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ILLUSTRATIONS

SPECIFICATIONS

RANGE ohms	Applied Current, milliamperes rms	Voltage Drop, microvolts rms	Maximum Dissipation in Sample, microwatts
0.001	14	14	0.2
0.003	14	42	0.6
0.01	14	144	2.00
0.03	4.7	144	0.66
0.1	1.4	144	0.2
0.3	.47	144	0.066
1.0	0.14	144	0.02
3.0	0.28	850	0.24
10	0.085	850	0.072
30	0.028	850	0.024
100	0.0085	850	0.0072
300	0.0028	850	0.0024
1000	0.00085	850	0.00072

RISE TIME (10% to 90%): 1 second on all ranges.

ACCURACY:
Normal Mode: ±3% of full scale on 1000-ohm to 0.003-ohm ranges; ±5% of full scale on 0.001-ohm range.
Note: Less than 2% error is added in measuring samples with a series reactance of 4% of sample resistance.
Voltage Limited Mode: Degraded from Normal mode by 2-10%; after an on-scale reading is obtained, the unit may be safely switched to the Normal mode for a more accurate reading.

SAFETY:
Normal Mode: Maximum voltage across sample, 1.4 volts. Maximum power dissipation due to improper range setting, 3 milliwatts. Maximum power dissipation due to component failure and improper range setting, 6 milliwatts.
Voltage Limited Mode: Maximum voltage applied across sample, 25 millivolts peak to peak. Maximum power dissipation due to improper range setting, 65 microwatts.

ZERO DRIFT: None.

WARM-UP TIME: 30 seconds.

INPUT ZERO: Lever switch prevents off-scale meter indications while changing samples.

REPEATABILITY: Within 2%.

CONNECTORS: Test Leads: Amphenol 80-PC2F

POWER: Battery Complement: Four E146 (8.4V); two RM401R (1.34 V), two RM42R (1.34V); 360 hours minimum life.

DIMENSIONS; WEIGHT: 10 in. high x 6¾ in. wide x 6¾ in. deep (255 x 170 x 170 mm); net weight, 9 pounds (3,9 kg).

ACCESSORIES SUPPLIED: Model 5022 Current and Voltage Leads; one set alligator clips; one set Miniprod adapters; mating connectors.

SECTION 1. GENERAL DESCRIPTION

1-1. GENERAL.

a. The Keithley Model 502A is a battery-operated milliohmmeter with 13 ranges from 0.001 ohm full scale to 1000 ohms. Minimum detectable resistance is 30 micro-ohms. Accuracy is ±3% of full scale on all ranges except the 0.001-ohm range, where it is ±5% of full scale.

b. The Milliohmmeter uses a 4-terminal ammeter-voltmeter technique to eliminate errors due to lead and contact resistance. A 94-cps square wave current is applied through one pair of terminals. The resulting voltage drop across the sample is measured through the other pair. A relatively high-impedance rectifier-type voltmeter measures the voltage.

c. Using a square wave test current eliminates zero drift and minimizes errors caused by thermal emf's. Also, the Model 502A can measure across a sample upon which a biasing dc current is superimposed without affecting the accuracy of the reading.

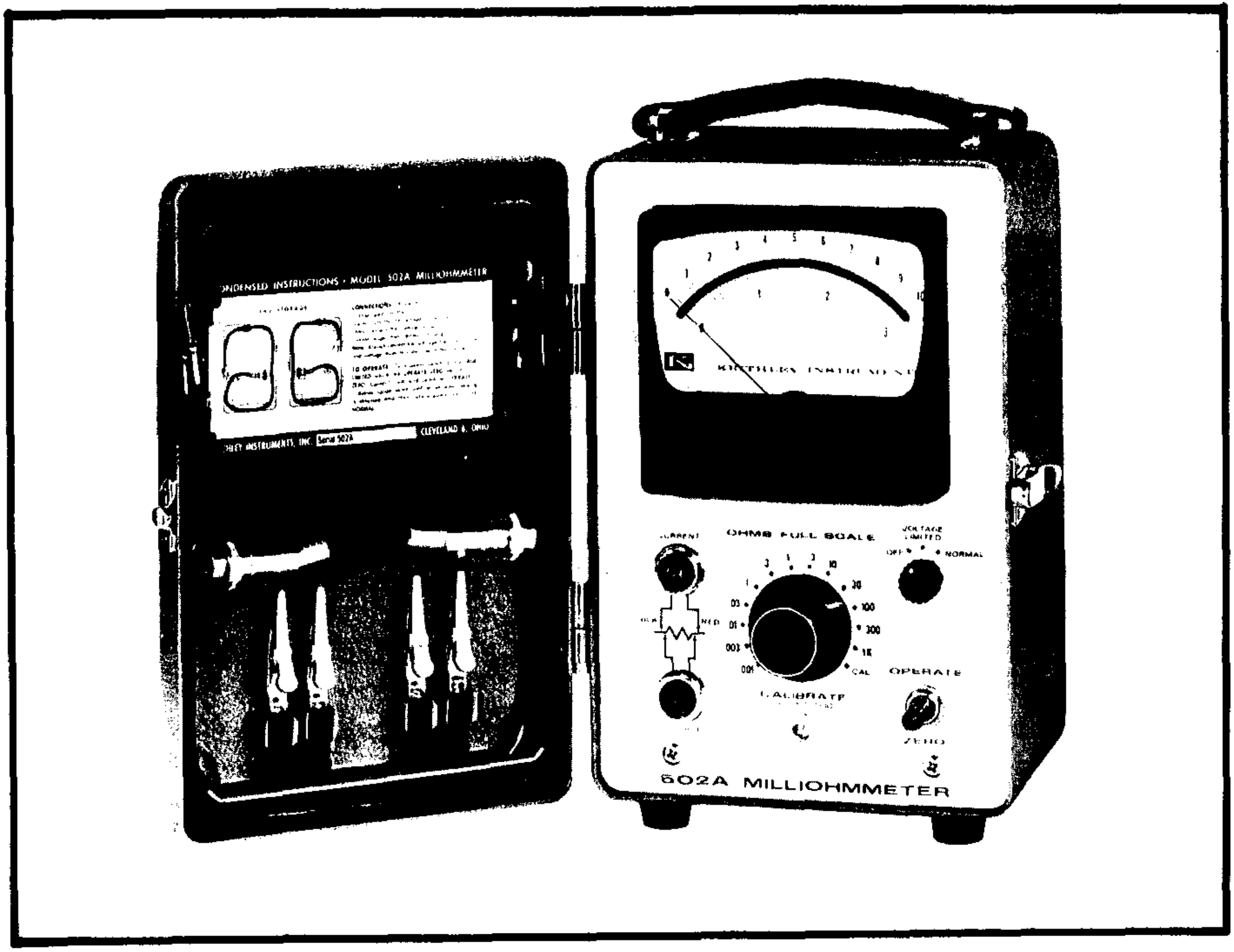


FIGURE 1. Keithley Instruments Model 502A Milliohmmeter. Furnished accessories are shown inside the carrying case.

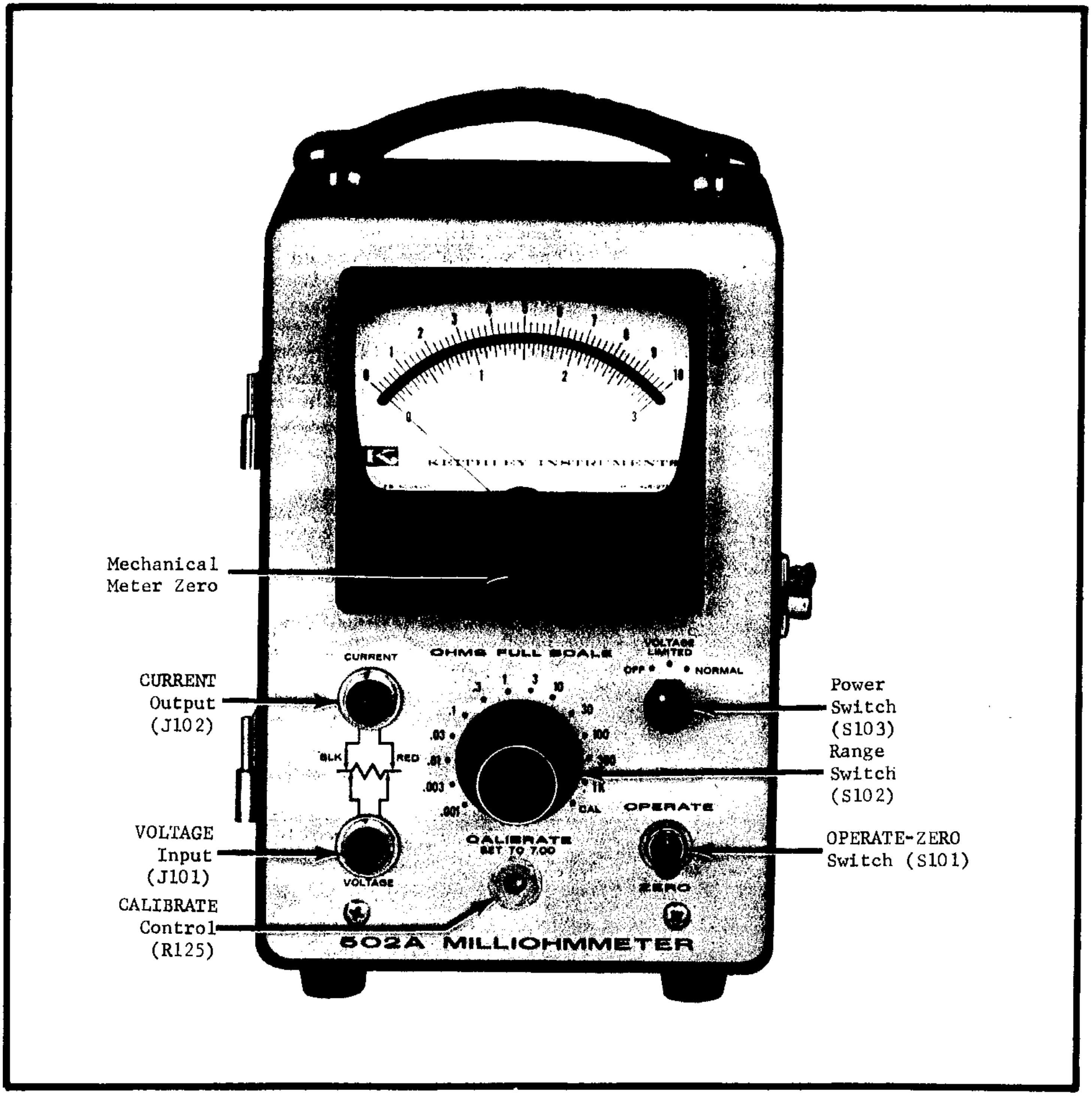


FIGURE 2. Model 502A Front Panel Controls and Terminals. Circuit designations refer to Replaceable Parts List and schematic diagram.

SECTION 2. OPERATION

2-1. FRONT PANEL CONTROLS AND TERMINALS (See Figure 2.)

a. Power Switch. The Power Switch has three positions: in OFF, the Model 502A power supply is disconnected. In VOLTAGE LIMITED, the maximum open-circuit voltage across the sample never exceeds 25 millivolts. This mode is used to initially determine the magnitude of the resistance. In NORMAL position, the Model 502A operates as an accurate milliohmmeter.

b. OPERATE-ZERO Switch. The OPERATE-ZERO Switch is a 2-position toggle switch. When the Switch is in the OPERATE position, the Milliohmmeter operates to measure resistances. Putting the Switch in ZERO position shorts the voltage input and allows connecting a sample to the input receptacles without overloading the instrument.

c. Range Switch. The Range Switch has 13 overlapping range positions from .001 ohm full scale to 1000 ohms. A CAL position is used to check the instrument for a meter deflection of 7.

d. CALIBRATE Control. The CALIBRATE Control is a potentiometer immediately beneath the Range Switch. It adjusts the meter deflection to 7 when the Range Switch is set to CAL.

e. CURRENT and VOLTAGE Receptacles. Two microphone-type receptacles are used for the Model 5022 Test Leads. Either lead may be used in either receptacle. A diagram shows the lead hookups for measuring a sample.

2-2. INPUT CONNECTIONS.

a. Measuring samples less than 3 ohms.

1. Connect the Model 5022 Test Leads to the VOLTAGE and CURRENT Receptacles. Connect same color alligator clips to the same side of the resistance sample.

2. Connect the voltage leads across that part of the sample which will be measured. The Model 502A measures the resistance only between the two points to which the voltage leads are connected. Connect the current leads to the sample outside the voltage leads. Make sure current flows through the entire portion of the sample to be measured.

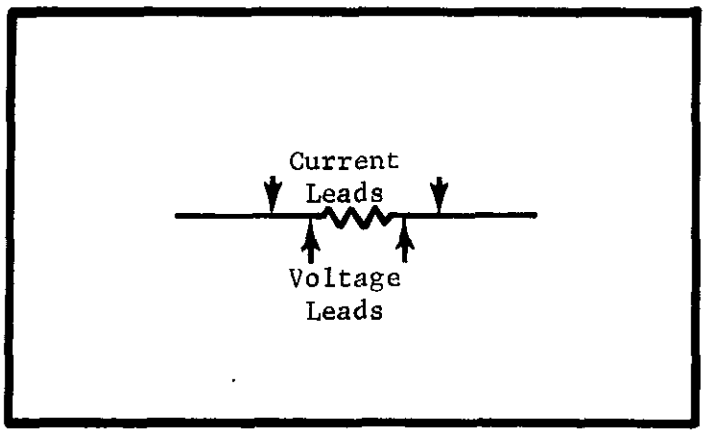


FIGURE 3. Model 502A Four-Terminal Input Connections. Make sure current leads are outside voltage leads and like color clips are on each end of the sample.

NOTE

Do not connect the voltage leads to the current leads when measuring resistances less than 3 ohms. In this connection, the clip resistance and the clip-to-sample contact resistance are significant enough to increase the reading.

b. Measuring samples 3 ohms and more: The clip-contact resistance is not significant when using the 3-ohm and greater ranges. Connect the voltage leads to the current leads. Then connect the current leads to the sample. The four-terminal methods, given above, may be used for these ranges, but the two-terminal method is faster for repeated testing.

2-3. OPERATING PROCEDURES.

a. Use the voltage limited operating mode, which greatly limits the applied voltage, to determine the magnitude of the resistance. Then switch to the normal mode for more accurate measurements without changing the applied voltage or power dissipation.

b. Turn the Power Switch to the VOLTAGE LIMITED position. Set the OPERATE-ZERO Switch to ZERO. Wait 30 seconds for the Milliohmmeter to warm up.

c. Connect the leads to the sample as described in paragraph 2-2.

d. Set the OPERATE-ZERO Switch to ZERO when connecting the leads to the sample. When the switch is at ZERO, the voltage input is shorted, and the Milliohmmeter can not be overloaded. An accidental overload will not damage the Model 502A. However, it will take approximately 30 seconds for the amplifier to recover. Set the OPERATE-ZERO Switch to OPERATE. Start at the highest ranges of the Range Switch and turn to the most sensitive range for an on-scale reading. Turn the Power Switch to NORMAL. Take the readings directly from the meter.

e. The Model 502A has a convenient calibration check. Set the Range Switch to CAL and the OPERATE-ZERO Switch to OPERATE. The Milliohmmeter should read within one minor division of 7. If necessary, adjust the CALIBRATE Control on the front panel to a meter deflection of 7. If the control will not make the adjustment, check the batteries within the instrument.

NOTE

Before storing the Milliohmmeter for a long time, remove all batteries.

2-4. ZERO OFFSET.

a. The Model 502A has a zero offset. The zero offset is characteristic of any ac voltmeter that uses rectifying diodes to detect the signal. If there is a zero applied signal and noise or another unwanted signal is present, the diodes will rectify the unwanted signal and the meter will see a net ac signal. This is the zero offset.

b. The zero offset will not be added to the signal being measured. If there is more than one signal present, the Model 502A will read the larger of the two signals. The smaller signal will be averaged out. That is, if a signal is applied whose peak value is larger than the peak value of the unwanted signal, the diodes will rectify this signal and the unwanted component will ride on top of the applied signal and be averaged out. Therefore, the Model 502A will read within specifications if the value of the signal being measured is greater than the zero offset being observed.

2-5. 60-CPS INTERFERENCE.

a. On the 1-ohm and lower ranges, the Model 502A is sensitive in the microvolt region and its pass band includes 60 cps. A voltage lead loop which encloses a 60-cps magnetic field may cause a meter deflection. Avoid such loops. Also be careful to avoid electrostatic pick-up, although it is not serious at the impedances involved.

Range, ohms	Maximum Series Inductance, millihenries	Maximum Shunt Capacitance, microfarads
0.001	.00006	over 1000
0.003	.0002	over 1000
0.01	.0006	over 1000
0.03	.002	over 1000
0.01	.006	700
0.3	.02	225
1.0	.06	70
3.0	.2	22.5
10	.6	7
30	2	2.25
100	6	.7
300	20	.225
1000	60	.07

TABLE 1. Maximum Capacitance and Inductance Allowed by Range. Capacitances and inductances in the sample or input circuit below the listed amount will not degrade the Model 502A.

b. To test for pick-up, remove the current leads when the voltage leads are connected to the sample. If no reading appears, there is no pick-up. If a reading appears, reduce pick-up by rotating the instrument for minimum deflection. Even if pick-up is present, however, the Milliohmmeter will still read within specifications above any residual reading. For example, if the Model 502A reads 0.002 ohm due to stray fields with the voltage leads shorted, a 0.003-ohm resistance being tested will still read 0.003 ohm. This is because the dc level of the rectified signal will be greater than the peak-to-peak value of the 60-cps signal. In this case, the 60-cps signal will be superimposed on the test signal and it will not be rectified.

2-6. INDUCTANCE AND CAPACITANCE.

a. The Model 502A measures resistance using 94-cps current through the sample. Using the ac current means inductive and capacitive components in the sample or in the input circuit will cause some wave form distortion and erroneous readings. The error normally encountered in a measurement is small and within the Model 502A specifications. For instance, at 94-cps series inductive impedance less than 4% of the resistance of the sample causes the reading to be less than 2% high. Shunt capacitive admittance less than 4% of the conductance causes the reading to be less than 2% low. Table 1 lists maximum capacitance and inductance values to maintain specified accuracy.

2-7. SUPER-IMPOSED CURRENTS AND VOLTAGES.

a. The Model 502A measures the voltage across a sample through which a known current flows. The meter is calibrated to read the voltage in ohms. Additional currents through the sample may change the voltage reading and distort the resistance readings.

b. Because the Milliohmmeter uses an ac current in its testing, large amounts of dc current in a sample do not affect the reading. In the milliohm ranges, 50 amperes dc through a sample will not cause error. However, even 0.01-ampere ac current whose frequency is within the Model 502A pass band will cause serious errors.

c. If a voltage greater than 0.05 volt dc is across the sample, use blocking capacitors in series with the current and voltage leads. Refer to Figure 4. On the voltage leads use a 1000-microfarad capacitor which has a voltage rating sufficient to handle the dc sample voltage. Table 2 lists values for the capacitor on the current leads.

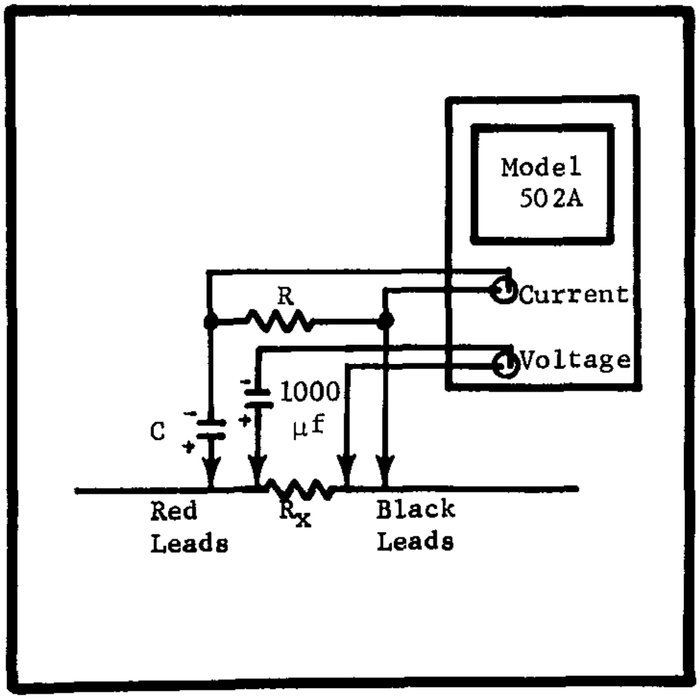


FIGURE 4. Circuit For Blocking Capacitors Across Sample. Use this circuit if more than 0.05 volt dc appears across the sample. Use resistor R to provide a dc return path for the output transistor, Q104. Refer to Table 2 for values of R and C.

Range, ohms	R, ohms	C Microfarads	Added Error
0.1	100	1000	-1%
0.03	47	1000	-3%
0.01	10	4000	-6%
0.003	10	4000	-6%
0.001	10	4000	-6%

TABLE 2. Component Values For DC Voltage Across Sample. The values are for the components in Figure 4. The added error is error caused by the additional voltage across the sample.

SECTION 3. CIRCUIT DESCRIPTION

3-1. GENERAL.

a. The Keithley Model 502A Milliohmmeter consists of a 94-cps constant current source combined with an ultra-sensitive ac vacuum tube voltmeter. Using ac techniques eliminates zero drift, and large negative feedback maintains factory calibration. Since both the current source impedance and the VTVM input impedance are high, connector and lead resistances are insignificant.

b. The current source consists of a pair of transistors connected as a multivibrator. An output transistor operates as a switch and places the full battery voltage in series with the resistor which determines the test current for each range.

c. The voltmeter consists of an input transformer with a 60:1 step-up ratio, a 5-stage subminiature tube amplifier, and an indicating meter in an overall feedback loop.

3-2. CURRENT SOURCE.

a. A multivibrator, made of transistors Q101 and Q102, generates the 94-cps square wave current. Potentiometer R159 adjusts the square wave symmetry. Transistors Q103 and Q104 are power amplifiers for the ac current. Transistor Q104 acts as a 94-cps switch, connecting and disconnecting battery BT107 across the sample and the series resistors, R134 and R145 through R154, selected with the Range Switch. Because the output peak voltage is more than 95% of the battery voltage, transistor parameter changes have little affect on the square wave amplitude.

b. Battery BT108 supplies a negative bias current through resistor R162 to the output transistor, Q104, to insure good cut-off characteristics at high ambient temperature.

c. When the Power Switch is in VOLTAGE LIMITED position, internal resistors R133 and R135 through R144 are shunted across the sample. The resistor values are chosen so that the maximum voltage drop due to current from the multivibrator is limited to 25 millivolts, even with an improper setting of the Range Switch.

3-3. AC VOLTMETER.

a. The input signal to the ac amplifier is matched to the vacuum tube input by an input transformer, T101, on the more sensitive ranges. Above the 1-ohm ranges, the transformer is not used.

b. The input voltage is compared to the feedback voltage through resistors R101 and R102 into the grid of tube V101. Tubes V101 through V105 amplify the signal. The output voltage is full-wave rectified by diodes D101 and D102 to supply indicating meter current. The current flows through resistors R130 to R132 to supply feedback voltage to the first stage.

c. Potentiometer R125 is used to calibrate the ranges which do not use transformer input; potentiometer R129 is used for calibrating the ranges which use the transformer input.

d. When the Range Switch, S102, is set on CAL, the Model 502A is placed on its 1000-ohm range. A 700-ohm, 1% resistor, R163, is connected into the test position and the external voltage and current leads are disconnected. The CALIBRATE potentiometer, R125, then can be used to adjust for a reading of 7 on the meter. Since the current drain is essentially the same on all ranges, a reading less than normal usually indicates faulty batteries.

SECTION 4. SERVICING

4-1. GENERAL. Section 4 contains the maintenance and troubleshooting procedures for the Model 502A Milliohmmeter. It is recommended that these procedures be followed as closely as possible to maintain the accuracy of the instrument.

4-2. SERVICING SCHEDULE.

a. The Model 502A requires no periodic maintenance beyond the normal care required of high-quality electronic equipment. No part should need replacement under ordinary use except batteries and, occasionally, tubes.

b. Recommended recalibration once a year; refer to Section 5.

4-3. PARTS REPLACEMENT. The Replaceable Parts List in Section 6 describes the electrical components of the Milliohmmeter. Replace components only as necessary. Use only reliable replacements which meet the specifications.

NOTE

Before replacing any vacuum tube, remove batteries BT101 and BT102. The plate supplies are always on and damage to other tubes can result by shorting tube leads together.

4-4. BATTERY REPLACEMENT.

a. To reach the batteries, remove the four screws at the rear of the Model 502A. Slide the instrument out of the case. All batteries are in holders at the top of the instrument.

b. Battery BT107, which supplies the current generator, and battery BT106, which supplies the vacuum tube filaments, should have a useful life of about 460 hours. If the Milliohmmeter is used continuously on the three most sensitive ranges, the life of BT107 may shorten to 360 hours.

c. Battery BT101, which supplies the plate potential to the output tube, V105, has about twice the life of batteries BT106 and BT107.

d. Batteries BT102 to BT104, the plate supply for the amplifier, the bias battery

Instrument	Use
Keithley Instruments Model 153 Microvolt-Ammeter, 100 megohm minimum input resistance, 5% accuracy	Check circuit voltages
Tektronix Type 504 Oscilloscope, 10 megohm minimum input resistance	Check wave forms

TABLE 3. Equipment Recommended for Model 502A Troubleshooting. Use these instruments or their equivalents.

BT105,and BT108, the negative bias for output transistor Q104, should last about two years.

NOTE

To insure good battery operation, it is a good practice to change all batteries whenever one is replaced. This makes sure all are in peak operating condition.

4-5. TROUBLESHOOTING.

a. The procedures which follow are for repairing troubles which might occur in the Model 502A. Use these procedures and use only specified replacement parts. Table 3 lists equipment recommended for troubleshooting. If the trouble cannot be readily located or repaired, Keithley Instruments, Inc., or its representative can service the instrument.

b. Find the difficulty through a circuit-by-circuit check, such as given in paragraph 4-6. Refer to the circuit desctiption in Section 3 to find the more critical components and to determine their function in the circuit. The Voltage Chart, 12256C, lists voltages for the tubes and transistors. The complete circuit schematic diagram, 18346E, is found at the back of the Manual.

4-6. PROCEDURES TO GUIDE TROUBLESHOOTING.

a. If the instrument will not operate, check the batteries. If they are all found satisfactory, continue to check.

b. Check the current wave form at the CURRENT Receptacle, J102. This should be a 94-cps square wave with about 1.3-volt amplitude (See Figure 14). Use the 3-ohm range to avoid oscilloscope loading. If the wave form is not correct, check the generator circuit stage-by-stage. Refer to the Voltage Chart, 12256C, to check the four transistors.

c. Check the voltage amplifier. Check operating potentials with those given in the Voltage Chart, 12256C. When operating points are all correct, check the amplifier stage by stage for amplification. Note that tube V105, used to supply meter current, has a voltage gain of only about one. The voltage required at the junction of capacitor C115 and diodes D101 and D102 for full-scale meter deflection is approximately 0.75 volt rms.

d. Figures 5 through 13 show the wave forms found at various points within a properly functioning Milliohmmeter. Check these points in the order in which they appear in the figures. Set the Model 502A Power Switch to NORMAL, the Range Switch to CAL, and the OPERATE-ZERO Switch to OPERATE.

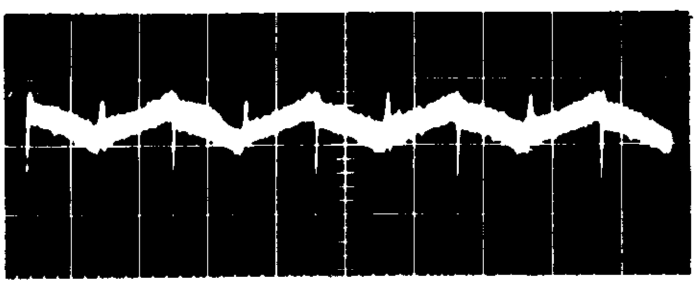


FIGURE 5. Correct Waveform at Grid of Tube V102 (Pin 4). Vertical sensitivity is 1 millivolt/cm; horizontal sweep is 5 milliseconds/cm.

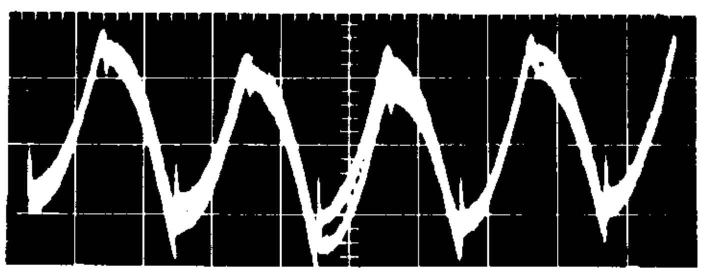


FIGURE 6. Correct Waveform at Plate of Tube V102 (Pin 1). Vertical sensitivity is 5 millivolts/cm; horizontal sweep is 5 milliseconds/cm.

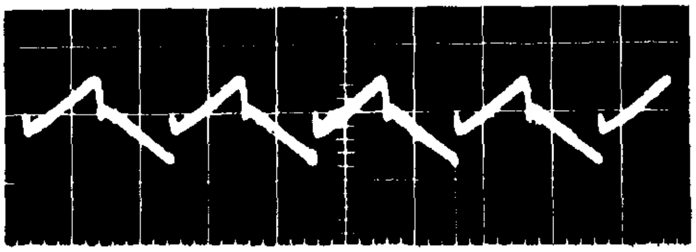


FIGURE 7. Correct Waveform at Grid of Tube V103 (Pin 4). Vertical sensitivity is 5 millivolts/cm; horizontal sweep is 5 milliseconds/cm.

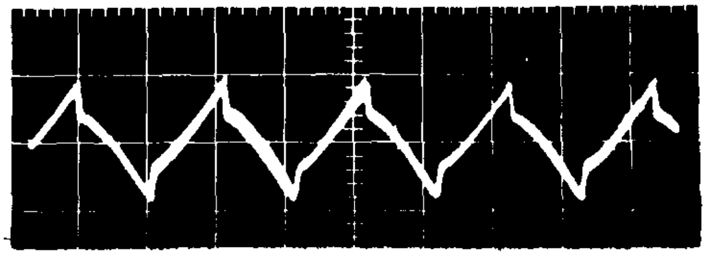


FIGURE 8. Correct Waveform at Plate of Tube V103 (Pin 1). Vertical sensitivity is 50 millivolts/cm; horizontal sweep is 5 milliseconds/cm.

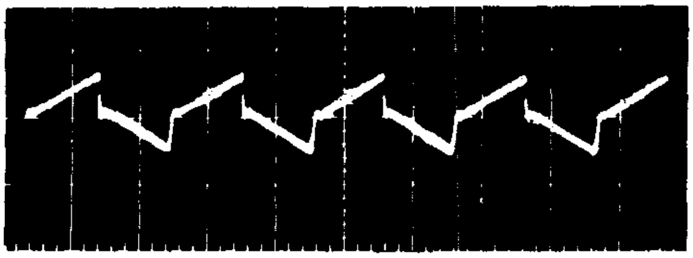


FIGURE 9. Correct Waveform at Grid of Tube V104 (Pin 4). Vertical sensitivity is 50 millivolts/cm; horizontal sweep is 5 milliseconds/cm.

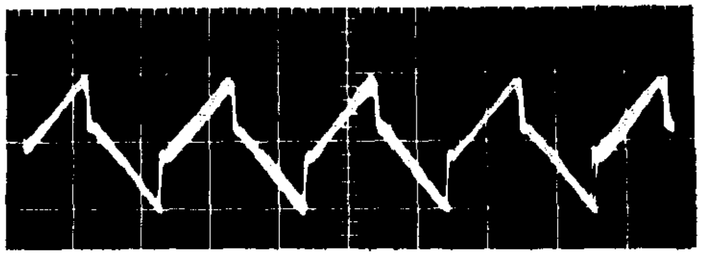


FIGURE 10. Correct Waveform at Plate of Tube V104 (Pin 1). Vertical sensitivity is 1 volt/cm; horizontal sweep is 5 milliseconds/cm.

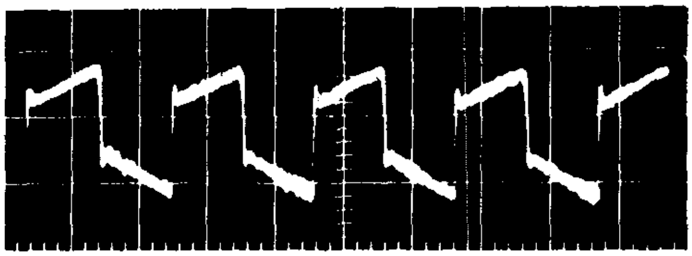


FIGURE 11. Correct Waveform at Grid of Tube V105 (Pin 4). Vertical sensitivity is 0.5 volt/cm; horizontal sweep is 5 milliseconds/cm.

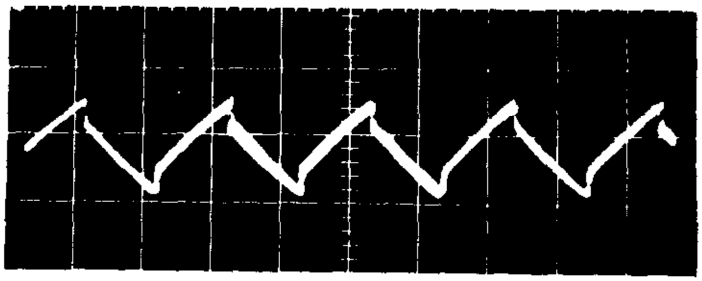


FIGURE 12. Correct Waveform at Plate of Tube V105 (Pin 1). Vertical sensitivity is 5 volts/cm; horizontal sweep is 5 milliseconds/cm.

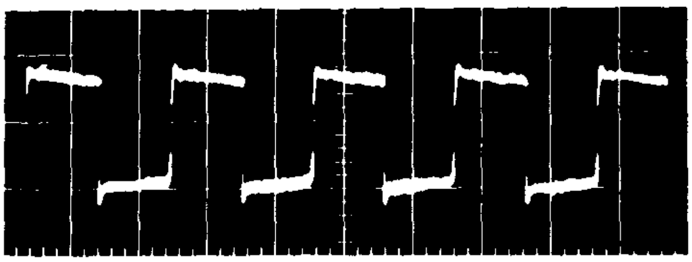


FIGURE 13 (left). Correct Waveform at Junctions of Diodes D101 and D102. Vertical sensitivity is 1 volt/cm; horizontal sweep is 5 milliseconds/cm.

SECTION 5. CALIBRATION

5-1. GENERAL.

a. The following procedures are recommended for calibrating and adjusting the Model 502A. Use the equipment recommended in Table 4. If proper facilities are not available or if difficulty is encountered, contact Keithley Instruments, Inc., or its representative to arrange for factory calibration.

b. Calibration is done in three steps: the ac test current is calibrated, and then the Model 502A is adjusted on its high and low resistance ranges.

c. If the Model 502A is not within specifications after the calibration, follow the troubleshooting procedures or contact Keithley Instruments, Inc., or its nearest representative.

5-2. CALIBRATION SCHEDULE. Calibrate the Model 502A every 12 months. This is necessary to compensate for any value changes in the circuit. Use the front panel calibration test, described in Section 2, as often as desired. If the test shows a discrepancy greater than one division on the meter scale, perform the complete calibration.

NOTE

Make the calibrations in the order of paragraphs 5-3 and 5-4.

5-3. CURRENT FREQUENCY AND SYMMETRY ADJUSTMENTS.

a. Set the Model 502A Range Switch to 3 ohms. Connect the Type 504 Oscilloscope to the Model 502A CURRENT Receptacle. Connect the Model 200CD Oscillator output to the horizontal input of the Oscilloscope. Set the Oscillator for a 94-cps output.

b. Set the Model 502A Power Switch to NORMAL and the OPERATE-ZERO Switch to OPERATE. Monitor the Milliohmmeter frequency and compare it to the Oscillator's. Frequency should be 94 cps ±1 cps. To increase the Model 502A frequency, decrease the resistance values of R158 and R160. To decrease the frequency, increase the resistance values of R158 and R160.

Instrument	Use
Hewlett-Packard Model 200CD Oscillator	Comparison for current frequency
Tektronix Type 504 Oscilloscope	Check Current Wave Form
Resistance standards, 0.001 to 30 ohms in 1x and 3x steps, absolute accuracy 0.1% Resistance standards, 100 to 1000 ohms in 100-ohm steps, absolute accuracy, 0.1%	Standard to check ranges

TABLE 4. Equipment Recommended for Model 502A Calibration. Use these instruments or their equivalents.

Control	Circuit Desig.	Fig. Ref.	Refer to Paragraph
Resistance Calibration	R125	15	5-4
Low resistance calibration	R129	15	5-4
Current symmetry adjustment	R159	15	5-3

TABLE 5. Model 502A Calibration Controls. The Table lists internal and front panel controls used to calibrate the Model 502A, the figure picturing the location and the paragraph describing the adjustment.

c. Check the square wave symmetry on the Oscilloscope. The wave should be approximately 1.3 volts peak-to-peak. Adjust potentiometer R159, if necessary, so the wave form resembles that shown in Figure 14.

NOTE

Use the 3-ohm range to check wave form symmetry. Using higher ranges will tend to lower the wave amplitude due to the series resistance of the range resistor and the Oscilloscope input impedance.

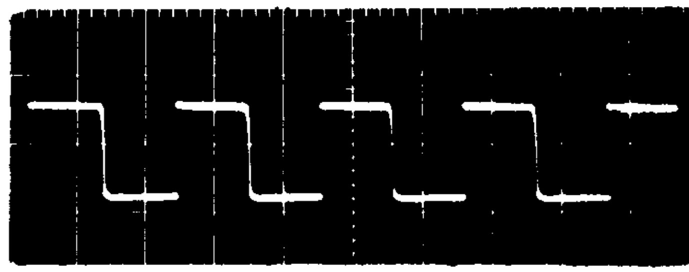


FIGURE 14. Symmetrical Square Wave with Potentiometer R159 Adjusted. Vertical sensitivity is 1 volt/cm; horizontal sweep is 5 milliseconds/cm.

5-4. RANGE CALIBRATION.

a. Set the Model 502A controls as follows:

Power Switch	NORMAL
OPERATE-ZERO Switch	OPERATE
Range Switch	CAL

Let the Milliohmmeter warm up 30 seconds.

b. Adjust the front panel CALIBRATE Control, R125, to exactly 7 on the upper meter scale.

c. Check meter tracking for the high resistance ranges. Connect the Model 5022 Current and Voltage Leads to the Model 502A. Set the Range Switch to 1K. Use Resistance Standards 100 to 1000 ohms in 100-ohm steps to check meter tracking. The Model 502A should read the values within ±30 ohms.

d. Check the 1000 to 3-ohm ranges for full-scale readings. Accuracy should be ±3% of full scale.

e. Set the Model 502A Range Switch to 1 ohm. Connect the Model 5022 Leads to 1-ohm resistance standard. Make sure connection is properly made (paragraph 2-2). Model 502A should read full scale ±3%. Adjust LO OHM CAL potentiometer, R129, if necessary, for full-scale deflection

f. Check the 1 through .003-ohm ranges for full-scale readings. Accuracy should be

±3% of full scale. Check .001-ohm range for accuracy ±5% of full scale. If necessary, adjust potentiometer R129 to split the error on the low ranges.

g. Set the Power Switch to LIMITED. Recheck all the ranges for full-scale readings. Expect an additional error of from 2 to 10% in this operating mode. The amount of error varies with test cable resistance.

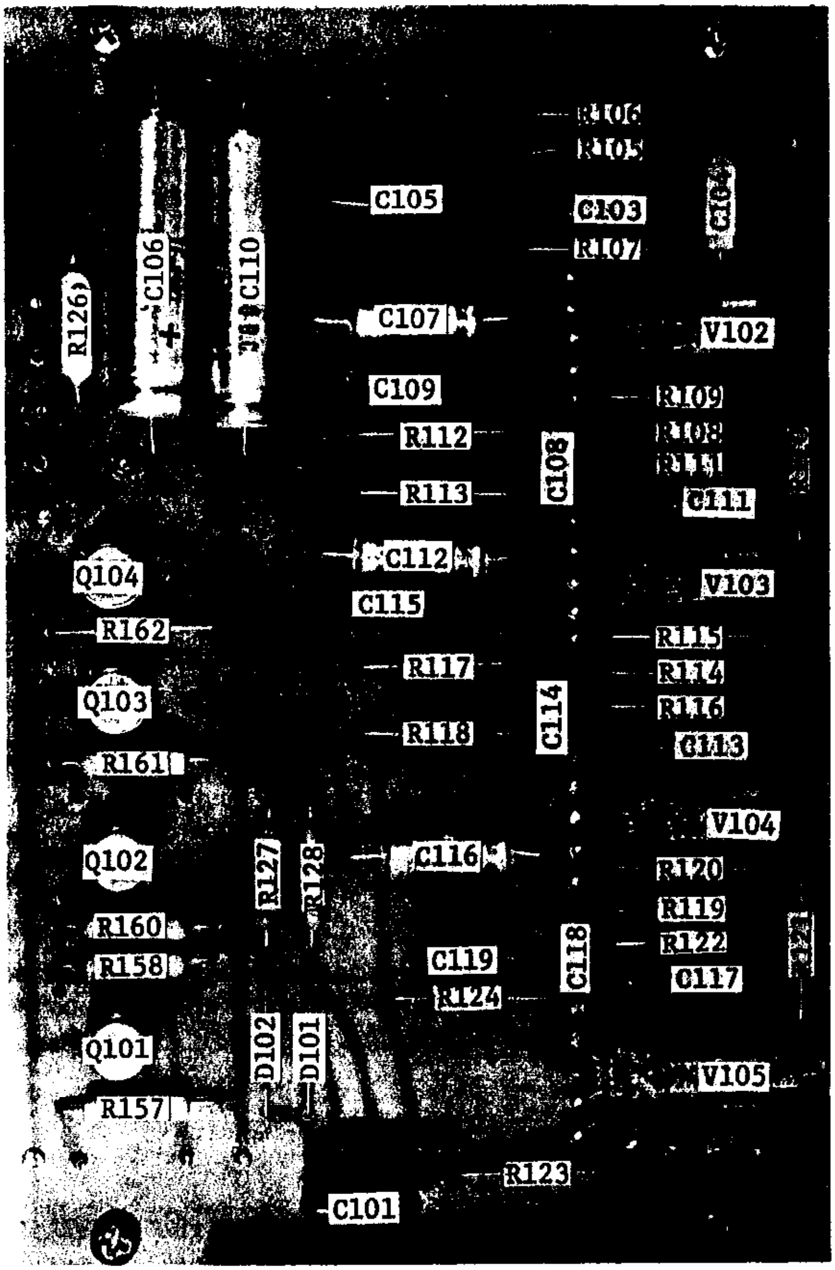


FIGURE 15. Component Layout, Printed Circuit Board.

SECTION 6. REPLACEABLE PARTS

6-1. REPLACEABLE PARTS LIST. The Replaceable Parts List describes the components of the Model 502A and its accessories. The List gives the circuit designation, the part description, a suggested manufacturer, the manufacturer's part number and the Keithley Part Number. The last column lists the figure picturing the part. The name and address of the manufacturers listed in the "Mfg. Code" column are contained in Table 7.

6-2. HOW TO ORDER PARTS.

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

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

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

TABLE 6. Abbreviations and Symbols.

MODEL 502A REPLACEABLE PARTS LIST

(Refer to Schematic Diagram 18346E for circuit designations.)

BATTERIES

Circuit Desig.	Description	Mfg. Code	Mfg. Part No.	Keithley Part No.		Fig. Ref.
BT101	8.4 v mercury	10608	E146	BA-9	BH-6	-
BT102	8.4 v mercury	10608	E146	BA-9	Battery	-
BT103	8.4 v mercury	10608	E146	BA-9	Holder	-
BT104	8.4 v mercury	10608	E146	BA-9		-
BT105	1.34 v mercury	10608	E401	BA-8		-
BT106	1.3 v mercury	37942	RM42R	BA-10		-
BT107	1.3 v mercury	37942	RM42R	BA-10		-
BT108	1.34 v mercury	10608	E401	BA-8		-
-	Battery Clip	-	-	14749A		-

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
C101	0.1 μf	50 v	My	84411	601PE	C41-.1M	15
C102	2.2 μf	50 v	ETB	05397	J2R2J50S	C149-2.2M	15
C103	.22 μf	50 v	My	84411	601PE	C41-.22M	15
C104	.0082 μf	100 v	My	84411	633UW-100	C38-.0082M	15
C105	.0022 μf	100 v	Poly	13934	E3FR-222-1-C	C152-.0022M	15
C106	50 μf	50 v	ETB	37942	TC39	C39-50M	15
C107	2.2 μf	50 v	ETB	05397	J2R2J50S	C149-2.2M	15
C108	270 pf	500 v	Mica	84171	DM15-271J	C21-270P	15
C109	.001 μf	100 v	Mica	84171	DM15-102J	C21-.001M	15
C110	50 μf	50 v	ETB	37942	TC39	C39-50M	15
C111	.22 μf	50 v	My	84411	601PE	C41-.22M	15
C112	2.2 μf	50 v	ETB	05397	J2R2J50S	C149-2.2M	15
C113	.22 μf	50 v	My	84411	601PE	C41-.22M	15
C114	820 pf	300 v	Mica	84171	DM15-821K	C21-820P	15
C115	100 pf	500 v	Mica	84171	DM15-101J	C21-100P	15
C116	2.2 μf	50 v	ETB	05397	J2R2J50S	C149-2.2M	15
C117	0.1 μf	50 v	My	84411	601PE	C41-.1M	15
C118	820 pf	300 v	Mica	84171	DM15-821K	C21-820P	15
C119	22 pf	500 v	Mica	84171	DM15-220J	C21-22P	15
C120	1.0 μf	100 v	My	13934	Type 3	C139-1M	15
C121	0.1 μf	50 v	My	84411	601PE	C41-.1M	15
C122	1.0 μf	100 v	My	13934	Type 3	C139-1M	15

DIODES

Circuit Desig.	Type	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
D101	Silicon	1N645	01295	RF-14	15
D102	Silicon	1N645	01295	RF-14	15

MISCELLANEOUS PARTS

Circuit Desig.	Description	Mfg. Code	Keithley Part No.	Fig. Ref.
J101	Receptacle, Microphone, VOLTAGE (Mfg. No. 80-PC2F)	02660	CS-32	2
J102	Receptacle, Microphone, CURRENT (Mfg. No. 80-PC2F)	02660	CS-32	2
---	Plug, Microphone, Mate of J1 and J2 (Mfg. No. 80MC2M)	02660	CS-33	-
M101	Meter	80164	ME-59	2
S101	Toggle Switch, OPERATE-ZERO (Mfg. No. 3003-DL)	82389	SW-59	2
S102	Rotary Switch less components, Range	80164	SW-196	2
S103	Rotary Switch less components, Power	80164	SW-195	2
T101	Transformer	80164	TR-53	-

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R101	1 MΩ	1%, 1/2 w	MtF	07716	CEC-1M-1%	R113-1M	15
R102	1 MΩ	1%, 1/2 w	MtF	07716	CEC-1M-1%	R113-1M	15
R103	2.2 MΩ	1%, 1/2 w	DCb	79727	CFE-15-2.2M	R12-2.2M	15
R104	10 MΩ	10%, 1/2 w	Comp	01121	EB-106-10%	R1-10M	15
R105	22 MΩ	10%, 1/2 w	Comp	01121	EB-226-10%	R1-22M	15
R106	100 kΩ	10%, 1/2 w	Comp	01121	EB-104-10%	R1-100K	15
R107	2.2 MΩ	10%, 1/2 w	Comp	01121	EB-225-10%	R1-2.2M	15
R108	2.2 MΩ	10%, 1/2 w	Comp	01121	EB-225-10%	R1-2.2M	15
R109	10 MΩ	10%, 1/2 w	Comp	01121	EB-106-10%	R1-10M	15
R110	47 kΩ	10%, 1/2 w	Comp	01121	EB-473-10%	R1-47K	15
R111	22 MΩ	10%, 1/2 w	Comp	01121	EB-226-10%	R1-22M	15
R112	100 kΩ	10%, 1/2 w	Comp	01121	EB-104-10%	R1-100K	15
R113	2.2 MΩ	10%, 1/2 w	Comp	01121	EB-225-10%	R1-2.2M	15

RESISTORS (Cont'd)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R114	2.2 MΩ	10%, 1/2 w	Comp	01121	EB-225-10%	R1-2.2M	15
R115	10 MΩ	10%, 1/2 w	Comp	01121	EB-106-10%	R1-10M	15
R116	22 MΩ	10%, 1/2 w	Comp	01121	EB-226-10%	R1-22M	15
R117	100 kΩ	10%, 1/2 w	Comp	01121	EB-104-10%	R1-100K	15
R118	2.2 MΩ	10%, 1/2 w	Comp	01121	EB-225-10%	R1-2.2M	15
R119	2.2 MΩ	10%, 1/2 w	Comp	01121	EB-225-10%	R1-2.2M	15
R120	10 MΩ	10%, 1/2 w	Comp	01121	EB-106-10%	R1-10M	15
R121	47 kΩ	10%, 1/2 w	Comp	01121	EB-473-10%	R1-47K	15
R122	10 MΩ	10%, 1/2 w	Comp	01121	EB-106-10%	R1-10M	15
R123	47 kΩ	10%, 1/2 w	Comp	01121	EB-473-10%	R1-47K	15
R124	2.2 MΩ	10%, 1/2 w	Comp	01121	EB-225-10%	R1-2.2M	15
R125	20 kΩ	10%, 5 w	WWVar	71450	AW-20KΩ	RP34-20K	15
R126	65 kΩ	1%, 1/2 w	DCb	79727	CFE-15-65	R12-65K	15
R127	5 kΩ	1%, 1/2 w	DCb	79727	CFE-15-5K	R12-5K	15
R128	5 kΩ	1%, 1/2 w	DCb	79727	CFE-15-5K	R12-5K	15
R129	1 kΩ	10%, 5 w	WWVar	71450	AW-1KΩ	RP3-1K	15
R130	95.3 Ω	1%, 1/2 w	MtF	07716	CEC-95.3-1%	R94-95.3	S102
R131	300 Ω	1%, 1/2 w	DCb	79727	CFE-15-300	R12-300	S102
R132	1 kΩ	1%, 1/2 w	DCb	79727	CFE-15-1K	R12-1K	S102
R133	1 Ω	1%, 1/2 w	DCb	79727	CFE-15-1	R12-1	S102
R134	60 Ω	1%, 1/2 w	DCb	79727	CFE-15-60	R12-60	S102
R135	3.33 Ω	1%, 1/2 w	DCb	79727	CFE-15-3.33	R12-3.33	S102
R136	10 Ω	10%, 1/2 w	Comp	01121	EB-100-10%	R1-10	S102
R137	33 Ω	10%, 1/2 w	Comp	01121	EB-330-10%	R1-33	S102
R138	100 Ω	10%, 1/2 w	Comp	01121	EB-101-10%	R1-100	S102
R139	56 Ω	10%, 1/2 w	Comp	01121	EB-560-10%	R1-56	S102
R140	180 Ω	1%, 1/2 w	DCb	79727	CFE-15-180	R12-180	S102
R141	560 Ω	10%, 1/2 w	Comp	01121	EB-561-10%	R1-560	S102
R142	1.8 kΩ	10%, 1/2 w	Comp	01121	EB-182-10%	R1-1.8K	S102
R143	5.6 kΩ	10%, 1/2 w	Comp	01121	EB-562-10%	R1-5.6K	S102
R144	18 kΩ	10%, 1/2 w	Comp	01121	EB-180-10%	R1-18K	S102
R145	180 Ω	1%, 1/2 w	DCb	79727	CFE-15-180	R12-180	S102
R146	604 Ω	1%, 1/2 w	DCb	79727	CFE-15-604	R12-604	S102
R147	1.8 kΩ	1%, 1/2 w	DCb	79727	CFE-15-1.8K	R12-1.8K	S102
R148	6 kΩ	1%, 1/2 w	DCb	79727	CFE-15-6K	R12-6K	S102
R149	3 kΩ	1%, 1/2 w	DCb	79727	CFE-15-3K	R12-3K	S102
R150	10 kΩ	1%, 1/2 w	DCb	79727	CFE-15-10K	R12-10K	S102
R151	30 kΩ	1%, 1/2 w	DCb	79727	CFE-15-30K	R12-30K	S102
R152	100 kΩ	1%, 1/2 w	DCb	79727	CFE-15-100K	R12-100K	S102
R153	300 kΩ	1%, 1/2 w	DCb	79727	CFE-15-300K	R12-300K	S102

RESISTORS (Cont'd)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R154	1 MΩ	1%, 1/2 w	DCb	79727	CFE-15-1M	R12-1M	S102
R155	1 MΩ	1%, 1/2 w	DCb	79727	CFE-15-1M	R12-1M	S102
R156	82 Ω	1%, 1/2 w	DCb	79727	CFE-15-82	R12-82	S102
R157	3 kΩ	1%, 1/2 w	DCb	79727	CFE-15-3K	R12-3K	15
R158	*6.98KΩ	1%, 1/2 w	DCb	79727	CFE-15-6.98K	R12-6.98K	15
R159	10 kΩ	10%, 2 w	WWVar	71450	WP-10K	RP9-10K	15
R160	*6.98KΩ	1%, 1/2 w	DCb	79727	CFE-15-6.98K	R12-6.98K	15
R161	3 kΩ	1%, 1/2 w	DCb	79727	CFE-15-3K	R12-3K	15
R162	15 kΩ	10%, 1/2 w	Comp	01121	EB-153-10%	R1-15K	15
R163	700 Ω	1%, 1/2 w	DCb	79727	CFE-15-700	R12-700	S102
R164	2.5 kΩ	1%, 1/2 w	DCb	79727	CFE-15-2.5K	R12-2.5K	15
R165	350 Ω	1%, 1/2 w	DCb	79727	CFE-15-350	R12-350	S102
R166	*	1%, 1/2 w	DCb	79727	CFE-15-*	R12-*	15

*Value selected at factory

TRANSISTORS

Circuit Desig.		Number	Mfg. Code	Keithley Part No.	Fig. Ref.
Q101	PNP	2N1381	01295	TG-8	15
Q102	PNP	2N1381	01295	TG-8	15
Q103	PNP	2N1381	01295	TG-8	15
Q104	PNP	2N1381	01295	TG-8	15

VACUUM TUBES

Circuit Desig.	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
V101	6419	81453	EV-CK6419	15
V102	6419	81453	EV-CK6419	15
V103	6419	81453	EV-CK6419	15
V104	6419	81453	EV-CK6419	15
V105	6418	80164	EV-CK6418-1 (or CK-592-1)	15

FURNISHED ACCESSORIES

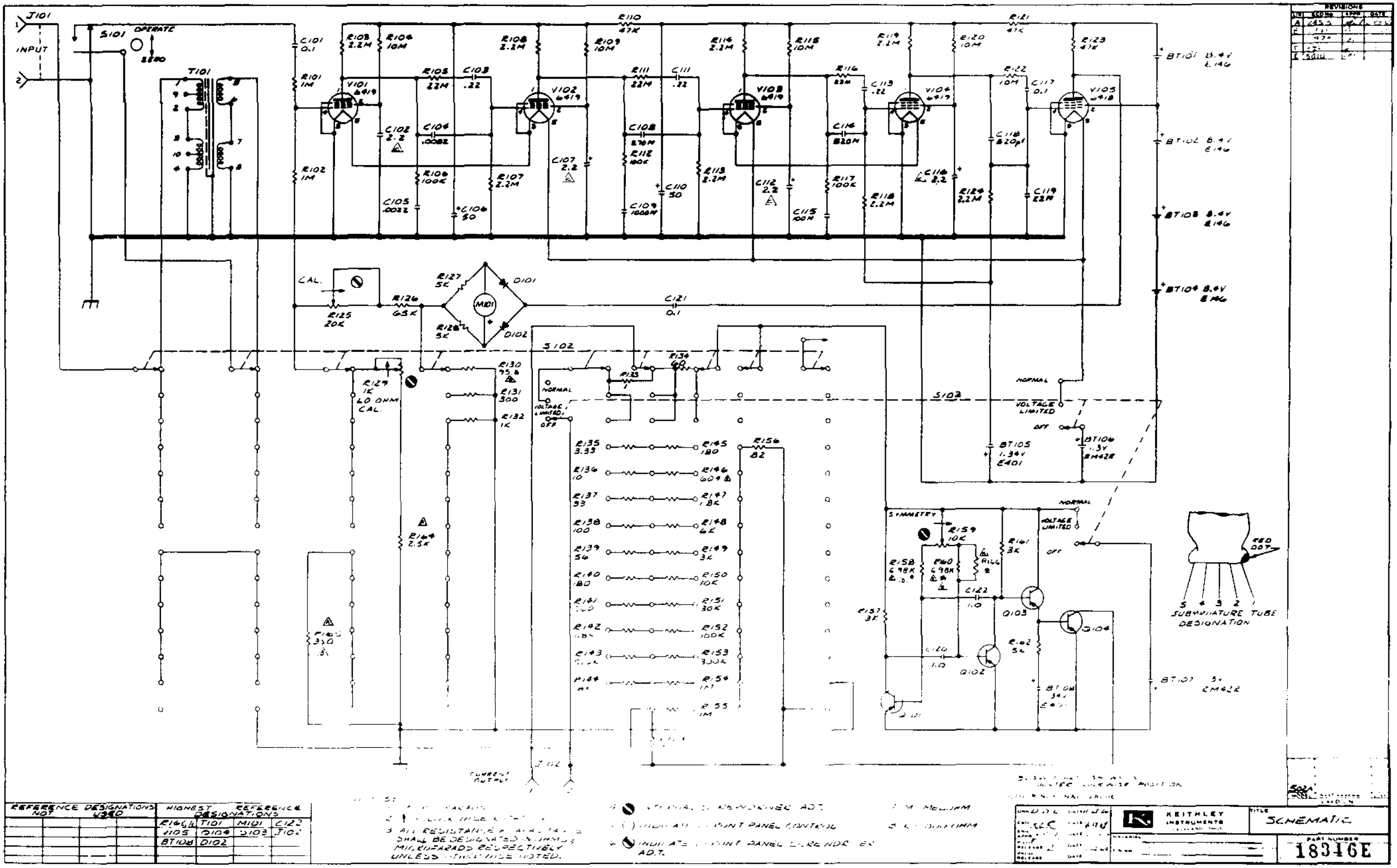
Description	Mfg. Code	Mfg. Part No.	Keithley Part No.
Two Alligator Clips, red	83330	304	AC-3R
Two Alligator Clips, black	83330	304	AC-3B

FURNISHED ACCESSORIES (Cont'd)

Description	Mfg. Code	Mfg. Part No.	Keithley Part No.
Two Miniprod Adapter Tips, red	08811	33-160	PP-3R
Two Miniprod Adapter Tips, black	08811	33-162	PP-3B
Current and Voltage Lead Assemblies	80164		18480C
. Plug, Microphone	02660	80MC2M	CS-33
. Phone Tip, Red	83330	237	PP-2R
. Phone Tip, Black	83330	237	PP-2B

00656	Aerovox Corp. New Bedford, Mass.
00686	Film Capacitors, Inc. New York, N. Y.
01121	Allen-Bradley Corp. Milwaukee, Wis.
01295	Texas Instruments, Inc. Semi-Conductor-Components Division Dallas, Texas
02660	Amphenol-Borg Electronics Corp. Broadview, Chicag, Illinois
04009	Arrow-Hart and Hegeman Electric Co. Hartford, Conn.
05397	Kemet Co. Cleveland, Ohio
07716	International Resistance Co. Burlington, Iowa
08811	G-C Electronics Co., Inc. Camden, N. J.
10608	Union Carbide Corp. New York, N. Y.
13934	Midwec Corp. Oshkosh, Nebr.
37942	Mallory, P. R., and Co., Inc. Indianapolis, Ind.
71450	CTS Corp. Elkhart, Ind.
75042	International Resistance Co. Philadelphia, Pa.
79727	Continental-Wirt Electronics Corp. Philadelphia, Pa.
80164	Keithley Instruments, Inc. Cleveland, Ohio
81453	Raytheon Co. Industrial Components Div. Industrial Tube Operation Newton, Mass.
82389	Switchcraft, Inc. Chicago, Ill.
83330	Smith, Herman H., Inc. Brooklyn, New York
84171	Arco Electronics, Inc. Great Neck, N. Y.
84411	Good-All Electric Mfg. Co. Ogallala, Nebr.

TABLE 7. Code List of Suggested Manufacturers. (Based on Federal Supply Code for Manufacturers, Cataloging Handbook H4-1.)



REFERENCE DESIGNATIONS NOT USED	HIGHEST REFERENCE DESIGNATIONS			
	R166	T101	M101	C122
	V105	Q104	S103	J102
	BT108	D102		

3. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS RESPECTIVELY UNLESS OTHERWISE NOTED.

KEITHLEY INSTRUMENTS

SCHEMATIC

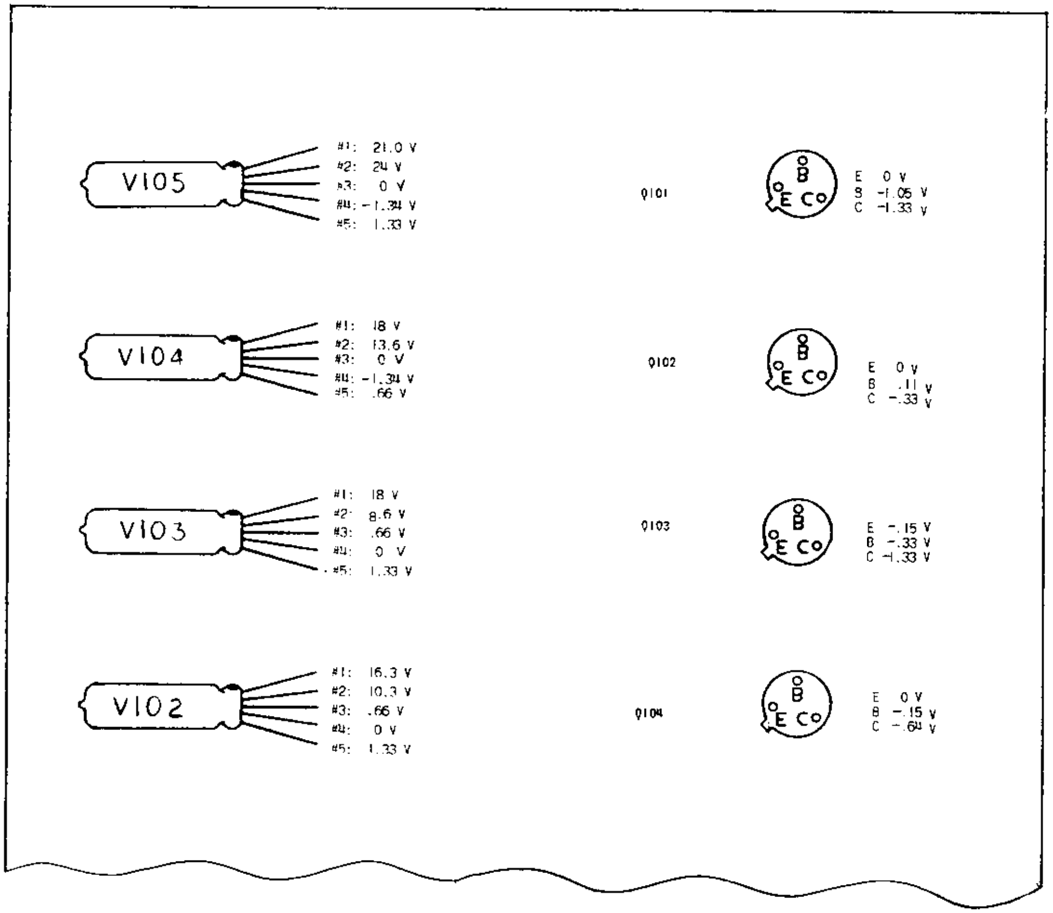
PART NUMBER 18316E

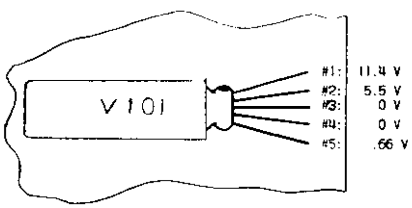
MODEL 502A VOLTAGE CHART

READINGS TAKEN WITH A 100 MEG INPUT VTVM WITH CONTROLS
SET AS FOLLOWS:
RANGE SWITCH AT BATTERY TEST, READ SHORT SWITCH AT SHORT

TUBE VOLTAGES REFERENCED TO CHASSIS GND.

TRANSISTOR VOLTAGES REFERENCED TO EMITTER OF Q104





REVISIONS			
LTR	ECO No.	APPR.	DATE
A	Release		5/64
B	2731		10-5-65

MODEL	NEXT ASSEMBLY	QUAN
502A		

USED ON

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED

FRAC.	DEC	ANG
± 1/64	± .005	± 1°

DO NOT SCALE

DRN — DATE 5/64
CKD — DATE 6/64
ENG APPR — DATE
PILOT-RELEASE — DATE
PROD RELEASE — DATE

KEITHLEY INSTRUMENTS CLEVELAND, OHIO

MATERIAL

FINISH

TITLE VOLTAGE CHART

PART NUMBER 12256C

KEITHLEY INSTRUMENTS, INC.
28775 AURORA ROAD
CLEVELAND, OHIO 44139

SERVICE FORM

MODEL NO. ________ SERIAL NO. ________ P.O. NO. ________ DATE ________ R-

NAME ______________________________ PHONE ____________

COMPANY ______________________________

ADDRESS ______________________ CITY ________ STATE ______ ZIP ______

1. Describe problem and symptoms using quantitative data whenever possible (enclose readings, chart recordings, etc.) ______________________________
____
______________________________ (Attach additional sheets as necessary).

2. Show a block diagram of your measurement system including all instruments connected (whether power is turned on or not). Also describe signal source.

3. List the positions of <u>all</u> controls and switches on both front and rear panels of the instrument. ______________________________
____

4. Describe input signal source levels, frequencies, etc. ______________________________
____
____

5. List and describe all cables used in the experiment (length, shielding, etc.).
____
____

6. List and describe all other equipment used in the experiment. Give control settings for each. ______________________________
____
____

7. Environment:
   Where is the measurement being performed? (Factory, controlled laboratory, out-of-doors, etc.) ______________________________
   What power line voltage is used? ________ Variation? ________ Frequency? ________
   Ambient temperature? ________ °F. Variation? ________ °F. Rel. Humidity? ________
   Other ______________________________

8. Additional Information. (If special modifications have been made by the user, please describe below.) ______________________________
____

REV 0774