HEWLETT hp PACKARD

CRYSTAL DETECTOR

models
423A &
8470A

OPERATING NOTE 16 JUNE 1967

Figure 1. Models 423A and 8470A Crystal Detectors and Model 11523A Load Resistor

1. INTRODUCTION.

2. The 423A and 8470A Crystal Detectors are 50-ohm (nominal) devices designed for measurement use in coaxial systems. They measure relative power up to 100 mW, ahd have a BNC output jack to connect the detected output to a meter, such as the 415E. Frequency range of the 423A is 10 MHz to 12.4 GHz. The 8470A has additional range up to 18 GHz.

3. Output polarity of the Detectors is negative unless the Option 03 version is purchased. Specifications and Options are listed in Table 1.

4. The optional Load Resistor, Model 11523A, is mounted in a separate housing to permit easy conversion from optimum square law to maximum output. Each load is identified by the serial number of the Detector to which it is matched. If you have more than one Model 11523A, always be sure that the proper one is in use for the Detector you are using.

5. PRECAUTIONS.

6. ELECTRICAL SHOCK.

7. DISCHARGE OF STORED ELECTRICAL ENERGY CAN EASILY DAMAGE THE CRYSTAL DETECTOR. A 100-pF capacitor, the equivalent of four feet of coaxial cable, charged to 14 volts stores 0.1 erg of energy which is the maximum safe pulse rating of the detector. Be certain that a cable is connected to associated equipment and discharged before connecting it to crystal detector.

8. HANDLING DETECTOR ELEMENT.

9. DO NOT HANDLE DETECTOR ELEMENT USED IN CRYSTAL DETECTOR NEEDLESSLY. Static electricity which builds up on a person, especially on a cold, dry day, must never be allowed to discharge through the Crystal Detector. Avoid exposed leads to or from the Crystal Detector, since these are often touched accidentally. Refer to Paragraph 24 for proper precautions.

01613-8

00423-90010

1501 Page Mill Road, Palo Alto, California, U.S.A., Cable: "HEWPACK" Tel: (415) 326-7000
Europe: 54 Route Des Acacias, Geneva, Switzerland, Cable: "HEWPACKSA" Tel. (022) 42.81.50

Printed in U.S.A.

Table 1. Specifications

Frequency Range:

423A: 10 MHz to 12.4 GHz.

8470A: 10 MHz to 18 GHz (Below 1 GHz, RF may leak through the video output connector. It can be eliminated, if objectionable, with suitable low pass filter.)

Frequency Response:*

423A: ±0.2 dB/octave 10 MHz to 8 GHz; ±0.5 dB overall.

8470A: ±0.2 dB/octave 10 MHz to 8 GHz; ±0.5 dB to 12.4 GHz; ±1.0 dB overall.

Maximum Power: 100 mW, peak or average.

Sensitivity:

High Level: <0.35 mW produces 100 mW output.
Low Level: >0.4 mVdc/μW CW.

Impedance: 50 ohms.

Reflection Coefficient:

423A and 8470A: 10 MHz to 4.5 GHz, 0.091 (1.2 SWR); 4.5 GHz to 7.0 GHz, 0.15 (1.35 SWR); 7.0 GHz to 12.4 GHz, 0.2 (1.5 SWR).

8470A: 12.4 GHz to 18.0 GHz, 0.26 (1.7 SWR).

Output Impedance: <15kΩ shunted by 10 pF.

Detector Element: Supplied. (Refer to Table 2 for replacement assemblies.)

Output Polarity: Negative. (Refer to options for positive polarity units.)

Noise: <200 μV p-p, with CW applied to produce 100 mVdc output.

*As read on a meter calibrated for square-law detectors (such as HP 415E SWR Meter).

Connectors:

423A:

Option 01: Matched pair. Frequency response characteristics (exclusive of basic sensitivity) track within ±0.2 dB per octave from 10 MHz to 8 GHz, ±0.3 dB from 8 to 12.4 GHz.

Option 02: Furnished with matched load resistor (11523A) for optimum square law characteristics at 24°C (75°F),* $<\pm0.5$ dB variation from square law over a range of at least 30 dB up to 50 mV peak output working into an external load >75k ohms. Sensitivity typically >0.1 mV/μW when load resistor is used. Overall length 4-1/2 in. (144 mm).

Option 03: Positive polarity output.

8470A:

Option 01: Matched pair. Frequency response characteristics (exclusive of basic sensitivity) track within ±0.2 dB per octave from 10 MHz to 8 GHz, ±0.3 dB from 8 to 12.4 GHz, ±0.6 dB from 12.4 to 18 GHz.

Option 02: Furnished with matched load resistor (11523A) for optimum square law characteristics at 24°C (75°F),* $<\pm0.5$ dB variation from square law over a range of at least 30 dB up to 50 mV peak output working into an external load >75kΩ. Sensitivity typically >0.1 mV/μW when load resistor is used. Overall length 4-1/2 in. (144 mm).

Option 03: Positive polarity output.

Option 12: Furnished with stainless steel type N male connector.

Option 13: Furnished with stainless steel type N female connector.

10. GENERAL.

11. The Crystal Detector can be used as a demodulator to obtain a pulse envelope which can then be observed on an oscilloscope. It can also be used as a general purpose detector.

12. When using the Crystal Detector with an oscilloscope and the waveshapes to be observed have rise times of less than 5 μsec, the coaxial cable connecting oscilloscope and detector should be as short as possible and shunted with a resistor. Ideally, this resistor should be 50 ohms to terminate the coaxial cable properly. However, with 50 ohms resistance, possibly the output video pulse may be too small to drive some oscilloscopes. Therefore, the cable should be shunted with the smallest value of resistance that will obtain suitable deflection on the oscilloscope; typically the value will lie between 50 and 2k ohms. The larger the resistance the more degradation of rise time.

13. The power applied to the Detector can be either modulated or continuous wave (CW). If modulated at a 1000-cps rate, the sensitive HP Model 415B/E can be used as the indicator. For CW detection, a dc milliammeter or millivoltmeter such as the HP Model 425A Microvolt-Ammeter can be used as the indicator.

14. PEAK POWER MEASUREMENT.

15. The arrangement of equipment for peak power measurement is shown in Figure 2. The procedure involves calibration of an oscilloscope which in turn is used to calibrate a CW generator. The output of the calibrated CW generator is measured with a power meter; the peak power of a pulse is thereby measured. The procedure is as follows:

a. Connect equipment as shown in Figure 2, step 1.

b. Observe pulse on a dc-coupled oscilloscope. Using a marking pencil, mark on the graticule the base-to-peak amplitude of the pulse envelope.

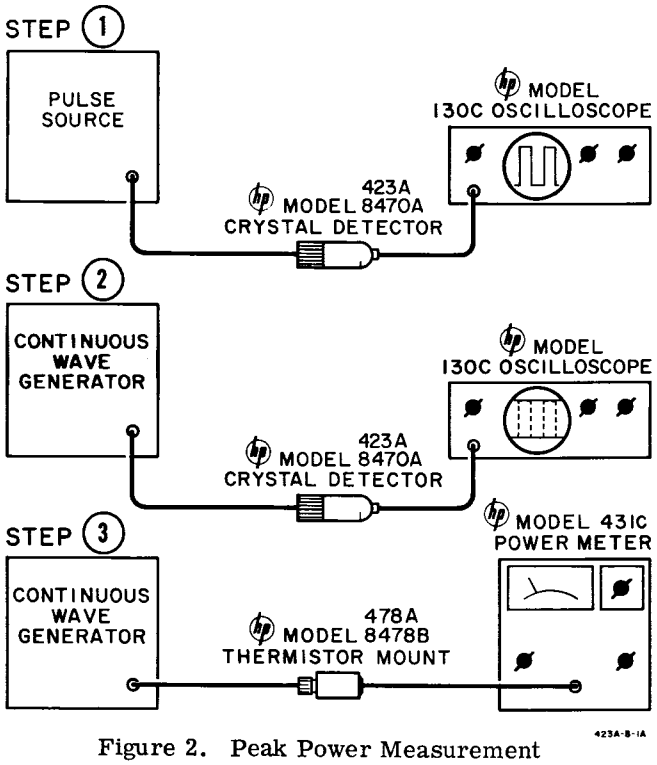


Figure 2. Peak Power Measurement

c. Replace the pulse source with a CW generator (step 2). While observing the oscilloscope trace, adjust amplitude of CW generator output to make crystal output equal to that of pulse generator as indicated by markings on graticule (step b).

d. While performing the next step, leave CW generator at setting obtained in step c. Disconnect Detector from CW generator. Connect output of CW generator to a thermistor and power meter. Measure adjusted level (step c) of CW generator output.

e. The peak power of the pulse envelope observed in step b is equal to the output power of the CW generator.

16. REFLECTOMETER APPLICATION.

17. For information about reflectometer systems and measurements, see HP Application Notes 54 and 61 and Hewlett-Packard Journal Vol. 12, No. 4, copies of which are available upon request.

18. HARMONIC FREQUENCY-COMPARISON MEASUREMENTS.

19. The Detector can be used as a mixer in harmonic-frequency comparison measurements. See HP Application Note 2.

20. REPLACEMENT OF PARTS.

21. Succeeding paragraphs give instructions for repair of the Detector, and the Option 02 Load Resistor, Model 11523A. Additional maintenance information can be obtained from your local Hewlett-Packard field office. Stock numbers for replaceable parts are given in Table 2.

22. The detector element assembly includes a detector element, an Option 02 load resistor for the 11523A, capacitive washer and a capsule spacer. The resistor is to load the diode for square-law operation, the capacitive washer is to match the diode for VSWR, while the capsule spacer is mainly for flatness of sensitivity. All should be replaced as a unit when the diode is replaced.

23. DETECTOR ELEMENT REPLACEMENT.

WARNING

The special detector element (see Figure 3) contained in the Detector can be damaged in handling, removal, or installation if certain precautions are not taken. The handling precautions which follow should be read before performance of any operation with the detector element when it is out of either the housing or the detector element shipping container.

24. DETECTOR ELEMENT HANDLING PRECAUTIONS.

a. Before installing detector into mount, touch exposed metal on mount with your hand to discharge static electricity. Then insert detector into mount.

b. When handing crystal to another person, touch hands first to ensure there is no difference in static electricity potential between you.

c. Ohmmeters should NOT be used to measure forward- and back-resistance since it is rather easy to damage these diodes. (The difficulty arises because of the ohmmeter open-circuit voltages and short-circuit currents. It is easy for these currents or voltages to damage the diode.)

25. REPLACING DETECTOR ELEMENT.

26. Parts mentioned in the following procedure are identified in Figure 3.

a. Remove connector cap from body. To remove connector cap, use a pair of gas pliers with plastic teeth or protect body with heavy paper or tape.

b. Remove old detector element, capsule spacer, and capacitive washer, and discard them.

c. Install the new capacitive washer, capsule spacer, and detector element. Install the washer first, the spacer with its polyiron side against the washer. Finally, install the detector element by inserting the resistive end into the center contact inside the Detector body.

CAUTION

When inserting the detector element, do not force the tip (resistive end) into the center conductor in the body as the fingers of the center conductor might be damaged.

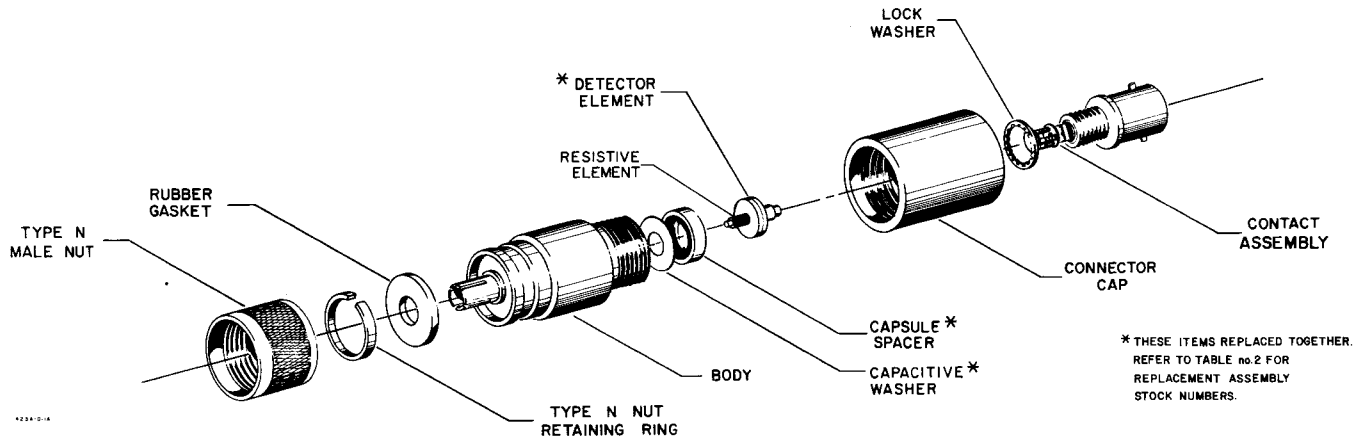


Figure 3. Model 423A Assembly

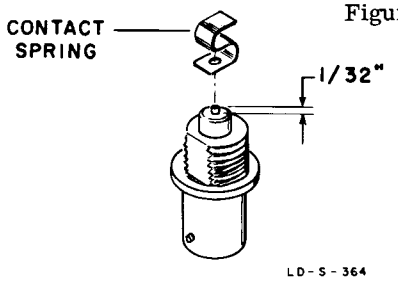


Figure 4. Cutting Center Conductor Lead to Accommodate Contact Spring

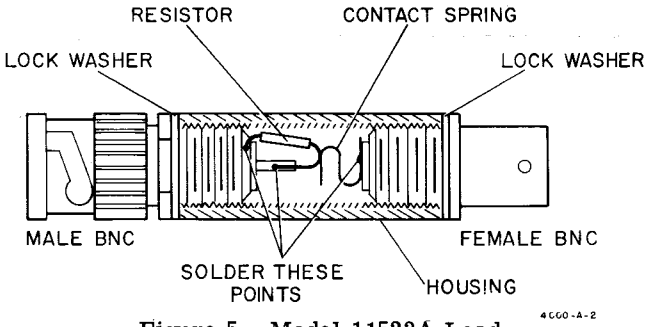


Figure 5. Model 11523A Load Resistor, Cutaway View

d. Replace connector cap and TIGHTEN FIRMLY.

Note

The Option 02 Detector Element Assembly includes a detector element and a resistor. The resistor is for use in the Model 11523A and must be installed to match it to the Detector.

27. REPLACING OUTPUT BNC CONNECTOR.

28. TOOLS REQUIRED.

a. Needle-point soldering iron

b. Wire cutters

d. Flat file, #4

d. Tweezers

29. PROCEDURE. Parts mentioned in the following procedure are identified in Figures 3 and 4.

a. Remove BNC connector and lockwasher.

b. Unsolder contact spring soldered to center conductor lead.

(1) Cut center conductor lead to approximately 1/32 inch (see Figure 4).

(2) With flat file, smooth end of lead; wipe off burr with tweezers or similar metal instrument.

c. Slip contact spring over center conductor lead, and solder.

CAUTION

Use solder sparingly or it will creep back on spring. Solder on spring destroys its usefulness, and solder is difficult to remove from spring.

d. Let spring cool, and then replace lockwasher and connector in connector cap.

30. REPLACEMENT OF 11523A PARTS.

31. Parts mentioned in the following procedure are identified in Figures 4 and 5. Tools required are listed in Paragraph 28.

32. REPLACING MALE BNC CONNECTOR.

a. Remove male BNC connector and lock washer from housing. To remove BNC, use a 3/8-inch open-end wrench and hold the housing either in a vise or with gas pliers. Before putting pliers on, protect the housing of the 11523A with material such as heavy paper.

b. Unsolder resistor.

c. Solder resistor to new BNC.

d. Let resistor cool and then check resistance from male BNC pin through resistor; resistance measured should be ±10% that indicated by the coding.

e. Replace lockwasher and male BNC.

Table 2. Replaceable Parts, Models 423A, 8470A, and 11523A

Description	Stock No.
Connector, male BNC for 11523A	1250-0045
Connector, female BNC	1250-0251
Connector Assembly, female BNC, including contact assembly	00423-600
Connector, Cap	00423-601
Housing for 11523A	5020-3215
11523A without resistor, includes serial plate to be attached to 423A	11523-600
423A Diode Replacement Assemblies*	
Single detector assembly:	
Negative polarity	00423-802
Positive polarity (Option 03)	00423-803
Single detector assembly with matching load resistor (Option 02):	
Negative polarity	00423-800
Positive polarity (Option 03)	00423-801
Matched pairs of assembly (Option 01):	
Negative polarity	00423-605
Positive polarity (Option 03)	00423-606
Matched pairs of elements with matching load resistor (Option 02):	
Negative polarity	00423-603
Positive polarity (Option 03)	00423-604
8470A Diode Replacement Assemblies*	
Single Detector Assembly:	
Negative Polarity	08470-6001
Positive Polarity (Option 03)	08470-6002
Single Detector Assembly with matching load resistor (Option 02):	
Negative Polarity	08470-6003
Positive Polarity (Option 03)	08470-6004
Matched Pairs of assemblies (Option 01):	
Negative Polarity	08470-6005
Positive Polarity (Option 03)	08470-6006
Matched pairs of assemblies with load resistors (Option 02):	
Negative Polarity	08470-6007
Positive Polarity (Option 03)	08470-6008
APC-7 Connector Assembly	1250-0745
Inner conductor contact	1250-0907
Inner conductor contact mechanism (contact plus outer body; assembled)	1250-0816
Support bead	5040-0273
Coupling nut	1250-0909
Center Conductor	08470-2001
Tools:	
APC-7 contact extractor	5060-0236
APC-7 Spanner wrench	5060-0237
Open-end wrench	8710-0877

*Refer to Table 1 for description of options

33. REPLACING FEMALE CONNECTOR.

a. Remove BNC connector. To remove or install BNC, use a BNC wrench or use a male BNC connector as a wrench.

b. Unsolder contact spring.

c. Prepare replacement BNC connector:

(1) Cut center conductor lead to approximately 1/32 inch.

(2) With flat file, smooth end of lead; wipe off burr with tweezers or similar metal instrument.

d. Slip contact spring over center conductor lead, and solder.

CAUTION

Use solder sparingly or it will creep back on spring. Solder on spring destroys its usefulness and is diffucult to remove.

e. Let contact spring cool and then screw connector into mount.

34. REPLACEABLE PARTS.

35. This section contains information pertaining to replaceable parts (see Table 2) and the ordering of these parts for the Models 423A, 8470A, and 11523A.

36. To order a replacement part, address order or inquiry to your local Hewlett-Packard field office (see list at rear of this Note).

37. Specify the following information for each part:

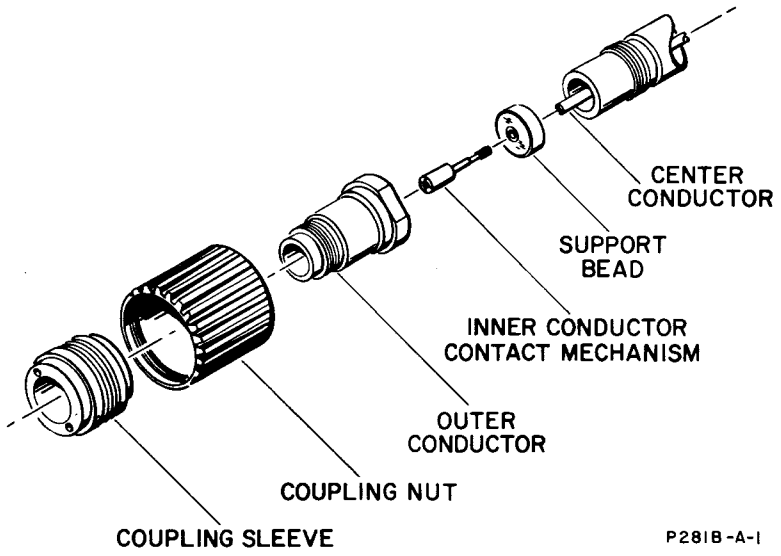
a. Model number

b. Hewlett-Packard stock number

c. Description of part.

38. PERFORMANCE CHECKS.

39. The following paragraphs suggest methods to use for checking detector specifications. For these checks the instrument operator should refer to the manuals of the equipment involved for operating instructions.



USE

To Connect:

1. On one connector, retract the coupling sleeve by turning the coupling nut counterclockwise until the sleeve and nut disengage.

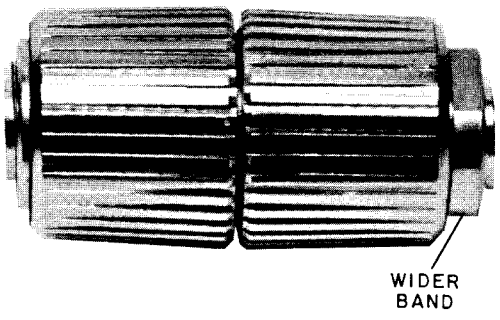
2. On the other connector, fully extend the coupling sleeve by turning the coupling nut clockwise. To engage coupling sleeve and coupling nut when the sleeve is fully retracted, press back lightly on the nut while turning it clockwise.

3. Push the connectors firmly together, and thread the coupling nut of the connector with retracted sleeve over the extended sleeve.

4. Close the gap between coupling nuts with the nut on the extended-sleeve connector.

To Disconnect:

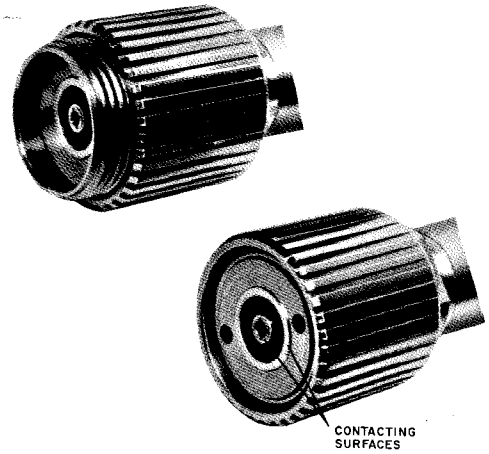
1. Loosen the coupling nut of the connector showing the wider gold band.



2. IMPORTANT: Part the connectors carefully to prevent striking the inner conductor contact.

CARE

1. Keep contacting surfaces smooth and clean. Irregularities and foreign particles can degrade electrical performance.



2. Protect the contacting surfaces when the connector is not in use by leaving the coupling sleeve extended.

3. Use lintless material and/or firm-bristled brush such as tooth brush for cleaning. If a cleaning fluid is needed use isopropyl alcohol. IMPORTANT: Do not use aromatic or chlorinated hydrocarbons, esters, ethers, terpenes, higher alcohols, ketones, or ether-alcohols such as benzene, toluene, turpentine, dioxane, gasoline, cellosolve acetate, or carbon tetrachloride. Keep exposure of the connector parts to both the cleaning fluid and its vapors as brief as possible.

Figure 6. APC-7 Connectors

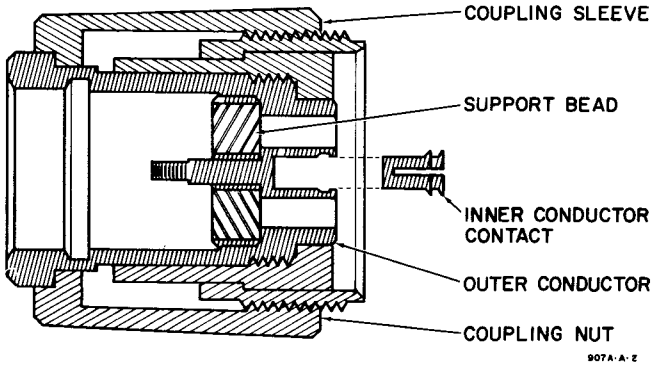
REPLACING AMPHENOL APC-7 CENTER CONTACT

Through wear or damage the contact in the center conductor may need replacing. This contact is a small four-pronged collet which snaps into a recess in the center conductor. This contact is normally held in by the spring-action of the four prongs. With a magnifying glass examine this contact to determine if it needs replacement. DO NOT REMOVE THIS CONTACT FOR INSPECTION (it may be damaged by removing). The contact should be free of burrs or wear and the prongs should be equally spaced. If the contact is removed do NOT re-use it (it may be damaged by removal). This contact is Amphenol* part number 131-129 and HP 1250-0907. If this contact needs replacement and a new contact is available proceed as follows:

1. Place the instrument so the connector faces down, if possible.

2. Tap the connector lightly and the contact should now protrude slightly. Insert the centering pin of the Hewlett-Packard collet remover, Stock Number 5060-0236, with the jaws open. If this tool is not available, an ordinary draftsman's mechanical pencil may be used (the end of the jaws may have to be filed to get a good grasp at the very end).

3. Allow the jaws on the tool used to close and pull straight away from the connector without twisting. The contact should come with the tool. If not, repeat the process. Do NOT re-use the contact.

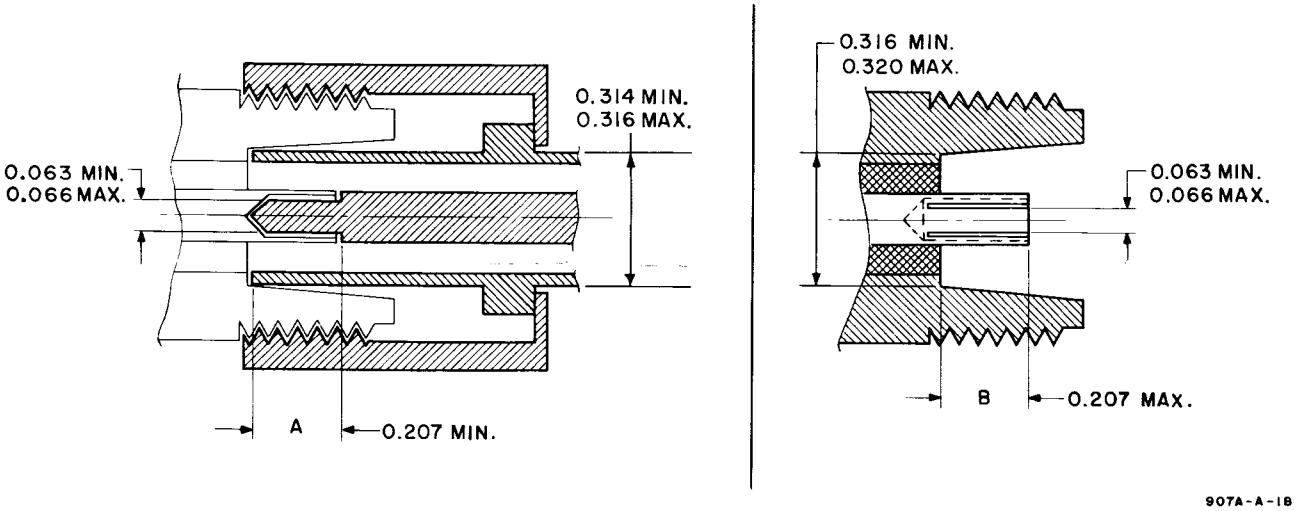


4. Snap in a new contact by pushing a new contact in place.

(Amphenol* Part number 131-129; HP Part number 1250-0907)

*Amphenol RF Division, Danbury, Conn.

Figure 7. APC-7 Connector



ALL DIMENSIONS IN INCHES

Figure 8. Type N Connector

40. FREQUENCY RESPONSE CHECK.

a. Using a 10 Mc to 12.4 Gc signal source and an SWR Meter as the indicator, connect the Detector to the signal source and set any convenient upper scale reference on the SWR meter.

b. Without changing the RF output level of the SWR meter settings, disconnect the Detector from the signal source.

c. Using a power meter/thermistor mount combination, measure the signal source RF output level and record.

d. Change the frequency to another point and reset the RF output level to that measured in step c.

e. Disconnect the power meter/ thermistor mount from the signal source and connect the Detector. The SWR meter indication should be within 1.0 dB of original reference.

f. Repeat steps b, c, d, and e at all points of interest across the frequency band.

41. SENSITIVITY CHECK.

a. Using a 10 MHz to 12.4 GHz signal source and a dc voltmeter as the indicator, connect the Detector to the signal source and adjust the RF power level for a 100 mW detected output from the Detector.

b. Disconnect the Detector from the signal source and measure the RF output level. Specification: less than 0.355 mW should produce 100 mV detected output.

42. SWR CHECK.

a. Equipment required:

(1) HP 250A RX Meter

(2) HP 803A VHF Bridge

(3) HP 417A Detector

(4) HP 809B/806B/444A Slotted Line

(5) HP 805C Slotted Line

(6) Signal sources: 10 MHz to 18.4 GHz

b. To measure the SWR of the Detector in the 10 to 250 MHz range an RX meter should be used. The method of measurement is explained below.

c. Using the HP 250A RX Meter, measure the resistance (R) and capacitance (C) of the Detector. Calculate the reactance of the Detector from the equation: X equals 1 divided by 2 times 3.1416 times the frequency of measurement (neglecting the sign of C). Calculate the Q (when Q equals R divided by X).

d. Calculate the Detector load impedance Z_L from the equation:

$$Z_L = R\sqrt{1 + (R/X)^2}$$

where Z_L = Detector load impedance

e. Calculate the SWR of the Detector from the following two equations:

(1) $$\rho = \frac{(Z_L/Z_O) - 1}{(Z_L/Z_O) + 1};$$

(2) $$SWR = \frac{1 + \rho}{1 - \rho}$$

where ρ = reflection coefficient

Z_O = characteristic impedance

f. To measure SWR in the 250-MHz to 500-MHz range use HP 803A and HP 417A.

g. To measure SWR in 500- to 4000-MHz use 805C Slotted Line and 415E SWR Meter.

h. To measure SWR in 4- to 12.4-GHz range use the HP 809B/806B/444A Slotted Line combination.

HEWLETT hp PACKARD

ELECTRONIC INSTRUMENTATION SALES AND SERVICE

UNITED STATES

ALABAMA
P.O. Box 4207
2003 Byrd Spring Road S.W.
Huntsville 35802
Tel: (205) 881-4591
TWX: 810-726-2204

ARIZONA
3009 North Scottsdale Road
Scottsdale 85251
Tel: 602 945-7601
TWX: 910-950-1282

232 South Tucson Boulevard
Tucson 85716
Tel: (602) 623-2564
TWX: 910-952-1162

CALIFORNIA
3939 Lankershim Boulevard
North Hollywood 91604
Tel: (213) 877-1282
TWX: 910-499-2170

1101 Embarcadero Road
Palo Alto 94303
Tel: (415) 327-6500
TWX: 910-373-1280

2591 Carlsbad Avenue
Sacramento 95821
Tel: (916) 482-1463
TWX: 910-367-2092

1055 Shafter Street
San Diego 92106
Tel: (714) 223-8103
TWX: 910-335-2000

COLORADO
7965 East Prentice
Englewood 80110
Tel: (303) 771-3455
TWX: 910-935-0705

CONNECTICUT
508 Tolland Street
East Hartford 06108
Tel: (203) 289-9394
TWX: 710-425-3416

111 East Avenue
Norwalk 06851
Tel: (203) 853-1251
TWX: 710-468-3750

DELAWARE
3941 Kennett Pike
Wilmington 19807
Tel: (302) 655-6161
TWX: 510-666-2214

FLORIDA
Suite 106
9999 N.E. 2nd Avenue
Miami Shores 33138
Tel: (305) 758-3626
TWX: 810-848-7262

P.O. Box 20007
Herndon Station 32814
621 Commonwealth Avenue
Orlando
Tel: (305) 841-3970
TWX: 810-850-0113

P.O. Box 8128
Madeira Beach 33708
410 150th Avenue
St. Petersburg
Tel: (813) 391-0211
TWX: 810-863-0366

GEORGIA
P.O. Box 28234
2340 Interstate Parkway
Atlanta 30328
Tel: (404) 436-6181
TWX: 810-766-4890

ILLINOIS
5500 Howard Street
Skokie 60076
Tel: (312) 677-0400
TWX: 910-223-3613

INDIANA
4002 Meadows Drive
Indianapolis 46205
Tel: (317) 546-4891
TWX: 810-341-3263

LOUISIANA
P.O. Box 856
1942 Williams Boulevard
Kenner 70062
Tel: (504) 721-6201
TWX: 810-955-5524

MARYLAND
6707 Whitestone Road
Baltimore 21207
Tel: (301) 944-5400
TWX: 710-862-0850

P.O. Box 727
Twinbrook Station 20851
12303 Twinbrook Parkway
Rockville
Tel: (301) 427-7560
TWX: 710-828-9684

MASSACHUSETTS
Middlesex Turnpike
Burlington 01803
Tel: (617) 272-9000
TWX: 710-332-0382

MICHIGAN
24315 Northwestern Highway
Southfield 48075
Tel: (313) 353-9100
TWX: 810-232-1532

MINNESOTA
2459 University Avenue
St. Paul 55114
Tel: (612) 645-9461
TWX: 910-563-3734

MISSOURI
9208 Wyoming Place
Kansas City 64114
Tel: (816) 333-2445
TWX: 910-771-2087

2812 South Brentwood Blvd.
St. Louis 63144
Tel: (314) 644-0220
TWX: 910-760-1670

NEW JERSEY
391 Grand Avenue
Englewood 07631
Tel: (201) 567-3933
TWX: 710-991-9707

NEW MEXICO
P.O. Box 8366
Station C 87108
6501 Lomas Boulevard N.E.
Albuquerque
Tel: (505) 255-5586
TWX: 910-989-1665

156 Wyatt Drive
Las Cruces 88001
Tel: (505) 526-2485
TWX: 910-983-0550

NEW YORK
1702 Central Avenue
Albany 12205
Tel: (518) 869-8462

1219 Campville Road
Endicott 13760
Tel: (607) 754-0050
TWX: 510-252-0890

236 East 75th Street
New York 10021
Tel: (212) 879-2023
TWX: 710-581-4376

82 Washington Street
Poughkeepsie 12601
Tel: (914) 454-7330
TWX: 510-248-0012

39 Saginaw Drive
Rochester 14623
Tel: (716) 473-9500
TWX: 510-253-5981

1025 Northern Boulevard
Roslyn, Long Island 11576
Tel: (516) 869-8400
TWX: 510-223-0811

5858 East Molloy Road
Syracuse 13211
Tel: (315) 454-2486
TWX: 710-541-0482

NORTH CAROLINA
P.O. Box 5187
1923 North Main Street
High Point 27262
Tel: (919) 882-6873
TWX: 510-926-1516

OHIO
5579 Pearl Road
Cleveland 44129
Tel: (216) 884-9209
TWX: 810-421-8500

2460 South Dixie Drive
Dayton 45439
Tel: (513) 298-0351
TWX: 810-459-1925

OREGON
Westhills Mall, Suite 158
4475 S.W. Scholls Ferry Road
Portland 97225
Tel: (503) 292-9171
TWX: 910-464-6103

PENNSYLVANIA
2500 Moss Side Boulevard
Monroeville 15146
Tel: (412) 271-0724
TWX: 710-797-3650

144 Elizabeth Street
West Conshohocken 19428
Tel: (215) 248-1600, 828-6200
TWX: 510-660-8715

TEXAS
P.O. Box 7166
3605 Inwood Road
Dallas 75209
Tel: (214) 357-1881
TWX: 910-861-4081

P.O. Box 22813
4242 Richmond Avenue
Houston 77027
Tel: (713) 667-2407
TWX: 910-881-2645

GOVERNMENT CONTRACT OFFICE
225 Billy Mitchell Road
San Antonio 78226
Tel: (512) 434-4171
TWX: 910-871-1170

UTAH
2890 South Main Street
Salt Lake City 84115
Tel: (801) 486-8166
TWX: 910-925-5681

VIRGINIA
P.O. Box 6514
2111 Spencer Road
Richmond 23230
Tel: (703) 282-5451
TWX: 710-956-0157

WASHINGTON
11656 N.E. Eighth Street
Bellevue 98004
Tel: (206) 454-3971
TWX: 910-443-2303

FOR AREAS NOT LISTED, CONTACT: Hewlett-Packard; 1501 Page Mill Road; Palo Alto, California 94304; Tel: (415) 326-7000; TWX: 910-373-1267; Telex: 34-8461

CANADA

ALBERTA
10010 - 105th Street
Edmonton
Tel: (403) 424-0718
TWX: 610-831-2431

BRITISH COLUMBIA
Hewlett-Packard (Canada) Ltd.
2184 West Broadway
Vancouver
Tel: (604) 738-7520
TWX: 610-922-5050

NOVA SCOTIA
7001 Mumford Road
Suite 356
Halifax
Tel: (902) 455-0511
TWX: 610-271-4482

ONTARIO
Hewlett-Packard (Canada) Ltd.
880 Lady Ellen Place
Ottawa 3
Tel: (613) 722-4223
TWX: 610-562-1952

Hewlett-Packard (Canada) Ltd.
1415 Lawrence Avenue West
Toronto
Tel: (416) 249-9196
TWX: 610-492-2382

QUEBEC
Hewlett-Packard (Canada) Ltd.
275 Hymus Boulevard
Pointe Claire
Tel: (514) 697-4232
TWX: 610-422-3022
Telex: 01-2819

FOR AREAS NOT LISTED, CONTACT: Hewlett-Packard Inter-Americas; 1501 Page Mill Road; Palo Alto, Calif. 94304; Tel: (415) 326-7000; TWX: 910-373-1267; Telex: 034-8461; Cable: HEWPACK Palo Alto

CENTRAL AND SOUTH AMERICA

ARGENTINA
Mauricio A. Suárez
Telecomunicaciones
Carlos Calvo 224
Buenos Aires
Tel: 30-6312, 34-9087
Cable: TELEPILOT Buenos Aires

BRAZIL
Ciental, Importacao e
Comércio Ltda.
Avenida 13 de Maio, 13-22° andar
Rio de Janeiro G.B.
Tel: 42-9483

Ciental, Importacao e
Comércio Ltda.
Rua Des. Eliseu Guilherme, 62
Sao Paulo 8
Tel: 70-2318
Cable: CIENTALCO, Sao Paulo

CHILE
Héctor Calcagni
Casilla 13942
Santiago
Tel: 490.505, 393.119

COLOMBIA
Instrumentacion
Henrik A. Langebaek & Cia. Ltda.
Cra. 7A N° 48-51/59
Apartado Aereo 6287
Bogota, 1 D.E.
Tel: 45-78-06, 45-55-46
Cable: AARIS Bogota

COSTA RICA
Lic. Alfredo Gallegos Gurdián
Apartado 3243
San José
Tel: 21-86-13
Cable: GALGUR San José

ECUADOR
Laboratorios de Radio-Ingenieria
Calle Guayaquil 1246
Post Office Box 3199
Quito
Tel: 12496
Cable: HORVATH Quito

EL SALVADOR
Electrónica
27 Avenida Norte 1133
Apartado Postal 1589
San Salvador
Tel: 25-74-50
Cable: ELECTRONICA
San Salvador

GUATEMALA
Olander Associates Latin America
Apartado 1226
7a. Calle, 0-22, Zona 1
Guatemala City
Tel: 22812
Cable: OLALA Guatemala City

MEXICO
Hewlett-Packard Mexicana,
S.A. de C.V.
Eugenia 408, Dept. 1
Mexico 12, D.F.
Tel: 43-03-79

NICARAGUA
Roberto Terán G.
Edificio Terán
Apartado Postal 689
Managua
Tel: 3451, 3452
Cable: ROTERAN Managua

PANAMA
Electrónica Balboa, S.A.
P.O. Box 4929
Ave. Manuel Espinosa No. 13-50
Bldg. Alina
Panama City
Tel: 30833
Cable: ELECTRON Panama City

PERU
Fernando Ezeta B.
Av. Petit Thouars 4719
Miraflores
Casilla 3061
Lima
Tel: 50346
Cable: FEPERU Lima

PUERTO RICO
San Juan Electronics, Inc.
P.O. Box 5167
Ponce de León 150, Stop 3
Puerta de Tierra Santa
San Juan 00906
Tel: (809) 725-3342
Cable: SATRONICS San Juan

URUGUAY
Pablo Ferrando
S.A. Comercial e Industrial
Avenida Italia 2877
Casilla de Correo 370
Montevideo
Tel: 40-3102
Cable: RADIUM Montevideo

VENEZUELA
Citec, C.A.
Edif. Arisan-Of. #4
Avda. Francisco de Miranda
Apartado del Este 10934 Chacaito
Caracas
Tel: 71.88.05
Cable: CITECAL Caracas

FOR AREAS NOT LISTED, CONTACT: Hewlett-Packard Inter-Americas; 1501 Page Mill Road; Palo Alto, Calif. 94304; Tel: (415) 326-7000; TWX: 910-373-1267; Telex: 034-8461; Cable: HEWPACK Palo Alto

HEWLETT hp PACKARD

ELECTRONIC INSTRUMENTATION SALES AND SERVICE

EUROPE

AUSTRIA
Unilabor H.m.b.H.
Wissenschaftliche Instrumente
Rummelhardtgasse 6/3
P.O. Box 33
Vienna IX/71
Tel: 426 181
Cable: LABORINSTRUMENT Vienna

BELGIUM
Hewlett-Packard Benelux S.A.
20-24 rue de l'Hôpital
Brussels
Tel: 11 22 20
Cable: PALOBEN Brussels

DENMARK
Tage Olsen A/S
Ronnegade 1
Copenhagen o
Tel: 29 48 00
Cable: TOCOPEN Copenhagen

FINLAND
INTO O/Y
Meritullinkatu 11
P.O. Box 10153
Helsinki 10
Tel: 61 133
Cable: INTO Helsinki

FRANCE
Hewlett-Packard France
2 rue Tête d'Or
Lyon, 6 - Rhône
Tel: 52 35 66

Hewlett-Packard France
150 Boulevard Massena
Paris 13e
Tel: 707 97 19
Cable: HEWPACK Paris

GERMANY
Hewlett-Packard Vertriebs-GmbH
Lietzenburger Strasse 30
1 **Berlin W** 30
Tel: 24 86 36

Hewlett-Packard Vertriebs-GmbH
Herrenberger Strasse 110
703 **Böblingen,** Württemberg
Tel: 07031-6971
Cable: HEPAG Boblingen

Hewlett-Packard Vertriebs-GmbH
Achenbachstrasse 15
4 **Düsseldorf** 1
Tel: 68 52 58/59

Hewlett-Packard Vertriebs-GmbH
Kurhessenstrasse 95
6 **Frankfurt** 50
Tel: 52 00 36
Cable: HEWPACKSA Frankfurt

Hewlett-Packard Vertriebs-GmbH
Beim Strohhause 26
2 **Hamburg** 1
Tel: 24 05 51/52
Cable: HEWPACKSA Hamburg

Hewlett-Packard Vertriebs-GmbH
Reginfriedstrasse 13
8 **Munich** 9
Tel: 69 51 21/22
Cable: HEWPACKSA Munich

GREECE
Kostos Karayannis
18, Ermou Street
Athens 126
Tel: 230 301
Cable: RAKAR Athens

IRELAND
Hewlett-Packard Ltd.
224 Bath Road
Slough, Bucks, England
Tel: Slough 28406-9, 29486-9
Cable: HEWPIE Slough

ITALY
Hewlett-Packard Italiana S.p.A.
Viale Lunigiana 46
Milan
Tel: 69 15 84
Cable: HEWPACIT Milan

Hewlett-Packard Italiana S.p.A.
Palazzo Italia
Piazza Marconi 25
Rome - Eur
Tel: 591 2544
Cable: HEWPACIT Rome

NETHERLANDS
Hewlett-Packard Benelux, N.V.
de Boelelaan 1043
Amsterdam, Z.2
Tel: 42 77 77
Cable: PALOBEN Amsterdam

NORWAY
Morgenstierne & Co. A/S
Ingeniofirma
6 Wessels Gate
Oslo
Tel: 20 16 35
Cable: MOROF Oslo

PORTUGAL
Telectra
Rua Rodrigo da Fonseca 103
P.O. Box 2531
Lisbon 1
Tel: 68 60 72
Cable: TELECTRA Lisbon

SPAIN
Ataio Ingerieros
Urgel, 259
Barcelona, 11
Tel: 230-69-88

Ataio Ingenieros
Enrique Larreta 12
Madrid, 16
Tel: 235 43 44
Cable: TELEATAIO Madrid

SWEDEN
HP Instrument AB
Hagakersgatan 7
Mölndal
Tel: 031 - 27 68 00

HP Instrument AB
Centralvägen 28
Solna
Tel: 08 - 83 08 30
Cable: MEASUREMENTS Stockholm

SWITZERLAND
HEWPAK AG
Zurcherstrasse
8952 Schlieren
Zurich
Tel: (051) 98 18 21
Cable: HEWPACKAG Zurich

TURKEY
Telekom Engineering Bureau
P.O. Box 376 - Galata
Istanbul
Tel: 49 40 40
Cable: TELEMATION Istanbul

UNITED KINGDOM
Hewlett-Packard Ltd.
224 Bath Road
Slough, Bucks
Tel: Slough **28406-9, 29486-9**
Cable: **HEWPIE Slough**

YUGOSLAVIA
Belram S.A.
83 avenue des Mimosas
Brussels 15, Belgium
Tel: 35 29 58
Cable: BELRAMEL Brussels

FOR AREAS NOT LISTED, CONTACT: Hewlett-Packard S.A.; 54 Route des Acacias; Geneva, Switzerland; Tel: (022) 42 81 50; Telex: 2.24.86; Cable: HEWPACKSA Geneva

AFRICA, ASIA, AUSTRALIA

AUSTRALIA
Hewlett-Packard Australia Pty. Ltd.
22-26 Weir Street
Glen Iris, S. E. 6
Victoria
Tel: 20-1371 (4 lines)
Cable: HEWPARD Melbourne

Hewlett-Packard Australia Pty. Ltd.
4 Grose Street
Glebe, New South Wales
Tel: 211-2235, 211-2888
Cable: HEWPARD Sydney

CEYLON
United Electricals Ltd.
P.O. Box 681
Yahala Building
Staples Street
Colombo 2
Tel: 5496
Cable: HOTPOINT Colombo

ETHIOPIA
African Salespower & Agency Private Ltd., Co.
P. O. Box 718
Addis Ababa
Tel: 44090
Cable: ASACO Addisababa

HONG KONG
Schmidt & Co. (Hong Kong) Ltd.
P.O. Box 297
1511, Prince's Building
10, Chater Road
Hong Kong
Tel: 240168, 232735
Cable: SCHMIDTCO Hong Kong

INDIA
The Scientific Instrument Co., Ltd.
6, Tej Bahadur Sapru Road
Allahabad 1
Tel: 2451
Cable: SICO Allahbad

The Scientific Instrument Co., Ltd.
240, Dr. Dadabhai Naoroji Road
Bombay 1
Tel: 26-2642
Cable: SICO Bombay

The Scientific Instrument Co., Ltd.
11, Esplanade East
Calcutta 1
Tel: 23-4129
Cable: SICO Calcutta

The Scientific Instrument Co., Ltd.
30, Mount Road
Madras 2
Tel: 86339
Cable: SICO Madras

The Scientific Instrument Co., Ltd.
B-7, Ajmeri Gate Extn.
New Delhi 1
Tel: 27-1053
Cable: SICO New Delhi

IRAN
Telecom, Ltd.
P. O. Box 1812
Teheran
Tel: 43850, 48111
Cable: BASCOM Teheran

ISRAEL
Electronics & Engineering Div. of Motorola Israel Ltd.
16, Kremenetski Street
Tel-Aviv
Tel: 35021/2/3
Cable: BASTEL Tel-Aviv

JAPAN
Yokogawa-Hewlett-Packard Ltd.
Shinhankyu Building
No. 8, Umeda
Kita-ku, **Osaka** City
Tel: 0726-23-1641

Yokogawa-Hewlett-Packard Ltd.
Ito Building
No. 59, Kotori-cho
Nakamura-ku, **Nagoya** City
Tel: 551-0215

Yokogawa-Hewlett-Packard Ltd.
Ohashi Building
No. 59, I-chome, **Yoyogi**
Shibuya-ku, **Tokyo**
Tel: 370-2281
Cable: YOKOHEWPACK Tokyo
Telex: 232-2034

KENYA
R. J. Tilbury Ltd.
P. O. Box 2754
Suite 517/518
Hotel Ambassadeur
Nairobi
Tel: 25670, 26803, 68206
Cable: ARJAYTEE Nairobi

KOREA
American Trading Co., Korea, Ltd.
Seoul P. O. Box 1103
112-35 Sokong-Dong
Jung-ku, **Seoul**
Tel: 3.7049, 3.7613
Cable: AMTRACO Seoul

LEBANON
Constantin E. Macridis
Clemenceau Street
Clemenceau Center
Beirut
Tel: 220846
Cable: ELECTRONUCLEAR Beirut

MALAYSIA
MECOMB Malaysia Ltd.
2 Lorong 13/6A
Section 13
Petaling Jaya, **Selangor**
Cable: MECOMB Kuala Lumpur

NEW ZEALAND
Sample Electronics (N.Z.) Ltd.
8 Matipo Street
Onehunga S.E. 5
Auckland
Tel: 667-356
Cable: ELPMAS Auckland

PAKISTAN (EAST)
Mushko & Company, Ltd.
31, Jinnah Avenue
Dacca
Tel: 80058
Cable: COOPERATOR Dacca

PAKISTAN (WEST)
Mushko & Company, Ltd.
Oosman Chambers
Victoria Road
Karachi 3
Tel: 51027, 52927
Cable: COOPERATOR Karachi

SINGAPORE
Mechanical and Combustion Engineering Company Ltd.
9, Jalan Kilang
Singapore, 3
Tel: 642361-3
Cable: MECOMB Singapore

SOUTH AFRICA
F. H. Flanter & Co. (Pty.), Ltd.
Rosella House
Buitencingle Street
Cape Town
Tel: 3-3817
Cable: AUTOPHONE Cape Town

F. H. Flanter & Co. (Pty.), Ltd.
104 Pharmacy House
80 Jorissen Street
Braamfontein, **Johannesburg**
Tel: 724-4172

TAIWAN
Hwa Sheng Electronic Co., Ltd.
P. O. Box 1558
21 Nanking West Road
Taipei
Tel: 46076, 45936
Cable: VICTRONIX Taipei

THAILAND
The International Engineering Co., Ltd.
P. O. Box 39
614 Sukhumvit Road
Bangkok
Tel: 913460-1-2
Cable: GYSOM Bangkok

VIETNAM
Landis Brothers and Company, Inc.
P.O. Box H-3
216 Hien-Vuong
Saigon
Tel: 20.805
Cable: LANBROCOMP Saigon

FOR AREAS NOT LISTED, CONTACT: Hewlett-Packard Export Marketing; 1501 Page Mill Road; Palo Alto, California 94304; Tel: (415) 326-7000; Telex: 034-8461; Cable: HEWPACK Palo Alto

5/67

HEWLETT hp PACKARD

CERTIFICATION

The Hewlett-Packard Company certifies that this instrument was thoroughly tested and inspected and found to meet its published specifications when it was shipped from the factory. The Hewlett-Packard Company further certifies that its calibration measurements are traceable to the U.S. National Bureau of Standards to the extent allowed by the Bureau's calibration facility.

WARRANTY AND ASSISTANCE

All Hewlett-Packard products are warranted against defects in materials and workmanship. This warranty applies for one year from the date of delivery, or, in the case of certain major components listed in the operating manual, for the specified period. We will repair or replace products which prove to be defective during the warranty period. No other warranty is expressed or implied. We are not liable for consequential damages.

For any assistance contact your nearest Hewlett-Packard Sales and Service Office. Addresses are provided at the back of this manual.