♦ PRECISION INSTRUMENTS FOR TEST AND MEASUREMENT ♦

1864-1644

Positive Polarity
Megohmmeter
User and Service Manual

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1864-1644 im/May 2011

IET LABS, INC.
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WARRANTY

We warrant that this product is free from defects in material and workmanship and, when properly used, will perform in accordance with applicable IET specifications. If within one year after original shipment, it is found not to meet this standard, it will be repaired or, at the option of IET, replaced at no charge when returned to IET. Changes in this product not approved by IET or application of voltages or currents greater than those allowed by the specifications shall void this warranty. IET shall not be liable for any indirect, special, or consequential damages, even if notice has been given to the possibility of such damages.

THIS WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO, ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE.

WARNING

OBSERVE ALL SAFETY RULES
WHEN WORKING WITH HIGH VOLTAGES OR LINE VOLTAGES.

Dangerous voltages may be present inside this instrument. Do not open the case
Refer servicing to qualified personnel

HIGH VOLTAGES MAY BE PRESENT AT THE TERMINALS OF THIS INSTRUMENT

WHENEVER HAZARDOUS VOLTAGES (> 45 V) ARE USED, TAKE ALL MEASURES TO AVOID ACCIDENTAL CONTACT WITH ANY LIVE COMPONENTS.

USE MAXIMUM INSULATION AND MINIMIZE THE USE OF BARE CONDUCTORS WHEN USING THIS INSTRUMENT.

Use extreme caution when working with bare conductors or bus bars.

WHEN WORKING WITH HIGH VOLTAGES, POST WARNING SIGNS AND KEEP UNREQUIRED PERSONNEL SAFELY AWAY.

CAUTION

DO NOT APPLY ANY VOLTAGES OR CURRENTS TO THE TERMINALS OF THIS INSTRUMENT IN EXCESS OF THE MAXIMUM LIMITS INDICATED ON THE FRONT PANEL OR THE OPERATING GUIDE LABEL.

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1864-1644 Front-panel Controls, Connectors and Indicators

1. Determine which ground link connection is to be used (paragraph 3.1.1).

2. Set the **TEST VOLTAGE** switch(es) to the proper voltage (paragraph 3.1.2).

3. Set the ∞ adjustments (paragraph 3.1.3).

4. Connect the unknown to the **UNKNOWN** terminals.

5. Measure the unknown with either the search (paragraph 3.2.2) or sort (paragraph 3.2.3) procedure.

Specifications

1864-1644 Specifications

Voltage Setting	Rmin (Full Scale left end) ("0.5" rdg)	Rmax (right end)		Useful Ranges
		(10% of scale) ("5" rdg)	(2.5% of scale) ("20" rdg)	
10 Vdc to 50 Vdc	50 kΩ	500 GΩ	2 TΩ*	7
50 Vdc to 100 Vdc	200 kΩ	5 TΩ	20 TΩ	8
100 Vdc to 500 Vdc	500 kΩ	5 TΩ	20 TΩ*	7
500 Vdc to 1090 Vdc	5 MΩ	50 TΩ	200 TΩ	8

*Recommended Limit

Range Accuracy (min reading 0.5):

Range 1-5: ±2 (meter reading+1)%
Where meter reading is the actual number indicated at the scale; e.g. for a reading of 900 kΩ on the 1 GΩ scale, the accuracy is ±2(.9+1)% or 3.8%

Range 6: add ±2% to accuracy above

Range 7: add ±3% to accuracy above

Range 8: add ±5% to accuracy above

Accuracy applies for >100 V;
For <100 V add 2%.

Meter Display:
Full mechanical zero at right end, so 2.5 % full-scale is near right end and full-scale is at left end. However, resistance values read naturally, increasing from left to right.

Voltage Accuracy (across unknown):
For >100 V ± 2%
For <100 V ± 4%

Short-Circuit Current:
Approximately 5 mA

Power:
100 - 125 *or* 200 - 250 V
50 - 400 Hz
13 W

Fuse:
For 100 to 125 V operation: 1/8 A
For 200 to 250 V operation: 1/16 A
Fuse holder is located under the IEC receptacle and holds a 5 x 20 mm fuse.

Dimensions:
6.63 x 10 x 6.75 in.

Weight:
9.5 lb.

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Chapter 1
INTRODUCTION

WARNING

High voltage is applied to the measurement terminals of 1864-1644 Megohmmeters at all times, except when the function switch is set to DISCHARGE. While the current is limited to a value that is not dangerous under most conditions, the energy stored in a capacitor connected to the terminals may be LETHAL. Always set the function switch to DISCHARGE before you connect or disconnect the unknown.

1.1 Description

The 1864-1644 (Figure 1-1) indicates resistance from 50 kΩ to 200 TΩ. These ranges are suitable for leakage-resistance measurements of most types of insulation used in electrical instruments, electronic devices and components, etc (Section 4). The 1864 has a voltage range from 10 to 1090 V that can be set in 1 Vdc steps from 10 to 109 V, and in 10 V steps from 100 to 1090 V by using the TEST VOLTAGE switches on the front panel.

The 100-volt setting is the EIA standard for measurement of composition, film, and wire-wound resistors above 100 kilohms. The 500-volt setting is a standard value in the measurement of the insulation resistance of rotating machinery, transformers, cables, capacitors, appliances, and other electrical equipment.

A regulated power supply and charging circuit permit rapid and accurate measurement of the leakage resistance of capacitors.

Guard and ground terminals permit measurement of grounded or ungrounded two-or three-terminal resistors.

A panel warning light indicates when voltage is applied to the test terminals and alerts users to the safe operation of the instrument.

1.2 Opening and Tilting the Cabinet

To open the cabinet, refer to the pictorial graphic on the rear panel of the unit; see Figure 1-2. The Flip-Tilt cabinet can be opened by placing the instrument on its rubber feet with the handle away from you. Push down on the handle and the instrument, located in the upper part of the case, will rotate to a vertical position. While holding the handle down with one hand, rotate the instrument to the desired position with the other hand and then slowly release the handle.

1.3 Controls, Connectors and Indicators

Figure 1-1 shows the front-panel controls, connectors and indicators of the 1864. Table 1-1 lists and identifies them. Figure 1-2 shows the rear panel controls and connectors, and Table 1-2 lists and identifies them.

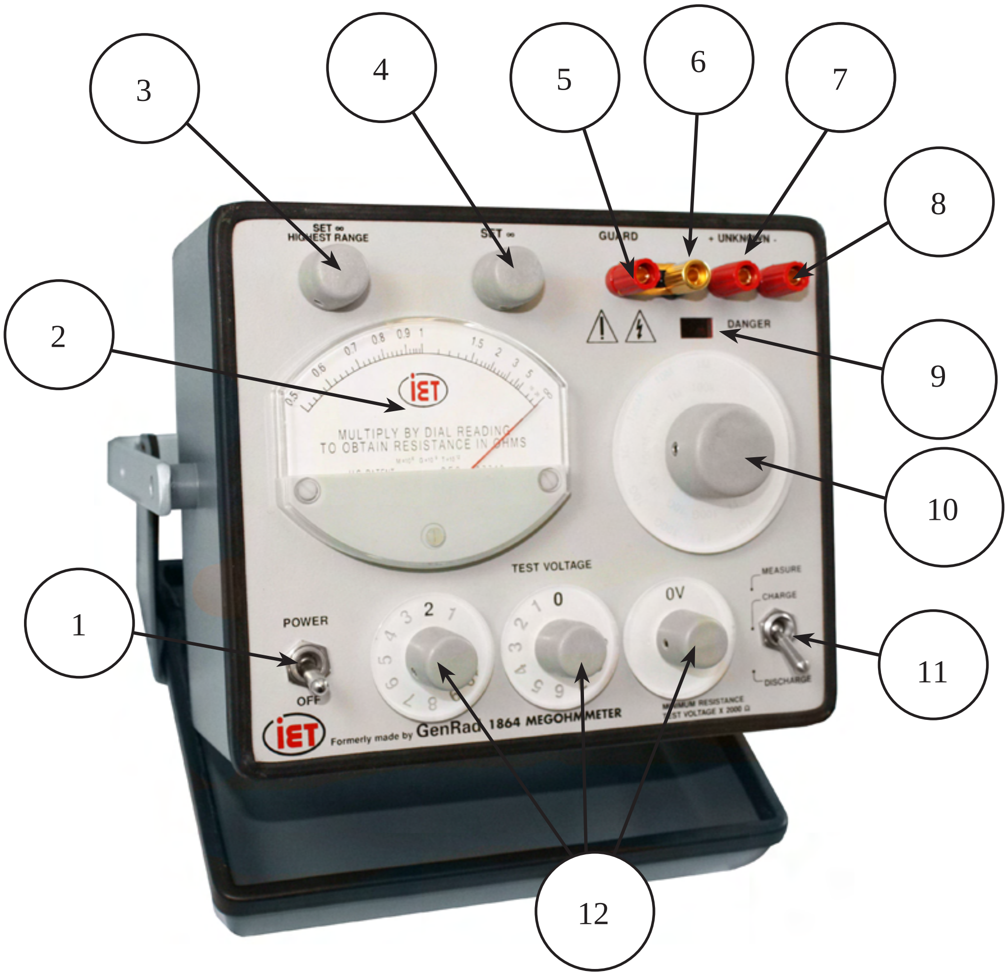

Figure 1-1. Type 1864-1644 Front-panel Controls, Connectors and Indicators

Figure 1.1 Reference	Name	Type	Function
1	POWER OFF	2-position toggle switch	Turn power on and off.
2	Meter	4-in. meter with plastic cover	Indicates the value to be multiplies by the multiplier switch.
3	SET ∞ HIGHEST RANGE	Knob-rotated control	Adjusts high end of meter scale on highest resistance range to compensate for offset current.
4	SET ∞	Knob-rotated control	Adjusts high end of meter scale on highest resistance range to compensate for offset voltage in the voltmeter.
5	GUARD	Insulated binding post	For guarded measurements. It can accept a shorting link to the ground post.
6	Ground	Uninsulated binding post	Grounds the Unknown- or guard. Contains a shorting link.
7	UNKNOWN -	Insulated binding post	Connects the - side of the unknown to the megohmmeter.
8	UNKNOWN +	Insulated binding post	Connects the + side of the unknown to the megohmmeter.
9	DANGER	Indicated light shaded red	Glows red when the function switch is in the CHARGE or MEASURE position.
10	Multiplier	8-position rotary switch	Selects resistance range.
11	MEASURE CHARGE DISCHARGE	3-position toggle switch	Selects the operating position applied to the unknown.
12	TEST VOLTAGE	3 rotary switches: 10-position 9-position 2-position	Select voltage in 1-V steps from 10 to 109 V and in 100-V steps from 100 to 1090 V.

Figure 1-2. Type 1864-1644 rear-panel controls and connectors

Table 1.2.

Figure 1-2 Reference	Name	Type	Function
1	Power Input	IEC Standard Power input receptacle.	Power input and circuit protection
2	Output	Phone jack	Provides a dc voltage output for recorder operation
3	Line Voltage	2-position slide switch	Connects wiring of power transformer for either 100 to 125 V or 200 to 250 V input
4	1/8 Amp	Integral fuse holder	Holder for 5 x 20 mm **For 100 to 125 V operation:** 1/8 A fuse **For 200 to 250 V operation:** 1/16 A fuse

1.4 Symbols

These instruments indicate the resistance of the unknown in multiples of ohms. The relationship between ohms (Ω), kilohms (kΩ), megohms (MΩ), gigaohms (GΩ), and teraohms (TΩ) is as follows:

1 MΩ= 10^6 Ω = 10^3 kΩ

I GΩ= 10^9 Ω = 10^6 kΩ= 10^3 MΩ

1 TΩ = 10^{12} Ω = 10^9 kΩ = 10^6 MΩ= 10^3GΩ

1.5 Connections

The UNKNOWN, GUARD and ground terminals are standard 3/4-in. spaced binding posts that accept banana plugs, standard telephone tips, alligator clips, crocodile clips, spade terminals and all wire sizes up to number eleven (Figure 1-3).

When several measurements of components with leads are to be made, consult IET for an appropriate test jig or fixture.

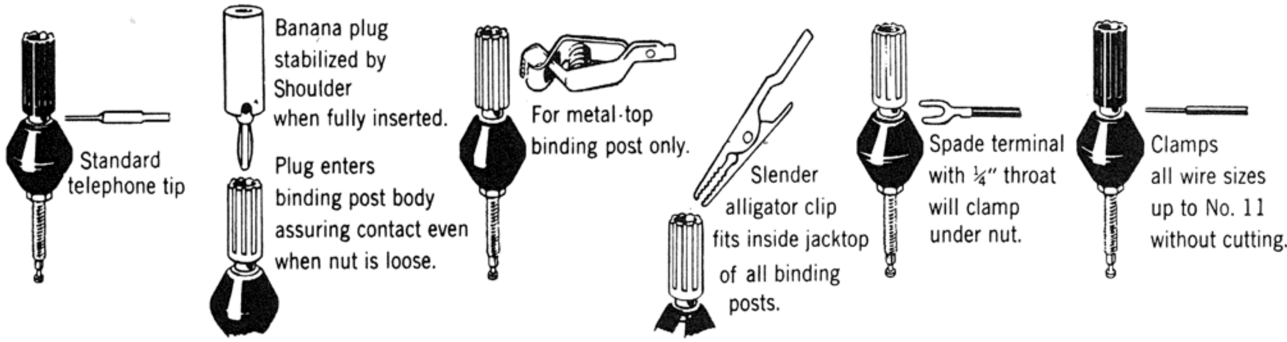

Figure 1-3. Methods of connection to the measurement terminals

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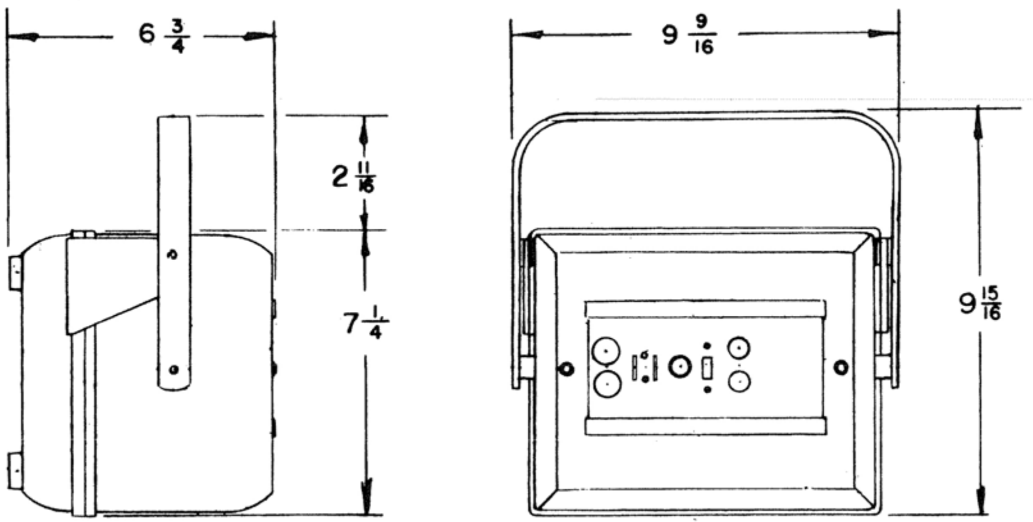
Chapter 2
INSTALLATION



Dimensions in inches

BENCH MOUNTED

Figure 2-1. Dimensions of the GR/IET 1864-1644 Megohmmeters

2.1 Initial Inspection

IET instruments receive a careful mechanical and electrical inspection before shipment. Upon receipt, verify that the contents are intact and as ordered. The instrument should then be given a visual and operational inspection.

If any shipping damage is found, contact the carrier and IET Labs. If any operational problems are encountered, contact IET Labs and refer to the warranty at the beginning of this manual.

Save all original packing material for convenience in case shipping of the instrument should become necessary.

2.2 Dimensions

The dimensions of the 1864-1644 are shown in both the rack and bench-mounted configurations in Figure 2-1.

2.3 Repackaging for Shipment

If the instrument is to be returned to IET Labs, contact the Service Department at the number or address, shown on the front cover of this manual, to obtain a "Returned Material Authorization" (RMA) number and any special shipping instructions or assistance. Proceed as follows:

1. Attach a tag with the following:
   - Owner's Name
   - Model Number
   - Serial Number
   - RMA Number
2. Wrap the instrument in heavy paper or plastic.
3. Protect the front panel and any other protrusions with cardboard or foam padding.
4. Place instrument in original container or equally substantial heavy carton.
5. Use packing material around all sides of instrument.
6. Seal with strong tape or bands.
7. Mark shipping container "DELICATE INSTRUMENT," "FRAGILE," etc.

2.4 Storage

If this instrument is to be stored for any lengthy period of time, it should be sealed in plastic and stored in a dry location. It should not be subjected to temperature extremes beyond the specifications. Extended exposure to such temperatures can result in an irreversible change in resistance, and require recalibration.

2.5 Bench Setup

The bench (portable) model of the megohmmeter is cased in a Flip-Tilt cabinet. The cabinet opens by pushing down on the handle and tipping the instrument into the desired operating position (paragraph 1.2).

2.6 Rack Mounting

Consult IET Labs.

2.7 Power Connections

The 1864-1644 Megohmmeter can be operated from either a 100- to 125-V or a 200- to 250-V, 50-to 60-Hz power line. Before connecting the 3-wire IEC power cord to the line, set the slide switch on the rear panel to the proper setting as indicated by the position of the white line on the slide switch. The slide can be actuated with a screwdriver blade. Verify that the correct size fuse for the input voltage selected has been installed (1/8 A slow blow for 100-125 V input or 1/16 A slow blow for 200-250 V input). If it is necessary to use a 3-wire adaptor plug, make certain that the third wire is connected to a good ground (water pipe or equivalent). If this is not possible, connect the panel of the 1864-1644 (uninsulated binding post) to a good ground. Plug the supplied IEC power cord into the instrument into a power receptacle. The power cord may of course be selected to match the available receptacle.

Chapter 3
OPERATION

3.1 Measurement Setup

3.1.1 Ground-Link Connection

The grounding link connected to the uninsulated, grounded, binding post can be connected from this ground terminal to the **GUARD** (paragraph 4.6) or the **+UNKNOWN** terminal (Figure 31). The ground link should be connected to the **GUARD** terminal if the sample to be measured is a small, separate component, or if it is a component mounted in an enclosure that should be guarded (see paragraph 4.6). However, if one terminal of the unknown must be grounded, then the link should tie the **+UNKNOWN** terminal to the instrument case. See Figure 3.1.

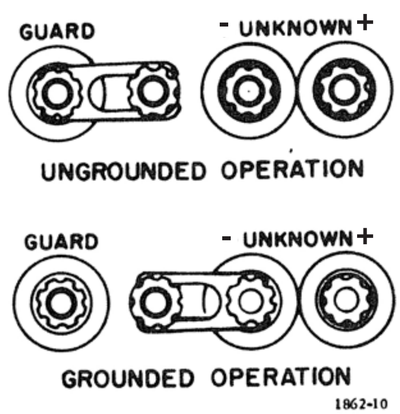


Figure 3-1 Ground-link connection to GUARD terminal (top) and to -UNKNOWN terminal (bottom)

3.1.2 Test Voltage Selection

The **TEST VOLTAGE** switch(es) should be set to the desired measurement voltage. The 1864-1644 Megohmmeter has a selection of 10 to 109 Vdc in 1-V steps or 100 to 1090 Vdc in 10-V steps. On the 1864, the right-hand **TEST VOLTAGE** switch must be set to the **V** position for the low voltages and to the **0 V** position for the high voltages.

3.1.3 Set ∞ Adjustments

To adjust the **SET** ∞ controls, proceed as follows:

1. Turn the instrument on.
2. Set the function switch to **DISCHARGE**.
3. Set the multiplier dial to any range.
4. Make certain that there nothing is connected to the **UNKNOWN** terminals.
5. Adjust the **SET** ∞ control for an ∞ reading on the meter.
6. Set the multiplier switch to 10-1T
7. Set the function switch to **MEASURE**.
8. Adjust the **SET** ∞ **HIGHEST RANGE** for an ∞ meter reading.

If this adjustment cannot be made electrically, turn the instrument off, and adjust the mechanical meter zero adjustment (the center screw on the meter) to give a meter reading of less than a line width beyond ∞. Repeat steps 1 through 7.

3.1.4 Connection of Unknown

Small components should be connected directly to the **UNKNOWN** terminals. Insulated leads can be connected to a nearby unknown; however, if the unknown resistance is high, leakage between the leads will cause a measurement error, and a change in capacitance to the high lead will cause a transient meter deflection. For such high resistance measurements, a shielded system is preferable (refer to paragraph 4.7).

3.2 Measurement Procedure

3.2.1 General

Either of two measurement procedures may be used, depending on whether or not the correct resistance-multiplier range is known. If the range is not known, the search procedure (paragraph 3.2.2) should be followed. If repetitive measurements are to be made on a given range (i.e., if similar components are to be sorted) the sort procedure (paragraph 3.2.3) should be used.

3.2.2 Search Procedure

When the approximate resistance of the sample to be measured is not known, proceed as follows:

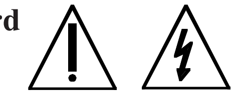
1. Set the multiplier switch to the lowest range.
2. Set the function switch to **DISCHARGE**.
3. Connect the unknown between the **UNKNOWN** + and - terminals.
4. Set the function switch to **MEASURE**.
5. Rotate the multiplier switch cw until the meter gives a reading of less than 5.
6. The resistance of the unknown is the meter reading multiplied by the multiplier-switch indication.
7. Make measurements towards the low end of the meter scale whenever possible, for best accuracy and resolution.

3.2.3 Sort Procedure

When the approximate resistance of the unknown is known, proceed as follows:

1. Set the function switch to **DISCHARGE**.
2. Set the multiplier switch to the desired range.
3. Connect the unknown between the **UNKNOWN +** and **-** terminals.
4. Set the function switch to **MEASURE**.
5. The resistance of the unknown is the meter reading multiplied by the multiplier-switch indication. For go-no-go checks, it can be useful to make high-and-low limit lines on the outside of the meter case with strips of masking tape.
6. Make measurements towards the low end of the meter scale whenever possible, for best accuracy and resolution.

3.2.4 Shock Hazard



Every precaution has been taken in the design of 1864 Megohmmeters to reduce the possibility of shock. However, high voltage must be present at the terminals to make measurements at the required voltage levels, and the operator should be aware of the dangers involved.

The current delivered by the megohmmeters under short-circuit conditions is approximately 5 mA. This 5-mA current is not lethal to most persons but might be lethal to those with poor hearts, and it is painful to all. The actual current that will flow through a person depends on the resistance of the part of the body that makes contact with the terminals. This resistance can be as low as 300 Ω. Note that any of the three insulated binding posts can be at high voltage, depending on the position of the shorting link.

When capacitors are tested there is an especially dangerous condition because a charged capacitor easily can have enough energy to cause heart fibrillation and death. The capacitor should always be shunted before connection to the megohmmeter, and the function switch should be set to **DISCHARGE** for a few seconds before the capacitor is disconnected.

We strongly recommend that additional precautions, such as rubber gloves and insulated benchtops, chairs and shoes should be used for anyone making repetitive measurements with the megohmmeter, particularly measurements on capacitors. These precautions should not take the place of careful discharge of the capacitors before and after measurement, but should be used as an additional safety measure.

3.3 Output Jack

The OUTPUT jack (J105) on the rear panel makes accessible a dc voltage that is directly proportional to the reciprocal of the meter reading, that is, the highest value is at the 0.5 scale reading and the lowest value is at ∞. The output voltage for a particular multiplier-switch setting can be calculated by

$$V_{OUT} = 0.02 \times V_{TEST} \times \frac{R_{RANGE}}{R_X}$$

where $\mathbf{V_{TEST}}$ is the **TEST VOLTAGE** setting, $\mathbf{R_{RANGE}}$ is the lower value for a particular multiplier-dial setting (100k for the 1 M/100 k range) and $\mathbf{R_x}$ is the value of the resistance being measured.

The output can be stored in a data file for plotting, display, or analysis. It can also feed the user's go/no-go indicator. The full-scale voltage value for any test voltage can be calculated from the $\mathbf{V_{out}}$ formula using 0.5 times the measurement range as the $\mathbf{R_x}$ value. These values are available on the 1864 along with the other levels that can be set with the variable **TEST VOLTAGE** switches (see table 3-1).

Table 3-1
OUTPUT VOLTAGE*

	Lower Multiplier-Dial Setting		Upper-Multiplier-Dial Setting		
Test Voltage (V)	50	100	200	250	500
Full-Scale Output Voltage (V)	2	4	0.8	1	2

*V_{OUT} at 0.5 scale reading.

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Chapter 4
APPLICATIONS

4.1 Insulation Testing

The insulation resistance of electrical machinery, transducers, etc, is one of several parameters that may indicate the condition of the insulation. Routine measurement of capacitance, dissipation factor, and leakage resistance provides useful data for monitoring the condition of the insulation and for guarding against incipient breakdown.

A routine test that has been widely adopted for insulation testing calls for the measurement of the apparent leakage resistance after a test voltage has been applied for one minute and again after the test voltage has been applied for 10 minutes. The ratio of the indicated resistances, sometimes referred to as the Polarization Index, can have some relation to the condition of the Insulation. The results of such a measurement are apt to be more dependent on the dielectric absorption of the insulator than on its true leakage resistance measured at equilibrium. A complete charge-current-vs-time plot will provide more useful information.

The 1864-1644 Megohmmeters can be used for either true leakage measurements or for measurements at 1-or 10-minute intervals following the operating procedure described in Section 3.

MIL-STD-202C gives procedures for insulation-resistance measurements of various components. On large machinery, one terminal must usually be grounded. The 1864-1644 Megohmmeter is designed so that the binding post grounding strap should be connected between the ground terminal and the **-UNKNOWN** terminal.

To determine the charge current, divide the test voltage by the indicated resistance. At the start of a charge-current-vs-time plot, the meter will be off scale. The resistance in series with the insulator is the reading of the upper dial multiplier divided by 500. Table 4-1 lists dial readings and resistor values.

Table 4-1

STANDARD RESISTOR VALUES (R_s)

Multiplier Range Lower Dial: 50, 100 V* 10 to 109 V†	Multiplier Range Upper Dial: 200, 250, 500 V* 100 to 1000 V†	Value (Ω)
100 k	1M	2 k
1 M	10 M	20 k
10 M	100 M	200 k
100 M	1 G	2 M
1 G	10 G	20 M
10 G	100 G	200 M
100 G	1 T	2G
1 T	10 T	2 G with feedback multiplication

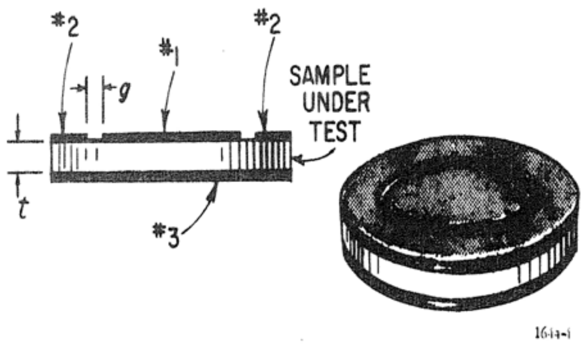

Figure 4-1. Electrode arrangement for resisitivity measurements

4.2 Test Sample Resistivity Measurements

The megohmmeter can be used for measuring the resistivity of test samples as described by ASTM Standard D257, which describes in detail the techniques for both surface-and volume-resistivity measurements. The most common electrode arrangement is that shown in Figure 4.1. In this configuration surface resistivity is measured with terminal 1 tied to the **-UNKNOWN** terminal, terminal 2 tied to the **+UNKNOWN** terminal and terminal 3 tied to **GUARD**. For volume resistivity measurements, terminal 1 is tied to the **-UNKNOWN** terminal, terminal 2 to the **GUARD** and terminal 3 to the **+UNKNOWN** terminal. The formulas required to convert from measured resistance to resistivity are given in the ASTM standard. Contact IET regarding the availability of resistivity test fixtures.

4.3 Capacitor Insulation Resistance

4.3.1 General

The insulation resistance, IR, of capacitors is measured by either the search or sort method (paragraph 3.2.2 and 3.2.3) used for resistors, except that some consideration must be given to the charge and discharge currents.

WARNING

Capacitors being measured may be charged and may contain lethal energy. Always set the function switch to DISCHARGE before connecting or disconnecting the capacitor under test.

4.3.2 Charging Time Constant

The time constant for charging a capacitor in the **CHARGE** position is determined by the value of the capacitor times the effective source impedance of the supply. The supply resistance is approximately,

$$R_0 = \frac{E}{I_{MAX}}\,\Omega = \frac{E}{0.005A}\,\Omega = \frac{E}{5}\,k\Omega$$

where E is the indicated test voltage in volts and I_{MAX} is the short-circuit current, which is approximately 5 mA. Therefore, the time constant is:

$$T = R_0 C_x = \frac{EC_X}{5000}\ \text{seconds}$$

where C_x is in µF. As an example, on the 500 V range, R_0 is approximately 100 kΩ so that the time constant for charging of a 1 µF capacitor is 0.1 s.

The time necessary for full charging depends on the type of capacitor and the leakage current that is to be measured. A capacitor with no dielectric absorption will have a charging current that decreases by a factor of 2.72 (the natural logarithm to the base e) for every time constant it is left in the **CHARGE** position.

Thus, the effective resistance at any moment is $R_0 E^{\left(\frac{t}{R_0 C_x}\right)}$. The capacitor could be considered fully charged when this resistance is substantially higher than the true leakage resistance, even though the charging current theoretically never reaches zero. As an example a 1 µF capacitor, with a leakage resistance of $10^{10}\Omega$ measured at 500 V, would have less than 1% error due to charging current, if measured after seventeen time constants, or 1.7 s.

Dielectric absorption (dipole and interfacial polarization) is present in many capacitors and insulators, especially those with a laminated structure. When voltage is applied to such material, the charge slowly diffuses throughout the volume and several minutes, hours, or even days, are required for equilibrium in order to make the charging current small compared with the true leakage current. A measure of this effect, called the Polarization Index, is the ratio of the resistance measured after 10 minutes of charging to that measured after 1 minute of charging. Often, the measured resistance after 1 minute of charging is called the insulation resistance, even though charging current may be much larger than the true leakage current. (Some capacitor specifications say less than 2 minutes).

4.3.3 Measurement Time Constant

When the function switch is set from the **CHARGE** position to the **MEASURE** position, the standard resistor is placed in series with the unknown capacitor. If the supply voltage is fixed, the capacitor must discharge by a voltage equal to that across the voltmeter at its final reading. The time constant for this discharge would be $C_X R_s$. Because 80% of the output voltage is fed back to the supply, this time constant is reduced by a factor of 5. As a result, the time necessary for an indication, assuming an ideal capacitor, depends on this time constant or that of the meter movement, whichever is longer.

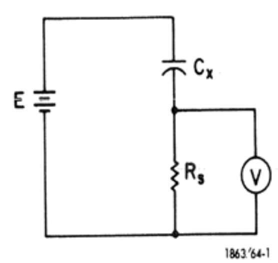

Figure 4.2 Basic megohmmeter circuit

4.3.4 Discharge Time

With the function switch set at **DISCHARGE**, the **UNKNOWN** terminals are connected through 470 Ω and the discharge time is approximately

0.0005 x C µs, where C is in µF. The red **DANGER** light is turned off by the function switch, so that the capacitor might be charged even after the light is extinguished. However, the discharge time is so short that this is not a practical consideration, except for capacitors greater than 100 µF.

Capacitors with high dielectric absorption (paragraph 4.3.2) can have a residual charge even after they are shunted and must be repeatedly shunted to be completely discharged. Usually this "voltage recovery" is only a few percent (i.e., 3%) of the original applied voltage and, therefore, not dangerous to the operator, but it can cause damage to sensitive circuit elements.

4.3.5 Large Capacitors, Very High Resistance

Measuring insulation resistance of large capacitors that have very low leakage is difficult by any method. Considering the basic circuit of Figure 4.2, if R_S is high, the $R_S C_X$ time constant can become very long on the high resistance ranges if C_X is large. If R_S is low, the voltmeter must be very sensitive for a given leakage resistance range and, therefore, the supply voltage (E) must be extremely stable to avoid large meter fluctuations. The design of the 1864 is a compromise between these factors. Measurements become difficult when the $R_S C_X$ product is 10^6, even under ideal conditions. This can be calculated as (C_X in µF) x (R_S in MΩ) or (C_X in F) x (R_S in Ω). Table 4.1 contains values for R_S

Measurements can be unsatisfactory even below this value for an $R_S C_X$ product for several reasons:

1. Dielectric absorbtion. (paragraph 4.3.2). This is the main cause of erroneous readings. Besides the difficulty in deciding what charging period should be used, the previous history of the capacitor will greatly affect its indicated leakage. For example, if a paper capacitor is charged to its rated value, discharged for a short time, and then its leakage current is measured at some low value, it probably will give a reading beyond ∞. This is due to voltage recovery that is a consequence of dielectric absorbtion. The voltage across the capacitor will increase above the test voltage causing current to flow in the reverse direction.

2. Temperature coefficient. If the temperature on the unknown changes and it has an appreciable temperature coefficient, the voltage on the capacitor will change in the **MEASURE** position. If R_S is large, the charge (Q) of the capacitor is more-or-less constant, so if its capacitance changes, its voltage must change (Q=CV). A temperature-controlled environment is recommended.

3. Test voltage changes. The test voltage can have rapid fluctuations due to large line-voltage transients even though good regulation is provided in the instrument, because when $R_S C_X$ is large, the test voltage fluctuations are transmitted to the voltmeter unattenuated. This difficulty can be reduced if the line voltage is regulated. Slow drift of the test voltage can cause erroneous readings if $R_S C_X$. is large, because even a slow drift rate can be fast compared to the $R_S C_X$ time constant. A decreasing test voltage can cause a reading beyond. Sufficient warm-up time (30 minutes) will allow the temperature inside the megohmmeter to stabilize and result in a more constant voltage at the **UNKNOWN** terminals.

4.4 Resistance Measurements

The recommended test voltage is 100 V for fixed composition resistors, film resistors, and wire-wound resistors above 100 kΩ. (Refer to EIA Standards RS172, RS196, and REC 229.) These resistors can be measured easily on the megohmmeter as long as the accuracy of the instrument is adequate. If the resistors are separate, we suggest that they be measured ungrounded (with the grounding link connected to the GUARD terminal).

4.5 Measurement of Voltage Coefficient

The 1864 Megohmmeter may be used to measure voltage coefficient as long as its accuracy is adequate. The voltage coefficient of resistance is defined as:

$$\frac{R_1 - R_2}{R_2(V_1 - V_2)} \times 100\%$$

where V1 > V2
R1 is the resistance at V1, the higher voltage
R2 is the resistance at V2

For example, if V1 = 500 V and V2 = 100 V

$$\text{Voltage coefficient} = \frac{R_{500V} - R_{100V}}{(400)R_{100V}} \times 100\%$$

$$= \frac{1}{4}\frac{\Delta R}{R_{100V}}\ \%$$

This voltage coefficient is usually negative (except for reversed semiconductor junctions).

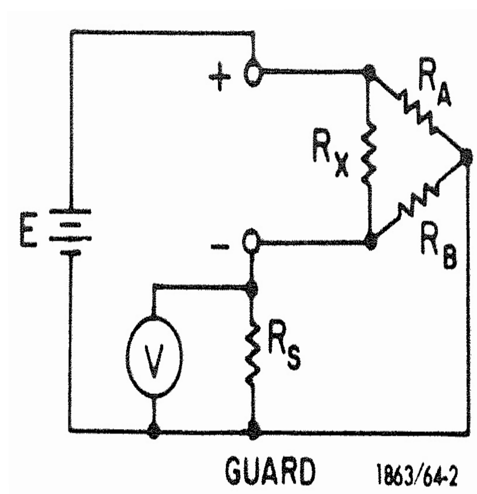

Figure 4-3. Guarded measurement of a three-terminal resistor

4.6 Guarded 3-Terminal Measurements

In many cases it is necessary to measure the resistance between two points in the presence of resistance from each of these points to a third point. This third point can often be guarded to avoid error caused by the extraneous resistances.

This situation can be shown diagrammatically as a three-terminal resistor (Figure 4-3). Here, R_X is the quantity to be measured in the presence of R_A and R_B. If the junction of R_A and R_B is tied to a guard, R_A is placed across the power supply and has no effect if it is greater than 500 kΩ. R_B shunts R_S and causes a much smaller error than that which would be present if no guard were used. The error is approximately $-R_S/R_B$ x 100%, where R_S equals the value shown in Table 4-1 for the various ranges. If a choice is possible, the higher of the two stray resistances should be connected as R_B.

The guard terminal can be used whether the **GUARD** or the **+ UNKNOWN** terminal is grounded, but note that if the **+UNKNOWN** terminal is grounded, the **GUARD** terminal will be a high (negative) voltage level. Often the terminal to be guarded is a large chassis and it is, therefore, safer to ground the **GUARD** terminal. If this third terminal is true ground then the **GUARD** terminal ***must be grounded***.

4.7 Remote Shielded Measurements

Measurements can be made on components that are some distance from the instrument if care is used to prevent leakage between the connecting leads and to avoid the shock hazard. A convenient way to do this is to use a shielded cable. If the unknown can be measured ungrounded, make the connection to the **+UNKNOWN** terminal with the shielded lead, tie the shield to the GUARD terminal, and connect the **GUARD** terminal to the panel ground with the connecting link. If one side of the unknown must be grounded, connect the grounding link to the **+UNKNOWN** terminal, shield the **+UNKNOWN** terminal, and tie the shield to the **GUARD** terminal. In this instance, the shield is not at ground potential and should be insulated.

4.8 Measurements Under Humid Conditions

The 1864 Megohmmeter has been designed to operate under conditions of high humidity but, nevertheless, a few simple precautions should be taken to ensure accurate measurements. These precautions are:

1. Allow several minutes warmup (internal heat will reduce humidity inside the instrument).
2. Clean the binding-post insulation with a dry, clean cloth.
3. Use ungrounded operation (tie the GUARD terminal to the panel ground).

To determine the presence of errors due to humidity, measure the resistance between the binding posts with no external connections. Note that with the **+UNKNOWN** terminal grounded, breathing on the terminals will cause a meter deflection because leakage from the insulator of the **-UNKNOWN** terminal to the panel is measured.

Actually, this problem is somewhat academic because the unknown to be measured is usually much more severely affected by humidity than is the megohmmeter.

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Chapter 5
THEORY

5.1 General

The 1864 Megohmmeter basically consists of a regulated dc power supply, a set of precision resistors, and a FET-input voltmeter (Figure 5.1). Switch S_1 is closed in the **DISCHARGE** position of the function switch and open in the CHARGE and **MEASURE** positions, while S_2 is open only in the **MEASURE** position.

The regulated voltage, E, is controlled by a resistance R_A. A meter sensitivity resistor, R_B , is ganged to the voltage control resistor, $R_{A,}$ to make the meter reading independent of applied voltage, (assuming that the unknown has no voltage coefficient). An inverse scale is used on a reversed meter to give a reading proportional to R_X (and not its reciprocal) and yet have a scale that increases from left to right (0 to ∞).

Metal-film standard resistors are used on all ranges. The top range of each instrument uses feedback to effectively multiply the value of the previous standard resistor by a factor of ten. In the 1864 the 2 GΩ resistor is multiplied to 20 GΩ. The specifications are again broadened to allow for the tolerance variations of this multiplication.

The voltmeter uses a FET-input, four-stage, unity-gain amplifier (AMP, Figure 5.2) to obtain high stability and low drift. The **SET ∞** control on both instruments is a voltage balance control, while the **SET ∞ HIGHEST RANGE** control compensates for the FET gate current on the highest ranges.

5.2 Circuit Description

5.2.1 General

The following paragraphs will relate specific components from the schematic diagrams of the 1863 (Figure 7.6) and 1864 (Figure 7.9) to the general components shown in Figure 5.1.

5.2.2 Type 1863 Megohmmeter (Figure 7.6)

The voltage supply section (RECT.) of the 1863 consists of five different circuits, three dc and two ac. One ac circuit is a voltage source for the three pilot lamps used, two to indicate the measurement range (P101, P102) and the third to light the **DANGER** indicator (P103). The second supplies filament voltage to the vacuum tube V101.

The first dc supply is a half-wave rectifier circuit with a 24-V Zener diode (CR 111) that supplies voltages to the amplifier (AMP) circuit. A second dc supply is a voltage doubler (CR101-CR104, C101-C102) that supplies the plate voltage to V101. The voltage to the plate is the same for the 50- to 250-V ranges but R109 is eliminated from the circuit for the 500 V range. The third dc supply is a half-wave rectifier with a 20-V Zener diode (CR211) to supply voltage levels to run the unity-gain amplifier (+1).

Tube V101 is a series regulator that is controlled by the 5.6 V Zener diode (CR112, REF) and the setting of R140.The voltage picked off R 140 is fed into one side (Q102) of the differential amplifier (Q102, Q103) while part of the output voltage is fed into the other side (Q103). The output of the amplifier is fed to the base of Q101 (AMP) and then to the grid of V101 for controlling the output voltage.

The output selection resistors are R124 through R133. These resistors determine the TEST VOLTAGE level. Resistors R211 through R219 are the standard resistors (R_S) that determine the measurement range. The output from this circuit is fed through the **SET ∞ HIGHEST RANGE** control (R241) to the FET amplifier.

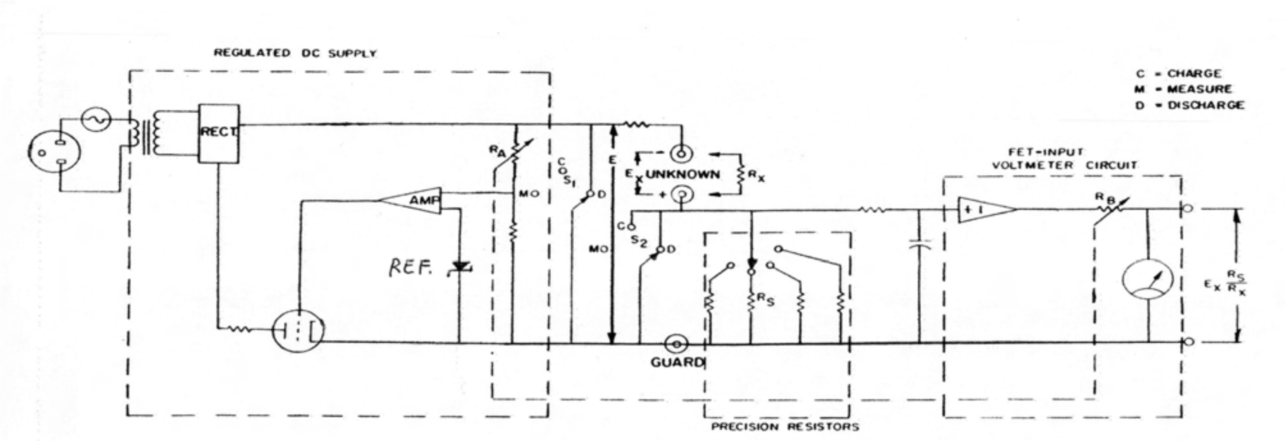

Figure 5-1. Megohmmeter block diagram.

Figure 5-1 Megohmmeter block diagram

A unity-gain FET-input amplifier (+1) follows the standard resistors in the circuit configuration. R210 and C203 comprise a low-pass filter input to FET Q204. The amplifier components include a differential amplifier (Q202, Q203), a coarse ∞ control (R244), the SET ∞ control (R242) and an output transistor (Q201). The signal then enters the series combination of R135 and R134 back to the GUARD terminal.

Resistors R221 through R223 (R_B) are meter-sensitivity resistors that are ganged to the voltage resistors R124 through R127 (R_A). R222 is used for both the 50 V and 500 V ranges, while the 200 V range uses the circuit resistance and has no added resistor. The remaining two resistors, R221 and R223, are used for the 250 and 100V ranges, respectively. Potentiometer R243 is an adjustable control in the meter sensitivity circuit.

5.2.3 Type 1864 Megohmmeter (Figure 7.9)

The circuit of the 1864 Megohmmeter is basically the same as that of the 1863 (paragraph 5.2.2). The exceptions are explained in the following paragraphs.

In the 1864 the second dc power supply is a quadrupler. This supply establishes the plate voltage of V101 with the use of resistors R109 through R114.

The regulator circuit has a slightly different input when the **TEST VOLTAGE** switch is switched from V (1) to 0 V (10). Resistors R124 and R125 are switched out of the circuit in the 0V (10) position.

Voltage-selection resistors for the 1864 are R126 through R133 and the meter sensitivity resistors are R221 through R228. An additional range resistor, R220, is in the 1864.

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Chapter 7
PARTS LISTS AND DIAGRAMS

ELECTRICAL PARTS LIST

1864 CHASSIS MOUNTED PARTS

REFDES	DESCRIPTION	PART NO.	FMC	MFGR PART NUMBER
C 110	CAP MYLAR .047UF 10 PCT 1000V	4860-8255	75042	663UW .047 UF 10PCT
C 111	CAP CER SQ .10UF 80/20PCT 100V	4403-4100	72982	8131M100651104Z
C 113	CAP CER DISC 6800PF 20PCT 1.4KV	4406-2689	72982	848-Z5U-6800PF20PCT
CR 106	RECT 1N4005 600PIV .75A SI A50A	6081-1003	14433	1N4005
CR 107	RECT 1N4005 600PIV .75A SI A50A	6081-1003	14433	1N4005
CR 108	DIODE RECTIFIER 1N4003	6081-1001	14433	1N4003
F 101	FUSE SLO-BLOW 1/8A 250V	5330-0450	75915	313 .125
F 102	FUSE SLO-BLOW 1/16A 250V	5330-0300	75915	313 .062
J 101	BINDING POST ASM	0938-3003	24655	0938-3003
J 102	BINDING POST ASM	0938-3022	24655	0938-3022
J 103	BINDING POST ASM	0938-3003	24655	0938-3003
J 104	BINDING POST ASM	0938-3003	24655	0938-3003
J 105	PHONE INS .281L 2 CKT	4260-1031	82389	N-111
M 101	METER	5730-1412	24655	5730-1412
P 101	LAMP FLANGE BASE 6V 0.2A 1000H	5600-0300	71744	CM-328
P 102	LAMP FLANGE BASE 6V 0.2A 1000H	5600-0300	71744	CM-328
P 103	LAMP FLANGE BASE 6V .04A 10000H	5600-0316	71744	CM-345
PL 501	CORD 3WR 10A 120V US 7FT HAMMER	4200-1800	24655	4200-1800
R 109	RES COMP 62 K 5PCT 1W	6110-3625	81349	RCR32G623J
R 110	RES COMP 68 K 5PCT 1W	6110-3685	81349	RCR32G683J
R 111	RES COMP 270 K 5PCT 1W	6110-4275	81349	RCR32G274J
R 112	RES COMP 120 K 5PCT 1/2W	6100-4125	81349	RCR20G124J
R 113	RES COMP 390 K 5PCT 1/2W	6100-4395	81349	RCR20G394J
R 114	RES COMP 1.2 M 5PCT 1/2W	6100-5125	81349	RCR20G125J
R 115	RES COMP 39 K 5PCT 1W	6110-3395	81349	RCR32G393J
R 116	RES COMP 47 K 5PCT 2W	6120-3475	81349	RCR42G473J
R 124	RES FLM 226K 1/2PCT 1/8W	6251-3226	81349	RN55D2263D
R 125	RES COMP 30 K OHM 5PCT 1/2W D	6100-3305	81349	RCR20G303J
R 126	RES FLM 499K 1/2 PCT 1/4W	6351-3499	81349	RN60D4993D
R 127	RES FLM 1M 1/2 PCT 1/2W	6451-4100	81349	RN65D1004D
R 128	RES FLM 2M 1/2 PCT 1/2W	6451-4200	81349	RN65D2004D
R 129	RES FLM 2M 1/2 PCT 1/2W	6451-4200	81349	RN65D2004D
R 130	RES FLM 49.9K 1/2 PCT 1/4W	6351-2499	81349	RN60D4992D
R 131	RES FLM 100K 1 PCT 1/4W	6350-3100	81349	RN60D1003F
R 132	RES FLM 200K 1 PCT 1/4W	6350-3200	81349	RN60D2003F
R 133	RES FLM 200K 1 PCT 1/4W	6350-3200	81349	RN60D2003F
R 137	RES COMP 11 OHM 5PCT 1/2W D	6100-0115	81349	RCR20G110J
R 141	RES COMP 30 K OHM 5PCT 1/4W D	6095-3305	81349	RCR07G303J
R 211	RES FLM 100K 1 PCT 1/8W	6250-3100	81349	RN55D1003F
R 212	RES FLM 11K 1 PCT 1/8W	6250-2110	81349	RN55D1102F
R 213	RES FLM 1.02M 1 PCT 1/2W	6450-4102	81349	RN65D1024F
R 214	RES FLM 2K 1/2PCT 1/8W	6251-1200	81349	RN55D2001D
R 215	RES FLM 20K 1 PCT 1/2W	6450-2200	81349	RN65D2002F
R 216	RES FLM 200K 1 PCT 1W	6550-3200	81349	RN75D2003F
R 217	RES FLM 2M 1 PCT 1/2W	6450-4200	81349	RN65D2004F
R 218	RES FLM 20M 1 PCT 1W	6550-5200	81349	RN75D2005F
R 219	RES FLM 200M 1PCT 100PPM 1W	6619-3407	24655	6619-3407
R 220	RES FILM CARBON 2G OHM 1 PCT	6740-1504	63060	RX-1
R 221	RES FLM 1.91K 1/2 PCT 1/4W	6351-1191	81349	RN60D1911D
R 222	RES FLM 3.83K 1/2 PCT 1/4W	6351-1383	81349	RN60D3831D
R 223	RES FLM 7.68K 1/2 PCT 1/4W	6351-1768	81349	RN60D7681D
R 224	RES FLM 7.68K 1/2 PCT 1/4W	6351-1768	81349	RN60D7681D
R 225	RES FLM 200 OHM 1 PCT 1/4W	6350-0200	81349	RN60D2000F
R 226	RES FLM 402 OHM 1 PCT 1/8W	6250-0402	81349	RN55D4020F
R 227	RES FLM 806 OHM 1 PCT 1/4W	6350-0806	81349	RN60D8060F
R 228	RES FLM 806 OHM 1 PCT 1/4W	6350-0806	81349	RN60D8060F
R 241	POT COMP KNOB 1K OHM 10 PCT LIN	6000-0300	01121	JAIN056S102UZ
R 242	POT COMP KNOB 2.5K OHM 10PCT LIN	6000-0400	01121	JAIN056S252UZ
R 245	RES WW AX LEAD 5.1K OHM 5PCT 3W	6680-2515	75042	AS-2 5.1 K 5PCT
S 101	SWITCH ROTARY ASM	7890-5350	24655	7890-5350
S 102	SWITCH ROTARY ASM	7890-5360	24655	7890-5360
S 103	SWITCH ROTARY ASM	7890-5370	24655	7890-5370
S 201	SWITCH ROTARY ASM	7890-5380	24655	7890-5380
S 202	SWITCH ASM	1864-0400	24655	1864-0400
S 501	SWITCH TOGGLE 2POS DPST STEADY	7910-1300	04009	83053
S 502	SWITCH SLIDE 2 POS DPDT STEADY S	7910-0832	82389	11A-1266
T 101	TRANSFORMER POWER	0345-4028	24655	0345-4028

ELECTRICAL PARTS LIST

REGULATOR & AMPLIFIER PC BOARD P/N 1864-2701

REFDES	DESCRIPTION	PART NO.	FMC	MFGR PART NUMBER
C 107	CAP ALUM 30 UF 75V	4450-6173	56289	43D300G075
C 108	CAP CER DISC .01UF 80/20PCT 100V	4401-3100	72982	0805540Z5U00103Z
C 109	CAP CER DISC 100PF 5PCT 500V	4404-1105	72982	0831082Z5D00101J
C 201	CAP ALUM 30 UF 75V	4450-6173	56289	43D300G075
C 202	CAP CER DISC .01UF 80/20PCT 100V	4401-3100	72982	0805540Z5U00103Z
C 203	CAP MICA 100PF 10PCT 500V	4620-1000	81349	CM15FD101K
CR 105	DIODE RECTIFIER 1N4003	6081-1001	14433	1N4003
CR 111	ZENER 1N970B 24V 5PCT .4W	6083-1054	14433	IN970B
CR 112	ZENER 1N753A 6.2V 5PCT .4W	6083-1006	14433	IN753A
CR 201	DIODE RECTIFIER 1N4003	6081-1001	14433	1N4003
CR 211	ZENER 1N968B 20V 5PCT .4W	6083-1018	14433	IN968B
CR 212	ZENER 1N965B 15V 5PCT .4W	6083-1015	14433	IN965B
Q 101	TRANSISTOR 2N3903	8210-1132	04713	2N3903
Q 102	TRANSISTOR 2N4250	8210-1294	07263	2N4250
Q 103	TRANSISTOR 2N4250	8210-1294	07263	2N4250
Q 201	TRANSISTOR 2N3903	8210-1132	04713	2N3903
Q 202	TRANSISTOR 2N3905	8210-1114	04713	2N3905
Q 203	TRANSISTOR 2N3905	8210-1114	04713	2N3905
Q 204	TRANSISTOR(STATIC PROTECT REQ)	8210-1143	04713	2N4220
Q 205	TRANSISTOR MPS-A14	8210-1246	04713	MPS-A14
Q 206	TRANSISTOR 2N3414	8210-1290	56289	2N3414
R 107	RES COMP 2.0 K OHM 5PCT 1/2W	6100-2205	81349	RCR20G202J
R 108	RES COMP 1.0 K 5PCT 1/2W	6100-2105	81349	RCR20G102J
R 117	RES COMP 220 OHM 5PCT 1/2W	6100-1225	81349	RCR20G221J
R 118	RES COMP 200 K OHM 5PCT 1/2W	6100-4205	81349	RCR20G204J
R 119	RES COMP 12 K 5PCT 1/2W	6100-3125	81349	RCR20G123J
R 120	RES COMP 8.2 K 5PCT 1/2W	6100-2825	81349	RCR20G822J
R 121	RES COMP 10 K 5PCT 1/2W	6100-3105	81349	RCR20G103J
R 122	RES COMP 10 K 5PCT 1/2W	6100-3105	81349	RCR20G103J
R 123	RES FLM 24.9K 1/2PCT 1/8W	6251-2249	81349	RN55D2492D
R 134	RES COMP 68 K 5PCT 1/2W	6100-3685	81349	RCR20G683J
R 135	RES COMP 16 K OHM 5PCT 1/2W	6100-3165	81349	RCR20G163J
R 138	RES COMP 22 K 5PCT 1/2W	6100-3225	81349	RCR20G223J
R 139	RES FLM 200K 1 PCT 1/4W	6350-3200	81349	RN60D2003F
R 140	POT WW TRM 5K OHM 10 PCT 1T	6056-0142	24655	6056-0142
R 201	RES COMP 1.2 K 5PCT 1/2W	6100-2125	81349	RCR20G122J
R 202	RES COMP 2.7 K 5PCT 1/2W	6100-2275	81349	RCR20G272J
R 203	RES COMP 27 K 5PCT 1/2W	6100-3275	81349	RCR20G273J
R 204	RES COMP 43 K OHM 5PCT 1/2W	6100-3435	81349	RCR20G433J
R 205	RES COMP 3.3 K 5PCT 1/2W	6100-2335	81349	RCR20G332J
R 206	RES COMP 10 K 5PCT 1/2W	6100-3105	81349	RCR20G103J
R 207	RES COMP 24 K OHM 5PCT 1/2W	6100-3245	81349	RCR20G243J
R 208	RES COMP 20 K OHM 5PCT 1/2W	6100-3205	81349	RCR20G203J
R 209	RES COMP 47 M 5PCT 1/2W	6100-6475	81349	RCR20G476J
R 210	RES COMP 47 M 5PCT 1/2W	6100-6475	81349	RCR20G476J
R 229	RES COMP 1.2 K 5PCT 1/2W	6100-2125	81349	RCR20G122J
R 230	RES COMP 100 K 5PCT 1/2W	6100-4105	81349	RCR20G104J
R 231	RES COMP 1.0 M 5PCT 1/2W	6100-5105	81349	RCR20G105J
R 232	RES COMP 10 M 5PCT 1/2W	6100-6105	81349	RCR20G106J
R 234	RES COMP 10 K 5PCT 1/4W	6099-3105	81349	RCR07G103J
R 235	RES COMP 100 OHM 5PCT 1/4W	6099-1105	81349	RCR07G101J
R 236	RES COMP 2.4 M OHM 5PCT 1/2W	6100-5245	81349	RCR20G245J
R 237	RES COMP 2.4 M OHM 5PCT 1/2W	6100-5245	81349	RCR20G245J
R 238	RES COMP 2.4 M OHM 5PCT 1/2W	6100-5245	81349	RCR20G245J
R 239	RES COMP 2.4 M OHM 5PCT 1/2W	6100-5245	81349	RCR20G245J
R 243	POT WW TRM 500 OHM 10 PCT 1T	6056-0136	24655	6056-0136
R 244	POT WW TRM 5K OHM 10 PCT 1T	6056-0142	24655	6056-0142
V 101	TUBE VACUUM 6AB4	8360-0100	79089	6AB4

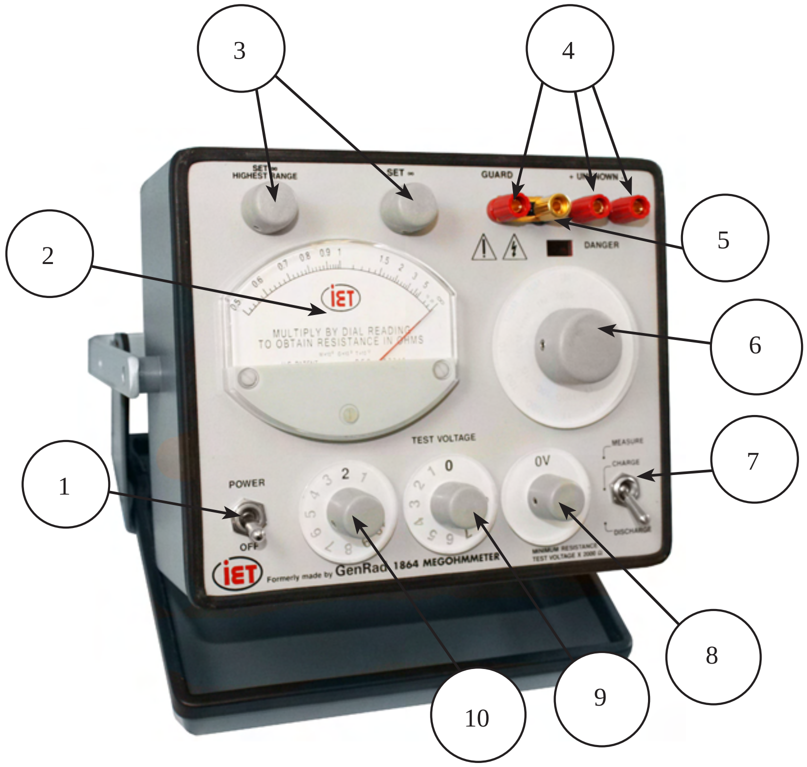


Figure 7-1. Replaceable mechanical parts on the 1864-1644

Replaceable parts list

Model Ref	IET Pt No	Description
1	7910-1300-02	Power switch
2	5730-1412-01	Meter assembly
3	5520-5220-AS	Knob assembly for 1863/64 potentiometers
4	3770-2	Red binding post
5	01-1008-1-0310	Gold binding post
6	1864-1200	Dial assembly
7	1864-0400	Measure-Charge-Discharge switch
8	1864-1220	Dial assembly for 1864 voltage range
9	1864-1230	Dial assembly for 1864 voltage setting B
10	1864-1210	Dial assembly for 1864 voltage setting A

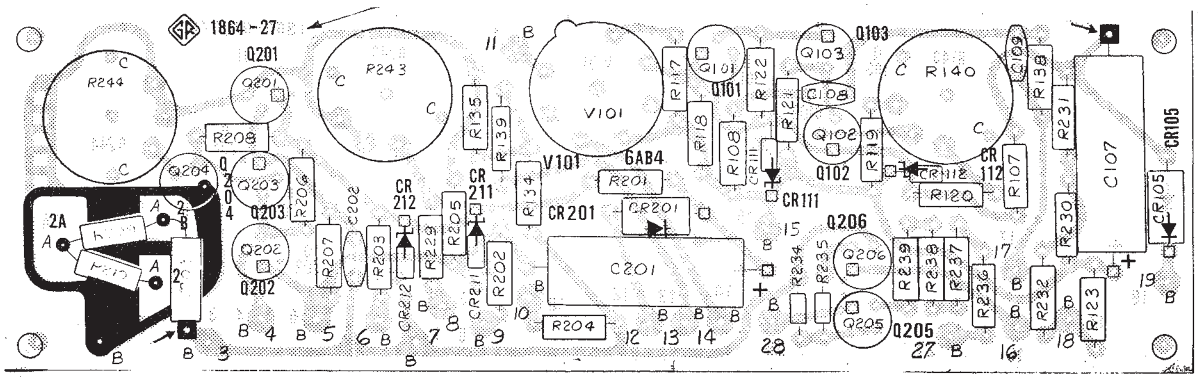


Figure 7-2. Regulator and amplifier circuits etched-board assembly

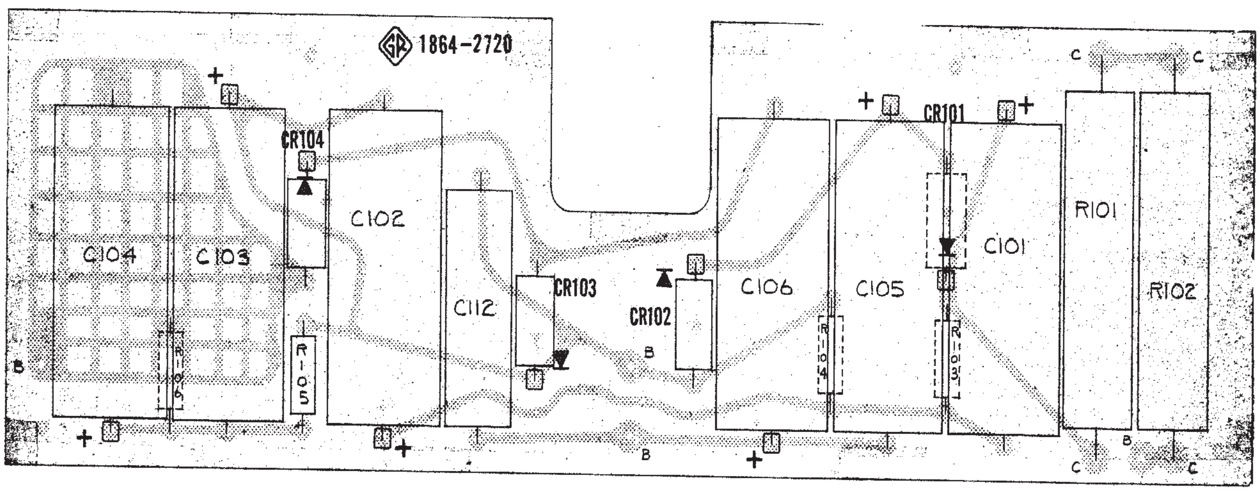
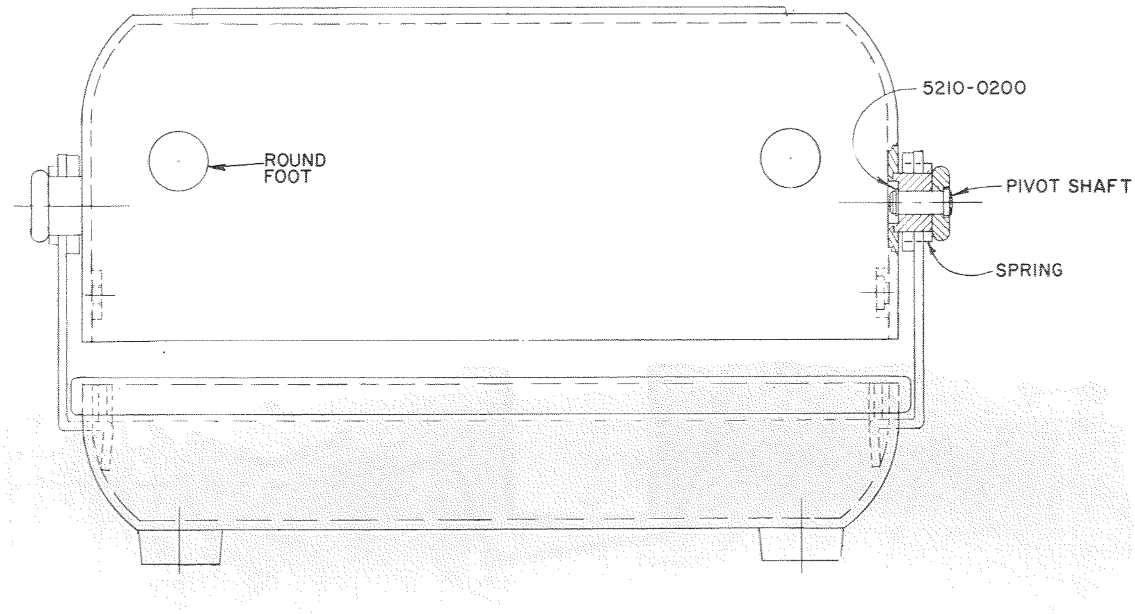


Figure 7-3. Type 1864 rectifier circuit etched-board assembly (P/N 1864-2720)

ELECTRICAL PARTS LIST

RECTIFIER PC BOARD P/N 1864-2720

REFDES	DESCRIPTION	PART NO.	FMC	MFGR PART NUMBER
C 101	CAP ALUM 10UF 475V	4450-6175	90201	TCG 10UF 475V
C 102	CAP ALUM 10UF 475V	4450-6175	90201	TCG 10UF 475V
C 103	CAP ALUM 10UF 475V	4450-6175	90201	TCG 10UF 475V
C 104	CAP ALUM 10UF 475V	4450-6175	90201	TCG 10UF 475V
C 105	CAP ALUM 10UF 475V	4450-6175	90201	TCG 10UF 475V
C 106	CAP ALUM 10UF 475V	4450-6175	90201	TCG 10UF 475V
C 112	CAP PAPER .0047UF 10PCT 600V U	4510-4300	56289	416P47296
CR 101	RECT 1N4006 800PIV .5A SI A50A	6081-1004	14433	1N4006
CR 102	RECT 1N4006 800PIV .5A SI A50A	6081-1004	14433	1N4006
CR 103	RECT 1N4006 800PIV .5A SI A50A	6081-1004	14433	1N4006
CR 104	RECT 1N4006 800PIV .5A SI A50A	6081-1004	14433	1N4006
R 101	RES FLM 100 K 5PCT 7W	6228-4105	14674	FP-5 100 K 5PCT
R 102	RES FLM 100 K 5PCT 7W	6228-4105	14674	FP-5 100 K 5PCT
R 103	RES COMP 470 K 5PCT 1/2W	6100-4475	81349	RCR20G474J
R 104	RES COMP 470 K 5PCT 1/2W	6100-4475	81349	RCR20G474J
R 105	RES COMP 470 K 5PCT 1/2W	6100-4475	81349	RCR20G474J
R 106	RES COMP 470 K 5PCT 1/2W	6100-4475	81349	RCR20G474J



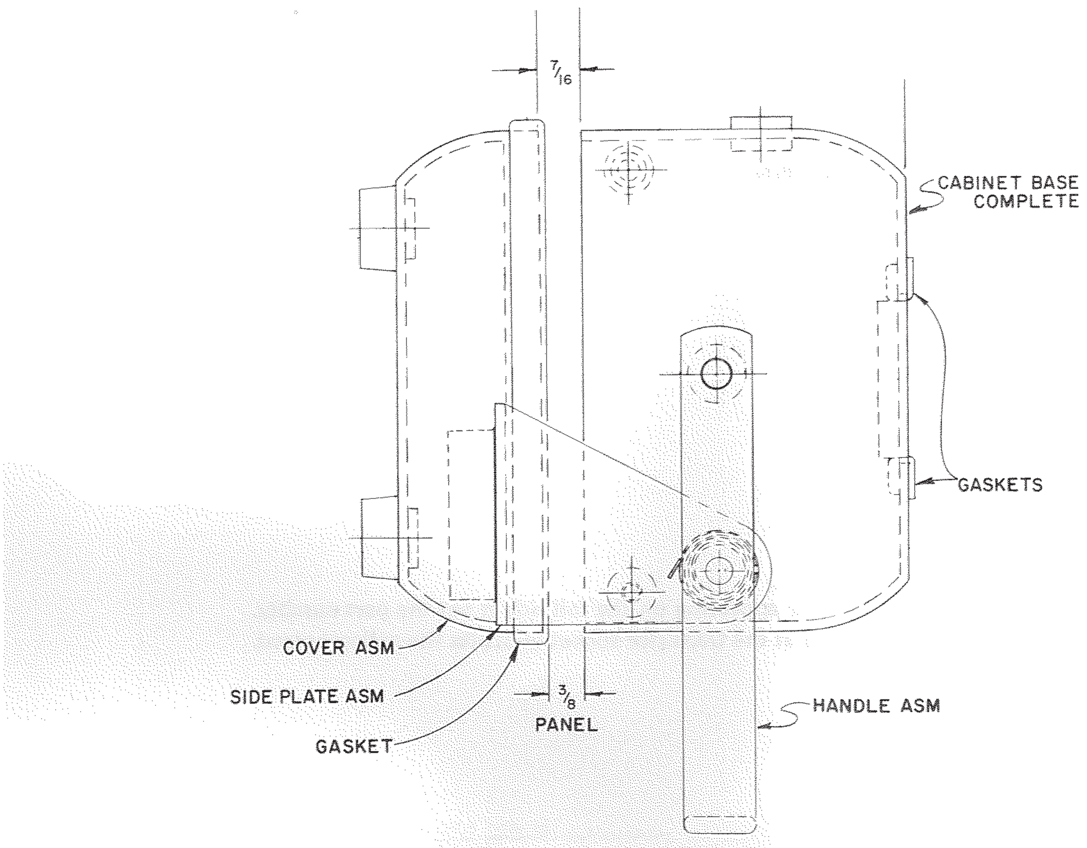


Figure 7-6. Complete cabinet assembly

Name	*GR Part Number*
Cabinet Base Complete	4182-1328
Cover Assembly	4182-1425
Handle Assembly	4182-1503
Gasket, base (2 required)	5168-3620
Gasket, cover	5168-3605
Foot, round (2 required)	5260-2051
Foot, square (4 required)	5260-2060
Hub Insert	4182-6010
Side Plate Assembly*	
Left	4182-1455
Right	4182-1475
Washer rubber* (2 required)	8030-1642
Spring*	4182-8000
Pivot Shaft* (2 required)	4182-6000
External Fastener Ring* (2 required)	5210-0200

*Part of Hardware Set 4182-3010.