OPERATING INSTRUCTIONS

TYPE 1230-A
DC AMPLIFIER AND ELECTROMETER

GENERAL RADIO COMPANY
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OPERATING INSTRUCTIONS

TYPE 1230-A
DC AMPLIFIER AND ELECTROMETER

Form 1230-0100-F
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GENERAL RADIO COMPANY
WEST CONCORD, MASSACHUSETTS, USA
SPECIFICATIONS

VOLTAGE RANGES

\[ \pm 30, \, 100 \text{ and } 300 \text{ dc millivolts full-scale; } \pm 1, \, 3 \text{ and } 10 \text{ dc volts full-scale. Accuracy is } \pm 2\% \text{ of full scale on all but the } 30 \text{ mv range where it is } \pm 4\% \text{ of full scale.} \]

CURRENT RANGES

\[ \pm 1 \text{ milliamperes (} 10^{-3} \text{ amp) dc full scale to } \pm 300 \text{ millimicroamperes (} 3 \times 10^{-13} \text{ amp) dc full scale, in 20 ranges (two per decade).} \]

ACCURACY

\[ \pm 3\% \text{ of full scale from } 10^{-3} \text{amp to } 10^{-9} \text{amp, and } \pm 10\% \text{ of full scale from } 3 \times 10^{-10} \text{amp to } 3 \times 10^{-13} \text{amp.} \]

RESISTANCE RANGES

Direct reading in resistance from 300 kilohms to 10 megohms (\(10^{13}\) ohms) at full scale (\(5 \times 10^{14}\) ohms at smallest meter division). There are 16 ranges (two per decade). At full scale deflection, accuracy is \(\pm 3\%\) from \(3 \times 10^5\) ohms to \(10^{10}\) ohms, and \(\pm 8\%\) from \(3 \times 10^{10}\) ohms to \(10^{13}\) ohms. At one third of full scale deflection, the error can possibly be an additional \(4\%\). The voltage across the unknown resistance is 9 volts.

The resistance range may be extended considerably by the use of external batteries and the most sensitive voltage range. With a 300-volt battery, the highest resistance range is \(10^{15}\) ohms full scale (\(6 \times 10^{16}\) ohms at the smallest meter division). The full battery voltage appears across the unknown resistance.

RESISTANCE STANDARDS

\(10^4, 10^5, 10^6, 10^7, 10^8, 10^9, 10^{10}, \text{ and } 10^{11}\) ohms. The switch also includes zero and infinity positions. The \(10^4\) and \(10^5\)-ohm resistors are wire wound and are accurate to 0.25%. The \(10^6, 10^7, \text{ and } 10^8\)-ohm resistors are of deposited-carbon construction and are accurate to 1%. The \(10^9, 10^{10}, \text{ and } 10^{11}\)-ohm resistors are carbon, and have been treated to prevent adverse humidity effects, and are accurate to 5%. A switch position permits a quick check of the higher resistance standards in terms of the wire-wound units.

INPUT RESISTANCE

The input resistance is determined by the setting of the resistance standards switch. In the infinity position, it is about \(10^{14}\) ohms.

INPUT CAPACITANCE

Less than 35 \(\mu\)F.

DRIFT

Less than 2 mv per hour after 1 hour warmup.

OUTPUT

Voltage, current, and resistance are indicated on a panel meter. Terminals are available for connection of a recorder (such as the General Radio Type 1521-A Graphic Level Recorder or the Esterline-Angus 5-ma or 1-ma graphic recorder). The recorder resistance can be up to 1500 ohms.

FREQUENCY CHARACTERISTIC

With a 1500-ohm load at the OUTPUT terminals, the frequency characteristic is flat within 5% from zero to 10, 30, 100, 300, 1000, and 3000 cps. at the 30-, 100-, 300-millivolt, 1-, 3-, and 10-volt ranges, respectively.

TERMINALS

The input is connected through a Type 874 coaxial terminal assembly. In addition, there are "low" terminals to provide versatility in guard and ground connections, as required, for example, in "three-terminal network" measurements.

INPUT SWITCH

A panel switch permits disconnecting the unknown without upsetting either the unknown or the measuring circuit.

INPUT INSULATION

Entirely teflon or siliconed glass.

TEMPERATURE, HUMIDITY, LINE-VOLTAGE EFFECTS

Negligible.

TUBES

One 5886 electrometer tube, one CK6418, one 6AN5, one 6AL5, one 6627, and three 0B2 tubes.

ACCESSORIES SUPPLIED

One Type 874-411 Adaptor, one Type 1230-P1-300 Panel Adaptor Assembly, two Type 274-MB Plugs, one Type 274-SB Plug, spare fuses, and power cord.

ACCESSORIES AVAILABLE

Type 1230-P1 Component Shield, Esterline-Angus case.

MOUNTING

Aluminum front and rear panels finished in gray lacquer and encased in an aluminum gray sleeve-like cabinet. The instrument can be mounted (by four screws in the rear panel) inside an Esterline-Angus case.

POWER SUPPLY

105 to 125 (or 210 to 250) volts, 50 to 60 cps. Power input is approximately 45 watts at 115 volts.

DIMENSIONS

Width 7-5/8 in., Height 13-1/4 in., Depth 9 in., (540 by 195 by 230 mm) over-all. 15-1/4 lb (7 kg).

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Figure 1. Front and Rear Views of Type 1230-A D-C Amplifier and Electrometer.
Section 1

INTRODUCTION

1.1 GENERAL. The Type 1230-A D-C Amplifier and Electrometer (Figure 1) is a power-line-operated, direct-current, vacuum-tube voltmeter of high sensitivity. The instrument, which uses neither a chopper nor a vibrator, has three direct-coupled stages of amplification. Its input resistance is extremely high because an electrometer-type tube is used in the first stage. The output is indicated on a 5-ma panel meter or on a recorder.

1.2 PURPOSE. The instrument is essentially a millivoltmeter. A panel switch, which allows the selection of a resistance standard in decimal steps from $10^4$ to $10^{11}$ ohms, adapts the instrument for use as a millimicroammeter and a megammegohmmeter. The provision for recording extends the use of the equipment to monitoring and curve-tracing applications.

1.3 CONTROLS. The following table lists the controls on the panel of the instrument:

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>MV-VOLTS-OHMS</td>
<td>Nine-position rotary switch</td>
<td>Selects voltage and resistance ranges.</td>
</tr>
<tr>
<td>INPUT RESISTANCE OR</td>
<td>10-position rotary switch</td>
<td>Selects resistance standard.</td>
</tr>
<tr>
<td>OHMS MULTIPLIER</td>
<td></td>
<td></td>
</tr>
<tr>
<td>POLARITY</td>
<td>Toggle switch</td>
<td>Selects polarity of input voltage or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>current.</td>
</tr>
<tr>
<td>ZERO (PUSH)</td>
<td>Push-lock button</td>
<td>Permits disconnecting input for check-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ing meter zero.</td>
</tr>
<tr>
<td>POWER</td>
<td>Four-position rotary switch</td>
<td>Controls power-line connection. Meter</td>
</tr>
<tr>
<td></td>
<td></td>
<td>open for first two positions.</td>
</tr>
<tr>
<td>GROUND</td>
<td>Three-position switch</td>
<td>Grounds one of three rear-panel terminals.</td>
</tr>
<tr>
<td>COARSE-ZERO-FINE</td>
<td>Two rotary knobs</td>
<td>Set meter to zero.</td>
</tr>
</tbody>
</table>

1.4 CONNECTIONS. The following table lists the rear-panel connections on the instrument:

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>INPUT</td>
<td>Coaxial connector</td>
<td>Input connection</td>
</tr>
<tr>
<td>none</td>
<td>Jack-top binding post</td>
<td>Ground terminal</td>
</tr>
<tr>
<td>I, R, E</td>
<td>Jack-top binding posts (3)</td>
<td>Low-impedance-level guard terminals</td>
</tr>
<tr>
<td>OUTPUT +, -</td>
<td>Jack-top binding posts (2)</td>
<td>Terminals for connecting recorder or accessory meter</td>
</tr>
<tr>
<td>115 (or 230) VOLTS 50 - 60 ~</td>
<td>Recessed male connector</td>
<td>Power Input</td>
</tr>
</tbody>
</table>

1
Section 2
THEORY OF OPERATION

2.1 VOLTAGE MEASUREMENTS.

2.1.1 The amplifier circuit is essentially a cathode-follower, where the "tube" is a three-stage, direct-coupled amplifier. (See Figure 2.) The net trans-conductance is so great that the voltage change across the cathode resistor is essentially the same as the voltage applied to the input terminals. The panel meter reads the current change in the cathode resistor \( R_B \) and is calibrated to read voltage directly. Different ranges are obtained by the selection of different values for \( R_B \). The meter zero is the same for all ranges. The full-scale ranges are 30, 100, and 300 millivolts, 1, 3, and 10 volts. The corresponding \( R_B \) values are 6, 20, 60, 200, 600, and 2000 ohms.

![Cathode-Follower Circuit](image)

Figure 2. Cathode-Follower Circuit.

2.1.2 Because the first stage is an electrometer tube, the grid current is small (about \( 10^{-14} \) amperes). The glass envelope of the tube has been treated with General Electric Drift-Film SC-87, and all other insulation of the input circuit is of teflon. As a consequence, the input resistance is determined by the setting of the INPUT RESISTANCE switch \( R_A \) (Figure 2), even under conditions of high humidity.

2.2 CURRENT MEASUREMENTS.

2.2.1 One method of measuring current is to note the voltage developed across the selected resistance standard \( R_A \) by the unknown current. Since the resistance values of the standards are multiples of 10, the meter reads current directly. The "ammeter resistance" of the instrument is equal to the resistance \( R_A \), as determined by the setting of the INPUT RESISTANCE switch.

2.2.2 A second method of measuring current results in an appreciably lower "ammeter resistance". Since the voltage at the input and the voltage across \( R_B \) are practically equal and of the same polarity, the voltage difference from the high INPUT terminal (grid of first tube) to the high side of \( R_B \) (I, Figure 3) is very small (about 150 \( \mu \)V at full scale). Any current source connected between these two points cannot develop appreciable voltage between the points, and the "ammeter resistance" is therefore very low. The unknown current, however, still flows through \( R_A \), and therefore the instrument indicates current in the same manner as that described in paragraph 2.2.1. The lower "ammeter resistance" is obtained at some sacrifice in stability, however, if the source impedance is relatively low. (Refer to paragraph 4.3.)

2.3 RESISTANCE MEASUREMENTS. Resistance measurements are made by means of an auxiliary voltage, \( E_3 \) (9.1 volts if internal, any voltage up to at least 600 volts if external), connected in the series network of standard and unknown resistors (see Figure 3). The resultant voltage drop across the standard resistor is a measure of the unknown resistance. The meter is calibrated to indicate this resistance directly when \( E_3 \) is internal.

![Guard-Point Arrangement](image)

Figure 3. Guard-Point Arrangement.

2.4 OUTPUT CIRCUIT. The resistance of the recorder or other network at the output terminals can be as great as 1500 ohms with no effect on performance.
2.5 GROUND AND GUARD. The unknown is usually connected from the high coaxial INPUT terminal to ground and the panel GROUND switch is set to R for resistance measurements, E for voltage measurements, and I or O for current measurements.

For measurement of three-terminal resistances or ungrounded resistances, a more flexible guard-ground system is desirable. To meet these situations, the Type 1230-A D-C Amplifier includes three guard terminals (I, R, and E), with provision for grounding any one of the three. Figure 3 shows the guard-point arrangement.

2.6 RESISTANCE STANDARDS CHECK. The $10^4$- and $10^5$-ohm resistance standards of the INPUT RESISTANCE switch are wire-wound and are accurate to within 0.25 percent. The other standards are selected for high accuracy and stability, but resistors up to $10^{11}$ ohms are not yet available with 0.25-percent commercial tolerance. A simple checking system is included whereby any resistance standard $R_A$ above $10^5$ ohms can be quickly measured to a fair degree of accuracy in terms of the resistance standard two switch positions below it $\left(\frac{R_A}{100}\right)$ . (Refer to paragraph 5.1.)

2.7 STABILITY. The instrument's high stability is largely due to the shock-mount construction adopted for the first two stages. To eliminate effects of line-voltage fluctuations, the voltage that supplies the grid-bias, filament-current, and screen-grid voltage of the first two amplifier tubes, as well as the plate voltage of the first tube, is carefully stabilized by means of two regulator stages.

Section 3
INSTALLATION

3.1 POWER SUPPLY. When connected to a 50-60-cycle power-line voltage as indicated on the plate below the power plug (115 or 230 volts), the Type 1230-A D-C Amplifier and Electrometer is ready for operation. If the instrument is not wired for the power-line voltage available, the fuses must be changed, the transformer terminals rewired (see Figure 15), and the plate at the power plug reversed to indicate the correct voltage.

3.2 RECORDER. Output terminals in series with the 0-5-ma meter allow the connection of a recorder, such as the General Radio Type 1521-A Graphic Level Recorder or the Esterline-Angus 0-5-ma or 0-1-ma Graphic Recorder. If the recorder sensitivity is greater than 5 ma, the recorder terminals can be shunted down so that the full-scale deflection is 5 ma. For example, if the Esterline-Angus 1-ma recorder is used, a 350-ohm shunt across the 1400-ohm recorder will reduce the sensitivity to 5ma full scale. A 190-ohm shunt would be used with the Type 1521-A Graphic Level Recorder. While a simple shunt is usually satisfactory, the response time may be large because the recorder is overdamped. With the Esterline-Angus Recorder, a series-parallel shunt consisting of 5600 ohms directly in series with the 1400-ohm recorder, and 1750 ohms shunted across the series pair, reduces the response time from about 3 seconds to 1.2 seconds while maintaining the net load at the Type 1230-A OUTPUT terminals at 1400 ohms.

If the 1-ma recorder is not shunted, the effective sensitivity is increased by a factor of five (e.g. 6 mv full scale at a 30-mv setting). The only adverse effect is the corresponding magnification of noise and drift.

When the POLARITY switch is at minus, the negative (lower) OUTPUT terminal is connected to the E terminal through an internal choke coil. If the GROUND switch is at E, the negative OUTPUT terminal (and any recorder connected to it) is grounded.

3.3 SHIELDING OF UNKNOWN. Because the instrument is a high-resistance device, and sensitive to very small potentials, its INPUT terminal must be shielded from any source of unwanted potential if the INPUT RESISTANCE switch is at A high setting. Also, any change in capacitance at the input is accompanied by a proportional change in voltage, since charge is constant ($Q = CE$). This is evident if the input is connected by a shielded cable, a slight mechanical disturbance of the cable can change its capacitance and hence its voltage enough to cause annoying surges. Similarly, if the input is unshielded and the resistance setting of the INPUT RESISTANCE control is set above $10^8$ ohms, the change in meter reading caused by the waving of a charged polystyrene rod is quite evident, even if the rod is some distance from the instru-
ment. Experiments of this nature will soon convince the operator of the need for adequate, rigid shielding.

The Type 1230-P1 Component Shield provides excellent shielding, yet ready accessibility of components under measurement. It plugs directly into the coaxial INPUT terminal of the amplifier and includes connections to the various guard terminals. This accessory contains a small (4 by 5 inch) shelf. The cylindrical cover is easily removed.

A Type 1230-P1-300 Panel Connector is supplied with the amplifier so that the user can extend complete shielding to any size box required.

The Type 874-411 Adaptor, supplied with the amplifier, permits interconnection of the coaxial input terminal with banana plugs or binding posts. At low resistance levels, external shielding may not be required. At higher levels, partially enclosing the unknown may be sufficient.

Section 4
OPERATING PROCEDURE

4.1 PRELIMINARY SETTINGS.

4.1.1 Before turning the power ON, set the panel switch to 10 volts, push the ZERO (PUSH) switch in and rotate it slightly to lock it. With the switch in this position, the INPUT terminal is disconnected. Close the output circuit at the OUTPUT terminals either by using the Type 274-SB Shorting Bar supplied with the instrument or by connecting a record or other external circuit (of less than 1500 ohms). (Refer to paragraph 3.2.)

4.1.2 Turn the power switch from OFF to ON. The power switch has four positions for optimum switching sequence. In the first position, power is off and the meter-output circuit is open. In the second position, power is on, with the meter-output circuit still open. In the third position, the meter circuit is connected but is shunted. In the fourth (ON) position, the shunt is removed and the instrument is ready for operation. Although no damage will be caused if the instrument is turned on by external means without following the above switching sequences, the meter surge may be greater.

4.1.3 Set the meter zero by means of the COARSE and FINE ZERO controls. The zero setting is the same for all voltage ranges. For the most precise adjustment, set the zero with the range switch at 30 mv. Do not permit the meter to deflect off scale for any appreciable time.

4.1.4 During the first fifteen minutes or so, the meter zero may change several millivolts; it is easily reset to zero. Warm-up time may be greater if the amplifier has not been used for some time, or if it is enclosed in an Esterline-Angus case.

After warm-up, the zero may continue to drift, but the drift rate should not exceed 2 mv per hour; in most instruments it is less than 1 mv per hour. Drift will usually approach zero as operation time is increased.

4.1.5 When pushed, the ZERO (PUSH) switch opens the high INPUT terminal, but does not otherwise disturb either the "unknown circuit" or the amplifier circuit. To lock it in the position that disconnects the INPUT terminal; rotate the control after pushing it in. The control springs out and reconnects the INPUT terminal when rotated further and released. When connections to the INPUT terminals are to be changed, the INPUT terminal must be opened and the INPUT RESISTANCE switch must be set to zero. Otherwise, under some conditions, the amplifier will be subjected to a large voltage surge and may require an appreciable time for equilibrium to be established.

4.1.6 The ZERO (PUSH) switch is also used to disconnect the unknown and so to permit the checking and readjustment of the meter zero. A zero check and readjustment may be desirable if the final INPUT RESISTANCE switch setting is at 1011 ohms because of possible grid-current effects. An occasional zero check and readjustment may also be desirable when data are being recorded on the more sensitive ranges.

4.1.7 Set the POLARITY switch for the polarity of the input voltage or current at the high INPUT terminal (center terminal of the coaxial assembly). The POLARITY switch does not function when the MV-VOLTS-OHMS switch is at OHMS.
4.2 VOLTAGE MEASUREMENTS.

a. Set the GROUND switch to E.
b. Set the MV-VOLTS-OHMS switch to 10 volts.
c. Connect the unknown voltage source from high INPUT to ground.
d. Set the INPUT RESISTANCE switch to the desired value and release the ZERO (PUSH) button.
e. Reset the MV-VOLTS-OHMS switch as necessary and operate the POLARITY switch to obtain a voltage reading on the meter. The appropriate meter scale is indicated by the final setting of the MV-VOLTS-OHMS switch.

4.3 CURRENT MEASUREMENTS. There are two methods of measuring current with the Type 1230-A D-C Amplifier and Electrometer, as described in the following paragraphs.

First Method. Connect the unknown-current source from the high INPUT terminal to ground and set the GROUND switch to E. The unknown current flows through the input resistance $R_A$ and the voltage drop across it is indicated on the meter. The unknown current is equal to the indicated voltage $E$ divided by the input resistance $R_A$. (See Figure 4a.)

$$I_x = \frac{E}{R_A}$$

Since this is essentially a voltage measurement, adjustments and connections are as outlined in paragraph 4.2. A method that provides a lower effective ammeter resistance is described in the next paragraph.

Second Method. Adjust the zero controls for an exact meter zero. Connect the unknown current source from the high INPUT terminal to ground. Set the GROUND switch to I. The unknown current is:

$$I_x = \frac{E}{R_A + R_B}$$

When the unknown current is less than 30 $\mu$A, the simpler equation can be used:

$$I_x = \frac{E}{R_A}$$

The connections are as shown in Figure 4b, and the effective ammeter resistance ($R_{eff}$) is small compared with $R_A$, the panel switch setting of INPUT RESISTANCE.

$$R_{(eff)} \approx \frac{R_A}{G_m R_B}$$

For typical transconductance ($G_m$) of 33 mhos,

$$R_{(eff)} = \frac{0.03 R_A}{R_B}$$

The value of $R_B$ is a function of the setting of the MV-VOLTS-OHMS switch as tabulated below:

<table>
<thead>
<tr>
<th>Switch Setting</th>
<th>$R_B$</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 mv</td>
<td>6 ohms</td>
</tr>
<tr>
<td>100 mv</td>
<td>20 ohms</td>
</tr>
<tr>
<td>300 mv</td>
<td>60 ohms</td>
</tr>
<tr>
<td>1 v</td>
<td>200 ohms</td>
</tr>
<tr>
<td>3 v</td>
<td>600 ohms</td>
</tr>
<tr>
<td>10 v</td>
<td>2000 ohms</td>
</tr>
</tbody>
</table>

Figure 4. Alternate Methods for Current Measurement.
An interesting result is that the effective input resistance does not change substantially if the \( R_A \) switch is changed by a given factor and the MV-VOLTS-OHMS switch (\( R_B \)) is changed by the same factor in the same direction. For accurate results, the resistance of the unknown-current source should be greater than the value (in ohms) tabulated below:

<table>
<thead>
<tr>
<th>( R_A )</th>
<th>VOLTS RANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>( 10^4 )</td>
<td>30 MV 100 MV 300 MV</td>
</tr>
<tr>
<td>( 10^5 )</td>
<td>2 x ( 10^3 ) 2 x ( 10^4 ) 5 x ( 10^2 ) 5 x ( 10^3 ) 2 x ( 10^2 ) 2 x ( 10^3 ) 5 x 10 5 x 10 ( 1.5 \times 10 )</td>
</tr>
<tr>
<td>( 10^6 )</td>
<td>2 x ( 10^5 ) 2 x ( 10^6 ) 5 x ( 10^4 ) 5 x ( 10^5 ) 2 x ( 10^4 ) 2 x ( 10^5 ) 5 x ( 10^3 ) 5 x ( 10^4 ) 1.5 x ( 10^2 )</td>
</tr>
<tr>
<td>( 10^7 )</td>
<td>2 x ( 10^7 ) 2 x ( 10^8 ) 5 x ( 10^6 ) 5 x ( 10^7 ) 2 x ( 10^6 ) 2 x ( 10^7 ) 5 x ( 10^5 ) 5 x ( 10^6 ) 1.5 x ( 10^4 ) 1.5 x ( 10^4 )</td>
</tr>
<tr>
<td>( 10^8 )</td>
<td>2 x ( 10^9 ) 2 x ( 10^{10} ) 5 x ( 10^8 ) 5 x ( 10^9 ) 2 x ( 10^8 ) 2 x ( 10^9 ) 5 x ( 10^7 ) 5 x ( 10^8 ) 1.5 x ( 10^6 ) 1.5 x ( 10^7 )</td>
</tr>
<tr>
<td>( 10^9 )</td>
<td>2 x ( 10^{10} ) 2 x ( 10^{11} ) 5 x ( 10^9 ) 5 x ( 10^{10} ) 2 x ( 10^9 ) 2 x ( 10^{10} ) 5 x ( 10^8 ) 5 x ( 10^9 ) 1.5 x ( 10^7 ) 1.5 x ( 10^7 )</td>
</tr>
</tbody>
</table>

Note from Figure 4b that the unknown source resistance and \( R_A \) form a potential divider across the degenerative resistor \( R_B \); consequently, if the source resistance is small compared to \( R_A \), the effective degeneration is decreased, and the tendency to instability is increased, particularly at the most sensitive range; that is why the zero controls must be set for an exact meter zero.

If the unknown source has appreciable capacitance, operate the instrument for a few seconds at the 10-volt range and at a low value of INPUT RESISTANCE (\( R_A \)) to avoid any initial instability.

If the unknown source contains an a-c component, the a-c source impedance may be small compared to \( R_A \), and the a-c component may not then be sufficiently degenerated, with consequent instability. In spite of these limitations, the method is useful in many applications.

4.4 RESISTANCE MEASUREMENTS WITH INTERNAL D-C SUPPLY.

a. Set the INPUT RESISTANCE OR OHMS MULTIPLIER switch to zero.

b. Set the MV-VOLTS-OHMS switch to 90 ohms, and adjust the zero control knobs for meter zero (to ohm resistance scales). The POLARITY switch does not function when the MV-VOLTS-OHMS switch is at an OHMS setting, as the low side of the unknown resistance is connected to the positive terminal of the internal 9.1-volt source.

c. Set the GROUND switch as follows:

1. If the unknown resistance is grounded, connect it from the high INPUT terminal to the adjacent ground terminal and set the GROUND switch to R. (See Figure 5.) Instrument leakage from INPUT to ground (about 10\( 14 \) ohms) will be across the unknown, and therefore may affect the final reading. The actual leakage value can be determined by a preliminary measurement with the unknown resistance \( R \) disconnected.

![Figure 5. Resistance Measurement with Internal D-C Supply.](image)

2. If the unknown resistance is not grounded, and especially if small high-resistance components (that need not be grounded) are to be measured, connect the unknown from the high INPUT terminal to the R terminal and set the GROUND switch to E (see Figure 5). Instrument leakage will be across the internal resistance standard \( R_A \) and will not introduce any error. Leakage across the unknown will be nonexistent.
(3) If the unknown resistance is a three-terminal resistance, (shown dotted in Figure 5), connect the third terminal to the E terminal. Connect the other two terminals in accordance with (1) and (2) above.

d. Advance the OHMS MULTIPLIER switch to a setting at which the meter reads upscale. Select between the 90-ohm and 30-ohm positions of the function switch for the higher meter deflection.

e. The unknown resistance in ohms is indicated on the appropriate OHMS scale of the meter as multiplied by the OHMS MULTIPLIER. Use the \( \propto \) to 90 scale if the OHMS switch is at 90 ohms, the \( \propto \) to 30 scale if the OHMS switch is at 30 ohms.

f. The voltage across the unknown is from 8.8 to 9.1 volts.

g. At full scale, the voltage across the standard \( R_A \) is 100 mv for the 90-ohm scale and 300 mv for the 30-ohm scale.

4.5 RESISTANCE MEASUREMENTS WITH EXTERNAL D-C SUPPLY.

4.5.1 CONDITIONS OF MEASUREMENT. The external supply must be either batteries or a stabilized line-operated supply. See Figure 6.

![Figure 6. Resistance Measurement with External D-C Supply.](image)

Since the supply is external, the Type 1230-A Amplifier merely measures the voltage drop across the resistance standard \( R_A \).

If the unknown resistance need not be grounded, the voltage of the external supply is not limited by the amplifier design. If the unknown must be grounded, the voltage of the external supply is limited to the 600-volt rating of C11 (Figure 6), a capacitor in the instrument. The unknown resistance must be capable of withstanding the full voltage of the supply.

The unknown resistance is normally calculated from the voltage indication of the Type 1230-A Amplifier. If the external supply is 90 volts, the OHMS scale (with an additional multiplying factor of ten) may be used with an acceptable degree of accuracy.

4.5.2 MEASUREMENT PROCEDURE.

a. Set the OHMS MULTIPLIER switch to zero. Set the MV-VOLTS-OHMS function switch to 30 MV to adjust the zero control knobs for meter zero. Reset the function switch to 10 volts.

b. Set the GROUND switch to R if the unknown is to be grounded, to E if the unknown is not to be grounded. In either case, note from Figure 6 that the external supply will be grounded. If the unknown resistance is grounded, instrument leakage from input to ground (about 10^4 ohms) will be across the unknown and therefore may affect the final reading. The actual leakage value can be determined from a preliminary measurement with the unknown resistance disconnected.

If the unknown resistance is to be ungrounded (preferably in measurement of small components), amplifier leakage will be across the internal resistance standard \( R_A \) and will not introduce an error. There will be no leakage across the unknown if due care is taken when connections are made.

c. Connect one end of the unknown resistance to the high INPUT terminal, and connect the other end to one terminal of the external d-c supply. Connect the other terminal of the d-c supply (preferably the positive terminal) to the E terminal of the amplifier.

d. If the unknown resistance is to be grounded, connect the junction of the external d-c supply and the unknown resistance to the R terminal or to the ground terminal. If the unknown is a three-terminal resistance (shown dotted in Figure 6) connect the third terminal to the E terminal.

e. Advance the OHMS MULTIPLIER switch until the meter reads upscale, reducing the VOLTS switch setting if necessary. The unknown resistance in ohms is the ratio of the external voltage \( E_0 \) to the indicated meter voltage \( E \) multiplied by the OHMS MULTIPLIER setting:

\[
R_x = \frac{E_0}{E} R_A - R_A
\]

When \( E \) is much smaller than \( E_0 \), \( R_x \approx \frac{E_0 R_A}{E} \).

Note that \( E \) in the equation must be expressed in volts rather than in millivolts.
f. The voltage across the unknown is:

\[ E_X = E_0 - E \]

4.6 MEASUREMENT OF CAPACITOR LEAKAGE RESISTANCE.

4.6.1 The leakage resistance of a capacitor is measured in the same manner as any other resistance. However, because the capacitance introduces a time factor, there are additional considerations necessary for accurate results.

The resistance-measurement method is basically a current measurement. The voltage drop in the resistance standard is a function of the current in the unknown. When the unknown has capacitance, the current is at first chiefly the charging current, the leakage-current component being negligible. Eventually, when the capacitor is fully charged, the only current flowing is that due to leakage resistance. The time required to charge the capacitor depends to some extent on the series resistance of the circuit (resistance standard), but to a much greater extent on the dielectric properties of the capacitor and the relative magnitude of the leakage.

Consider for example, the circuit shown in Figure 7. The capacitor \( C_X \) will have absorbed about two thirds of its final charge from \( E_0 \) in a time determined by the \( R_A C_X \) product if there is no appreciable dielectric absorption. This is true of air capacitors. For most dielectrics, the time necessary for the capacitor to absorb the charge is much greater than the \( R_A C_X \) product because of interfacial polarization. Consequently, when a potential is applied to a capacitor, the time required for a complete charge can be a matter of seconds, hours, or even days, depending on the dielectric and on the leakage.

\[ \text{Figure 7. Capacitor Leakage-Resistance Measurement.} \]

To determine the component of current due to leakage, it is not necessary to wait until the capacitor is fully charged; it is necessary to wait only until the meter reading attains a constant value. The greater the leakage, the sooner the final determination can be made.

4.6.2 When measuring the leakage resistance of a capacitor (see Figure 7), start with the OHMS MULTIPLIER switch (\( R_A \)) at zero. With the function switch at either 30 MV (with an external d-c supply) or 90 OHMS (internal supply), advance the OHMS MULTIPLIER switch to obtain a meter reading. Monitor the meter reading until it has decreased to a steady value, that is, until the decreasing charge current is small compared with the leakage current. While the charging current is still appreciable, a change in the OHMS MULTIPLIER setting will, for a short time (about \( R_A C_X \) seconds), upset the rate at which the meter reading approaches an equilibrium value.

If a resistance limit, rather than the absolute value of resistance, is being sought, the meter reading need be monitored only until it attains the limit.

4.6.3 Charge currents and discharge currents of capacitors, as well as recovery voltage after short-circuit, can be recorded, providing valuable information for the determination of dielectric relaxation frequencies, very-low-frequency dielectric constant, and dissipation factor behavior.\(^1\,2\)

\(^1\) Field, Robert F., "The Basis for the Nondestructive Testing of Insulation", AIEE Transactions, September, 1941.
4.7 TYPE 1230-P1 COMPONENT SHIELD. This unit is an extension of the terminal system of the amplifier into a completely shielded, yet readily accessible compartment. The I-, R-, and E-LOW terminals are brought out to facilitate connections to external power sources. The shield is especially useful in measurement of the small components (resistors, capacitors, back resistance of silicon diodes, etc) at a level above $10^8$ ohms. A shelf is included on the panel of the unit.

The wiring of the Type 1230-P1 Component Shield is shown in Figure 8. The E-LOW and R-LOW terminals are wired for easy access. The I-LOW terminal may be connected to the I-BATT terminal for external access. The I-LOW terminal is supplied unwired to permit use of the I-BATT terminal in those applications where $R_X$ is ungrounded and external battery voltage exceeds 600 volts. The connections are shown in Figure 9.

4.8 HIGH-VOLTAGE MEASUREMENTS. Voltage measurements up to the kilovolt range can be made with the Type 1230-A Amplifier when an external resistance standard $R_X$ is used. See Figure 10.

$$E_X = \frac{R_X + R_A}{R_A} E_2 = \frac{R_X}{R_A} E_2$$

Thus, when $R_X$ is $10^{12}$ ohms and $R_A$ is set to $10^8$ ohms, $E$ will be 3 volts for an $E_X$ of 30 kv. External resistance standards of adequate accuracy are available to $10^{11}$ at 125 kv, to $10^{14}$ at 15 kv.

If the unknown voltage does not exceed 5 kv, the standard ($R_X$) can be mounted in the Type 1230-P1 Shield (HIGH to I-BATT); the unknown voltage is then connected from the I-BATT terminal to ground. See Figure 9.
CHECKS AND ADJUSTMENTS

5.1 CHECKING INTERNAL RESISTANCE STANDARDS. When the MV-VOLTS-OHMS switch is set in the CHECK position, the instrument indicates the resistance of any higher RESISTANCE MULTIPLIER standard. This indication is given on the 90 OHMS scale. (See Figure 11.) The resistance of the standard, $R_A$, is given in terms of the standard two steps below it ($\frac{R_A}{100}$). The lower-resistance standards ($10^4$ ohms and $10^5$ ohms) are wire-wound resistors, accurate to ±0.25 percent. Since the meter reading is near full scale, the higher standards can be checked with a considerable degree of accuracy. A single measurement is sufficient to determine the correct value of either the $10^6$-ohm or $10^7$-ohm standard. Two measurements are required to determine the value of either the $10^8$-ohm or $10^9$-ohm standard. (For instance, the $10^9$-ohm standard is measured in terms of the $10^7$-ohm standard, and the $10^7$-ohm standard is in turn measured in terms of the $10^5$-ohm standard.) Three measurements are necessary to determine the value of either the $10^{10}$-ohm or $10^{11}$-ohm standard. The preliminary zero setting, which is on the OHMS scale, should be made with the INPUT RESISTANCE OR OHMS MULTIPLIER switch set at $10^5$ ohms for greatest accuracy. The GROUND switch may be set at any of its three positions. Lock the ZERO (PUSH) in to open the INPUT terminal.

5.2 AUXILIARY ZERO CONTROL. Normally, the two ZERO controls on the panel of the instrument are sufficient to obtain a zero setting. However, if tubes have been changed, or if the instrument has seen considerable service, the panel ZERO controls may not be adequate. In such an instance, the auxiliary zero control (R26, see Figure 13) can be adjusted to bring zero within the range of the panel controls. The auxiliary zero control is inside the cabinet, on the shelf, to the left of the meter. This control can be set by means of a long-handled screwdriver, without requiring removal of the cabinet.

5.3 INTERNAL VOLTAGE ADJUSTMENT. A highly stabilized voltage supply of 9.10 volts is built into the instrument for the measurement of unknown resistances. This built-in voltage can be measured and adjusted by the following procedure:

a. Set the MV-VOLTS-OHMS switch to 90 OHMS.
b. Push in the ZERO switch, and connect a high-resistance voltmeter from the E terminal to the R terminal. The meter resistance must be greater than 2 megohms.
c. If the voltage is not exactly 9.10 volts, set it to this value by adjusting R33 (see Figure 12), which is located inside the cabinet, on the shelf, to the right of the meter. This control can be adjusted by means of a long-handled screwdriver, without requiring removal of the cabinet.

![Figure 11. Check on Internal Resistance Standard.](image-url)
SECTION 6
SERVICE AND MAINTENANCE

6.1 GENERAL. The two-year warranty given with every General Radio instrument attests the quality of materials and workmanship in our products. When difficulties do occur, our service engineers will assist in any way possible.

In case of difficulties that cannot be eliminated by the use of these service instructions, please write or phone our Service Department, giving full information of the trouble and of steps taken to remedy it. Be sure to mention the serial number and type numbers of the instrument.

Before returning an instrument to General Radio for service, please write to our Service Department or nearest district office (see back cover), requesting a Returned Material Tag. Use of this tag will insure proper handling and identification. For instruments not covered by the warranty, a purchase order should be forwarded to avoid unnecessary delay.

6.2 REMOVAL OF CABINET. Remove the two screws from the top of the instrument, and the four feet from the bottom. Slide the cabinet away from the panel. Tubes, adjustments, and most components are now accessible.

6.3 TUBE REPLACEMENT AND ADJUSTMENT. If V1 is replaced, R26 may require adjustment (paragraph 5.2). Any excessive grid current or meter drift will diminish if the instrument is operated for several hours to age the new tube. To measure grid current, note the increase in meter reading at the +30 MV range with the INPUT RESISTANCE switch at 10 MΩ. A 2-MV increase is normal.

To extract V1 or V2 from its socket, use a No. 14 or No. 12 wire, bent at a right angle 1/2 inch from the end, as a tool to pull out the leads simultaneously.

V1 has four leads adjacent to the red dot. Cut these to 7/16-inch and bend them at right angles. The fifth lead is the grid lead. Do not cut it; if possible, treat the glass around it with GE Dri-Film SC-87 to eliminate leakage in high humidity.

The leads of a replacement tube V2 should be cut to 7/16-inch and bent. Replacement of V2, V3, V5, V6, V7 or V8 should not require component readjustment.

6.4 OPENING THE INSTRUMENT. After the cabinet is removed, the instrument can be further opened out as follows:

a. Unsolder the lead from the rear of the INPUT RESISTANCE switch to the anchor terminal that mounts R10.

b. Remove the two 5/16-inch hex-head screws from the front panel and the three hex-head screws from the rear panel. Keep the teflon insulation free from dirt.

When reassembling, make sure the ZERO (PUSH) switch functions properly and that the lead from the INPUT RESISTANCE switch to the R10 anchor terminal is resoldered. If the contacts of the INPUT RESISTANCE switch or of the MV-VOLTS-OHMS switch (mounted on teflon bushings) need lubrication, use as little lubricant as possible to avoid smearing insulation.

6.5 VOLTAGE AND RESISTANCE CHART. The following table gives normal d-c voltages and resistances from tube socket pins to ground.

<table>
<thead>
<tr>
<th>TUBE (TYPE)</th>
<th>PIN</th>
<th>VOLTS TO GND</th>
<th>RES TO GND</th>
<th>TUBE (TYPE)</th>
<th>PIN</th>
<th>VOLTS TO GND</th>
<th>RES TO GND</th>
<th>TUBE (TYPE)</th>
<th>PIN</th>
<th>VOLTS TO GND</th>
<th>RES TO GND</th>
</tr>
</thead>
<tbody>
<tr>
<td>V1 (5886)</td>
<td>1</td>
<td>11.2</td>
<td>15 M</td>
<td>V3 (6AN5)</td>
<td>6</td>
<td>216</td>
<td>14 k</td>
<td>V5 (6B2)</td>
<td>4</td>
<td>108</td>
<td>14 k</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2.2</td>
<td>16 k</td>
<td>7</td>
<td>108</td>
<td>28 k</td>
<td>5</td>
<td>108</td>
<td>28 k</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>3.5</td>
<td>410</td>
<td></td>
<td>108</td>
<td>20 M</td>
<td>7</td>
<td>108</td>
<td>28 k</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>2.3</td>
<td>380</td>
<td></td>
<td>108</td>
<td>200</td>
<td>7</td>
<td>108</td>
<td>28 k</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>10 M</td>
<td>10 M</td>
<td></td>
<td>108</td>
<td>200</td>
<td>7</td>
<td>108</td>
<td>28 k</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V2 (CK6418)</td>
<td>1</td>
<td>100</td>
<td>2.8 M</td>
<td>V4 (6627)</td>
<td>1</td>
<td>108</td>
<td>9 k</td>
<td>V7 (6B2)</td>
<td>1</td>
<td>108</td>
<td>28 k</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>58</td>
<td>4800</td>
<td>2</td>
<td>108</td>
<td>9 k</td>
<td>5</td>
<td>108</td>
<td>28 k</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
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<td>1600</td>
<td>4</td>
<td>0</td>
<td>200</td>
<td>7</td>
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<td></td>
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<tr>
<td></td>
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<td>14.2</td>
<td>15 M</td>
<td>5</td>
<td>0</td>
<td>200</td>
<td>7</td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>17</td>
<td>1600</td>
<td></td>
<td>0</td>
<td>200</td>
<td>7</td>
<td>0</td>
<td>200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V3 (6AN5)</td>
<td>1</td>
<td>100</td>
<td>2.8 M</td>
<td>V5 (6B2)</td>
<td>1</td>
<td>108</td>
<td>200</td>
<td>V8 (6AL5)</td>
<td>1</td>
<td>108</td>
<td>11 k</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>100</td>
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<td>108</td>
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<td>4</td>
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<td>4</td>
<td>2.3</td>
<td>108</td>
<td>5</td>
<td>0</td>
<td>200</td>
<td>2</td>
<td>108</td>
<td>28 k</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>260*</td>
<td>108</td>
<td>7</td>
<td>216</td>
<td>14 k</td>
<td>7</td>
<td>108</td>
<td>28 k</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:
* Measured with vacuum-tube voltmeter.
** 4.6 to 7.4 V, depending on zero set.
† 14 to 19 k, depending on zero set.
Switch Settings: MV-VOLTS-OHMS MULTIPLIER at 10⁴
VOLTS at 1
Ground at E
Measurements made with 20,000-ohm-per-volt multimeter.
Figure 12. Interior View of Type 1230-A D-C Amplifier and Electrometer.
Figure 13. Interior View of Type 1230-A D-C Amplifier and Electrometer.

FRONT VIEW OF SI DETAILS
### Section 7

### Parts List

<table>
<thead>
<tr>
<th>GR NO. (NOTE A)</th>
<th>MISCELLANEOUS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RESISTORS (NOTE B)</td>
</tr>
</tbody>
</table>
| R1 101 M ± 1% 2 w | REF-3-3 | VIC | V | (A) Type designations for resistors and capacitors are as follows:
| R2 1030 M ± 5% | Victoreen RX-1 | -3 | V | COC - Capacitor, ceramic
| R3 10,300 M ± 5% | Victoreen RX-1 | 1 | V | COE - Capacitor, electrolytic
| R4 103,000 M ± 5% | Victoreen RX-1 | 1 | V | COL - Capacitor, oil
| R5 10.1 M ± 1% 2 w | RX-1 | 3 | V | COW - Capacitor, wax
| R6 1 M ± 1% 1 w | RX-1 | 3 | V | POSW - Potentiometer, wire-wound
| R7 100 k ±0.25% 1/3 w | RX-1 | 1 | V | REW - Resistor, wire-wound
| R8 10 k ±0.25% 1/3 w | RX-1 | 1 | V | (B) All resistances are in ohms as otherwise indicated by k (kilohms) or M (megohms).
| R9 10 M ± 10% 1/2 w | RX-1 | 1 | V | (C) All capacitances are in microfarads.
| R10 10 M ± 10% 1/2 w | RX-1 | 1 | V | * R12 part of P1 socket assembly.
| R11A 6 ± 0.25% | 510-419 | 1 | V | ** Base of V1 tube to be coated with GE Dryfilm SC37 GR Co. No. TUB-3.
| R11B 14 ± 0.25% 1/2 w | REW-3C | 1 | V | 15 % ± 10% 1/2 w | REW-70 | 1 | V | 2200 K V | IN695
| R12 10 k ±0.25% 1/2 w | REW-3 | 1 | V | 300 K V | IN695
| R13 25 k ± 1% 1/2 w | REW-3 | 1 | V | 300 K V | IN695
| R14A 140 ±0.25% | REW-3 | 1 | V | 300 K V | IN695
| R14B 400 ±0.25% 1/2 w | REW-3 | 1 | V | 300 K V | IN695
| R14C 1400 ±0.25% | REW-3 | 1 | V | 300 K V | IN695
| R15 2.2 M ± 10% 2 w | REW-3 | 1 | V | 300 K V | IN695
| R16 2.2 M ± 10% 2 w | REW-3 | 1 | V | 300 K V | IN695
| R17 180 ± 1% | REW-3 | 1 | V | 300 K V | IN695
| R18 1200 ± 1% | REW-3 | 1 | V | 300 K V | IN695
| R19 3600 ± 1% | REW-3 | 1 | V | 300 K V | IN695
| R20 4700 ± 1% | REW-3 | 1 | V | 300 K V | IN695
| R21 15 k ± 1% 1/3 w | REW-3 | 1 | V | 300 K V | IN695
| R22 5 k ± 1% 2 w | REW-3 | 1 | V | 300 K V | IN695
| R23 5 k ± 1% 2 w | REW-3 | 1 | V | 300 K V | IN695
| R24 300 k ± 1% 1/2 w | REW-3 | 1 | V | 300 K V | IN695
| R25 200 k ± 1% 1/2 w | REW-3 | 1 | V | 300 K V | IN695
| R26 10 k ± 10% 2 w | REW-3 | 1 | V | 300 K V | IN695
| R27 10 k ± 10% 2 w | REW-3 | 1 | V | 300 K V | IN695
| R28 5.6 k ± 5% 10 w | REW-3 | 1 | V | 300 K V | IN695
| R29 2.4 k ± 5% 10 w | REW-3 | 1 | V | 300 K V | IN695
| R30 100 k ± 10% 1/2 w | REW-3 | 1 | V | 300 K V | IN695
| R31 10 k ± 10% 1/2 w | REW-3 | 1 | V | 300 K V | IN695
| R32 12 k ± 10% 1/10 w | REW-3 | 1 | V | 300 K V | IN695
| R33 2 k ± 10% 2 w | REW-3 | 1 | V | 300 K V | IN695
| R34 15 k ± 10% 1/2 w | REW-3 | 1 | V | 300 K V | IN695
| R35 15 k ± 10% 1/2 w | REW-3 | 1 | V | 300 K V | IN695
| R36 2.7 M ± 1% 1 w | REW-3 | 1 | V | 300 K V | IN695
| R37 300 ± 5% 2 w | REW-3 | 1 | V | 300 K V | IN695
| R38 300 ± 5% 2 w | REW-3 | 1 | V | 300 K V | IN695
| R39 3 k ± 10% 2 w | REW-3 | 1 | V | 300 K V | IN695
| R40 8.2 k ± 1% 1/2 w | REW-3 | 1 | V | 300 K V | IN695
| R41 10 k ±10% 1/2 w | REW-3 | 1 | V | 300 K V | IN695
| R42 330 k ±10% 1/2 w | REW-3 | 1 | V | 300 K V | IN695
| R43 1.5 k ±10% 1/2 w | REW-3 | 1 | V | 300 K V | IN695
| R44 10 ±10% 1/2 w | REW-3 | 1 | V | 300 K V | IN695
| R45 2.7 ±10% 1/2 w | REW-3 | 1 | V | 300 K V | IN695
| R46 47 M ± 5% 1/2 w | REW-3 | 1 | V | 300 K V | IN695
| R47 3 k ± 10% 2 w | REW-3 | 1 | V | 300 K V | IN695
| R48 3 k ± 10% 2 w | REW-3 | 1 | V | 300 K V | IN695
| R49 3 k ± 10% 2 w | REW-3 | 1 | V | 300 K V | IN695

| **WI** | 5886 | V4 | 081-8W(RCA) | 0B2 | 0B2 |
| **V2** | CK6418 | V3 | 6ANS | V7 | 0B2 |
| **V3** | 6ANS | V4 | 081-8W(RCA) | V8 | 0B2 |
| **V4** | 081-8W(RCA) | V5 | 0B2 | V5 | 0B2 |

### Fuses

| FUSE, 0.6-amp Slo-Bio 3AG (for 115-volt input) | F1 | V1 |
| FUSE, 0.3-amp Slo-Bio 3AG (for 230-volt input) | F2 | V2 |
| FUSE, 0.6-amp Slo-Bio 3AG (for 115-volt input) | F3 | V3 |
| FUSE, 0.3-amp Slo-Bio 3AG (for 230-volt input) | F4 | V4 |
Figure 14. Detailed Schematic Diagram for Type 1230-A D-C Amplifier and Electrometer.
S2 Shown in 30 mv Position

Diagram for Type 1230-A D-C Amplifier and Electrometer.
Figure 15. Elementary Schematic Diagram for Type 1230-A D-C Amplifier and Electrometer.
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