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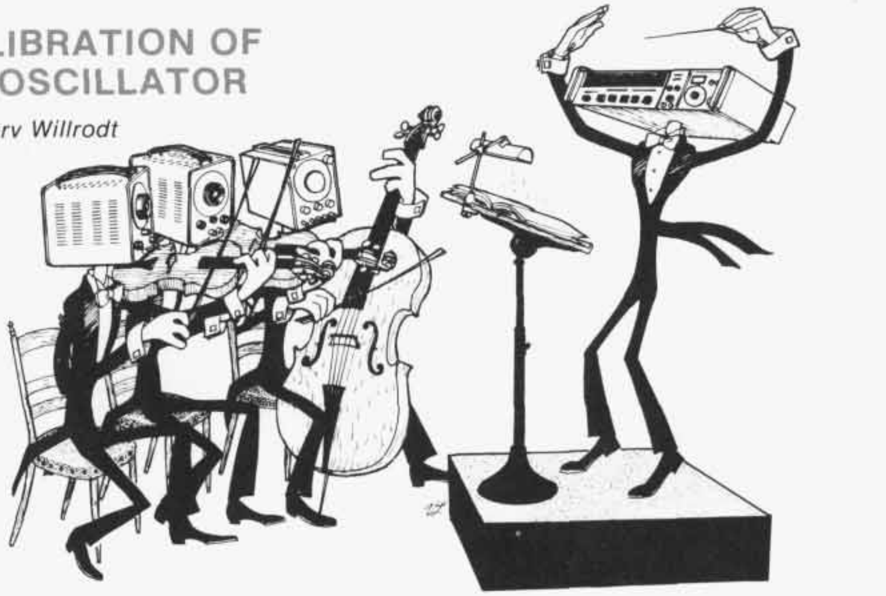
CALIBRATION OF AN OSCILLATOR

by Marv Willrodt



Calibration of a crystal oscillator in a counter or other device requires several pieces of equipment plus a systematic procedure. First of all, one must have a reference standard which is more accurate than the specification to be met. This usually takes the form of an "in house" frequency standard — a quartz oscillator, a Rubidium frequency standard, or a Cesium Beam frequency standard. The standard is compared to the National Bureau of Standards station WWVB on 60 kHz using an HP model 117A VLF comparator for locations within the continental United States or an appropriate receiver to receive one of the other world-wide frequency services for stations outside the U.S. For example, the H44-117A can be used to receive station HBG in Prangins, Switzerland.

WWV high frequency transmissions should NOT be used for calibrating a high stability oscillator because the variations due to noise and doppler shift can introduce more error than 10 to 100 days aging of the oscillator. These transmissions can be used to calibrate an oscillator to a part in 10^6 or so and can be used to check a stable oscillator for gross error due to some malfunction. This procedure is shown in Figure 1.

The HP 5360A computing counter can be used to measure the oscillator frequency of most other devices since it will resolve 1×10^{-10} in one second. Other counters are generally not satisfactory for setting precision oscillators because even on a 10 second gate the ±1 count error for a one megahertz signal is 1×10^{-7}, whereas a good oscillator can easily have a stability 10 to 1000 times better than this.

TRIGGERED OSCILLOSCOPE METHOD:

A triggered sweep oscilloscope is the easiest device to use for setting one oscillator to agree with another. Resolution is good; furthermore, the oscilloscope gives a continuous indication of both the direction and magnitude of error. In addition, when the unknown oscillator is adjusted to stop the motion of the scope pattern, any errors in the scope sweep drop out completely. See Figure 2.

PHASE DETECTOR WITH STRIP CHART RECORDER:

While the oscilloscope method still works when comparing very stable oscillators (for instance, when comparing a Rubidium standard to a Cesium standard) a phase detector driving a strip chart recorder gives a more useful record. Sinçe the record is continuous, the operator can visually ignore noise and other obvious known discrepancies when making the comparison.

A modified version of the 117A can be used to make a phase comparison between an unknown 100 kHz standard and the local standard, as well as compare the local standard to WWVB. HP has also built the K05-5060A and K19-5061A linear phase comparators for making high resolution comparisons between 105A/B oscillators, 5060A/5061A Cesium standards, 5065A Ruidium standard, and similar high stability sources. The 8405A vector voltmeter

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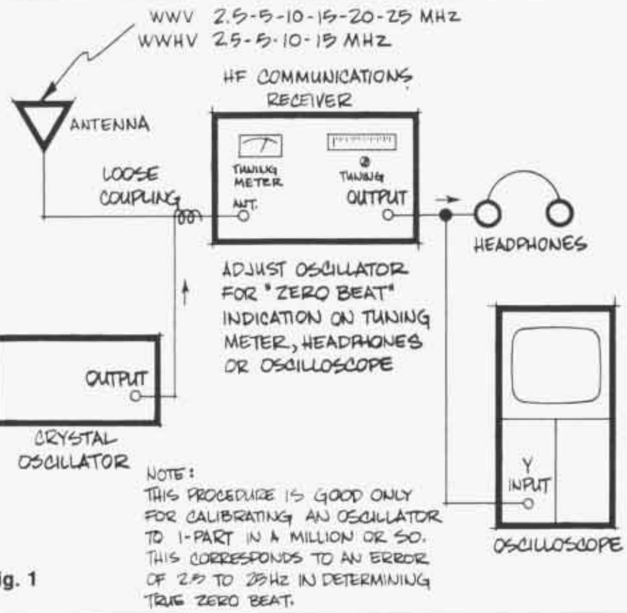
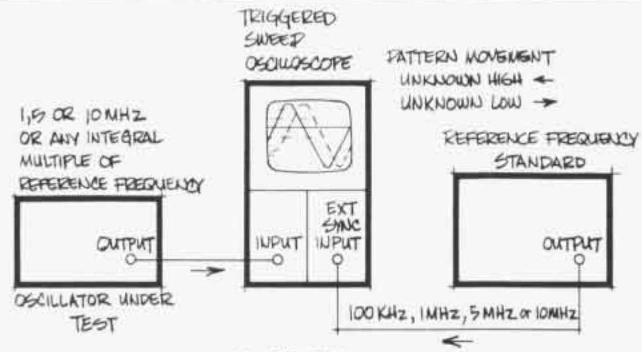


Fig. 1



CALIBRATION

MOVEMENT	SWEEP SPEED 1μSEC/CM	0.1μSEC/CM	.01μSEC/CM	NOTES
1 CM/SEC	1×10^{-6}	1×10^{-7}	1×10^{-8}	TIME SCOPE TRACE MOVEMENT WITH SECOND HAND OF WATCH OR CLOCK
1 CM/10 SEC	1×10^{-7}	1×10^{-8}	1×10^{-9}	
1 CM/100 SEC	1×10^{-8}	1×10^{-9}	1×10^{-10}	

Fig. 2

can also be used to make high resolution phase comparisons between frequency standards as outlined in Application Note AN 77-2, "Precision Frequency Comparison."

Figure 3, which is taken from the 117A manual, is useful for determining the offset between two standards when the phase change and the time required for the phase change are known. Special templates are supplied with the 117A VLF comparator so this offset can be read without charts or calculations.

For example, assume that on a particular day the phase change is 10.8μs in 1 hour. This corresponds to a frequency offset of 3 parts in 10^9. Assume that the phase change 24 hours later is 3.6μs in 1 hour. This corresponds to a frequency offset of 1 part in 10^9. Thus the aging rate for this 24-hour period is the difference between the offsets. This is 2 parts in 10^9 if the offsets are both higher than or both lower than the reference. The aging rate is 4 parts in 10^9 if one reading is above and one reading below the reference frequency.

The frequency offset chart is determined by noting that an hour contains 3.6×10^9μs. Thus dividing this into a given frequency change (in μs per hour) will yield the offset. In the first example above,

$$\frac{10.8\mu s/\text{hour}}{3.6 \times 10^9 \mu s/\text{hour}} = 3 \times 10^{-9}.$$

FREQUENCY MULTIPLIER METHOD:

A frequency multiplier as shown in the block diagram of Figure 4 can also be used to increase the resolution with which a crystal oscillator frequency can be measured in a given measurement time. The "times 200" multiplication in this case was achieved by using a 5245M/5254C. The unknown standard was connected to the EXTERNAL standard input on the 5245M. The 5245C is tuned to 1.0 GHz and the 1 GHz output is taken from the coax which connects to the center of the 5254C cavity.

This output signal will be exactly 200 times the nominal 5 MHz external standard input. This output is measured on a 5254C in a second 5245L/M or 5248L/M with a second 5254C tuned to .95 GHz.

Fig. 3 Frequency Offset Chart

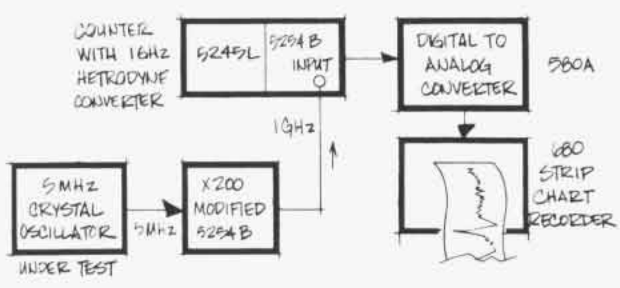


Fig. 4

The counter will

display	50 000 000 Hz
5254C dial to	+ 950 000 000 Hz

Frequency measured by 2nd 5245L/5254C = 1 000 000 000 Hz

Note the resolution is 1 part in 10^9 for a 1-second measuring time and would be 1 part in 10^{10} for a 10-second measuring time. For very high accuracy work, you may want to drive the time base of the second counter from a Cesium or Rubidium reference standard. This measurement system is linear so all chart readings are meaningful and frequency change can be determined by a simple subtraction.

A simple check of the overall system can be made by driving the EXT STD Input of the first counter with a standard frequency output of the second counter instead of from the unknown standard. The second counter should then read 50 000 000 ±1 Hz or 50 000 000.0 ±0.1 Hz, depending on the measurement time.

A difference frequency comparator can also be used to compare frequency standards. This device multiplies the difference in frequency between an unknown input and a reference input by decade steps until it is large enough to read on an analog meter or display on an oscilloscope. It can be checked as indicated above by feeding the same frequency to each input and noting a difference of zero.

WARM-UP CYCLE

If the crystal oven of a high stability oscillator is allowed to cool—even for a few minutes—the temperature gradient may stress the quartz plate enough so it has to go through another warm-up cycle. Some charts of typical (not guaranteed) turn-on curves on the 5245L oscillator both for oven hot and oven cold turn-on are shown in Figures 5 through 8. The oven on the 5245L is operating whenever the power

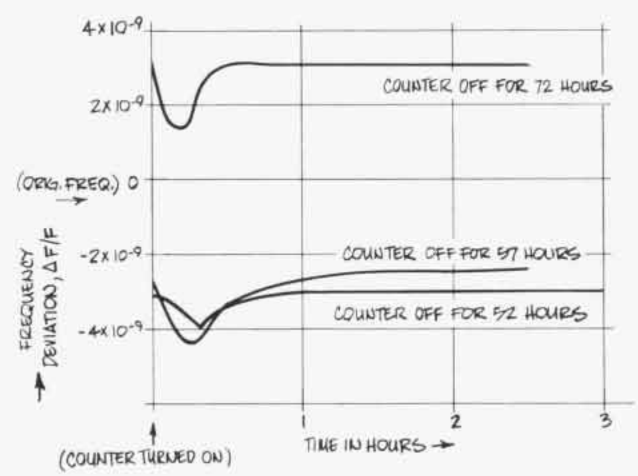


Fig. 5 Three Typical Counters at Room Temperature, Line Voltage Connected, with Counter Switch Off. (Oven Operating)

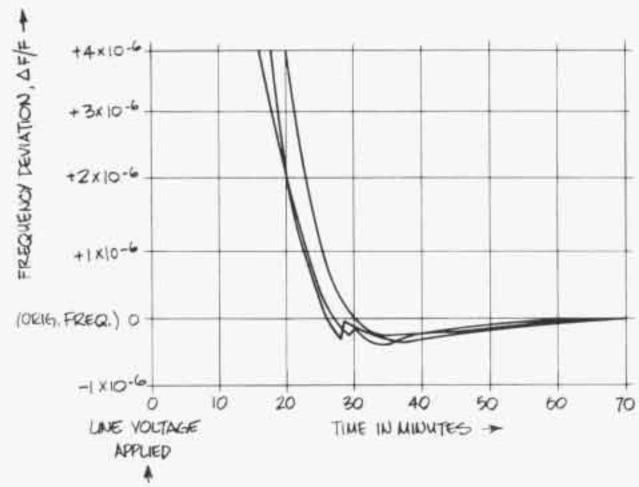


Fig. 6 Three Typical Counters at Room Temperature. Disconnected from Line Voltage for more than 48 hours.

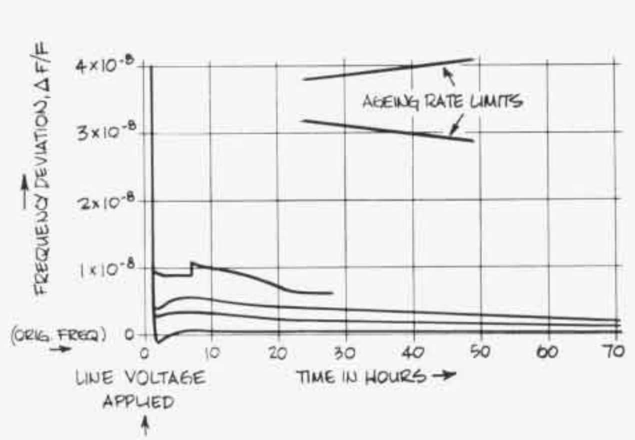


Fig. 7 Four Typical Counters at Room Temperature, Disconnected from Line Voltage for more than 48 hours.

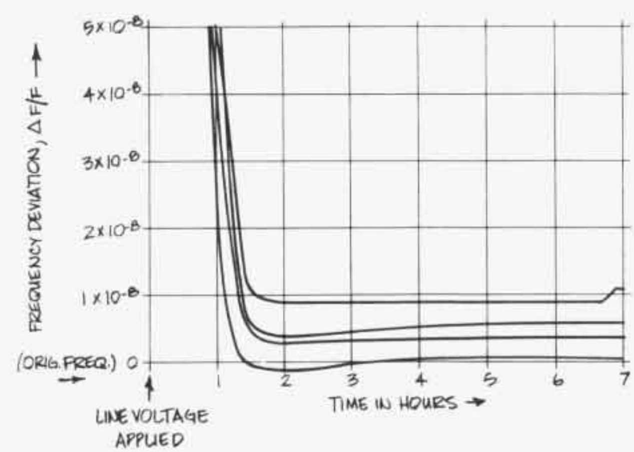


Fig. 8 Four Typical Counters at Room Temperature. Disconnected from line Voltage for more than 48 hours.

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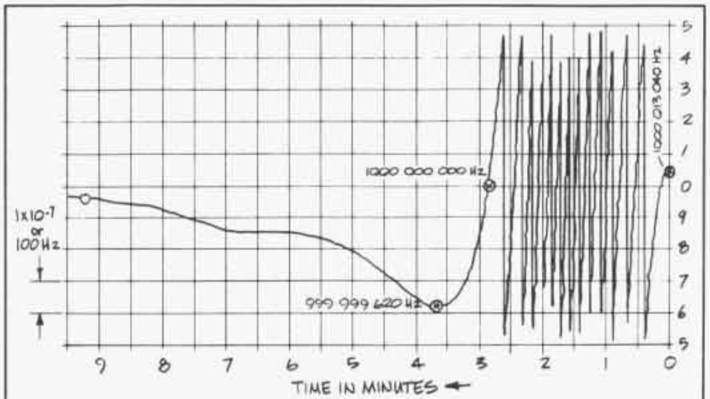

Fig. 9

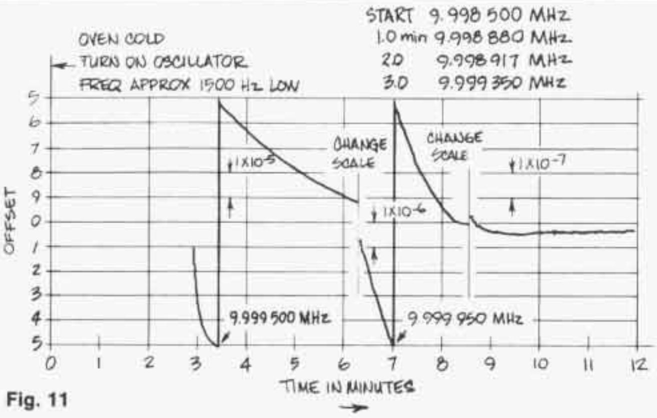

Fig. 11

cord is energized. A warm-up curve for the 5245M/105A crystal oscillator, Figure 9, which was measured using the Frequency Multiplier Setup, is also included. In this case, both the oven and oscillator operate whenever the power cord is plugged into a live outlet.

Once the oscillator has been calibrated, the easiest way to determine the total error in any measurement is to look for the accuracy chart in the manual for the counter of interest. Figure 10 is the accuracy chart for a 5245L counter. This chart takes into account all of the errors in the frequency or period modes of operation. Each counter will have its own error chart so be sure to use the correct one for your model of counter.

To determine the error, locate the input frequency being measured on the horizontal scale. For frequency measurements, move upward to the appropriate line for the gate time selected by the front panel control. For period average measurements, move upward to the appropriate line for the number of periods being averaged. Then move left to read the total error, which can be expressed as a fraction, as a power of ten, or as a percentage.

Figure 11 shows a typical warm-up frequency vs time plot for a 10544A oven oscillator. This oscillator, which is available as an option in a number of HP products, has a fast warm-up feature. Note that frequency readings are listed for the first few minutes instead of a plot because of limitations of the measuring technique used.

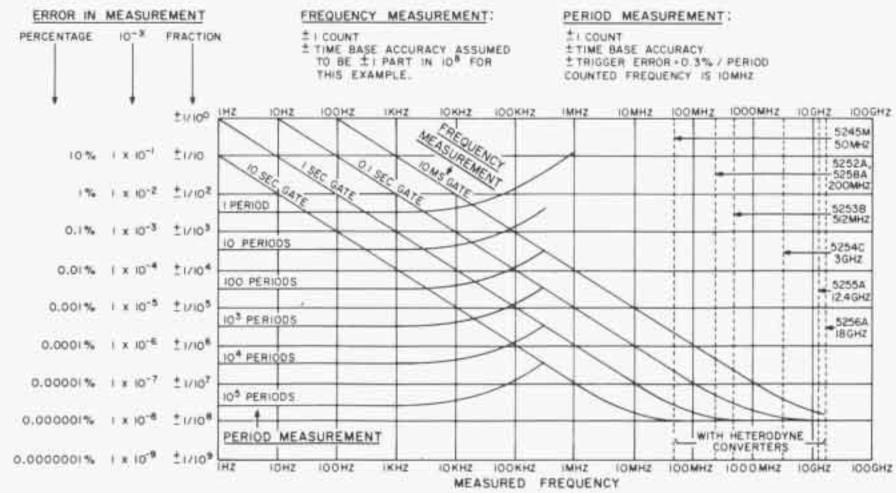

Fig. 10 Accuracy Chart

Marv Willrodt, an Applications Engineer with the Santa Clara Division of Hewlett-Packard, is currently working on a user's guide for a new electronic frequency counter. He began his career with HP in 1951 as a design engineer. He was involved with the 524 counters, AC-4 decoder, 218A digital delay generator and 5214L preset counter.

Widely recognized as a frequency standards expert, Marv is the author of many contributions to the electronics industry; his most recent involvement has been as one of the authors in a McGraw-Hill book, Basic Electronic Instrument Handbook *which is edited by Clyde Coombs.*

He is a stereo sound enthusiast in addition to a photography buff.

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supplement to BENCH BRIEFS SERVICE NOTE INDEX

On the next page is a listing of the latest Service Notes available for Hewlett-Packard products. Service Notes contain information that will help you get the most out of your purchases.

Many times design changes or other improvements are made in products currently being manufactured. HP often recommends including these changes in products previously sold; this is done by writing a Service Note for the product.

OCTOBER 1973

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NEW

SERVICE NOTES

M-51 Equipment necessary to calibrate and check performance of HP Real Time Oscilloscopes.

136A X-Y RECORDER

136A-2 Serials prefixed 705 and below. Y2 chopper replacement.

1150A PROGRAMMABLE WAVEFORM PROCESSOR

1150A-1 Removal of boards from "Blue Stripe" program.

1208A, B DISPLAY

1208A/H11-2 Serial prefix 1130A and below. Changes on storage pulse assembly A4.
1208A/H11-3 Serial prefix 1212A and below. Modification to improve storage uniformity.

1300A X-Y DISPLAY

1300A/H82-1 All serial prefixes. Transfer to production option status.
1308A-5 Serial prefix 1303A and below. New CRT graticule.
1308A-6 Serial prefix 1315A and below. Addition of heat sinks on X/Y output stage transistors.
1309A-4 All serial prefixes. Error in manual change sheets.
1309A-5 Serial prefix 1252A and below. New CRT graticule.
1309A-6 Serial prefix 1318A and below. Addition of heat sinks on X/Y output stage transistors.

1310A COMPUTER GRAPHIC DISPLAY

1310A-6 Serial prefix 1301A and below. Correction for drive defocusing.
1310A-7 Serial prefix 1301A and below. Improved high voltage power supply.
1310A-8 Serial prefix 1316A and below. Modification to reduce coupling between the Z-Axis input and the X/Y inputs.

1311A COMPUTER GRAPHIC DISPLAY

1311A-6 Serial prefix 1238A and below. Correction for drive defocusing.
1311A-7 Serial prefix 1238A and below. Improved high voltage power supply.
1311A-8 Serial prefix 1316A and below. Modification to reduce coupling between the Z-Axis input and the X/Y inputs.

1402A DUAL TRACE AMPLIFIER

1402A-9 Serials prefixed 716 and below. Preferred replacement for Q302.

1405A DUAL TRACE AMPLIFIER

1405A-2 Serials prefixed 450 and below. Preferred replacement for Q404.

1415A TIME DOMAIN REFLECTOMETER

1415A-11 (Option 014 and Option H08) Time Domain Reflectometer preferred parts replacement.
1420A-6 Serials prefixed 014 and below. Preferred replacement for Q101.

1815A/B TDR/SAMPLER

1815A/B-4 Serial prefix 1130A and below; 1815B Serial prefix 1139A and below. Improved 1106A tunnel diode mount reliability.

1920A PULSE GENERATOR OUTPUT AMPLIFIER

1920A-2 Serials prefixed 1211A and below. Preferred replacement for A2Q14, Q15, Q31, Q32.

3330A/B AUTOMATIC SYNTHESIZER

3330A-3 Serial number 1145A 00112 and below. Modification to prevent power supply oscillations.
3330B-3 Serial numbers 1305A00260 and below. Modification to prevent power supply oscillations.

3459A DIGITAL VOLTMETER

3459A-11 All serials. Replaced the oven controlled power supply.

5216A ELECTRONIC COUNTER

5216A-2 Serial prefix 976 and below. Solution for A4 decade divider reset problem.

5300A FREQUENCY COUNTER

5300A-2 Serial number 1208A02161 and below. Modification to prevent thermal runaway.
5300A-1A All serials. Instructions to measure power line frequency.

5303A 500 MHz COUNTER MODULE

5303A-1 Serial prefix 1124A and below. Modification to install input overload protection.

5310A BATTERY PACK

5310A-1 All serials. Precautions for battery replacement.

5326/5327 SERIES UNIVERSAL TIMER/COUNTER

5326A/B/C/5327A/B/C-4 All serials. Modification to prevent Q1 and Q2 failures.
5326A/B/C/5327A/B/C-5 All serials. Field installation of Option 011.
5326A/B/C/5327A/B/C-6 All serials. Field installation of Option 010.
5326A/B/C/5327A/B/C-7 All serials. Optional addition of fuse to protect +175 volt power supply.

5340A MICROWAVE FREQUENCY COUNTER

5340A-1 Serial number 1252A00269 and below. Modification to eliminate oscillation on Hi-Z input.
5340A-2 Serial number 1320A00450 and below. Modification to improve chassis vibration stability.
5340A-3 All serials. Troubleshooting and checkout information for HP interface bus (Opt. 003).
5340A-4 All serials. Mixer assembly A11 calibration after A11U1 replacement.

5360A COMPUTING COUNTER

5360A-6 All serials. List of parts in the 5360A Computing Counter service kit, HP part number 10636A.
5360A-7 Serials below 1240A01076. New pana plex display for improved reliability.

8410A NETWORK ANALYZER

8410A-6 Serials 935-01131 through 1144A02227. New replacement hardware for mounting fan.
8410A-7 Serials 1310A02411 and below. Modification to eliminate inherent cross-talk problems associated with the rear panel outputs.

8605 COMMUNICATIONS SWEEP OSCILLATOR

8605A-1 Serial number 1317A00210 and below. Improved operational amplifiers for A2 and A3 driver assemblies.
8605A-2 Serial number 1317A00220 and below. Power line filter capacitor change for 230 volt operation.
8605Z-1 Serial number 1317A00230 and below. Improved operational amplifiers for A2 and A3 driver assemblies.

8620 SERIES SWEEP OSCILLATORS

8620A-2A Serial prefix 1102A and below. Modification to reduce residual FM.

8640A/B AM-FM SIGNAL GENERATOR

8640A-5/8640B-6. 8640A serial prefix 1245A and below. 8640B serial prefix 1246A and below. Replacement F/Range switch assembly.
8640A-6/8640B-7. Serial prefix 1310A and below. Improved AM noise performance.
8640A-7/8640B-8. 8640A serial prefix 1243A and below. 8640B serial prefix 1244A and below. AM bandwidth improvement.
8640A-8/8640B-9. 8640A serial prefix 1250A and below. 8640B serial prefix 1251A and below. Front panel meter replacement.
8640A-9/8640B-10. Serial prefix 1301A and below. Improvements in AM and pulse circuits.
8640A-10/8640B-11. 8640A serial prefix 1243A and below, 8640B serial prefix 1244A and below. Reduction in RFI leakage from front panel.
8640A-11/8640B-12. All serials. RF On/Off switch modification.
8640A-12. Serial prefix 1313A and below. Recommended A8 mechanical dial replacement.

8654A SIGNAL GENERATOR

8654A-1 Serial prefix 1305A and below. Output attenuator replacement.

8660A SYNTHESIZED SIGNAL GENERATOR

8660A-13 Serials 1246A00350 and below. 500 MHz amplifier heatsink.
8660A-14 All serials. "The Indirect Generation" service video tape supplement.

8660B SYNTHESIZED SIGNAL GENERATOR

8660B-8 Serials 1247A00320 and below. 500 MHz amplifier heatsink.
8660B-9 Serial prefix 1247A and below. Improved keyboard entry.
8660B-10 Serials 1247A00300 and below. Improved 3M cable, 14 pin connector.
8660B-11 Serials 1312A00401 and below. Digital control unit mechanical checks.

8690 SERIES SWEEP OSCILLATORS

8690A-12A All serials. Replacement of capacitors containing PCB.

86200 SERIES RF PLUG-INS FOR 8620A/B

86242A-1 All serial numbers. YIG oscillator replacement assemblies.
86250A/B-1 All serial numbers. YIG oscillator replacement assemblies.

11661A EXTENSION MODULE

11661A-3 All serials. Installation checks and adjustments.

86300 SERIES RF MODULES FOR 8620A,B

86342A-1 All serials. YIG oscillator replacement assemblies.
86350A-2 All serials. YIG oscillator replacement assemblies.
86351A-1 All serials. YIG oscillator replacement assemblies.
86352A-1 All serials. YIG oscillator replacement assemblies.

86320/86330 MODULES

86330A-4 Serial prefix 1142A and below. Modification to 86330A and 86331A for compatibility with 8700A.
86331A-2 Serial prefix 1142A and below. Modification to 86330A and 86331A for compatibility with 8700A.

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☐ 86330A-4
☐ 86331A-2

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Would you take a moment to answer a few questions?

Hewlett-Packard is always interested in improving the usefulness of operating and service manuals. One area that has attracted some interest is microfiche. This is a method of putting an entire service manual on several 4 by 6-inch cards. These are then used with a viewing machine to retrieve the information. Thus the amount of storage space needed for manuals is greatly reduced; in fact, many times the documentation for an instrument can be stored in a small pocket inside the instrument.
We would like your opinion about microfiche.

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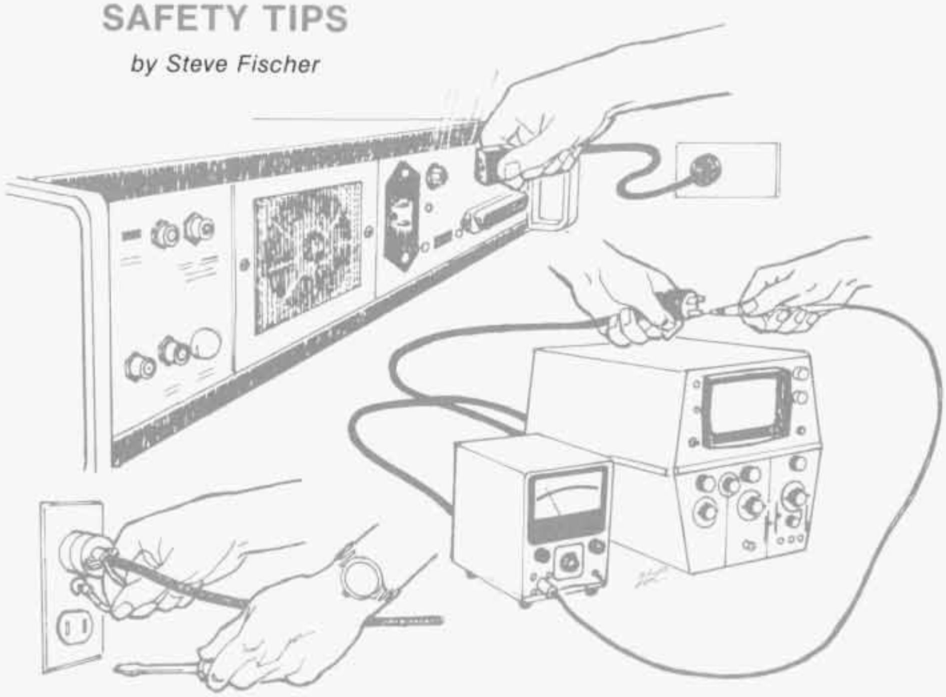


The experienced service person is always looking for ways to reduce the repair time on instruments. Sometimes safety is compromised in the process, unfortunately.

One of your primary concerns when servicing or maintaining an instrument should be *your* safety *and* the safety of those who will use the product following your work on it.

It may be helpful for the novice as well as the veteran to review some precautions which should be taken during the servicing of *any* electrical product.

1. Before removing covers, even if you will need to make measurements afterward, disconnect the power source. To rely on the instrument's power switch to disconnect both sides of the line may get you in trouble, especially on older products. Even if the power switch is double pole type, you still risk the consequences of dropping a cover, screw, or your hand on the power input terminals while disassembling the instrument.

2. Before reconnecting the instrument to power for making your measurements, it is a good practice (and should become routine) to check the continuity of the third wire ground if the product is equipped with a three-wire power cord. An ohmmeter connected from the instrument chassis or case to the ground pin on the plug should read less than 1.0 ohm. Flex the cord a few times while making this measurement to detect any intermittent break. A cord may look good and still be open or intermittent, so be certain to check it thoroughly.

3. Instruments should be connected only to outlets that are properly connected to earth ground. If a three-wire to two-wire adaptor is used, be certain to connect the green wire to a good ground. Products have a third wire connected to chassis to protect the operator in the event of a short circuit in the instrument. Maintaining a good earth ground connection will ensure having this protection.

Making measurements carefully, deliberately and one at a time will reduce the chance of an error or accident. Taking a few extra seconds to work safely is time well spent.

Steve Fischer is the Product Safety Officer at Hewlett-Packard in Palo Alto. Previously he was a Product Support Engineer at the Avondale, Pennsylvania division.

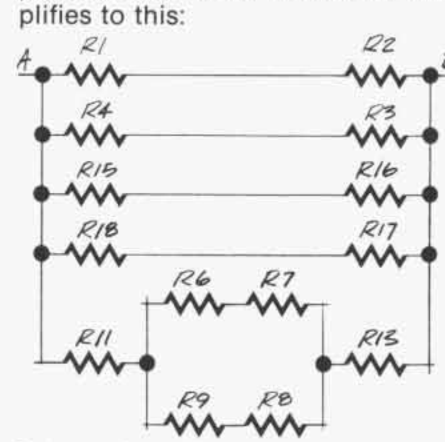
Additional tips of this nature will be published in future issues.

SHORT QUIZ SOLUTION

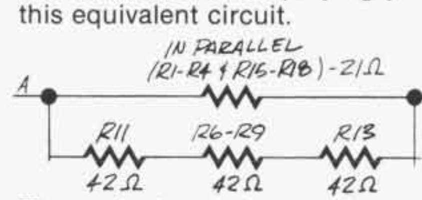
The last issue presented a cube of 42 ohm resistors and asked for the equivalent resistance between points A and B. Also how much voltage can be placed between A and B without exceeding ¼ watt in any resistor?

This problem could be solved by loop equations, but a much simpler approach is to recognize that R5, R12, R10 and R14 are in an equipotential plane since the cube could be looked upon as an elaborate balanced bridge.

Therefore, these four resistors can be replaced with an open or short circuit with no change in circuit performance. Thus the circuit simplifies to this:



Substituting 42 ohms for each of the resistors and simplifying yields this equivalent circuit.



The equivalent resistance is

$$\frac{(126)\,(21)}{126 + 21} = 18 \text{ ohms}$$

The ¼ watt rating of the resistors means that any resistor can have a maximum voltage across it of 3.24v (since $P=\frac{E^2}{R}$, substituting P=0.25 and R=42 yields $E=\sqrt{(.25)\,(42)} = 3.24$). But the equivalent circuit shows two resistors in series in several legs; therefore, the maximum voltage allowed between Points A and B is 6.48v.

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VIDEO TAPES

another dimension in education and service

Video tapes provide a convenient and efficient way to obtain service training on specific HP products or general techniques. The HP Tutorial Series covers technical concepts such as VSWR, Logic Troubleshooting, or dB and dBm. Video tapes are available in a variety of formats. A letter suffix is attached to the product number in the space provided. This determines the format. All tapes are NTSC.

A = 1-inch Ampex format	C = ½-inch Sony AV (EIAJ-1) format
B = 1-inch Sony format	D = ¾-inch Sony U-matic videocassette format

For example, to order **Choosing the Right AC Voltmeter** for a Sony ½-inch playback unit, place your order for: 1 each 90030C Opt. 605 **Choosing the Right AC Voltmeter**

The U.S. prices range from $75 to $150 each depending on the tape size and the quantity ordered. To order any tape, or for more information, contact your local HP office. Below is a listing of video tapes currently available in the Tutorial Series:

	Product #	Option #
Choosing the Right AC Voltmeter Overview of the field of AC measurements identifying the proper AC voltmeter for measuring AC current, etc. (22 min.)	90030_	605
Improved Counter Measurements Instruction on how to find the total measurement error of a frequency measurement, etc. (23 min.)	90030_	721
Basic Electronic Counter Functions The seven basic counter functions best suited to a particular measurement need. (17 min.)	90030_	534
The Reflectometer Calculator: Reflection Terms A short, important rundown on how to use the reflectometer calculator slide rule. (4 min.)	90030_	763
High Frequency Detectors and Terms Identifies the four categories of high frequency detectors. (10 min.)	90030_	643
Reflection Terms The four reflection terms used to describe impedance at high frequencies. (15 min.)	90030_	636
Source VSWR A comprehensive discussion of Source VSWR at a termination level. (10 min.)	90030_	711
Power Measurements: Types of Systems Choosing the right method to measure high frequency power. (13 min.)	90030_	645
Transmission Lines An explanation of transmission line terms and functions. (14 min.)	90030_	593
The Smith Chart Explanation of the Smith Chart and its use. (29 min.)	90030_	642
Count Any Signal The proper AC-DC Switch, Attenuator and level control settings for a frequency counter for all types of signals. (10 min.)	90030_	635
Time Interval Measurement Review of the function known as Time Interval (T.I.) and how to select compatible instruments. (15 min.)	90030_	637
Time Interval Averaging A thorough program offering sound practical advice on Time Interval Averaging. (24 min.)	90030_	633
What Is A dB? An explanation, with examples, of common conversions used in electronics. (16 min.)	90030_	614
Directional Coupler Introduction An explanation of the terms used to specify and describe couplers. (14 min.)	90030_	578
Digital Magnetic Tape Basics A summary of the applications for digital mag tapes and comparison with other storage media. (20 min.)	90030_	501
Time Domain Reflectometry Basic theory of TDR measurements and major practical considerations in using the technique. (31 min.)	90060_	450
High-Reliability Component Terms Terminology associated with HI-REL devices. (13 min.)	90030_	722
Logic Symbology Clarification of the majority of HP-used logic symbols and an explanation of the functions of the devices themselves. (20 min.)	90030_	489
S-Parameter Design Techniques Part 1 of 2 presents a thorough review of microwave theory. (54 min.)	90060_	586

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S-Parameter Design Techniques Part 2 describes the characteristics of HP's 12 GHz transistor including its S-Parameters. (56 min.)	90060_	600
Troubleshooting Transistor Circuits Faster A valuable collection of proven trouble-shooting techniques. (17 min.)	90030_	683
Troubleshoot FET Circuits Faster Describes the various types of FETs encountered in electronics equipment and discusses basic FET theory. (16 min.)	90030_	727
Numbering Systems and Digital Devices An examination of the binary numbering system to aid in conversion of numerical data to and from decimal, binary, octal, BCD, etc. (25 min.)	90030_	784
Digital Building Blocks Characteristics of gates and flip-flops and their applications. (18 min.)	90030_	783
Functional Analysis The basic functional building blocks of digital design and comprehensive coverage of algorithms. (22 min.)	90030_	785
Electrical Analysis Covers the specialized triggering requirements and noise problems unique to digital systems. (20 min.)	90030_	786
Data Communications Discusses basic data communications terminology, component parts of a basic communications network, and measurement problems. (29 min.)	90030_	787

In addition, many instrument-related video tapes are available for specific HP products. In many cases these can easily show a complex mechanical disassembly or adjustment sequence. This may prove extremely helpful for the serviceman about to perform that particular task.

Below is listed the video tapes currently available for HP electronic instruments.

Video tapes also exist for other disciplines, such as medical and systems. A free catalog is available which lists all HP tutorial and product-related video tapes. Check the video tape catalog box on the order form on page 7.

	Product #	Option #
183A Oscilloscope Mainframe Adjustments Calibration procedures for 183A/B (25 min.)	90030_	503
1700 Series Service—Part 1 Review of controls and assemblies on Model 1700A (14 min.)	90030_	673
1700 Series Service—Part 2 Block diagrams and schematics of DC-DC converter power supply and logic-controlled trigger circuit. (20 min.)	90030_	674
CRT Service and Troubleshooting Review of cathode ray tubes: their construction, adjustments and trouble-shooting techniques. (18 min.)	90030_	704
Understanding HP Storage Scopes—Theory Theory and operation of mesh-storage cathode ray tube, plus use of operating modes of storage oscilloscopes. (29 min.)	90030_	449
Understanding HP Storage Scopes—Service Storage CRTs: common failures; troubleshooting techniques, minor repairs, etc. (37 min.)	90060_	359
8064A Spectrum Analyzer Service How to localize problems with the 8064A to the board level to utilize board exchange program. (35 min.)	90060_	632
746A Maintenance 746A High Voltage Amplifier: Operational theory and block diagramming, high voltage danger areas. Correct techniques for replacing boards & tubes. (28 min.)	90030_	408
3490A Multimeter Self-Test Troubleshooting Use of self-test feature of 3490A Multimeter. (22 min.)	90030_	705
432A Power Meter Maintenance Block diagram explanation of 432A followed by maintenance and adjustment procedures. (60 min.)	90060_	298
8410A/8411A Network Analyzer Service Theory of operation of 8410A/8411A followed by phase-lock loop and sampler troubleshooting techniques. (23 min.)	90030_	490
8660 Series Signal Generator Service: Part 1 8660A/B family block diagram discussion followed by explanation of the function of connectors, controls, light indicators & internal assemblies. (23 min.)	90030_	566
5061A Cesium Beam Tube Replacement Replacement of cesium beam tubes & alignment. (30 min.)	90030_	664
5360A Computing Counter Maintenance Troubleshooting procedures for 5360A and Board Exchange Service Kit use. (27 min.)	90030_	513
5500A Replacing the Laser Tube: Service Alignment and calibration of 5500A Laser Interferometer plus proper operation, troubleshooting and replacement of the laser tube. (24 min.)	90030_	456
8050A Spectrum Analyzer Maintenance Do-it-yourself maintenance of the 8050A. (20 min.)	90030_	616
8064A Spectrum Analyzer Recalibration Step-by-step recalibration of the 8064A. (35 min.)	90060_	663
5050A/B Digital Recorder Maintenance Maintenance procedures for the printer mechanism section of the 5050A/B. (43 min.)	90060_	300

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MORE ON dB AND dBm WITHOUT LOGS

Many readers commented on the article in the May/June issue about determining power ratios from dB without the use of logarithms (page 4).

The article states that not all numbers can be calculated with this method and it goes on to suggest using the technique to obtain an approximation for these situations. As many readers pointed out, *any* number can be calculated with combinations of 10 and 3. For example, 8dB is 10dB + 10dB - 3dB - 3dB - 3dB - 3dB, or a power ratio of 10 x 10 x ½ x ½ x ½ x ½ or 6.25.

It should also be pointed out that this method introduces a very small error because 3dB is not exactly a ratio of 2 to 1.

Letters to the editor are encouraged because I can then share your comments with all the readers in a future issue. These letters also indicate the type of articles that are preferred, and they thus help determine the content of this service publication. Thanks for the feedback.

The Editor

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