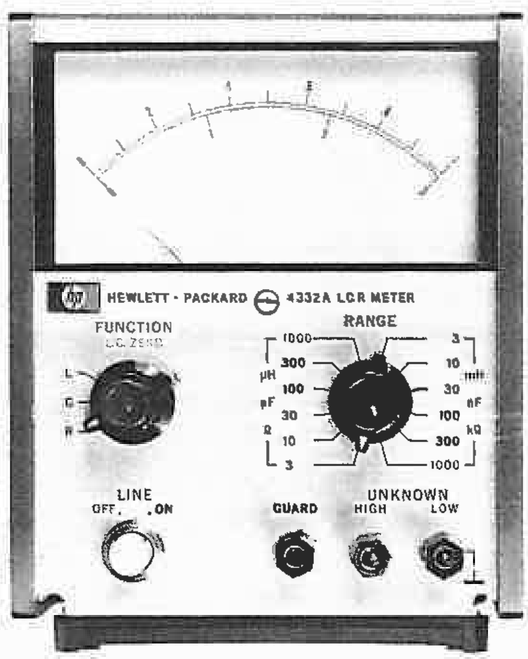
HP 4332A

OPERATING AND SERVICE MANUAL

LCR METER

4332A



HEWLETT PACKARD

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OPERATING AND SERVICE MANUAL

MODEL 4332A
LCR METER

SERIAL PREFIXED : 1703J-

See Section VII for Other Serial Prefixes.

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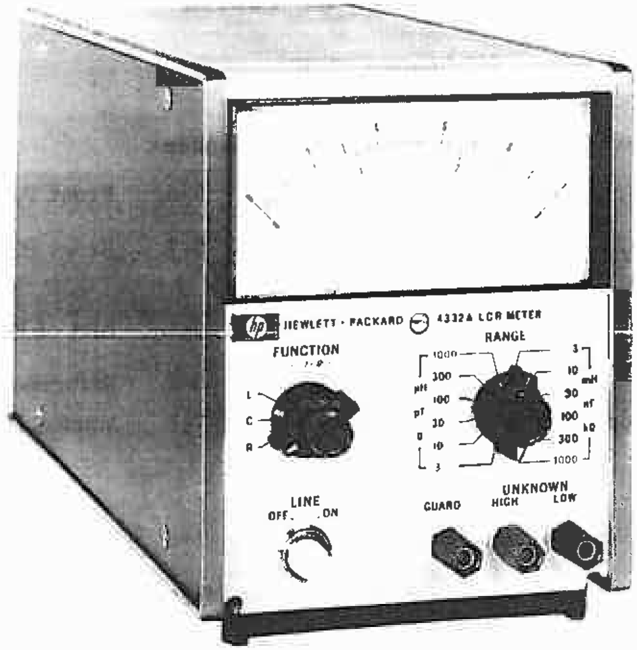


Figure 1-1. Model 4332A LCR METER

Table 1-1. Specifications

INDUCTANCE MEASUREMENT

Range: 3μH - 1H full scale in 12 ranges in a 1, 3, 10 sequence.

Measurement Frequencies:
100kHz ±5% for 3μH - 1000μH ranges.
1kHz ±5% for 3mH - 1000mH ranges.

Voltage Across Sample: Less than 1.5 mV rms.

Measurement Equivalent Circuit: Series.

Accuracy: ±[1% of reading + (1.5 + 3/Q)% of full scale + 0.03μH] (at 25°C).

CAPACITANCE MEASUREMENT

Range: 3pF - 1μF full scale in 12 ranges in a 1, 3, 10 sequence.

Measurement Frequencies:
100kHz ±5% for 3pF - 1000pF ranges.
1kHz ±5% for 3nF - 1000nF ranges.

Voltage Across Sample: Approximately 70mVrms.

Measurement Equivalent Circuit: Parallel

Accuracy: ±[1% of reading + (1.5 + 3/Q)% of full scale + 0.03pF.] (at 25°C).

RESISTANCE MEASUREMENT

Range: 3Ω - 1MΩ full scale in 12 ranges in a 1, 3, 10 sequence.

Measurement Frequency: 1kHz ±5%

Voltage Across Sample: Less than 1mV rms.

Accuracy: ±(0.5% of reading +2% of full scale + 0.03Ω) for 3Ω-30kΩ ranges (at 25°C).
±(1% of reading +2% of full scale) for 100kΩ - 1000kΩ ranges.

ANALOG OUTPUT

1.0 VDC full scale independent of the range in use. Output impedance: approximately 500Ω.

1.0 or 0.3 VDC full scale corresponding to the range in use. Output impedance: approximately 500Ω.

Overrange: 110% of full scale.

Accuracy: Better than meter deflection by 0.5% of full scale.

GENERAL

Response Time:
Typically 0.25 sec. on ANALOG OUTPUT.
Typically 1.0 sec. on meter deflection.

Operating Temperature: 0°C - 50°C.

Temperature Coefficient of Accuracy and Analog Output: ±0.05% of full scale/°C for 0°C - 50°C.

DC Bias: 100 VDC maximum.

Power: 115V/230V ±10%, 48 - 66Hz 8W.

Dimensions: 6-3/32"H x 5-1/8" W x 11"D.
(155 x 130 x 279 mm).

Weight: Net 3.5kg.

Accessories furnished: Model 16138A Test Leads, Power Cord P/N 8120-1348.

SECTION I
GENERAL INFORMATION

1-1. INTRODUCTION

1-2. This section contains general information about the Model 4332A LCR Meter. Included are: description of instrument, specifications and instrument-manual identification.

1-3. DESCRIPTION

1-4. The Model 4332A LCR Meter measures inductance (L), capacitance (C) and resistance (R). The measurement ranges are 3μH to 1H full scale for inductance, 3pF to 1μF full scale for capacitance and 3Ω to 1MΩ full scale for resistance. Measuring frequency is 1kHz or 100kHz depending upon the range in use in L or C measurements and is 1kHz in resistance measurements.

1-5. The Model 4332A measures inductance or capacitance and provides direct meter reading with very little effect of the loss component on reading by means of a phase detector. The resistance measurement is performed with very little effect of the reactive component provided by the phase detector.
The voltage across sample is less than 1.5mV in L measurement, approximately 70mV in C measurement and less than 1.0mV in R measurement.

1-6. Two analog outputs are provided on the 4332A rear panel. One is 1.0V full scale for all ranges and the other is 0.3V or 1.0V full scale corresponding to the range in use.

1-7. SPECIFICATION

1-8. Table 1-1 lists the specifications for the Model 4332A.

1-7. INSTRUMENT/MANUAL IDENTIFICATION

1-10. Hewlett-Packard uses a two-section serial number to identify instruments. The first part is the serial number prefix, consisting of a number-letter combination denoting the date of a significant design change and the country of manufacture. The first two digits indicate the year (10=1970, 11=1971, etc); and the letter "A", "G", "J" or "U" designates the U.S.A., West Germany, Japan or United Kingdom, respectively, as the country of manufacture. The second part is the serial number; a different 5-digit sequential number is assigned to each instrument.

1-11. The group of instruments to which this manual applies directly is identified on the title page. For older instruments (lower serial numbers), make manual changes listed in Section VII. For newer instruments, having serial numbers higher than those listed on the title page, manual change sheets are included, describing the required changes. The manual for an instrument having a special electrical modification will include an insert sheet describing that modification. If a change sheet or special information sheet is missing, the information sheet can be supplied by any Hewlett-Packard Sales and Service Office listed at the back of this manual.

SECTION II
INSTALLATION

2-1. INTRODUCTION

2-2. This section contains information for unpacking, inspection, repackaging, storage and installation of the Model 4332A.

2-3. UNPACKING AND INSPECTION

2-4. If the shipping carton is damaged, ask that the carrier's agent be present when the instrument is unpacked. Inspect the instrument for damage (scratches, dents, broken knobs, etc.). If the instrument is damaged or fails to meet specifications, notify the carrier and the nearest Hewlett-Packard field office (see list at back of this manual). Retain the shipping carton and the padding material for the carrier's inspection. The field office will arrange for the repair or replacement of your instrument without waiting for the claim against the carrier to be settled.

2-5. STORAGE AND SHIPMENT

2-6. PACKAGING. To protect valuable electronic equipment during storage or shipment always use the best packaging methods available. Your Hewlett-Packard field office can provide packing material such as that used for original factory packaging. Contract packaging companies in many cities can provide dependable custom packaging on short notice. Here are a few recommended packaging methods:

a. RUBBERIZED HAIR. Cover painted surfaces of instrument with protective wrapping paper. Pack instrument securely in strong corrugated container (350 lb/sq. in. bursting test) with 2-inch rubberized hair pads placed along all surfaces of the instrument. Insert fillers between pads and container to ensure a snug fit.

b. EXCELSIOR. Cover painted surfaces of instrument with protective wrapping paper. Pack instrument in strong corrugated container (350 lb/sq in. bursting test) with a layer of excelsior about 6 inches thick packed firmly against all surfaces of the instrument.

2-7. ENVIRONMENT. Conditions during storage and shipment should normally be limited as follows:

a. Maximum altitude, 20,000 feet.

b. Minimum temperature, -40° F (-40° C).

c. Maximum temperature, 167° F (75° C).

2-8. INSTALLATION

2-9. The Model 4332A is a submodular unit, equipped with plastic feet and tilt stand for bench operation as shipped from the factory. However, when used in combination with other submodular units it can be bench and/or rack mounted. The HP combining case and adapter frame are designed for this purpose and are available through your Hewlett-Packard Sales and Service Office.

2-10. ADAPTER FRAME

2-11. The 5060-0797 Adapter Frame is shown in Figure 2-1. The frame will accept a variety of submodular units in a manner suitable for rack mounting. Submodular units, in combination with any necessary spacers, are assembled within the frame. A submodular unit cannot be removed individually.

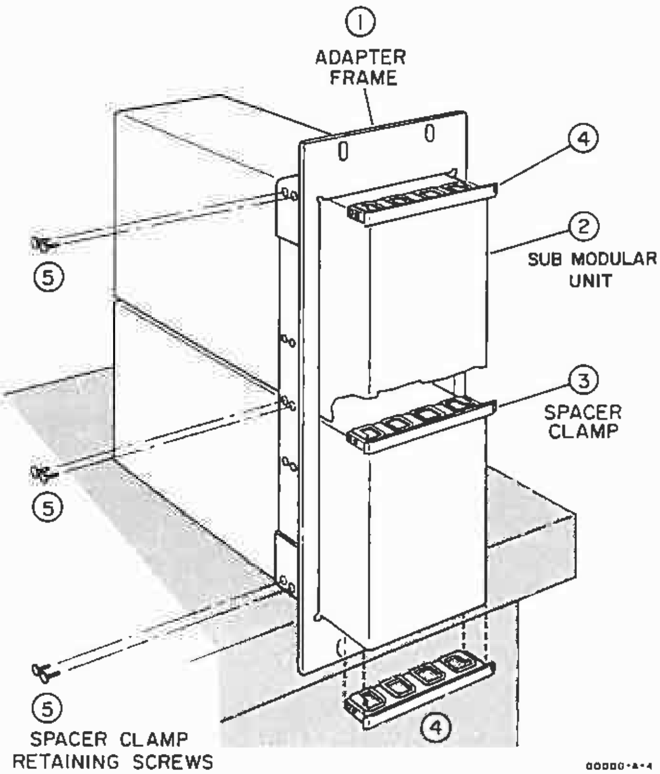


Figure 2-1. Sub-module Installation in Rack Adapter Frame

2-12. COMBINING CASE

2-13. A Model 1051A Combining Case is shown in Figure 2-2. This case is full rack width and accepts varying combinations of submodular instruments. The case, purchased separately, is provided with a rack mounting kit. The combining case will hold three instruments the same size as the Model 4332A. When instruments are installed in the combining case, they may be installed or removed individually.

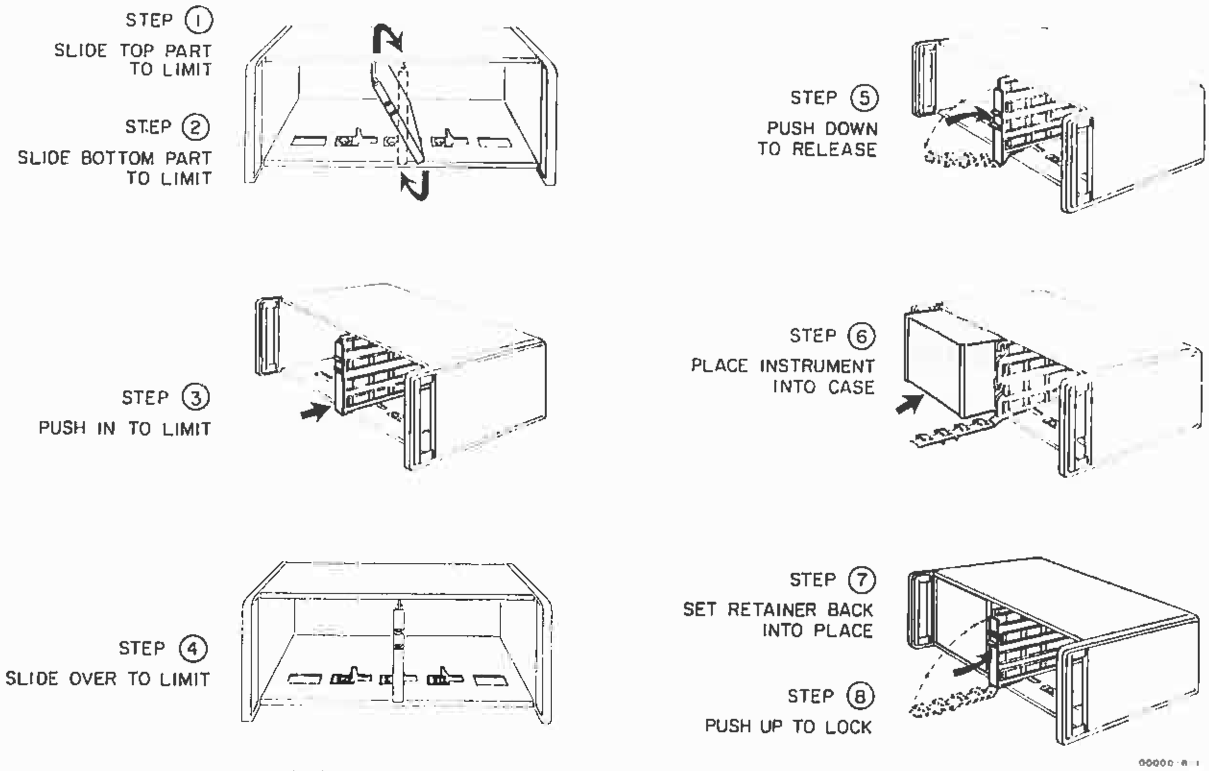


Figure 2-2. HP Model 1051A Combining Case Instrument Installation

2-14. POWER CONNECTION

2-15. LINE VOLTAGE. The Model 4332A may be operated from either 115- or 230- volt (±10%) 48 to 66Hz power lines, which can supply approximately 8 watts. A slide switch in the power line module on the rear panel permits quick conversion for operation from either voltage. To convert to desired operating voltage:

a. Disconnect power cable from the instrument (power line module).

b. Slide the clear plastic door of power line module to the left (exposes fuse and slide switch).

c. Pull the "FUSE PULL" lever. Remove fuse.

d. Slide the switch to the right for 115-volt operation or to the left for 230-volt operation with a screwdriver.

e. Depress the "FUSE PULL" lever.

f. Insert fuse.

The Model 4332A is supplied with 115-volt fuse, be sure to replace this fuse for 230-volt operation; see Table 2-1.

CAUTION

To avoid damage to the instrument, before connecting the power cable, set the 115/230 switch for the line voltage to be used.

Table 2-1. AC Line Fuse

Conversion	115-volt	230-volt
Slide Switch	Right	Left
AC Line Fuse	0.2 amperes Slow Blow 2100-0235	0.1 amperes Slow Blow 2110-0234

2-16. POWER CABLE. To protect operating personnel, the National Electrical Manufacturers' Association (NEMA) recommends that instrument panels and cabinets be grounded. Accordingly, the Model 4332A is equipped with a detachable three-conductor power cable which, when plugged into an appropriate receptacle, grounds panel and cabinet. The offset pin of the three-prong connectors is the ground pin. Proceed as follows for power cable installation:

a. Connect flat plug (3-terminal connector) to LINE receptacle at rear of instrument.

b. Connect plug (2-blade with round grounding pin) to 3-wire (grounded) power outlet. Exposed portions of instrument are grounded through the round pin on the plug for safety; when only 2-blade outlet is available, use connector adapter (HP Part No. 1251-0048) then connect short wire from side of adapter to ground to preserve the protection feature.

SECTION III
OPERATION

3-1. INTRODUCTION

3-2. This section contains instructions and information necessary for the operation of the Model 4332A. Included are description of controls, connectors, operating instructions for L, C and R measurements and application of DC bias.

3-3. CONTROLS AND CONNECTORS

3-4. All controls and connectors required for normal operation of the Model 4332A are located on the front and the rear panels of the instrument. Figure 3-3 and 3-4 show the location and description of all controls and connectors.

3-5. OPERATING INSTRUCTIONS

3-6. Detailed operating instructions of various measurements are described in the following figures:

Figure 3-5. Inductance Measurement
Figure 3-6. Capacitance Measurement
Figure 3-7. Resistance Measurement
Figure 3-8. Measurement with DC Bias

3-7. MODEL 16138A TEST LEADS

3-8. The Model 16138A Test Lead Ass'y shown in (Figure 3-1) consists of two leads and three banana plugs in a molded block. The letters "G", "H" and "L" printed on molded block indicate where GUARD, HIGH and LOW terminals of 4332A are to be connected. The red lead for HIGH terminal is covered with a shield which is internally connected to GUARD terminal and the black lead is internally connected to LOW terminal. The effect of GUARD in 16138A is shown in Figure 3-2. When HIGH and LOW leads are not shielded as shown in Figure 3-2 (a), the stray capacitance Cs across the leads is added to the unknown Cx and the 4332A measures (Cx + Cs). In 16138A the GUARD terminal is provided with the same voltage both in magnitude and phase by the low output impedance Guard Amplifier. The current through the capacitance C_{HG} is zero, and the current through the capacitance C_{LG} is provided by the Guard Amplifier. Therefore no current flows from HIGH terminal to LOW terminal except for the current through the unknown. The additional error resulting from the stray capacitance Cs is, in this way, eliminated.

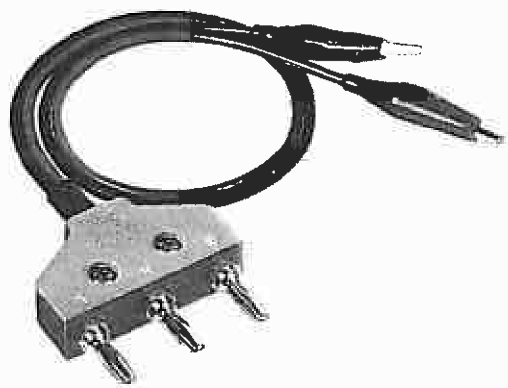


Figure 3-1. Model 16138A Test Leads.

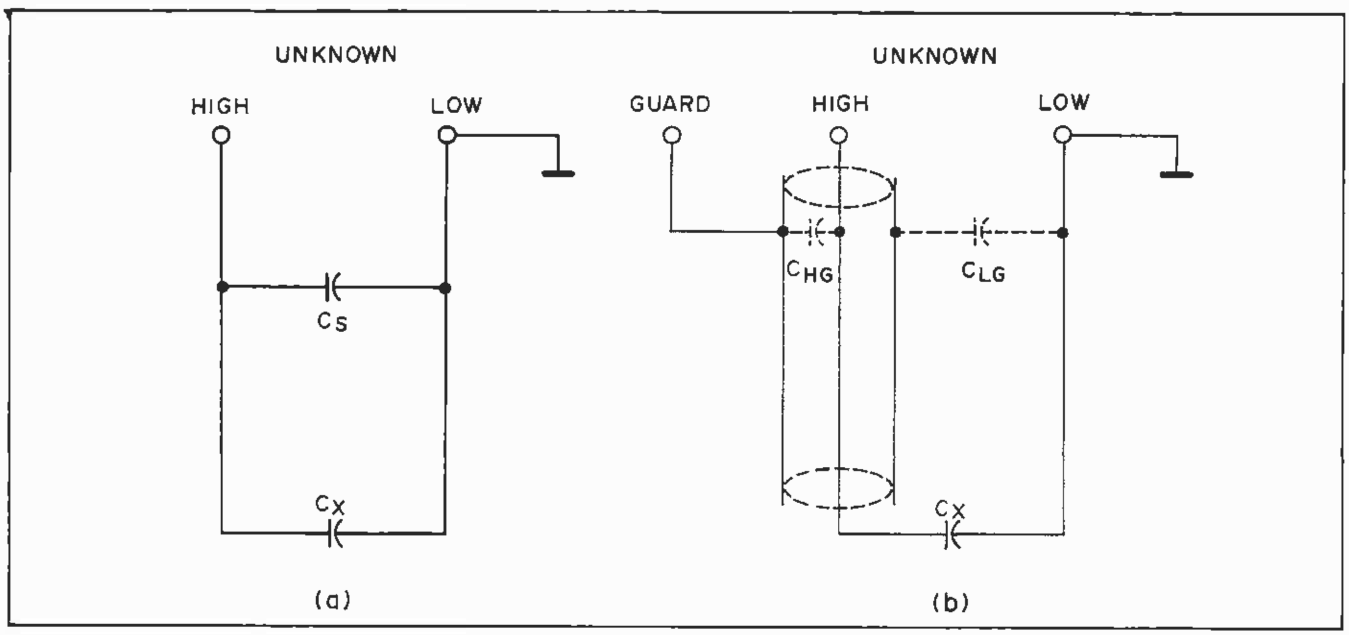
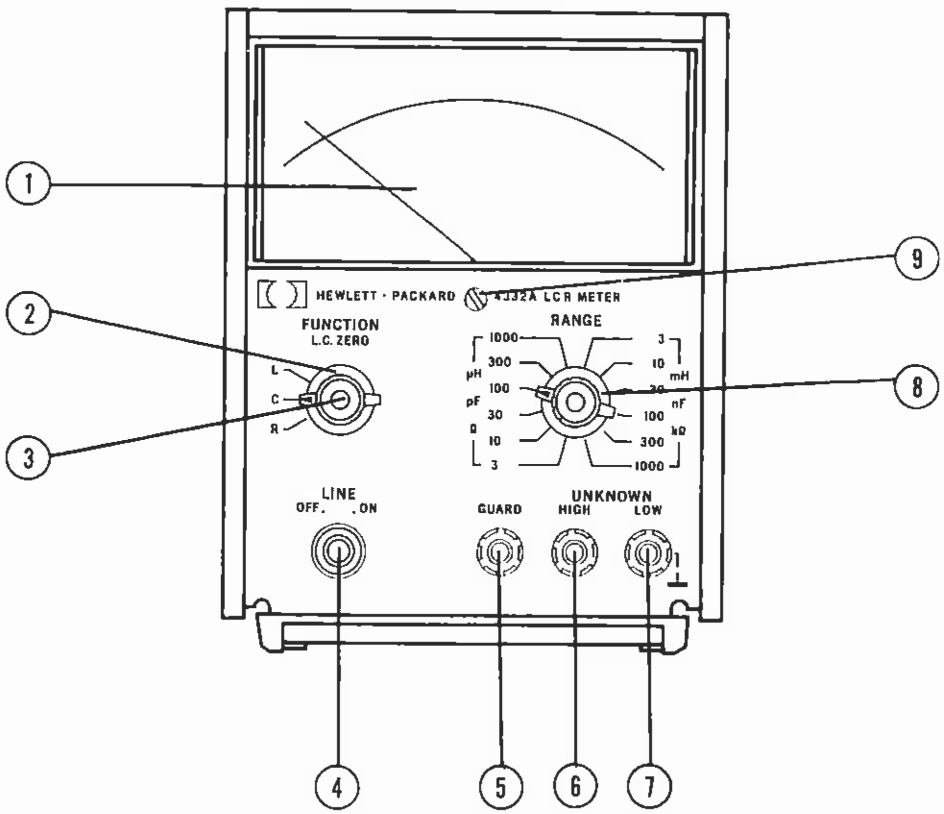


Figure 3-2. Effect of GUARD in Model 16138A Test Leads



1. INDUCTANCE/CAPACITANCE/RESISTANCE Meter: Provides direct reading of L, C or R within the range selected by the RANGE selector. The minimum division of the scale is 0.02 for 0 - 1.0 scale and 0.05 for 0 - 3.0 scale

2. FUNCTION switch: Selects measurement function either Inductance (L), Capacitance (C) or Resistance (R).

3. L. C. ZERO Control: Provides adjustment for electrical zero of the meter in Inductance and Capacitance measurements. In Resistance measurement, the zero control is disabled.

4. LINE Switch: Applies ac power to the instrument. Push ON and OFF' Illuminates in "ON" position.

5. GUARD Terminal: Provides a voltage same as that at UNKNOWN HIGH terminal in Capacitance or Resistance Measurements (300kΩ, 1000kΩ RANGE). A guard terminal of the device under test should be connected to this GUARD terminal to prevent the stray capacitance. No signal is applied in Inductance measurement and Resistance Measurement (3Ω to 100kΩ RANGE).

6. UNKNOWN HIGH Terminal: Device under test is connected across this terminal and UNKNOWN LOW terminal.

⚠ CAUTION

Do not apply more than +100V DC bias voltage.

WARNING

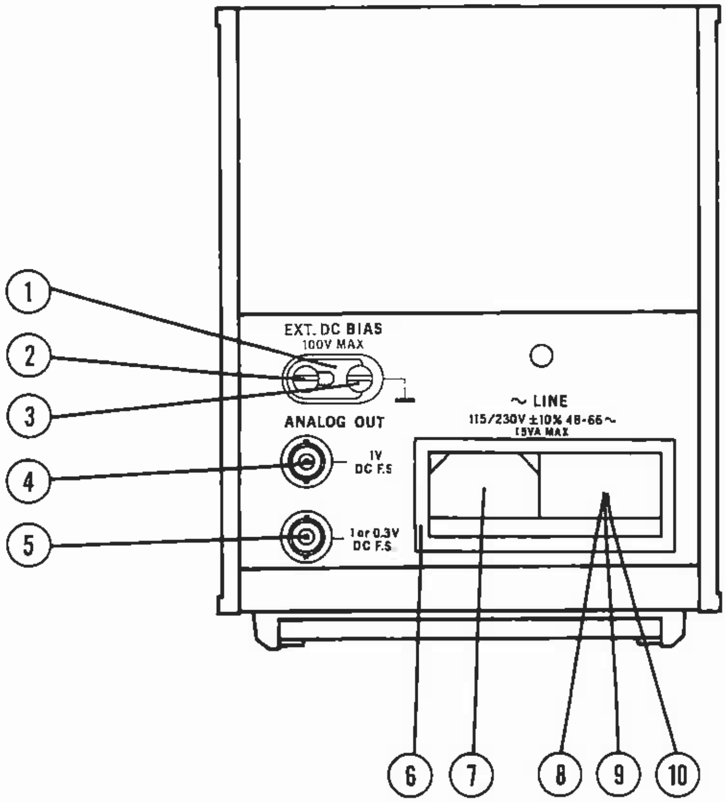
Do not touch or change unknown during measurement. An applied DC voltage may exist between UNKNOWN HIGH - LOW terminals.

7. UNKNOWN LOW Terminal: Is connected to cabinet, therefore has the ground potential.

8. RANGE Switch: Selects full scale range of meter.

9. Mechanical zero adjustment: Provides screw driver adjustment for mechanical zero of panel meter.

Figure 3-3. Front Panel Controls and Connectors



1. EXT DC BIAS Shorting Strap: Should be disconnected when EXT DC BIAS Terminals are used for a Capacitance Measurement with dc bias.

2,3. EXT DC BIAS Terminals: Terminal 2 is connected to UNKNOWN HIGH Terminal through a 51.1kΩ resistor and to RANGE resistor inside instrument. Terminal 3 is connected to chassis and cabinet and is used for grounding instrument. The maximum dc voltage that can be applied is ±100V. Therefore, the maximum short circuit I is about 2mA. Thus, the instrument can not be damaged if the UNKNOWN terminal is accidentally shorted.

4. DVM Analog Output: Provides dc output of +0.3V full scale at 3, 30 or 300 position of the RANGE switch, or dc output of +1.0V full scale at 10, 100 or 1000 position of the RANGE switch. Output is proportional to the meter deflection. Overrange is 110% of full scale.

5. Recorder Analog Output: Provides dc output of +1.0V full scale at any setting of the RANGE switch. Overrange is 110% of full scale.

6. Power Line Module: Includes power line receptacle, voltage selector switch and fuse holder. The module satisfies the Underwriters Loboratories and International Electrotechnical Commission safety criteria.

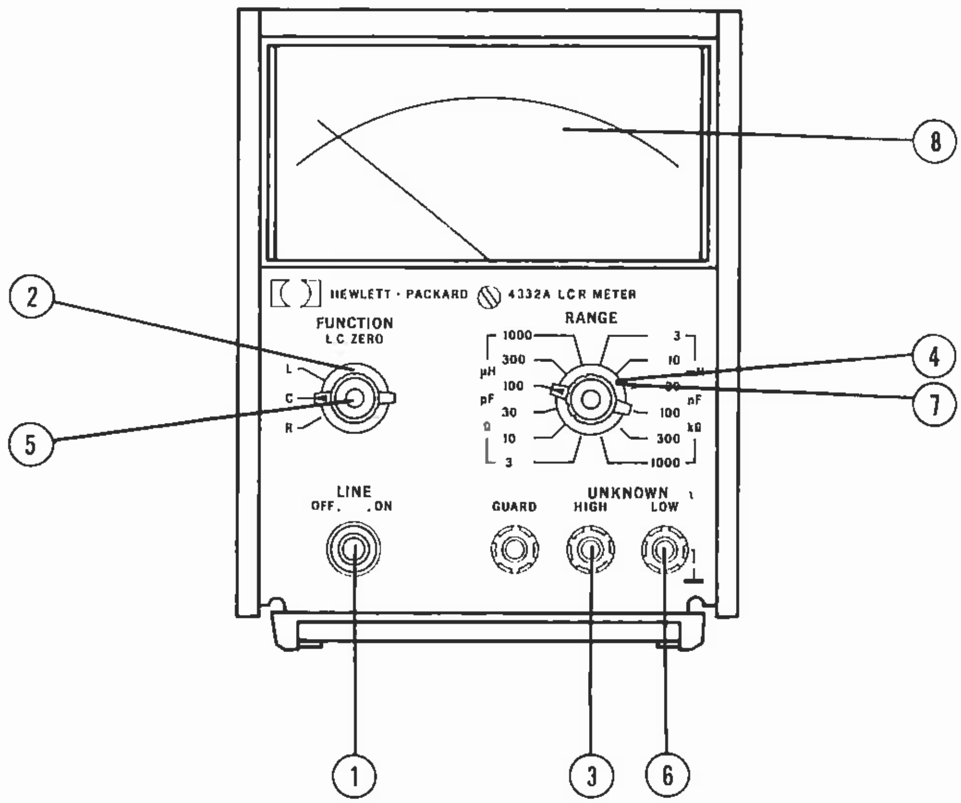
7. Power Line Receptacle: Use power cord furnished, HP Part No. 8120-1348. Check FUSE rating and position of line voltage slide switch before connecting power.

8. Line Fuse: For 115V, use 0.2 amp. slow-blow fuse and for 230V, use 0.1 amp. slow-blow fuse.

9. Line Voltage Slide Switch: Set to line voltage available(115V or 230V, 48 - 66 Hz).

10. FUSE PULL Lever: Pull lever to remove fuse or when changing operating voltage.

Figure 3-4. Rear Panel Controls and Connectors



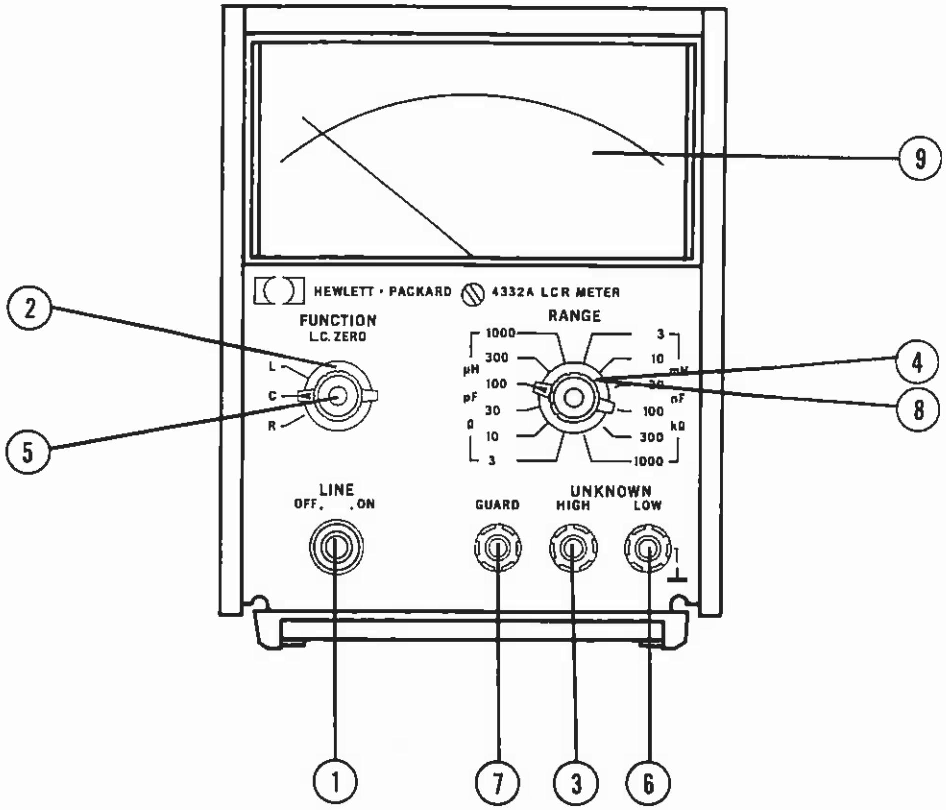
1. Depress LINE switch to turn instrument on.
2. Set FUNCTION switch to L.
3. Short UNKNOWN HIGH and LOW terminals. If test lead or test fixture is used, their ends should also be shorted.
4. Set RANGE switch to 3 μH.
5. Adjust L. C. ZERO control (red) for exact zero position of the meter. The range of L. C. ZERO control is approximately 3 μH.

NOTE

Zero control is disabled when RANGE switch is set at a range from 3mH to 1000 mH. Steps 3. to 5. can be eliminated when the unknown has an inductance greater than 1mH.

6. Remove shorting bar from UNKNOWN HIGH and LOW terminals and connect device to be measured to these terminals.
7. Set RANGE switch to appropriate range for an easy-to-read deflection of the meter.
8. Read the meter deflection of inductance value.

Figure 3-5. Inductance Measurement



1. Depress LINE switch to turn instrument on.

2. Set FUNCTION switch to C.

3. Leave UNKNOWN terminals open (with nothing connected). If test lead or test fixture is used, their ends should be open.

4. Set RANGE switch to 3pF.

5. Adjust LC ZERO control (red) for the exact zero position of the meter.

NOTE

Zero control is disabled when RANGE switch is set from 3nF to 1000nF. Step 3 to 5 can be eliminated when the unknown has a capacitance greater than 1nF.

6. Connect the device to be tested across UNKNOWN HIGH and LOW terminals.

7. If there is stray capacitance in parallel with the sample to be tested, set up a guard on the sample and connect it to GUARD terminal.

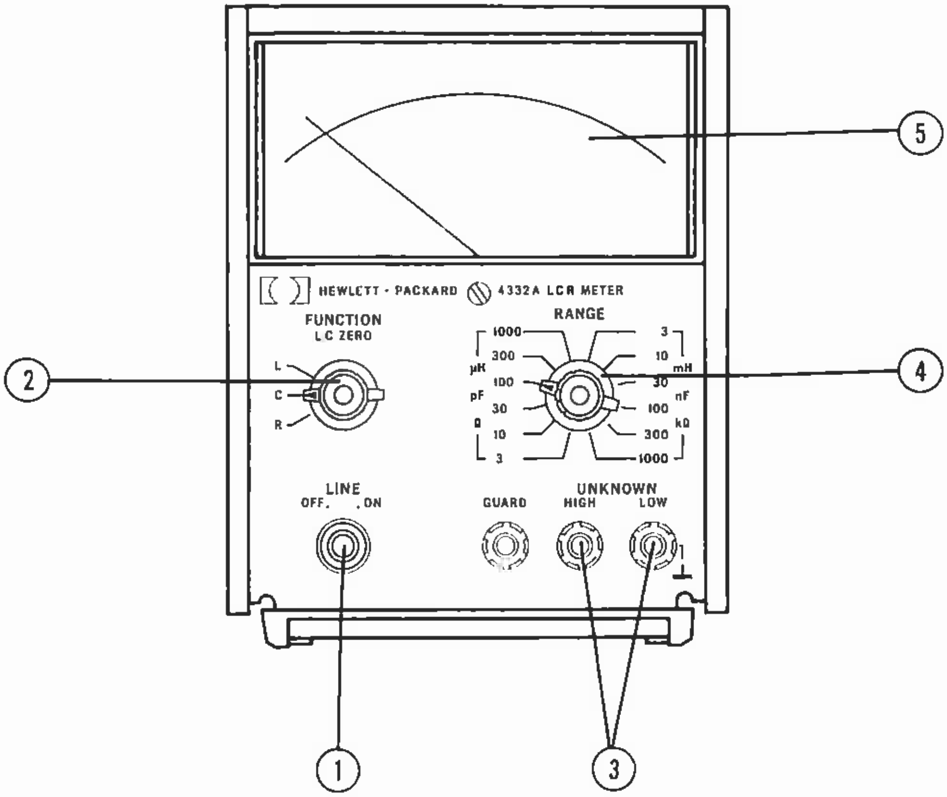
NOTE

Stray capacitance up to about 200pF can be compensated for by the GUARD terminal. If the stray capacitance exceeds 200pF, it will cause an error in the reading.

8. Set RANGE switch to appropriate range for an easy-to-read deflection of meter.

9. Read the meter deflection of capacitance value.

Figure 3-6. Capacitance Measurement



1. Depress LINE switch to turn instrument on.

2. Set FUNCTION switch to R.

3. Connect the sample to be tested across UNKNOWN HIGH and LOW terminals.

Note

If there is stray capacitance in parallel with the sample to be tested, it may cause an error because of the 1kHz ac measurement. When higher values of resistance (100kΩ - 1000kΩ) are measured, connect the sample directly to UNKNOWN terminals.

4. Set RANGE switch to appropriate range for an easy-to-read deflection of the meter.

5. Read the meter deflection of resistance value.

Figure 3-7. Resistance Measurement

A. Capacitance Measurement with dc bias-

1. Before making a capacitance measurement, proceed as follows:
   a. Disconnect the Shorting Strap from EXT DC BIAS Terminals.
   b. Connect the output of an external dc power supply to EXT DC BIAS Terminals.

B. L & R Measurements with dc bias-

1. In the L & R Measurements, the dc current through the unknown or the dc voltoge across the unknown depends on the RANGE switch setting and the value of the unknown.
2. The external dc power supply, therefore, should be applied to UNKNOWN HIGH terminal through an output impedance Zs and an ammeter or a voltmeter for monitoring should be connected as shown in Figure 3-8.

NOTE

The value of Zs should be greater than 100 Zx so that the additional error will be less than 1% (Zx is the impedance of the unknown).

⚠ CAUTION

Do not apply more than +100V DC bias voltage. If the common of the DC power supply is grounded, it should be connected to UNKNOWN LOW or EXT DC BIAS low terminal.

WARNING

Do not touch or change unknown during measurement. An applied DC voltage may exist between UNKNOWN HIGH - LOW terminals.

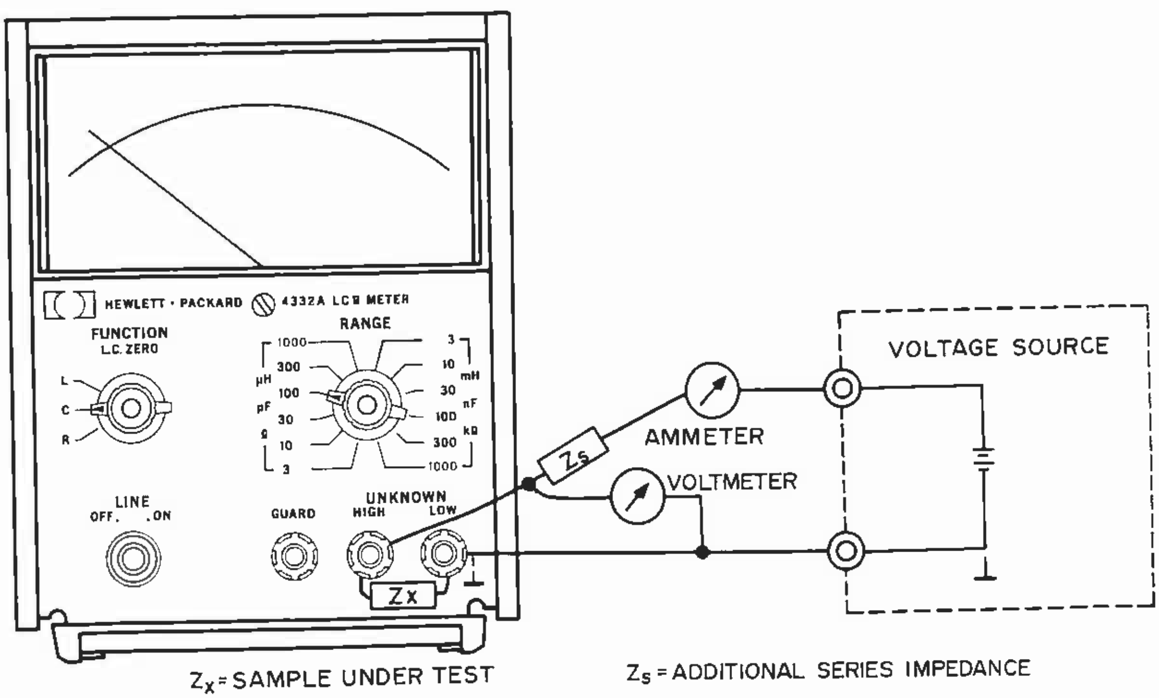


Figure 3-8. Measurement with DC Bias

SECTION IV
THEORY OF OPERATION

4-1. GENERAL INFORMATION

4-2. This section describes theory of operation. Fundamental theory of measurement for each function is explained in paragraphs 4-3 through 4-10. Simplified block diagrams are used. Actual circuit techniques and theory are described stage by stage under paragraph 4-11.

4-3. FUNDAMENTAL THEORY OF MEASURMENT

4-4. The following paragraphs describe the fundamental measurement theory for each of the electrical units L (Inductance), C (Capacitance) and R (Resistance) that the 4332A is designed to measure.

4-5. INDUCTANCE MEASUREMENT (L)

4-6. Figure 4-1 is a simplified block diagram of the circuit for measuring inductance (L). In L measurement the RANGE resistance R_L is much larger than the UNKNOWN impedance ($r + j\omega L$) connected to the UNKNOWN terminals, such that a constant current flows thru the UNKNOWN inductor. The voltage drop across the UNKNOWN inductor is is amplified and supplied as one of the inputs to the SYNCHRONOUS DETECTOR. The other input to the SYNCHRONOUS DETECTOR is a square wave phase reference signal. The SYNCHRONOUS DETECTOR detects the voltage drop across UNKNOWN inductor which is in phase with the phase reference signal and provides a dc voltage output proportional to Lx. Lx, can be expressed in the following equations:

$$i_L = \frac{e}{j\omega Lx + r + R_L} \doteqdot \frac{e}{R_L} \quad (\because R_L \gg r, \omega Lx)$$

$$e_L = i_L(r + j\omega Lx) = \frac{e}{R_L} \cdot r + \frac{e}{R_L} \cdot j\omega Lx$$

$$e_{Lx_j} = \omega Lx \cdot \frac{e}{R_L} \cdot A$$

$$Lx = \frac{R_L}{\omega \cdot e \cdot A} \cdot e_{Lx_j}$$

If RANGE resistor R_L is known, then Lx and a constant may be expressed as:

$$Lx = k1 e_{Lx_j} \quad (k1 = R_L / \omega \cdot e \cdot A = \text{constant})$$

Where-

e: Oscillator output voltage
ω: $2\pi f$ (f: measuring frequency)
i_L: Current flowing through UNKNOWN inductor (L)
e_{Lx}: Voltage drop across UNKNOWN terminals
e_{Lx_j}: SYNCHRONOUS DETECTOR output voltage
A: Gain of AMPLIFIER and SYNCHRONOUS DETECTOR
r: Loss resistance of UNKNOWN inductor
Lx: UNKNOWN inductance (L)
R_L: RANGE resistance

This shows that the output voltage e_{Lx_j} is proportional to Lx and that the inductance can be measured without the influence of the series resistor r.

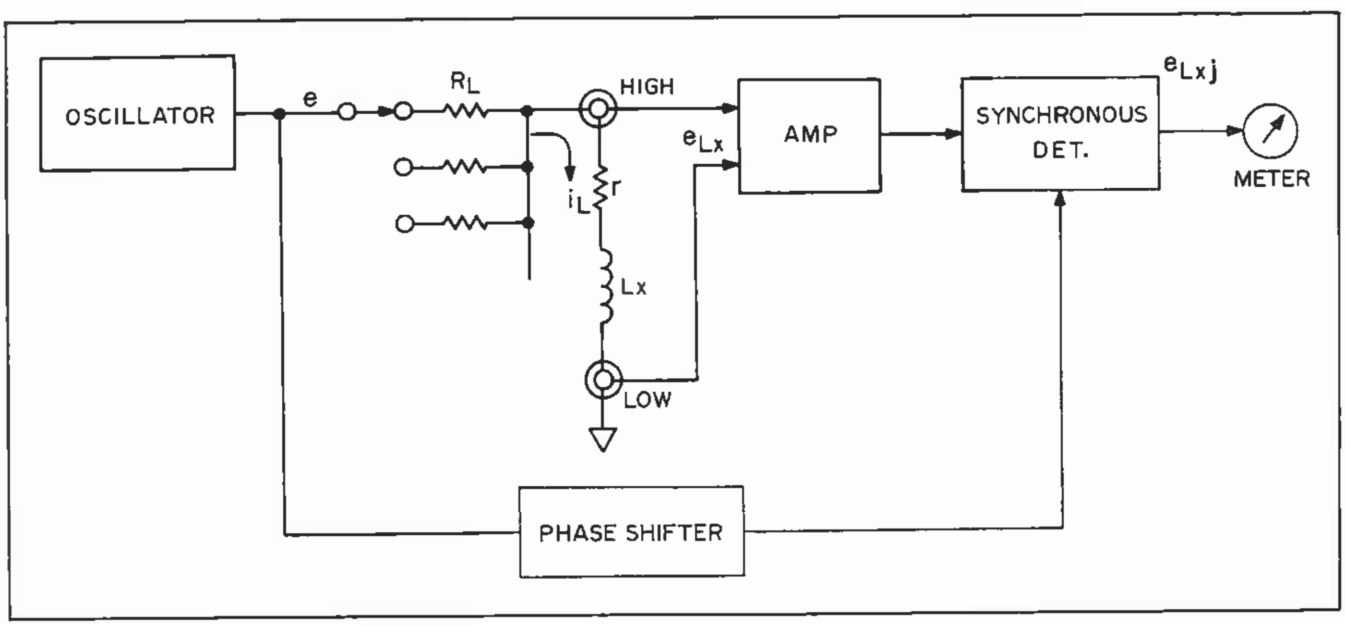


Figure 4-1. Inductance Measurement-Simplified Block Diagram

4-7. CAPACITANCE MEASUREMENT (C)

4-8. Generally speaking, the parallel equivalent circuit is used when discussing small capacitances. This explanation uses the parallel equivalent circuit to develop the capacitance measurement circuit techniques used in the Model 4332A. Refer to Figure 4-2 which shows the theoretical circuit. Since RANGE resistance Rc is negligible compared to the impedance of the UNKNOWN capacitance $[r/(1 + j\omega Cx\ r)]$, a constant voltage is thus applied to the UNKNOWN capacitor. The current which flows through the UNKNOWN capacitor is sensed as a voltage drop across Rc and is amplified. AMPLIFIER output is fed to a SYNCHRONOUS DETECTOR. The SYNCHRONOUS DETECTOR detects the signal and provides a dc voltage proportional to Cx only. This is expressed mathematically as:

$$i_C = \frac{e}{Rc + r/(1 + j\omega Cx \cdot r)} = \frac{(1 + j\omega Cx \cdot r)e}{r}$$

$$[Rc \ll r/(1 + j\omega Cx \cdot r)]$$

$$e_{Cx} = (\frac{Rc}{r} + j\omega Cx \cdot Rc)e$$

$$e_{Cxj} = \omega Cx Rc \cdot e \cdot A$$

e, ω, A and Rc are constant.

$$Cx = k_2 e_{Cxj} \qquad (k_2 = 1/\omega Rc \cdot e \cdot A)$$

Where-
e: Oscillator output voltage
ω: $2\pi f$ (f: measuring frequency)
i_c: Current which flows through Rc, r and Cx
e_{Cx}: Voltage drop across RANGE resistor Rc
e_{Cxj}: SYNCHRONOUS DETECTOR output voltage
A: Gain of AMPLIFIER and SYNCHRONOUS DETECTOR
r: Loss resistor
Cx: UNKNOWN capacitance
Rc: RANGE resistance

This shows that the output of the SYNCHRONOUS DETECTOR is proportional to the UNKNOWN capacitor and that capacitance can be measured without the influence of the resistance loss.

4-9. RESISTANCE MEASUREMENT (R)

4-10. Resistance in the Model 4332A is measured with a 1kHz carrier signal. This is because it is easier to use ac rather than dc in a resistance measuring instrument. Common resistors do not distinguish ac signals from dc signals in a measurement circuit. Refer to Figure 4-3 for block diagram. Basically, resistance measurement (R) is much the same as inductance measurement (L). That is, the RANGE resistance is much larger than the UNKNOWN resistor Rx. Thus, the current i_R which flows thru Rx is constant regardless the *size of Rx.

* Within the measurement range.

The voltage drop across Rx is amplified and detected by a SYNCHRONOUS DETECTOR. Output voltage of the SYNCHRONOUS DETECTOR is in phase with OSCILLATOR output (e). At this point the measurement technique is different from that of an Inductance Measurement (L). The resultant detector output is only proportional to Rx. Mathematically, the measurement method is expressed as:

$$i_R = \frac{e}{R_R + Rx + j\omega l} = \frac{e}{R_R} \qquad (\because R_R \gg Rx, \omega l)$$

$$e_{Rx} = (\frac{Rx}{R_R} + \frac{j\omega l}{R_R})e$$

$$e_{RxR} = \frac{Rx}{R_R} \cdot e \cdot A$$

$$Rx = \frac{R_R}{e \cdot A} \cdot e_{RxR} = k3 e_{RxR} \quad (k3 = R_R/e \cdot A)$$

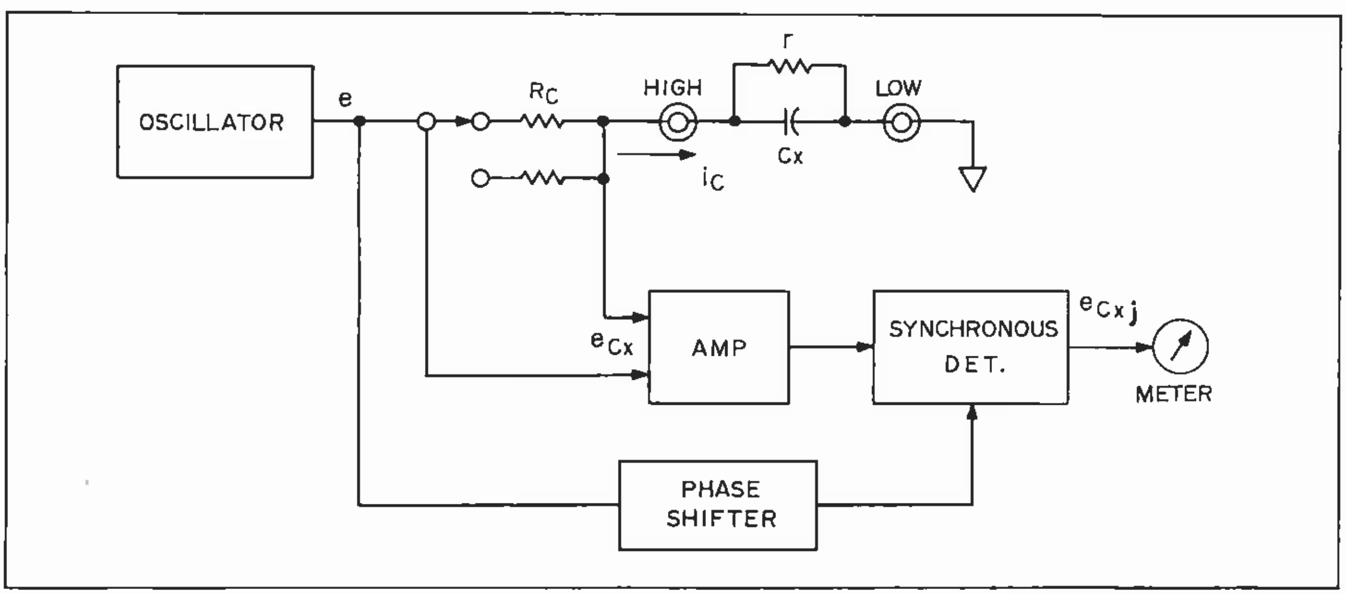


Figure 4-2. Capacitance Measurement-Simplified Block Diagram

e: OSCILLATOR output voltage
ω: 2πf (f: measuring frequency)
i_R: Current which flows through R_R, l and Rx
e_{Rx}: Voltage drop across UNKNOWN terminals
e_{RxR}: SYNCHRONOUS DETECTOR Output voltage
A: Gain of AMPLIFIER and SYNCHRONOUS DETECTOR
l: Residual inductance of UNKNOWN resistor
Rx: UNKNOWN resistance
R_R: RANGE resistance

4-11. CIRCUIT DESCRIPTION-L, C AND R FUNCTIONS

a. OSCILLATOR (A1)
The OSCILLATOR is composed of IC1, IC2, IC3, Q1 and Q2. IC1 is a high gain amplifier. The basic Wien Bridge is composed of R1, R2, R3, R7, R8, R9, C1, C2, C3 and C6. Relay K1 turns "on" when the FUNCTION switch is set to L or C and the RANGE switch is set to "low" side (μH or pF). IC2 works as a peak detector with CR2 and provides a dc voltage proportional to the peak of the OSCILLATOR output thru Q2 to the voltage comparator IC3. IC3 compares the IC2 output with the reference voltage and keeps the OSCILLATOR output constant thru Q1.

b. LOW OUTPUT IMPEDANCE AMPLIFIER (A1)
This amplifier is composed of Q4 thru Q7 and IC5. IC5 is a wide band 30dB differential amplifier with feedback and unity gain. The OSCILLATOR output is divided between R36 and R37 with 70mVrms across R37. This voltage provides the signal to the RANGE resistors thru the LOW OUTPUT IMPEDANCE AMPLIFIER (A1). Measurement voltage across the RANGE resistors is a constant 70mV. T1 detects the current in the RANGE resistor and leads the voltage proportional to the current. The output voltage of T1 compensates for any residual inductance of the TEST LEADS through FUNCTION switch to #2 HIGH Zin AMPLIFIER on A4 board.

c. PHASE SHIFTER (A1)
IC4 and Q3 form the PHASE SHIFTER. The output voltage of the PHASE SHIFTER leads its input by 90°. K2 turns on at L, C and R high range (mH, nF & kΩ)--when the measuring frequency is 1kHz.

d. First & Second HIGH Zin AMPLIFIERS (A4)
The structure of each amplifier is the same and consists of Q1, Q2 and Q3. They work as full feedback amplifiers with a gain of about one. These amplifiers detect the voltage drop across the RANGE resistor and UNKNOWN terminals and supply it to the input of the First 30dB AMPLIFIER.

e. First 30dB AMPLIFIER (A4)
The First 30dB AMPLIFIER is composed of Q4, Q5 and IC1. Q4 and Q5 are emitter followers and IC1 is a wide band differential amplifier. This output is supplied to Second 30dB AMPLIFIER. The output voltage is about 30mV when the meter reads full scale.

f. GUARD AMPLIFIER (A4)
The GUARD AMPLIFIER consists of only Q6. It produces the guard voltage which is the same as that of UNKNOWN HIGH terminal in amplitude and phase thru FUNCTION switch and GUARD terminal. R32 and R34 adjust amplitude and phase of the guard voltage. CR1 and CR2 protect Q6 and C15 from over range.

g. L ZERO AMPLIFIER (A4)
The L ZERO AMPLIFIER consists of Q7. It compensates for the leads in L FUNCTION. Transformer T1 picks up a voltage proportional to the measuring current flowing thru the RANGE resistor. This voltage is divided by the L.C. ZERO variable resistor and is connected thru Q7 to Second HIGH Zin AMPLIFIER.

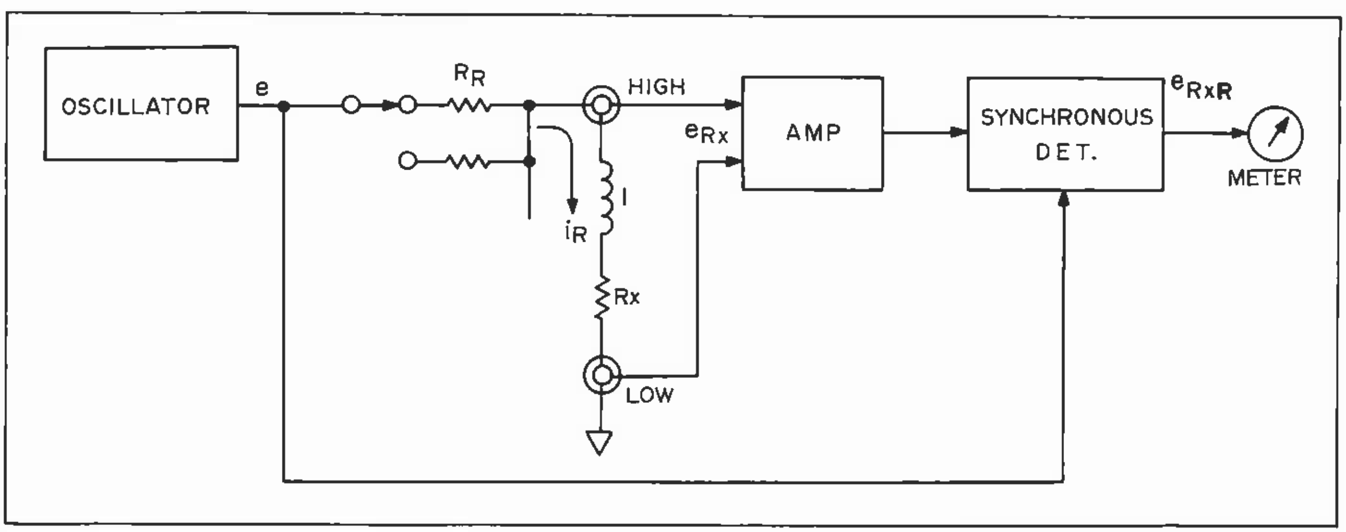


Figure 4-3. Resistance Measurement-Simplified Block Diagram.

h. C ZERO AMPLIFIER (A2)
C ZERO AMPLIFIER is composed of Q7, Q8 and Q9. This produces a signal to compensate for the stray capacitance at the UNKNOWN HIGH terminal in C FUNCTION. It flows thru Q3 to the L. C. ZERO variable resistor R1. R25 adjusts the phase of this signal. R37 picks up the signal to compensate for the same stray capacitance on 3nF RANGE.

k. SECOND 30dB AMPLIFIER (A2)
The SECOND 30dB AMPLIFIER is formed by Q10, Q11, and Q12. Q10 and Q11 form an ac wide band amplifier and its output is fed thru emitter follower Q12 to the SYNCHRONOUS DETECTOR. The output voltage is about 1Vrms at TP2 when the meter is at full scale.

j. SYNCHRONOUS DETECTOR (A2)
The SYNCHRONOUS DETECTOR is composed of Q13 and Q14 and works as a switch. That is, Q13 and Q14 are alternately turned on by the signal from the LIMIT AMPLIFIER. The output of the Second 30dB AMPLIFIER is proportional to the UNKNOWN sample and is fed to the METER DC AMPLIFIER.

k. FET SWITCH (A2)
FET SWITCH is formed by Q1 thru Q4. Its on-off behavior is controlled by the RANGE and FUNCTION switch. Q1, Q2, or Q3 turn on in succession as the FUNCTION is set to L, C, or R and supply a voltage from the PHASE SHIFTER (A1) or OSCILLATOR (A1) to the LIMIT AMPLIFIER. A4 turns on at ranges (3 - 1000pF) of C FUNCTION and supplies the C ZERO AMPLIFIER output to the L. C. ZERO variable resistor R1.

l. LIMIT AMPLIFIER (A2)
The LIMIT AMPLIFIER is formed by IC1, Q5 and Q6. This circuit changes the sinewave from the PHASE SHIFTER or OSCILLATOR to a symmetrical square wave. This square wave is used as a phase reference signal and fed to the SYNCHRONOUS DETECTOR. The Schmitt Trigger Circuit is composed of Q5 and Q6 and generates two channels of square wave signals whose phases are exactly the inverse of each other.

m. METER DC AMPLIFIER (A2)
The METER DC AMPLIFIER consists of IC2. IC2 is a dc differential amplifier. The dc output of SYNCHRONOUS DETECTOR is connected to a CR filter to attenuate its ripple. R60 adjusts its output to zero when the input to the METER DC AMPLIFIER is zero. R67 adjusts the meter full scale. The output of this amplifier drives the meter and is present across the analog output terminals.

n. OVER SCALE AMPLIFIER (A2)
The OVER SCALE AMPLIFIER is composed of Q15 and Q16. This amplifier drives the meter overscale when the input voltage to 1st 30dB AMPLIFIER and SYNCHRONOUS DETECTOR becomes too high. The output from the 1st 30dB AMPLIFIER is amplified and connected to the rectifier circuit. The output from this rectifier circuit is connected thru emitter follower Q16 and CR12 to the output of IC2.

o. DC POWER SUPPLY (A3)
The DC POWER SUPPLY is composed of Q1 thru Q7. It provides three voltages, +12, -15 and -6V which are used throughout the instrument. Q1, Q2, Q4, Q5 and Q7 combine to form the series regulator. CR3, CR6 and CR7 produce the reference voltage. CR2 and CR5 attenuate output ripple.

Table 5-1. Recommended Test Equipment

Instrument type	Required Characteristics	Use	Recommended Model
Standard Inductor	100μH Accuracy:<±0.25% 1000μH Accuracy:<±0.1%	Adjustment Adjustment	GR 1482-B GR 1482-E
Standard Capacitor	100pF Accuracy:<±0.1% 100nF Accuracy:<±0.1%	Adjustment Adjustment	GR 1404-B GR 1409-T
Standard Resistor	1000Ω Accuracy:<±0.1%	Adjustment	GR 1440-9631
Decade Inductor	Range: 3μH to 1000mH 1, 3, 10 sequence Accuracy:<±0.2%	Performance Check	GR 1491F*
Decade Capacitor	Range: 3pF to 1000nF 1, 3, 10 sequence Accuracy:<±0.2%	Performance Check	GR 1413**
Decade Resistor	Range: 2.70Ω to 1MΩ Accuracy:<±0.2%	Performance Check	GR 1433B & 1433W
Digital Voltmeter	Range: 1000mV, 10V, 100V Accuracy: ±0.1% Input Impedance: 10MΩ	Performance Check Adjustment Troubleshooting	HP 3440A with 3443A
Frequency Counter	Range: 100kHz Accuracy: ± 1 count ± time base accuracy	Performance Check Adjustment	HP 5300A with 5301A
Oscilloscope	Frequency Range: dc to 1MHz Sensitivity: 0.005V/cm	Performance Check Adjustment Troubleshooting	HP 180A with 1820C & 1801A
DC Voltage Supply	Range: 5V	Troubleshooting	HP 721A
Variable Resistor	1000Ω Accuracy: ±10%	Troubleshooting	hp Part No. 2100-1466
Capacitor	2200pF	Adjustment	hp Part No. 0160-1543
Resistor	619Ω 61.9Ω 16.2kΩ	Adjustment Adjustment Adjustment	hp Part No. 0757-0418 hp Part No. 0757-0276 hp Part No. 0757-0447

* GR 1491F
Calibrated to within ±0.2% for all ranges except 3, 10 & 30μH.

** Calibrated to within ±0.2%

SECTION V
MAINTENANCE

5-1. INTRODUCTION

5-2. This section contains information necessary to maintain the Model 4332A LCR meter. It includes Performance checks, Calibration, and Troubleshooting procedures.

5-3. REQUIRED EQUIPMENT

5-4. Table 5-1 is a list of the equipment necessary to properly maintain the Model 4332A. If the model recommended in Table 5-1 is not available, a substitute may be used as long as it meets the specifications.

5-5. MECHANICAL ZERO ADJUSTMENT

5-6. Before beginning a performance check or calibration, the following mechanical zero adjustment should be made:

a. With instrument turned off, rotate meter adjustment screw clockwise until pointer approaches zero mark from the left.

b. Continue rotating clockwise until pointer coincides with the zero mark. If pointer overshoots, repeat step a.

c. Rotate adjustment screw about three degrees counterclockwise to disengage it from the meter suspension.

5-7. PERFORMANCE CHECKS

5-8. The performance checks are "in-cabinet" tests designed to compare the -hp- Model 4332A with its specifications (See Table 1-1). These operations should be completed before any attempt is made to adjust or calibrate the instrument. Allow a five minute warm-up period before making performance checks. These checks may be used for incoming inspection, periodic preventative maintenance, for systems checking, or to verify specifications after repair.

5-9. RESISTANCE MEASUREMENT

5-10. This check insures that Model 4332A meets its analog output and panel meter resistance measurement specifications within the tolerances given in Table 5-2. Analog output meter accuracies are:

Analog Accuracy (at 25° C):

3Ω - 30kΩ Ranges

± (0.5% of reading +1.5% of full scale +0.03Ω)

100kΩ - 1000kΩ Ranges

± (1% of reading +1.5% of full scale)

Panel Meter Accuracy: Add 0.5% of full scale to above analog accuracy.

a. Connect equipment as shown in Figure 5-1.

b. Set the 4332A FUNCTION to R and RANGE to 3Ω.

c. Set the decade resistor to 2.70Ω.

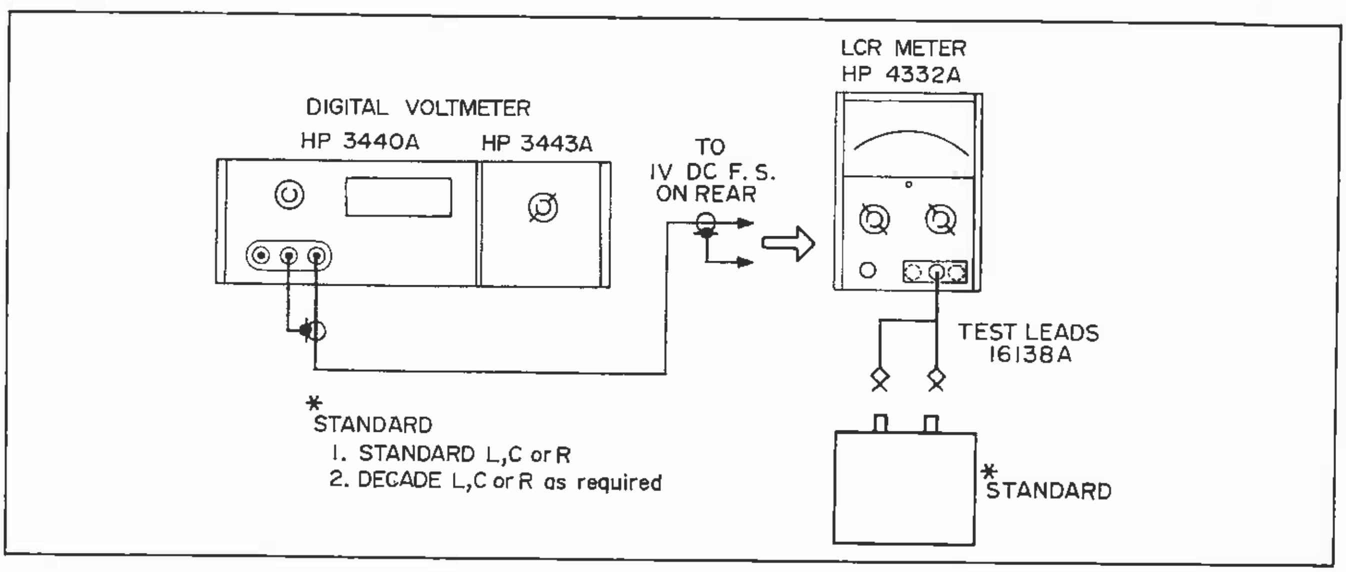


Figure 5-1. General Test Setup for Performance Checks

Table 5-2. Resistance Tolerances

4332A Range	Resistance Decade	4332A Meter Reading		DVM Reading	
		Lower	Upper	Lower	Upper
3Ω	2.70Ω*	2.61Ω	2.79Ω	873.5mV	926.5mV
10 "	9.00	8.75	9.25	880.5	919.5
30 "	27.00	26.4	27.6	882.5	917.5
100 "	90.00	87.8	92.2	884.2	916.8
300 "	270.00	264	276	884.4	916.6
1000 "	900.00	~~978~~ 878	922	884.5	916.5
3kΩ	2700	2.64kΩ	2.76kΩ	884.5	916.5
10 "	9000	8.78	9.22	884.5	916.5
30 "	27000	26.4	27.6	884.5	916.5
100 "	90000	87.3	92.7	879.0	921.0
300 "	270000	262	278	879.0	921.0
1000 "	900000 **	873	927	879.0	921.0

* Zero Resistance should be less than 5mΩ.
** Stray Capacitance should be less than 1pF.

d. Observe the 4332A meter indication and the analog reading on the digital voltmeter. Both should be within the tolerances listed in Table 5-2.

e. Repeat steps b. through d. for each range.

f. Readings should be within tolerances listed in Table 5-2.

5-11. Tracking Check

a. Connect equipment as shown in Figure 5-1. Set FUNCTION to R and RANGE to 3kΩ.

b. Connect 1kΩ standard resistor to UNKNOWN terminals. The indication on the DVM should be 333.3 ±13.6mV.

c. Disconnect 1kΩ resistor and connect 2kΩ standard resistor. The indication on the DVM should be 666.6mV ±15.3mV.

5-12. INDUCTANCE MEASUREMENT

Analog output accuracy: ± 1.0% of reading + (1.0 +3/Q)% of full scale +0.03μH (at 25°C)

a. Connect equipment as shown in Figure 5-1.

b. Set FUNCTION to L and RANGE to 3μH.

c. Connect 3μH standard inductor to UNKNOWN.

d. Observe the digital voltmeter reading which should be within tolerance listed in Table 5-3.

e. Repeat steps b. through d. for each range.

5-13. Tracking Check

a. Connect equipment as shown in Figure 5-1.

Table 5-3. Inductance Tolerances

4332A Range	Standard Inductor	DVM Reading	
		Lower	Upper
3μH	3μH	970.0mV	1030.0mV
10 "	10 "	977.0	1023.0
30 "	30 "	979.0	1021.0
100 "	100 "	979.7	1020.3
300 "	300 "	979.9	1020.1
1000 "	1000 "	980.0	1020.0
3mH	3mH	980.0	1020.0
10 "	10 "	980.0	1020.0
30 "	30 "	980.0	1020.0
100 "	100 "	980.0	1020.0
300 "	300 "	980.0	1020.0
1000 "	1000 "	980.0	1020.0

b. Set FUNCTION to L and RANGE to 3mH.

c. Connect 1000μH standard inductor to UNKNOWN.

d. The indication on the DVM should be 333.3mV ±8.3mV.

5-14. CAPACITANCE MEASUREMENT

Analog output accuracy: ± 1.0% of reading + (1.0 +3/Q)% of full scale +0.03pF.

a. Connect equipment as shown in Figure 5-1.*

b. Set FUNCTION to C and RANGE to 3pF.

c. Set the decade capacitor to 3.00pF.

d. Digital voltmeter readings should be within tolerance listed in Table 5-4.

e. Repeat steps b. through d. for each range.

* Connect one end of an additional lead at the 4332A GUARD terminal and the other end at the GUARD terminal of the standard capacitor.

5-15. Tracking Check

a. Connect equipment as shown in Figure 5-1.

b. Set FUNCTION to C and RANGE to 3nF.

c. Connect 1000μF standard capacitor to UNKNOWN.

d. The indication on the DVM should be 333.3mV ±8.3mV.

5-16. FREQUENCY CHECK

Accuracy: 100kHz ±5%
1kHz ±5%

a. Connect equipment as shown in Figure 5-2.

Table 5-4. Capacitance Tolerance

4332A Range	Standard Capacitor	DVM Reading	
		Lower	Upper
3pF	3pF	970.0mV	1030.0mV
10 "	10	977.0	1023.0
30 "	30	979.0	1021.0
100 "	100	979.7	1020.3
300 "	300	979.9	1020.1
1000 "	1000	980.0	1020.0
3nF	3nF	980.0	1020.0
10 "	10	980.0	1020.0
30 "	30	980.0	1020.0
100 "	100	980.0	1020.0
300 "	300	980.0	1020.0
1000 "	1000	980.0	1020.0

b. Set FUNCTION to C and RANGE to 1000pF.

c. The frequency should be 100kHz ±5kHz.

d. Set FUNCTION to R and RANGE to 3kΩ.

e. The frequency should be 1kHz ±50Hz.

5-17. ADJUSTMENT AND CALIBRATION PROCEDURES

5-18. The following is a complete adjustment procedure for the 4332A. This procedure should be conducted only if the 4332A does not meet performance checks. If proper performance can not be obtained by adjustment procedures, refer to troubleshooting procedures, paragraphs 5-28 through 5-34.

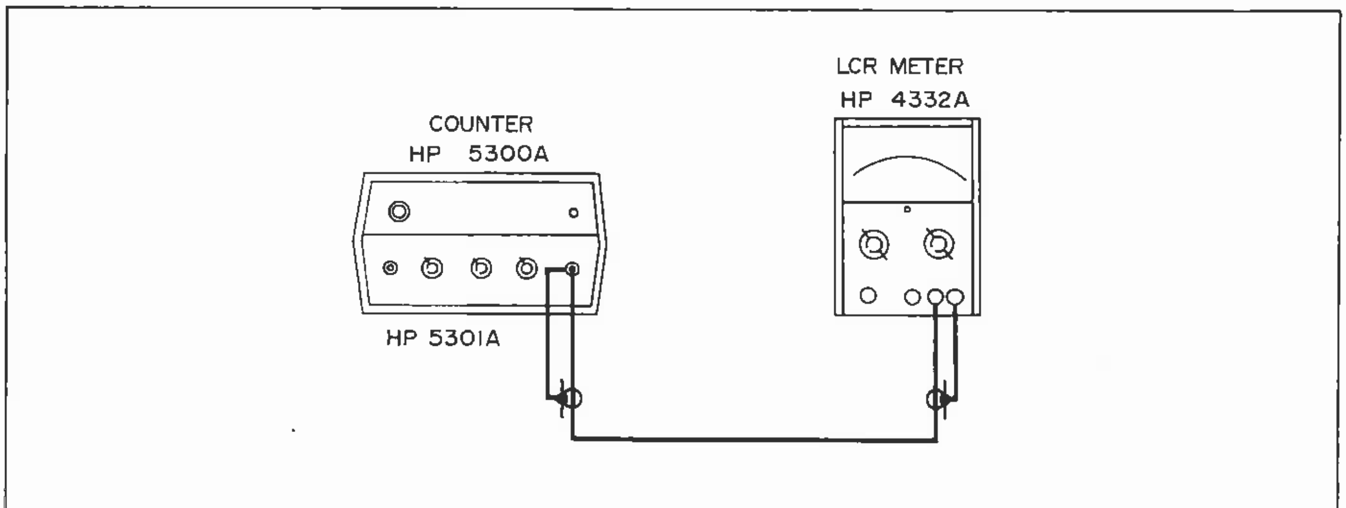


Figure 5-2. Frequency Measurement

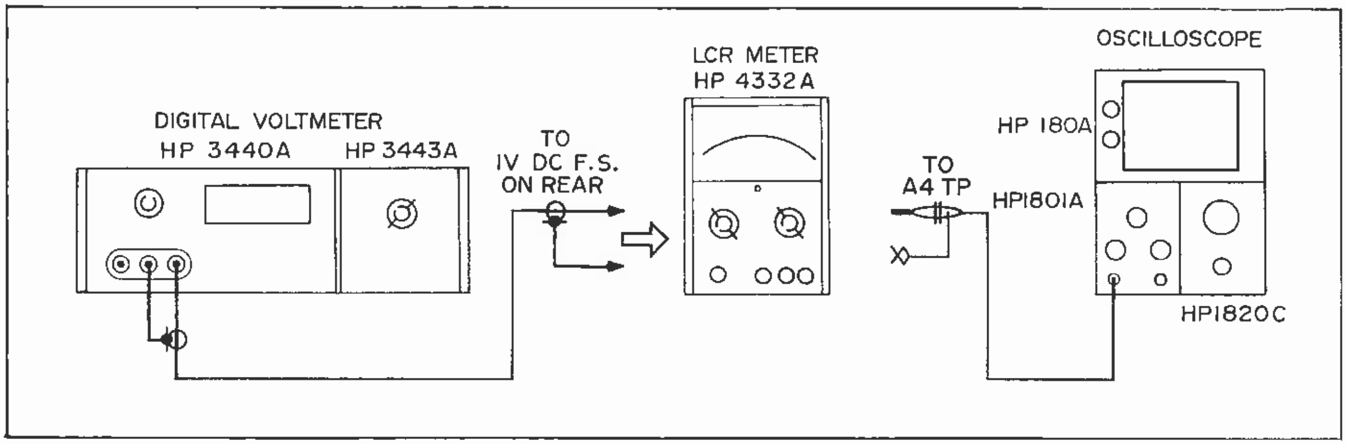


Figure 5-3. Meter Zero Adjustment

5-19. POWER SUPPLY

Measure the voltage with DVM and check ripple with oscilloscope at TP (+12V), TP (-15V) and TP (-6V).

Table 5-5. Power Supply Tolerances

Test Point	Voltage	Ripple
+ 12V	+ 12V ± 0.3V	30mV p-p
- 15V	- 15V ± 0.5V	30mV p-p
- 6V	- 6V ± 0.3V	30mV p-p

5-20. METER ZERO ADJUSTMENT

5-21. This adjustment procedure sets the electronic zero adjustment circuitry for R, L and C functions.

a. Connect equipment as shown in Figure 5-3.

b. Set FUNCTION to R and RANGE to 1000Ω and short UNKNOWN terminals. Adjust ZERO (A2R60) for a DVM reading of 000.0mV ±1.0mV.

c. Remove short from UNKNOWN terminals. Set FUNCTION to C and RANGE to 1000pF. Adjust CMR (A4R26) for minimum output at A4TP. Adjust 100kø (A4R19) for a DVM reading of 000.0mV ±2.0mV.

d. Set RANGE to 30pF. Adjust C ZEROø (A2R25) for a minimum output at A4TP. Adjust L, C. ZERO on front panel for a DVM reading of 000.0mV ±2.0mV.

e. Connect a 2200pF capacitor (hp part No. 0160-1543) between GUARD and HIGH. Adjust GRDø (A4R32) for a minimum output at A4TP. The indication should be less than 50mV p-p. Adjust GRD Amplifier (A4R34) for a minimum DVM reading.

f. Repeat steps d. and e. until the difference of the DVM reading between steps d. and e. is less than 20mV.

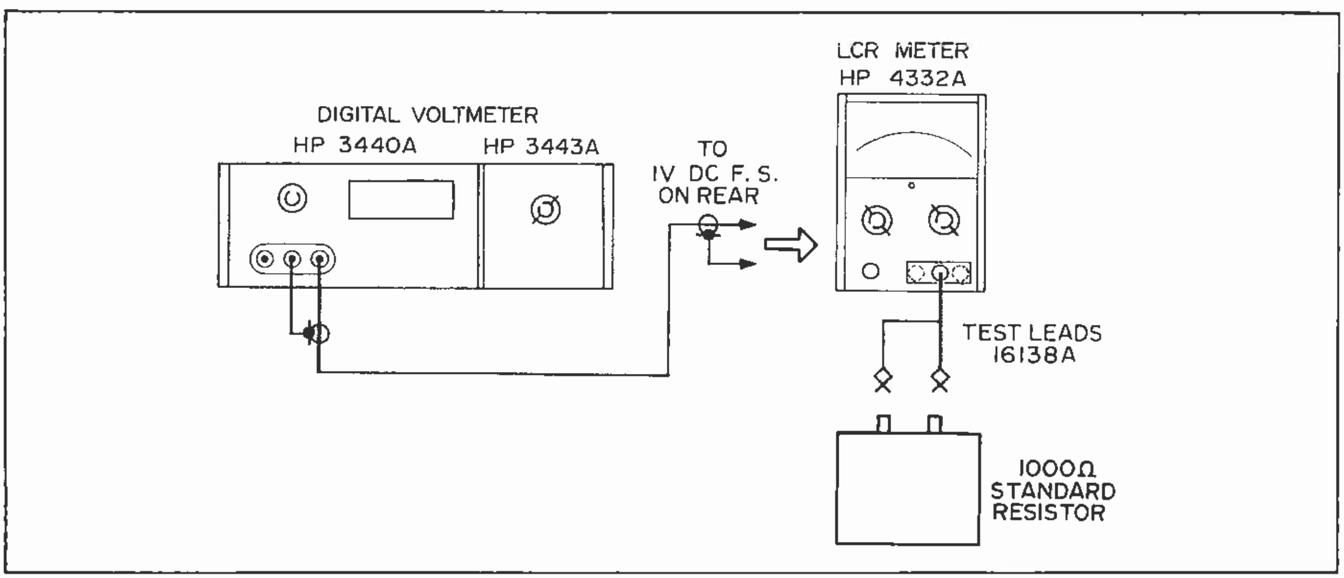


Figure 5-4. Resistance Measurement Adjustment

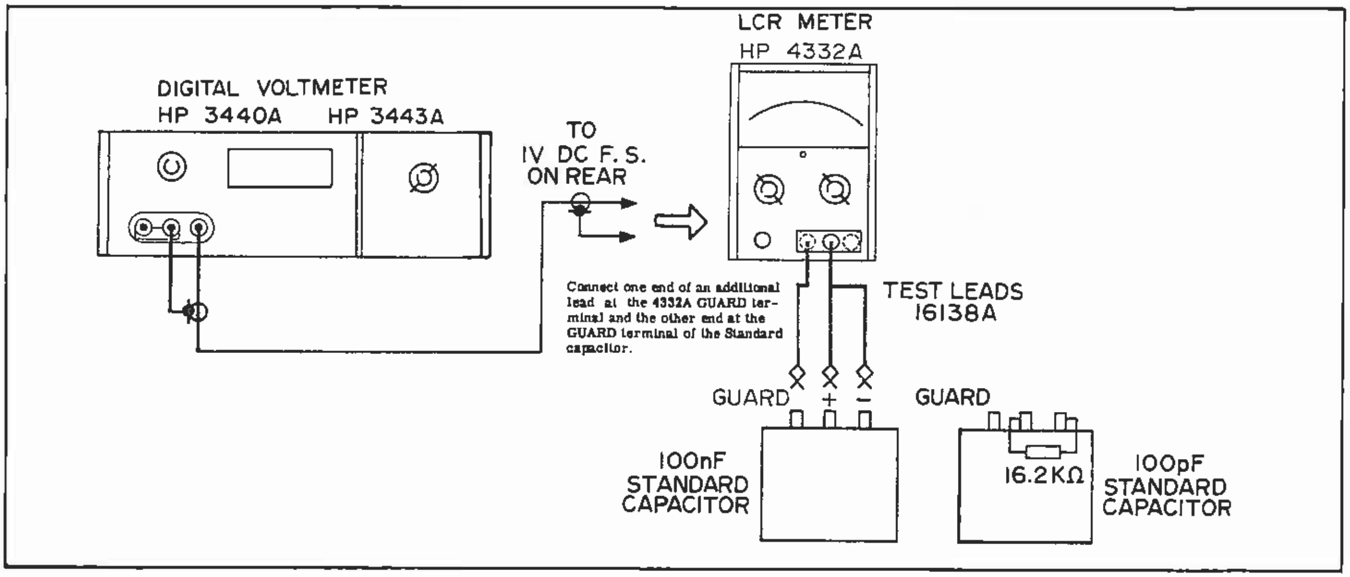


Figure 5-5. Capacitance Measurement Adjustment

g. Disconnect the 2200 pF capacitor from GUARD and HIGH. Set RANGE to 1000nF. Adjust 1kø (A4R17) for a DVM reading of 000.0mV ±1.0mV.

h. Set RANGE to 3nF. Adjust 3nF (A2R37) for a DVM reading of 000.0mV ±2.0mV.

5-22. RESISTANCE CALIBRATION

5-23. This adjustment sets this calibration of the resistance measurement function of the 4332A.

a. Connect equipment as shown in Figure 5-4.

b. Set FUNCTION to R and RANGE to 1000Ω. Connect a 1000Ω standard resistor to UNKNOWN terminals. Adjust RFS (A1R20) for a DVM reading of 1000.0mV ±2.0mV. Adjust MTR FS (A2R67) for a 4332A meter reading of 1000Ω.

5-24. CAPACITANCE CALIBRATION

5-25. This adjustment sets calibration of the capacitance measurement funcion of the 4332A.

a. Connect equipment as shown in Figure 5-5.

b. Set FUNCTION to C and RANGE to 100nF. Connect a 100nF standard capacitor to UNKNOWN terminals. Adjust 1kø (A1C1) for a DVM reading of 1000.0mV ±2.0mV. Disconnect 100nF capacitor.

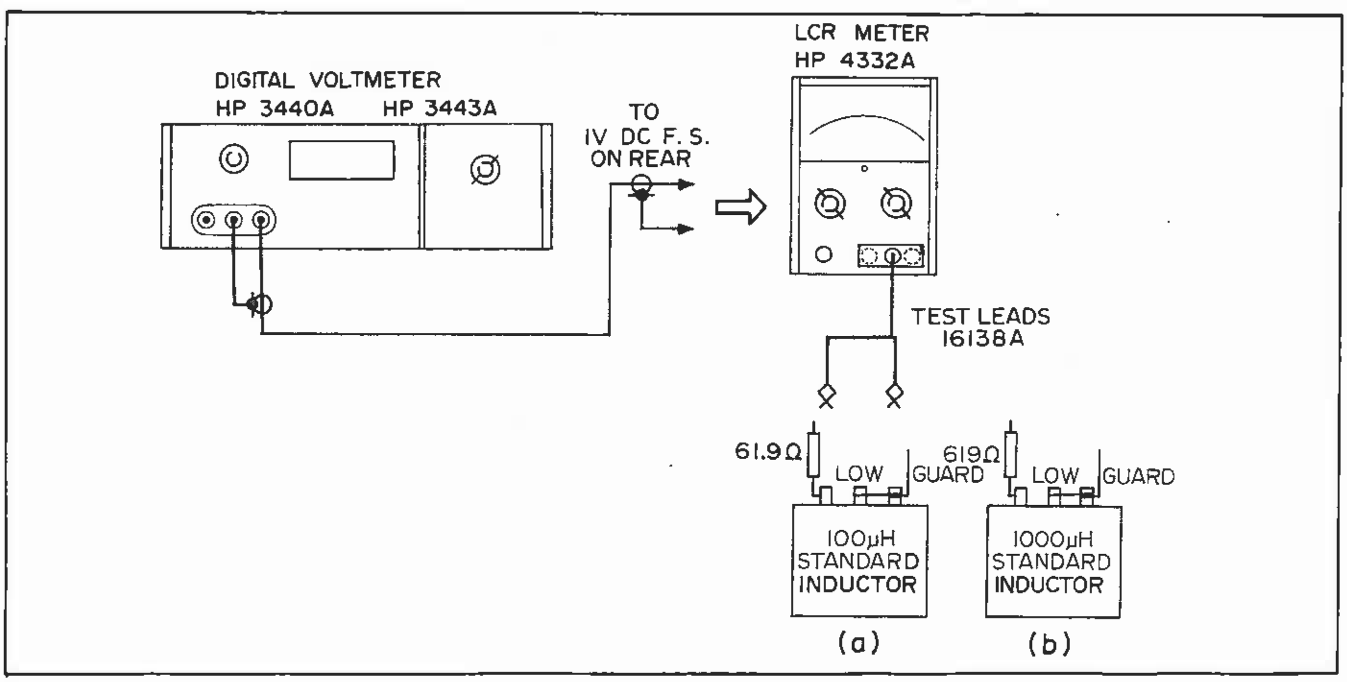


Figure 5-6. Inductance Measurement Adjustment

c. Set RANGE to 100pF. Connect a 100pF standard capacitor to UNKNOWN. Adjust 100kø (A1C9) for a DVM reading of 1000.0mV ±2.0mV.

d. Connect a 16.2kΩ resistor (hp part No. 0757-0447) in parallel with 100pF standard capacitor at UNKNOWN. Adjust Cø (A2R2) for a DVM reading of 1000.0mV ±2.0mV.

5-26. INDUCTANCE CALIBRATION

5-27. This adjustment sets calibration for the inductance measurement function of the 4332A.

a. Connect equipment as shown in Figure 5-6.

b. Set FUNCTION to L and RANGE to 100μH. Short test leads together. Adjust L. C. ZERO for a DVM reading of 000.0mV ±1.0mV.

c. Connect a 100μH standard inductor and a 61.9Ω resistor (hp part No. 0757-0276) in series to UNKNOWN as shown in Figure 5-6 (a). Adjust Lø (A2R1) for a DVM reading of 1000.0mV ±2.0 mV. Disconnect inductor and resistors from UNKNOWN.

d. Set RANGE to 1000μH. Connect a 1000μH. standard inductor and a 619.0Ω resistor (0757-0418) in series to UNKNOWN as shown in Figure 5-6 (b). Adjust C2 for a DVM reading of 1000.0mV ±2.0mV.

5-28. TROUBLESHOOTING

5-29. Troubleshooting information on the Model 4332A LCR meter is contained in this section. Troubleshooting should be undertaken only after it has been established that the difficulty cannot be eliminated by the Adjustment and Calibration Procedures, Paragraphs 5-17 through 5-27. An investigation should also be made to insure that the trouble is not a result of conditions external to the Model 4332A. A visual check of the Model 4332A should be made for possible burned or loose components, loose connections, or any other condition which might suggest a source of trouble. Check to insure that all printed circuit boards are properly inserted in the instrument.

5-30. Location of Troubles

5-31. An UNKNOWN open or short check can be useful in isolating the trouble to a specific stages. Refer to Tables 5-6 and 5-7. Table 5-6 shows the 4332A meter indication when the UNKNOWN terminals are open or shorted. If the meter indication is as shown in Table 5-6, then the indicated stage may be defective. Table 5-7 shows trouble symptoms and possible problem areas. These procedures cover failures which are peculiar to separate L, C, and R functions. The troubleshooting tree Table 5-8 covers failures common to all three functions.

Table 5-6. Front Panel Troubleshooting Procedures (1)

UNKNOWN / FUNCTION	Open	Short	Open	Short	Open	Short	Open	Short
L	Overscale	Zero	Negative Deflection or on scale	Zero	Overscale	No Zero Adjust on 3pF range	Overscale	Zero
C	Zero	Overscale	Zero	Negative Deflection or on scale	Zero	Overscale	No Zero Adjust on 3pF range	Overscale
R	Overscale	Zero	Negative Deflection or on scale	Zero	Overscale	Zero	Overscale	Zero
Condition	Normal		Overscale Amplifier may be defective. Refer to Figure 5-8 (A)		L zero Amplifier may be defective		C zero Amplifier may be defective	
Note: Measurements should be taken with RANGE switch at mid-range.								