 kΩ	10%, 1/2 w	Comp	01121	EB	R1-4.7K
R168	5.6 kΩ	10%, 1/2 w	Comp	01121	EB	R1-5.6K
R169	2.2 kΩ	10%, 1/2 w	Comp	01121	EB	R1-2.2K
R170	1 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-1K
R171	1 MΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-1M
R172	100 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-100K
R173	9 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-9K
R174	10 kΩ	3%, 5 w	WWVar	73138	A-R10K-125	RP4-10K
R175	100 MΩ	1%, 2 w	DCb	91637	DC-2	R14-100M
R176	10 k	10%, 1/2 w	Comp	01121	EB	R1-10K
R177	10 kΩ	10%, 2 w	WWVar	71450	WP10K	RP9-10K
R178	75 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-75K
R179	75 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-75K
R180	30 kΩ	5%, 10 w	WW	63743	10F	R5-30K
R181	**100 kΩ	1%, 1/4 w	WW	80164		R18-21-100K
R182	**1 MΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-1M
R183	*1 MΩ	10%, 1/2 w	Comp	01121	EB	R1-1M
R184	*82 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-82
R501	100 Ω	10%, 2 w	Comp	01121	HB	R3-100
R502	100 Ω	10%, 2 w	Comp	01121	HB	R3-100
R503	5 kΩ	5%, 10 w	WW	44655	BLUME	R5-5K
R504	5 kΩ	5%, 10 w	WW	44655	BLUME	R5-5K
R505	22 kΩ	10%, 2 w	Comp	01121	HB	R3-22K
R506	10 MΩ	10%, 1/2 w	Comp	01121	EB	R1-10M
R507	220 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-220K
R508	33 kΩ	10%, 1/2 w	Comp	01121	EB	R1-33K
R509	33 kΩ	10%, 1/2 w	Comp	01121	EB	R1-33K
R510	1 MΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-1M
R511	600 kΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-600K
R512	6 Ω	10%, 5 w	WW	44655	4654	R4-6

* Nominal value, factory selected.

** Not usually in instrument but supplied upon request.

VACUUM TUBES

Circuit Desig.	Number	Mfg. Code	Keithley Part No.
V1	6084	73445	EV-6084/E80F
V2	EF86	73445	EV-EF86/6267
V3	EF86	73445	EV-EF86/6267
V4	12AX7	73445	EV-12AX7
V5	12AT7	73445	EV-12AT7
V6	6CM6	00011	EV-6CM6
V7	***0A2	80164	EV-0A2
V8	12B4A	85599	EV-12B4A
V9	***5651	80164	EV-5651
V10	12AX7	73445	EV-12AX7

MODEL 1501 REPLACEABLE PARTS LIST

Description	Mfg. Code	Keithley Part No.
Plug Assembly	80164	13011B
Cable, 48 inches, Vinyl, shielded	86696	SC-5
Alligator Clamps, (2), (Mfg. No. 60C5)	76545	AC-8

MODEL 1502 REPLACEABLE PARTS LIST

Description	Mfg. Code	Keithley Part No.
Plug Assembly	80164	13011B
Cable, 10 feet, Vinyl, shielded	86696	SC-5

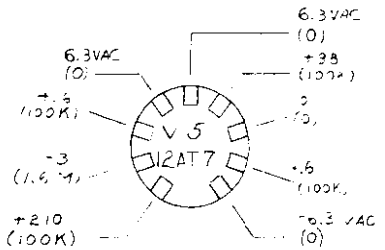
*** Specially aged tubes.

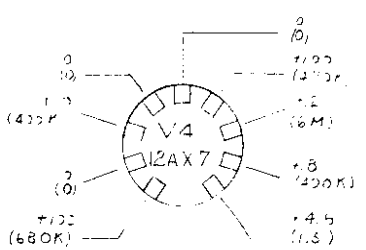
00011	Sylvania Electric Products, Inc. Buffalo Operations of Sylvania Electronic Systems Buffalo, N. Y.	02660	Amphenol-Borg Electronics Corp. Broadview Chicago, Illinois
00656	Aerovox Corp. New Bedford, Mass.	04009	Arrow-Hart and Hegeman Electric Co. Hartford, Conn.
01121	Allen-Bradley Corp. Milwaukee, Wis.	05397	Kemet Co. Cleveland, Ohio
01686	RCL Electronics, Inc. Riverside, N. J.	08804	Lamp Metals and Components Department G. E. Co. Cleveland, Ohio

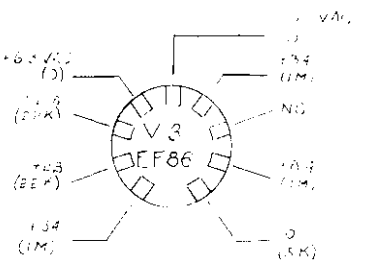
TABLE 2 (Sheet 1). Code List of Suggested Manufacturers. (Based on Federal Supply Code for Manufacturers, Cataloging Handbook H4-1.)

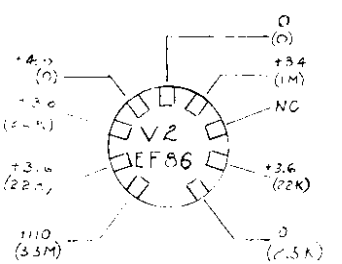
12954	Dickson Electronics Corp. Scottsdale, Ariz.	75915	Littelfuse, Inc. Des Plaines, Ill.
14655	Cornell-Dubilier Electric Corp. Newark, N. J.	76545	Mueller Electric Co. Cleveland, Ohio
24655	General Radio Co. West Concord, Mass.	79727	Continental-Wirt Electronics Corp. Philadelphia, Pa.
44655	Ohmite Mfg. Co. Skokie, Ill.	80164	Keithley Instruments, Inc. Cleveland, Ohio
56289	Sprague Electric Co. North Adams, Mass.	81483	International Rectifier Corp. El Segundo, Calif.
58474	Superior Electric Co., The Bristol, Conn.	82879	Royal Electric Corp. Pawtucket, R. I.
63743	Ward Leonard Electric Co. Mount Vernon, N. Y.	83125	General Instrument Corp. Capacitor Division Darlington, S. C.
71450	CTS Corp. Elkhart, Ind.	84171	Arco Electronics, Inc. Great Neck, N. Y.
72982	Erie Technological Products, Inc. Erie, Pa.	85599	Tube Department G. E. Co. Schenectady, N. Y.
73138	Helipot Division of Beckman Instruments, Inc. Fullerton, Calif.	86696	Radix Wire Co. Cleveland, Ohio
73445	Amperex Electronic Co. Division of North American Philips Co., Inc. Hicksville, N. Y.	91637	Dale Electronics, Inc. Columbus, Nebr.
75042	International Resistance Co. Philadelphia, Pa.		

TABLE 2 (Sheet 2). Code List of Suggested Manufacturers. (Based on Federal Supply Code for Manufacturers, Cataloging Handbook H4-1.)

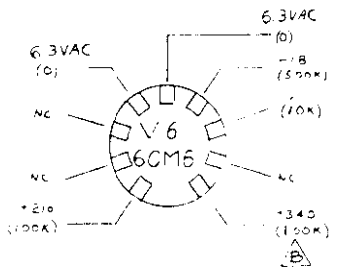


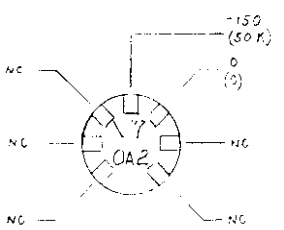


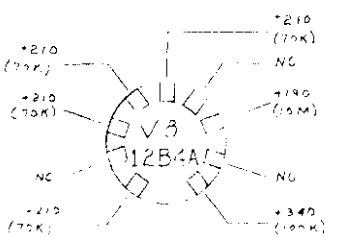


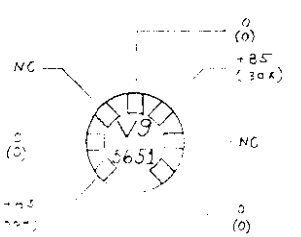


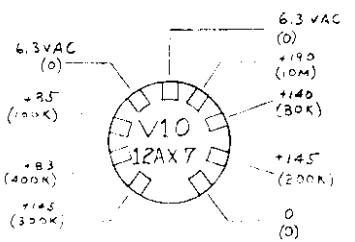
PC-22











MODEL 150A

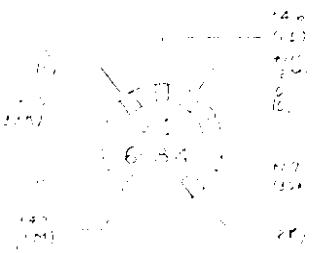
VOLTAGE AND RESISTANCE CHART

A

MEASUREMENTS FROM TUBE PIN TO GROUND USING [illegible] WITH 10 MEG INPUT RESISTANCE. FUNCTION SWITCH AT MILLIVOLTS, MULTIPLIER RANGE SWITCH AT 1000, ZERO SUPPRESS OFF.

ALL READINGS ARE APPROX MATE

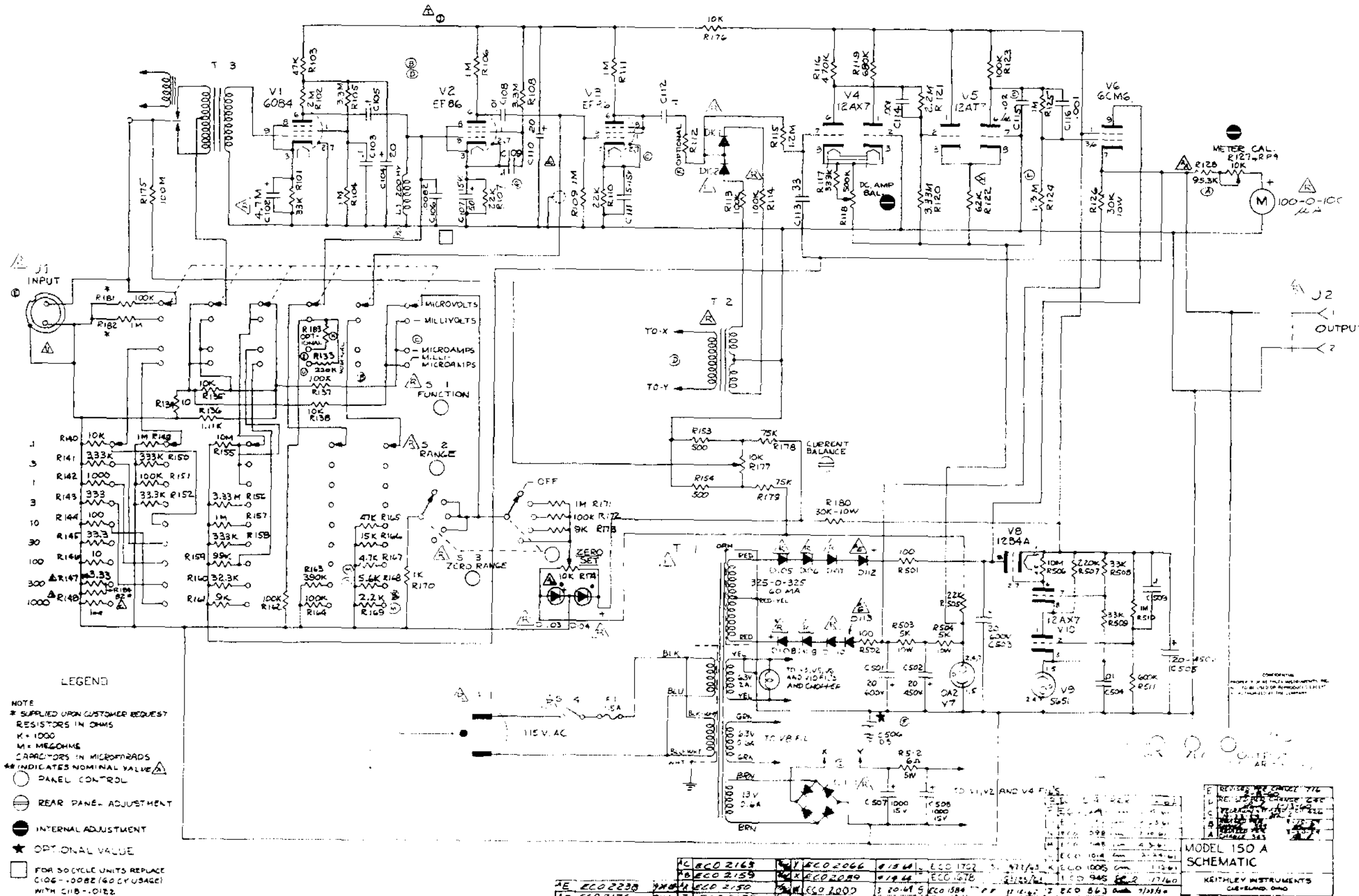
RESISTANCES ARE GIVEN IN OHMS; K=1000, M=MEGOHMS



C	[illegible]	[illegible]	3/22/65
B	PER D.C.N. 1440 500K 5.26.65		
A	PER D.C.N. 1345 FOR PRODUCTION		

KIN[illegible] INSTRUMENTS

12393C



MODEL 150 A
SCHEMATIC
KEITHLEY INSTRUMENTS
CLEVELAND, OHIO
12188D
LEGEND
NOTE
* SUPPLIED UPON CUSTOMER REQUEST
RESISTORS IN OHMS
K = 1000
M = MEGOHMS
CAPACITORS IN MICROFARADS
** INDICATES NOMINAL VALUE
PANEL CONTROL
REAR PANEL ADJUSTMENT
INTERNAL ADJUSTMENT
OPTIONAL VALUE
FOR 50 CYCLE UNITS REPLACE C106 - .0082 (60 CY USAGE) WITH C118 - .0122
J1 INPUT
J2 OUTPUT
S1 FUNCTION
S2 RANGE
S3 ZERO RANGE
ZERO SET
CURRENT BALANCE
METER CAL.
DC AMP BAL.
MICROVOLTS
MILLIVOLTS
MICROAMPS
MILLI-MICROAMPS
OFF
115 V. AC
TO V1, V2 AND V4 FIL'S
TO V8 FIL
TO V5, V6 AND V10 FIL'S AND CHOPPER
V1 6084
V2 EF86
V3 EF86
V4 12AX7
V5 12AT7
V6 6CM6
V7 OA2
V8 12B4A
V9 5651
V10 12AX7
T1
T2
T3
TO-X
TO-Y
100-0-100 μA
ECO 2238
ECO 2176
ECO 2163
ECO 2159
ECO 2150
ECO 2138
ECO 2066
ECO 2089
ECO 2009