

BENCH BRIEFS

SERVICE INFORMATION FROM HEWLETT-PACKARD

SPECIAL
COMBINED
ISSUE

MAY-AUGUST 1977

FRACTIONAL N SIMPLIFIES FREQUENCY SYNTHESIS

by Kenneth Jessen,
HP Loveland Division

INTRODUCTION

Hewlett-Packard is introducing several new instruments that use a new frequency synthesis technique known as fractional N. This new technique overcomes many of the limitations of the traditional divide-by-N loop. Any given divide-by-N loop can only produce frequencies which are integral multiples of the reference frequency. The 3330B Automatic Synthesizer, for example, uses four divide-by-N loops of different frequency ranges to produce an overall range from 0.1 Hz to 13,000,999.9 Hz. The first, second and third digits of the output frequency are controlled by the first divide-by-N loop. The fourth and fifth digits are controlled by the second divide-by-N loop; the sixth and seventh digits are controlled by the third loop and the remaining two digits by the fourth loop. (Summation loops are also required to sum the outputs of the divide-by-N loops but they are ignored to simplify this discussion.)

The new HP3335A Synthesizer/Level Generator can produce frequencies from 200.00 Hz to 80,099,999,999 Hz using *only two loops*. One loop is a common divide-by-N loop producing 39 MHz to 79 MHz in 1 MHz steps. The second loop, and topic of this article, is a fractional N loop able to generate frequencies from 1 MHz to 1.999999999 MHz in 0.001 Hz steps. The advantages of fractional N are obvious; greater frequency resolution, wider frequency range and fewer loops.

DIVIDE-BY-N LOOP

In order to more readily understand how a fractional N loop works, one must first understand the more traditional phase lock loop with a divide-by-N element. The fractional N loop is really a modified divide-by-N loop.

Figure 1 illustrates the basic concept involved in a phase lock loop. The phase detector compares the Voltage Controlled Oscillator (VCO) output to the reference signal and produces a tune voltage proportional to the phase difference of these two inputs. The tune voltage is "cleaned up" by passing it through a low-pass filter to suppress noise and high frequency components. The polarity of the tune voltage is such that it will pull the VCO frequency in a direction to phase-track the reference frequency.

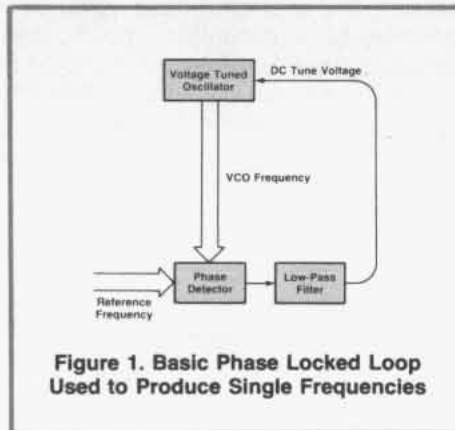


Figure 1. Basic Phase Locked Loop Used to Produce Single Frequencies

In the previous example, the frequency of the VCO must match that of the reference. For single frequency applications this is fine, but to extend the usefulness of the loop, a divide-by-N element must be added as shown in Figure 2. The basic difference is that the VCO frequency is N times the reference frequency. The modulus of the

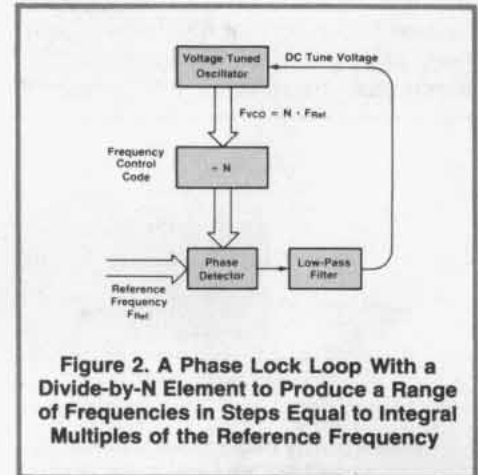


Figure 2. A Phase Lock Loop With a Divide-by-N Element to Produce a Range of Frequencies in Steps Equal to Integral Multiples of the Reference Frequency

divide-by-N block can be stepped to produce frequencies that are integral multiples of the reference. The VCO can now produce a range of discrete frequencies, all phase locked to the reference.

FRACTIONAL N LOOP — OPEN LOOP CONDITION

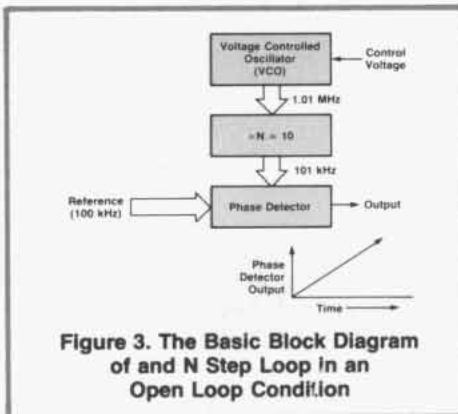
A fractional N loop is simply a modified divide-by-N loop. The fractional N loop is capable of operating at frequencies which are *not* integral multiples of the reference signal. In fact, the fractional N loop can be made to operate at any frequency greater than the reference frequency up to the upper limit of the

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VCO. As mentioned previously, the divide-by-N loop in the 3335A Synthesizer/Level Generator produces 39 MHz to 79 MHz in 1 MHz steps (using a 1 MHz reference), and the fractional N loop in the 3335A produces from 1 MHz to 1.999999999 MHz in 0.001 Hz steps using a 100 kHz reference signal.

The best place to begin this explanation is to assume an open loop configuration for a normal divide-by-N loop (see Figure 3). For this example, assume that the reference frequency is



100 kHz and that the divide-by-N number is 10. Also assume that the VCO frequency is 1.01 MHz. This means that the VCO is operating at a *fractional multiple* (10.1) of the reference signal. It would be impossible to close this loop if it were a divide-by-N loop because the phase detector compares the reference signal to the divide-by-N signal, and then generates a dc level equivalent to the phase difference. That is, the VCO is not operating at an integral number times the reference signal, but rather as a fractional component; this means the *phase of the VCO is advancing*. Since the phase of the VCO signal (divided by 10) is advancing relative to the phase of the reference signal, the phase detector puts out an ever increasing dc level. In the normal case (closed divide-by-N loop), the phase detector's output would be used as the tune voltage back to the VCO forcing its frequency to drop from 1.01 MHz to 1.00 MHz. In the fractional N loop, the phase is allowed to advance and the phase detector outputs a ramp.

Reference periods are defined using Figure 3 as follows: While the reference signal goes through one period, the VCO, operating 10.1 times as fast,

goes through 10.1 cycles. To put this another way, the VCO advances one-tenth of a cycle relative to its integral part for every reference period. After the passage of two reference periods, the VCO has gone 20.2 cycles and after ten reference periods, the VCO has advanced 101 cycles (100 cycles plus one extra cycle which represents the fractional component). Table 1 illustrates this point quite well.

Note that after ten reference periods, the VCO has gone *one full cycle* beyond what would be needed to close

integral multiple of the reference frequency (100 kHz in this example) and the system can be phase locked. Between removals of one cycle, however, the instantaneous frequency is still 1.01 MHz.

The element required to achieve this mode of operation is a pulse remover and is shown in Figure 5. The output of the phase detector is a sawtooth riding on a dc voltage. The output of the phase detector increases linearly as the phase of the VCO divided-by-N advances on the reference signal. Each

Table 1. Phase Relationship of the Integral Part of the VCO Frequency Times N Relative to its Fractional Part as Expressed in Phase Advancement.

No. of Ref. Periods (Fref=100 kHz)	No. of Completed Cycles of		Phase Advancement
	$N \times \text{Fref} = 1 \text{ MHz}$	$N \cdot F = 1.01 \text{ MHz}$	
1	10	10.1	0.1 cycle of phase
1	10	10.1	0.2 cycle of phase
3	30	30.3	0.3 cycle of phase
4	40	40.4	0.4 cycle of phase
.	.	.	.
.	.	.	.
.	.	.	.
9	90	90.9	0.9 cycle of phase
10	100	101.0	1 full cycle of phase (360°)

* $N \times \text{Fref}$ = Integer part of the VCO frequency

** $N \cdot F$ = Integer and fractional part of the VCO frequency

the loop and phase lock this system. If one VCO cycle could somehow be *removed* from the string of VCO cycles after the passage of ten reference periods, the average phase advancement would be cancelled. That is, the output of the phase detector, instead of increasing without bound as shown in Figure 3, would be reset to zero every ten reference periods as shown in Figure 4. By cancelling the average phase advancement, the *average* frequency from the divide-by-N block becomes an

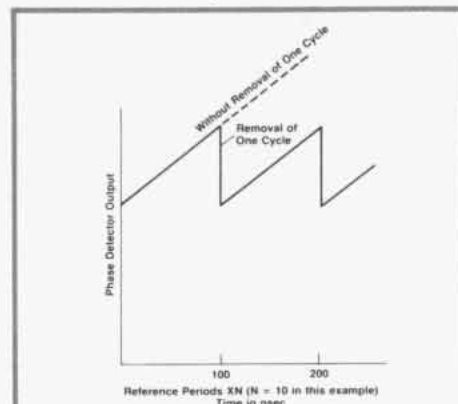


Figure 4. The Output of the Phase Detector Shown Here is a Sawtooth Riding on a dc Voltage.

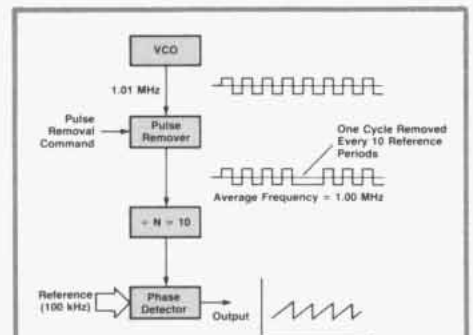


Figure 5. The Basic Block Diagram of a Modified N Step Loop With a Pulse Remover Added to Allow the VCO to Operate at a Fractional Frequency

time the VCO advances one full cycle, the pulse remover is actuated and the phase advancement is reset to its zero degree level. The dc voltage level which the sawtooth is riding on can then be used as the tune voltage needed to phase lock the system.

The next step is to devise a method to trigger the pulse remover by determining when the VCO frequency has advanced one full cycle. The fractional portion of the VCO contains the information needed to accomplish this. The fractional portion is stored in a register and added to a second register each



reference period. This second register, called the phase register, then contains a running total of the phase advancement. The contents of the phase register are represented in the right-hand column of Table 1. When the phase register reaches or exceeds unity, the VCO has advanced one full cycle and the overflow of this register is used to trigger the pulse remover.

Now assume that the VCO operates at a frequency such as 10.3 MHz which is not evenly divisible into 1.0. After one reference period, the VCO frequency has advanced 10.3 cycles; after two reference periods 20.6 cycles, and after three periods 30.9 cycles. At this point, the phase register contains 0.9. In the fourth reference period, the VCO has advanced 41.2 cycles which causes the phase register to overflow, in turn, triggering the pulse remover. Note that when the phase register overflowed, it contained a count of 1.2. To preserve the correct relationship between pulse removal and the reference frequency, the next sequence begins with the excess count of 0.2 loaded in the phase register (instead of zero if the VCO frequency was 1.01 MHz).

Figure 6 shows the elements needed to properly remove a pulse automatically whenever the VCO has advanced one full cycle relative to the reference frequency. The next step is to close the loop. Note that the phase detector's output is a sawtooth riding on a dc level. The dc portion is the part which

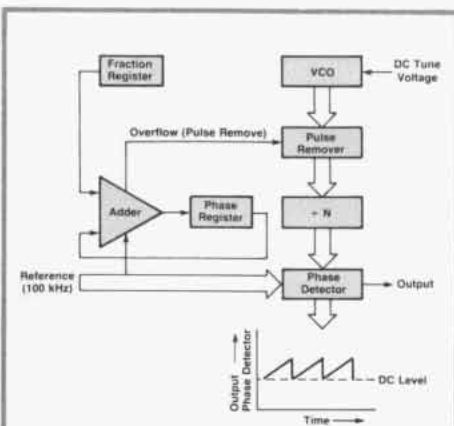
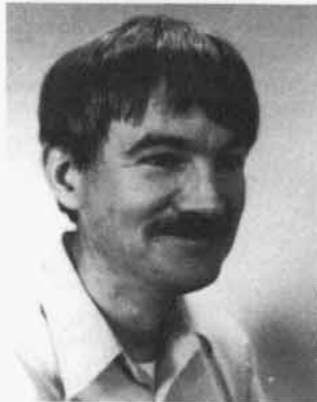


Figure 6. Fractional N Loop Showing a Phase Register Used to Trigger the Removal of One VCO Cycle (or Pulse).



Ken Jessen received his BSEE and MBA from the University of Utah before joining HP in 1965. Ken is in Customer Service at the Loveland, Colorado, Division where he is Service Manager for the sources and analyzer product line.

Spare time activities include writing both technical articles for trade publications, as well as historical articles on Colorado rail transportation for local newspapers. Ken is also a member of the Loveland Public Library board of directors.

represents the proper tune voltage to be fed into the VCO. Anything other than dc fed to the VCO will prevent phase lock and cause frequency modulation.

Since the phase register is incremented each reference period, its contents represent an instantaneous fractional sum which grows until one cycle of phase advancement has occurred. The contents of the phase register as viewed with respect to time, is shown in Figure 7. The contents of the phase register can be represented by a staircase ramp resetting each time a pulse is removed. Note that the phase register, when viewed graphically, has the same characteristics as the sawtooth output from the phase detector.

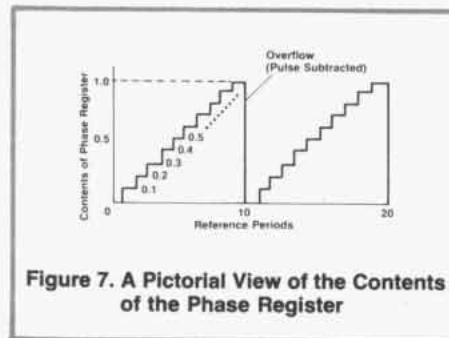


Figure 7. A Pictorial View of the Contents of the Phase Register

Figure 8 shows the addition of a digital-to-analog converter (DAC) to the output of the phase register. By converting the contents of the phase register into voltage through the DAC, the sawtooth output of the phase detector can be approximated. The next step is to smooth the output of the DAC to

remove the stairs, invert it and sum it with the output of the phase detector. This essentially eliminates the sawtooth portion of the output of the phase detector and when filtered, produces a clean dc tune voltage for the VCO.

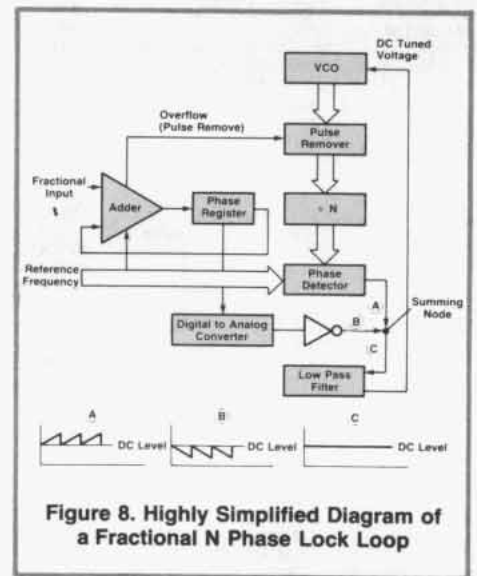


Figure 8. Highly Simplified Diagram of a Fractional N Phase Lock Loop

This ends a simplified explanation of the concepts involved in a fraction N loop. Actual implementation is more complex. For example, to convert the staircase output of the phase register into a smooth sawtooth requires current sources and an integrator. A sample and hold circuit is used to produce a transient free dc tune voltage. A tune current is needed to allow the loop to relock after a large change in VCO frequency. Despite the additional circuitry, the basic principle given in this article will still hold true. □

COUNTRIES AND THEIR VOLTAGES

Following is a complete and up-to-date guide to foreign voltages. In general, all references to 110V apply to the range 100V to 160V. References to 220V apply to the range from 200V to 260V. Where 110/220V is indicated, voltage varies within country, depending on location.

Aden	220V	Curacao	110V
Afghanistan	220V	Cuba	110V
Algeria	110/220V	Cyprus	220V
Angola	220V	Czechoslovakia	110/220V
Anguilla	220V	Dahomey	220V
Antigua	110/220V	Denmark	220V
† Argentina	220V	Dominica	220V
Aruba	110V	Dominican Rep.	110/220V
† Australia	220V	Ecuador	110/220V
Austria	220V	Egypt	110/220V
Azores	110/220V	El Salvador	110V
Bahamas	110/220V	Ethiopia	110/220V
Bahrain	220V	Fiji	220V
Bangladesh	220V	Finland	220V
Barbados	110/220V	France	110/220V
Belgium	110/220V	French Guiana	110/220V
Bermuda	110/220V	Gabon	220V
Bhutan	220V	Gambia	220V
Bolivia	110/220V	† Germany	110/220V
Bonaire	110/220V	Ghana	220V
Botswana	220V	Gibraltar	220V
† Brazil	110/220V	* Great Britain	220V
Brit. Honduras	110/220V	† Greece	110/220V
Brit. Virgin I.	110/220V	Greenland	220V
Bulgaria	110/220V	Grenada	220V
Burma	220V	Grenadines	220V
Burundi	220V	Guadeloupe	110/220V
Cambodia	110/220V	Guatemala	110/220V
Cameroon	110/220V	Guinea	220V
Canada	110/220V	Guyana	110/220V
Canal Zone	110/220V	Haiti	110/220V
Canary I.	110/220V	Honduras	110/220V
Cayman I.	110V	* Hong Kong	220V
Gen. African Rep.	220V	Hungary	220V
Chad	220V	Iceland	220V
Channel I. (Brit)	220V	† India	220V
† Chile	220V	Indonesia	110/220V
China	220V	Iran	220V
Colombia	110V	Iraq	220V
Costa Rica	110/220V	Ireland	220V
		Isle of Man	220V

Israel	220V	* Rhodesia	220V
Italy	110/220V	Romania	110/220V
Ivory Coast	220V	Rwanda	220V
Jamaica	110/220V	Saba	110/220V
Japan	110V	St. Barthelemy	220V
Jordan	220V	St. Eustatius	110/220V
Kenya	220V	St. Kitts	220V
Kuwait	220V	St. Lucia	220V
Laos	110/220V	St. Maarten	110/220V
Lebanon	110/220V	St. Vincent	220V
Lesotho	220V	Saudi Arabia	110/220V
Liberia	110/220V	Scotland	220V
Libya	110/220V	Senegal	110V
Liechtenstein	220V	Seychelles	220V
Luxembourg	110/220V	Sierra Leone	220V
Macao	110/220V	* Singapore	110/220V
† Madeira	220V	Somalia	110/220V
Majorca	110V	South Africa	220V
Malagasy Rep.	220V	South Korea	220V
Malawi	220V	Spain	110/220V
Malaysia	220V	Sri Lanka	
Malta	110/220V	(Ceylon)	220V
Malta	220V	Sudan	220V
Martinique	110/220V	Surinam	110/220V
Mauritania	220V	Swaziland	220V
Mexico	110/220V	† Sweden	110/220V
Monaco	110/220V	Switzerland	110/220V
Montserrat	220V	Syria	110/220V
Morocco	110/220V	Tahiti	110/220V
Mozambique	220V	Taiwan	110/220V
Nepal	220V	Tanzania	220V
Netherlands	110/220V	Tobago	110/220V
Neth. Antilles	110/220V	Togo	110/220V
Nevis	220V	Tonga	220V
New Caledonia	220V	Trinidad	110/220V
New Guinea	220V	Tunisia	110/220V
New Hebrides	220V	Turkey	110/220V
New Zealand	220V	Turks & Calcos I.	110V
Nicaragua	110/220V	Uganda	220V
Niger	220V	Upper Volta	220V
* Nigeria	220V	Uruguay	220V
Northern Ireland	220V	United Arab Emirates	220V
Norway	220V	USA	110V
Okinawa	110V	USSR	110/220V
Oman	220V	U.S. Virgin I.	110V
Pakistan	220V	Venezuela	110/220V
Panama	110V	Vietnam	110/220V
† Paraguay	220V	Wales	220V
Peru	220V	Yemen	220V
Philippines	110/220V	Yugoslavia	220V
Poland	110/220V	Zaire	220V
Portugal	110/220V	Zambia	220V
Puerto Rico	110V		
Qatar	220V		

* Denotes countries in which plugs with 3 square pins are used (in whole or part).

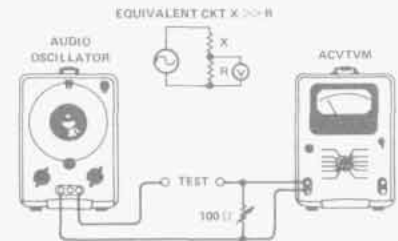
† Countries using DC in certain areas.

FAST L-C MEASUREMENTS!!!

Here is a very old but convenient method for determining the value of unmarked capacitors or inductors using instruments commonly found in most maintenance shops and labs. The method is based on the axiom that when an impedance is fed from a constant-current source, the voltage across the impedance is a function of the magnitude of the impedance.

See figure below. To calibrate the setup connect a known value capacitor or inductor to the TEST terminals. Set the oscillator to the desired frequency with maximum output. For example, I used 10 Hertz to calibrate on a 1.0 microfarad capacitor and 100kHz to calibrate on a 100pF capacitor. Set the VTVM to the 0.1 volt range and adjust the 100 ohm resistor for an indication on the VTVM that agrees with the value of the known capacitor or inductor.

Example: 100pf = 0.1v, 50pf = 0.5v, etc., or the reciprocal for a known inductor. Connect the unknown to TEST and read directly capacitance or reciprocal of inductance. NOTE: For best accuracy the ratio of X to R should be 100:1 or greater.



Digital Troubleshooting

AN HP VIDEOTAPE TRAINING PROGRAM

"Digital Troubleshooting" ... a videotape series developed to train HP's own technicians is a course especially useful in showing how to approach real problems in real equipment. These videocassettes provide:

- Practical demonstrations
- Flexibility of use for classroom or individual study
- Latest in digital troubleshooting tools

- Most recent logic symbology (ANSI Y32.14/IEEE 91-1973)
- Useful troubleshooting tips

This course was designed, developed, and made for technicians. It is an appropriate bridge from transistors to digital electronics, or a digital refresher course. Equivalent in coverage to a college term of 13 weeks, Digital Troubleshooting is presented in color on 14 videocassettes having a total running time of 5 hours and 31 minutes. The lab demonstrations shown in video are from the workbook included with the series. Also included is a 180 page text and a study guide.

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There is ample use of reinforcement in the presentation and in the self-scoring quizzes at the end of most of the modules.

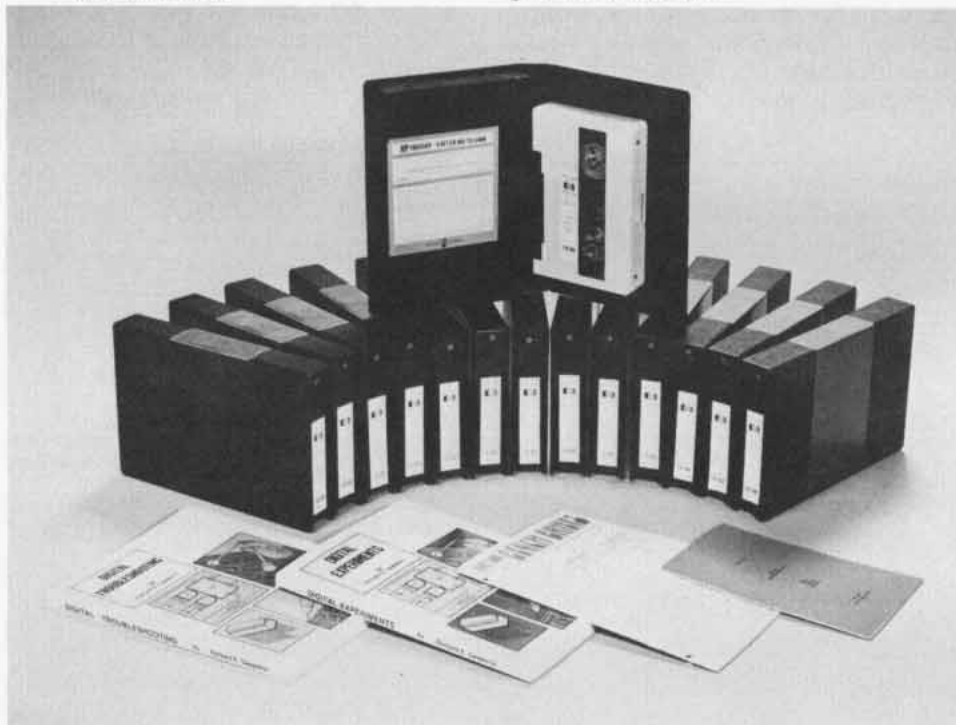
Individual tapes are:

1. Introduction To Digital Electronics (12 minutes)
2. Binary Nature of Digital Circuits (18 minutes)
3. Basics of Transistors and IC's (18 minutes)
4. Logic Gates and Symbols (25 minutes)
5. Introduction To Digital IC Families (29 minutes)
6. Modern Digital IC Families (27 minutes)
7. Simple Troubleshooting Techniques (18 minutes)

8. Troubleshooting Digital IC's (27 minutes)
9. Flip-Flops (31 minutes)
10. Counters and Shift Registers (30 minutes)
11. Combinational Logic Circuits (30 minutes)
12. Display Technologies (30 minutes)
13. IC Manufacturing (11 minutes)

14. Memories (25 minutes)

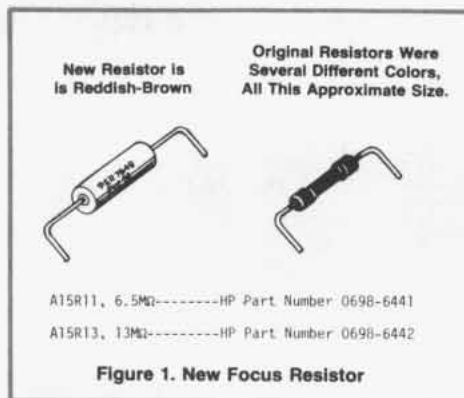
The videocassettes are available in the NTSC Standard only. Formats other than 3/4" videocassette can be quoted on request. The part number is 90420D which includes all tapes and study material, plus midterm and final exams, exam solutions and certificates of completion. See your local HP field engineer for details.



1700 Series Oscilloscopes

FOCUS PROBLEMS?

Are you having problems adjusting the beam focus on your HP1700 series oscilloscope? Service Notes for the 1710B, 1712A, 1720A, and 1722A scopes describe the problem as being related to resistors A1R11 (6.5 megohms) and A15R13 (13 megohms) changing value. Improved resistors from a different vendor are now being used (same part number). The new resistors have a reddish-brown body. The original resistors had reddish-brown, gray, or white bodies and are substantially smaller than the current resistors in use. The Figure below shows the relative size of the new and old resistors.



SAFETY-RELATED SERVICE NOTES

Service Notes from HP relating to personal safety and possible equipment damage are of vital importance. To make you more aware of these important notes, HP has recently modified the Safety Service Note format. The note is now printed on paper with a red border, and a "-S" suffix has been added to the note's number. In order to make you immediately aware of any potential safety problems, we are highlighting safety-related Service Notes here with a brief description of each problem. Also, in order to draw your attention to safety-related Service Notes on the Service Note order form at the rear of *Bench Briefs*, each appropriate number is highlighted by being printed in color.

745AC CALIBRATOR



HP 745A Calibrators with serials 00741-00101 thru 1319A01250 have the COUNTER OUTPUT BNC connector shell connected to the output LO SENSE terminal. When the 745A output is floated above ground, this BNC connector will have the same potential as the LO SENSE and LO

OUTPUT terminals. Use the following procedure to test your instrument for this condition.

1. Turn the power switch off, disconnect all power cords and signal cables. Disconnect the ground strap between LO OUTPUT and chassis ground.
2. Set an ohmmeter to the 1 kilohm range and connect one end to the LO SENSE terminal.
3. Connect the other ohmmeter lead to the outer shell of the COUNTER OUTPUT jack on the rear panel.
4. The ohmmeter should indicate infinity. If not, order the following parts and Service Note to modify the 745A to conform to current safety standards.

Service Note 745A-12A-S
Modification Kit 00745-89503

Troubleshooting Tip

DC REGULATED POWER SUPPLIES

by John Whidden,
HP New Jersey Division

Most HP power supply schematics seldom show operating voltages on transistors inside the feedback loop. The reason is that a DC regulated power supply is a closed loop device; when a component fails, all voltages inside that loop go to one extreme or another. Therefore any closed loop voltages

specified would be meaningless in a failed mode.

Since troubleshooting tables usually refer to a high or low output condition, fault finding is reduced to adjusting the voltage control to its mid-point, opening the feedback loop, then driving each stage into conduction or cutoff by either shorting or opening the previous stage. If the stage can be turned on and off, there is a 99% chance it will also work in between those points where it's supposed to. If the stage doesn't react as expected, then you have effectively

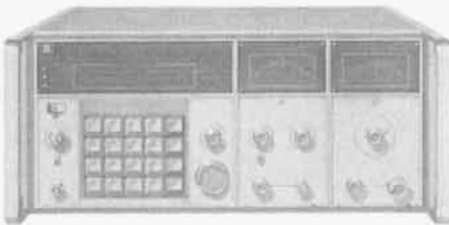
narrowed the search down to a few components.

If the problem is more subtle, try measuring the offset voltage across the comparison amplifier. If the summing point voltage is near zero, then the amplifier is following the programming as it should.

If the summing point voltage is not zero, it may be possible to force it there with the voltage control. The power supply may appear to work, but excessive current drawn through the voltage control circuit will not allow the power supply to meet its performance tests.

A SERVICE MANUAL FOR THE 8660 SIGNAL GENERATOR

by Gary Sprader,
HP Stanford Park Div.



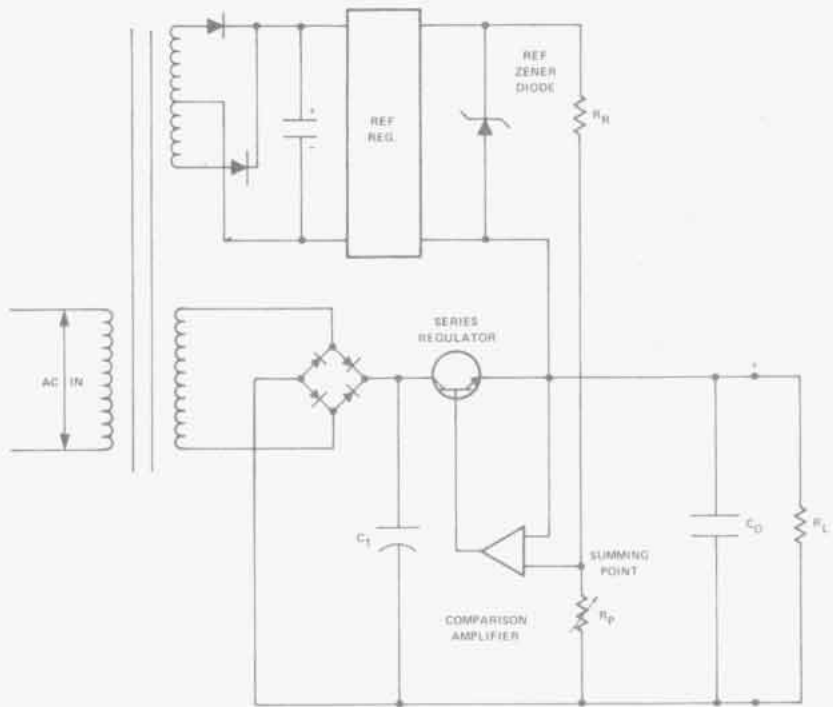
A new manual that explains the 8660 Synthesized Signal Generator system from a service point of view is now available. This manual begins with an explanation of phase lock loops and how they are used in the 8660, and continues with the functional modules and plug-ins. The book, which is really a service training course in itself, is designed for someone not familiar with the 8660.

To obtain a copy, contact your HP Sales and Service office and order HP part number 08660-90072.

DO YOU KNOW . . .

what IC manufacturers mean by SSI, MSI, LSI and GSI?

- SSI — Small Scale Integration; fewer than 12 logic gates on a chip.
- MSI — Medium Scale Integration; 12-100 logic gates on a chip.
- LSI — Large Scale Integration; 100-1000 logic gates on a chip.
- GSI — Grand Scale Integration; over 1000 logic gates on a chip.



John Whidden, service engineer at the New Jersey Division, joined HP in 1961 and became involved with power supply service and applications for field service and customer training.

John spends his spare time in photography and TV/radio repair. He is married and has three children.

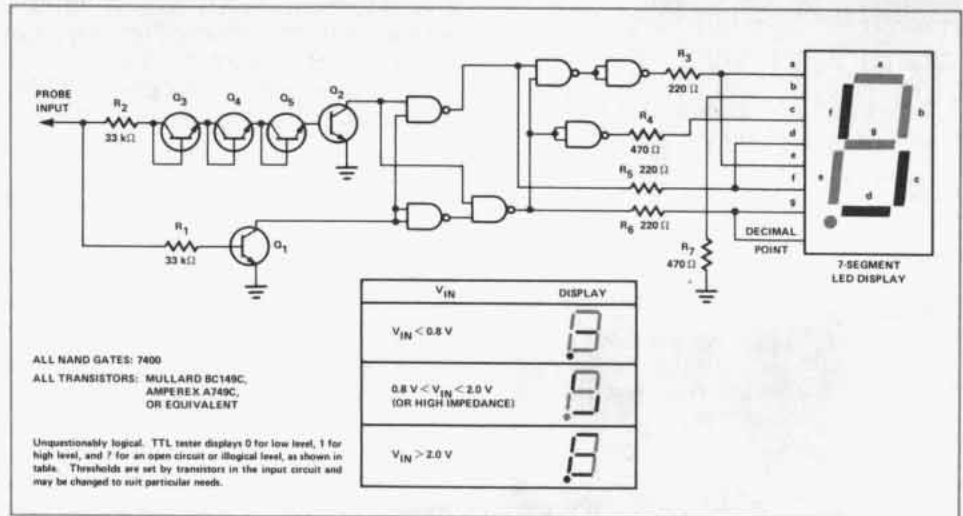
LOGIC TESTER HAS UNAMBIGUOUS DISPLAY

by S. Jayasimha Prasad and
M.R. Muralidharan
India Institute of Technology,
Madras, India

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1977

It usually takes a little time to interpret the display of most logic probes. But this tester flashes a totally unambiguous 0 or 1 or ? on its seven-segment display (the question mark indicating any voltage level not within the logic thresholds).

The circuit, built around transistor-transistor logic NAND gates, is shown in the figure. The output character display is controlled by the logic of input transistors Q_1 and Q_2 . If an input of less than 0.8 v is encountered, both transistors are off and the display is gated to indicate a 0. For an input greater than 2.0 v, both transistors are on, and the display indicates a 1.



For an input that lies between 0.8 v and 2.0 v, Q_1 is on while Q_2 is off, and the NAND gating causes a question mark to be indicated on the display. A high impedance at the input registers a similar output.

The logic thresholds, being set by the voltage drops of the transistors, can be tailored to suit other needs. Transistors Q_3 - Q_5 , which determine the logic-1

threshold, may be replaced with an appropriate number of diodes, and diodes may even be added in the base circuit of Q_1 to raise the logic-0 threshold.

Resistors R_1 and R_2 limit the input current, and R_3 - R_7 limit the currents to the display, which may be any low-power seven-segment light-emitting diode unit.

DIRECT-READING OHMMETER NEEDS NO CALIBRATION

by V. Ramprakash
Electronic Systems Research,
Madurai, India

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11, 1976; Copyright © McGraw-Hill,
Inc., 1976

A direct-reading ohmmeter with a linear scale can be made by connecting an operational amplifier, a milliammeter, a zener diode, and some resistors as shown in the circuit diagram. This ohmmeter does not require calibration, is self-zeroing, and is insensitive to the supply voltage.

The value of an unknown resistor is measured by connecting it as R_x . The reading on the milliammeter, I_m , is then R_x/R_c , where R_c is the resistance of a known standard resistor in the circuit. The current through the meter equals $(V_o - V_z)/R_m$, where V_o is the voltage at the output of the op amp, V_z is the drop across the zener diode (3 v), and R_m is the resistance in the meter circuit; here R_m is (2.9 + 0.1) kilohms. Since the

voltages at the inverting and noninverting input terminals of the op amp must be equal, $V_o R_c/(R_c + R_x)$ must equal V_z . Therefore: $V_o = V_z(R_c + R_x)/R_c$, or $I_m = (V_z/R_m)(R_x/R_c)$. The values of V_z and R_m shown yield:

$$R_x = (R_c)(I_m)$$

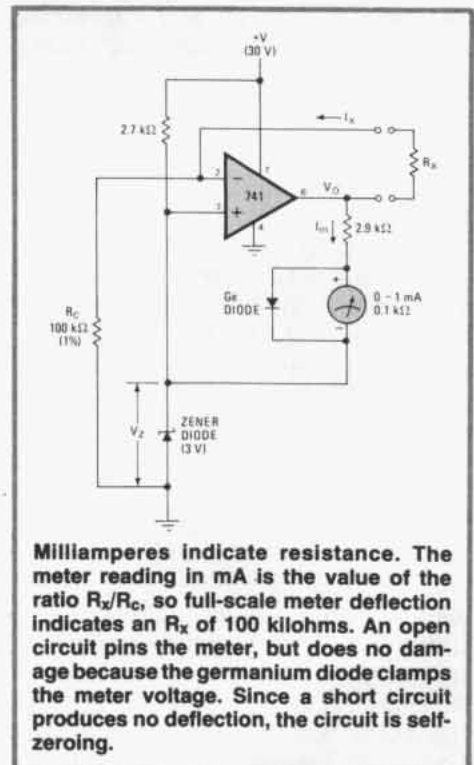
if I_m is the meter reading in milliamperes.

For an R_c of 100 kilohms, the 1-mA meter deflects full scale when R_x is 100 kilohms. Similarly, full scale can be made to indicate 10 kilohms or 1 kilohm by selecting these values for R_c . A range switch can be included in the circuit to set these values.

The current through the unknown resistor, I_x , is independent of the value of R_x . The equality of the op-amp input voltages makes V_z equal to $I_x R_c$, so $I_x = V_z/R_c$.

The meter has automatic zeroing because, if the measuring leads are short-circuited, V_o rises to exactly 3 v, sending no current into the meter. No calibration is necessary because the meter deflection has direct correspondence to the value of resistance being measured.

The germanium diode limits the voltage across the meter, and thus protects it from over-current when the measuring leads are left open.



Improved Power Switch

ATTENTION INSTRUMENTATION TAPE RECORDER OWNERS



HP Model 3964A/3968A/8864A/8868A Instrumentation Tape Recorders received a new push button power switch starting with serial prefix 1706A. This change is described in Service Note 3964A-6/3968A-7/8864A-6/8868-7.

If your machine has one of the older toggle switches and it fails, you can order a new pushbutton type with a higher surge current rating from the following list.

Model	HP Part No.
3964A	03964-60060
3964A-009,8864A (white panel)	03964-60061
3968A	03968-60060
3968A-009,8868A (white panel)	03968-60061

AUTOMATIC AUTORANGING?

There may be a time when you might use an autoranging voltmeter on the ohms scale to measure front-to-back ratio on transistors. All at once the meter begins switching back and forth between ranges. What's wrong? Actually nothing. It's a peculiarity that sometimes takes place when measuring a diode device (transistor junction) with a non-linear load line. What is happening is that since the load line is not linear, and the meter puts out a different current on each ohms range, the voltage/ current ration is constantly changing. When the current becomes excess the meter autoranges. As the current drops the meter autoranges again. The solution is to switch the meter to a fixed scale or change to a multi-meter.

THINK METRIC

Part of the metric system we are facing involves temperature measurement. Here is a little history lesson in Centigrade, Celsius, and Fahrenheit provided by André Rudé, HP Santa Clara Division.

Our present variety of scales dates back to the early 1700's and the beginning of modern temperature measurement. Then there were roughly as many scales as there were people who knew how to measure. Among them were Gabriel Fahrenheit, a Pole; Anders Celsius, a Swede; and later on, Lord Kelvin, a Briton.

Fahrenheit, who invented the mercury thermometer, based "zero" on the lowest temperature he could obtain with a mixture of salt and ice, which turned out to be 32 degrees (Fahrenheit) below the freezing point of water. As a second reference point, he picked the blood temperature of the human body and then divided the distance

between these two points in 96 degrees. (Actually blood temperature is two or three degrees higher than Fahrenheit reckoned, but inaccuracies in his original instrument caused this discrepancy.)

Celsius, meanwhile, developed a scale defined by the freezing and boiling points of pure water at sea level. Since he divided the space between these two points into 100 degrees, the scale was called "Centigrade" (from the Latin "centum"—one hundred).

In 1927, the multinational General Conference on Weights and Measures defined an international temperature scale which was, in fact, the Centigrade system. In the meantime, the Fahrenheit scale had come into common use in England and the United States.

Centigrade became Celsius at the 1948 meeting of the General Conference, a difference in name only. The principal reasons for the change were a desire for uniformity (in some parts of

Europe it was already called "Celsius") and a desire to honor the originator of the scale.

Comparison between the two scales is not necessary in learning Celsius temperature, just learn a handful of temperatures which become points of reference. In addition to the freezing (0°C) and boiling points (100°C) of water, know what the temperature is on a typical early morning for where you live; it could be 10°C in the summer and -5°C in the winter. 20°C is a comfortable room temperature; 30°C is getting warm and about time to turn the air conditioning on. 37°C is normal body temperature; 40°C for body temperature is alarming.

Get a metric thermometer and place it by your desk or outside and estimate the temperature at different times of the day. It is an easy way to start to think metric. Always remember that it's best not to convert back to Fahrenheit. Learn your temperature in Celsius and stick with it.

MICROPROCESSOR BUZZ WORDS

The Seventies will probably be known as the era of the microprocessor. It will become a decade that will see the unprecedented growth of a product which will change the world of electro-mechanics, electronic testing, and the communications industry. Its effect on our daily lives will be comparable to that of the computer.

It takes about 10 years for new words to find their way into the dictionary. Waiting so long to learn the new meaning of a word in so fast moving an industry as electronics could have a blighting effect on the education of those who wish to keep up to date. Schweber Electronics periodically publishes "BUZZ WORDS" a glossary of words that are the currency of the industry, words that mirror the present state of the art and give you a peek into the future.

Scanning these buzz words, you will soon realize that although the technology is new, the words are in common everyday use, but technology has given them uncommon meanings and only those in the know can communicate with them. "PORT", which we know as an embarkation point for ships, becomes the microprocessor's contact with the outside world. "BUS", a convenient vehicle for picking up and discharging passengers becomes an electrical conductor inside the microprocessor which facilitates data flow; "DAISY CHAIN", a circular group of people holding hands becomes a group of devices interconnected in such a way that the data flows from one unit to the next in serial fashion.

Hewlett-Packard thanks Schweber Electronics Corporation for their permission to reprint these Microprocessor Buzz Words.

A

ABBREVIATED ADDRESSING: A modification of the Direct Address mode which uses only part of the full address and provides a faster means of processing data because of the shortened code.

ACCUMULATOR: One or more registers associated with the ALU which temporarily store sums and other arithmetical and logical results of the ALU.

ACIA (Asynchronous Communications Interface Adapter): A Motorola device which interfaces the microprocessor's bus-organized system with incoming serial synchronous communication information. The parallel data of the multi-bus system is serially transmitted by the asynchronous data terminal. The ACIA interfaces directly with low-speed Modems to enable microprocessor communication over telephone lines.

ADAPTER: A device used to effect operative capability between different parts of one or more systems or subsystems.

ADDRESSING MODES: An address is a coded instruction designating the location of data or program segments in storage. The address may refer to storage in registers or memories or both. The address code itself may be stored so that a location may contain the address of data rather than the data itself. This form of addressing is common in microprocessors. Addressing modes vary considerably because of efforts to reduce program execution time.

ALU (Arithmetic and Logic Unit): The ALU is one of the three essential components of a microprocessor the other two being the registers and the control block. The ALU performs various forms of addition and subtraction; the logic mode performs such logic operations as ANDING the contents of two registers, or masking the contents of a register.

ARCHITECTURE: Any design or orderly arrangement perceived by man; the architecture of the microprocessor. Since the extant microprocessors vary considerably in design, their architecture has become a bone of contention among specialists.

ASSEMBLER PROGRAM: The Assembler Program translates man readable source statements (mnemonics) into machine understandable object code.

ASSEMBLY LANGUAGE: A machine oriented language. Normally the program is written as a series of source statements using mnemonic symbols that suggest the definition of the instruction and is then translated into machine language.

ASYNCHRONOUS: Operation of a switching network by a free-running signal which signals successive instructions, the completion of one instruction triggering the next. There is no fixed time per cycle.

B

BAUD RATE: A measure of data flow. The number of signal elements per second based on the duration of the shortest element. When each element carries one bit, the Baud rate is numerically equal to bits per second (bps). The Baud rates on UART data sheets are interchangeable with bps.

BCD (Binary Coded Decimal). Each decimal digit is binary coded into 4-bit words. The decimal number 11 would become 0001 0001 in BCD. Also known as the 8421 code.

BENCHMARK: Originally a surveyor's mark used as a reference point in surveys. In connection with microprocessors, the benchmark is a frequently used routine or program selected for the purpose of comparing different makes of microprocessors. A flow chart in assembly language is written out for each microprocessor and the execution of the benchmark by each unit is evaluated on paper. It is not necessary to use hardware to measure capability by benchmark.

BIDIRECTIONAL: A term applied to a port or bus line that can be used to transfer data in either direction.

BINARY: A system of numbers using 2 as a base in contrast to the decimal system which uses 10 as a base. The binary system requires only two symbols, 0 and 1. Two is expressed in binary by the number 10 (read one, zero). Each digit after the initial 1 is multiplied by the base 2. Hence the following table expresses the first ten numbers in decimal and binary:

Decimal	Binary	Decimal	Binary
0	0	5	101
1	1	6	110
2	10	7	111
3	11	8	1000
4	100	9	1001

BRANCH: Refers to the capability of a microprocessor to modify the function or program sequence. Such modification depends on the actual content of the data being processed at any given instant.

BREAKPOINT: A program point indicated by a breakpoint flag which invites interruption to give the user the opportunity to check his program before continuing to its completion.

BUFFER: A circuit inserted between other circuit elements to prevent interactions, to match impedances, to supply additional drive capability, or to delay rate of information flow. Buffers may be inverting or non-inverting.

BUS DRIVER: An integrated circuit which is added to the data bus system to facilitate proper drive to the CPU when several memories are tied to the data bus line. These are necessary because of capacitive loading which slows down the data rate and prevents proper time sequencing of microprocessor operation.

BUS SYSTEM: A network of paths inside the microprocessor which facilitate data flow. The important busses in a microprocessor are identified as Data Bus, Address Bus, and Control Bus.

BYTE: Indicates a pre-determined number of consecutive bits treated as an entity. For example, 4-bit or 8-bit bytes. "Word" and "Byte" are used interchangeably.

C

CLOCK: A generator of pulses which controls the timing of switching circuits in a microprocessor. Clock frequency is not the only criterion of data manipulation speed. Hardware architecture and programming skill are more important. Clocks are a requisite for most microprocessors and multiple phased clocks are common in MOS processors.

COMBINATIONAL LOGIC: A circuit arrangement in which the output state is determined by the present state of the input. Also called Combinatorial logic. (See also Sequential Logic.)

COMPILERS: Compilers translate higher-level languages into machine code.

CONDITION CODE: Refers to a limited group of program conditions such as carry, borrow, overflow, etc., which are pertinent to the execution of instructions. The codes are contained in a Condition Codes Register.

CONTROL BLOCK: This is the circuitry which performs the control functions of the CPU. It is responsible for decoding microprogrammed instructions, and then generating the internal control signals that perform the operations requested.

CONTROL BUS: Conveys a mixture of signals which regulate system operation. These "traffic" signals are commands which may also originate in peripherals for transfer to the CPU or the reverse.

CONTROL PROGRAM: The Control Program is a sequence of instructions that will guide the CPU through the various operations it must perform. This program is stored permanently in ROM memory where it can be accessed by the CPU during operations.

CPU (Central Processing Unit): The heart of any computer system. Basically the CPU is made up of storage elements called registers, computational circuits in the ALU, the Control Block, and I/O. As soon as LSI technology was able to build a CPU on an IC chip, the microprocessor became a reality. The one-chip microprocessors have limited storage space, so memory implementation is added in modular fashion. Most current microprocessors consist of a set of chips, one or two of which form the CPU.

CROM (Control Read Only Memory): This is a major component in the control block of some microprocessors. It is a ROM which has been microprogrammed to decode control logic.

CROSS-ASSEMBLER: When the program is assembled by the same microprocessor that it will run on, the program that performs the assembly is referred to simply as an assembler. If the program is assembled by some other microprocessor, the process is referred to as cross-assembly. Occasionally the phrase "native assembler" will be used to distinguish it from a cross-assembler.

D

DAISY CHAIN: A bus line which is interconnected with units in such a way that the signal passes from one unit to the next in serial fashion. The architecture of the Fairchild F-8 provides an example of daisy-chained memory chips. Each chip connects to its neighbors to accomplish daisy-chaining of interrupt priorities beginning with the chip closest to the CPU.

DATA BUS: The microprocessor communicates internally and externally by means of the data bus. It is bidirectional and can transfer data to and from the CPU, memory storage, and peripheral devices.

DATA COUNTER: (See Program Counter)

DATA DOMAIN: Analysis of logic-function or algorithmic-state-machines as a function of the **data** sequence or the state-space sequence. "Data" is used in the generic sense--the data at any given event-time (or state-space) defines the status of a machine at that point (e.g. address, instruction, operation, and status words as well as "data" words in the sense of operator and/or operand). The data domain is distinguished from the classical electronic analysis domains of time and frequency. Analysis of parametric behavior as a function of time-- $f(t)$ --is considered **time-domain** analysis. Usually used in electronics in terms of voltage vs time (e.g. as displayed by an oscilloscope trace); distinguished from the **frequency domain** where electrical analysis is usually voltage **gain** as a function of frequency.

DATA FIELD POINTER: (See Stack Pointer)

DEBUG: As used in connection with microprocessor software, debugging involves searching for and eliminating sources of error in programming routines. Finding a bug in software routine is said to be as difficult as finding a needle in the proverbial haystack. A single step tester is the suggested method, so that each instruction operation can be checked individually.

D-BUS: (See Data Bus)

DECREMENT: A programming instruction which decreases the contents of a storage location. (See also increment and decrement.)

DEDICATED: To set apart for some special use. A dedicated microprocessor is one that has been specifically programmed for a single application such as weight measurement by scale, traffic light control, etc. ROMs by their very nature (Read-Only) are "dedicated" memories.

DIRECT ADDRESSING: This is the standard addressing mode. It is characterized by an ability to reach any point in main storage directly. Direct addressing is sometimes restricted to the first 256 bits in main storage.

DMA (Direct Memory Access): A method of gaining direct access to main storage to achieve data transfer without involving the CPU. The manner in which CPU is disabled while DMA is in progress differs in different models and some use several methods to accomplish DMA.

E

EXECUTION TIME: Usually expressed in clock cycles necessary to carry out an instruction. Since the clock frequency is known, the actual time can be calculated. Clock frequencies can be varied.

EXTENDED ADDRESSING: Refers to an addressing mode that can reach any place in memory. See also Direct Addressing.

F

FETCH: To go after and return with things. In a microprocessor, the "objects" fetched are instructions which are entered in the instruction register. The next, or a later step in the program will cause the machine to execute what it was programmed to do with the fetched instructions. Often referred to as an "instruction fetch."

FIELDS: A source statement is made up of a number of code fields, usually four, which are acceptable by the assembler. The four fields may connote Label, Operator, Operand, and Comment. Fields are also applicable to data storage. The eight bits stored in a memory location might contain two 4-bit fields, or eight 1-bit fields, etc.

FIRMWARE: Software instructions which have been permanently frozen into a ROM are sometimes referred to as Firmware.

FLAG BIT: An information bit which indicates some form of demarcation has been reached such as overflow or carry. Also an indicator of special conditions such as interrupts.

FLOW CHART OR FLOW DIAGRAM: A sequence of operations charted with the aid of symbols, diagrams, or other representations to indicate an executive program. Flowcharts enable the designer to visualize the procedure necessary for each item on the program. A complete flowchart leads directly to the final code.

H

HANDSHAKING: A colloquial term which describes the method used by a modem to establish contact with another Modem at the other end of a telephone line. Often used interchangeably with buffering and interfacing, but with a fine line of difference in which handshaking implies a direct package to package connection regardless of functional circuitry.

HARDWARE: The individual components of a circuit, both passive and active, have long been characterized as hardware in the jargon of the engineer. Today, any piece of data processing equipment is informally called hardware.

HARD-WIRED LOGIC: Random Logic design solutions require interconnection of numerous integrated circuits representing the logic elements. An example of hard-wired logic is the use of a hand-wired diode matrix instead of a ROM. These interconnections, whether done with soldering iron or by printed circuit board, are referred to as hard-wired logic in contrast to the software solutions achieved by a programmed ROM or Microprocessor.

HIGH LEVEL LANGUAGE: This is a problem-oriented programming language as distinguished from a machine-oriented programming language. The former's instruction approach is closer to the needs of the problems to be handled than the language of the machine on which they are to be implemented.

HEXADECIMAL: Whole numbers in positional notation using 16 as a base. (See Octal and compare.) Since there are 16 hexadecimal digits (0 through 15) and there are only ten numerical digits (0 through 9) an additional six digits representing 10 through 15 must be introduced. Recourse is had to the alphabet to provide the extra digits. Hence, the least significant hexadecimal digits read: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F. The decimal number 16 becomes the hexadecimal number 10. The decimal number 26 becomes the hexadecimal number 1A.

I

IMMEDIATE ADDRESSING: In this mode of addressing, the operand contains the value to be operated on, and no address reference is required.

INCREMENT (and Decrement): These two words are software operations most often associated with the stack and stack pointer. Bytes of information are stored in the stack register at the addresses contained in the stack pointer. The stack pointer is decremented after each byte of information is entered into the stack; it is incremented after each byte is removed from the stack. The terms can also refer to any addressable register.

INDEX REGISTER: The Index Register contains address information subject to modification by the Control Block without affecting the instruction in the memory. The IR information is available for loading onto the stack pointer when needed.

INDIRECT ADDRESSING: Addressing a memory location which contains the address of data rather than the data itself.

INSTRUCTION SET: Constitutes the total list of instructions which can be executed by a given microprocessor and is supplied to the user to provide the basic information necessary to assemble a program.

INTERFACE: Indicates a common boundary between adjacent components, circuits, or systems enabling the devices to yield and/or acquire information from one another. In the face of common usage, one must regretfully add that the words Buffer, Handshake, and Adapter are interchangeable with Interface.

INTERRUPT: An interrupt involves the suspension of the normal programming routine of a microprocessor in order to handle a sudden request for service. The importance of the interrupt capability of a microprocessor depends on the kind of applications to which it will be exposed. When a number of peripheral devices interface the microprocessor, one or several simultaneous interrupts may occur on a frequent basis. Multiple interrupt requests require the processor to be able to accomplish the

following to delay or prevent further interrupts; to break into an interrupt in order to handle a more urgent interrupt; to establish a method of interrupt priorities; and after completion of interrupt service, to resume the interrupted program from the point where it was interrupted.

INTERRUPT MASK BIT: The Interrupt Mask Bit prevents the CPU from responding to further interrupt requests until cleared by execution of programmed instructions. It may also be manipulated by specific mask bit instructions.

I/O (Input/Output): Package pins which are tied directly to the internal bus network to enable I/O to interface the microprocessor with the outside world.

J

JUMP: The Jump operation, like the Branch operation is used to control the transfer of operations from one point to a more distant point in the control program. Jumps differ from Branching in not using the Relative Addressing mode.

L

LABEL: A label may correspond to a numerical value or a memory location in the programmable system. The specific absolute address is not necessary since the intent of the label is a general destination. Labels are a requisite for jump and branch instructions.

LIBRARY: A collection of complete programs written for a particular computer, minicomputer, or microprocessor. For example, Second Order Differential Equation may be the name of a program in the Library of a particular computer; this program will contain all the subroutines necessary to perform the solution of second order differential equations written in machine language and using the instruction set of this machine.

LIFO: Last-In-First-Out buffer. (See Push Down Stack.)

LOGIC: A mathematical treatment of formal logic in which a system of symbols is used to represent quantities and relationships. The symbols or logical functions are called AND, OR, NOT, to mention a few examples. Each function can be translated into a switching circuit, more commonly referred to as a "gate." Since a switch (or gate) has only two states—open or closed—it makes possible the application of binary numbers for the solution of problems. The basic logic functions obtained from gate circuits is the foundation of complex computing machines.

LOGIC ANALYZERS

State: An instrument designed to operate synchronously with a clock or strobe from the system under test. Used primarily to determine the state of data transactions in relation to that clock.

Time: An instrument designed to operate asynchronously with the system under test using an internal clock. Used to determine the time relationship between data transitions.

LOOK AHEAD: 1.) A feature of the CPU which allows the machine to mask an interrupt request until the following instruction has been completed. 2.) A feature of adder circuits and ALUs which allow these devices to look ahead to see that all carries generated are available for addition.

LOOPING: Repetition of instructions at delayed speeds until a final value is determined (as in a weight scale indication) is called looping. The looped repetitions are usually frozen into a ROM memory location and then jumped to when needed. Looping also occurs when the CPU is in a wait condition.

LSI (Large Scale Integration): At the beginning of the LSI era a count of 100 gates qualified for LSI. Today an 8-bit CPU can be fabricated on a single chip.

M

MACHINE LANGUAGE: The only language the microprocessor can understand is binary. All other programming languages must be translated into binary code before entering the processor and decoded back into the original language after leaving it.

MACRO COMMAND: A program entity formed by a string of standard, but related, commands which are put into effect by means of a single macro command. Any group of frequently used commands can be combined into a macro command. The many become one.

MACROLOGIC: A group of LSI chips which, when combined, will form a microprocessor. These devices can be arranged to permit the user to microprogram his own microprocessor. In such an arrangement he is not limited to a fixed instruction set and is able to build his own instruction set.

MAIL BOX: The Mail Box is a set of locations in a common RAM storage area reserved for data addressed to specific peripheral devices as well as other microprocessors in the immediate environment. Such an arrangement enables the co-ordinator CPU and the supplementary microprocessors to transfer data among themselves in an orderly fashion with minimal hardware.

MNEMONIC CODE: These are designed to assist the human memory. The microprocessor language consists of binary words which are a series of 0's and 1's making it difficult for the programmer to remember the instructions corresponding to a given operation. To assist the human memory, the binary numbered codes are assigned groups of letters (or mnemonic symbols) that suggest the definition of the instruction. LDA for load accumulator, etc. Source statements can be written in this symbolic language and then translated into machine language.

MICROPROGRAM: This word pre-dates the microprocessor and refers to computer instructions which do not reference the main memory storage. It is a computer technique which performs subroutines by manipulating the basic computer hardware and is often referred to as "computer within computer." The word has not changed its basic meaning when used in connection with microprocessors, but is not to be construed as native to microprocessors. A series of instructions stored in a ROM, any portion of which can implement a higher language program, is labeled a micro-program.

MICROINSTRUCTION: (See Microprogram)

MEMORY: The part of a computer system into which information can be inserted and held for future use. Storage and memory are interchangeable expressions. Memories accept and hold binary numbers only. Memory types are core, disk, drum, and semiconductor.

MOS (Metal Oxide Semiconductor): The structure of an MOS Field Effect Transistor (FET) is metal over silicon oxide over silicon. The metal electrode is the gate; the silicon oxide is the insulator; and carrier doped regions in the silicon substrate become the drain and source. The result is a sandwich very much like a capacitor, which explains why MOS is slower than bipolar since the "capacitor sandwich" must charge up before current can flow. The three great advantages of MOS are its process simplicity because of reduced fabrication stages; the savings in chip real estate resulting in functional density; and the ease of interconnection on chip. These qualities enabled MOS to break the LSI barrier, something bipolar is just beginning to achieve. The hand-held calculator and the microprocessor are triumphs of MOS-LSI technology.

MICROPROCESSOR: The microprocessor is a Central Processing Unit fabricated on one or two chips. While no standard design is visible in existing units, a number of well-delineated areas are present in all of them: Arithmetic & Logic Unit, Control Block, and Register Array. When joined to a memory storage system, the resulting combination is referred to in today's usage as a Microprocessor. It should be added that each microprocessor is supplied with an Instruction Set, and this software manual may be just as important to the user as the hardware.

MULTIPLEXING: Multiplexing describes a process of transmitting more than one signal at a time over a single link, route, or channel. Of the two methods in use, one frequency-shares the bandwidth of a channel in the same way hurdlers run and jump in their assigned lanes thus permitting many contestants to compete simultaneously on the same track. The second way is to time-share multiple signals in the same way that pole vaulters jump over the same bar one after the other. The two methods may be described as parallel and serial processing. Time-sharing may not seem "simultaneous," but it should be remembered that the signal speed is so fast that it is possible to multiplex four different numbers through a single decoder-driver and have them appear on four different displays without a flicker to disturb the eye.

N

NESTING: Nesting is referred to when a subroutine is enclosed inside a larger routine, but is not necessarily part of the outer routine. A series of looping instructions may be nested within each other.

O

OBJECT PROGRAM: The end result of the source language program after it has been translated into machine language.

OCTAL: Whole numbers in positional notation using 8 as a base. The decimal or base 10 number, 125, becomes 175 in octal or base 8. Here is a convenient way to convert a decimal number into an octal number:

Divide the decimal number by 8. The answer is 15 and 5 left over.

$$\begin{array}{r} 15 \\ 8 \overline{) 125} \\ \underline{80} \\ 45 \\ \underline{40} \\ 5 \end{array}$$

Divide the answer, 15, by 8 again. The answer is 1 and 7 left over.

The octal number is 175.

To prove your answer is correct, do the following:

$$\begin{array}{r} 5 \times 1 = 5 \\ 7 \times 8 = 56 \\ 1 \times 64 = 64 \\ \hline 125 \end{array}$$

The least significant digit represents one's, so multiply 5 x 1 = 5.

The next digit in the octal number represents 8's, so multiply 7 x 8 = 56.

The third digit of the octal number represents

64's, so multiply $1 \times 64 = 64$.

The sum is the decimal number 125.

OPERAND: A quantity on which a mathematical operation is performed. One of the instruction fields in an addressing statement. Usually the statement consists of an operator and an operand. The operator may indicate an "add" instruction; the operand will indicate what is to be added.

OVERFLOW: Overflow results when an arithmetic operation generates a quantity beyond the capacity of the register. Also referred to as arithmetical overflow. An overflow status bit in the condition code register can be checked to determine if the previous operation caused an overflow.

OPERATING CODE (Opcode): Source statements which generate machine codes after assembly are referred to as operating codes.

P

PARALLEL OPERATION: Processing all the digits of a word or byte simultaneously by transmitting each digit on a separate channel or bus line.

PARTY-LINE: Party-line as used in its telephone sense to indicate a large number of devices connected to a single line originating in the CPU.

PIPELINE: Computers which execute serial programs only are referred to as pipeline computers.

PLA (Programmed Logic Arrays): The PLA is an orderly arrangement of logical AND and logical OR functions. Its application is very much like a glorified ROM. It is primarily a combinational logic device.

POLLING: Polling is the method used to identify the source of interrupt requests. When several interrupts occur at one time, the control program decides which one to service first.

PORT: Device terminals which provide electrical access to a system or circuit. The point at which the I/O is in contact with the outside world.

PROGRAM: A procedure for solving a problem and frequently referred to as Software.

PROGRAM COUNTER: One of the registers in the CPU which holds addresses necessary to step the machine through the program. During interrupts, the program counter saves the address of the instruction. Branching also requires loading of the return address in the program counter.

PUSH DOWN STACK: A register that receives information from the Program Counter and stores the address locations of the instructions which have been pushed down during an interrupt. This stack can be used for sub-routine. Its size determines the level of subroutine nesting (one less than its size or 15 levels of subroutine nesting in a 16 word register. When instructions are returned they are popped back on a last-in-first-out (LIFO) basis.

P-STACK: (See Push Down Stack)

R

RALU (Register, Arithmetic, and Logic Unit): Unlike the discrete ALU package which functions as an Arithmetic and Logic unit only, the ALU in the microprocessor is equipped with a number of registers.

RAM (Random Access Memory): Random in the sense of providing access to any storage location point in the memory immediately by means of vertical and horizontal co-ordinates. Information may be "written" in or "read" out in the same rapid way.

RANDOM LOGIC DESIGN: Designing a system using discrete logic circuits. Numerous gates are required to implement the logic equations until the problem is solved. Even then, the design is not completed until all redundant gates are weeded out. Random logic design is no guarantee of optimum gate count.

REAL TIME OPERATION: Data processing technique used to allow the machine to utilize information as it becomes available, as opposed to batch processing at a time unrelated to the time the information was generated.

REGISTER: A register is a memory on a smaller scale. The words stored therein may involve arithmetical, logical, or transferral operations. Storage in registers may be temporary, but even more important is their accessibility by the CPU. The number of registers in a microprocessor is considered one of the most important features of its architecture.

RELATIVE ADDRESSING: The relative addressing mode specifies a memory location in the CPU's Program Location Counter register. This addressing mode is used for Branch instructions in which case an opcode is added to the Relative Address to complete the branching instruction.

ROM (Read Only Memory): In its virgin state the ROM consists of a mosaic of undifferentiated cells. One type of ROM is programmed by mask pattern as part of the last manufacturing stage. Another, more popular type better known as P/ROM, is programmable in the field with the aid of programmer equipment. Program data stored in ROMs are often called firmware because they cannot be altered. However, another type of P/ROM is now on the market called EPROM which is erasable by ultra violet irradiation and electrically reprogrammable.

S

SCRATCHPAD: This term is applied to information which the Processing unit stores or holds temporarily. It is a memory containing subtotals for various unknowns which are needed for final results.

SEQUENTIAL LOGIC: A circuit arrangement in which the output state is determined by the previous state of the input. (See also Combination Logic.)

SOFTWARE: What sheet music is to the piano, software is to the computer. Looked at from a practical point of view, one might say that software is the computer's instruction manual. The name, software, was obviously chosen to contrast with the formidable hardware which confronted the first programmers. Software is the language used by a programmer to communicate with the computer. Since the only language spoken by a computer is mathematical, the programmer must convert his verbal instructions into numbers. In the case of microprocessors, which vary from maker to maker, software libraries are assembled by the manufacturer for the benefit of the user.

SOURCE STATEMENT: A program written in other than machine language, usually in three-letter mnemonic symbols, that suggest the definition of the instruction. There are two kinds of source statements: "executive instructions" which translate into operating machine code (opcode); and "assembly directives" which are useful in documenting the source program, but generate no code.

SIMULATOR: A special program that simulates the logical operation of the microprocessor. It is designed to execute object programs generated by a cross-assembler on a machine other than the one being worked on and is useful for checking and debugging programs prior to committing them to ROM firmware.

STACK: The stack is a block of successive memory locations which is accessible from one end on a last-in-first-out basis (LIFO). The stack is co-ordinated with the stack pointer which keeps track of storage and retrieval of each byte of information in the stack. A stack may be any block of successive information locations in the read/write memory.

SLICE: A type of chip architecture which permits the cascading or stacking of devices to increase word bit size.

STACK POINTER: The stack pointer is co-ordinated with the storing and retrieval of information in the stack. The stack pointer is decremented by one immediately following the storage in the stack of each byte of information. Conversely, the stack pointer is incremented by one immediately before retrieving each byte of information from the stack. The stack pointer may be manipulated for transferring its contents to the Index register or vice versa.

STATUS WORD REGISTER: A group of binary numbers which informs the user of the present condition of the microprocessor. In the Fairchild F8, the Status Register provides the following five pieces of information: plus or minus sign of the value in Accumulator, overflow indication, carry bit, all zero's in accumulator, and interrupt bit status.

STORAGE: The word storage is used interchangeably with memory. In fact, it has been recommended as the preferred term by people who would rather not imply that the computer has any relationship with the human brain.

SUBROUTINE: Part of a master routine which may be used at will in a variety of master routines. The object of a Branch or Jump command.

T

THROUGHPUT: The speed with which problems or segments of problems are performed is called Throughput. Defined in this way, it is obvious that throughput will vary from application to application. As an index of speed, throughput is meaningful only in terms of your own application.

TIME DOMAIN: See Data Domain for comparative definition.

TWO'S COMPLEMENT NUMBERS: The ALU performs standard binary addition using the 2's complement numbering system to represent both positive and negative numbers. The positive numbers in 2's complement representation are identical to the positive numbers in standard binary. $+127$ in standard binary = 01111111 $+127$ in 2's complement = 01111111 . Note that the eighth or most significant digit indicates the sign: 0 = plus; 1 = minus.

However, the negative 2's complement is the reverse of the negative standard binary plus 1. -127 in standard binary = 11111111 . To form the 2's complement of -127 . First reverse all the digits except the sign

$$\begin{array}{r} 10000000 \\ \text{Then add 1} \quad \quad \quad 1 \\ \hline 10000001 = -127 \text{ in 2's complement.} \end{array}$$

U

UART (Universal Asynchronous Receiver Transmitter): This device will interface a word parallel controller or data terminal to a bit serial communication network.

V

VECTOR INTERRUPT: This term is used to describe a microprocessor system in which each interrupt, both internal and external, have their own uniquely recognizable address. This enables the microprocessor to perform a set of specified operations which are pre-programmed by the user to handle each interrupt in a distinctively different manner.

W

WORD: A group of "characters" treated as a unit and given a single location in computer memory. Presumably a byte is a group of bits in contrast to a word which is a group of numeric and/or alphabetic characters and symbols, but the two words are used interchangeably more often than not.

X

X-BUS: (See Address Bus)

For More Information, Call Your Local HP Sales Office or, in U.S., East (301) 948-6370 Midwest (312) 677-0400 South (404) 434-4000 West (213) 877-1282 Or, Write Hewlett-Packard, 1501 Page Mill Road, Palo Alto, California 94304 In Europe, Post Office Box 85, CH-1217 Meyrin 2, Geneva, Switzerland In Japan, YHP, 1-59-1, Yoyogi, Shibuya-Ku, Tokyo, 151

CUSTOMER SERVICE SEMINARS

Hewlett-Packard continually offers training to customers on a worldwide basis to help keep service skills current with HP's extensive product line. Seminars are provided throughout Europe and the United

States in an effort to bring our training facilities closer to your area. For registration please use the form on page 15 of *Bench Briefs* or contact your Hewlett-Packard Sales and Service Office.

COURSE CONTENT

LECTURE

- I. Introduction
- II. Features and Model Options
- III. Front Panel Features
 - A. Video Tape
 - B. Demonstration
- IV. Theory
 - A. Block Diagram
 - B. Assembly Locations
 - C. Schematic

LAB

- I. Adjustments
- II. Performance Tests
- III. Troubleshooting

PREREQUISITES — Basic knowledge of digital logic circuits and general knowledge of electronics including operational amplifiers and phase lock circuits.

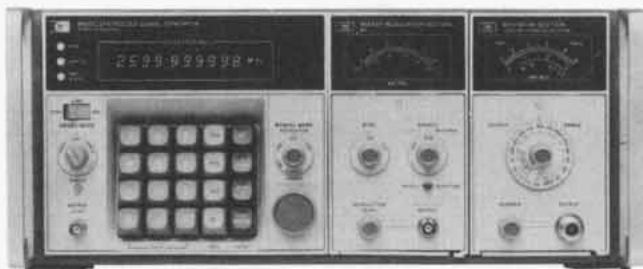
PRESTUDY

— Review digital logic and block diagram information in 8640, 8660 and 435/436 manuals.

Read pages 1-48 in "Signal Generator Seminar" textbook.

View video tape 90030—566 (Optional).

8640 AM/FM SIGNAL GENERATOR
8660 SYNTHESIZED SIGNAL GENERATOR
435/436 POWER METERS
8480 SENSOR AND 11683A CALIBRATOR
AUG 29-SEPT 2, PALO ALTO, CA



**5340A MICROWAVE FREQUENCY
COUNTER**
SEPT 1-2, PARAMUS, NJ

COURSE CONTENT

LECTURE

- I. Overall Block Diagram
- II. Numerical Examples of Frequency Measurements
- III. Input Phase Lock Loop Circuit Description
- IV. Transfer Phase Lock Loop Circuit Description
- V. Instrument Flow Diagram and Algorithmic State Machine
- VI. Options

LAB

The lecture is given in a lab environment. Attendees make voltage and waveshape measurements at different times during the lecture. A familiarization with adjustment procedures is also included.

PREREQUISITES – Basic knowledge of microwave measuring techniques

PRESTUDY – April 1973 HP Journal describing 5340A. "The Fundamentals of Electronic Frequency Counters", Application Note 172.



**5062C CESIUM BEAM
FREQUENCY STANDARD**
OCT 10-14, SANTA CLARA, CA



COURSE CONTENT

LECTURE

- I. General Information
 - A. High Resolution Frequency Measurement
 - B. 5062C Specifications
- II. Block Diagram Theory and Controls
 - A. Cesium Tube Characteristics
 - B. RF Circuits
 - C. LF Circuits
 - D. Front Panel Controls and Status Lamps
 - E. Instrument Turn-On
- III. Instrument Operation
 - A. C-Field/Frequency Setting
 - B. Operating Routine

- IV. Cesium Beam Tube
 - A. Operation
 - B. Performance Verification
- V. Circuit Alignment
 - A. Procedure
 - B. Circuit Alignment
- VI. Troubleshooting
 - A. Procedures
 - B. Troubleshooting
- VII. Subassembly Theory and Repair
 - A. Discussion of each Major Circuit Assembly
 - B. Troubleshooting
- VIII. Options
 - A. Battery
 - B. Clock
 - C. Troubleshooting
- IX. Summary
 - A. Review
 - B. Non Field Repairable Parts
 - C. Test Equipment Requirements

LAB

The lecture will be given in a lab environment.

PREREQUISITES – Familiarity with analog and digital circuits.

PRESTUDY – None

supplement to
BENCH BRIEFS
 SERVICE NOTE INDEX

NEED ANY SERVICE NOTES?

Here's the latest listing of Service Notes available for Hewlett-Packard products. To obtain information for instruments you own, remove the order form and mail it to the nearest HP distribution center.

197A OSCILLOSCOPE CAMERA

197A-7. All serials. Repair kits.

745A AC CALIBRATOR

745A-10A. Serials 1319A01251 through 1319A-01670, and 745A-H18's only serial numbers 319A01671 and above. Triax counter output connector.

745A-12A-S. Serials 00741-00101 through 1319A01250. Elimination of potential safety hazard. Supersedes 745A-12.

745A-13A. Serials 00741-00101 through 1319A01670, and 745A-H18's only serial numbers 1319A01671 and above. Installation of isolated BNC counter output modification kit HP part no. 00745-89503.

1332A X-Y DISPLAY

1332A-5. All serials. Improved reliability for the Z-axis amplifier.

1333A X-Y DISPLAY

1333A-1. All serials. Improved reliability for the Z-axis amplifier.

1335A X-Y DISPLAY

1335A-2. All serials. Improved storage circuitry reliability.

1335A-3. All serials. Improved reliability for the Z-axis amplifier.

1645A DIGITAL ERROR ANALYZER

1645A-6. All serials. Preferred replacement for TTL decade counter.

1645A-7. All serials. Inverted clock phase.

1700A OSCILLOSCOPE

1700A-7. All serials. Handle replacement kit.

1700B OSCILLOSCOPE

1700B-3. Handle replacement kit.

1701A OSCILLOSCOPE

1701A-7. All serials. Handle replacement kit.

1701B OSCILLOSCOPE

1701B-2. Handle replacement kit.

1702A OSCILLOSCOPE

1702A-3. Handle replacement kit.

1703A OSCILLOSCOPE

1703A-7. Handle replacement kit.

1706A/B OSCILLOSCOPE

1706A/B-1. All serials. Handle replacement kit.

1707A OSCILLOSCOPE

1707A-5. All serials. Handle replacement kit.

1707B OSCILLOSCOPE

1707B-6. Handle replacement kit.

1710A OSCILLOSCOPE

1710A-6. All serials. Handle replacement kit.

1710B OSCILLOSCOPE

1710B-13A. All serials. Improved focus resistors.

1712A OSCILLOSCOPE

1712A-12A. All serials. Improved focus resistors.

1720A OSCILLOSCOPE

1720A-16A. All serials. Improved focus resistors.

1722A OSCILLOSCOPE

1722A-16A. All serials. Improved focus resistors.

3435A/B DIGITAL MULTIMETER

3435A-1A. All serials. Replacement part numbers for LED displays.

3465A MULTIMETER

3465A-3A. Serials prior to 1546A01501. Replacement of fine-line resistor pack A1R75.

3465A-4A. All serials. Replacement part numbers for LED displays.

3465B DIGITAL MULTIMETER

3465B-1A. All serials. Replacement part numbers for LED displays.

3495A SCANNER

3495A-2. Modification to ease insertion and improve alignment with 3495A Mainframe.

3551A TRANSMISSION TEST SET

3551A-5 All serials. Replacement part numbers for LED displays.

3556A PSOPHOMETER

3556A-U-1003. Serial numbers 1547U and below. New battery modification.

3702B IF/BB RECEIVER

3702B-34A. Serials 1642U-01746 and below. Modification to prevent D.C. offset on I.F. display.

3702Z DEMODULATOR DISPLAY

3702Z-8. Serials 1119U-01176 and below. Preferred replacement for rectifier assy (A24).

3745A/B SELECTIVE LEVEL MEASURING SET

3745A/B-6A. Serials 1647U and below. Intermittent operation of +5.2V power supply.

3745A/B-8. Serials 1690U and below. Replacement A107 CPU I/O assembly.

3745A/B-9. Serials 1538U and below. Protection of processor filter-control outputs.

3745A/B-10. Serials 1715U and below. Reduction of 10MHz and 20MHz spurious signals when using the 15580A active probe accessory.

3770A AMPLITUDE/DELAY DISTORTION ANALYSER

3770A-33. All serials. Incorrect part number of power switch.

3770B TELEPHONE LINE ANALYSER

3770B-8. Serials U-00166 and below. Ensuring enough range in A12 retransmission adjustment.

3770B-9. All serials. Incorrect part number of power switch.

**3964A INSTRUMENTATION
TAPE RECORDER**

3964A-7/8864A-7/3968A-8/8868A-8. All serials.
Calibrator output shorts.

3964A-8/8864A-8/3968A-9/8868A-9. All serial numbers. Field effect transistor lead configuration.

**3968A INSTRUMENTATION
TAPE RECORDER**

3964A-7/8864A-7/3968A-8/8868A-8. All serials.
Calibrator output shorts.

3964A-8/8864A-8/3968A-9/8868A-9. All serials.
Field effect transistor lead configuration.

5045A DIGITAL IC TESTER

5045A-1. All serials. Textool zip dip socket replacement.

**5150A THERMAL PRINTER
OPTION 002 BCD INTERFACE**

5150A-1. All serials. Modification to improve immunity to spurious print signals.

5150A THERMAL PRINTER

5150A-2. All serials. Repair of and adjustments to the print head assembly.

5304A TIMER/COUNTER

5304A-1. Serials 1704A03241 and below;
Serials 1632U01490 and below. Modification to improve performance.

5328A UNIVERSAL COUNTER

5328A-3. Modification to prevent annunciator lighting problem.

5328A-4. Serials 1704A02560 and below.
Spurious oscillation in arm lines.

5340A MICROWAVE FREQUENCY COUNTER

5340A-8. All serials. Using a logic state analyzer for 5340A ASM troubleshooting.

5340A-9. Serials 1644A04200 and below. Line fuse change for improved transformer protection.

5340A-10. Serials 1644A04300 and above.
Thermal switch change.

7200A/7201A/7202A GRAPHIC PLOTTERS

7200A-17A/7201A-7A/7202A-17A/9125A/B-5A.

Serials 1620A and below. New chart hold (autogrip) module.

8552A SPECTRUM ANALYZER, IF SECTION

8552A-12. Serials 1650A and below. Modification to reduce fuse blowing in IF section when switching the log/linear mode switch.

8552B SPECTRUM ANALYZER, IF SECTION

8552B-12. Serial 1650A and below. Modification to reduce fuse blowing in IF section when switching the log/linear mode switch.

8554B SPECTRUM ANALYZER RF SECTION

8554B-4. Serials 1643A and below. Modification to prevent spike at the beginning of scan.

8555A SPECTRUM ANALYZER RF SECTION

8555A-7. Serials 1642A and below. Modification to prevent spike at the beginning of scan.

8601A SWEEPER/GENERATOR

8601A-11. Serials 1612A and below. Power supply ripple improvement.

**8864A INSTRUMENTATION
TAPE RECORDER**

3964A-8/8864A-7/3968A-8/8868A-8. All serials.
Calibrator output shorts.

3964A-7/8864A-8/3968A-9/8868A-9. All serials.
Field effect transistor lead configuration.

**8868A INSTRUMENTATION
TAPE RECORDER**

3964A-7/8864A-7/3968A-8/8868A-8. All serials.
Calibrator output shorts.

3964A-8/8864A-8/3968A-9/8868A-9. All serials.
Field effect transistor lead configuration.

8951A SYSTEM INTERFACE

8951A-2. Serials 1636A and below. Notch filter replacement.

9125A/B GRAPHIC PLOTTER

7200A-17A/7201A-7A/7202A-17A/9125A/B-5A.
Serials 1620A and below. New chart hold (autogrip) module.

9872A GRAPHICS PLOTTER

9872A-2. Serials 1712A and below. Autogrip wiring change.

59309A HP-IB DIGITAL CLOCK

59309A-2. All serials. Programming the clock to store and output time correctly.

59403A COMMON CARRIER INTERFACE

50403A-1. Serials 1426A00281 and below.
Modification to improve protection of CCI circuits in dedicated line operation.

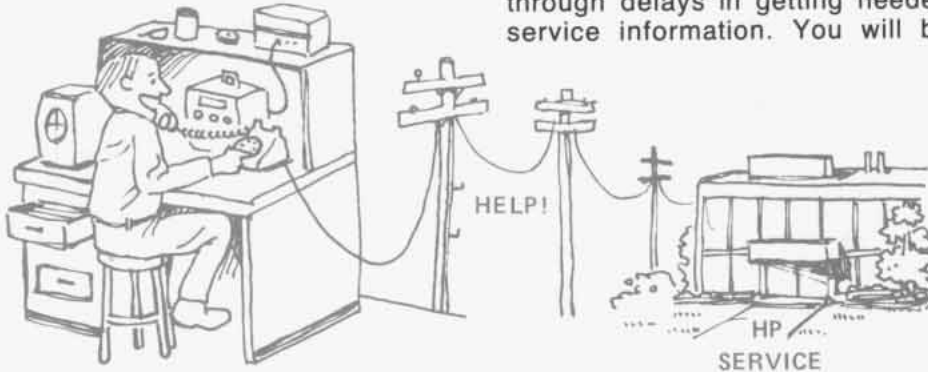
86290A RF PLUG-IN

86290A-1A. Serials 1450A and below. Coupler/modulator replacement kit.

86601A RF SECTION

86601A-1C. Serials 1223A00320 and below.
86601A meter replacement kits.

NEED HELP ON AN INSTRUMENT?



Hewlett-Packard is in the process of installing toll-free direct lines into our larger Instrument Service Centers located throughout the United States. This non-transferrable line bypasses receptionists allowing you to cut through delays in getting needed service information. You will be

promptly answered by competent service representatives ready to provide instrument maintenance pricing, parts and troubleshooting information, and other technical support assistance.

Not all areas of the country are on the toll-free lines yet, and the telephone numbers will vary from area to area. So check with your local Hewlett-Packard Sales and Service Office for toll-free status in your area.

Customers with analytical, medical, computer and calculator products will continue to be best served by contacting their nearest HP office also.

We are prepared to help solve your instrument support problems — simply call.

READERS CORNER

EQUATIONS CORRECTED

Dear Editor:

Gee wheeze — before solving your "Equations that Changed The World", please be warned that this letter is Belng Typed by the SAmE typesetter who type\$et the Readers Corner (Sept.-Dec. 1976 i\$Sue)

That $1 + 1 = 2$, is true only on base 10, and it would fit (4), but only if the tallying is done by non-computers.

So, (a) corresponds to (4) and (b) goes with (5) while (c) will pick on (1) Now (d) will make Napier (and others) cringe, because the exponent of "e" contains a mysterious "one". Anyway, tell your type\$etter — and proofreader? — that "ell enn" is the proper notation for logarithms. NOW (6) will go with (d), won't it?

Pythagoras will approve of (e) and (2) — as is! Bravo

(f) joins (7), though not as standard notation.

Tsilkovskii's formula (g) and (3) can also stand a bit of clean-up while in (g), again the mysterious "one" "enn" !!!

De Broglie will delight in the light equation (h), but — shudder, we can hear Maxwell turn in his grave — (i) is *totally* wrong: a sloppy V crept in where a "del" should be legally placed. At any rate, with barely a C- for a passing grade to your prinTeR, match (i) with (10). ∇^2 , not V^2 .

And, last but not least, the lever formula, cleverly or sloppily, allows for a short lever (small x_1) and a long one (cap X_2), so let (j) and (8) join hands.

SiNcErEiY YOuR S
S. Kurni, Professor
Albuquerque, New Mexico

You are absolutely right Mr. Karni. I am passing your letter on to Doubleday, the original typesetter.

Incidentally, Mr. Karni correctly matched up the answers before the January-February issue of Bench Briefs came out. His letter was postmarked January 19 and I received it April 7. That's why the delay in acknowledgement.

Editor

PERMISSION FOR REPRINT

Editor, Bench Briefs

In your July-August 1976 issue you included a one-page article "Shock Hazard Considerations".

As Assistant Editor of the RARA RAG, monthly magazine of the Rochester Amateur Radio Association, I would like to include that article in a future issue. Our club has lots of newcomers this year. I have a feeling it will enlighten both oldsters and newcomers. Please reply whether you can give your permission.

Thank You
Dwight Hill
Rochester, N.Y.

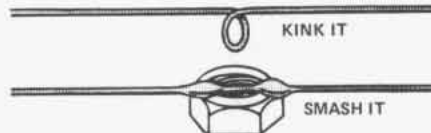
By now I am sure you have received our letter of permission. HP is very concerned about safety and hopes all of our customers will look for the Safety Service Notes described in each issue of Bench Briefs.

Editor

NUT HOLDER

Here's a handy tip from Bob Lindsay, Group Training Manager and Editor of Computer Systems Newsletter from HP's Data Systems Division.

Have you ever had to start a nut on a screw in a corner of an instrument behind the transformer, or in some other inaccessible place where you just can't quite reach with your fingers, or anything else? The next time that happens try this little trick Bob uses. Take a piece of solder and pull a kink in it. Lay the kink over the nut and tap it with the ball end of a ball-pen hammer. The idea is to smash the solder down into the nut to catch a thread, you might even try screwing the nut on to the location and hold it in place long enough to start a few threads.



A SHEEP PUZZLE

This puzzle is reprinted from The Grapevine, an HP Santa Rosa Div. employee newsletter.

Two brothers sold a flock of sheep which they owned in partnership. For each sheep they received as many rubles as the number of sheep in the original flock. The money was divided in the following manner:

First, the older brother took 10 rubles; then the younger brother took 10 rubles; the older brother

took another 10 rubles, then the younger brother took another 10 rubles. They continued dividing the money this way until the younger brother, whose turn it was, found there were fewer than 10 rubles left, so he took what remained. To make the division just, the older brother gave the younger brother his penknife which was valued at 4 rubles.

How many sheep were in the flock? Hint — There are multiple answers so use the first one that satisfies the above conditions.

What They Mean

SAFETY SYMBOLS IN MANUALS

Hewlett-Packard instruments and their operating and service manuals use a standardized set of safety symbols to convey safety information to the user. They are provided here as a reference to our customers. When used in the manual, these symbols will be described in terms related to the specific application.



Instruction manual symbol: the product will be marked with this symbol when it is necessary for the user to refer to the instruction manual in order to protect against damage to the instrument.



Indicates dangerous voltage (terminals fed from the interior by voltage exceeding 1000 volts must be so marked).



Protective conductor terminal. For protection against electrical shock in case

of a fault. Used with field wiring terminals to indicate the terminal which must be connected to ground before operating equipment.



Low-noise or noiseless, clean ground (earth) terminal. Used for a signal common, as well as providing protection against electrical shock in case of a fault. A terminal marked with this symbol must be connected to ground in the manner described in the installation (operating) manual, and before operating the equipment.



Frame or chassis terminal. A connection to the frame (chassis) of the equipment which normally includes all exposed metal structures.



Alternating current (power line).



Direct current (power line).



Alternating or direct current (power line).

WARNING

The WARNING sign denotes a hazard. It calls attention to a procedure, practice, or the like, which, if not correctly performed or adhered to, could result in personal injury.

CAUTION

The CAUTION sign denotes a hazard. It calls attention to an operating procedure, practice, or the like, which if not correctly performed or adhered to, could result in damage to or destruction of part or all of the product.

In other words, violating this restriction will wreak havoc upon the user, the like of which he may never have before experienced. Blinding flashes of lightning will cross the repair shop and mighty thunder claps will be heard; the instrument, the user, and his toolbox will crumble and vanish into dust, to be swept away by the night janitor.

5345'S NEED AIR TOO



When the air filters in the 5345 go unchanged for a long period of time, dirt build-up eventually clogs air flow, resulting in abnormal heat rise inside the unit. This increased temperature, of course, adversely affects the 5345's reliability. Also, once the filters are clogged, the fan begins drawing air through the front panel switches. Dust eventually collects around the switch contacts and impairs their proper operation.

After a careful review of the situation,

the factory has approved removal of the air filters altogether. Experiments show that in a normal operating environment, dust build-up will only be slightly higher. This is more than offset by the reduction in ambient temperature. Of course, instruments that operate in particularly dusty environments should retain their filters, and they should be regularly maintained. If new filters are needed they can be ordered by specifying HP part number 3150-0241 for the bottom filter, and 3150-0242 for the side filter.

SERVICE NOTE ORDER FORM

INSTRUCTIONS

1. If you want service notes please check the appropriate boxes below and return this form separately to one of the following addresses.

For European customers (ONLY)

Hewlett-Packard
Central Mailing Dept.
P. O. Box 529
Van Hueven Goedhartlaan 121
AMSTELVEEN-1134
Netherlands

All other customers

Hewlett-Packard
1820 Embarcadero Road
Palo Alto, California 94303

Name _____

Company Name _____

Address _____

City _____ State _____ Zip _____

- 197A-7
 745A-10A
 745A-12A-S
 745A-13A
 1332A-5

- 1333A-1
 1335A-2
 1335A-3
 1645A-6
 1645A-7

- 1700A-7
 1700B-7
 1701A-7
 1701B-2
 1702A-3

- 1703A-7
 1706A/B-1
 1707A-5
 1707B-6
 1710A-6

- 1710B-13A
 1712A-12A
 1720A-16A
 1722A-16A
 3435A-1A

- 3465A-3A
 3465A-4A
 3465B-1A
 3495A-2
 3551A-5

- 3556A-U-1003
 3702B-34A
 3702Z-8
 3745A/B-6A
 3745A/B-8

- 3745A/B-9
 3745A/B-10
 3770A-33
 3770B-8
 3770B-9

- 3964A-7/3968A-8/
8864A-7/8868A-8
 3964A-8/3968A-9/
8864A-9/8868A-9
 5045A-1

- 5150A-1
 5150A-2
 5304A-1
 5328A-3
 5328A-4

- 5340A-8
 5340A-9
 5340A-10
 7200A-17A/7201A-7A/
7202A-17A/9125A/B-5A

- 8552A-12
 8552B-12
 8554B-4
 8555A-7
 8601A-11

- 8951A-2
 9872A-2
 59309A-2
 59403A-1
 86290A-1A
 86601A-1C

U.S. SEMINAR REGISTRATION FORM

COURSE	DATE	COST	COORDINATOR/ LOCATION
8640 8660			
<input type="checkbox"/> 435 436 8480 11683	Aug. 29- Sept. 2	\$350/Student	Bill Whitney 1501 Page Mill Road Palo Alto, CA 94304
<input type="checkbox"/> 5340	RESCHEDULED Sept. 2	\$200/Student	Pete Johnson W 120 Century Road Paramus, N.J. 07652
<input type="checkbox"/> 5062	Oct. 10-14	\$450/Student	Fran Groat 5301 Stevens Creek Blvd. Santa Clara, CA 95050

Name _____

Company Name _____

Address _____

City _____ State _____ Zip _____

REGISTRATION INSTRUCTIONS

To enroll in any of the seminars, fill out the registration form and mail it with your check to the address shown for the coordinator/location. Please use separate registration forms for each student. Make

your check payable to Hewlett-Packard Company in U.S. currency.

Upon receipt of your registration and check we will confirm your enrollment

by returning all necessary prestudy material along with a list of nearby motel accommodations and reservation forms. Attendees are responsible for their own transportation, accommodations, and meals.

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BENCH BRIEFS

MAY-AUG 1977

Volume 17 Number 3

Service information from
Hewlett-Packard Company

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Editor: Jim Bechtold, HP Palo Alto
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Permit No.
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