

IET/ESI 242D

PRECISION RESISTANCE MEASURING SYSTEM

User Manual

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IET LABS, INC.
formerly manufactured by
esi/Tegam

www.ietlabs.com
Email: info@ietlabs.com
TEL: (516) 334-5959 • FAX: (516) 334-5988

◆ PRECISION INSTRUMENTS FOR TEST AND MEASUREMENT ◆



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www.ietlabs.com
Email: info@ietlabs.com
TEL: (516) 334-5959 • FAX: (516) 334-5988

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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
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USE MAXIMUM INSULATION AND MINIMIZE THE USE OF BARE
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WHEN WORKING WITH HIGH VOLTAGES, POST WARNING SIGNS AND
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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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MODEL 240C KELVIN RATIO BRIDGE, INSTRUCTION MANUAL

MODEL RS 925D RESISTANCE STANDARD, INSTRUCTION MANUAL

MODEL 801 DC GENERATOR-DETECTOR, INSTRUCTION MANUAL

SECTION I

INTRODUCTION

The Model 242D Resistance Measuring System provides the facility for making precision resistance measurements and comparing resistance standards. When used in conjunction with a set of Model SR 1010 Resistance Transfer Standards, the system can be used for accurately comparing different value resistance standards. For example, a 10 kilohm certified standard can be used for checking a 120 ohm resistor to an accuracy of a few ppm. The Model 242D is a major part of the equipment necessary for calibrating voltage dividers to highest accuracy.

The system consists of Models 240C Kelvin Ratio Bridge, RS 925D Decade Resistance Standard, and 801 DC Generator-Detector. The value of the unknown resistor is read as the product of a decade reading and a multiplier reading. A deviation dial is also provided for reading the difference between the actual ratio and the nominal ratio of the standard and unknown resistors in parts per million or percent.

The Model 240C Kelvin Ratio Bridge is a four-terminal comparison bridge using a modification of the Kelvin double-bridge circuit. The bridge has four-terminal connections to eliminate test lead resistance in series with the unknown. It uses switches and terminals designed to minimize insulation leakage in parallel with the unknown. Front-panel controls allow lead and yoke adjustment as part of the measurement cycle. All ratios are adjustable with narrow-range trimmers so that the bridge can be maintained with its initial accuracy indefinitely.

The Model RS 925D Decade Resistance Standard provides resistance values from 10 milliohms to 1.2 megohms in 100 microhm steps. The usual zero resistance problem is eliminated by not going below 10 milliohms. The lead and contact resistances are included in the 10 milliohm resistors so that the resistance the bridge "sees" is the same as the dials read. Four-terminal connection to the bridge avoids lead and contact resistance problems between the units. The first four decades of the resistance standard have narrow-range trimmers on each step so that the standard can be adjusted for very high accuracy at all steps.

The Model 801 DC Generator-Detector provides an optimum signal source and null detector combination for the Model 242D System. Six generator voltage-resistance combinations are available for matching the generator to the bridge input over a wide range of measurement values. To protect the bridge and the components being measured, no more than one watt can be supplied to the bridge with each voltage-resistance combination. The Model 801 has maximum protection from hum pickup. Provision has been made for operation by an external switch.

Specifications for the Model 242D Resistance Measuring System are summarized in Figures 1-1, 1-2 and 1-3. The resolution, accuracy, and sensitivity are shown in proportional parts (as well as parts per million and percent) of the measured resistance.

Resolution and accuracy shown in Figures 1-1 and 1-2 are characteristics of the Model RS 925D Resistance Standard (solid lines) and the Model 240C Kelvin Ratio Bridge (dashed lines) regardless of generator or detector. Sensitivity shown in Figure 1-3 is at maximum generator power and detector sensitivity of the Model 801 Generator-Detector.

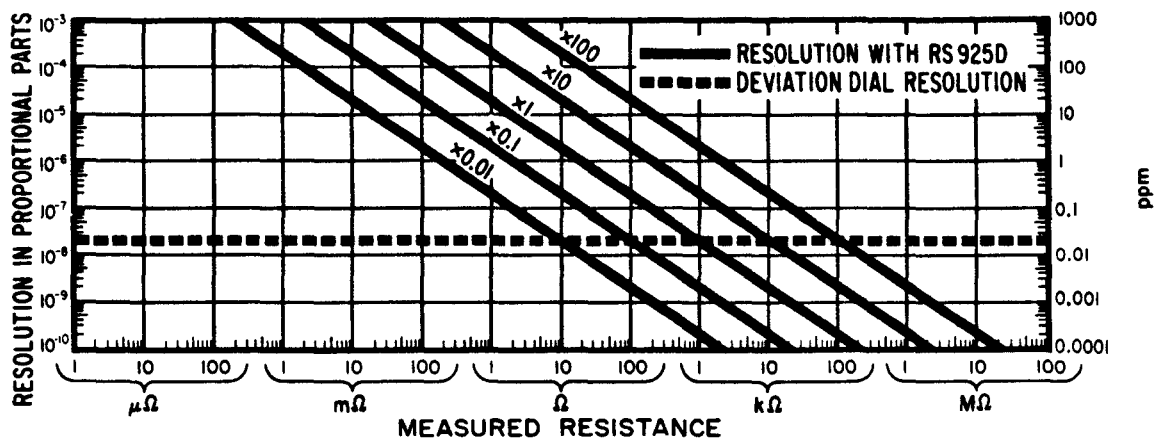


Figure 1-1. Model 242D Resolution

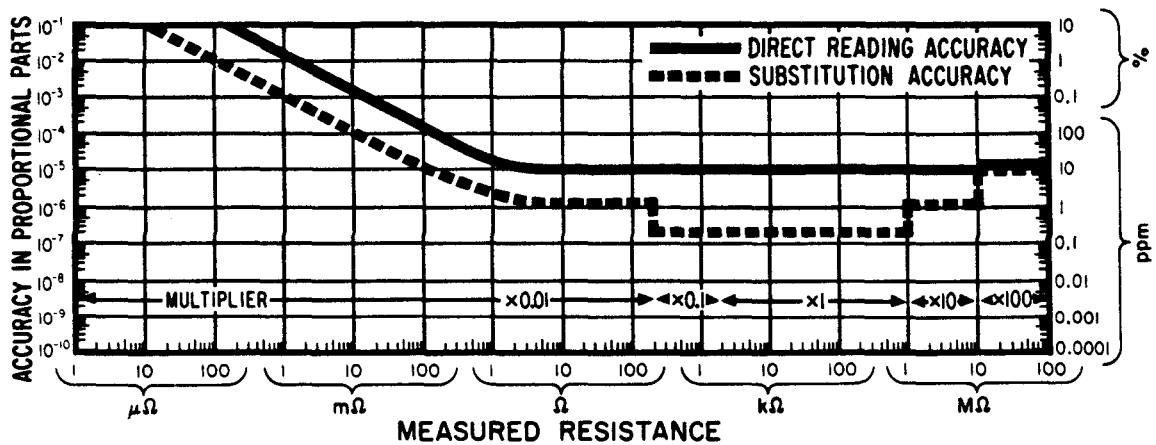


Figure 1-2. Model 242D Accuracy

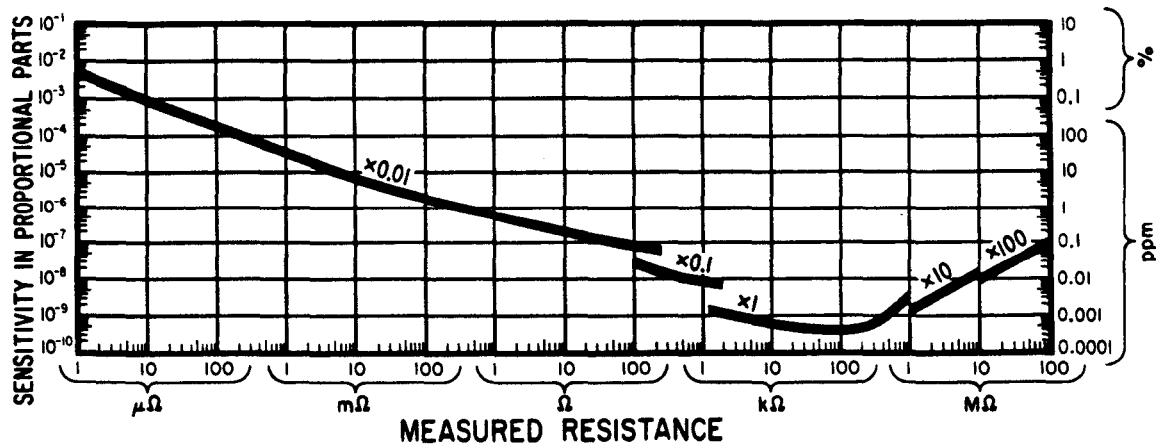


Figure 1-3. Model 242D Sensitivity

SECTION II

OPERATION

2.1 INTERCONNECTION

Interconnection of the instruments that comprise the system is shown in Figure 2-1. The KELVIN KLIPS set is optional; you may use four separate wires for connecting four-terminal resistors or a holding fixture such as Model KK 511 KELVIN KLAMPS. The short swing lug is normally installed as shown, but it may be used in other locations to ground some other point of the circuit (see the manuals for Model 240C and Model 801 for details on alternate grounding schemes).

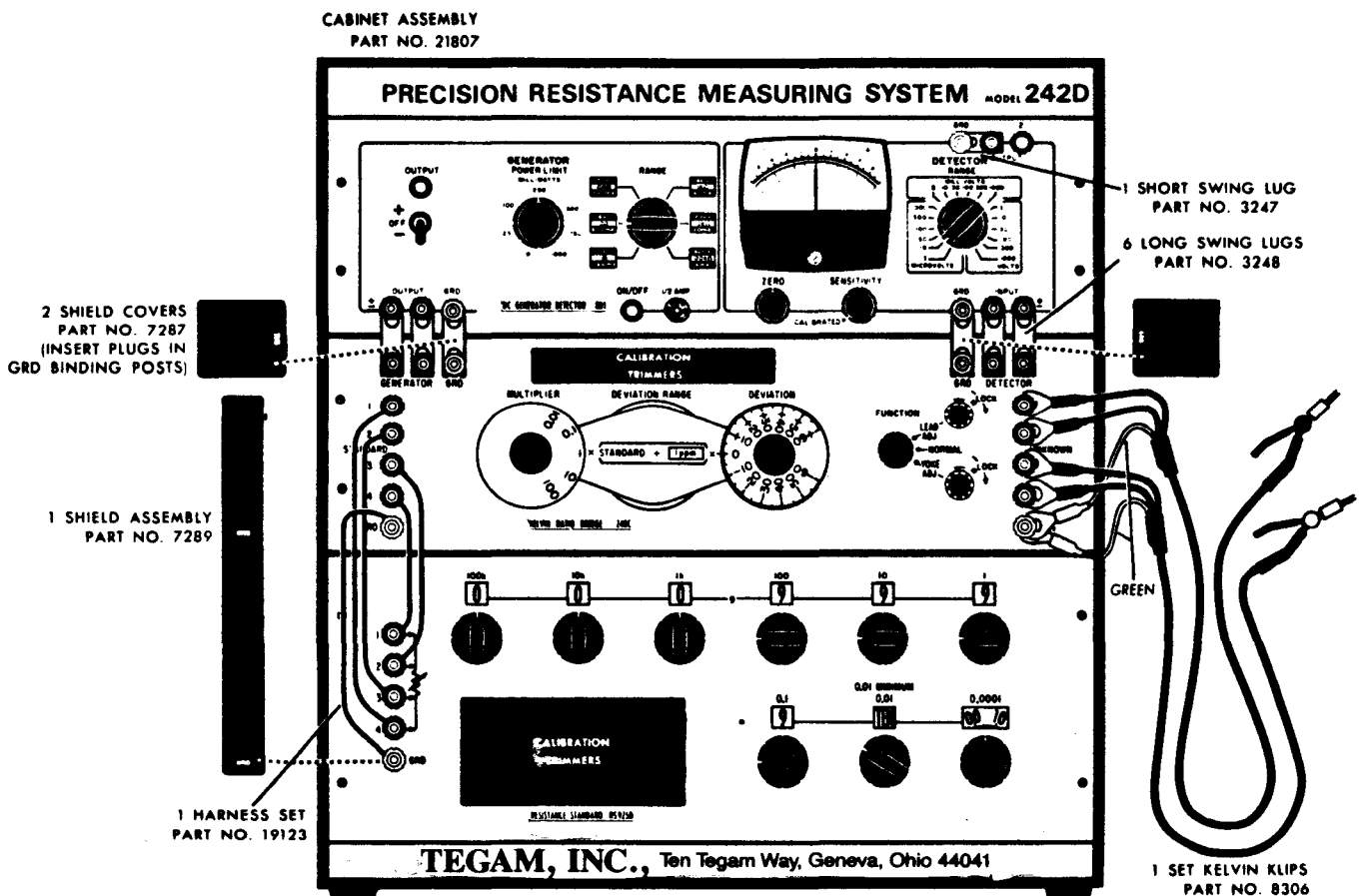


Figure 2-1. Model 242D Interconnection

2.2 OPERATION

The operating procedures in this section are for the basic operation of the system. For finer points of operation see the manuals for Models 240C, RS 925D and 801

2.2.1 Measurement Methods

There are two fundamental methods of measuring resistors with the Model 242D Resistance Measuring System: direct-reading and substitution. The direct-reading method is simpler and accurate enough for most purposes: simply connect the unknown resistor to the bridge, and following the steps described below, read the actual value and/or the deviation from nominal directly from the dials after finding the null.

The substitution method is slightly more complex and requires a standard resistor that is nearly the value of the unknown resistor. (Models SR 1010 and SR 1050 Resistance Transfer Standards can be used to build up or down from a known value to another value.) To use the substitution method, first measure the standard resistor with the DEVIATION dial set to the known deviation of the standard resistor. Use the procedure below, skipping 7a. This measurement calibrates the system in the neighborhood of one specific value. Next, measure the unknown resistor without changing the setting of the decade resistance dials. Use the same procedure using step 7a, skipping 7b. Read the deviation of the unknown resistor from nominal value from the DEVIATION dial.

2.2.2 Basic Operating Procedure

The following procedure is basic to measuring resistors. In general, a balance can be considered correct when:

1. Generator power and detector sensitivity are sufficient to balance the bridge to desired precision.
2. Bridge is nulled at all three FUNCTION switch settings where a null is defined as no change in the meter reading when the power is turned on and off or reversed.

NOTE: It may be convenient to lower detector sensitivity in LEAD ADJ and YOKE ADJ positions to where it is easy to adjust these controls to within $\frac{1}{2}$ dial division.

With practice you will find shortcuts to the step-by-step procedure, depending on the resistance values measured and accuracies required.

See Figure 2-2 for identification of system controls.

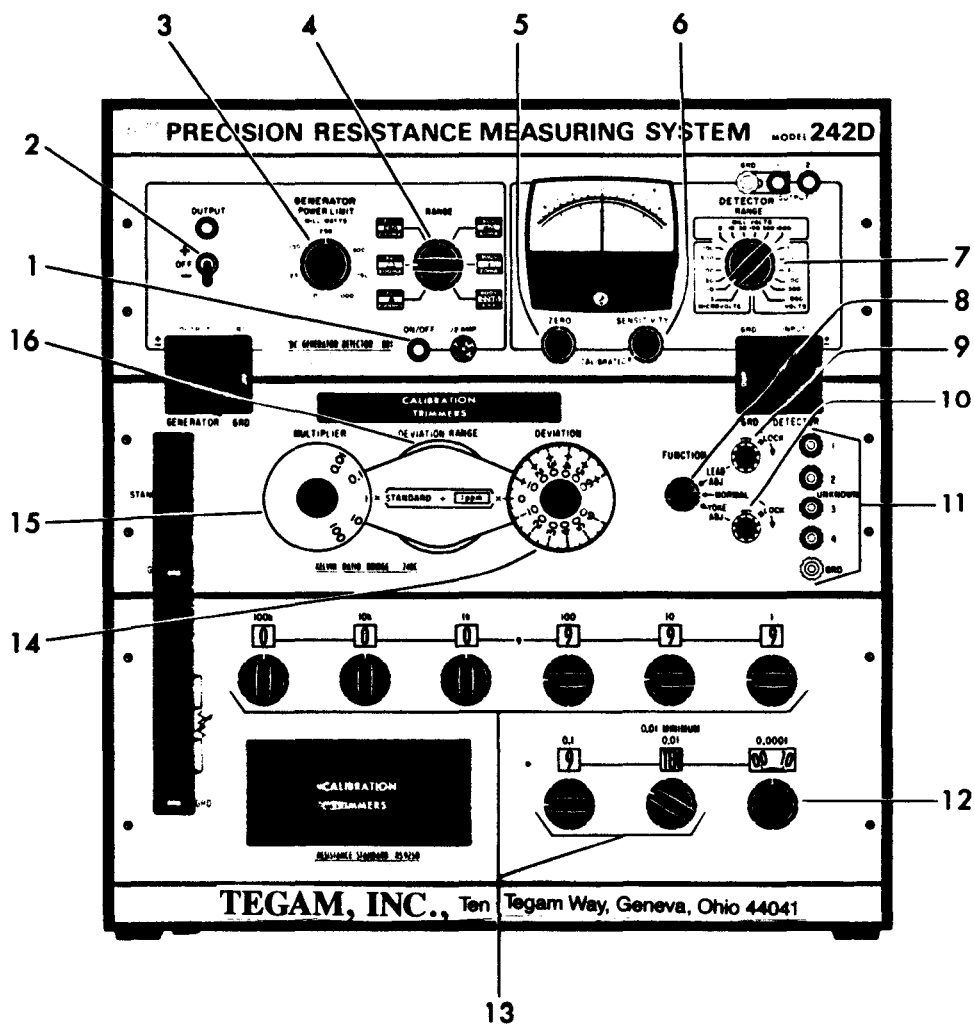


Figure 2-2. Controls

1. Check the following controls to be sure they are set as indicated:
 ON/OFF pushbutton (1): Should be lit. If not, press to turn on power.
 OUTPUT switch (2): OFF.
 SENSITIVITY control (6): Fully counterclockwise to CALIBRATED.
 FUNCTION switch (8): NORMAL.

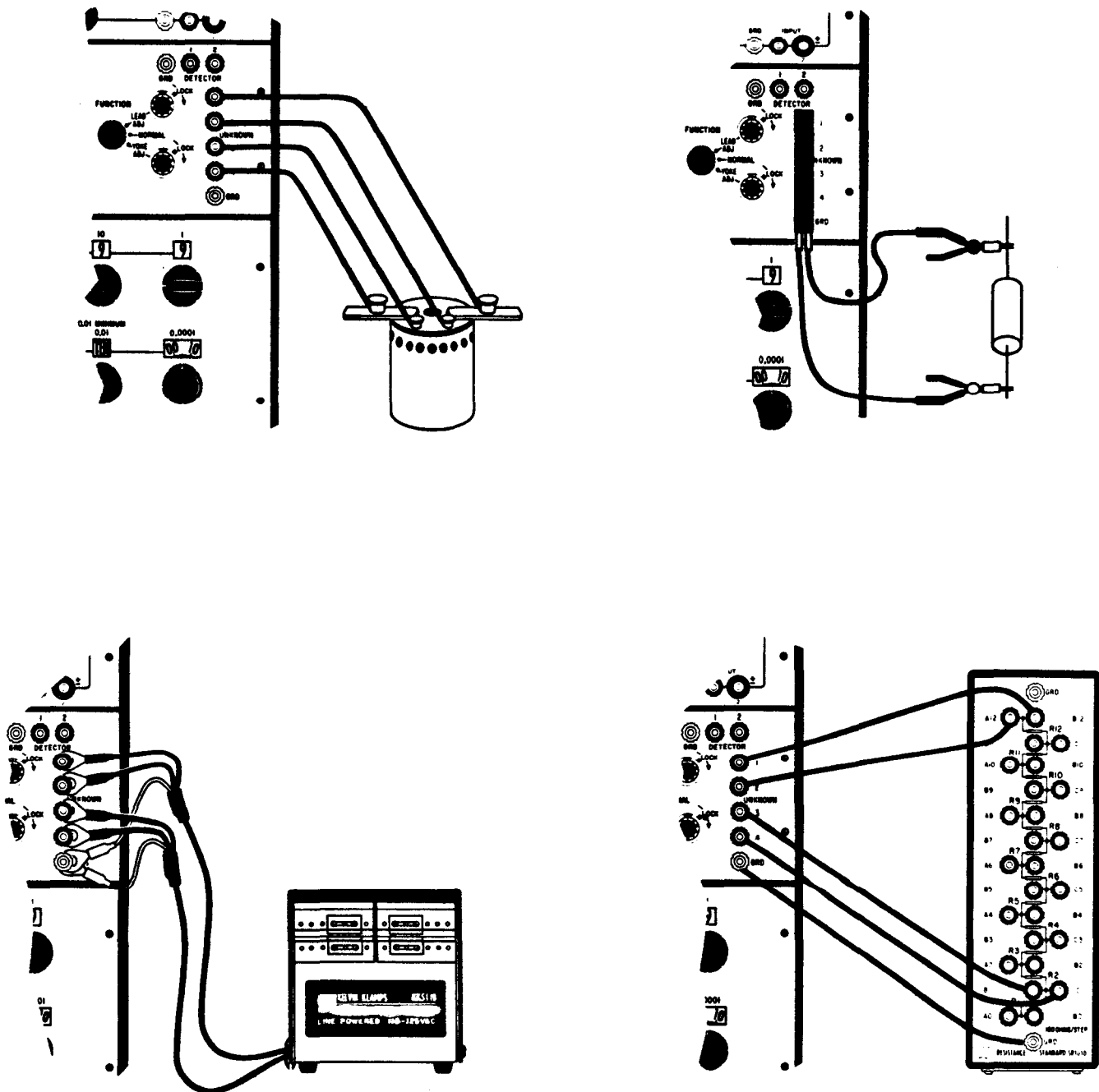


Figure 2-3. Connections to Unknown

2. Connect the unknown resistor to the UNKNOWN binding posts of the bridge (11). Use KELVIN KLIPS or KELVIN KLAMPS to make four-terminal connection to two-terminal devices. Use four separate wires to connect to four-terminal resistors (see Figure 2-3).

3. Set MULTIPLIER (15), GENERATOR POWER LIMIT (3) and GENERATOR RANGE (4) to settings indicated for nominal value of unknown resistor. Set DETECTOR RANGE (7) for sensitivity well below maximum given in the table, but still on scale.

Nominal Value of Unknown Resistor	MULTIPLIER	GENERATOR		DETECTOR RANGE
		POWER LIMIT	RANGE	
0.1 m Ω to 10 m Ω	0.01	250	1 Ω	10 MICROVOLTS
10 m Ω to 100 m Ω	0.01	250	10 Ω	3 MICROVOLTS
100 m Ω to 1 Ω	0.01	100	100 Ω	3 MICROVOLTS
1 Ω to 10 Ω	0.01	100	1 k Ω	3 MICROVOLTS
10 Ω to 200 Ω	0.01	100	1 k Ω	10 MICROVOLTS
200 Ω to 2 k Ω	0.1	100	1 k Ω	30 MICROVOLTS
2 k Ω to 100 k Ω	1.0	100	10 k Ω	30 MICROVOLTS
100 k Ω to 1 M Ω	1.0	100	100 k Ω	10 MICROVOLTS
1 M Ω to 10 M Ω	10	100	100 k Ω	30 MICROVOLTS
10 M Ω to 100 M Ω	100	100	100 k Ω	30 MICROVOLTS

4. Set decade resistance dials (13) to nominal value of unknown resistor, multiplied by the appropriate power of ten, depending on the setting of the MULTIPLIER dial. Note that the 0.01 Ω /step dial will not go to zero. This means in most cases that a sequence of zeros must be represented by a sequence of nines followed by TEN. For example, 10000.00 ohms must be set as 0 0 9 9 9 9 . 9 TEN.
5. Set DEVIATION RANGE dial (16) appropriately for the accuracy required of the measurement.
6. Adjust DETECTOR ZERO control (5) while the generator OUTPUT switch is still OFF.
7. The next step depends on what you wish to find from the measurement.
 - a. If you know the nominal resistance and want to find deviation from nominal: Set OUTPUT switch (2) to - and adjust DEVIATION dial (14) for null indication on the meter.
 - b. If you know the deviation of the system from nominal (it may be zero) and want to find resistance in ohms: Set DEVIATION dial (14) to deviation of the system, set OUTPUT switch (2) to +, and adjust decade dials (12 and 13) for null indication on the meter.
8. Set FUNCTION switch (8) to LEAD ADJ to check for lead compensation. Adjust LEAD ADJ control (9) for null indication if necessary.
9. Set FUNCTION switch (8) to YOKE ADJ to check yoke adjustment. Adjust YOKE ADJ control (10) for null indication if necessary.
10. Set DETECTOR RANGE switch for increased sensitivity. Repeat steps 6 through 9 after each increase, until null is satisfactory without further adjustments.

SECTION III

CALIBRATION PROCEDURE

3.1 PRELIMINARY REMARKS

For maximum accuracy the bridge and standard in the Model 242D Resistance Measuring System should be calibrated together. The system calibration procedure is outlined as follows:

1. Adjust mechanical setting of Model 240C DEVIATION dial.
2. Adjust Model 240C DEVIATION RANGE trimmers for best accuracy.
3. Calibrate individual and cumulative steps of resistance transfer standard (by substitution comparison with reference standard).
4. Adjust decade trimmers of Model RS 925D and MULTIPLIER trimmers of Model 240C.

Because this procedure adjusts the trimmable parts of the system to compensate for the untrimmable, most unstable parts, both the bridge and standard will contain small equal and opposite indeterminate errors, thus limiting their use to within the system. Also recalibrating will be a lengthy process, as adjustment of the first trimmer will necessitate an equal re-adjustment of all other trimmers.

For those who wish to use the ratio bridge and standard separately, or to avoid a lot of repetitive trimming, an alternate procedure is provided. Loss of system accuracy will be negligible for measurements above 10 ohms.* The alternate procedure is outlined as follows:

1. Adjust mechanical setting of Model 240C DEVIATION dial.
2. Adjust Model 240C DEVIATION RANGE trimmers for best accuracy.
3. Calibrate individual and cumulative steps of resistance transfer standard (by substitution comparison with reference standard).
4. Adjust Model 240C MULTIPLIER trimmers for correct ratios.
5. Adjust Model RS 925D trimmers for best accuracy.

3.2 EQUIPMENT REQUIREMENTS

1. Reference Standard: 10 kilohms, ± 5 ppm accuracy, ± 1 ppm calibration accuracy
(Model SR 104 or equivalent).
2. Resistance Transfer Standard: 10 kilohms per step, ± 1 ppm transfer accuracy, trimmable
(Model SR 1010 MT or equivalent).
3. (Alternate procedure only) Shorting Bars: Approximately $100\mu\Omega$ resistance per bar, end to end (Model SB 103 or equivalent).

*Measurements below 10 ohms will equal or exceed specifications for Model 242B.

3.3 MECHANICAL ADJUSTMENT

1. Turn DEVIATION dial clockwise through -60 to $+60$. There should be a perceptible change in the feel of the dial action between these settings. There should be a smooth region between them, and a slight detent at both $+60$ and -60 .
2. If the detents are not within 1 dial division of $+60$ and -60 , turn the dial to locate the detent that corresponds with -60 .
3. Loosen the setscrews on the dial and slip it to read -60 , then tighten the setscrews.

3.4 DEVIATION RANGE CALIBRATION

1. Connect a 10 kilohm reference resistance standard to the UNKNOWN terminals of the bridge.
2. Set Generator-Detector controls as follows:
OUTPUT: OFF
POWER LIMIT: 100
GENERATOR RANGE: 10 k Ω
DETECTOR RANGE: 30 MICROVOLTS
(ON/OFF pushbutton should be lit)
3. Set Model 240C Kelvin Ratio Bridge dials to read $1 \times \text{STANDARD} + 0.1 \text{ ppm} \times 0$. Be sure that index is lined up at 0.
4. Set Model 925D Resistance Standard dials to read 9 9 9 9 . 9 TEN (00) ohms. (The resistance standard is used only as a tare in this procedure, and does not need to be calibrated).
5. Adjust Detector ZERO control for null indication and then turn DETECTOR RANGE switch back to 30 MILLIVOLTS.
6. Set OUTPUT switch to + to turn on generator.
7. Turn DETECTOR RANGE switch counterclockwise one step at a time until the meter deflection is near end-scale or until the switch reaches 30 MICROVOLTS. Adjust Resistance Standard (not DEVIATION dial) for meter null at each step.
8. Check and (if necessary) adjust LEAD ADJ and YOKE ADJ controls.
9. Turn DEVIATION RANGE dial to $1 \text{ ppm} \times 0$ and adjust RANGE 1 trimmer for null.
10. Turn DEVIATION RANGE dial to $.001\% \times 0$ and turn DETECTOR RANGE switch to 300 MICROVOLTS and adjust RANGE 10 trimmer for null.
11. Turn DEVIATION RANGE dial to $.01\%$ and turn DETECTOR RANGE switch to 3000 MICROVOLTS and adjust RANGE 100 trimmer for null.

3.5 TRANSFER STANDARD CALIBRATION

1. Connect the 10 kilohm reference resistance standard to the UNKNOWN binding posts of the bridge.
2. Set Generator-Detector controls as follows:
OUTPUT: OFF
POWER LIMIT: 100
GENERATOR RANGE: 10 k Ω
DETECTOR RANGE: 30 MICROVOLTS
3. Set Model 240C Kelvin Ratio Bridge controls to $1 \times \text{STANDARD} + 0.1 \text{ ppm} \times \dots$.
4. Set DEVIATION dial to exact resistance deviation of reference standard as corrected for temperature effects.
5. Set Model 925D Resistance Standard dials to 9 9 9 9 . 9 9 (99) ohms.
6. Adjust Detector ZERO control for null indication, then turn DETECTOR RANGE switch to 30 MILLIVOLTS.
7. Set OUTPUT switch to + .
8. Adjust Resistance Standard dials for null indication, set DETECTOR RANGE switch to 30 MICROVOLTS and repeat the adjustment. Check and (if necessary) adjust YOKE ADJ and LEAD ADJ controls for null.
9. Set OUTPUT switch to OFF. Turn DEVIATION RANGE dial to 1 ppm.
10. Connect each resistor of the Resistance Transfer Standard in turn to the UNKNOWN terminals. Repeat the following three steps for each resistor.
11. Check and (if necessary) adjust Detector ZERO control for null indication.
12. Set OUTPUT switch to - and adjust DEVIATION dial for null. (If the transfer standard is Model SR 1010/MT, adjust it for null with the DEVIATION dial at 0).
13. Set OUTPUT switch to OFF and record DEVIATION dial reading.
14. Calculate the cumulative deviation for each resistance step (For the Nth step, this is the average deviation of the first N resistors). See the Instruction Manual for Model SR 1010 for further details.

3.6 SYSTEM CALIBRATION PROCEDURE

NOTE: See Section 3.7 for alternate procedure.

1. Set Generator-Detector controls as follows:

POWER LIMIT to 100

OUTPUT to OFF

DEVIATION RANGE dial to 1 ppm.

MULTIPLIER, GENERATOR RANGE and DETECTOR RANGE as indicated in Table 3-1.

MULTIPLIER Settings	GENERATOR RANGE	DETECTOR RANGE
100 x STANDARD	10 k Ω	10 MICROVOLTS
10 x STANDARD	10 k Ω	100 MICROVOLTS
1 x STANDARD	10 k Ω	300 MICROVOLTS
0.1 x STANDARD	10 k Ω	100 MICROVOLTS
0.01 x STANDARD	1 k Ω	10 MICROVOLTS

Table 3-1

2. Connect N resistors (starting with 1) of transfer standard to bridge UNKNOWN terminals. Set Generator-Detector sensitivity as indicated in Table 3-1 and set Model RS 925D as indicated in Table 3-2.
3. With Generator OUTPUT switch in either polarity, set bridge FUNCTION switch to LEAD ADJ position and adjust lead adjust control for null indication on Detector.
4. Return OUTPUT switch to OFF position.
5. Set DEVIATION dial to the cumulative deviation for the resistors connected to the bridge, as calculated in Section 3.4, step 14. (If Model SR 1010/MT is used, this setting will be zero for all cases.)
6. Adjust Detector ZERO control for null indication.
7. Set Generator OUTPUT switch to + and adjust appropriate trimmer for null indication, as listed in Table 3-2.
8. Turn Generator on and check for null with FUNCTION switch in YOKE ADJ position. Adjust if necessary.
9. Set FUNCTION switch to NORMAL and check again for null. Readjust trimmer if necessary.
10. Repeat steps 8 and 9 until null is maintained on both FUNCTION switch positions. Turn Generator OUTPUT switch OFF.
11. Repeat steps 4 through 10, using next listing in Table 3-2.

Trimmer to be Adjusted	Number of Transfer Standard Resistors Used (N)	Model RS 925D Dial Setting*
Adjust the following with MULTIPLIER set to 100 × STANDARD		
MULTIPLIER 100**	1	0 0 0 0 9 9 . 9 TEN (00)
100 Ω, 1	2	0 0 0 1 9 9 . 9 TEN (00)
100 Ω, 2	3	0 0 0 2 9 9 . 9 TEN (00)
100 Ω, 3	4	0 0 0 3 9 9 . 9 TEN (00)
100 Ω, 4	5	0 0 0 4 9 9 . 9 TEN (00)
100 Ω, 5	6	0 0 0 5 9 9 . 9 TEN (00)
100 Ω, 6	7	0 0 0 6 9 9 . 9 TEN (00)
100 Ω, 7	8	0 0 0 7 9 9 . 9 TEN (00)
100 Ω, 8	9	0 0 0 8 9 9 . 9 TEN (00)
100 Ω, 9	10	0 0 0 9 9 9 . 9 TEN (00)
100 Ω, 10	11	0 0 0 TEN 9 9 . 9 TEN (00)
Adjust the following with MULTIPLIER set to 10 × STANDARD		
MULTIPLIER 10**	1	0 0 0 9 9 9 . 9 TEN (00)
1 kΩ, 1	2	0 0 1 9 9 9 . 9 TEN (00)
1 kΩ, 2	3	0 0 2 9 9 9 . 9 TEN (00)
1 kΩ, 3	4	0 0 3 9 9 9 . 9 TEN (00)
1 kΩ, 4	5	0 0 4 9 9 9 . 9 TEN (00)
1 kΩ, 5	6	0 0 5 9 9 9 . 9 TEN (00)
1 kΩ, 6	7	0 0 6 9 9 9 . 9 TEN (00)
1 kΩ, 7	8	0 0 7 9 9 9 . 9 TEN (00)
1 kΩ, 8	9	0 0 8 9 9 9 . 9 TEN (00)
1 kΩ, 9	10	0 0 9 9 9 9 . 9 TEN (00)
1 kΩ, 10	11	0 0 TEN 9 9 9 . 9 TEN (00)
Adjust the following with MULTIPLIER set to 1 × STANDARD		
MULTIPLIER 1**	1	0 0 9 9 9 9 . 9 TEN (00)
10 kΩ, 1	2	0 1 9 9 9 9 . 9 TEN (00)
10 kΩ, 2	3	0 2 9 9 9 9 . 9 TEN (00)
10 kΩ, 3	4	0 3 9 9 9 9 . 9 TEN (00)
10 kΩ, 4	5	0 4 9 9 9 9 . 9 TEN (00)
10 kΩ, 5	6	0 5 9 9 9 9 . 9 TEN (00)
10 kΩ, 6	7	0 6 9 9 9 9 . 9 TEN (00)
10 kΩ, 7	8	0 7 9 9 9 9 . 9 TEN (00)
10 kΩ, 8	9	0 8 9 9 9 9 . 9 TEN (00)
10 kΩ, 9	10	0 9 9 9 9 9 . 9 TEN (00)
10 kΩ, 10	11	0 TEN 9 9 9 9 . 9 TEN (00)
Adjust the following with MULTIPLIER set to 0.1 × STANDARD		
MULTIPLIER 0.1**	1	0 9 9 9 9 9 . 9 TEN (00)
100 kΩ, 1	2	1 9 9 9 9 9 . 9 TEN (00)
100 kΩ, 2	3	2 9 9 9 9 9 . 9 TEN (00)
100 kΩ, 3	4	3 9 9 9 9 9 . 9 TEN (00)
100 kΩ, 4	5	4 9 9 9 9 9 . 9 TEN (00)
100 kΩ, 5	6	5 9 9 9 9 9 . 9 TEN (00)
100 kΩ, 6	7	6 9 9 9 9 9 . 9 TEN (00)
100 kΩ, 7	8	7 9 9 9 9 9 . 9 TEN (00)
100 kΩ, 8	9	8 9 9 9 9 9 . 9 TEN (00)
100 kΩ, 9	10	9 9 9 9 9 9 . 9 TEN (00)
100 kΩ, 10	11	10 9 9 9 9 9 . 9 TEN (00)
100 kΩ, 11	12	11 9 9 9 9 9 . 9 TEN (00)
Adjust the following with MULTIPLIER set to 0.01 × STANDARD		
MULTIPLIER 0.01**	1	9 9 9 9 9 9 . 9 TEN (00)

*For alternate procedure, this is NOMINAL setting.

**For alternate procedure, DO NOT TRIM MODEL 240C. Instead, adjust Model RS 925D for null on meter, without moving dials to left of dashed line. On all other steps, trim Model RS 925D moving only dials to left of dashed line.

Table 3-2

3.7 ALTERNATE CALIBRATION PROCEDURE

Perform all of Sections 3.3, 3.4 and 3.5. Substitute the following for Section 3.6:

3.7.1 Model 240C Ratio Calibration

1. Connect a 10 kilohms-per-step transfer standard in 10 k Ω configuration (series-parallel connection) to Model 240C STANDARD terminals and connect a 10 kilohm reference standard to the UNKNOWN terminals, as shown in Table 3-1.
2. Set MULTIPLIER dial to 1 x STANDARD and DEVIATION dial to exact deviation of reference standard. Set Generator-Detector as indicated in Table 3-1.

MULTIPLIER Settings	GENERATOR RANGE	DETECTOR RANGE
100 x STANDARD	10 k Ω	10 MICROVOLTS
10 x STANDARD	10 k Ω	100 MICROVOLTS
1 x STANDARD	10 k Ω	300 MICROVOLTS
0.1 x STANDARD	10 k Ω	100 MICROVOLTS
0.01 x STANDARD	1 k Ω	10 MICROVOLTS

Table 3-1

3. Adjust LEAD ADJ and YOKE ADJ controls for null indication. Return FUNCTION switch to NORMAL.
4. Adjust MULTIPLIER x1 trimmer for null indication.
5. Check null with FUNCTION switch at YOKE ADJ. Adjust if necessary, then return FUNCTION switch to NORMAL and recheck null with trimmer.
6. Disconnect transfer standard from STANDARD terminals and connect in 100 k Ω configuration (series connection) to UNKNOWN terminals. Reconnect Model RS 925D.
7. Set DEVIATION RANGE dial to 0.1 ppm, set DEVIATION dial to 0.0 and MULTIPLIER dial to 1 x STANDARD.
8. Adjust Model RS 925D for null indication (approximately 100 kilohms), making lead and yoke adjustments as in step 3.
9. Change transfer standard connections to 10 k Ω configuration (series-parallel connection).
10. Set MULTIPLIER dial to 0.1 x STANDARD. Set Generator-Detector as indicated in Table 3-1. Do not disturb Model RS 925D or DEVIATION dial settings.
11. Check lead and yoke adjustments as in step 3.
12. Adjust MULTIPLIER x0.1 trimmer for null indication and recheck yoke adjustment as in step 5.
13. Change transfer standard connections to 1 k Ω configuration (parallel connection).
14. Set MULTIPLIER dial to 0.01 x STANDARD. Set Generator-Detector as indicated in Table 3-1.

15. Check lead and yoke adjustments as in step 3.
16. Adjust MULTIPLIER $\times 0.01$ trimmer for null indication and recheck yoke adjustment as in step 5.
17. Set MULTIPLIER dial to $1 \times \text{STANDARD}$. Set Generator-Detector as indicated in Table 3-1.
18. Check lead and yoke adjustments as in step 3.
19. Adjust Model RS 925D for null indication (approximately 1 kilohm).
20. Change transfer standard connections to $10\text{ k}\Omega$ configuration (series-parallel connection).
21. Set MULTIPLIER dial to $10 \times \text{STANDARD}$. Set Generator-Detector as indicated in Table 3-1. Do not disturb Model RS 925D or DEVIATION dial settings.
22. Check lead and yoke adjustments as in step 3.
23. Adjust MULTIPLIER $\times 10$ trimmer for null indication and recheck yoke adjustment as in step 5.
24. Change transfer standard connections to $100\text{ k}\Omega$ configuration (series connection).
25. Set MULTIPLIER dial to $100 \times \text{STANDARD}$. Set Generator-Detector as indicated in Table 3-1.
26. Check lead and yoke adjustments as in step 3.
27. Adjust MULTIPLIER $\times 100$ trimmer for null indication and recheck yoke adjustment as in step 5.

3.7.2 Model RS 925D Decade Calibration

After calibrating Model 240C, perform all steps in Section 3.6 with the following exceptions:

1. Omit all steps calling for adjustment of Model 240C trimmers.
2. For the first adjustment at each new MULTIPLIER setting, adjust decade dials instead of Model 240C trimmers. Do not move dials to left of dashed line in Table 3-2.
3. On all other steps, trim Model RS 925D, moving only dials to left of dashed line in Table 3-2.



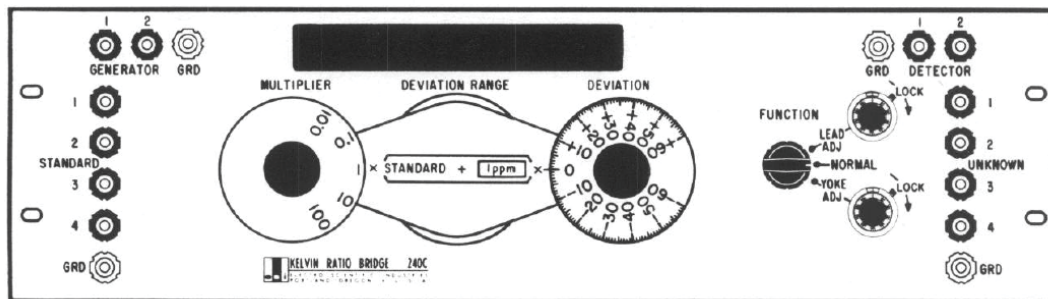
When making two terminal measurements, terminals 1 and 2 must be connected together and terminals 3 and 4 must also be connected together. The unknown must be connected across terminals 2 and 3.

Failure to make the above connections will result in incorrect readings from your instrument.

240C

KELVIN RATIO BRIDGE

User Manual



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www.ietlabs.com
Email: info@ietlabs.com
TEL: (516) 334-5959 • FAX: (516) 334-5988

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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
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THE FRONT PANEL OR THE OPERATING GUIDE LABEL.

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PORTAMETRIC[®] Portable Measuring Instrument
PVB[®] Potentiometric Voltmeter Bridge

SECTION I

INTRODUCTION

1.1 DESCRIPTION

ESI Model 240C Kelvin Ratio Bridge is a highly precise and accurate instrument used to compare resistances. The accuracy can be maintained by adjusting trimmers behind a small panel.

The bridge has four-terminal connections for the standard as well as the unknown resistors. YOKE and LEAD ADJ controls can be used to compensate for the resistance of test leads that are as high as 0.1 ohm, which corresponds to approximately 25 feet of No. 16 wire

All circuits of the bridge are guarded to prevent errors due to leakage in measuring high-valued resistors.

1.2 SPECIFICATIONS

Multiplier Ratios: 0.01, 0.1, 1, 10, 100

Ratio	×100	×10	×1	×0.1	×0.01
Accuracy after Trimming	2 ppm	1 ppm	1 ppm	2 ppm	2 ppm
Temperature Coefficient	3 ppm/°C	3 ppm/°C	2 ppm/°C	2.5 ppm/°C	3 ppm/°C

Power Coefficient of Ratio: ± 0.1 ppm/mW in ratio resistors

Lead and Yoke Adjustments: Panel controls to compensate for resistance up to 100 milliohms in the test leads to the unknown.

Yoke Resistance: Approximately 25 milliohms internal to bridge

Guarding: The bridge is designed to prevent leakages from appearing across high resistance standard or unknown resistors.

Deviation Ranges:

Range		Each Dial Division	
Min	Max	ppm	%
- 6 ppm	6 ppm	0.1	0.00001
- 60 ppm	60 ppm	1	0.0001
- 0.06%	0.06%	10	0.001
- 0.6%	0.6%	100	0.01

Deviation Linearity: ± 1 dial division

Deviation Resolution: 1/4 dial division

Breakdown Voltage to Case: 1500 Volts

Dimensions: Width 19 in. (48.25 cm), height 5.25 in. (13.3 cm), depth 7 in. (17.8 cm)

Weight: 11 lbs (5 kg)

1.3 ACCESSORY REQUIREMENTS

The Kelvin Ratio Bridge is only part of a measurement system. In order to measure resistors, you also need a dc null detector, a dc generator, and a resistance standard.

1.3.1 Generator Requirements

The dc generator (which may be a battery) must be well insulated from ground, and preferably guarded, with a minimum leakage resistance of 10^{10} ohms from one terminal and 10^{12} ohms from the other terminal to ground.

Generator switching must be guarded so that there are no measurable leakage currents to ground in either the on or the off position. (Measurable at the maximum sensitivity of the detector used).

The generator should be power-limited to a maximum of one watt, either by a current limiter, or by a series resistance of at least

$$\frac{(E_{\max})^2}{4} \text{ ohms}$$

for a generator open-circuit voltage of E_{\max} .

Several different generator voltages, each with an appropriate limiting resistance, should be available for selection to yield maximum sensitivity in measuring different resistance values. If batteries are to be used, the following typical combinations are suggested. The series limiting resistor must be capable of dissipating four watts.

Maximum Voltage (Open Circuit) Approximately	Series Limiting Resistor Approximately	Maximum Current (Short Circuit) Approximately
1.5 volts	0.56 ohm	2.7 amperes
6 volts	10 ohms	0.6 ampere
22.5 volts	120 ohms	190 milliamperes
90 volts	2.2 kilohms	41 milliamperes
300 volts	22 kilohms	14 milliamperes

If a line-operated dc generator is used with a modulator type dc detector, the generator ac ripple output and the ac voltage from the output terminals to ground should be low enough to avoid ac interference problems in the dc detector. (The amount that can be tolerated depends upon the detector used.)

1.3.2 Detector Requirements

In order to make full use of the accuracy of the bridge, the detector should be capable of detecting dc signals very close to theoretical noise level at a source resistance in the vicinity of 10 kilohms. It must operate well with source resistances from 100 ohms to 1 megohms.

The detector should be relatively insensitive to interference from ac signals into its input; the amount which can be tolerated will dictate the care which must be taken in shielding the measurement set up and selecting the generator to be used.

A detector with internally grounded input may be used for all normal bridge applications, however, a detector with floating input will allow certain alternate modes of operation:

1. If the detector can be operated with its low input terminal insulated from ground, but essentially at ground potential, a connection for lower sensitivity to ac pickup in low resistance measurements is possible.
2. If the detector can be operated with its low input terminal at a high dc voltage above ground without observable indication (thorough guarding required), a connection for higher accuracy and sensitivity in high resistance measurements is possible.

1.3.3 Standard Resistor Requirements

A five-terminal, shielded (guarded) construction is recommended for all resistance standards to be used with the bridge; the standard preferably should be four-terminal below 10 kilohms and a guarded (three-terminal, shielded) above 10 kilohms. The five-terminal construction includes both cases.

For highest accuracy calibration measurements, a working standard resistor should be available which has the same value as the resistor to be measured, within ± 6 ppm. It may be either certified or calibrated by transfer techniques.

For measurements at one resistance value traceable to the calibration of a standard resistor of a different resistance value, series-parallel resistor buildup techniques should be used. ESI Model SR 1010 and SR 1050 are specifically designed for this transfer of calibration from one resistance level to another, with an accuracy of a few parts per million throughout the range from 1 ohm to 100 megohms.

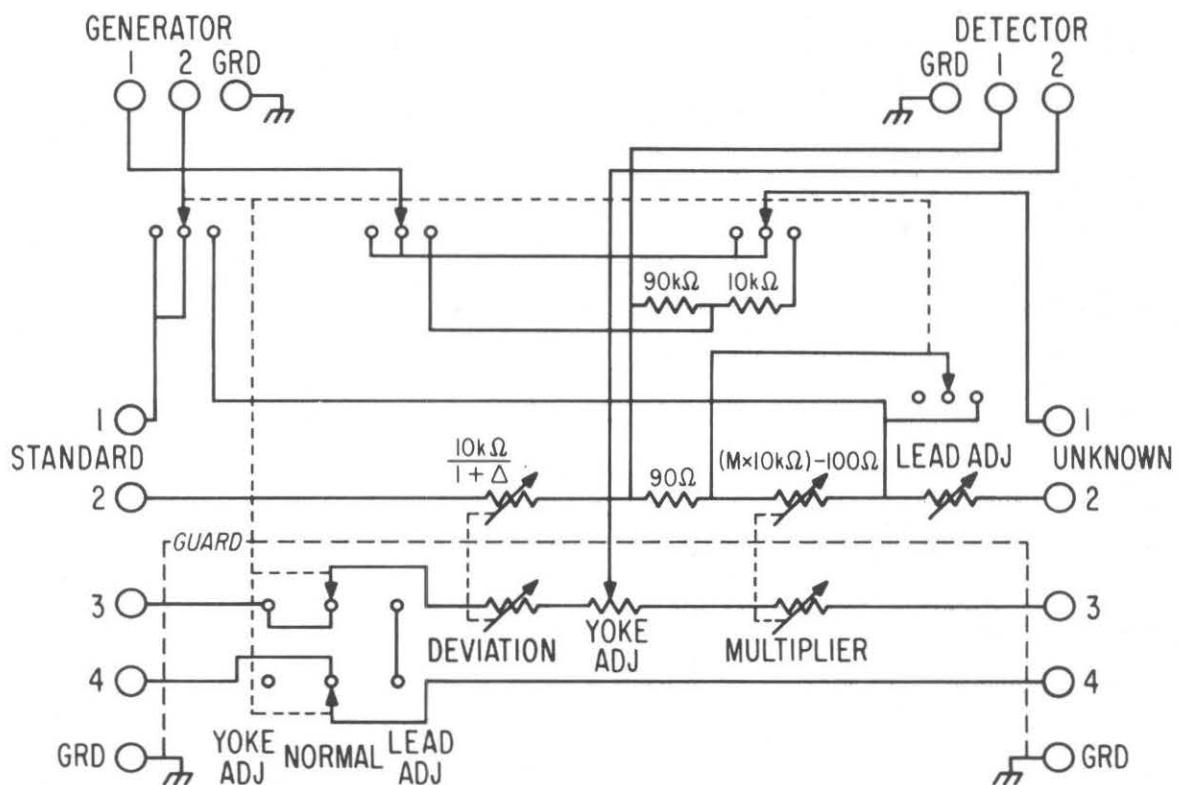


Figure 1-1 Simplified Schematic Diagram

OPERATION

Normally you have to use three of the controls on ESI Model 240C Kelvin Ratio Bridge when you are comparing resistors. The other controls are to compensate for the resistance of test leads. The three controls most used are:

DEVIATION dial which is usually used as the balancing control of the bridge. The reading of this dial (times the reading of the DEVIATION RANGE dial) is the exact amount by which the unknown resistor differs from the standard resistor (times the reading of the MULTIPLIER dial) when the bridge is balanced.

The in-line reading of these three dials, when the bridge is balanced, shows exactly how the unknown resistor differs from the standard resistor. The other three controls; LEAD ADJ, YOKE ADJ, and FUNCTION switch are used to compensate for the resistance of the leads. The FUNCTION switch selects the proper circuit configuration for each adjustment and points to the adjustment to be made. Once these adjustments have been made for a given test-lead set, they will probably not need to be changed unless you change the leads, but the adjustments should be checked frequently.

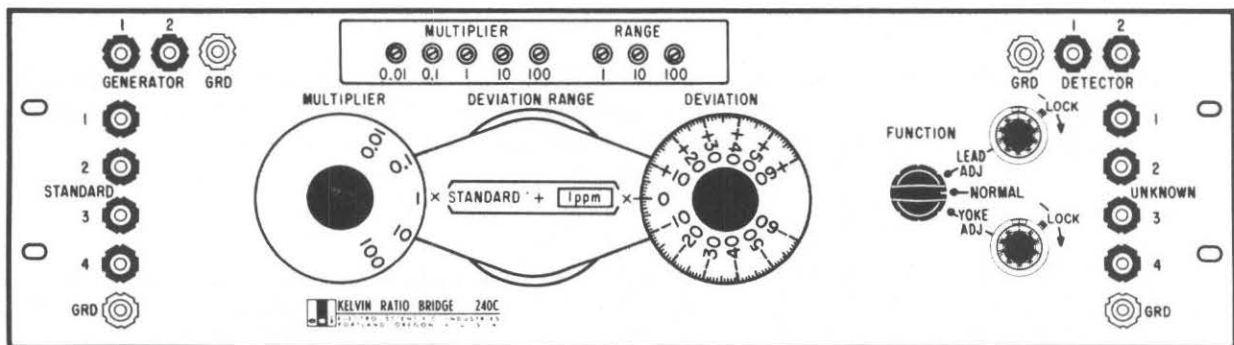


Figure 2-1. Controls

2.2 BASIC OPERATING PROCEDURE

2.2.1 Measurement

The exact method you use to make a resistance measurement with the Model 240C Bridge depends to some extent on the other equipment connected to it. You have to use the controls on the detector, the generator, and (if it is variable) the resistance standard. Once the generator, detector and the resistance standard are connected to the bridge, the basic operating procedure is as follows:

1. Connect the unknown resistor to the UNKNOWN binding posts of the bridge. (Use KELVIN KLIPS® or KELVIN KLAMPS® to make a four-terminal connection to a two-terminal device. Use four separate wires for measuring a four-terminal resistor.)
2. Set the MULTIPLIER dial to the proper setting for the approximate value of the unknown resistor and the resistance standard. Be sure that the FUNCTION switch is in the NORMAL position. (Check at this time to see that the resistance standard is set to the proper value if it is adjustable.)
3. Turn the generator off if it is not already off, and zero the detector on the most sensitive detector range that you are going to use.
4. Set the detector to a range that is insensitive enough to keep it on scale when you turn on the generator, then, (after setting it to the desired output level) turn on the generator.
5. The next step depends on what you wish to find from the measurement.
 - a. If you want to find the deviation of the unknown resistor from the value of the resistance standard, adjust the DEVIATION RANGE and DEVIATION controls for null-detector null indication.
 - b. If you know the deviation of the standard and wish to find the nominal value of the unknown resistor, set the DEVIATION RANGE and DEVIATION controls for the given value and adjust the resistance standard for null-detector null indication.
6. After each adjustment, increase the detector sensitivity so that the indication stays on scale but is clearly perceptible. Continue this process until the detector is balanced at the most sensitive range needed for the measurement.

2.2.2 Lead Compensation

If KELVIN KLIPS® Four-Terminal Clips or some other four-terminal connection is used to connect the resistor to the bridge, the following steps should be performed when the test leads are changed. (If measurements to be made are of resistors higher than 100 kilohms, these steps may be omitted).

- a. Reduce the sensitivity of the detector again and set the FUNCTION switch to LEAD ADJ. Adjust the LEAD ADJ control for detector null, increasing detector sensitivity as required.
- b. Set the FUNCTION switch to NORMAL and repeat steps 5 and 6.

- c. Reduce the detector gain again and set the FUNCTION switch to YOKE ADJ. Adjust the YOKE ADJ control for detector null, increasing the detector sensitivity as required.
- d. Set FUNCTION switch to NORMAL after adjusting controls.

2.3.1 Normal Connections

The 240C Bridge is designed for four-terminal connections to the standard and unknown resistors. Four binding posts are provided for four separate leads to the standard and unknown resistors. On each side the leads from terminals 1 and 2 are to be connected to one end of the resistor and the leads from terminals 3 and 4 to the other end, as shown in Figure 2-2.

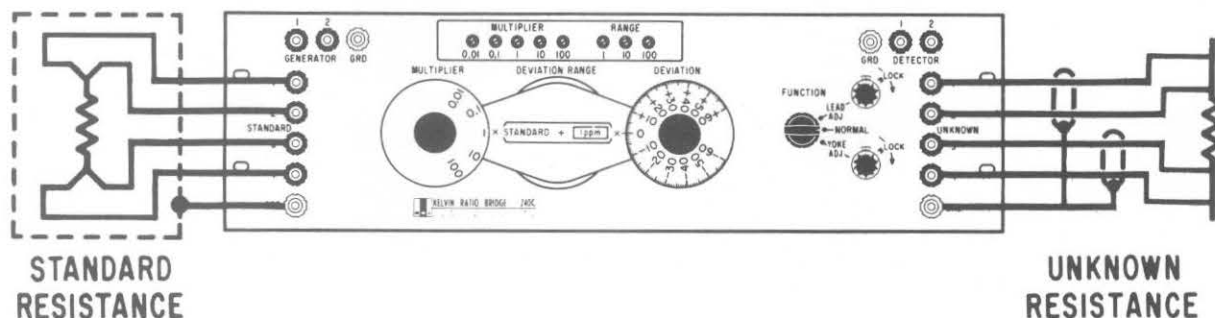


Figure 2-2. Normal Connections

It is advisable to use shielded leads for connecting to the unknown and standard resistors. The shields should be connected to the bridge ground. This not only prevents leakage between the leads from appearing in shunt with the standard or unknown resistor, it also reduces ac pickup which may be a problem when an electronic detector is used. Since leakage between terminals 1 and 2, or 3 and 4 will not affect the measurement, each pair may be enclosed in the same shield. However, leakage between the enclosed leads and the shield will appear across internal bridge arms, thus it is necessary that the leads be adequately insulated from the shield. ESI KELVIN KLIPS[®] (four-terminal connectors) or Belden 8422 cable is recommended for this application.

In connecting the standard and unknown resistors it is necessary to consider the effects of the lead resistances. The resistance of the lead connected to terminal 1 on both the standard and unknown side of the bridge is in series with the generator and will not affect the measurement accuracy. The resistance of the lead connected to terminal STANDARD 2 appears in series with a 10-kilohm bridge arm. This could cause a 1-ppm ratio error for each 10 milliohms of lead resistance. On the unknown side, the lead compensation adjustment makes it possible to compensate for lead resistances under 100 milliohms in series with UNKNOWN 2 and 3. Lead resistance in series with STANDARD terminals 1 and 4 and UNKNOWN terminals 1 and 4 will not be critical except for low-value resistance measurements. When making low-value resistance measurements the connections shown in Figure 2-5 can be used to reduce the yoke resistance. The yoke resistance referred to throughout this manual is the resistance between terminal STANDARD 4 and UNKNOWN 4 plus the resistance of the leads connected to these two terminals, including the leads inside four-terminal standard and unknown resistors.

As an alternate connection for high resistance measurements, where the Kelvin bridge advantages are not needed, the pair of leads to each end of each resistor may be replaced by a single lead, and UNKNOWN terminal 1 connected to 2, and 3 connected to 4 at the bridge. There is normally little need for this connection, however, since the Kelvin Klip leads or other test lead pairs used for low resistance measurements can be used equally well for high resistance measurements.

2.3.2 Guarded Unknown And Standard Resistor Connections

The Model 240C Bridge is so designed that internal leakages will not appear in shunt with either the resistor under test or the standard. This makes it possible to measure very high resistance. However, it is necessary that the resistor under test is not subject to external leakage effects. When a resistor is mounted between two terminals on an insulating block, the leakage of the block shunts the resistors. When separate insulators are mounted on a conducting support, however, as illustrated in Figure 2-3, the leakages can be separated from the resistor.

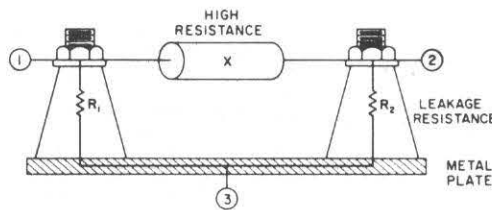


Figure 2-3. Leakage Resistance

When the third terminal (the case or mounting plate) is connected to the Kelvin bridge as shown in Figure 2-4 the leakages are placed across other arms of the bridge circuit. Leakage resistances R_2 and R_4 are essentially across the detector and will cause no error. Leakage resistance R_1 will be across a 10 kilohm internal bridge arm. This means R_1 must be greater than 10^{10} ohms before it can be considered as causing a negligible error (less than 1 ppm). Leakage resistance R_3 must be greater than 10^{10} ohms times the standard multiplier setting to have a negligible effect.

When making high resistance measurements with the Model 240C bridge, it is advisable to use shielded leads for connecting to the unknown and standard resistors. The shields should be connected to the bridge ground. This not only prevents leakage between the leads from appearing in shunt with the standard or unknown resistor, it also reduces ac pickup which may be a problem when an electronic detector is used.

2.3.3 Connections For Resistance Measurements At High Current

To measure low-value resistors using a high current, an external current loop should be formed as shown in Figure 2-5. This method will also permit a lower yoke resistance to be used than that internal to the bridge.

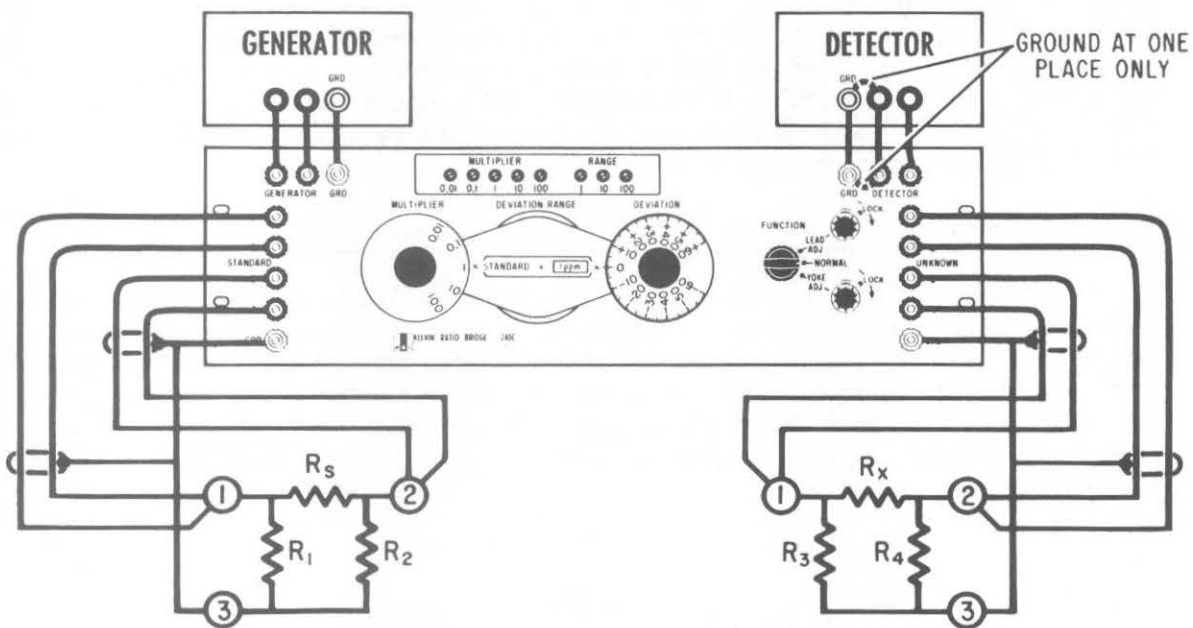


Figure 2-4. Guarded Connections

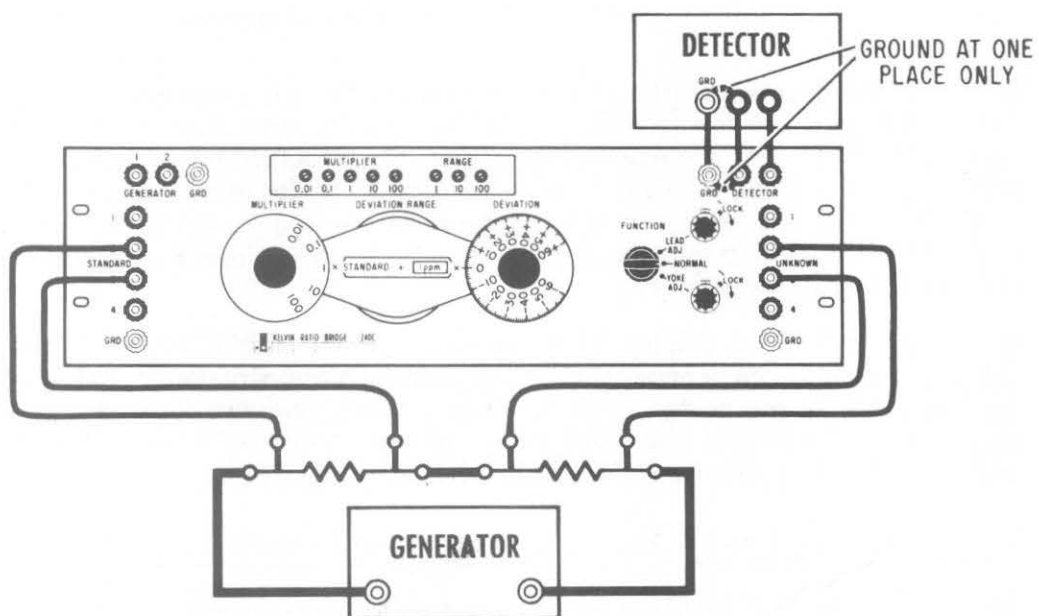


Figure 2-5. Measurement With High Current

2.3.4 Connections For Resistance Measurements At High Voltage

To measure high-value resistors at voltages high enough that they could cause breakdown in the bridge (1000 volts or more) or where it is desired to have equal voltage across the standard and unknown resistors instead of equal current, the connections shown in Figure 2-6 should be used. (The connections shown are for three-terminal resistors). It is necessary to have either a high-voltage power supply which is of completely guarded construction, (the guarded terminal being the one connected to the junction of the unknown and standard) or a detector which can be isolated from ground.

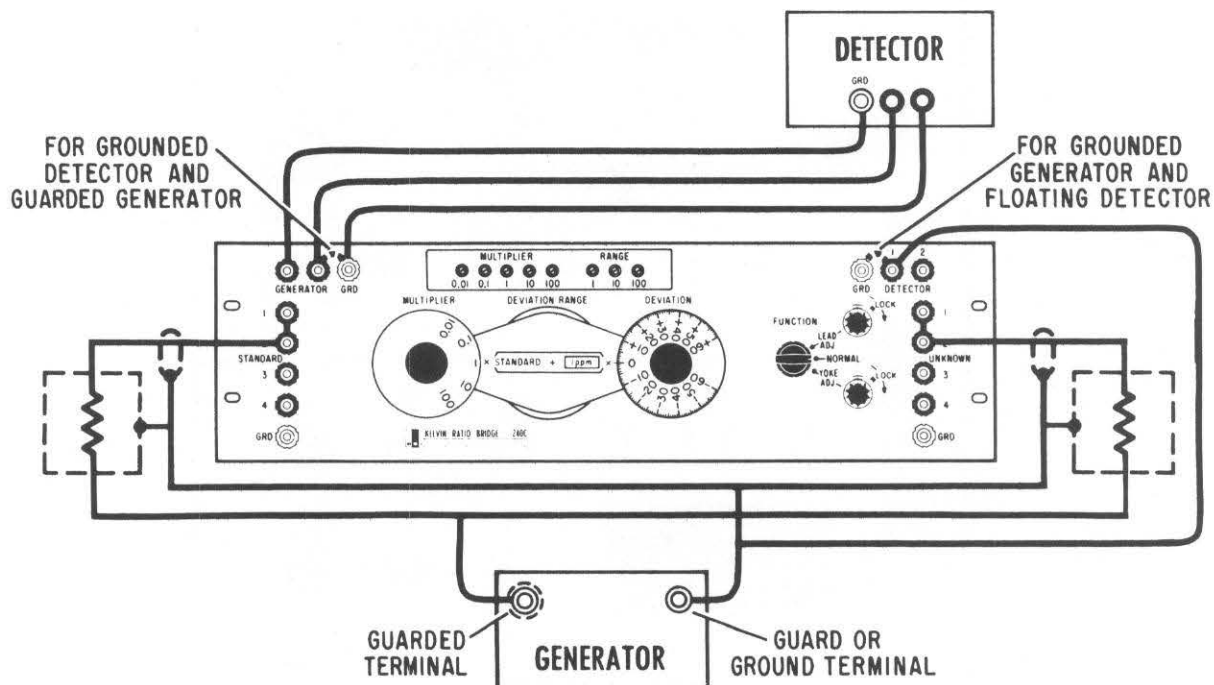


Figure 2-6. Measurement With High Voltage

ESI Model 240C Kelvin Ratio Bridge is a highly versatile instrument that can be used in several ways to compare resistances. In most cases, the instrument is used as part of a system that includes generator, detector, and resistance standard. Such a system is shown in Figure 2-7.

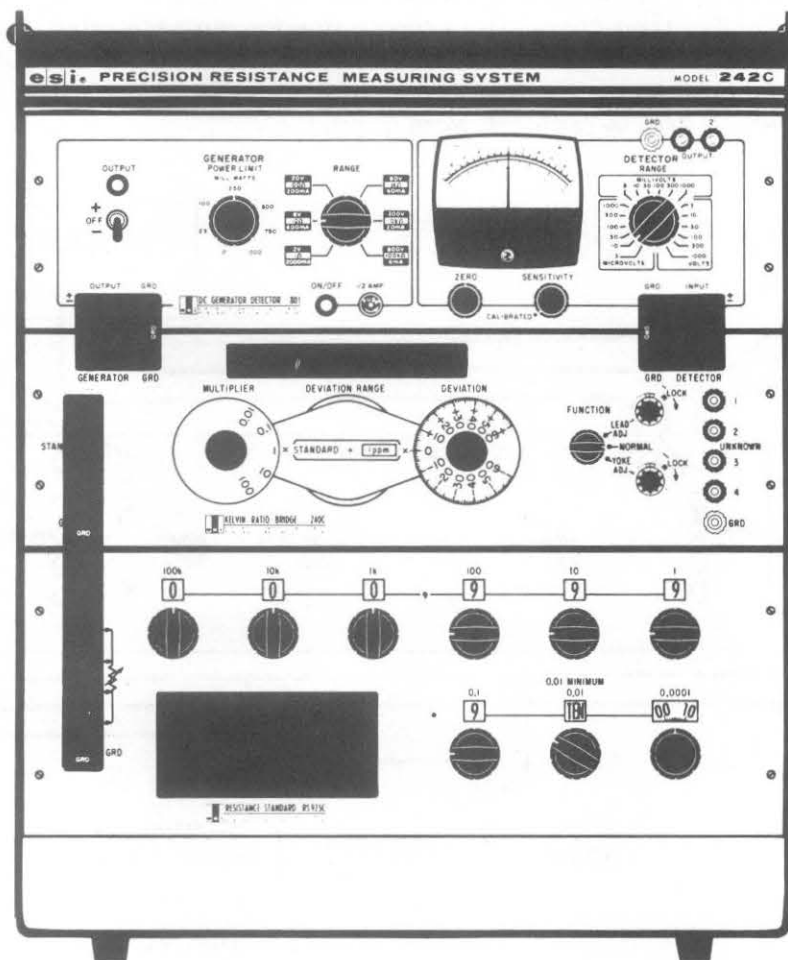


Figure 2-7. Model 242C Resistance Measuring System

The bridge is usually left connected to the rest of the system, but some of the techniques that follow require different connections.

2.4.1 Traceable Resistance Calibration

In precision resistance measurement the calibration of any resistor must be traceable through a succession of precise resistance comparisons to the unit of resistance maintained as a national or international standard. The resolution and short-term stability of the Model 240C bridge makes it possible to compare two like resistance values to an accuracy better than 0.2 parts per million.

A standard resistor can be compared with a parallel-connected group of resistors yielding the same resistance value. The same group of resistors can then be connected in series to provide a calibrated standard of a different resistance value. ESI Model SR1010 and Model SR1050 Resistance Transfer Standards are designed to make this series-parallel transfer with negligible loss in accuracy. The use of a set of Model SR1010 Transfer Standards with

the Model 240C Bridge will permit calibration of resistors from an ohm to a megohm with an accuracy of a few parts per million, relative to a reference standard certified by the National Bureau of Standards.

The comparison of like resistance values required for this type of calibration can be made independent of the absolute accuracy and long-term stability of the bridge ratio by using either of the two methods described in the following sections.

2.4.2 Resistance Comparison By The Interchange Method

In the comparison of two nominally equal resistors by the interchange method, the calculated deviation from the standard resistor of the unknown resistor will normally be accurate to within 1 ppm for resistors matched within 60 ppm; accurate to within 0.1 ppm for resistors matched within 6 ppm.

Follow the basic procedure of Section 2.2 to perform the following pair of measurements:

1. With the known resistor connected to the STANDARD terminals and the unknown resistor connected to the UNKNOWN terminals, balance the bridge and read the DEVIATION dial. Call this reading d_1 .
2. With the unknown resistor connected to the STANDARD terminals and the known resistor connected to the UNKNOWN terminals, balance the bridge and read the DEVIATION dial. Call this reading d_2 .
3. Calculate $\frac{d_1 - d_2}{2}$. This is the deviation of the unknown resistor from the standard resistor. To obtain the deviation of the unknown resistor from nominal value, add to this calculated value the deviation of the standard resistor from nominal value.

2.4.3 Resistance Comparison By The Substitution Method

In the comparison of two nominally equal resistors by the substitution method, a working standard resistor is left connected to the STANDARD terminals of the ratio bridge while two measurements are made -- one with an accurately known resistor connected to the UNKNOWN terminals, the other with the unknown resistor connected to them.

This method is particularly convenient when a decade standard such as the ESI Model RS 925 is used, since it makes possible direct dial readings corrected to agree with the calibration of the known resistor and expressed either in ohms or in part-per-million deviation from the nominal value.

This method is based on the fact that either the DEVIATION dial or the decade standard can be used as a calibration adjustment to make the other one read exactly the value of a known resistor connected to the unknown terminals; with the reading exactly correct at this setting, it will be correct within one ppm at all nearby settings (to at least ± 60 ppm).

Follow the basic procedure of Section 2.2 to perform either of the following pairs of measurements.

a. To read value in ohms

1. With the known resistor connected to the UNKNOWN terminals, set the decade standard to its given resistance value, then use the DEVIATION dial to balance the bridge.

2. Disconnect the known resistor and connect the unknown resistor.
3. Leaving the deviation dial setting alone, use the decade standard adjustment to balance the bridge. Its reading will be the value of the unknown resistor.

b. To read deviation from nominal value

1. With the known resistor connected to the unknown terminals, set the deviation dial to its given deviation from nominal value, then use the decade standard dials to balance the bridge.
2. Disconnect the known resistor and connect the unknown resistor.
3. Leaving the decade standard setting alone, use the deviation dial to balance the bridge. Its reading will be the deviation of the unknown resistor from nominal value.

2.4.4 Comparison of Low Resistance Values

When the values of the standard and unknown resistors are so low that the voltage drop in the "yoke" circuit connecting them in series becomes an appreciable fraction of the sum of the voltage drops in the standard and the unknown resistors, the accuracy of the "yoke" or "auxiliary" ratio in the comparison bridge becomes important. The YOKE ADJ control allows the operator to adjust the yoke resistance during the measurement process. You should be careful to check the YOKE ADJ setting as described in subsection 2.2.2 whenever the resistance to be measured is less than 100 ohms.

You can demonstrate the need for yoke adjustment by measuring a resistor and while the detector is nulled and the generator is still on, turn the YOKE ADJ control about 10 divisions. If there is no perceptible change in the null (as there should not be when the unknown resistor is 10 kilohms or higher), there is no need to be concerned with the YOKE ADJ control.

2.4.5 High Resistance Measurement

For comparing two resistors having a very high resistance value, a higher voltage can be applied to the standard and unknown resistors, and the bridge sensitivity thereby increased by interchanging the generator and the detector. This connection may also be useful in other applications where it is desirable to have the same voltage applied to the standard and the unknown; the usual connection makes their currents the same; on ranges higher or lower than $1 \times \text{STANDARD}$, the relative power dissipated by the standard and the unknown will be interchanged by the generator-detector interchange. (The normal connection applied the greater power to the larger resistance. The interchanged connection applied the greater power to the smaller resistance).

If the detector used is sufficiently insulated from ground, the generator lead connected to the DET 2 terminal of the bridge should be grounded. However, if the detector is designed to operate with one of its terminals grounded the generator must be floated. Which GEN terminal should be connected to the ground detector lead will depend on the multiplier used.

NOTE: ESI Model 801 Generator-Detector can be used with either detector or generator isolated from ground.

SECTION III

CALIBRATION ADJUSTMENTS

3.1 BASIC PROCEDURE

The following procedure is recommended for those instruments that are normally used without a trimmable decade resistance standard such as the ESI Model RS 925C. ESI Models 240C and RS 925C are normally part of the ESI Model 242C Resistance Measuring System. Instructions for calibrating the entire system are given in the manual for the system.

Calibration of the Model 240C consists of adjusting MULTIPLIER and RANGE trimmers. The recommended procedure (if the instrument is not used as part of the Model 242C System) is outlined as follows:

1. Adjust DEVIATION dial mechanically
2. Adjust 1-to-1 ratio with MULTIPLIER 1 trimmer.
3. Adjust deviation ranges for best accuracy with RANGE 1, 10, and 100 trimmers.
4. Adjust 100-to-1 and 1-to-100 ratios with MULTIPLIER 0.01 and 100 trimmers.
5. Adjust 10-to-1 and 1-to-10 ratios with MULTIPLIER 0.1 and 10 trimmers

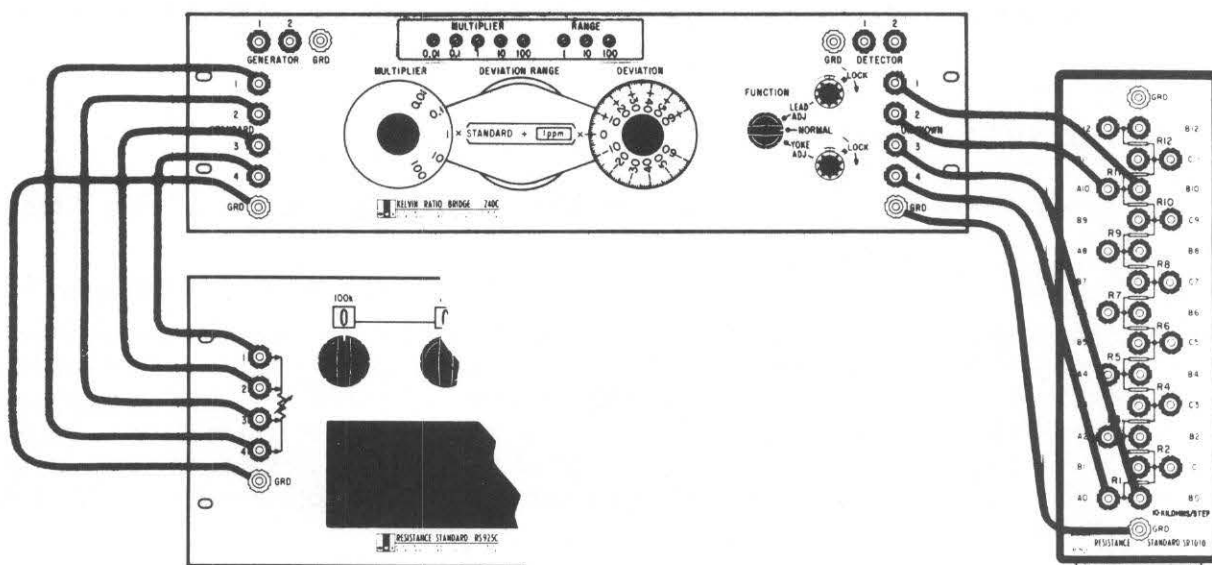


Figure 3-1. 1-to-1 Calibration Connection

1. Transfer Standard, 10-kilohms-per-step; ESI Model SR 1010 or equivalent.
2. Shorting Bars: (for connecting transfer standard resistors in parallel or series-parallel). ESI Model SB 103 or equivalent.
3. Decade Resistance Standard: (Used as a tare resistor in this procedure) ESI Model RS 925C or equivalent (usually supplied with Model 240 series bridges in Model 242 series resistance measuring systems).
4. Generator-Detector: (See subsection 1.3 for specifications) ESI Model 801 or equivalent
5. Test Leads: Flexible 24-inch leads with spade lugs for connections. Pomona Electronics Model No. 1693-24 or equivalent.

3.3 MECHANICAL ADJUSTMENTS

1. Turn DEVIATION dial clockwise through -60 to +60. There should be a perceptible change in the feel of the dial action between these two settings. There should be a smooth region between them and a slight detent at both +60 and -60.
2. If the detents are not within one dial division of +60 and -60, turn the dial to locate the detent that corresponds with -60.
3. Loosen the setscrews on the dial and slip it to read -60, then tighten the setscrews.

3.4 1-TO-1 RATIO CALIBRATION

1. Generator and detector should be connected to the bridge. Connect them if they are not.
2. Set dials to read $1 \times \text{STANDARD} + 0.1 \text{ ppm} \times 0$. Be sure index is lined up with 0.
3. Connect decade resistance standard to STANDARD binding posts and connect ten resistors of transfer standard to UNKNOWN binding posts. Use 24-inch flexible test leads so that connections between STANDARD and UNKNOWN binding posts can be interchanged. Be sure to use four-terminal connections (see Figure 3-7). Terminals 1 and 2 should be connected (electrically) at the standards, as should terminals 3 and 4. Use ordinary wire or test leads to ground the cases of both standards to the bridge GRD terminals.
4. Turn on generator and adjust decade resistance standard for null. Check and (if necessary) adjust LEAD and YOKE ADJ controls using the procedure in subsection 2.2.
5. Interchange the connections on UNKNOWN and STANDARD binding posts. Do not disconnect test leads from decade standard or from transfer standard. Be sure that all four leads on each standard are connected to the bridge.
6. Check and (if necessary) adjust LEAD and YOKE adjustments. Adjust the decade standard to remove half the indicated deflection and (with a screwdriver) adjust MULTIPLIER 1 control to remove the other half of the indicated deflection.

7. Repeat steps 5 and 6: Interchange standard and unknown and remove half the indicated deflection by adjusting the decade resistance and the other half by adjusting the MULTIPLIER 1 trimmer.
8. When there is no detectable difference in deflection when the standards are interchanged, reconnect the decade standard to the standard binding posts with the solid insulated wires provided. Do not make any further adjustments to the MULTIPLIER 1 trimmer.

NOTE: Do not change the setting of the decade resistance standard. This setting will be used in the following steps.

3.5 DEVIATION RANGE CALIBRATION

1. Be careful not to change the setting of the decade resistance standard that was adjusted in the preceding step. This resistance has been adjusted to be the same as the ten resistors of the transfer standard.
2. Connect the same ten resistors of the transfer standard that were used in the previous procedure to the UNKNOWN terminals. Use the same test leads as before.
3. Set dials of bridge to read $1 \times \text{STANDARD} + .01\% \times 0$. Be sure index is lined up with 0. Be sure that FUNCTION switch is set to NORMAL.
4. Turn on generator and adjust range 100 trimmer for null. Check and (if necessary) adjust LEAD and YOKE adjustments using the procedure in subsection 2.2. Repeat adjustment of trimmer with function switch on normal if necessary.
5. Turn off generator and set DEVIATION RANGE to .001%.
6. Turn on generator and adjust range 10 trimmer for null. Check and (if necessary) adjust LEAD and YOKE adjustments. Repeat adjust of trimmer if necessary.
7. Turn off generator and set DEVIATION RANGE to 1 ppm.
8. Turn on generator and adjust RANGE 1 trimmer for null. Check and (if necessary) adjust LEAD and YOKE adjustments. If necessary, repeat adjustment of trimmer with the function switch set to normal.

NOTE: Do not change the settings of the decade resistance standard. This setting will be used in the following steps.

3.6 100-TO-1 RANGE CALIBRATIONS

1. Connect same ten resistors of transfer standard that were used in previous step to UNKNOWN binding posts. Use same test leads.
2. Set dials of bridge to read $1 \times \text{STANDARD} + 0.1 \text{ ppm} \times 0$.
3. Turn on generator and adjust deviation dial for null if necessary. Check and (if necessary) adjust lead and yoke adjustments. Be sure to set function switch back to NORMAL.
4. Turn off generator. Connect shorting bars to transfer standard so that the ten resistors used are connected in parallel.
5. Set MULTIPLIER to $0.01 \times \text{STANDARD}$, then turn on generator. Do not change setting of DEVIATION dial.

6. Adjust MULTIPLIER 0.1 trimmer for detector null.
7. Turn off generator. Set dials to $1 \times \text{STANDARD} + 0.1 \text{ ppm} \times 0$. Be sure index is lined up with 0.
8. Set decade resistance standard to $1/100$ of its present setting.
9. Turn on generator and adjust decade resistance standard for null.
10. Turn off generator. Remove shorting bars from transfer standard and connect the first ten resistors in series to the UNKNOWN binding posts of the bridge.
11. Set MULTIPLIER to $100 \times \text{STANDARD}$, then turn on generator.
12. Adjust MULTIPLIER 100 trimmer for detector null.

3.7 10-TO-1 RANGE CALIBRATIONS

1. Connect 9 resistors of transfer standard in series-parallel with shorting bars. The resistance of the network is the same as the resistance of one step of the transfer standard.
2. Connect the 9 series-paralleled resistors to the UNKNOWN binding posts of the bridge. Use the same test leads as in the previous steps.
3. Set dials of bridge to $1 \times \text{STANDARD} + 0.1 \text{ ppm} \times 0$. Be sure that index is lined up with 0.
4. Turn on generator and adjust decade standard for null.
5. Turn off generator. Connect tenth resistor of transfer standard to UNKNOWN binding posts of bridge. Remove the shorting bars to make this connection.
6. Set DEVIATION RANGE dial to $+ 1 \text{ ppm} \times \dots$
7. Turn on generator and adjust DEVIATION dial for null. Do not adjust decade resistance standard.
8. Turn off generator set dials of bridge to $10 \times \text{STANDARD} + 0.1 \text{ ppm} \times \dots$. Do not change setting of DEVIATION dial. Changing the DEVIATION RANGE without changing the DEVIATION dial effectively divides the DEVIATION dial setting by 10. This is the effect that you need for this procedure.
9. Connect first ten resistors of transfer standard (in series) to UNKNOWN binding posts.
10. Turn on generator and adjust MULTIPLIER 10 trimmer for null.
11. Turn off generator and connect the first ten resistors of the transfer standard in parallel.
12. Connect the paralleled resistors to the UNKNOWN binding posts.
13. Set dials of bridge to $0.1 \times \text{STANDARD} + 1 \text{ ppm} \times$. Do not change setting of DEVIATION dial.
14. Turn on generator and adjust MULTIPLIER 0.1 trimmer for null.

SECTION IV

THEORY

4.1 THE KELVIN BRIDGE

The Kelvin Ratio Bridge was originally designed to measure low values of resistance. It is basically a Wheatstone Bridge with a second (yoke) pair of resistance ratio arms ganged to the primary ratio arms. This feature allows the bridge to compensate for lead resistance by making a four-terminal measurement, as we will show below. At high resistances the need for compensation for low-resistance effects disappears. At high resistances the Kelvin bridge effectively approaches the configuration of the Wheatstone bridge, and if the bridge is guarded, it can be used for high-resistance measurements as well as for low.

4.2 THEORY OF OPERATION

Figure 4-1 is a simplified schematic diagram of the Model 240C Kelvin Ratio Bridge with unknown and standard resistors connected and test-lead resistances shown. If the resistance of the DEVIATION arm is A , the resistance of the MULTIPLIER arm is B , the resistance of the standard is S , and the resistance of the unknown is X , it is easy to see that if the lead resistances (L_1 through L_4) were zero, the bridge is balanced when:

$$\frac{A}{B} = \frac{S}{X} \quad \text{or} \quad X = \frac{SB}{A}$$

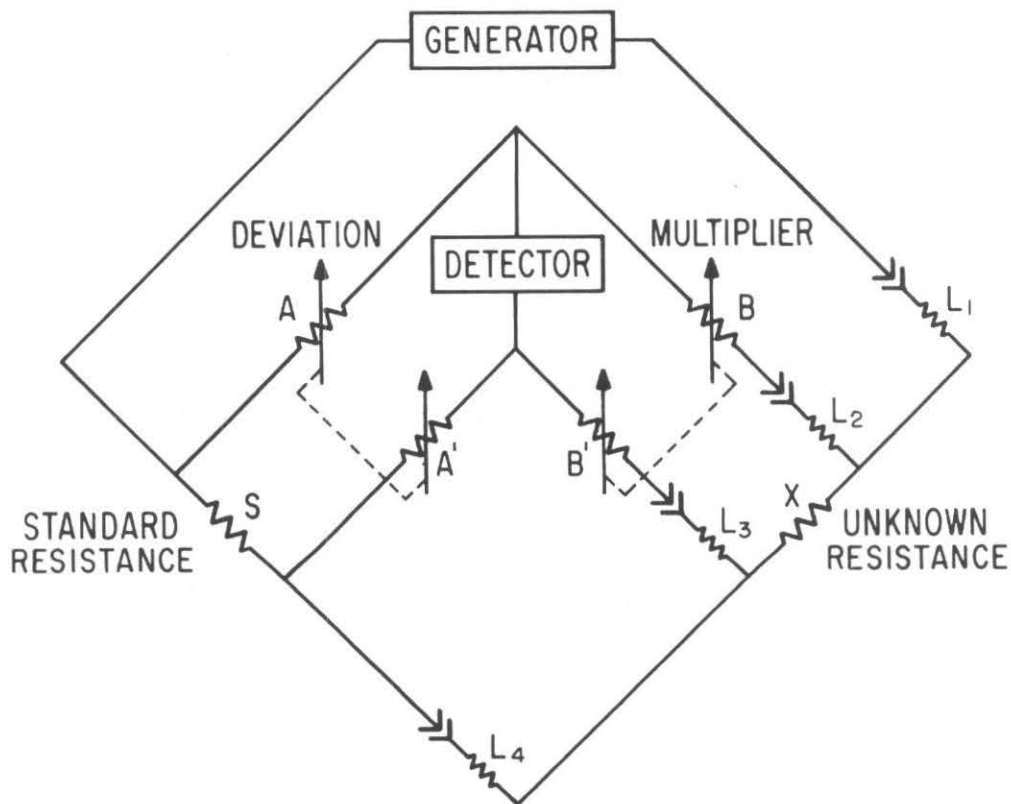


Figure 4-1. Simplified Schematic Diagram

The bridge is so constructed that:

$$A = \frac{10k\Omega}{1 + \text{DEVIATION}} \quad \text{and} \quad B = (\text{MULTIPLIER} \times 10k\Omega) + L_2$$

where DEVIATION and MULTIPLIER indicate the numerical reading of the dials named. Note that the resistance of one lead (L_2) is included in the value of B. The LEAD ADJ control is used to subtract that value from the resistance of the bridge arm.

Assuming that $L_2 = 0$ for the moment, from the above we find:

$$X = \frac{S (\text{MULTIPLIER} \times 10k\Omega)}{\frac{10k\Omega}{\text{DEVIATION} + 1}}$$

Or:
$$X = S (\text{MULTIPLIER}) (\text{DEVIATION} + 1)$$

If the lead and contact resistances designated by L_1 through L_4 are not zero, the resistances A' and B' , the yoke ratio resistances, enter the calculations. Note first that lead resistance L_1 is in series with the generator and not in series or parallel with any bridge arm. For this reason it has no effect on the accuracy of the measurement. As before, the LEAD ADJ control is used to subtract the value of test-lead resistance L_2 from the resistance of the MULTIPLIER arm.

The yoke resistances A' and B' compensate for the remaining test lead resistances, L_3 and L_4 . In order to compensate properly, resistance A' is adjusted so that:

$$\frac{A'}{B' + L_3} = \frac{S}{X}$$

To show how this adjustment does compensate, consider the Delta—Y transform of resistances A' , $(B' + L_3)$, and L_4 as shown in Figure 4-2.

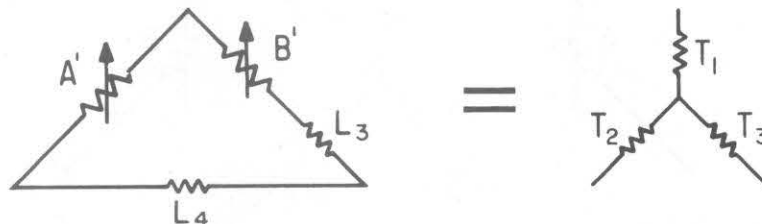


Figure 4-2. Delta—Y Transform

From the usual transform equations, the transform resistances T_1 , T_2 , T_3 are:

$$T_1 = \frac{A' (B' + L_3)}{A' + B' + L_3 + L_4}$$

$$T_2 = \frac{A' L_4}{A' + B' + L_3 + L_4}$$

$$T_3 = \frac{(B' + L_3) L_4}{A' + B' + L_3 + L_4}$$

From this we can see that:

$$\frac{T_2}{T_3} = \frac{A' L_4}{(B' + L_3) L_4} = \frac{A'}{B' + L_3}$$

Since by adjustment:

$$\frac{A'}{B' + L_3} = \frac{S}{X}$$

Then:

$$\frac{T_2}{T_3} = \frac{S}{X} \text{ or } T_2 = \frac{T_3 S}{X}$$

From this, considering the transformed bridge in Figure 4-3,

$$\frac{S + T_2}{X + T_3} = \frac{S + \left(\frac{T_3 S}{X}\right)}{X + T_3} = \frac{S X + S T_3}{X (X + T_3)} = \frac{S (X + T_3)}{X (X + T_3)} = \frac{S}{X}$$

And thus the ratio of the standard and unknown resistances plus the lead resistances equals the ratio of the standard and unknown resistances without the lead resistances.

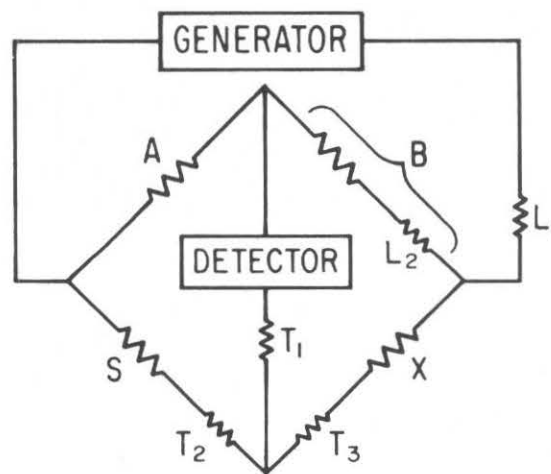


Figure 4-3. Transformed Bridge

4.3 YOKE AND LEAD ADJUSTMENTS

4.3.1 Lead Adjustment

When the FUNCTION switch is in the LEAD ADJ position, the circuit of the bridge is as shown in Figure 4-4. This configuration of the circuit is a bridge that compares the test lead and the LEAD ADJ rheostat (in series) to a 90-ohm resistance in the MULTIPLIER arm. The total of the test lead resistance and the rheostat resistance is adjusted to 10 ohms when the bridge is balanced.

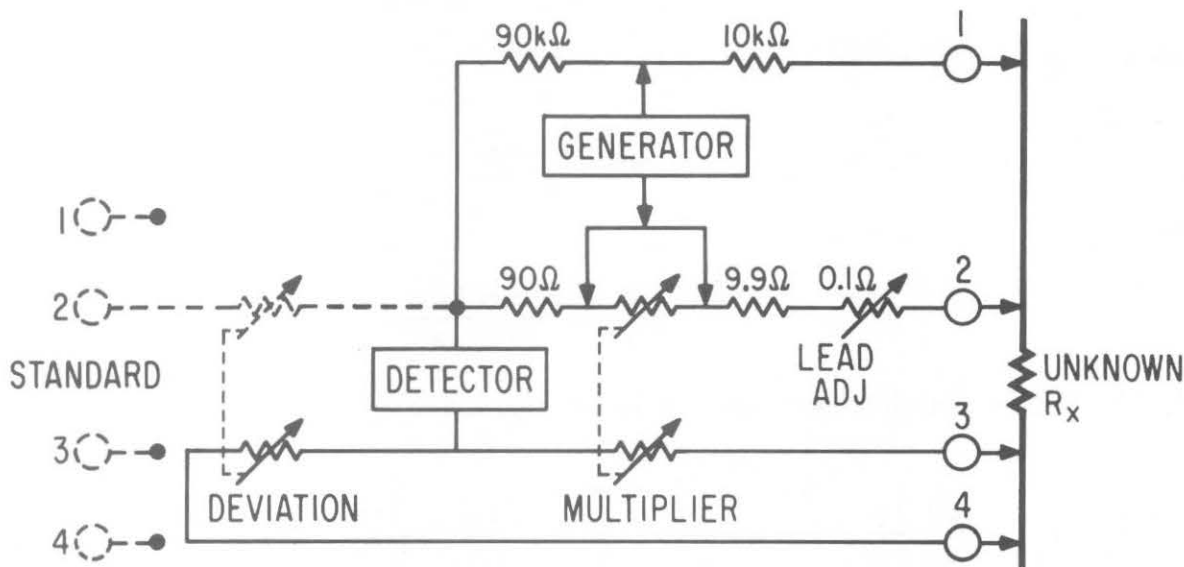


Figure 4-4. Lead Adjustment

4.3.2 Yoke Adjustment

When the FUNCTION switch is in the YOKE ADJ position, the circuit of the bridge is as shown in Figure 4-5. In this configuration, the low-resistance connection between the standard and unknown resistors is opened. The YOKE ADJ control is adjusted so that the series combination of the standard resistor, the YOKE ADJ rheostat, and the rheostat ganged to the DEVIATION control (call this combination $R_S + A'$) are in the same ratio to the series combination of the unknown resistor, lead resistance L_3 , and the resistance selected by the MULTIPLIER control (call this combination $R_X + L_3 + B'$) as the main ratio arms. That is:

$$\frac{R_S + A'}{R_X + L_3 + B'} = \frac{A}{B} = \frac{S}{X}$$

Where the latter two expressions are the same as in subsection 4.2 above.

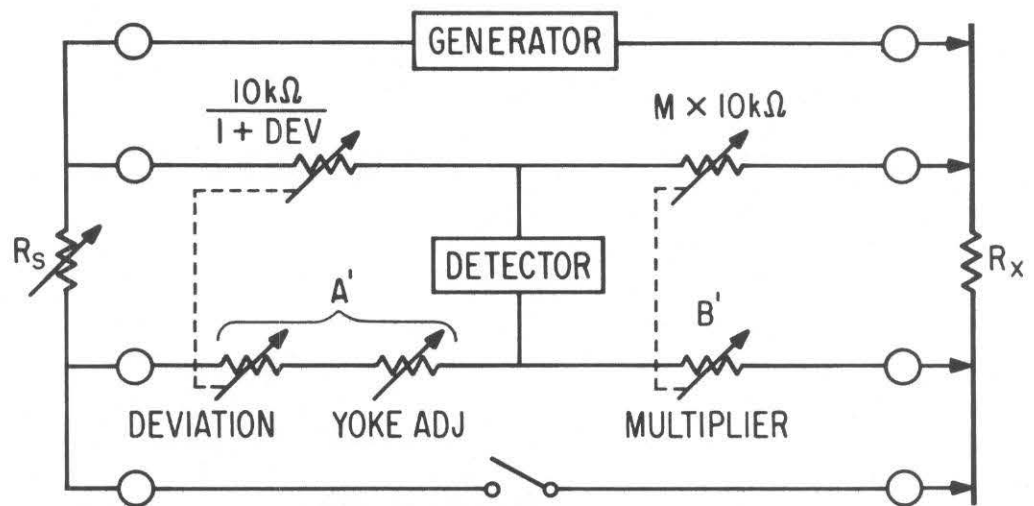


Figure 4-5. Yoke Adjustment

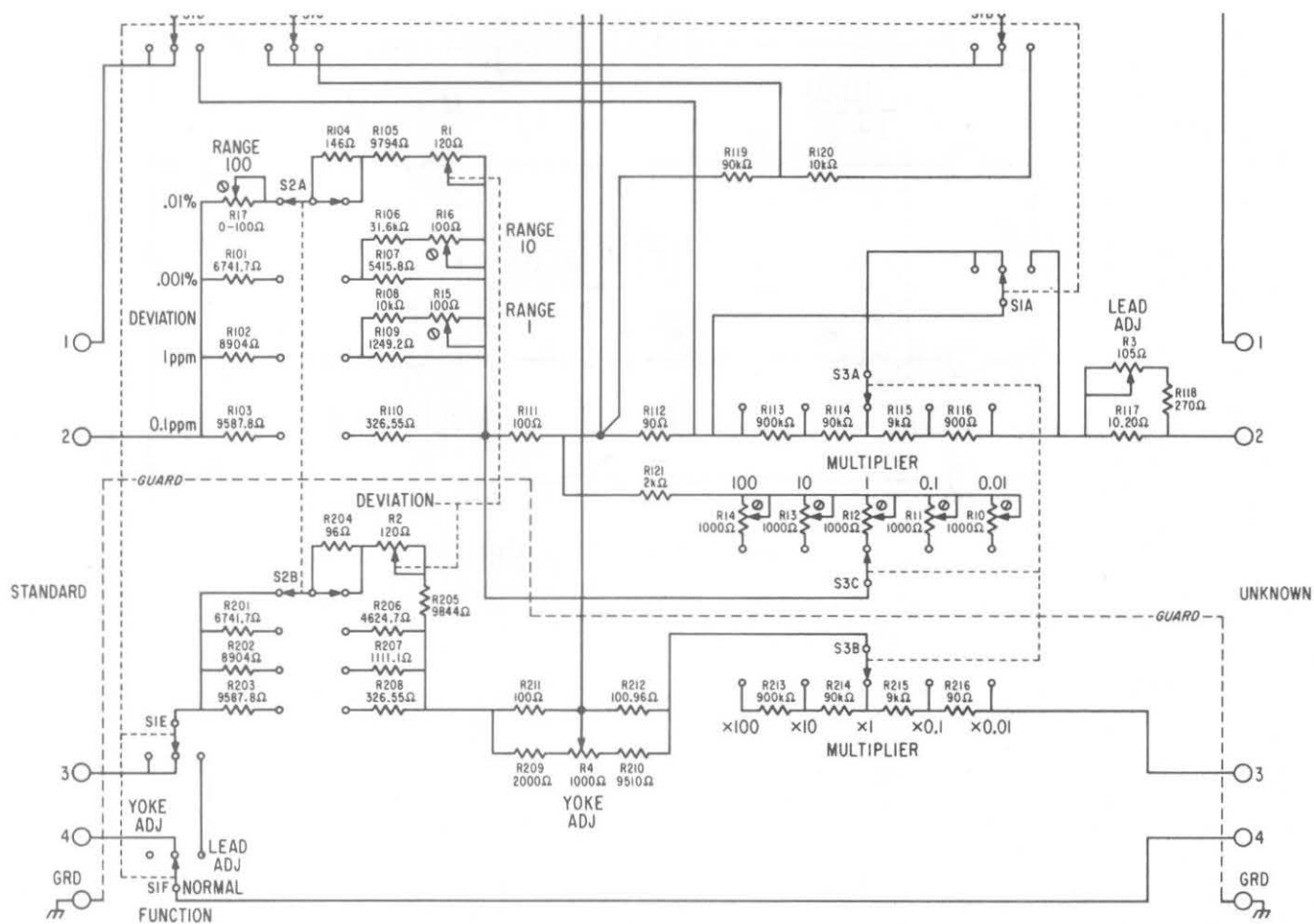
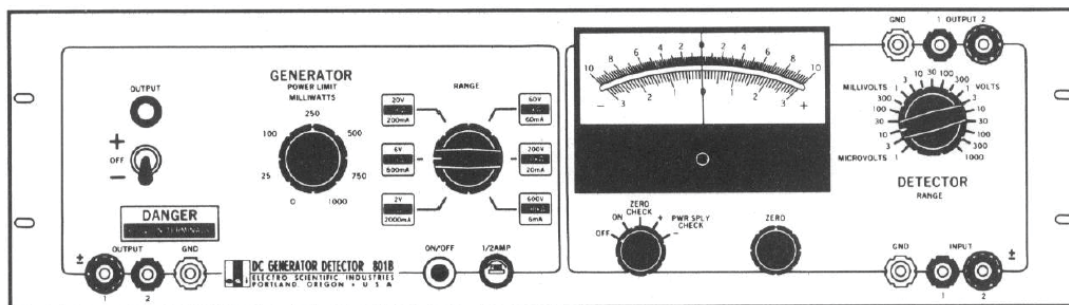


Figure 4-6. Model 240C Schematic Diagram

801B

DC GENERATOR/DETECTOR

User Manual



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IET LABS, INC.
formerly manufactured by
esi/Tegam

www.ietlabs.com
Email: info@ietlabs.com
TEL: (516) 334-5959 • FAX: (516) 334-5988

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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.

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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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ACKNOWLEDGMENTS

We wish to thank Keithley Instruments Inc. for information concerning theory of operation, maintenance, schematic diagrams, and calibration and adjustment procedures for the detector. In particular, Sections 3.2, and 4.2 were adapted from the instruction manual for the Keithley 155 Null Detector-Microvoltmeter by permission of Keithley.

SECTION 1

DESCRIPTION

1.1 INTRODUCTION

The ESI Model 801B is a DC Generator and null Detector (microvolt-meter). The instrument features double-chassis construction, or guarding, to greatly reduce stray leakage paths to ground.

The output of the generator is continuously variable and is limited to a maximum of one watt into a matched load. A front panel control selects six output impedance ranges to match loads from 1 ohm to 100 kilohms.

An active circuit line regulator reduces the effect of line transients by a factor of more than ten. Unique guarded relays that control generator power allow remote operation of the generator. In this way, an operator can control the generator with a foot switch or the instrument can be operated by automatic equipment. The generator output terminals are short-circuited when the generator is turned off, which inhibits transient pulses at the instant of turn-on.

The detector features a very sensitive modulator-type DC amplifier. Trouble caused by stray AC pickup from the device under test is greatly reduced by a rejection filter. The modulator operates above the AC line frequency, thus further reducing the AC pickup.

The double-chassis construction and complete integrity of guarding allow either the detector or the generator to be floated more than 600 volts above ground.

the double-chassis construction and complete integrity of guarding allow either the detector or the generator to be floated more than 600 volts above ground.

The unique design features of the Model 801B make it suitable to a number of applications:

1. Very high resistance bridge measurements can be made with superior accuracy because of the special guarding and shielding features, and because of line transient reduction.
2. Very low resistance bridge measurements can also be made with high accuracy because of the detector sensitivity and the provision for matching the generator to the load.
3. The same features apply to make the 801B an ideal generator-detector combination for calibrating precision voltage dividers.
4. The 801B can be used directly to measure extremely low conductance (high resistance). See Section 2.7.
5. The 801B generator can be used separately wherever a variable, guarded, and power limited DC supply is needed.
6. The 801B detector can be used separately as a voltmeter or microvoltmeter with ranges up to 1,000 volts.

1.2 SPECIFICATIONS

1.2.1 Generator

Range: 6 ranges, continuously variable, 0 to 600V. Power limited to 1 watt.

Regulation: Active-circuit line regulator reduces effect of line transients by a factor of more than ten.

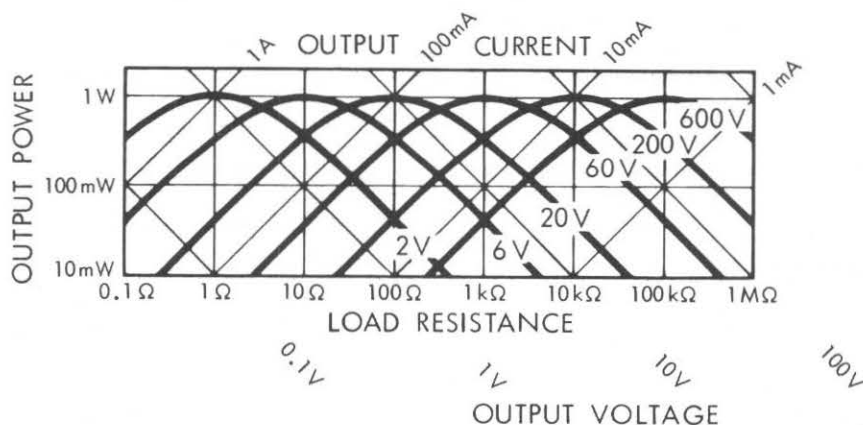


Figure 1-1. Maximum Output of 801B Generator

Insulation Resistance: Terminal 1 greater than 10^{14} ohms.
Terminal 2 greater than 10^{11} ohms.

Output Resistance:

OPEN CIRCUIT VOLTAGE (VOLTS)	2	6	20	60	200	600
SHORT CIRCUIT CURRENT (mA)	2000	600	200	60	20	6
OUTPUT RESISTANCE (OHMS)	1	10	100	1k	10k	100k

1.2.2 Detector

Range: ± 1 microvolt full scale to ± 1000 volts on zero center meter in 19 overlapping 1X and 3X ranges.

Accuracy: $\pm 1\%$ of full scale at recorder output, $\pm 2\%$ of full scale at meter, exclusive of noise and drift.

Zero Drift: Less than 0.5 microvolt per 24 hours, typically less than 0.1 microvolt per $^{\circ}\text{C}$. Long-term drift is non-cumulative.

Meter Noise: Less than 0.03 microvolt RMS (0.15 microvolt peak-to-peak) on most sensitive range with input shorted.

Input Resistance:

100 megohms	3V	to	1kV	ranges;
10 megohms	300mV	to	1V	ranges;
1 megohm	1 μ V	to	100mV	ranges.

Normal Mode Rejection: An applied 50-60Hz signal which is 80dB greater than full scale peak-to-peak will not affect reading on most sensitive range (equivalent to 100dB NMRR). Rejection decreases to 20dB on the 10 millivolt and higher ranges. Peak AC and DC must never exceed 1200 volts.

Common Mode Rejection: Common mode voltage DC or 50-60Hz AC - 120dB greater than full scale up to 1200 volts peak will not affect reading (equivalent to 140dB CMRR).

Isolation: Greater than 10^{11} ohms shunted by 0.01 microfarad between chassis ground (case) and input low at up to 50% relative humidity and 25°C .

Rise Time: (10%-90%): 1 second on 10 microvolt range and above, increasing to 5 seconds on 1 microvolt range.

Zero Suppression: ± 25 microvolts.

Overload: Up to 1200 volts peak may be applied momentarily on any range. Recovery from overload 10^6 times full scale for 1 second with 10 kilohm source is within 5 seconds on the 30 microvolt and higher ranges, increasing to 20 seconds on the 1 microvolt range.

1.2.3 Physical

Height: 5 1/4 inches (13.3cm)

Length: 19 inches (48.25cm)

Depth: 11 inches (25.7cm)

Weight: 21 pounds (9.5kg)

Power requirements: 117 or 230 VAC selected by internal switch, 50 to 400Hz (cps), 15 watts.

SECTION 2

OPERATING INSTRUCTIONS

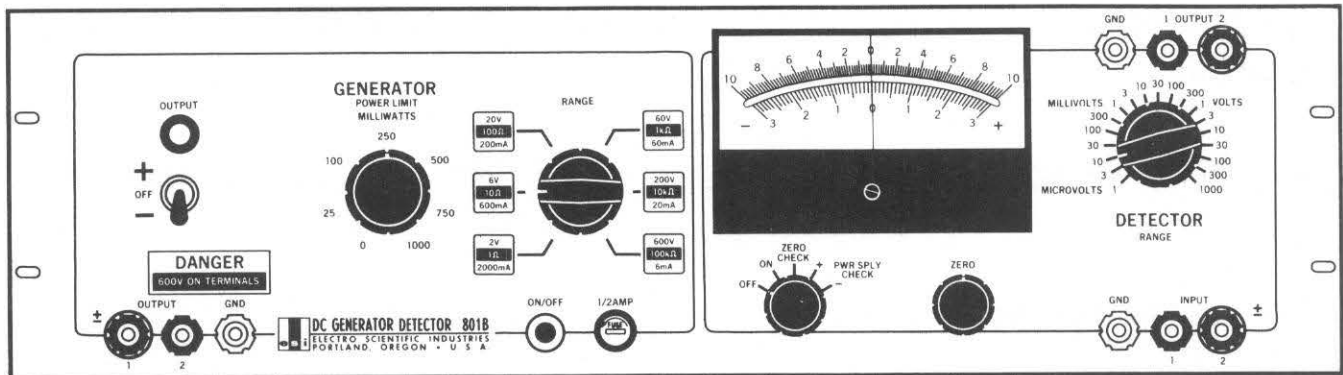


Figure 2-1. Terminals and Controls

2.1 TERMINALS AND CONTROLS

Detector ON/OFF Switch: Controls line power to detector, selects ZERO CHECK mode, and tests positive and negative supply voltages.

Detector INPUT Terminals: The lower righthand terminals are for connecting the detector to an external circuit.

Detector OUTPUT Terminals: The upper righthand terminals are provided so an external meter or recorder may be conveniently connected to the detector.

Detector ZERO Control: Adjusts the detector zero.

Detector RANGE Selector: Selects detector sensitivity range.

Generator OUTPUT Terminals: The lower lefthand terminals are for connecting the generator to an external circuit.

Generator POWER LIMIT Control: Varies the power limit level of the generator from 0 to 1 watt maximum.

Generator OUTPUT Switch: Connects the generator output of the selected polarity to the OUTPUT terminals.

Generator RANGE Selector: Selects the generator limiting resistor, the maximum (open circuit) voltage, and maximum (short circuit) current.

Generator ON/OFF Switch: Controls line power to the generator.

2.2 BASIC OPERATING PROCEDURE

This section describes the basic procedure for using the Model 801B to test or adjust any three-terminal or four-terminal resistive circuit by applying the generator output to one pair of terminals and observing the resulting signal at another pair of terminals with the detector. The procedure is applicable both to null balance applications, such as bridge balancing and voltage divider calibration, and to meter deflection applications, such as ohmmeter, attenuator, and unbalanced bridge measurement.

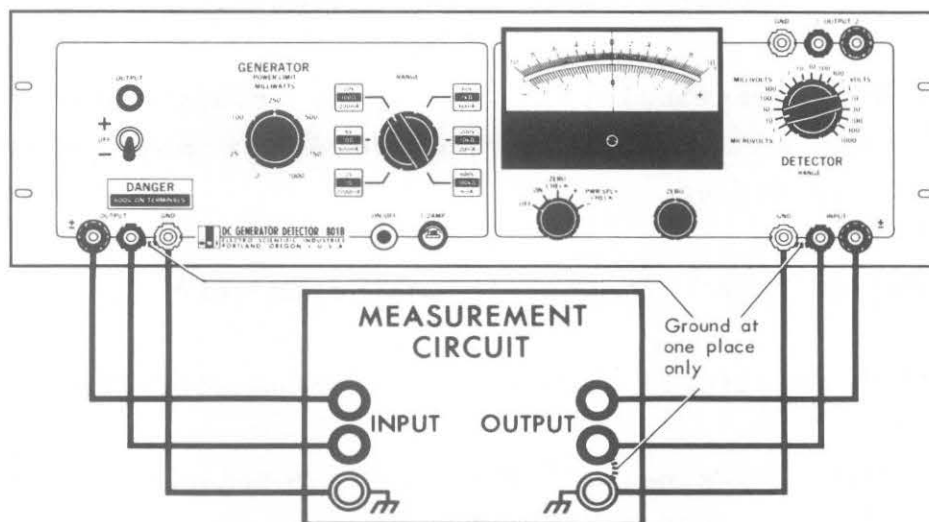


Figure 2-2. Basic Operating Procedure

Various specific applications are discussed in the sections of the manual following this one. The basic operating procedure for all of these applications is as follows:

<u>Operating Procedure</u>	<u>Comments</u>
1. Be sure the generator OUTPUT switch is off, then turn the ON/OFF switches on and allow time for warmup.	Turn on both the power switch for the detector and the power switch for the generator.
2. Connect the measurement circuit to the generator OUTPUT and detector INPUT terminals as shown in Figure 2-2	The measurement circuit should be grounded at one point only, so that ground currents between generator and detector chassis cannot flow through these leads.
3. Set the detector RANGE switch at 3 MICROVOLTS and adjust the ZERO control for meter zero.	Always adjust zero with detector input connected to the measurement circuit, not open or short circuited, to cancel effects causing zero shift with change in source resistance.
4. Change the detector RANGE switch to a range higher than the voltage expected when the generator is first turned on.	This will avoid meter recovery delays caused by input signals greater than full scale.
5. Set the generator POWER LIMIT control to a value which will not cause resistance changes due to heating.	A power setting lower than the lowest rated resistor in the measurement circuit is always safe.

Operating Procedure

Comments

- | | |
|--|--|
| 6. Set the generator RANGE control as desired. | At a setting most nearly equal to the input resistance of the measurement circuit, the generator output will be a maximum, and will usually be approximately equal to the generator power setting. |
| 7. Turn on the generator by setting the OUTPUT switch as desired; the marking indicates the polarity of OUTPUT terminal 1. | The detector polarity is fixed, the direction of the meter deflection corresponding to the polarity if INPUT terminal 2. |
| 8. Adjust the generator POWER LIMIT and RANGE controls as required. For maximum power find the generator RANGE setting giving maximum detector deflection. To reduce the power below the generator POWER LIMIT setting, use generator RANGE settings away from the maximum setting; both voltage and current will be reduced as a result of resistance mismatch in either direction. | For further reduction of power, connect either a low value shunt resistor across the generator OUTPUT terminals 1 and 2 or a high value series resistor in the OUTPUT 1 lead, and use a generator RANGE setting far away from the value of the shunt or series resistor. |
| 9. Change the detector RANGE setting as required for detector sensitivity. | Turn off the generator OUTPUT switch and recheck detector ZERO adjustment each time detector RANGE is changed toward higher sensitivity. |

Operating Procedure

10. Take as the final meter reading the change in reading with generator on and generator off (or half the change with generator polarity reversal), to eliminate the effect of imperfect zero adjustment.

Comments

Take readings after switching transients have disappeared (normally within one second after turning generator on or off). For maximum sensitivity in null balance applications, generator power can often be increased for final adjustment if generator OUTPUT switch is left on only a few seconds at a time to minimize resistor heating.

2.3 USING THE 801B FOR BRIDGE MEASUREMENTS

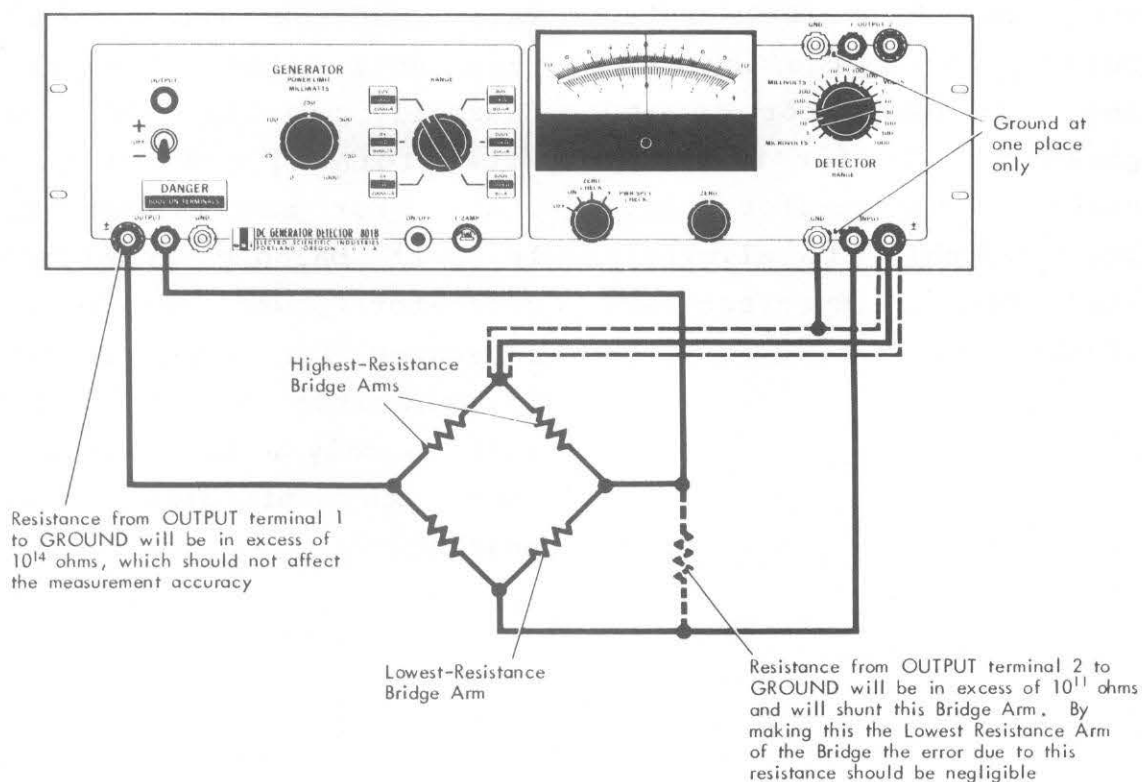


Figure 2-3. Bridge Measurement Connection

Connect the bridge to the generator OUTPUT and detector INPUT terminals as shown in Figure 2-3, then balance bridge following basic operating procedure of Section 2.2.

2.4 USING THE 801B FOR VOLTAGE DIVIDER CALIBRATION

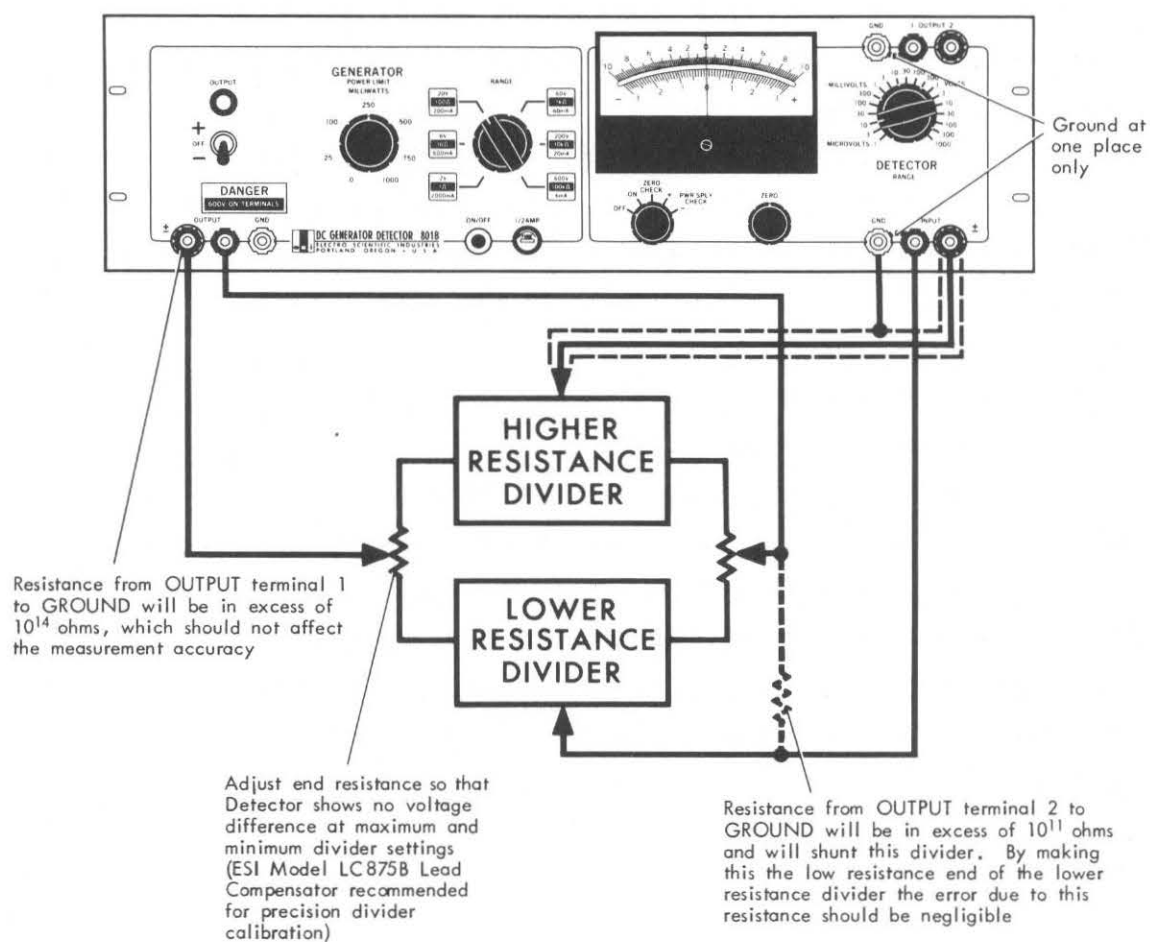


Figure 2-4. Voltage Divider Connection

Connect the pair of dividers or attenuators to the generator OUTPUT and detector INPUT terminals as shown in Figure 2-4, then adjust to find pairs of settings giving detector null indications, following the basic operating procedure of Section 2.2.

2.5 USING THE 801B FOR TOLERANCE CHECKING BY DEFLECTION

Where repeated measurements are to be made to detect small variations of a resistive circuit from a standard value, meter deflection methods can save a great deal of time. Such applications are the checking of batches of resistors for accuracy, the calibration of voltage dividers where an exact null balance is not convenient, or the testing of resistors or resistive networks for changes with temperature or other ambient conditions.

For such deflection measurements, use the appropriate bridge or divider connection as discussed in Sections 2.3 and 2.4. Follow the basic procedure of Section 2.2 in the initial adjustment of the circuit. At steps 9 and 10, adjust the generator POWER LIMIT or the detector RANGE control so that a small change in the bridge or divider setting produces a conveniently related number of divisions of meter change. Now adjust the bridge or standard divider for a meter null at the standard value and read changes from this value in terms of meter deflection.

To measure the approximate value of a very low resistance, such as a switch or relay contact or a piece of wire, use the circuit shown in Figure 2-5.



For ± 20 percent accuracy:

- 2 - 9
801B 8/84

4. Connect the unknown resistor R_x in the circuit of Figure 2-5.
5. Leaving generator RANGE and POWER settings alone, but changing detector RANGE as required, measured the voltage. Call this voltage reading E_x .
6. Calculate the unknown resistance value from the formula:

$$\frac{R_x}{E_x} = \frac{\text{Generator RANGE Resistance Setting}}{E_g}$$

For ± 5 percent accuracy:

1. Connect a known standard resistor, having a value R_s not greater than 1000 ohms, in the circuit of Figure 2-5.
2. Set the generator RANGE to a value at least 100 times the value of the standard resistor.
3. Adjust generator POWER LIMIT so that the voltage reading is conveniently related to the standard resistance value. Call this voltage reading E_s .
4. Remove the standard resistor and connect the unknown resistor R_x .
5. Leaving generator RANGE and POWER LIMIT settings alone, but changing detector RANGE as required, measure the voltage. Call this voltage reading E_x .
6. Calculate the unknown resistance value from the formula:

$$\frac{R_x}{E_x} = \frac{R_s}{E_s}$$

2.7 USING THE 801B AS AN ULTRA-HIGH RESISTANCE OHMMETER

To measure the approximate value of a very high resistance, such as the leakage in an insulator, use the circuit shown in Figure 2-6.

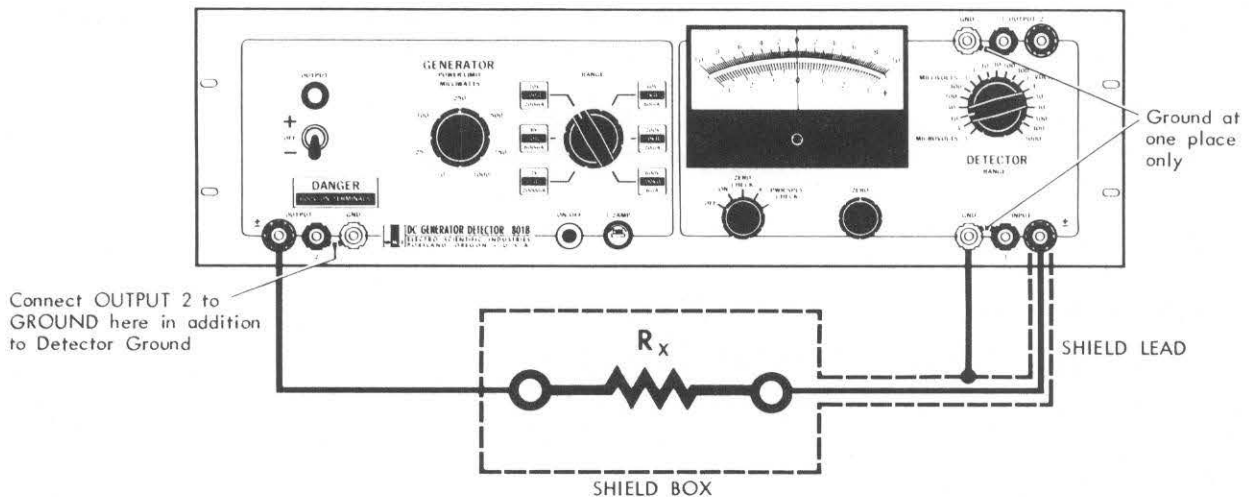


Figure 2-6. High-Resistance Measurement

Following the basic procedure of Section 2.2 with the following additions:

1. Before connecting the unknown resistance, connect the detector INPUT 2 lead to the generator OUTPUT 1 lead (or connect a short circuit across the unknown resistance).
2. Set generator RANGE to 100 kilohms.
3. Set generator OUTPUT switch either to + or - position and adjust POWER LIMIT control for a detector reading of 500 volts. (Other voltages may be used, but the conversion chart, Figure 2-7, is intended for use with a 500-volt setting.)
4. Connect the unknown resistance R_x in the circuit of Figure 2-6.

5. Leaving the generator RANGE and POWER LIMIT settings alone, but changing detector RANGE as required, measure the voltage. Call this voltage reading E_x .
6. Use the conversion chart, Figure 2-7, to convert the voltage reading to the resistance. If a voltage other than 500 volts was used in Step 3, use the following conversion formula:

$$R_x = \frac{E_g R_d}{E_x} - R_d$$

where R_x is the unknown resistance,
 E_g is the generator voltage,

R_d is the detector resistance, which depends on the RANGE setting:

1 MICROVOLT	to	100 MILLIVOLTS;	1 megohm
300 MILLIVOLTS	to	1 VOLT;	10 megohms
3 VOLTS	to	1000 VOLTS;	100 megohms

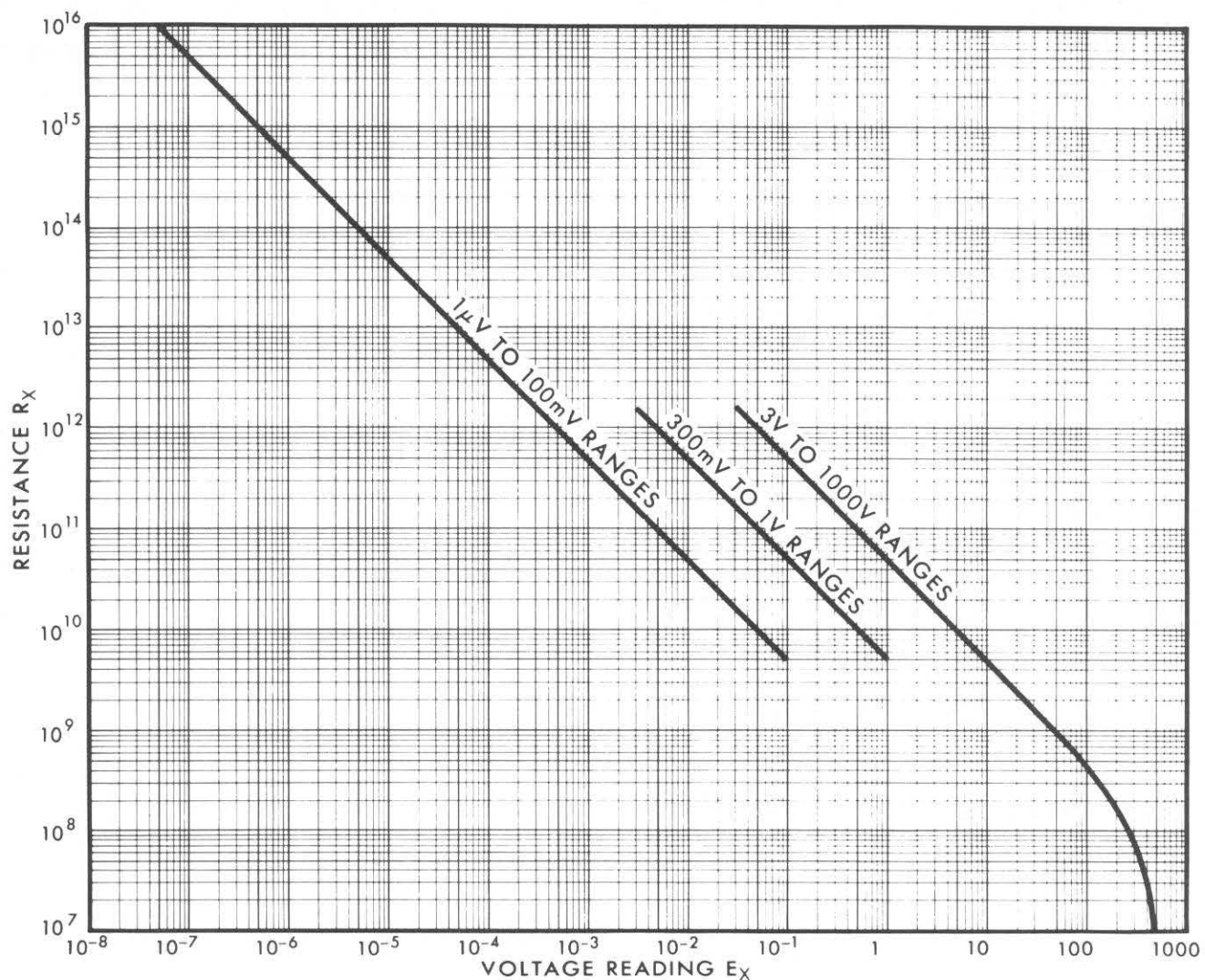


Figure 2-7. Voltage to Resistance Conversion Chart

2.6 USING THE 801B AS A VOLTMETER

To use the Model 801B detector as a voltmeter, connect the voltage to be measured to the detector INPUT terminals, and set the RANGE selector to the appropriate voltage range. If there is any doubt about the voltage, use a higher range first, then decrease it.

The voltage (times the range factor) is indicated on the meter. The polarity marked on the meter is the polarity of the voltage connected to INPUT terminal 2.

2.9 REMOTE GENERATOR OPERATION

The generator output is controlled by two unique guarded relays that are controlled either by the OUTPUT switch or by remote switches. A terminal board in the back of the instrument is supplied to connect remote switches such as foot operated switches or automatic sequencing equipment.

In order to apply a positive voltage to OUTPUT terminal 1, a remote switch must be connected to short-circuit the + and the COM terminals in the rear of the instrument. Similarly, to apply a negative voltage, a remote switch must short-circuit the - and the COM terminals.

There is no necessity to prevent simultaneous connections; if both terminals in the rear are short-circuited to COM or if, for example, the - terminal is connected to the COM terminal and the OUTPUT switch is set to +, no damage will be done since the relays will disconnect the generator when they are both energized.

Figure 2-8 is a simplified schematic of the generator control circuits.

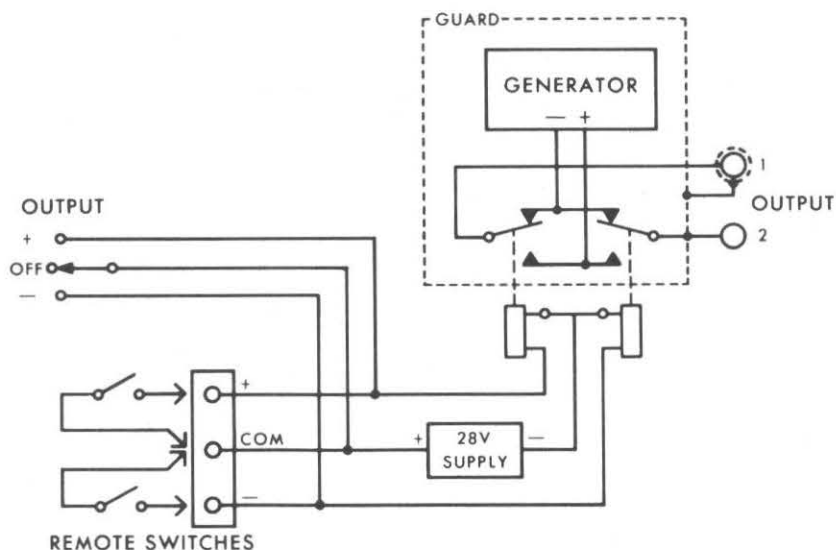


Figure 2-8. Remote Generator Control

2.10 CHANGING THE INPUT LINE VOLTAGE

The Model 801B Generator-Detector may be operated on either 117 volt or 230 volt AC power. An internal switch selects the input wiring to accommodate either voltage.

If the setting of the switch is not correct for the power line to be used, change the setting of the switch before plugging in the instrument.

To access the switch remove the plastic safety cover. The switch is located on a chassis support immediately behind the upper center of the front panel. Slide the switch with a fingernail or with a small screwdriver so that it indicates 115 or 230 as appropriate.

SECTION 3

THEORY OF OPERATION

3.1 GENERATOR

The generator is a line regulated, guarded DC power supply with variable output power and a provision for matching the output impedance to a wide range of values. The guarding of the generator makes accurate high resistance bridge measurements possible. The diagrams below illustrate how this is done.

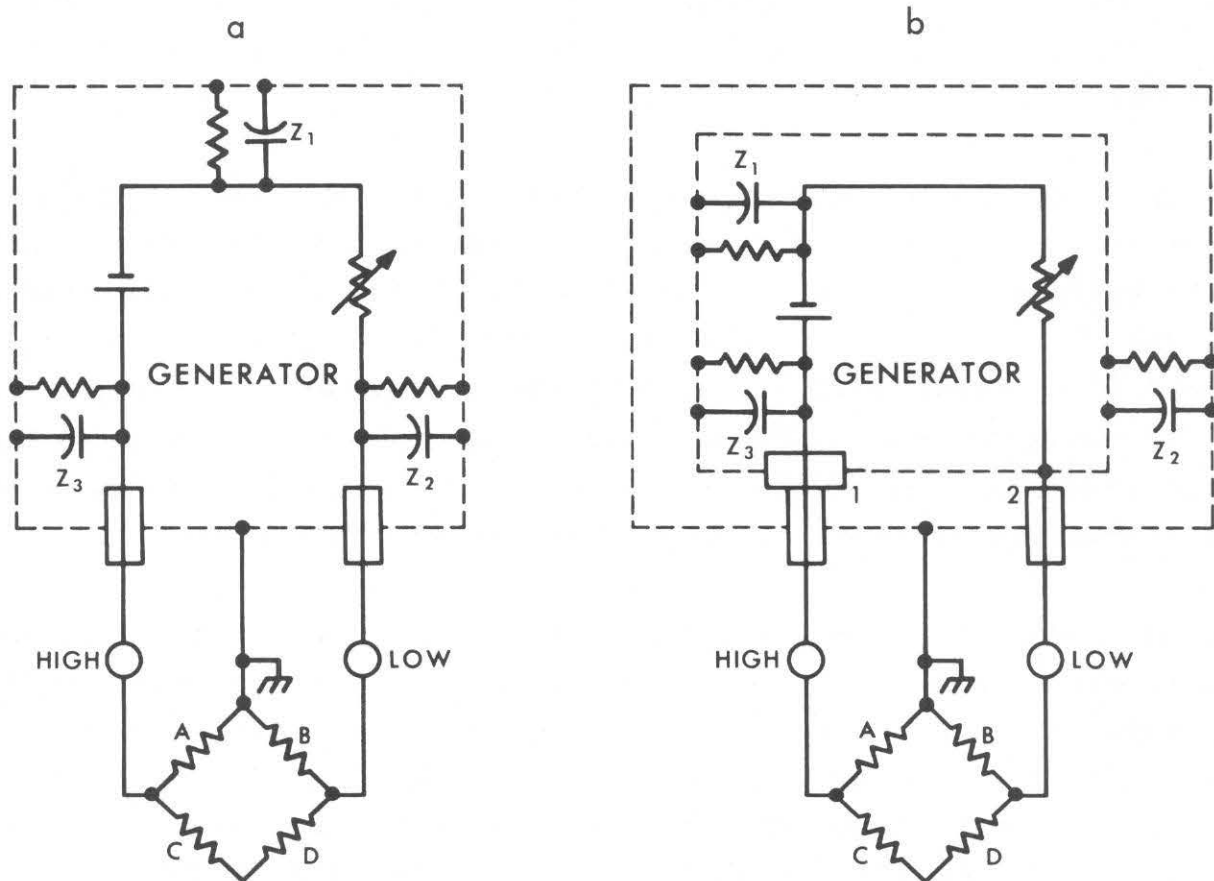


Figure 3-1. Generator Circuits

In the unguarded circuit shown in Figure 3-1a, the leakage impedances Z_2 and Z_3 appear in parallel with bridge arms A and B. If these were

high resistance arms, an appreciable error would result. The leakage impedance Z_1 is also in parallel with arms A and B. Since this leakage is at a higher emf than those at the terminals, it will cause even more error.

The 801B generator uses the guarded circuit as shown in Figure 3-1b. Z_1 and Z_3 appear in parallel with the generator, and cause no trouble. Z_2 is kept to better than 10^{11} ohms by use of high quality insulators, both as a feed-through insulator for the low terminal and as support insulators for the guard chassis. By keeping bridge arm B (or whatever resistance is attached to the low terminal) small relative to 10^{11} ohms, no appreciable error is experienced. The guarding also keeps any AC voltage across Z_1 from getting into the detector via bridge arms A and B, since this AC voltage is returned to the low terminal.

The primary of the power transformer is separately shielded and air-insulated from the core to prevent capacitive coupling and leakage of AC voltages to the guard chassis. If an AC voltage were present on the guard chassis, it would appear from the low output terminal to ground and, thus, directly across the bridge arm B (Figure 3-1) in bridge measurements. The AC would then appear on the detector and would cause an error nulling reading. The separate shielding of the transformer is connected to ground to prevent this error.

The generator is line operated and has a solid state line voltage regulator. The input voltage, which may be 117 volts or 230 volts AC, is increased (if necessary) by the input transformer to 230 volts. This voltage is clipped by the line regulator to 117 volts, which is applied to continuously-variable autotransformer. The autotransformer output is applied to a high isolation guarded transformer which supplies power to the rectifier and filter networks.

Filtered DC is supplied to the output terminals through various resistances. The resistances and output voltages are selected by the generator RANGE selector. Each voltage and resistance combination is calculated to allow no more than one watt in any measurement circuit connected to the generator terminals.

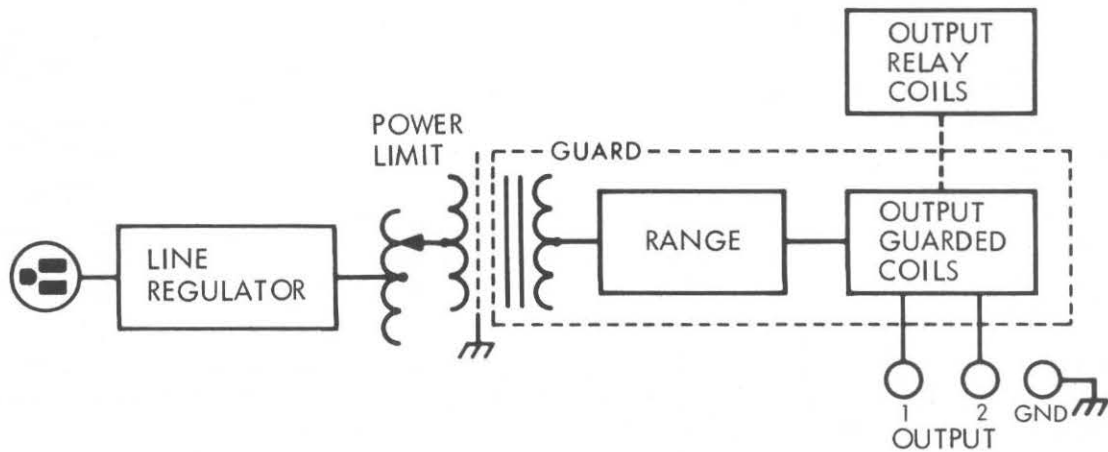


Figure 3-2. Generator Simplified Circuit

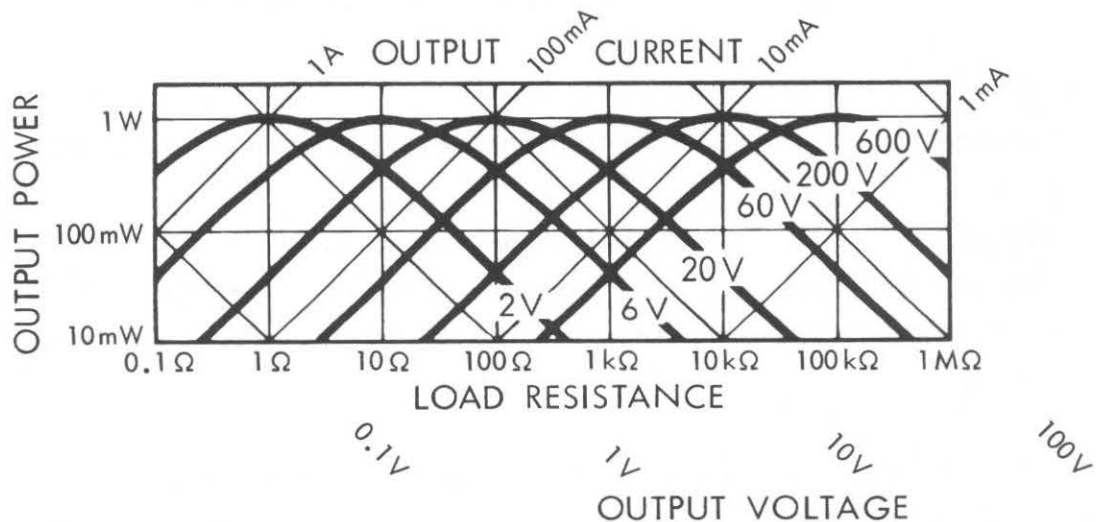


Figure 3-3. Generator Output

3.2 DETECTOR

The detector of the Model 801B is a high-sensitivity solid-state DC voltmeter. It is made up of the following circuits: (1) an input attenuator, (2) a modulator and demodulator, (3) multivibrator, (4) an AC amplifier, (5) DC amplifier, (6) a meter, and (7) a feedback network. Figure 3-4 is a block diagram of the detector circuit.

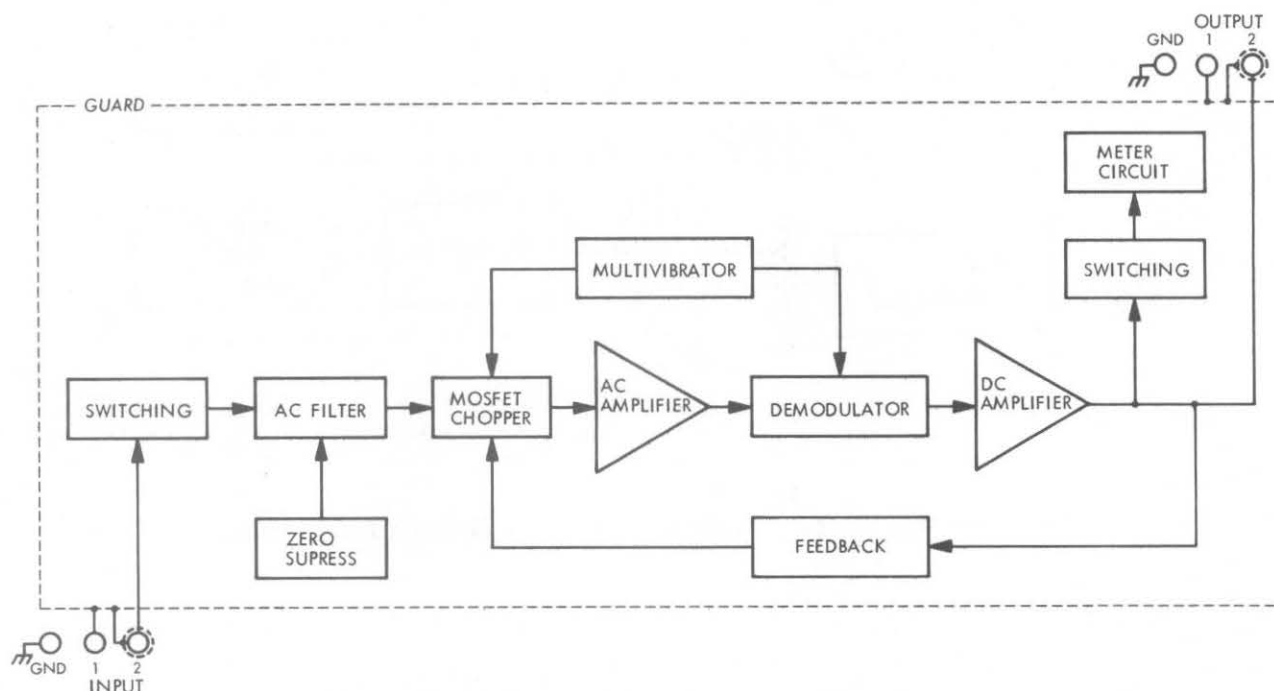


Figure 3-4. Detector Block Diagram

A DC voltage measured by the detector is applied to the input attenuator, which is a resistive divider operated by the RANGE switch.

The DC output of the input attenuator is fed into a MOSFET chopper circuit which modulates the DC signal. Synchronization of the chopper with the demodulator is accomplished with a multivibrator switching both circuits.

The output of the chopper is a square-wave signal that has an amplitude which is proportional to the amplitude of the DC signal. This output is amplified first by a low noise AC amplifier followed by a variable gain AC amplifier.

After AC amplification the signal is demodulated producing a DC voltage that has an amplitude proportional to the square-wave output of the AC amplifier.

Finally the DC signal is amplified and fed to the front-panel meter, output terminals, and the feedback network.

Feedback is sampled at the output and compared to the input of the chopper to provide gain stability and accuracy.

3.2.1 Input Attenuator

The chopper amplifier has a minimum gain of 100 and a maximum output voltage of $\pm 1V$. This means it is necessary to attenuate signals larger than 10mV to prevent saturation of the chopper amplifier. The input attenuator resistors R102 through R106 and R113 through R117, are switched by the RANGE switch, S101. One decade of attenuation is necessary to handle signals as high as 100mV. Two decades of attenuation are necessary to handle signals as large as 1V. Input attenuation is switched in a decade at a time, and the gain of the chopper amplifier is alternated between 333 and 100 for all ranges above 10mV.

Because of potential instability in the resistance value of high value resistors, potentiometers have been placed in series with the attenuator string. Thus, the instrument can be accurately calibrated even if the high value resistors drift.

3.2.2 MOSFET Chopper (Modulator)

The field-effect transistor when used as a chopping device provides low offset currents, low offset voltages, low noise and low drive power. A series shunt chopping configuration provides low noise and high input impedance.

Transistors Q101 and Q102 are the chopper. Resistor R184 and capacitor C104 are used to minimize the problem of the chopper drive feeding into the signal channel.

3.2.3 AC Amplifier

The AC amplifier is composed of a low noise amplifier and a variable gain amplifier.

A bi-polar transistor, Q103, biased for operation at low current levels, is the input device. Transistors Q103, Q104, and associated components, are a low noise amplifier with a gain of 34, as fixed by the feedback resistor R129 and R131.

The low noise amplifier is followed by a variable gain AC amplifier consisting of transistors Q105, Q106, Q107, and associated components. It is necessary to have high gain when measuring very low voltages, and less gain when the total chopper amplifier is to be used at lower gain to prevent oscillations. For this reason, the gain of the second amplifier is varied by switching the feedback resistor. Resistor R147 and R148 along with capacitor C128 provide a high frequency cut off for the attenuation of the spikes generated in the chopper by the chopper drive.

3.2.4 Demodulator

Field-effect transistor Q118 acts as a switch which is synchronized with input chopper and thus provides synchronous demodulation. The average value of the signal obtained at the junction of capacitor C112 and resistor R149 is proportional to the DC input signal. Because of the switching action of Q118, the signal at this junction is shorted to ground for each half of each chopping cycle. Consequently, this DC signal has a large chopper frequency component.

3.2.5 DC Amplifier

The function of this amplifier is twofold: it gives additional amplification to the relatively small signal seen at the output of the demodulator; and it integrates the output of the demodulator, thus removing most of the chopper frequency ripple which appears there. Direct coupled output is used for the amplifier to meet the requirements of providing 1mA of output current.

The DC amplifier is composed of three differential amplifiers and an emitter follower. The signal from the output of the demodulator is applied to the first differential DC amplifier, composed of transistors Q116 and Q108 and amplified. The second amplifier, transistors Q109 and Q110, amplifies the output signal from the first amplifier and applies it to the third differential amplifier, Q111 and Q112, for further amplification. Emitter followers Q113, Q114 and Q115 are an impedance changing circuit to provide low output impedance.

3.2.6 DC Feedback

The detector uses negative feedback to achieve gain accuracy and stability and assures high input impedance. The resistors are switched into the feedback current in such a way as to maintain low feedback current and avoid excessively high value resistors in the feedback loop.

The feedback network, composed of resistors R118 through R185, is formed from the output of the DC amplifier to the input of the chopper amplifier. The RANGE switch, S101, selects the feedback ratio used for each range.

3.2.7 Multivibrator

The multivibrator circuit generates the drive voltage for the chopper and demodulator.

Transistors Q120 through Q123 and their associated components are an astable multivibrator. Output voltages are taken at the emitters of Q120 and Q123. These output voltages are opposite phase square waves and are used directly as the chopper drive. The output at the emitter of Q120 is also used as the demodulator drive.

3.2.8 Offset Suppression Circuits

When measuring signals in the microvolt region it is often desirable to suppress the zero voltage level so that small changes may be readily observed. For this reason a front panel ZERO control, R173, is provided. This control is nonlinear so that for normal operation (suppression of less than $\pm 5\mu\text{V}$) accurate zeroing may be easily achieved, while still having available suppression of at least $\pm 25\mu\text{V}$. Offset current is suppressed by the circuit consisting of potentiometer R104 and resistors R110 and R186.

3.2.9 High Frequency Attenuator Input Filter

The frequency attenuating filter at the input of the detector provides approximately 50dB of AC rejection at 60Hz. The filter is a three section RC ladder filter consisting of resistors R107, R108, R111, R112, and capacitors C101, C102, and C103.

SECTION 4

MAINTENANCE

WARNING

DANGEROUS VOLTAGE POTENTIALS EXIST INSIDE THIS INSTRUMENT. MAINTENANCE INSTRUCTIONS WITHIN THIS MANUAL ARE FOR USE BY QUALIFIED SERVICE PERSONAL ONLY. TO AVOID ELECTRICAL SHOCK, DO NOT ATTEMPT SERVICING OTHER THAN CONTAINED IN THE OPERATING INSTRUCTIONS UNLESS YOU ARE QUALIFIED TO DO SO.

4.1 PREVENTATIVE MAINTENANCE

The following procedures should be performed periodically (approximately once a year) to insure maximum accuracy and reliability from the Model 801B Generator-Detector.

If the need for major repairs is apparent, it is recommended that the unit be sent to the factory for service. The service department will be glad to furnish the necessary information for repairs as well as any replacement parts. However, unauthorized repairs will invalidate the instrument warranty.

4.1.1 Visual Inspection

Inspect the unit for dial orientation and damage to binding posts and binding post caps. Also check for dirt around binding post insulators. Then remove the case as described in Paragraph 4.1.2 and inspect the unit for possible internal defects. These defects include such things as loose or broken connections, damaged or dirty switch contacts, and heat damaged resistors.

Prepare a soft, clean place to set the instrument. Be sure that no projections or pointed objects will be underneath the panel. See that there are no metal filings in the area.

Place the unit face down on the prepared surface. Remove the screws on the back of the instrument and carefully slide the case off.

4.1.3 Cleaning and Lubrication

Clean the front panel with a soft, dry, lint free cloth, being particularly careful to remove all dirt from around the binding post insulators. The only internal components that require cleaning and lubrication are the switches. The switches are carefully lubricated at the time of manufacture and are protected from contamination by the instrument case. They should rarely, if ever, require maintenance. It is recommended that they be cleaned or lubricated only if it is determined that they are not making good electrical contact. If the switch decks are in need of cleaning or lubrication, proceed as follows:

- a. Apply solvent (Freon printed circuit solvent or equivalent) to the contact surfaces with a small brush or pipe cleaner.
- b. Wipe surfaces with clean, dry brush or dry with low pressure air.
- c. Apply a thin coating of lubricant (Oak #2008 or equivalent) to the contact surfaces with a hypodermic needle.

- d. Apply two drops of the same oil to each of the switch bearings and detent mechanisms.
- e. Remove excess oil with a clean, dry cloth and remove all traces of lint with a soft brush.

4.1.4 Replacing the Case

Be sure that the interior of the case is completely clear of all foreign material. Slip the case over the unit and replace the screws.

4.1.5 Removing Inner Covers

The generator and the detector have inner covers to provide complete guarding and shielding of components. To remove the generator covers (top and bottom), remove the four screws holding each cover plate. To remove the detector cover, remove the 2 screws on the cover side facing the front panel, and the 3 screws on the back of the cover. The cover may now be removed, but cannot be completely detached because of the wires connected to the DC/DC converter. The wires are long enough to move the cover out of the way for detector access.

4.1.6 Servicing Etched Circuit Cards



REMOVE THE FIVE COLORED WIRES FROM THE CIRCUIT CARDS IN THE DETECTOR BEFORE UNPLUGGING THE CARDS.

The Model 801B has etched circuit cards. Use caution when removing them to avoid damaging mounted components. The assembly and Keithley or ESI part number are on the circuit card to identify it.

The detector etched circuit cards are a plated-through type. The electrical connection between sides of the card is made by a layer of metal plated through the component holes. When working on these cards, observe the following general rules:

- a. Use a low-heat (25 to 50 watts) small-tip soldering iron and a small-diameter rosen-core solder.
- b. Circuit components can be removed by placing the soldering iron on the component lead on either side of the card and pulling up on the lead. If a component is obviously damaged, clip leads as close to component as possible and then remove. Excess heat can cause the circuit and card to separate or cause damage to the component.
- c. Component lead hole should be cleaned before inserting new lead.
- d. To replace components, shape new leads and insert them in holes. Reheat with iron and add solder as required to insure a good electrical connection.
- e. Clean excess flux from the connection and adjoining area.
- f. To avoid surface contamination of the printed circuit, clean with weak solution of warm water and mild detergent after repair. Rinse thoroughly with clean water. When completely dry, spray lightly with KRYLON (#1302 or equivalent).

4.2 PERFORMANCE TESTS AND CALIBRATION PROCEDURES

The performance tests presented in this section are front panel procedures designed to compare the Model 801B with its published specifications. These tests may be incorporated in periodic maintenance, post repair, and incoming quality control inspection. These tests should be conducted before any attempt is made at instrument calibration.

The test equipment required for maintenance of the Model 801B is listed in Table 4-1. Equipment having similar characteristics may be substituted for the equipment listed.

Table 4-1. Test Equipment Required

Description	Specification
Oscilloscope	
Precision Voltage Source	
Frequency Counter	
DC Calibrator	100mV, 1V ($\pm 0.002\%$)
Voltage Divider	10^5 to 1, 10^3 to 1 ratios (ESI RV722 or equivalent)
DMM	4 1/2 digit
Resistor	10 kilohms, $\pm 10\%$
Capacitor	5 microfarads, $\pm 10\%$, 200V

4.2.1 Generator Voltage Check

Check on a one year basis the output voltages for each generator range. This is done as follows:

Step 1. Turn instrument on and allow 5 minutes to warm up.

- Step 3. Set generator RANGE control to 1 .
- Step 4. Connect detector INPUT to generator OUTPUT terminals.
- Step 5. Set POLARITY to +.
- Step 6. Set generator POWER LIMIT control to maximum.
- Step 7. Read voltage using the detector as a voltmeter.
- Step 8. Repeat all steps for all other settings of the generator RANGE control.

The voltages should be:

<u>Range</u>	<u>Voltage</u>
1	1.6 to 2.4V
10	5.0 to 7.6V
100	10 to 24V
1k	50 to 76V
10k	160 to 240V
100k	500 to 760V

4.2.2 Mechanical Zero Adjustment

The mechanical zero adjustment is located on the instrument front panel. If the meter pointer does not indicate zero when the instrument power has been off for at least one minute, mechanically zero the meter by turning the screwdriver adjustment on the meter.

Table 4-2. Detector Trimmer Controls

Control	Component Number
Accuracy Set	R101
Accuracy Set	R104
Offset Current Suppress	R109
DC Amplifier Balance	R151
Multivibrator Frequency Set	R178
Meter Calibrate	R183

Table 4-3. Detector Test Points

Test Point	Voltage
1	-15V
2	+15V
3	+13.7V
4	-13.7V
5	+6 +2V
6	-6 +2V

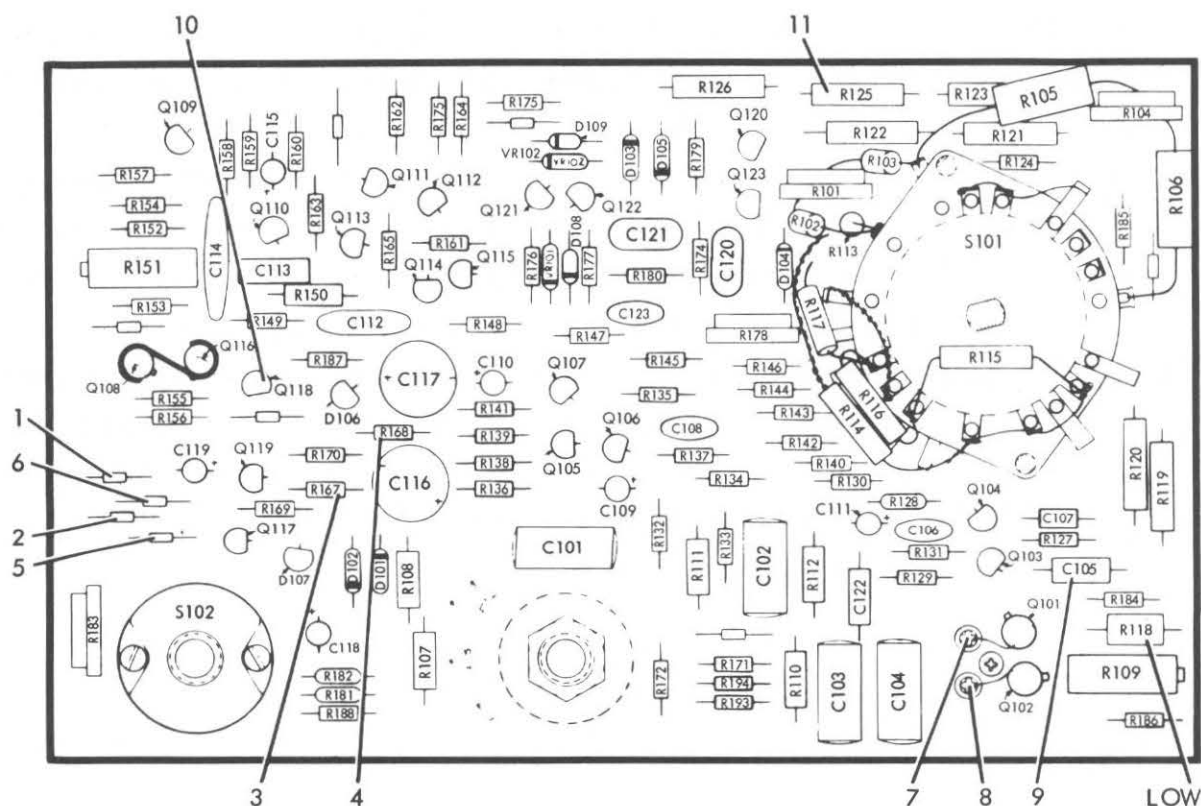


Figure 4-1. Detector Test Points

4.2.3 Preliminary Detector Calibration Procedures

- Step 1. Check the detector power supply by setting the power switch to PWR SPLY CHECK (+) and (-) positions. For each polarity the meter needle should indicate 70% to 100% of full scale. After checking the power supply condition, set the power switch to OFF.
- Step 2. Make sure that offset current suppress potentiometer, R109, is at least one turn from either end. Short R186 with a jumper wire. Do not remove this short until specifically stated in Section 4.2.6.
- Step 3. Turn the power switch to ZERO CHECK. Within a few moments the meter needle should come to zero indication. If necessary, zero the meter with the ZERO control. Increase the detector sensitivity to 100uV and zero the meter.
- Step 4. If the detector is inoperative, that is, if the meter pins, check the voltage given in Table 4-3 to the values indicated. If these voltages are found satisfactory, check the multivibrator. If all the above checks are satisfactory, localize the trouble to the AC or DC section of the amplifier by shorting the demodulator test point (test point 10) to low and adjusting the DC amplifier balance potentiometer, R151, from one end to the other. If potentiometer R151 can swing the meter full scale from (+) to (-) and vice versa, the problem is in the AC section of the amplifier. If it cannot, the problem is in the DC section.

4.2.4 Multivibrator Adjust

- Step 1. Connect the frequency counter between either test point 7 or 8 and COMMON (Figure 4-1). Adjust the multivibrator frequency set potentiometer, R178, for a reading of 220Hz \pm 3Hz.
- Step 2. Connect the oscilloscope between test points 7 or 8 and COMMON and observe the waveform. The oscilloscope should be set at 2V per division vertical and at a 1ms sweep. The waveform should be a near symmetrical 7 to 12V peak-to-peak square wave.

4.2.5 DC Amplifier Balance Adjust

- Step 1. Connect the detector output to the DMM. Set the detector power switch to ZERO CHECK and read zero from the 200mV range.
- Step 2. Set the detector RANGE switch to 100uV and adjust the ZERO control for 0 \pm 5mV at the output exclusive of noise. (Typical noise is from 2 to 10mV peak-to-peak.)
- Step 3. Set the RANGE switch to 1000V and adjust the DC amplifier balance potentiometer, R151, for 0 \pm 0.5mV at the output.
- Step 4. Once adjusted, step the RANGE switch from 100uV through 1000V. Large zero shifts (8mV or more) between ranges generally indicates that input FETs Q101 and Q102 may be defective.

Note: Make sure the detector cover is on during this test procedure. Diodes D101 through D105 may be sensitive to light and the adjustment is void without the cover on.

- Step 1. Remove the short from R186 and disconnect the DMM.
- Step 2. Shield the detector input. (The input may be shielded by affixing banana plugs inside a metal case and covering the three front panel binding posts with the case, being careful to insert the banana plugs into INPUT terminal 1 and the ground terminal). Shielding is necessary to reduce pickup.
- Step 3. Set the detector power switch to ZERO CHECK and the RANGE switch to 100uV.
- Step 4. Adjust the ZERO control for zero meter indication.
- Step 5. Open the input by setting the power switch to ON and adjust the offset current suppress potentiometer, R109, for near zero meter indication.
- Step 6. Set the power switch to ZERO CHECK and the RANGE switch to 30uV.
- Step 7. Adjust the ZERO control for zero meter indication.
- Step 8. Set the power switch to ON and adjust potentiometer R109 for less than a $\pm 5\mu\text{V}$ shift (0 ± 5 minor divisions on the lower meter scale).
- Step 9. If necessary, repeat steps 1 and 2 to obtain less than 5uV shift on the meter when switching the power switch between ZERO CHECK and ON positions.

Step 10. With the power switch set to ON step the RANGE switch from 30uV to 1V. Offset on the 100 and 300uV ranges should be less than 5uV decreasing to a negligible offset on the 1mV through 1V ranges.

4.2.7 Meter Calibration

Step 1. Connect a voltage source to the detector input and connect the output to the DMM.

Step 2. Set the detector RANGE switch to 1V and apply $\pm 1V$ to the input with the voltage source.

Step 3. Adjust the ZERO control and/or the input voltage to obtain a +1.000V at the output.

Step 4. Adjust the meter calibrate potentiometer, R183, for a full scale positive deflection on the detector meter scale.

Step 5. Apply -1V to the detector input and adjust the ZERO control and/or the input voltage to obtain -1.000V at the output.

Step 6. Note the negative full scale deflection.

Step 7. If necessary, adjust potentiometer R183 to split the difference between positive and negative full scale deflections.

Step 8. Typical positive and negative full scale error is less than 1% (1/2 minor division).

4.2.8 Accuracy Set Calibration

The full-scale calibration consists of performing a 1V and a 10V adjustment.

Step 1. Keep the detector connected as in the previous Section (4.2.7).

Step 2. Set the RANGE switch to 1V and the power switch to ZERO CHECK.

Step 3. Adjust the ZERO control for 0.000V at the output.

Step 4. Apply 1.000V to the input and adjust the accuracy potentiometer, R101, for 1.000V at the output.

Step 5. Set the RANGE switch to 10V and power switch to ZERO CHECK.

Step 6. Adjust the ZERO control for 0.000V at the output.

Step 7. Apply 10.000V to the input and adjust the accuracy potentiometer, R104, for 1.000V at the output terminals.

Note: Always adjust potentiometer R101 before potentiometer R104 because R101 affects R104.

4.2.9 Detector Noise Test

Note: Keep the detector cover on to minimize noise pick-up.

To determine whether detector noise is excessive, proceed as follows:

- Step 1. Set the detector power switch to ZERO CHECK and the RANGE switch to 1 microvolt. Zero the instrument with the ZERO control. After zeroing, observe the meter noise for less than 150 nanovolts peak-to-peak (7 minor divisions on the upper meter scale). Observe the meter for a period of 15 seconds.
- Step 2. Observe the meter noise in the same manner on the 3 microvolt range. The noise should be approximately the same 150 nanovolts (1-1/2 minor divisions on the lower scale) as that on the 1 microvolt range.
- Step 3. Observe the meter noise in the same manner on the 100 microvolt range. The noise should be indicated at less than 1% (1/2 division on the upper meter scale).

Note: Keep detector cover on to minimize noise pick-up.

- Step 1. Set up the test circuit shown in Figure 4-2.
- Step 2. Set the detector RANGE switch to $1\mu\text{V}$ and the power switch to ON. Set the voltage divider to divide the input voltage by 10^5 .
- Step 3. Zero the detector with the front panel ZERO control. Set the DC calibrator to output $+100\text{mV}$. The output of the voltage divider should be $+1\mu\text{V}$ (0.000001V). As the DC calibrator is set to output 100mV observe the detector 10% to 90% rise time on the meter. This rise time must be less than five seconds. Typically it is less than three seconds.
- Step 4. Repeat the previous step with a negative signal.
- Step 5. Set the detector RANGE switch to $100\mu\text{V}$ and the power switch to ON. Set the voltage divider to divide the input signal by 10^4 .
- Step 6. Zero the detector with the front panel ZERO control.
- Step 7. Set the DC calibrator to output $+1\text{V}$. The output of the voltage divider should be $+100\mu\text{V}$. As the DC calibrator is set to output 1V observe the detector 10-90% rise time on the oscilloscope. The rise time must be less than one second and typically is less than 0.5 second.

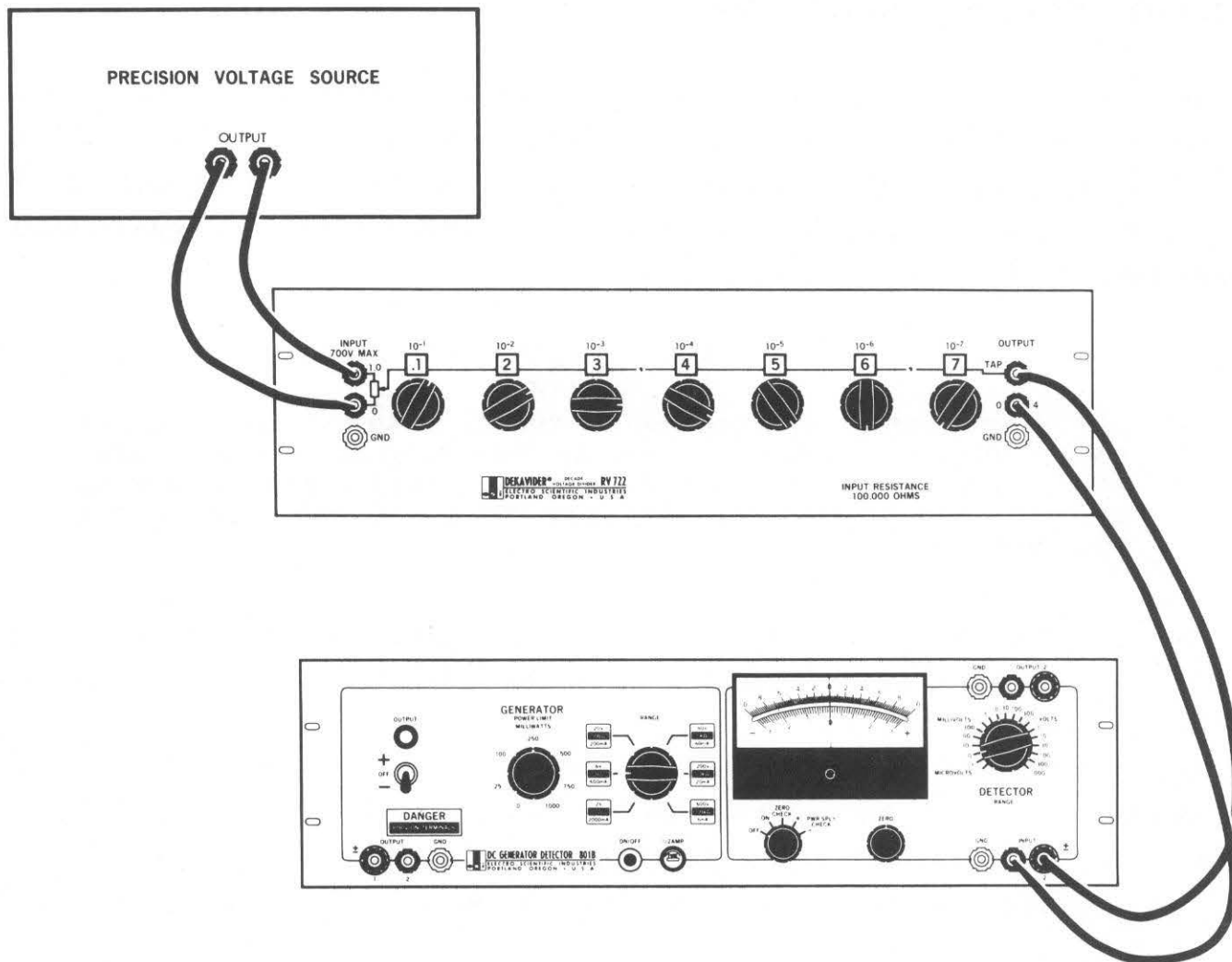


Figure 4.2 Detector Rise Time Test

4.2.11 Detector Accuracy Test

The accuracy performance test setup is illustrated in Figure 4-3. Check the 1000V through 100uV ranges for 1V $\pm 1\%$ at the detector output and $\pm 2\%$ of full scale (1 minor upper scale division) on the meter. Check the 30uV through 1uV ranges for $\pm 2\%$ full scale exclusive of noise and drift.



WHILE PERFORMING THE FOLLOWING TESTS, START AT THE HIGHEST RANGE (1000V) AND WORK TOWARD THE LOWEST RANGE (1uV). ALWAYS DECREASE THE SETTING OF THE VOLTAGE SOURCE BEFORE THAT OF THE DETECTOR. FAILURE TO DO SO MAY DAMAGE THE DETECTOR.

- Step 1. To check the 1000V through 3V ranges use a DC calibrator to apply voltages to the detector input. Monitor the output with a DMM.
- Step 2. To check the 1V through 1uV ranges, use a DC calibrator and a voltage divider to apply voltage to the detector input. Monitor the output on the 1V through 100uV ranges with a DMM.
- Step 3. Check the 1000V and 10uV ranges for both positive and negative polarity. All other ranges may be checked using only one polarity.

If necessary, adjust the accuracy set potentiometer, R104, to bring all ranges from 3V to 1000V within tolerance. Also, the accuracy set potentiometer, R101, may be adjusted to bring the 300mV and 1V ranges within tolerance.

Note: Readjusting potentiometer R101 will require rechecking the 3V through 1000V ranges.

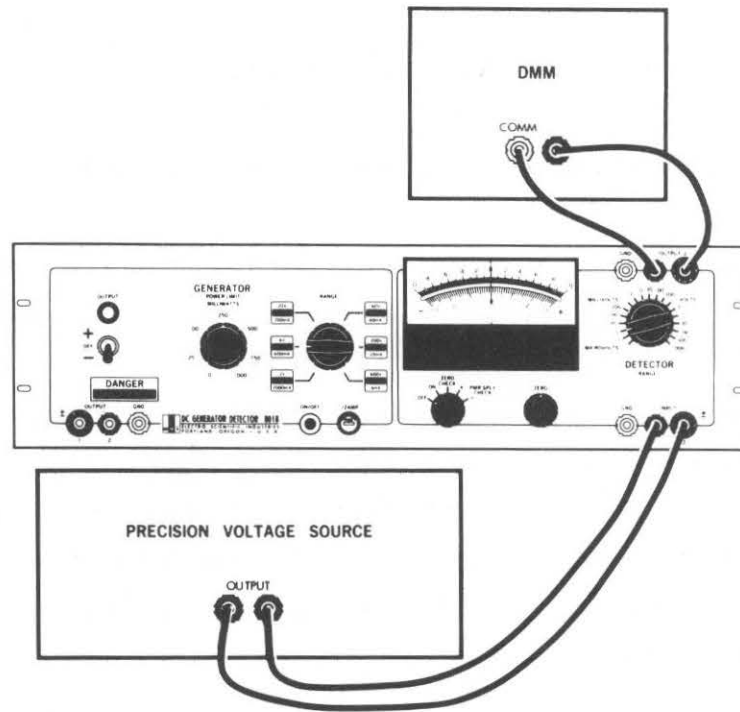


Figure 4-3a. Detector Accuracy Test (3V-100V)

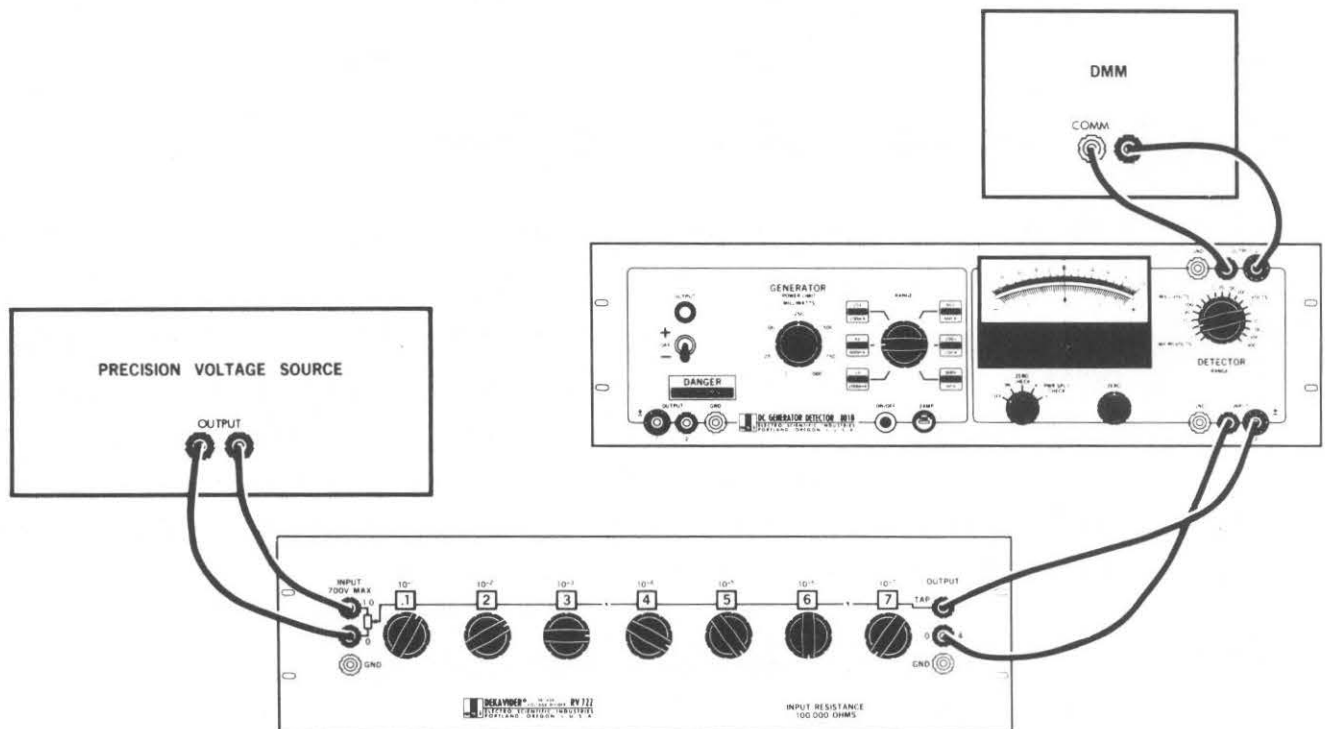


Figure 4-3b. Detector Accuracy Test (1μV-1V)

4.2.12 Detector Overload Recovery Check

- Step 1. Place a 10 kilohm resistor across the detector input.
- Step 2. Set the detector RANGE switch to 30uV and the power switch to ON. Zero the meter with the ZERO control.
- Step 3. Connect the common lead of the voltage source to INPUT terminal 1 of the detector. Program the voltage source to output +30V. Connect the high (+) terminal of the voltage source to INPUT terminal 2 of the detector for approximately one second. The detector should recover from this overload within five seconds.
- Step 4. Set the RANGE switch to 1uV and zero the meter. Apply 1V to the detector in the same manner as in step 3. The detector should recover from this overload within 20 seconds.
- Step 5. Remove the 10 kilohm resistor from the detector input.

4.2.13 Detector Normal Mode Rejection Check

- Step 1. Set the detector power switch to ZERO CHECK.
- Step 2. Set up the rejection check equipment as follows: apply a signal from the function generator through a 5uF capacitor to the voltage divider to divide by 10^3 and connect the divider output to the detector input. Connect the detector INPUT terminal 1 and ground terminal together. Monitor the function generator with an oscilloscope.
- Step 3. Set the function generator frequency to 50Hz and the output to a minimum.

- Step 4. Set the detector power switch to ON, RANGE switch to 1uV, and zero the detector with the zero control. Due to thermals on the input, it should require approximately one minute for the instrument to stabilize.
- Step 5. Increase the function generator output to 10V peak-to-peak. There should be no shift in the meter reading. (Do not confuse noise and drift for a shift in meter reading.)

4.2.14 Detector Common Mode Rejection Check

- Step 1. Use the same setup as in the previous section (Section 4.2.13) except apply the signal between the INPUT terminal 2 and ground terminal and connect INPUT terminals 1 and 2 together.
- Step 2. Check the detector zero.
- Step 3. Set the function generator frequency to 50Hz and output to minimum.
- Step 4. Set the detector power switch to ON, RANGE switch to 1uV and zero the instrument with the ZERO control. Allow time for the unit to stabilize (approximately one minute).
- Step 5. Increase the function generator output to 1V peak-to-peak. There should be no shift in the meter reading. (Do not confuse noise and drift for a shift in meter reading.)

4.2.15 Generator Leakage Resistance Check

To check the leakage resistance from each generator terminal to ground:

- Step 1. Connect jumper strap between detector INPUT terminal 1 and ground.
- Step 2. Connect generator OUTPUT terminal 1 to detector INPUT terminal 2 with shielded lead and plug.
- Step 3. Cover generator OUTPUT terminal with a grounded shield. Make sure that the shield does not touch the terminal.
- Step 4. Set detector RANGE to 3 VOLTS.
- Step 5. Set generator RANGE to 600V, turn POWER LIMIT control fully clockwise, and set OUTPUT switch to +.
- Step 6. Meter should indicate less than 600 millivolts. (This indicates resistance greater than 10^{11} ohms.)
- Step 7. Set OUTPUT switch to OFF and connect generator OUTPUT terminal 2 to detector INPUT terminal 2 using shielded cable and plug. Again, as in test above, do not let plug touch terminal.
- Step 8. Set detector RANGE to 10 MICROVOLTS and generator RANGE to 600V.
- Step 9. Set generator OUTPUT switch to + and turn POWER LIMIT control fully counterclockwise. Do not be concerned if meter indication goes off scale; it should be back on scale in a few seconds.

Step 10. Within 30 seconds, the meter should indicate not more than 6.0 microvolts. (This indicates resistance greater than 10^{14} ohms.)

4.2.16 Detector Leakage Check

To check leakage resistance from each detector terminal to ground:

Step 1. Disconnect any ground strap or jumper between either detector INPUT or OUTPUT terminals and ground.

Step 2. Connect a jumper strap between generator OUTPUT terminal 2 and ground.

Step 3. Connect generator OUTPUT terminal 1 to detector INPUT terminal 2 with a shielded lead and plug.

Step 4. Cover detector INPUT terminal 1 with a grounded shield. Make sure the shield does not touch the terminal.

Step 5. Set detector RANGE to 3 VOLTS and the generator RANGE to 600V.

Step 6. Turn generator RANGE and POWER LIMIT controls fully clockwise, and set OUTPUT switch to +.

Step 7. Meter should indicate less than 600 millivolts. (This indicates resistance greater than 10^{11} ohms.)

Step 8. Set OUTPUT switch to OFF and connect generator OUTPUT terminal 2 to detector INPUT terminal 1 using shielded cable and plug.

Step 9. Set detector RANGE to 1 MILLIVOLT and generator RANGE to 600V.

Step 10. Set generator OUTPUT switch to + and turn POWER LIMIT control fully clockwise. Do not be concerned if meter indication goes off scale; it should be back on scale in a few seconds.

Step 11. Within 30 seconds, the meter should indicate not more than 600 microvolts. (This indicates resistance greater than 10^{12} ohms.)

SECTION 5

PARTS LISTS AND DIAGRAMS

5.1 801B FINAL ASSEMBLY (P/N 30802)

<u>CIRCUIT NO.</u>	<u>DESCRIPTION</u>	<u>ESI PART NO.</u>
C2, C3	Capacitor, 0.01 microfarad, 1%, 1000V	01918
DS2	Pilot Lamp	18412
F1	Fuse, 0.5A	01802
	Carrier, Fuse 3AG QRA	45966
K1, K2	Relay	18439
S1/DS1	Switch, Push, with Lamp	18418
S2	Switch, Lever	06599
T1	Transformer, Relay Supply	18445
T2	Variable Autotransformer	08068
	Circuit Assy, Generator	18870
	Circuit Assy, Relay Power Supply	18437
	Line Volt Clipper Reg Assy	01618
	Generator Power Supply	18420
	Circuit, Detector Power Supply	52715
	Detector, Keithly	52922
	Chassis, Detector	52833
	Plate, Front Shield	18423
	Dust Cover	18446
	Panel Bushing	04167
	Shaft	18455
	Capacitor, Binding Post, Gold	01172
	Washer, DELRIN, 20 x 49 x 13	07790
	Binding Post	45253
	Knob, Lg Bar Filled	01266
	Knob, Sm Round Filled	01305
	Knob, Lg Round Filled	01271
	Spacer	04051
	Grommet 1/4 inch	01601
	Grommet 1/2 inch	01602
	Swing Lug	03247
	Capacitor, Binding Post, Blk	01170
	ESI Medallion	01946
	Binding Post, Short	23870
	Panel, Front	52836
	Chassis, Generator	52834
	Bracket, Detector	52138
	Cover, Detector	52138
	Kit, Wire	53185
	Shaft Coupler	53318
	Shaft, Control	52985
	Coupler, Shaft	53318

5.1 801B FINAL ASSEMBLY (P/N 30802) (Continued)

<u>CIRCUIT NO.</u>	<u>DESCRIPTION</u>	<u>ESI PART NO.</u>
	Shaft, Detector	52986
	Spacer, 5 x 0.397 x 0.725	01481
	Washer, Shoulder LEXAN 50 x 75 x 64	01482
	Washer, Spacer DELRIN 20 x 12	07725
	Washer, KL-F 10	01390
	Sleeve, DELRIN 26 x 50 x 41	08059
	Washer, LEXAN 20 x 50 x 20	18430
	Strip 003 Term	18415
	Power, 3 Cond N18 CEE	48524
	Bushing Str Rel	03134
	Strip, 3 Terminal 3/8 Sp	01753
	Lug, Solder 10	05912
	Grommet, 0.62H1 x 0.06 Pnl	15398
	Post, Binding W/Cap	25518
	Ring, Ring C Style	02682
	Grommet, Horse Shoe 312D	47125
	Washer, Int 4 Lock	03577
	Shield, Shock	52809
	Standoff, 0.375 x 250 6-32	18417
	Spacer, 0.22H x 0.50D	52974
	Bracket, Angle 6-32 L	04283
	Nut, Speed 6-32	03553
	Standoff, 0.375 x 600 6-32	29165
	Holder, Fuse	45968
	Carrier, Fuse Metric	45965
	Fuse, 0.5A Metric	49743
	Plate, 62 x 206 12BTP	18029
	Bracket, AC Shield	18429

5.2 RELAY POWER SUPPLY CIRCUIT ASSEMBLY (P/N 18437)

<u>CIRCUIT NO.</u>	<u>DESCRIPTION</u>	<u>ESI PART NO.</u>
	PC Board, Relay Power Supply	18426
C1	Capacitor, 500 microfarad, 50V	01942
CR1-CR8	Diode, 1N4005	01779
R1	Resistor, 27 kilohm, 10%, 1/2W	01962
R2	Resistor, 470 ohm, 10%, 1W	02056
R3	Resistor, 10 kilohm, 10%, 1/2W	01961
S3	Switch, DPDT (110V-220V)	18424
	Mtg Fixture Nylon	01711

5.3 LINE VOLTAGE CLIPPER REGULATOR ASSEMBLY (P/N 01618)

<u>CIRCUIT NO.</u>	<u>DESCRIPTION</u>	<u>ESI PART NO.</u>
CR9, CR10	Diode, Zener	18407
CR11, CR12	Diode, Zener	18453
Q1, Q2	Transistor, 40318	18452
R4, R5	Resistor, 27 kilohm, 10%, 1/2W	01962
R6, R7	Resistor, 100 ohm, 5W	01990

NOTE: Please refer to Figure 5-1 for schematic diagram.

5.4 GENERATOR POWER SUPPLY CIRCUIT ASSEMBLY (P/N 18420)

<u>CIRCUIT NO.</u>	<u>DESCRIPTION</u>	<u>ESI PART NO.</u>
C106	Capacitor, 18,000 microfarad	08035
C107	Capacitor, 0.1 microfarad, 1kV	50013
S101-S103	Switch, Generator Range	08050
T101	Transformer, Generator	08091

5.5 GENERATOR CIRCUIT ASSEMBLY (P/N 18870)

<u>CIRCUIT NO.</u>	<u>DESCRIPTION</u>	<u>ESI PART NO.</u>
	PC Board, Generator	18869
C101-C104	Capacitor, 4 microfarad, 450V	02183
C105, C108	Capacitor, 200 microfarad, 10%, 150V	02138
CR101-CR114	Diode, 1N4005	01779
R101	Resistor, 4 kilohm, 5%, 5W	02484
R102	Resistor, 270 kilohm, 10%, 2W	01645
R103	Resistor, 39 kilohm, 10%, 2W	02469
R104	Resistor, 47 kilohm, 10%, 2W	02474
R105	Resistor, 4.5 kilohm, 5%, 5W	02070
R106, R110	Resistor, 33 ohm, 10%, 2W	02045
R107	Resistor, 2.7 kilohm, 10%, 2W	02065
R108	Resistor, 1 kilohm, 5%, 5W	02061
R109	Resistor, 50 ohm, 5%, 5W	02047
R111	Resistor, 10 ohm, 5%, 5W	02040
R112, R113	Resistor, 1 ohm, 5%, 3W	02036
	Mtg Fixture, Nylon	01711

NOTE: Please refer to Figure 5-1 for schematic diagram.

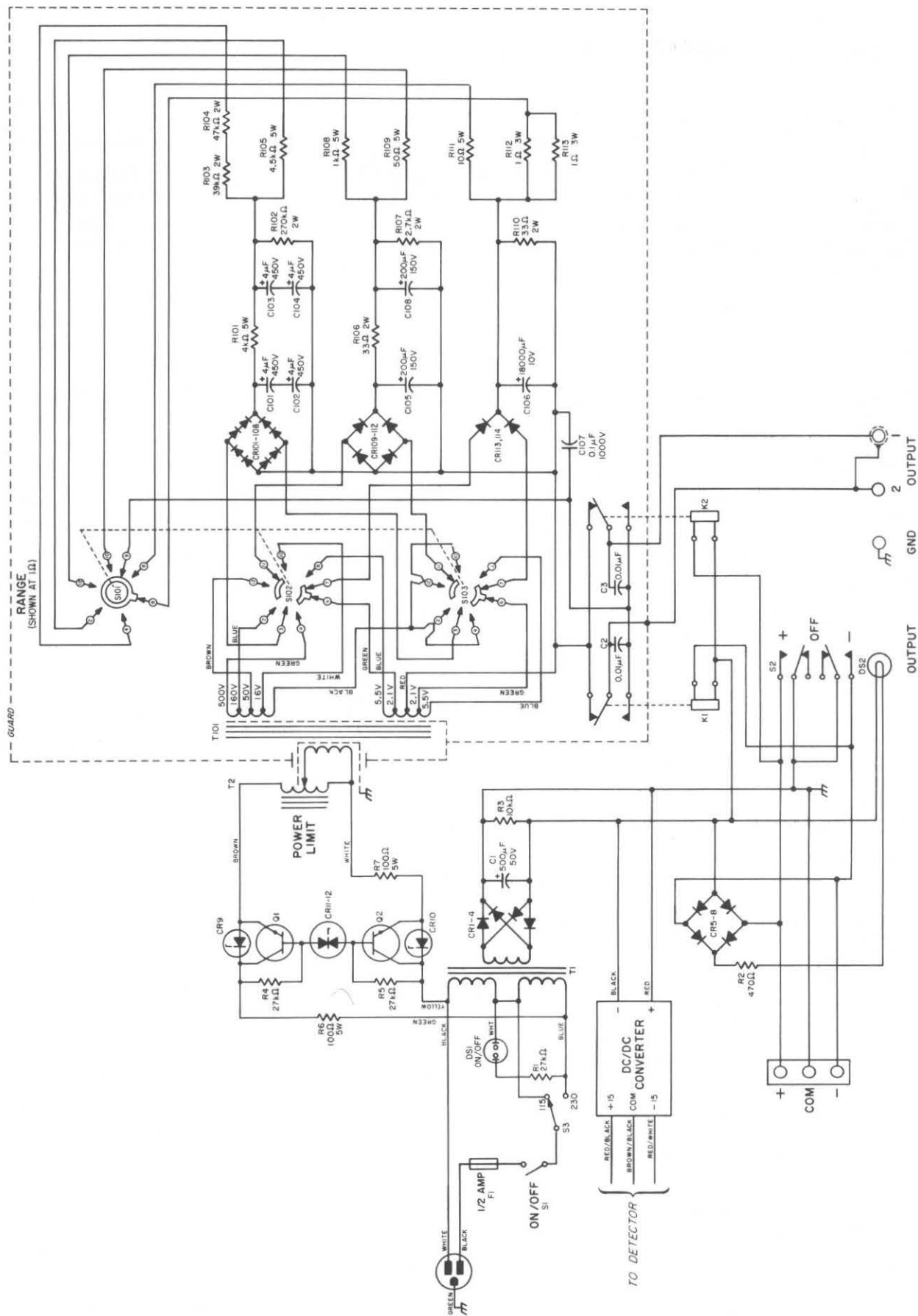


Figure 5.1 Power Supply and Generator Schematic Diagram (P/N 18870)

5.6 DETECTOR ASSEMBLY (P/N 52922)

<u>CIRCUIT NO.</u>	<u>DESCRIPTION</u>	<u>ESI PART NO.</u>
C124	Capacitor, 0.01 microfarad, 10%, 1200V	56405
M101	Assembly, Meter Movement	53471
Q101, Q102	Transistor, FET	53469
S101	Switch, Rotary	53470



RS-925D

Resistance Standard

User and Service Manual



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RS-925D Sept. 2014



IET LABS, INC.

www.ietlabs.com

Email: info@ietlabs.com

TEL: (516) 334-5959 • FAX: (516) 334-5988

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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Chapter 1

INTRODUCTION

1.1 Introduction

The RS-925 Resistance Standard provides a very broad-range high-performance resistance source.

The RS-925D Resistance Standard is a precision resistance source with excellent characteristics of accuracy, stability, temperature coefficient, and power coefficient. All these features serve to make it a laboratory resistance standard, exceeded in performance only by stand-alone standard resistors.

Hermetically sealed wirewound resistors are used for 1 Ω steps and over. These resistors are carefully conditioned under power and temperature in order to develop the best stability characteristics. Actual experience has shown them to exhibit a storage stability of better than 5 ppm/year, improving as they age. The low-resistance resistors are constructed with resistance wire with a minimum of copper resistance in series to limit temperature coefficient effects.

The unit has a fixed minimum resistance of 10 m Ω . This is implemented by mechanically limiting the 10 m Ω decade from going below the “1” position. In this manner, no zero resistance subtractions have to be made, and the accuracy given is for the absolute reading.

The RS-925D Resistance Standard employs completely enclosed dust-tight very low contact resistance switches. They feature solid silver alloy contacts and quadruple-leaf silver alloy wipers which keep switch contact resistance to under 1 m Ω per decade, and more importantly, keep switch contact resistance *reproducible*, insuring repeatable instrument performance.

High quality gold plated tellurium copper binding posts minimize the thermal emf effects which would artificially reflect a change in dc resistance measurements. All other conductors within the instrument, as well as the solder employed, contain no metals or junctions that contribute to thermal emf problems.

The RS-925D Resistance Standard is designed to allow very convenient maintenance of calibration over time. Most decades are calibratable without changing components or soldering resistors. The decades for the 100 Ω through 100 k Ω steps are calibrated with convenient trimmers. Trimming of the lower decades is also possible.

With a resolution as low as 20 $\Omega\Omega$ and a maximum available resistance of over 12.1 M Ω , the RS-925D-11-0.001-RH may be employed for exacting precision measurement applications requiring high accuracy and stability. It can be used as components of dc and low frequency ac bridges, for calibration, as transfer standards, and as RTD simulators.



Figure 1-1: RS-925 Resistance Standard

Chapter 2

SPECIFICATIONS

For convenience to the user, the pertinent specifications are given in a typical **OPERATING GUIDE**, like the one shown in Figure 2.1, affixed to the case of the instrument.

SPECIFICATIONS

Resistance per step	Total decade resistance	Max current whichever applies first	Max power	Temperature coefficient (±ppm/°C)	Power coefficient (±ppm/mW)	Accuracy*	Stability (±ppm/yr)	Decade positions	Resistor type		
100 μΩ/division 20 μΩ resolution	10 mΩ	2 A	NA	20	1			Continuous	Rheostat		
1 mΩ	10 mΩ	2 A	NA	20	1	±(20 ppm+0.5 mΩ)	20 ppm+0.5 mΩ	11 positions "0"-"10"	Resistance wire		
10 mΩ	100 mΩ	2 A	NA	20	1			10 positions "1"-"10" (10 mΩ minimum reading)			
100 mΩ	1 Ω	2 A	NA	20	1			11 positions "0"-"10" (12 positions "0"-"11" for highest decade)	Wirewound hermetically sealed low-inductance		
1 Ω	10 Ω	1 A	5 W	20	0.4						
10 Ω	100 Ω	0.33 A	5 W	10	0.3						
100 Ω	1 kΩ	0.1 A	5 W	3	0.1						
1 kΩ	10 kΩ	33 mA	5 W	3	0.1		10 ppm (<5 ppm typical)				
10 kΩ	100 kΩ	10 mA	5 W	3	0.1						
100 kΩ	1 MΩ	3 mA	2,000 V peak	3	0.1						
1 MΩ	10 MΩ	1 mA	2,000 V peak	3	0.1						
10 MΩ	100 MΩ	2,000 V peak		15	0.2	±0.02%	50 ppm		Metal oxide		
Wiring and switch resistance		NA		50 μΩ/°C	0.2 μΩ/W	NA					

*At 23°C “true ohm” measurement, 30-70% RH, absolute reading, SI traceable
No zero subtraction required

Minimum resistance:

10 m Ω \pm 0.5 m Ω ; determined by the lowest settable position, “1”, of the 10 m Ω /step decade

Resistance repeatability:

Better than 100 $\mu\Omega$, short-term, average value

Leakage Resistance:

$>$ 10 G Ω

Environmental Conditions:

Operating Temperature: 0°C to 55°C

Storage Temperature: -40°C to 70°C

Switch Type:

Multiple solid silver contacts; dust-tight diallyl-phthalate body.

To allow continuous rotation, a blank position is added on most decades.

Terminals

Four, 5-way, gold-plated, tellurium-copper binding posts with low thermal emf and low resistance, for four-terminal Kelvin measurements, plus one binding post connected to case for shielding. Rear outputs are available as an option.

Mechanical Information:

Model	Dimensions	Weight
8 decades	48.3 cm W x 17.8 cm H x 19.7 cm D (19" W x 7" H x 7.8" D)	5.1 kg (11 lb)

RS925D OPERATING GUIDE

CONSULT INSTRUCTION MANUAL FOR PROPER INSTRUMENT OPERATION

Resistance per step	Total decade resistance	Max current whichever applies first	Max power	Temperature coefficient (±ppm/°C)	Power coefficient (±ppm/mW)	Stability (±ppm/yr)	Decade positions	Resistor type
100 µΩ division 20 µΩ resolution 1 mΩ	10 mΩ	2 A	NA	20	1	Continuous	Continuous	Rheostat
	10 mΩ	2 A	NA	20	1	11 positions "0"±10° 10 positions "1"±10° (10 mΩ minimum reading)		Resistance wire
10 mΩ	100 mΩ	2 A	NA	20	1	20 ppm±0.5 mΩ		
100 mΩ	1 Ω	2 A	NA	20	1			
1 Ω	1 A	5 W	20	0.4				
10 Ω	10 Ω	0.33 A	5 W	10	0.3			
100 Ω	1 kΩ	0.1 A	5 W	3	0.1			
1 kΩ	10 kΩ	33 mA	5 W	3	0.1		11 positions "0"±10°	Wirewound hermetically sealed low-inductance
10 kΩ	100 kΩ	10 mA	5 W	3	0.1			
100 kΩ	1 MΩ	3 mA	2,000 V peak	3	0.1		12 positions "0"±11°	
Wiring and switch resistance		NA		50 µΩ/°C	0.2 µΩ/W		NA	

Accuracy

 $\pm(20 \text{ ppm} + 0.5 \text{ m}\Omega)$

At 23°C "true ohm" measurement, 30-70% RH, absolute reading, case grounded, SI traceable
No zero subtraction required

Minimum resistance:

10 m Ω \pm 0.5 m Ω ; determined by the lowest settable position, "1", of the 10 m Ω /step decade

Resistance repeatability:

Better than 100 $\mu\Omega$, short-term, average value

Environmental Conditions:

Operating Temperature: 0°C to 55°C

Storage Temperature: -40°C to 70°C

Switch Type:

Multiple solid silver contacts; dust-tight diallylphthalate body.

Terminals:

Four, 5-way, gold-plated, tellurium-copper binding posts with low thermal emf and low resistance, for four-terminal Kelvin measurements, plus one binding post connected to case for shielding. Rear outputs are available as an option.

For Best Performance:

Whenever the unit has been idle, turn each switch 7-10 times both ways before using. This switch "break-in" procedure is standard metrology practice required for best accuracy to remove any silver oxide film on the contact surfaces, typically <1 m Ω .

SN: D4-1405569

MODEL: RS925D

WARNING

Observe all safety rules when working with high voltages or line voltages. Connect the (GND) terminal to earth ground in order to maintain the case at a safe voltage. When ever hazardous voltages (>45 V) are used, take all measures to avoid accidental contact with any live components: a) Use maximum insulation and minimize the use of bare conductors. b) Remove power when adjusting switches. c) Post warning signs and keep personnel safely away.



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- Long Island, NY • Email: info@ietlabs.com
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RS-925D label.indd/01-18-2013

Figure 2-1: Typical Operating Guide Affixed to Unit

Chapter 3 Installation

3.1 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.

3.2 Installation

For a rack mounted model, installation in a 19 inch rack may be made using the slots in the rack mounting ears. A mounting location that does not expose the unit to excessive heat is recommended. For bench models there is no required installation.

Since this is a high accuracy instrument, it is recommended that a space be provided that would not expose it to mechanical abuse and keep it maintained at laboratory standard temperatures near 23°C.

3.3 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 to the instrument identifying the owner and indicate the service or repair to be accomplished. Include the model number, the full serial number of the instrument, the RMA number, and shipping address.
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.

3.4 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.

Chapter 4

OPERATION

4.1 Initial Inspection and Setup

This instrument was carefully inspected before shipment. It should be in proper electrical and mechanical order upon receipt.

An OPERATING GUIDE is attached to the case of the instrument to provide ready reference to specifications.

4.2 Connection

4.2.1 General Considerations

Four insulated low-thermal-emf binding posts labeled **CURRENT HI**, **CURRENT LO**, **SENSE HI**, and **SENSE LO** provide two current and two potential terminals, respectively, for 4-terminal measurement. 2-terminal measurements may be made by shorting **CURRENT HI** to **SENSE HI**, and **CURRENT LO** to **SENSE LO**, preferably with shorting links or other substantial means. The four terminal connection is important of course for low resistances.

A fifth metal binding post labeled **GND** (Ground) is connected to the case and may be used as a guard or shield terminal. It may also be connected using the shorting link to either terminal to implement a 2-terminal as opposed to a 3-terminal measurement.

4.2.2 Electrical Considerations

In order to make proper use of the full performance capabilities of the RS-925D unit, especially if low resistance or low resistance increments are important, care must be taken in connecting to the terminals of the decade box.

In particular, to keep contact resistance to a minimum, 4-terminal connections should be employed, and the most substantial and secure connection to the binding posts should be made. They accept banana plugs, telephone tips, spade lugs, alligator clips, and bare wire. The largest or heaviest mating connection should be made, and, where applicable, the binding posts should be securely tightened.

These considerations may be relaxed whenever single milliohms not considered significant for the task being performed.

4.2.3 Thermal emf Considerations

The highest quality low emf components are used in the RS-925D Series. In particular, the terminals are made of gold plated tellurium copper, which exhibits low emf and low resistance. There nevertheless may be some minute thermal emf generated at the user's test leads where they contact the RS-925D banana jacks. This will depend on the test lead material. Whenever this is critical, brass and iron materials should be avoided.

This emf will not manifest itself if an ac measurement instrument is employed. It will also be eliminated if a meter with so called "True Ohm" capability is used. Otherwise it may appear as a false component of the dc resistance measurement, and can be the order of milliohms.

4.3 Dial Setting

The resistance setting may be read directly from the dial settings. For additional flexibility and range, each decade provides a “10” position setting. This “10” position on any one decade equals the “1” position on the next higher decade if any. It adds about 11 % to the nominal total decade resistance. The most significant decade also has an “11” position to extend the resistance range to over 1.2 M Ω . The 10 m Ω decade, however, does not go below the “1” position in order to maintain a precise and constant minimum resistance of 10 m Ω , so that no subtraction of zero resistance is required.

To determine the resistance obtained when any one or more “10” or “11” settings are used, simply add 1 to the next higher decade. For example, a setting of “10-11-10-10-10-10-1-10” becomes:

11	1	1	0	0	0	0.	0	0	0		
10		1	0	0	0	0.	0	0	0		
10			1	0	0	0.	0	0	0		
10				1	0	0.	0	0	0		
10					1	0.	0	0	0		
10						1.	0	0	0		
1							.	0	1	0	
10								.	0	1	0
<hr/>											
Total	1	2	1	1	1	1.	0	2	0		

In order to obtain a zero in the 10 m Ω position, set the 10 m Ω decade to the “10” position, i.e. 100 m Ω , and take the 100 m Ω setting, in the next decade, into consideration. To get 1.000 Ω , for example, the switches should be set to show “0.-9-10-0”.

Since the highest decade has an additional “11” position, resistance values of over 1.2 times nominal maximum value can be obtained.

4.4 Rheostat Operation

For high-resolution applications, an optional rheostat may be used. It provides up to 10 m Ω of resistance in 0.1 m Ω steps. To get the rheostat reading in milliohms, multiply the dial setting by 0.1. See Figure 4-1.



Figure 4-1: Rheostat Dial

In order to eliminate contact resistance and thermal emf, the RS-925D integrates the rheostat as shown in Figure 4-2. This way, the wiper is in the low potential circuit, which is the high impedance lead. As a result, voltage and contact resistance effects are removed by being effectively added to the input impedance of the measuring instrument.

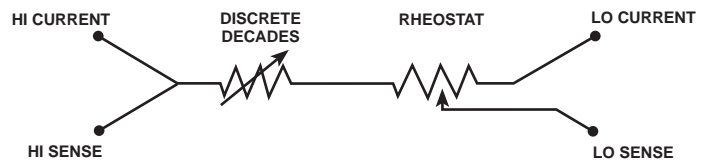


Figure 4-2: Rheostat Schematic

4.5 Power Considerations

To maintain the maximum possible accuracy and precision, power applied to the RS-925D should be kept as low as possible, preferably below 0.1 W. For best protection of the instrument, it is advisable to limit the input power to 1 W. This may be implemented with a series resistor or fuse.

4.6 Environmental Conditions

For optimal accuracy, the decade box should be used in an environment of 23°C. It should be allowed to stabilize at that temperature for at least four hours after any significant temperature variation.

Humidity should be maintained at laboratory conditions of 30% to 70% RH.

4.7 Switch Conditioning

The switch wipers employed in this unit are self cleaning. They have solid silver alloy contacts. After being left idle, the wipers and contacts must be conditioned or “broken in” again to remove the film of silver oxide that develops over time. This is standard metrology practice when high accuracy is required. This effect is of the order of less than 1 mΩ, So it may be ignored whenever measurements of that magnitude are not important.

To perform this “breaking in,” simply rotate each switch seven to ten times in each direction.

4.8 Meter Shunt Applications

To measure the current in a 4-terminal resistor:

1. Measure the voltage drop between the two terminals of the resistor not connected to the current source.
2. Determine the current by the ratio of the measured voltage to the known resistance.

Using the 4-terminal technique helps avoid errors caused by the voltage drops in the current-carrying leads and contacts. Errors caused by lead and contact resistances in the voltage measuring circuit are negligible if the current in this circuit is small.

4.9 Kelvin Bridge Applications

Use 4-terminal resistance standard for all Kelvin bridge measurements. When connected as shown in Figure 4-3, errors caused by lead and contact resistances can be made negligible because they appear as part of the generator or yoke resistance, or in series with high resistance bridge arms.

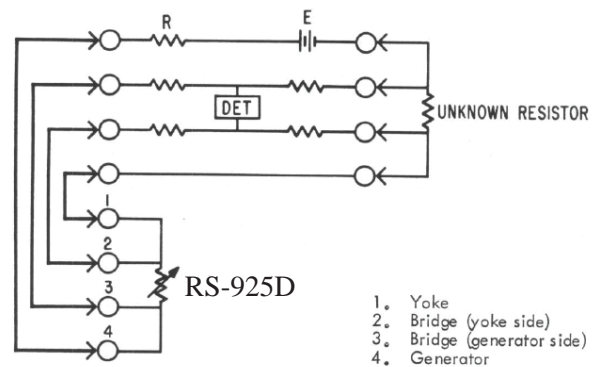


Figure 4-3: Kelvin Bridge Connections

For maximum protection and accuracy, limit power input to RS-925D to 1Watt. This may be accomplished by placing a resistor in series with the bridge generator or battery.

The value of this resistance can be calculated from the following formula:

$$R = \frac{E^2}{4}$$

where:

R = value of the power-limiting resistor

E = open circuit voltage of the generator

The protective resistor should have a power rating of 4 W or more. Input power should be limited to 1/10 W or less for most accurate measurements.

Chapter 5

MAINTENANCE

5.1 Maintainability and Reliability

It is possible to maintain Model RS-925D indefinitely. It is reliable due to its closed design and sealed switches and resistors. It is possible to adjust the unit, if necessary, because it has 6 trimmable decades. The unit is resistant to electromagnetic interference (EMI) because of its metal enclosure.

5.2 Preventive Maintenance

Keep the unit in a clean environment. This will help prevent possible contamination.

The Model RS-925D is packaged in a closed case and uses completely sealed switches. This limits the entry of contaminants and dust to the inside of the switches. If it is maintained in a clean or air-conditioned environment, cleaning will seldom be required.

Should cleaning be needed:

1. Remove the 4 housing screws from the side of the instrument, and remove the housing.
2. Remove any dust or debris using optical grade dry compressed air or a clean brush.
3. Replace the housing and reattach the 4 housing screws.

The front panel should be periodically cleaned to eliminate any leakage paths from near or around the binding posts. To clean the front panel:

Wipe the front panel clean using alcohol and a

lint-free cloth.

5.3 Calibration

The Model RS-925D may be employed as a stand-alone instrument or as an integral component of a system. If used as part of a system, it should be calibrated as part of the overall system to provide an optimum system calibration.

If the RS-925D is employed as a stand alone device, the following should be observed:

- Calibration Interval
- General Considerations
- Required Equipment
- Calibration Procedure

5.3.1 Calibration Interval

The recommended RS-925D Series calibration interval is twelve (12) months.

If the instrument is used to transfer resistance values only, recalibration is not required, assuming that there has been no drastic change in the deviations of any individual resistors.

5.3.2 General Considerations

Before starting the calibration procedure, you need to consider the following:

- Calibration environment should be 23°C and less than 50% relative humidity.
- Test instruments should be sufficiently more accurate than the RS-925D unit, and/or the uncertainty of the measurement instrumentation has to be considered in the calibration Test Uncertainty Ratio (TUR).
- The testing equipment and the RS-925D unit should stabilize at laboratory conditions for at least 24 hours.
- Kelvin type 4-wire test leads should be used to obtain accurate low resistance measurements.
- Steps should be taken to minimize thermal emf effects, such as using a meter with “True Ohm” capacity.
- Accepted metrology practices should be followed.

5.3.3 Required Equipment

Many combinations of standards, transfer standards, meters, and bridges may be used to calibrate this instrument. The following are some possible choices:

- Resistance Standards or Transfer Standards for 1 Ω , 10 Ω , 100 Ω , 1 k Ω , 10 k Ω , 100 k Ω , 1 M Ω , and 10 M Ω per step, calibrated to ± 10 ppm. IET options include the following models:

- HATS-LR
- HATS-Y
- SRL Series

The 1 Ω , and 10 Ω transfer standards are optional, and are only used to take advantage, if desired, of the trimmability of these two decades

- Precision resistance measurement bridge or multimeter, with a transfer accuracy of ± 1 ppm. Options include:
 - Guildline Model 9975
 - Measurements International Model 6000A

- ESI model 242, 242A, 242C, or 242D
- A high-precision, high-stability digital multimeter (e.g. Fluke 8508A) along with a set of resistance standards for ratio mode.

5.3.4 Calibration Procedure

To calibrate the RS-925D unit, proceed as follows:

1. Set up the calibration equipment in the resistance measurement mode and exercise the switches 10 times in each direction.
2. Allow the switches to cool for 15 minutes.
3. Confirm the minimum resistance of the unit.
Allow a confidence band for the uncertainty of the measuring instrument and setup.
4. Determine the allowable upper and lower limits for each resistance setting of each decade based on the specified accuracy and the confidence band.
*For the RS-925D series, the limits for any resistance “R” are:
 $[R \pm (20 \times 10^{-6}R + 0.0005\Omega)]$.*
5. Confirm that the resistances fall within these limits.
6. If any resistances fall outside these limits, the associated switch assembly may require service or replacement.

5.4 Adjustments

If one or more resistances fall outside the limits, the associated resistor should be trimmed. This applies for 1 Ω steps and over. There is a trimming network provided for each resistance in these ranges. These may be accessed by removing the housing and accessing the particular decade PC board.

If the minimum 10 m Ω needs to be adjusted, consult IET Labs. For other resistors, adjust the resistors from lowest to highest. The order of decades does not matter.

Whereas it is possible to adjust any one resistance step, note that the n^{th} step of a decade is the sum of resistances 1 through n , so that errors are cumulative. It is therefore recommended that whenever any resistance of a particular decade is trimmed, that all the resistances of that decade be tested and trimmed as required.

To adjust any of the resistances, the following should be observed:

- Trimming considerations
- Trimming procedure

5.4.1 Trimming Considerations

Before trimming any resistances, observe the following:



The RS-925D front panel should be connected to the test instrument's guard point.

The equipment measuring the unit should conform to the guidelines provided in Section 5.3.

5.4.2 Trimming Procedure

To trim any resistances, **proceed as follows:**

1. Stabilize RS-925D at laboratory temperature of 23 °C for at least 8 hours.
2. Remove the 4 housing screws from the sides of the instrument and remove the housing.
3. Using the binding posts in the 4-terminal connection, connect RS-925D to a resistance meter.
4. Rotate all knobs approximately 10 times.
Breaking in the switches helps eliminate any residual contact corrosion resistance.
5. Set all dials to 0, except for the 10 m Ω decade.
10 m Ω decade has a minimum stop at position 1.
6. Measure the 10 m Ω setting
If an adjustment is needed, consult IET technical support.
7. Measure 1 m Ω , 10 m Ω , and 100 m Ω steps.
If adjustment is needed, proceed as follows:
 - If the resistance is **high**, reduce it by adding a small bit of solder to an exposed portion of the wire
 - If the resistance is **low**, increase it by gently filing the wire in one spot.



Make these steps carefully and slowly, allowing the wire to cool down before remeasuring.

8. Measure the higher decades. If an adjustment is needed, proceed as follows:
Starting with the lowest setting, adjust the associated trim pots.
See Table 5-1 and Figure 5-1 for reference
9. Replace the housing and reinstall the 4 housing screws.

Switch Position	Potentiometer Designation*
1	T0 or T1
2	T1 or T2
3	T2 or T3
4	T3 or T4
5	T4 or T5
6	T5 or T6
7	T6 or T7
8	T7 or T8
9	T8 or T9
10	T9 or T10
11	T10 or T11 (100 k steps only)

*Designation may vary for different decades

Table 5-1: Trimming Potentiometers

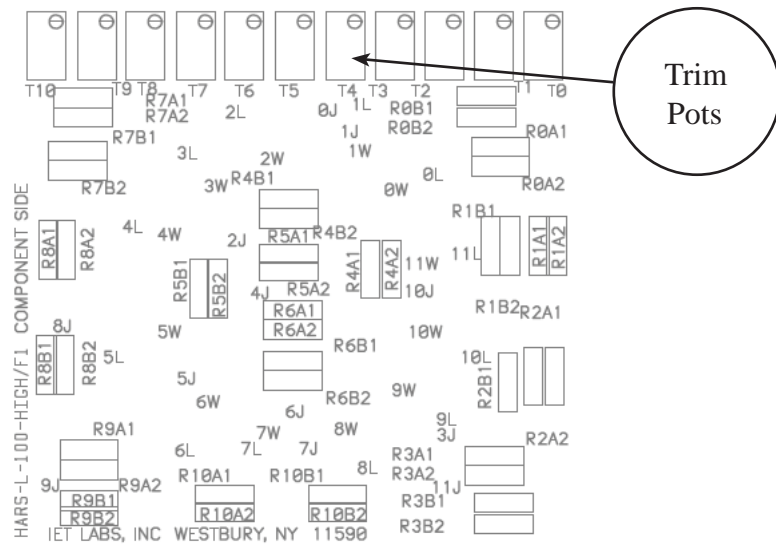


Figure 5-1: Typical Trimmer Board

5.5 Replaceable Parts List

Model Ref	IET Pt No	Description
1	BP-1000-RD	Binding Post, Red
2	BP-1000-BK	Binding Post, Black
3	BP-1000-GN	Binding Post, Green
4	RS-925D-4300-KNB	Knob Assembly
5	RS-925D-RH	Rheostat Assembly
Not Shown	RS-925D-3100	Foot
Not Shown	HARS-4000-LX-.001	1 m Ω /step Decade Switch Assembly
Not Shown	HARS-4000-LX-0.01	10 m Ω /step Decade Switch Assembly
Not Shown	HARS-4000-LX-0.1	100 m Ω /step Decade Switch Assembly
Not Shown	HARS-4000-LX-1	1 Ω /step Decade Switch Assembly
Not Shown	HARS-4000-LX-10	10 Ω /step Decade Switch Assembly
Not Shown	HARS-4000-LX-100	100 Ω /step Decade Switch Assembly
Not Shown	HARS-4000-LX-1k	1 k Ω /step Decade Switch Assembly
Not Shown	HARS-4000-LX-10k	10 k Ω /step Decade Switch Assembly
Not Shown	HARS-4000-LX-100k	100 k Ω /step Decade Switch Assembly
Not Shown	HARS-4000-LX-1M	1 M Ω /step Decade Switch Assembly
Not Shown	HARS-4000-LX-10M	10 M Ω /step Decade Switch Assembly

Table 5-2: Replaceable Parts List



Figure 5-2: RS-925D Replaceable Parts

