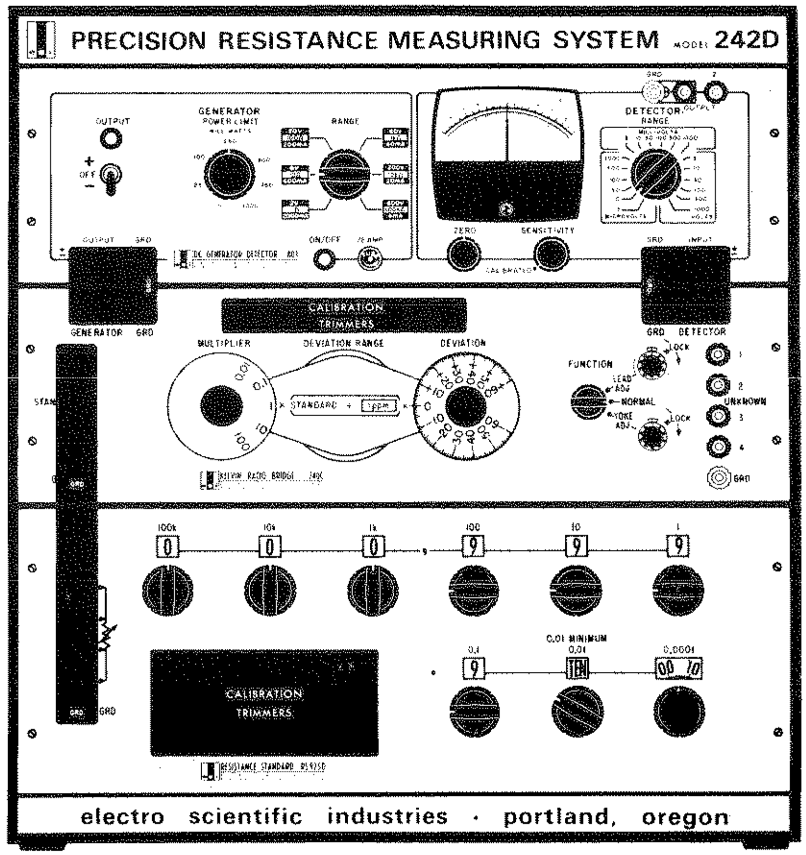
Instruction Manual

JUNE 1971

MODEL 242D

PRECISION RESISTANCE MEASURING SYSTEM



SERIAL NUMBER: ____________

PART NUMBER: 19625

esi®

Electro Scientific Industries

13900 N. W. SCIENCE PARK DRIVE, PORTLAND, OREGON 97229

The following table lists the most recent revision of each page at the present printing:

PAGES	DATE
Title	6/71
A	6/71
i and ii	6/71
1-1 and 1-2	6/71
2-1 thru 2-5	6/71
3-1 thru 3-8	6/71

C A U T I O N !

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.

Part No. 23141

TABLE OF CONTENTS

The following are registered trademarks of Electro Scientific Industries, Inc.:

ESI® Electro Scientific Industries, Inc.
ESIAC® Algebraic Computer
ESIPOT® Potentiometer
DEKABOX® Decade Resistors and Capacitors
DEKABRIDGE® Bridge Circuit
DEKADIAL® Decade Dials
DEKAMATIC® Automatic Unit
DEKAPOT® Decade Potentiometers
DEKASTAT® Decade Rheostat
DEKAPACITOR® Decade Capacitor
DEKAVIDER® Decade Voltage Divider
KELVIN KLAMPS® Four-Terminal Clamps
KELVIN KLIPS® Four-Terminal Clips
PORTAMETRIC® Portable Measuring Instrument
PVB® Potentiometric Voltmeter Bridge

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 ESI 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.

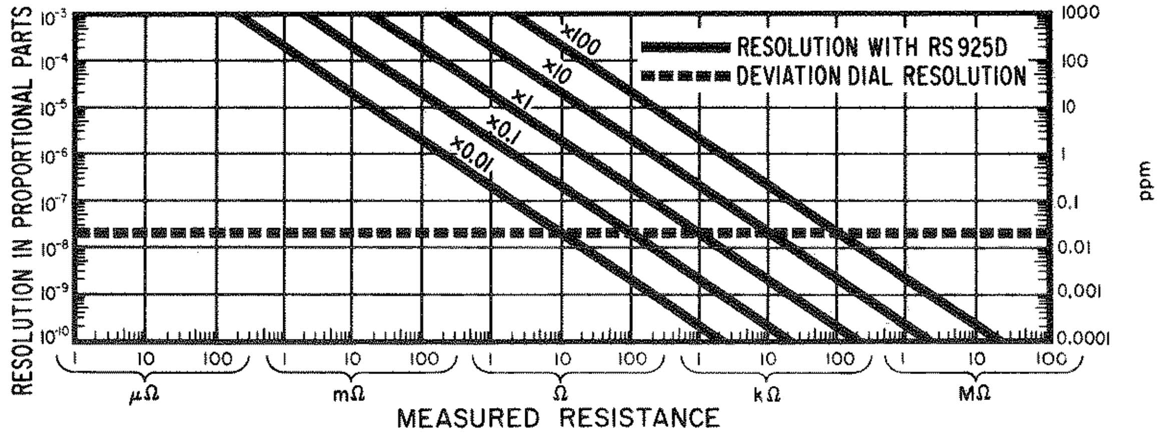


Figure 1-1. Model 242D Resolution

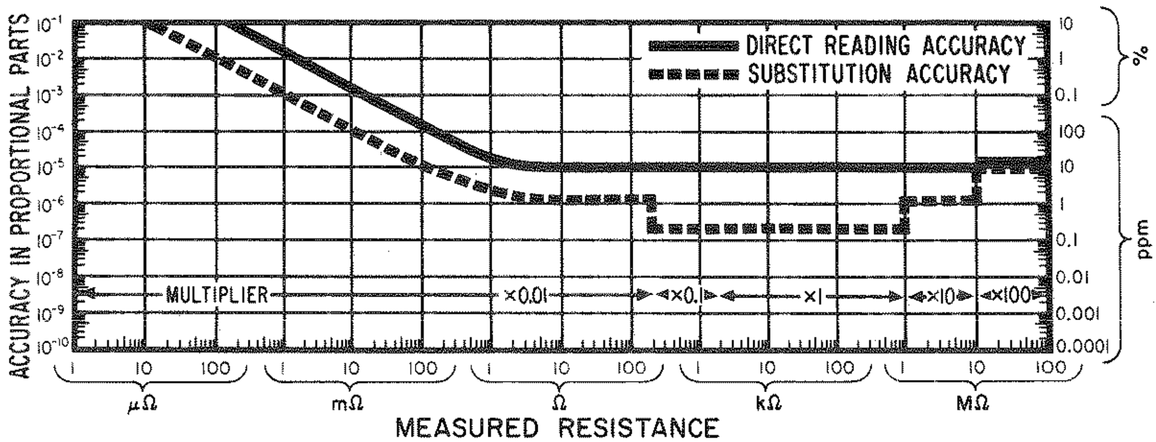


Figure 1-2. Model 242D Accuracy

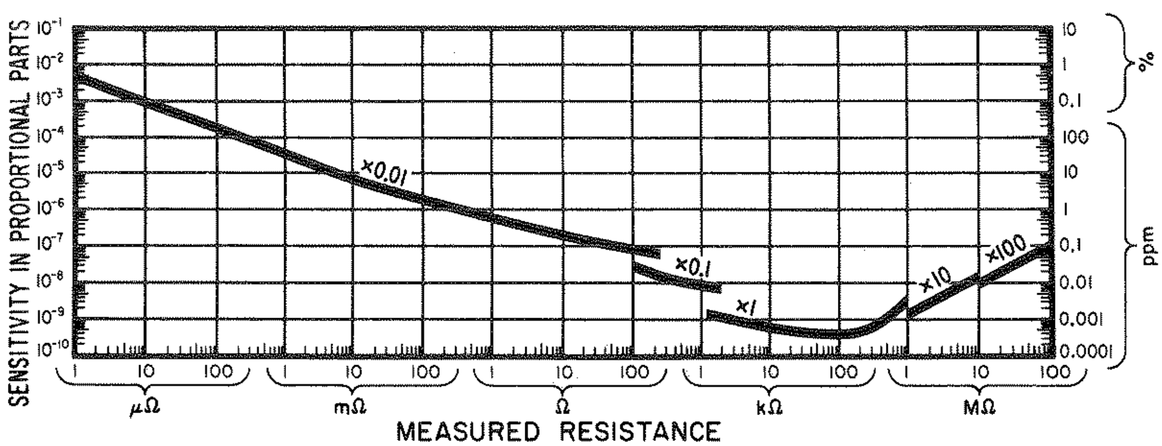


Figure 1-3. Model 242D Sensitivity

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 ESI 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).

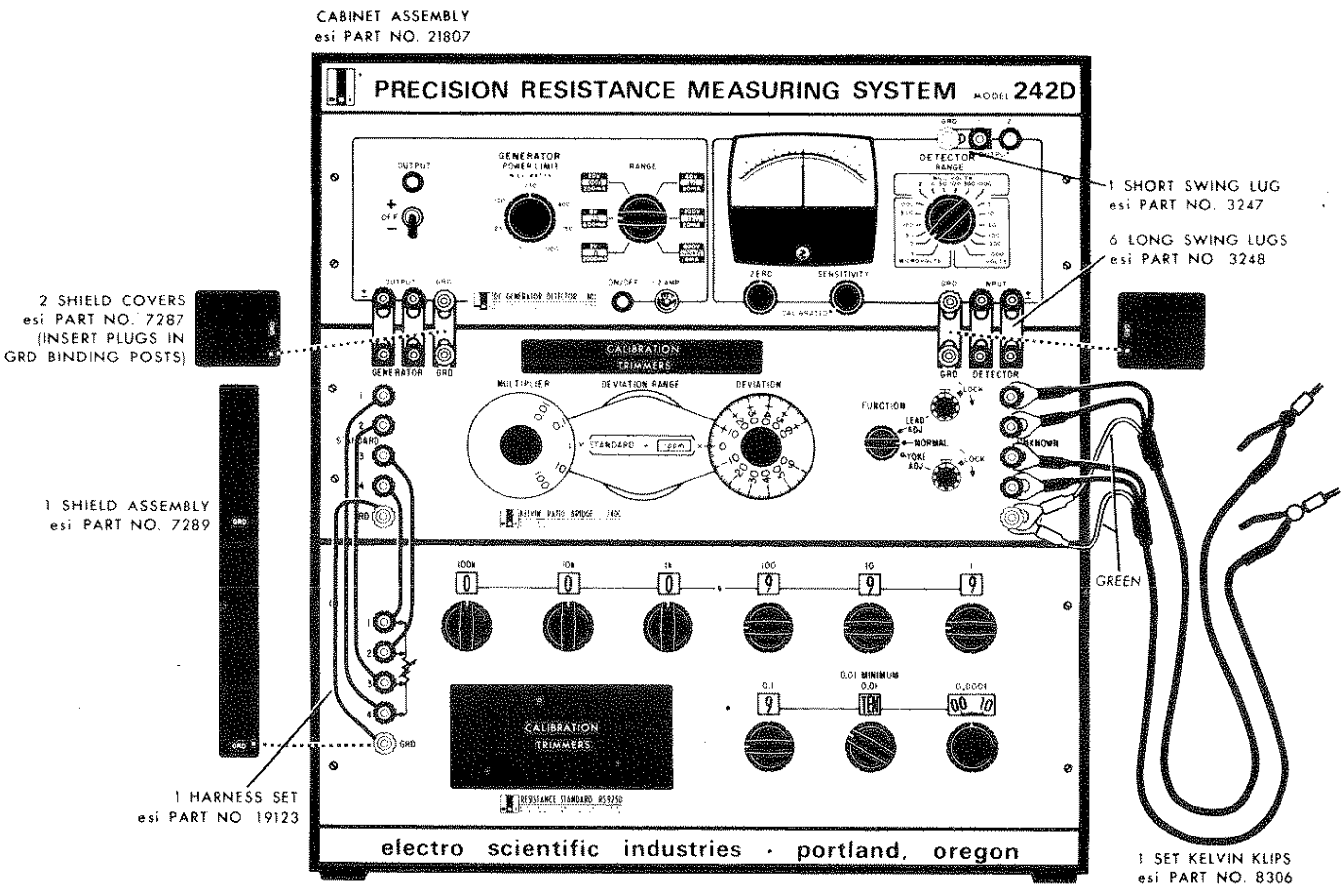


Figure 2-1. Model 242D Interconnection

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. (ESI 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 ½ 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.

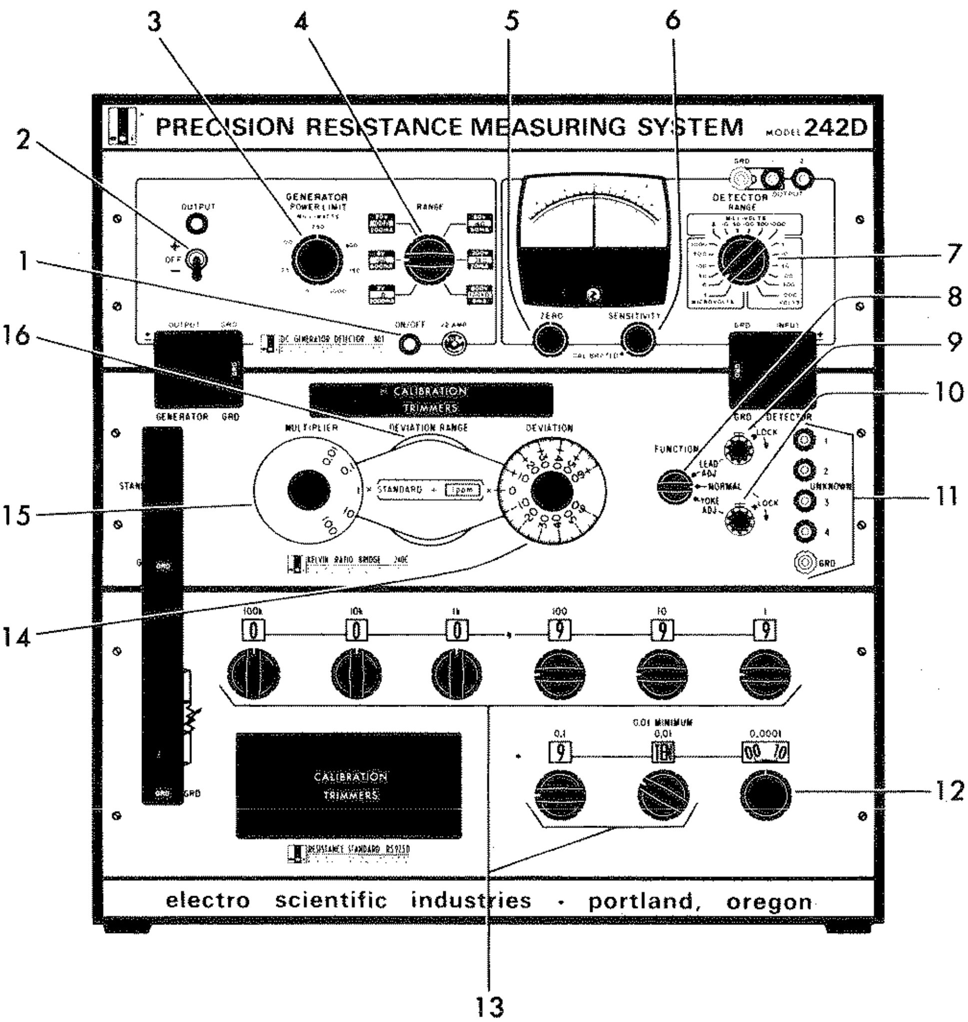


Figure 2-2. Controls

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.

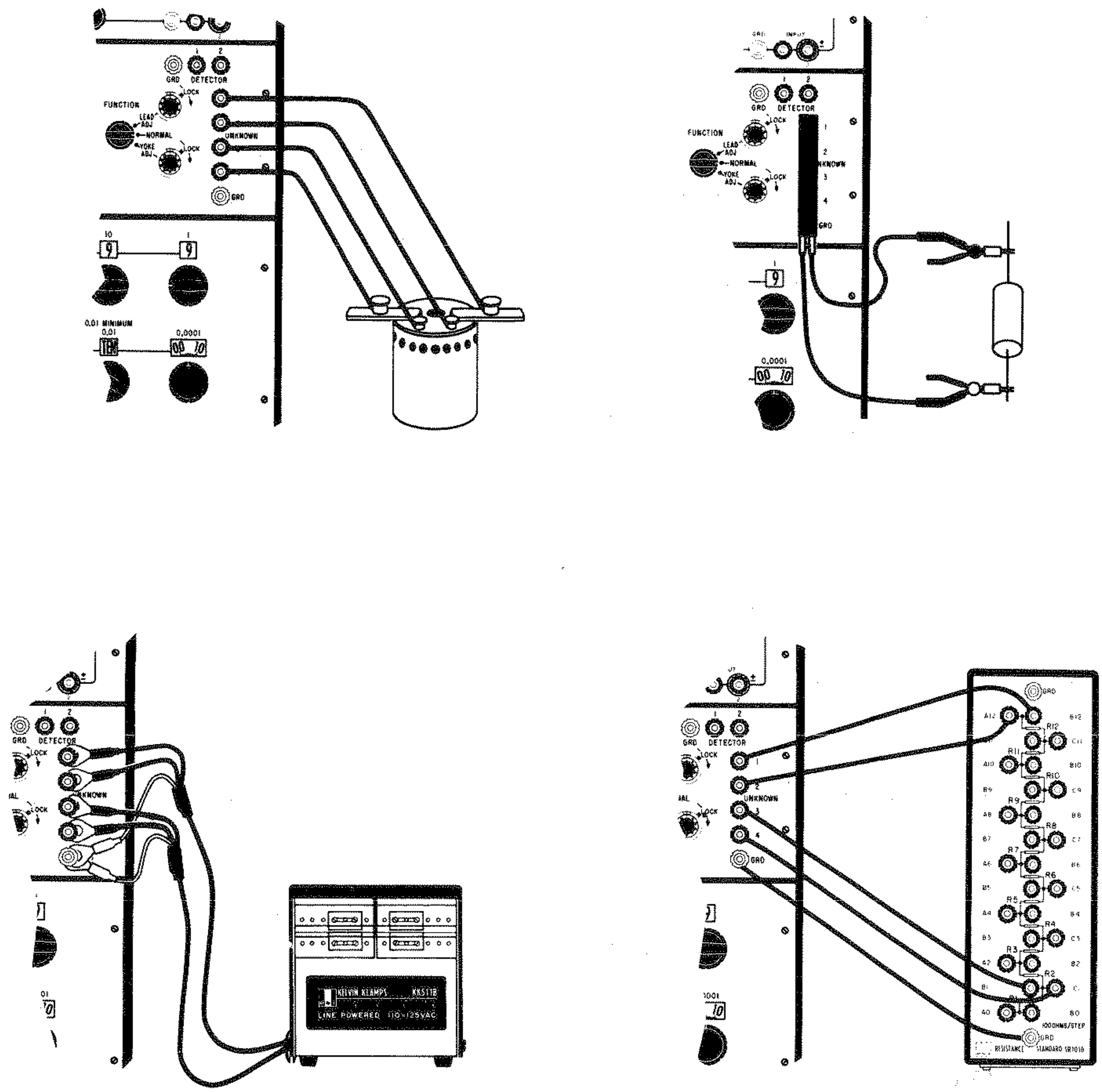


Figure 2-3. Connections to Unknown

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 POWER LIMIT	GENERATOR RANGE	DETECTOR RANGE
0.1 mΩ to 10 mΩ	0.01	250	1 Ω	10 MICROVOLTS
10 mΩ to 100 mΩ	0.01	250	10 Ω	3 MICROVOLTS
100 mΩ to 1 Ω	0.01	100	100 Ω	3 MICROVOLTS
1 Ω to 10 Ω	0.01	100	1 kΩ	3 MICROVOLTS
10 Ω to 200 Ω	0.01	100	1 kΩ	10 MICROVOLTS
200 Ω to 2 kΩ	0.1	100	1 kΩ	30 MICROVOLTS
2 kΩ to 100 kΩ	1.0	100	10 kΩ	30 MICROVOLTS
100 kΩ to 1 MΩ	1.0	100	100 kΩ	10 MICROVOLTS
1 MΩ to 10 MΩ	10	100	100 kΩ	30 MICROVOLTS
10 MΩ to 100 MΩ	100	100	100 kΩ	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 indeterminable 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 (ESI Model SR 104 or equivalent).
2. Resistance Transfer Standard: 10 kilohms per step, ±1 ppm transfer accuracy, trimmable (ESI Model SR 1010 MT or equivalent).
3. (Alternate procedure only) Shorting Bars: Approximately 100 $\mu\Omega$ resistance per bar, end to end (ESI Model SB 103 or equivalent).

*Measurements below 10 ohms will equal or exceed specifications for ESI 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 kΩ

   DETECTOR RANGE: 30 MICROVOLTS

   (ON/OFF pushbutton should be lit)

3. Set Model 240C Kelvin Ratio Bridge dials to read 1 x STANDARD + 0.1 ppm x 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 ppm x 0 and adjust RANGE 1 trimmer for null.

10. Turn DEVIATION RANGE dial to .001% x 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 kΩ

   DETECTOR RANGE: 30 MICROVOLTS

3. Set Model 240C Kelvin Ratio Bridge controls to 1 x STANDARD + 0.1 ppm x ···.

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 ESI 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 ESI 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 kΩ	10 MICROVOLTS
10 x STANDARD	10 kΩ	100 MICROVOLTS
1 x STANDARD	10 kΩ	300 MICROVOLTS
0.1 x STANDARD	10 kΩ	100 MICROVOLTS
0.01 x STANDARD	1 kΩ	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 ESI 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 kΩ 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 kΩ	10 MICROVOLTS
10 x STANDARD	10 kΩ	100 MICROVOLTS
1 x STANDARD	10 kΩ	300 MICROVOLTS
0.1 x STANDARD	10 kΩ	100 MICROVOLTS
0.01 x STANDARD	1 kΩ	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 kΩ 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 kΩ 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 kΩ 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 x0.01 trimmer for null indication and recheck yoke adjustment as in step 5.

17. Set MULTIPLIER dial to 1 x 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 kΩ configuration (series-parallel connection).

21. Set MULTIPLIER dial to 10 x 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 x10 trimmer for null indication and recheck yoke adjustment as in step 5.

24. Change transfer standard connections to 100 kΩ configuration (series connection).

25. Set MULTIPLIER dial to 100 x STANDARD. Set Generator-Detector as indicated in Table 3-1.

26. Check lead and yoke adjustments as in step 3.

27. Adjust MULTIPLIER x100 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.

3.8 CROSSCHECK PROCEDURE

1. Connect reference standard to Model 240C UNKNOWN terminals.

2. For each MULTIPLIER dial setting, adjust DEVIATION dial for null indication instead of trimmer. (Make lead and yoke adjustments as called for in calibration procedure.)

3. Calculate the difference between each DEVIATION dial reading and the known error of the reference standard to find the precision of each trimming adjustment.

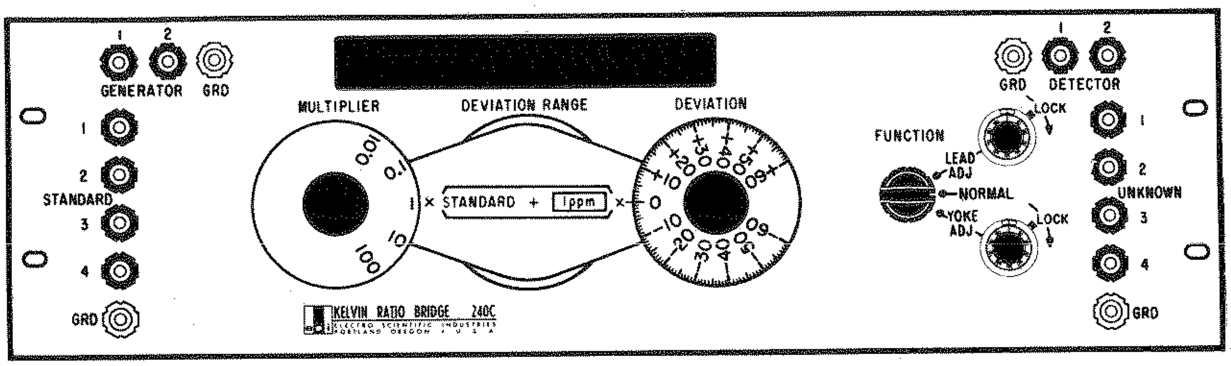
> NOTE: *Tolerance is ±10 ppm (±80 ppm for 0.01 MULTIPLIER with alternate procedure). If desired precision is not achieved, repeat calibration procedure in part or total.*

Instruction Manual

OCTOBER 1971
REPLACES MARCH 1968

MODEL 240C

KELVIN RATIO BRIDGE



SERIAL NUMBER: ____________
PART NUMBER: 19441

esi

Electro Scientific Industries
13900 N. W. SCIENCE PARK DRIVE, PORTLAND, OREGON 97229

The following table lists the most recent revision of each page at the present printing:

PAGES	DATE
Title	10/71
A	10/71
i and ii	3/68
1-1 thru 1-3	3/68
2-1 thru 2-10	3/68
3-1 and 3-2	10/71
3-3 and 3-4	3/68
4-1 thru 4-6	3/68

TABLE OF CONTENTS

The following are registered trademarks of Electro Scientific Industries, Inc.:

ESI® Electro Scientific Industries, Inc.
ESIAC® Algebraic Computer
ESIPOT® Potentiometer
DEKABOX® Decade Resistors and Capacitors
DEKABRIDGE® Bridge Circuit
DEKADIAL® Decade Dials
DEKAMATIC® Automatic Unit
DEKAPOT® Decade Potentiometers
DEKASTAT® Decade Rheostat
DEKAPACITOR® Decade Capacitor
DEKAVIDER® Decade Voltage Divider
KELVIN KLAMPS® Four-Terminal Clamps
KELVIN KLIPS® Four-Terminal Clips
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 Votage (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 vincinity 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 SR1010 and SR1050 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.

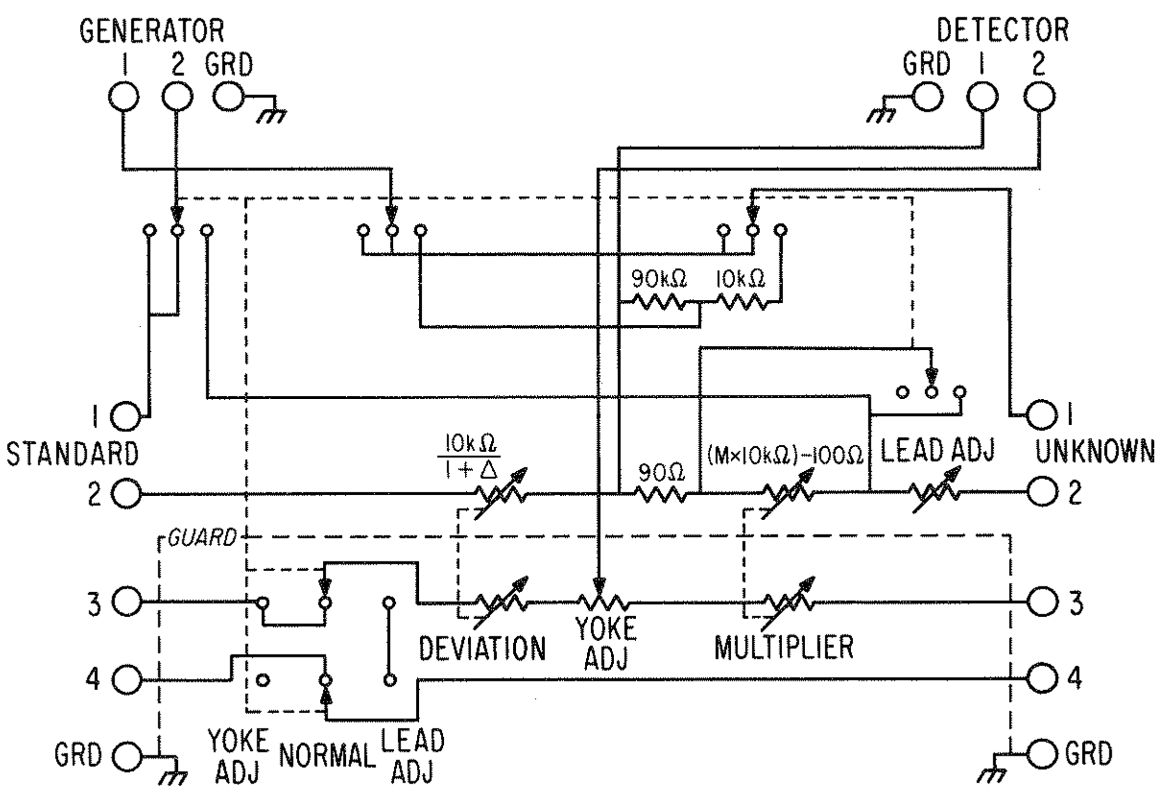


Figure 1-1 Simplified Schematic Diagram

SECTION II

OPERATION

2.1 CONTROLS

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:

MULTIPLIER dial which indicates the power of ten by which the standard and the unknown resistors differ. If the dial is set at 1, of course, the standard and unknown should be nearly the same value. If the dial is set at 0.01, the unknown should be approximately 100 times smaller than the standard. This dial is normally used as a range-changing dial.

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.

DEVIATION RANGE dial which is obviously a multiplier for the DEVIATION dial.

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.

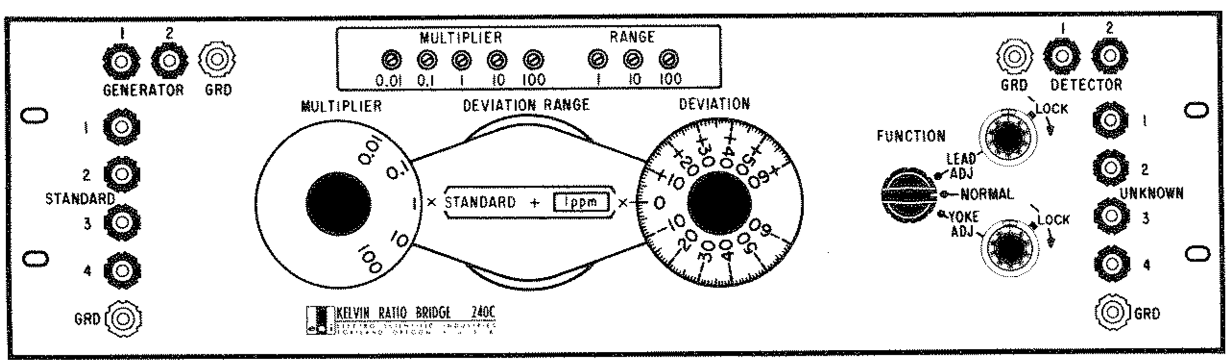


Figure 2-1. Controls

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 perceptable. 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 CONNECTIONS TO STANDARD AND UNKNOWN RESISTORS

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.

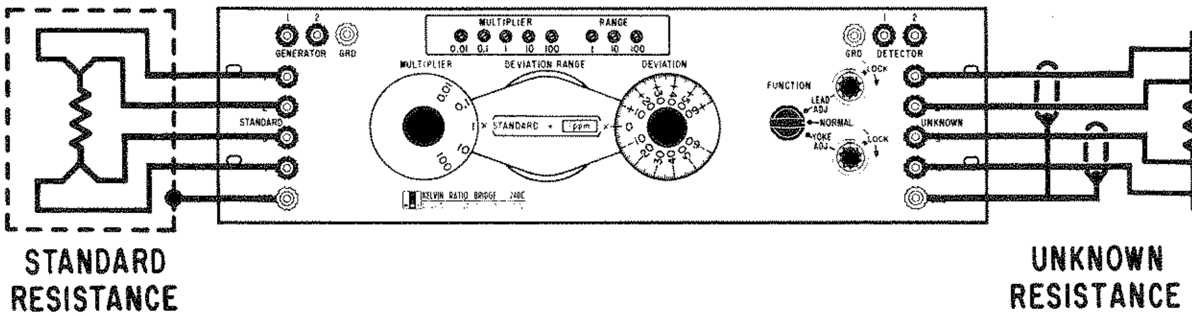


Figure 2-2. Normal Connections

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 resitance 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.

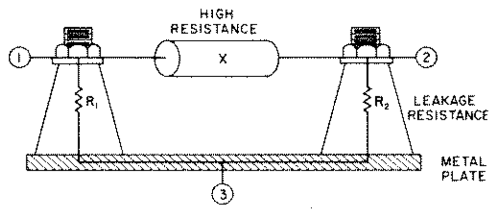


Figure 2-3. Leakage Resistance

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.

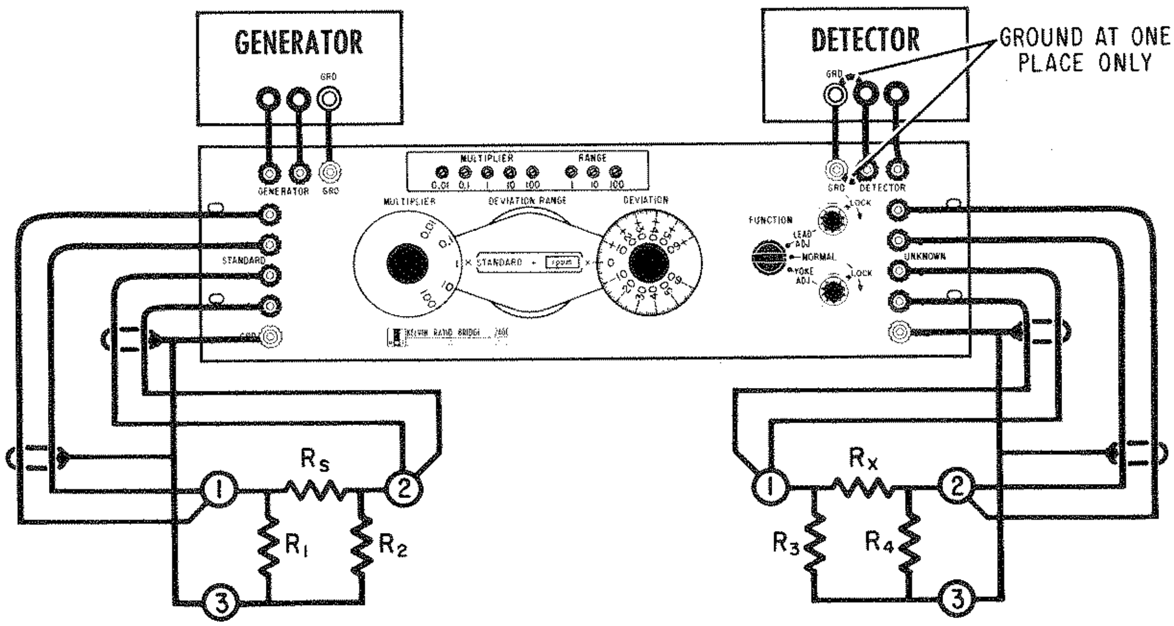


Figure 2-4. Guarded Connections

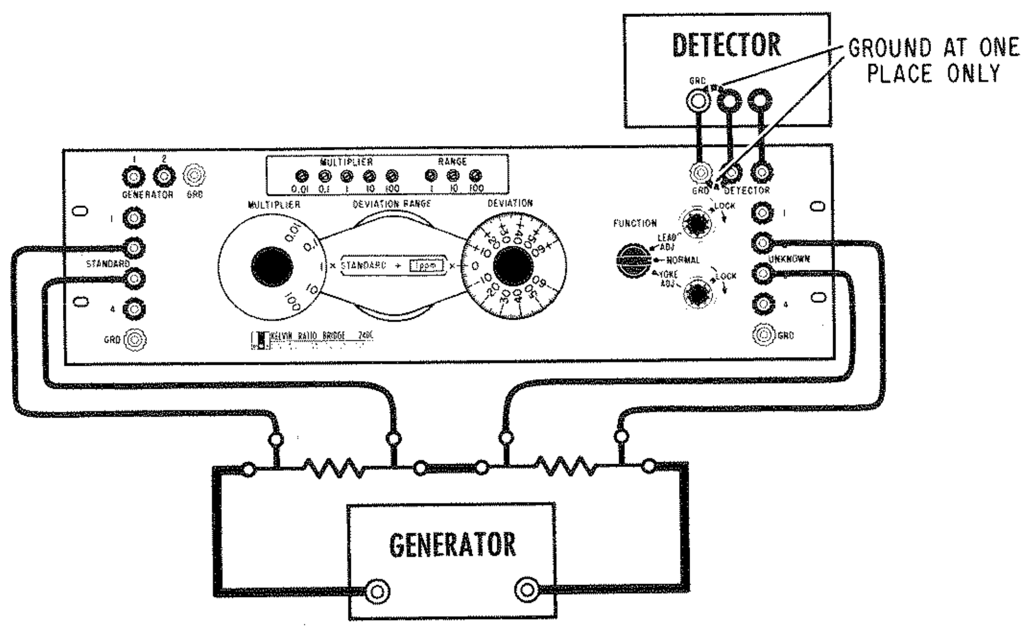


Figure 2-5. Measurement With High Current

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.

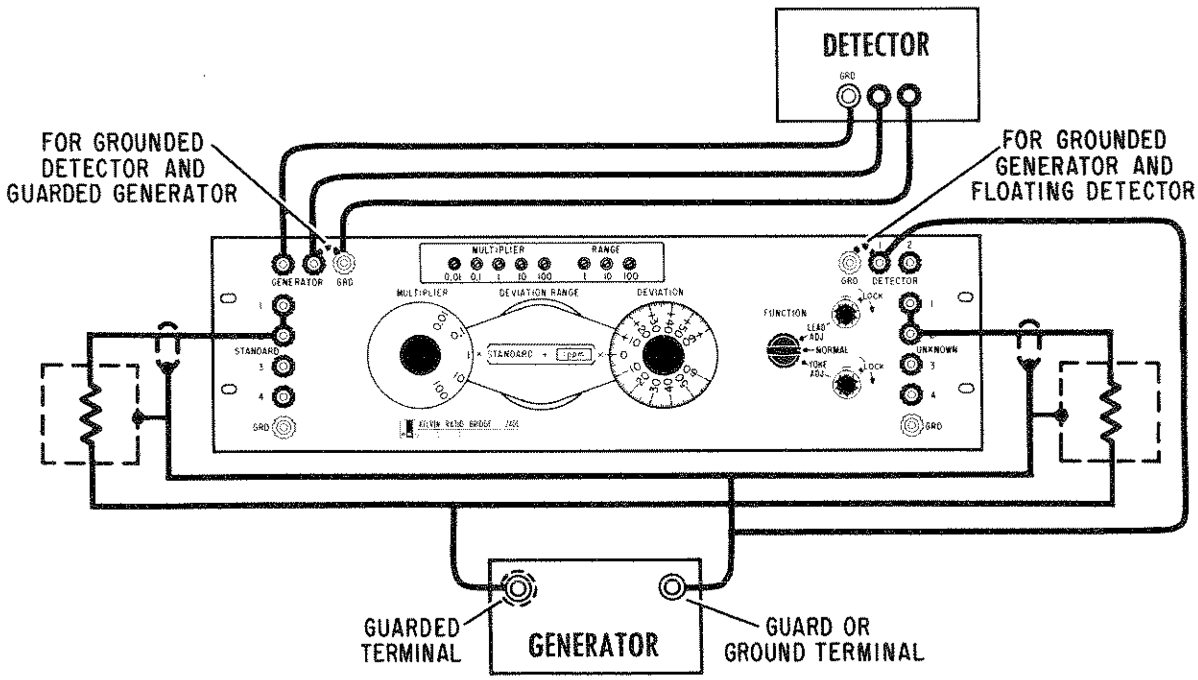


Figure 2-6. Measurement With High Voltage

2.4 MEASUREMENT TECHNIQUES

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.

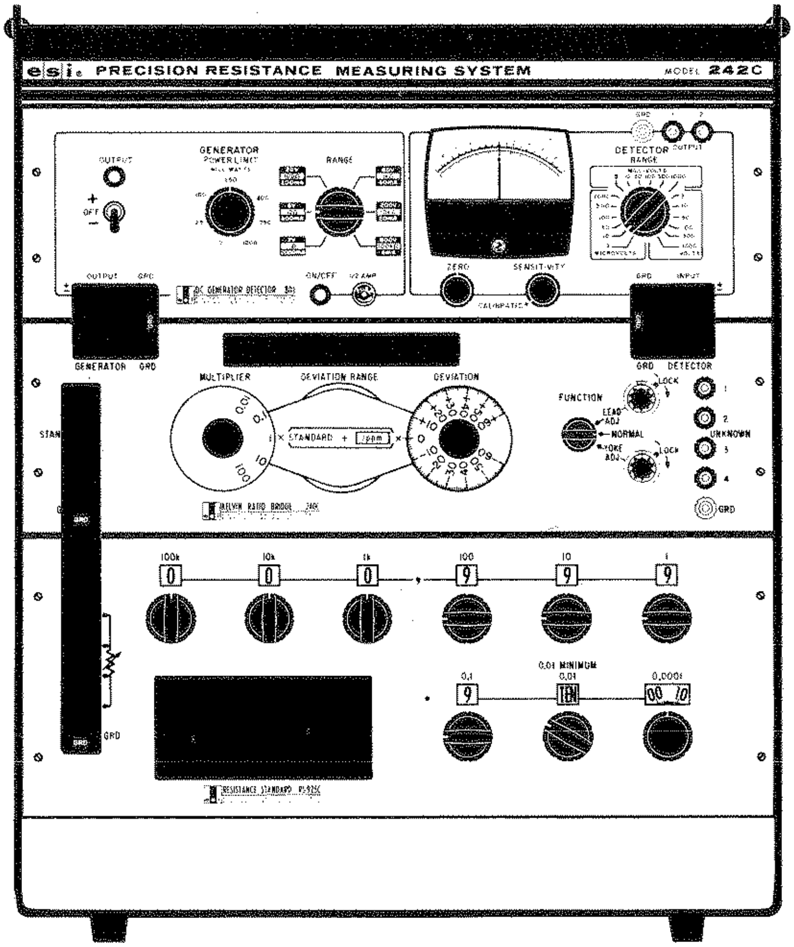


Figure 2-7. Model 242C Resistance Meauring System

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. <u>To read value in ohms</u>

   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 x 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

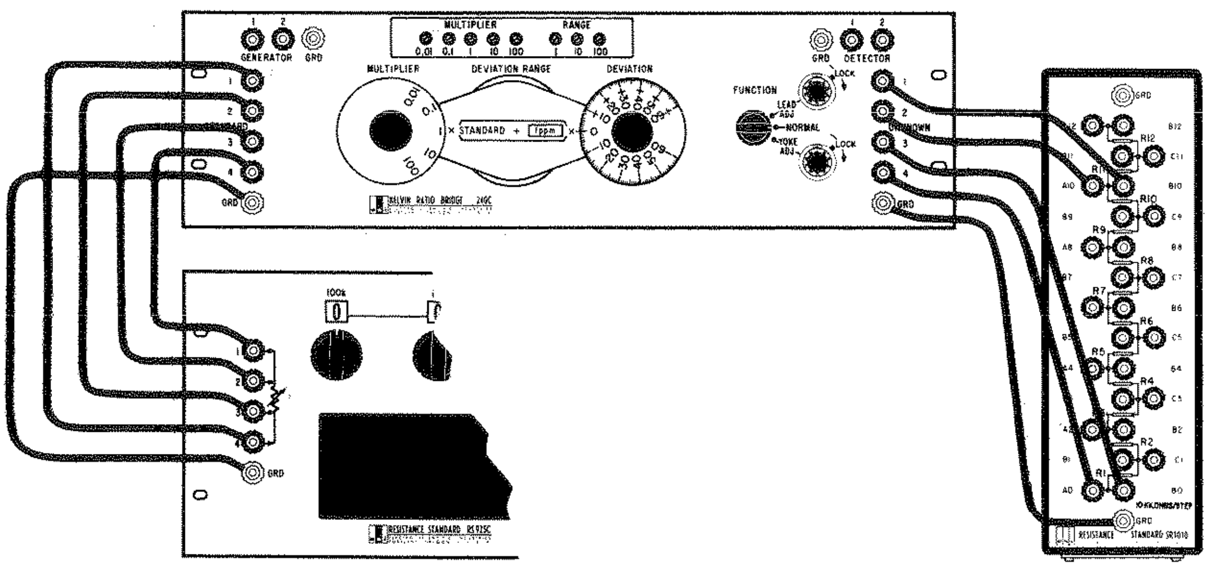


Figure 3-1. 1-to-1 Calibration Connection

3.2 EQUIPMENT REQUIRED

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 x STANDARD + 0.1 ppm x 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 interchangec 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 x STANDARD + .01% x 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 x STANDARD + 0.1 ppm x 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 x STANDARD, then turn on generator. Do not change setting of DEVIATION dial.

6. Adjust MULTIPLIER 0.01 trimmer for detector null.

7. Turn off generator. Set dials to 1 x STANDARD + 0.1 ppm x 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 x 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 x STANDARD + 0.1 ppm x 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 ppm x ....

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 x STANDARD + 0.1 ppm x .... 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 parallelled resistors to the UNKNOWN binding posts.

13. Set dials of bridge to 0.1 x STANDARD + 1 ppm x. 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:

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

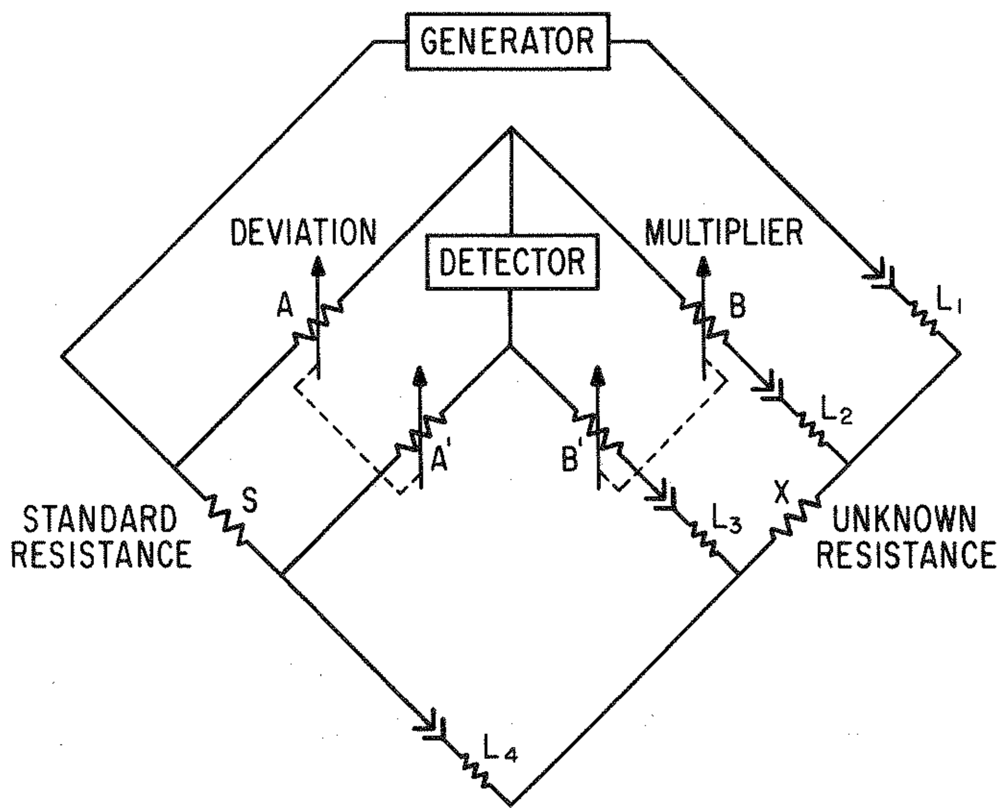


Figure 4-1. Simplified Schematic Diagram

The bridge is so constructed that:

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

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:

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

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.

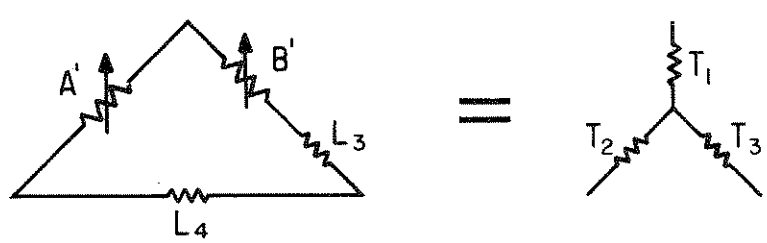


Figure 4-2. Delta—Y Transform

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:

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

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.

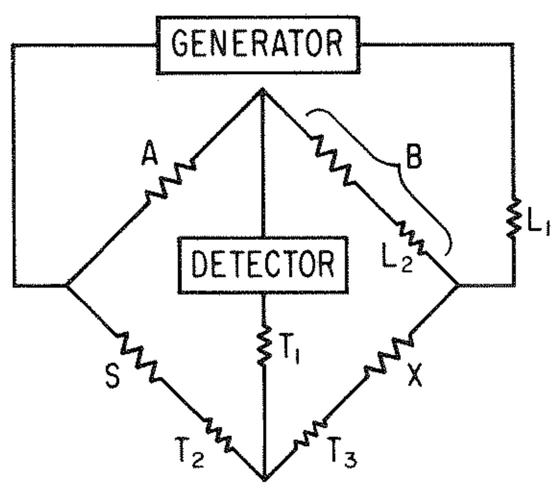


Figure 4-3. Transformed Bridge

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.

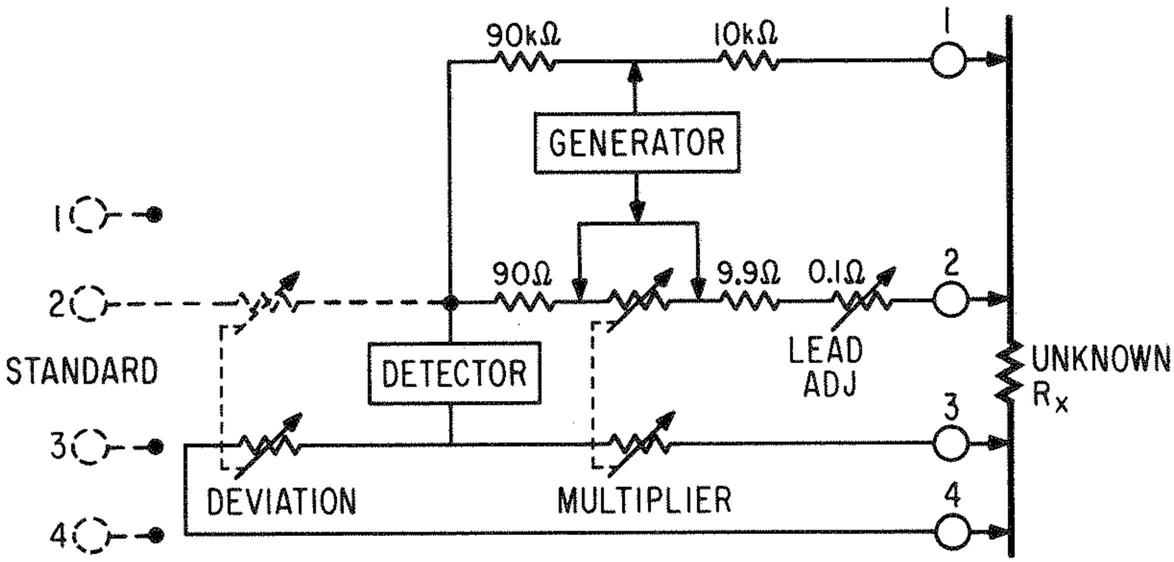


Figure 4-4. Lead Adjustment

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.

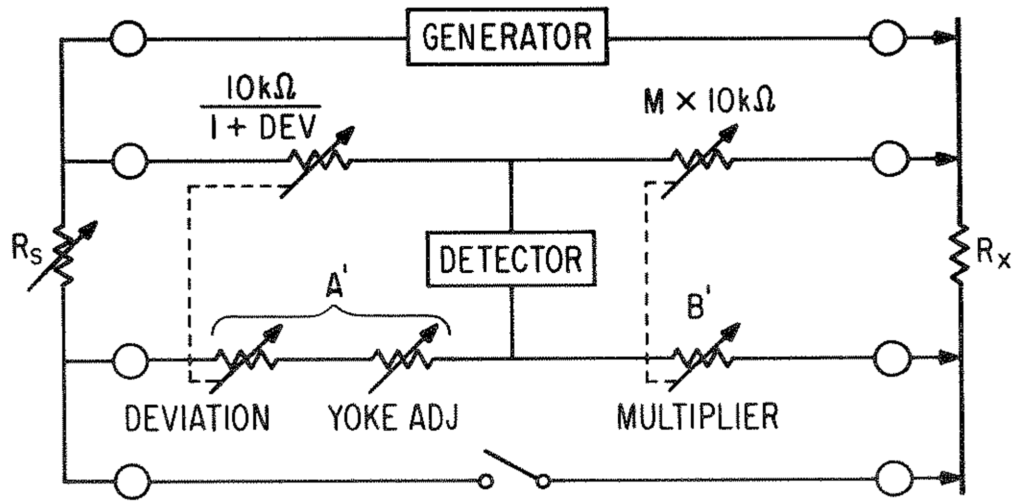


Figure 4-5. Yoke Adjustment

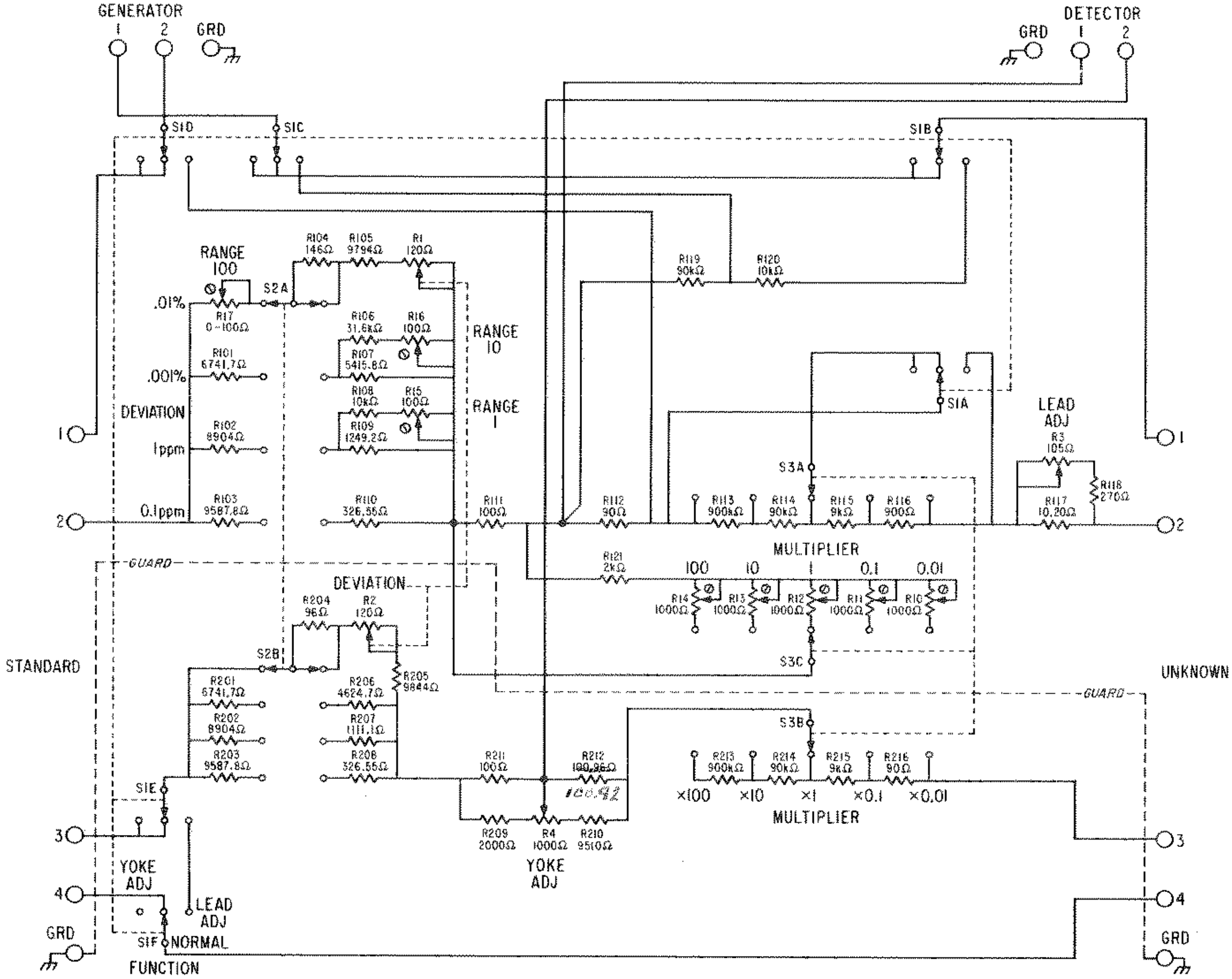


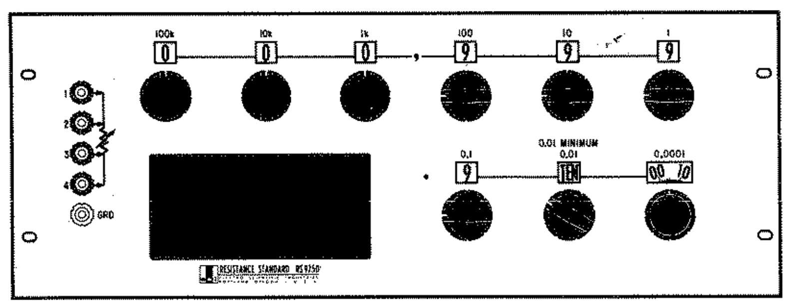
Figure 4-6. Model 240C Schematic Diagram

Instruction Manual

DECEMBER 1970

MODEL RS 925D

RESISTANCE STANDARD



SERIAL NUMBER: ____________

PART NUMBER: 19622

e|s|i®

Electro Scientific Industries

13900 N. W. SCIENCE PARK DRIVE, PORTLAND, OREGON 97229

The following table lists the most recent revision of each page at the present printing:

PAGES	DATE
Title	12/70
A	12/70
i and ii	12/70
1-1	12/70
2-1 thru 2-4	12/70
3-1 thru 3-5	12/70
4-1 thru 4-3	12/70

TABLE OF CONTENTS

The following are registered trademarks of Electro Scientific Industries, Inc.:

ESI® Electro Scientific Industries, Inc.
ESIAC® Algebraic Computer
ESIPOT® Potentiometer
DEKABOX® Decade Resistors and Capacitors
DEKABRIDGE® Bridge Circuit
DEKADIAL® Decade Dials
DEKAMATIC® Automatic Unit
DEKAPOT® Decade Potentiometers
DEKASTAT® Decade Rheostat
DEKAPACITOR® Decade Capacitor
DEKAVIDER® Decade Voltage Divider
KELVIN KLAMPS® Four-Terminal Clamps
KELVIN KLIPS® Four-Terminal Clips
PORTAMETRIC® Portable Measuring Instrument
PVB® Potentiometric Voltmeter Bridge

SECTION I

INTRODUCTION

1.1 DESCRIPTION

ESI Model RS 925D Resistance Standard is a wide-range, four-terminal decade resistor with four decades that can be trimmed to maintain high accuracy indefinitely. The use of trimmed decades, special ESI resistors, and multiple-contact low-resistance switches assures high accuracy and short-term accuracy of better than 2 parts per million.

1.2 SPECIFICATIONS

Resistance Range: 10^{-2} Ω to 1.2×10^{6} Ω

Resolution: 20 microhms

Accuracy after Adjustment of Trimmed Decades:

100 kΩ	±1.5 ppm
10 kΩ	±1.0 ppm
1 kΩ	±1.5 ppm
100 Ω	±2.0 ppm

Initial Accuracy of the Untrimmed Decades: ±(20 ppm + 0.001 Ω)

Stability after Adjustment: ±(20 ppm + 0.0005 Ω/year

Short Term Resistance Reset Repeatability: Better than 100 μΩ

Calibration Conditions: 4-terminal measurement
23°C ±1°C. 30% to 70% R.H.

Temperature Coefficient:

100 Ω/step and higher	±3 ppm/°C
10 Ω/step	±15 ppm/°C
1 Ω/step and lower	±20 ppm/°C
Wiring and Switches	±50 μΩ/°C

Power Coefficient of Resistance:

100 Ω/step and higher	±0.1 ppm/mW/step
10 Ω/step	±0.3 ppm/mW/step
1 Ω/step	±0.4 ppm/mW/step
(0.1 and 0.01 Ω/step	±1.0 ppm/mW/step
Wiring and Switches	+ 50 μΩ/W Total

Power Rating: 1.0 watt/step or 5.0 watts total, or 2.0 ampere maximum current.

Breakdown Voltage: 1500 V peak to case

Dimensions: Width 19 in. (48.25 cm), Height 7 in. (17.8 cm), Depth 8 in. (20.3 cm)

Weight: 14 lbs (6.4 kg)

SECTION II

OPERATION

2.1 RESISTANCE CONTROLS

The first knob on the left in the top row is used to change the four-terminal resistance in steps of 100 kilohms. The successive seven knobs are used to adjust the resistance in units down to 10 milliohms. The last knob in the bottom row varies a 10.5 milliohm potentiometer which is connected as a four-terminal variable resistor. The dial reading in the window above each knob is an in-line resistance reading.

Engraved above each window is the resistance per step of that decade. A decimal point is engraved on the panel to the left of the 0.1 ohm per step decade.

The minimum reading on the 0.01 ohm per step decade is 0.01 ohm, since this is the minimum internal resistance of the RS 925D. An effective zero reading may be obtained on the 0.01 ohm per step dial by reducing the setting of the 0.1 ohm per step dial one position and setting the 0.01 ohm per step dial at (TEN).

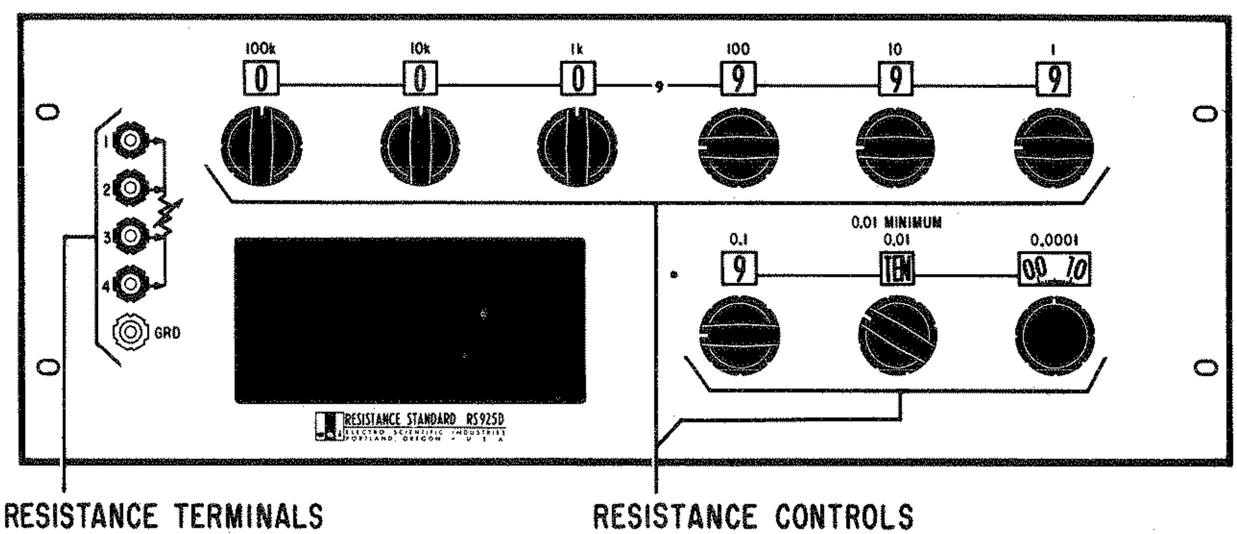


Figure 2-1. Model RS 925D Panel Controls

2.2 RESISTANCE TERMINALS

The terminals provided permit four-terminal connection to an external circuit. The ground terminal is provided for convenience.

2.3 FOUR-TERMINAL APPLICATIONS

ESI Model RS 925D is constructed so that it resembles electrically the diagram shown in Figure 2-2. Resistance R is varied by the front-panel controls from 0.01 ohm to more than 1.2 megohms. R3 and R4 are resistances of the connecting wiring; R1 and R2 include interpolation rheostat resistances which vary slightly with dial setting. The schematic diagram (Figure 4-1) shows the exact circuit of the interpolation rheostat, but it is sufficient to consider only how different settings affect the equivalent circuits R1 and R2 and R.

R changes directly with the setting of the rheostat, which is the desired condition. R2 varies through a range of 0.01 ohms in a predictable manner, but R1 represents contact resistance of the rheostats as well as other resistive effects. If thermoelectric or triboelectric voltages are present, they are most likely to appear at R1. For these reasons, it is advisable to connect R1 to a part of the circuit where lead resistance changes and small voltage effects will have little or no effect.

If current is passed from one of the four terminals to a terminal at the opposite end of the resistor R, and the voltage is measured between the remaining two terminals, the resistance of R is the ratio of the measured voltage to the current. Four-terminal resistors are normally used for meter shunt applications and as resistance standards for Kelvin bridge measurements.

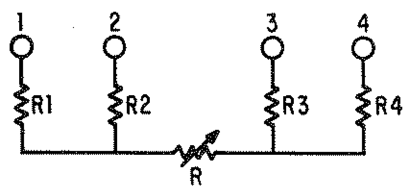


Figure 2-2. Four-Terminal Resistance

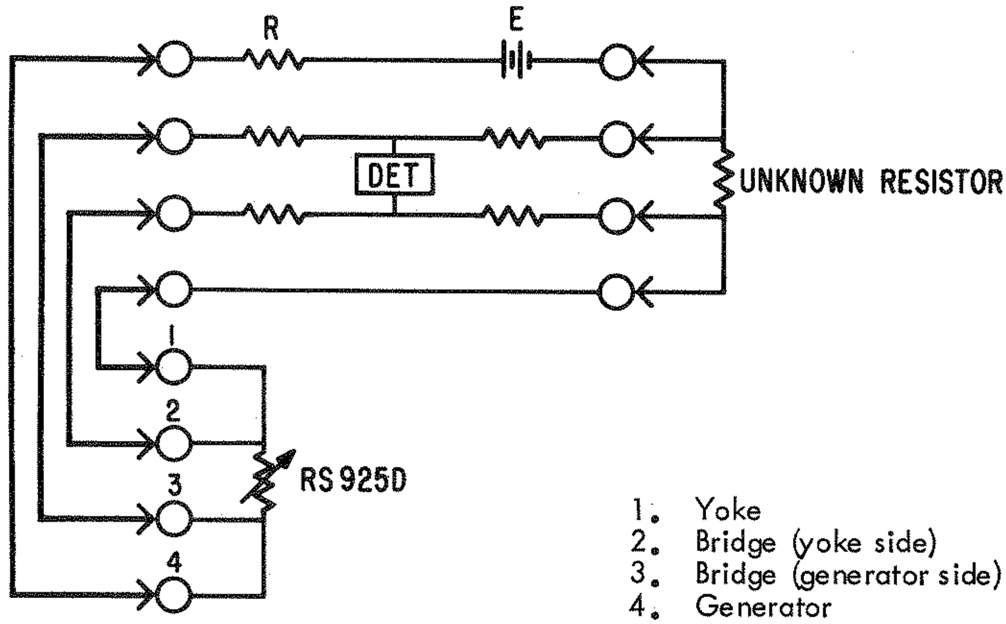
2.3.1 Meter Shunt Applications

To measure the current in a four-terminal resistor, the voltage drop is measured between the two terminals of the resistor not connected to the current source. The current is then determined by the ratio of the measured voltage to the known resistance. Use of the four-terminal technique avoids measuring errors caused by 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.

2.3.2 Kelvin Bridge Applications

A four-terminal resistance standard is used for all Kelvin bridge measurements. When connected as shown, 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.

For optimum performance with a Kelvin bridge, connect the Model RS 925D terminals as follows:



1. Yoke
2. Bridge (yoke side)
3. Bridge (generator side)
4. Generator

Figure 2-3. Kelvin Bridge Connections

2.4 POWER LIMITATIONS

For maximum protection and accuracy it is recommended that the available power to the Model RS 925D Resistance Standard be limited to ONE WATT. This is 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 is the value in ohms of the power limiting resistor

E is the open circuit voltage of the generator

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

SECTION III

CALIBRATION PROCEDURE

3.1 BASIC PROCEDURE

If the Model RS 925D Resistance Standard is part of a resistance measuring system such as ESI Model 242D Resistance Measuring System, it should be calibrated as part of the system rather than as a separate instrument. The combined adjustments of the system can be made more accurate than the adjustments of separate instruments.

The recommended procedure for calibrating the instrument as part of ESI Model 242D Resistance Measuring System is described in the instruction manual for that system. The recommended procedure for calibrating the Model RS 925D where it must be used separately is outlined as follows:

1. Calibrate 100-ohms-per-step, 1-kilohm-per-step, 10-kilohms-per-step, and 100-kilohms-per-step transfer standards.

2. Compare transfer standards to decades of Model RS 925D, using substitution methods with a Kelvin ratio bridge and adjust each step of each decade for correct resistance.

All steps in the following procedure assume the use of recommended test equipment. If any other equipment is used, the procedure should be modified appropriately.

3.2 EQUIPMENT REQUIREMENTS

1. Resistance Transfer Standards: 100 ohms, 1 kilohm, 10 kilohms, and 100 kilohms per step, calibrated to ±10 ppm. (ESI Models SR 1010 and SR 1050 or equivalent.)

2. Precision Resistance Measuring System: Transfer accuracy ±1 ppm. (ESI Models 242, 242A, 242C or 242D Precision Resistance Measurement System or equivalent.)

3.3 PRELIMINARY OPERATIONS

Calibrate the resistance transfer standards in order to find their errors. Record the deviation of each resistor in each transfer standard and calculate the cumulative deviation of the series-connected sets of resistors. (This procedure is described in the Instruction Manual for ESI Model SR 1010 Resistance Transfer Standard, SECTION IV.)

3.4 CALIBRATION PROCEDURE

Perform all steps in this procedure for each setting of the first four (100 kΩ through 100 Ω) decades of the instrument. (Control and setting nomenclature refer specifically to the recommended equipment.)

1. Set Generator Detector controls as follows:

OUTPUT: OFF

POWER LIMIT: 100

Decade to be Calibrated	GENERATOR RANGE	DETECTOR RANGE
100 Ω	1 kΩ	30 MICROVOLTS
1 kΩ	1 kΩ	100 MICROVOLTS
10 kΩ	10 kΩ	300 MICROVOLTS
100 kΩ	10 kΩ	100 MICROVOLTS

2. Set Kelvin Ratio Bridge controls to read "1 x STANDARD + 1 ppm x ..."

> NOTE: *Perform steps 3 through 9 for each of the 41 dial settings of the instrument to be calibrated.*

3. Connect the appropriate transfer standard to the UNKNOWN terminals of the bridge using four-terminal connection as illustrated in Figure 3-1. Start with two resistors of the 100-ohms-per-step standard, then proceed to three resistors in series and so forth to eleven resistors. Then do likewise with the 1-kilohm-per-step transfer standard, the 10-kilohms-per-step and the 100-kilohms-per-step transfer standards. (See Table 3-1.)

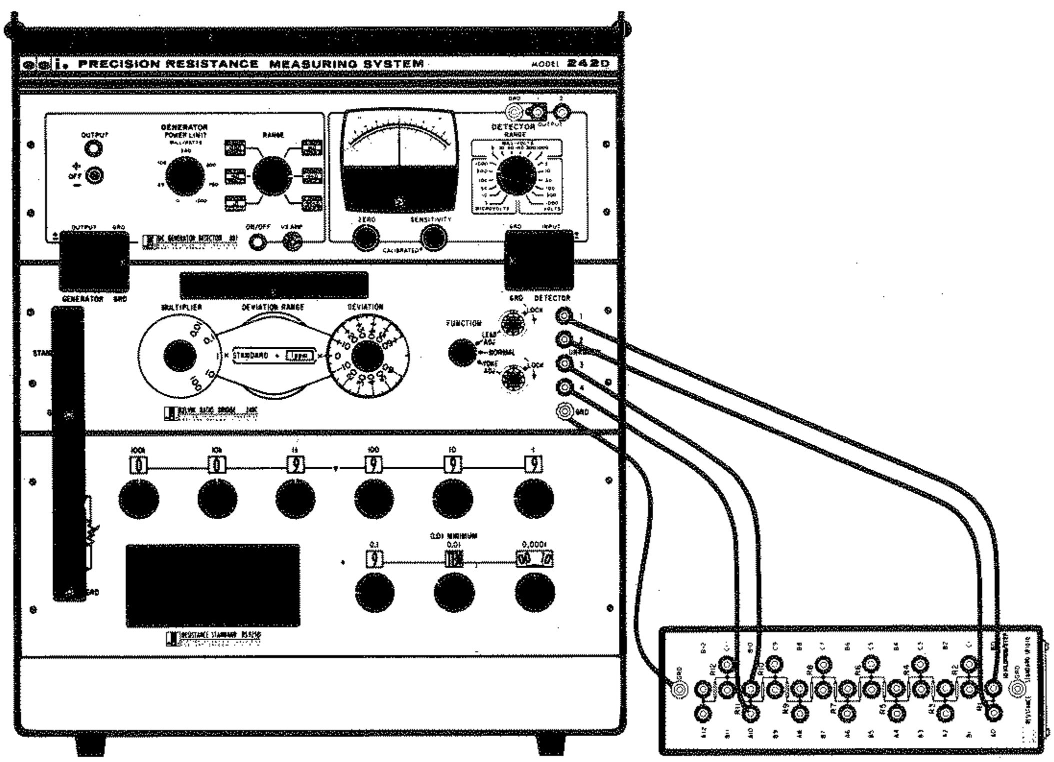


Figure 3-1. Transfer Standard Connection

4. Set the DEVIATION dial of the Kelvin Ratio Bridge to the cumulative deviation of the resistors connected to the bridge. (This is the cumulative deviation that was determined in Section 3.3.)

5. Set the resistance standard of the measurement system to the nominal value of the transfer standard connected.

6. Adjust the ZERO control of the detector for null while the generator is still off.

7. Set the GENERATOR OUTPUT switch to + .

8. Adjust the resistance standard of the measurement system for detector null. Do not adjust DEVIATION control.

9. Set the GENERATOR OUTPUT :o OFF and record resistance standard setting.

10. Disconnect the transfer standard from the measurement system and connect the instrument to be calibrated to the UNKNOWN terminals of the bridge.

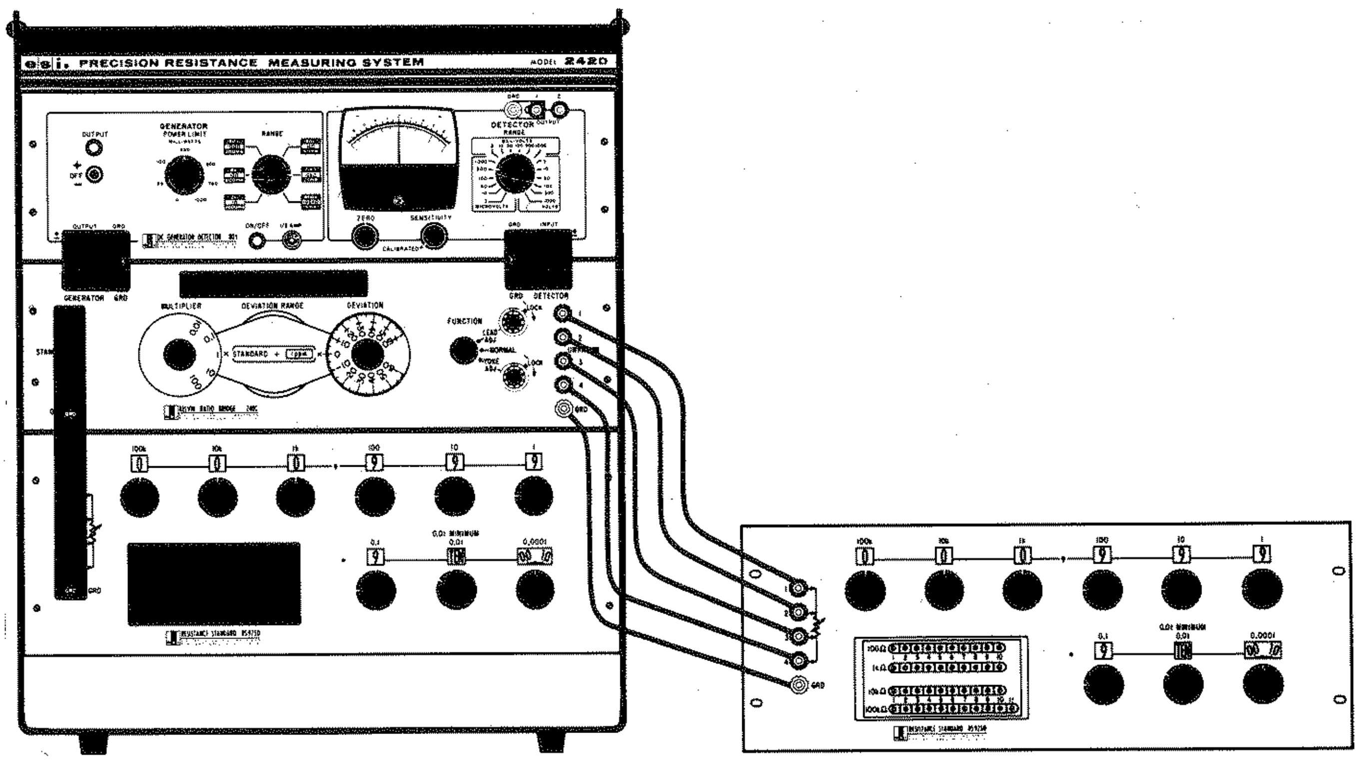


Figure 3-2. Test Instrument Connection

11. Set the controls of the instrument to be calibrated as follows:

Set all decades to the left of the decade to be calibrated to 0. Set all decades to the right of the decade to be calibrated to 9. Set the rheostat to 100.

12. Set DEVIATION dial of Kelvin Ratio Bridge to 0.

13. Set the resistance standard of the measurement system to the setting recorded for that resistance in step 9.

14. Adjust the ZERO control of detector for null while the generator is still off.

15. Set the GENERATOR OUTPUT switch to + .

16. Adjust the trimmer that corresponds to the setting of the decade being calibrated. See Figure 3-3 and Table 3-1.

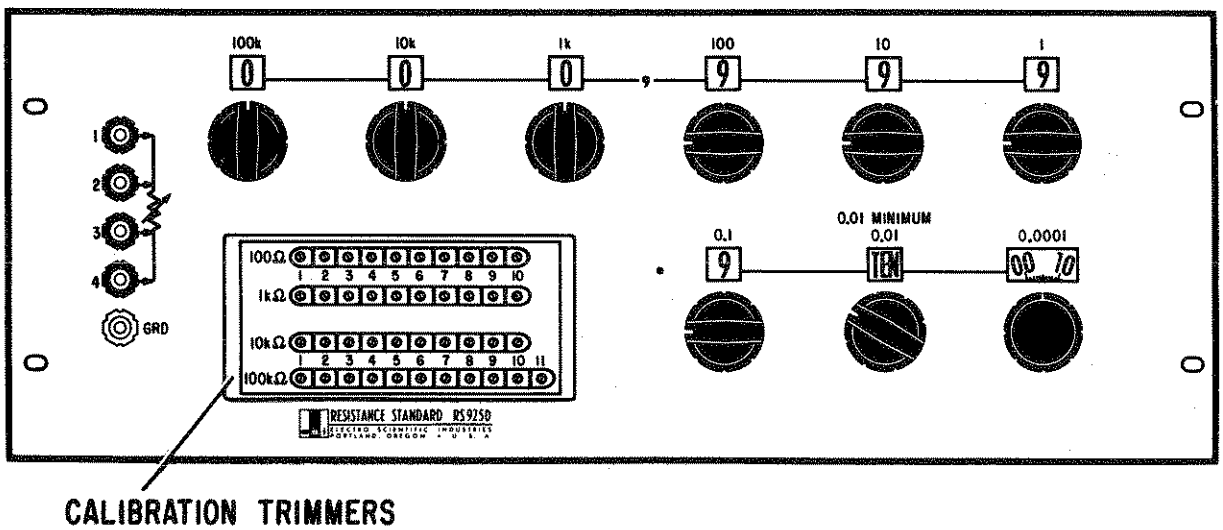


Figure 3-3. Trimmer Locations

Test Instrument Dial Setting	Transfer Standard Value per Step	Transfer Standard Number of Resistors	Trimmer Row	Trimmer Number
0 0 0 1 9 9 . 9 9 99	100 Ω	2	100 Ω	1
0 0 0 2 9 9 . 9 9 99		3		2
0 0 0 3 9 9 . 9 9 99		4		3
0 0 0 4 9 9 . 9 9 99		5		4
0 0 0 5 9 9 . 9 9 99		6		5
0 0 0 6 9 9 . 9 9 99		7		6
0 0 0 7 9 9 . 9 9 99		8		7
0 0 0 8 9 9 . 9 9 99		9		8
0 0 0 9 9 9 . 9 9 99		10		9
0 0 0 TEN 9 9 . 9 9 99		11		10
0 0 1 9 9 9 . 9 9 99	1 kΩ	2	1 kΩ	1
0 0 2 9 9 9 . 9 9 99		3		2
0 0 3 9 9 9 . 9 9 99		4		3
0 0 4 9 9 9 . 9 9 99		5		4
0 0 5 9 9 9 . 9 9 99		6		5
0 0 6 9 9 9 . 9 9 99		7		6
0 0 7 9 9 9 . 9 9 99		8		7
0 0 8 9 9 9 . 9 9 99		9		8
0 0 9 9 9 9 . 9 9 99		10		9
0 0 TEN 9 9 9 . 9 9 99		11		10
0 1 9 9 9 9 . 9 9 99	10 kΩ	2	10 kΩ	1
0 2 9 9 9 9 . 9 9 99		3		2
0 3 9 9 9 9 . 9 9 99		4		3
0 4 9 9 9 9 . 9 9 99		5		4
0 5 9 9 9 9 . 9 9 99		6		5
0 6 9 9 9 9 . 9 9 99		7		6
0 7 9 9 9 9 . 9 9 99		8		7
0 8 9 9 9 9 . 9 9 99		9		8
0 9 9 9 9 9 . 9 9 99		10		9
0 TEN 9 9 9 9 . 9 9 99		11		10
1 9 9 9 9 9 . 9 9 99	100 kΩ	2	100 kΩ	1
2 9 9 9 9 9 . 9 9 99		3		2
3 9 9 9 9 9 . 9 9 99		4		3
4 9 9 9 9 9 . 9 9 99		5		4
5 9 9 9 9 9 . 9 9 99		6		5
6 9 9 9 9 9 . 9 9 99		7		6
7 9 9 9 9 9 . 9 9 99		8		7
8 9 9 9 9 9 . 9 9 99		9		8
9 9 9 9 9 9 . 9 9 99		10		9
10 9 9 9 9 9 . 9 9 99		11		10
11 9 9 9 9 9 . 9 9 99		12		11

Table 3-1

SECTION IV

PERIODIC MAINTENANCE

The following procedures should be performed approximately once a year to insure maximum accuracy and reliability from the ESI Model RS 925D Resistance Standard.

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 happy to furnish the necessary information and replacement parts for minor repairs. Unauthorized repairs, however, will invalidate the instrument warranty.

4.1 ACCESSING COMPONENTS

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

To remove the instrument from the rack remove the four mounting screws on the front panel. Place it face down on the prepared surface, remove the 2 screws on the back of the instrument, and carefully slide the dust cover off.

4.2 VISUAL INSPECTION

Inspect the outside of the unit for dial orientation and damage to binding posts and binding post caps. Check for dirt around binding post insulators. Inspect the interior for loose or broken connections, damaged or dirty switch contacts, worn or dirty potentiometers and sliders, heat-damaged resistors, and resistors touching each other or the grounded switch structure.

4.3 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 component that may require cleaning and lubrication are the potentiometer and, occasionally, the switch decks. Clean and lubricate the potentiometer as follows:

CAUTION

Do not use solvents on the potentiometer. Solvents will leave a residue which may affect their performance.

1. Polish the contact surface lightly with an abrasive cloth (Crocus cloth or equivalent).

2. Remove loose particles by wiping with a nylon cloth.

3. Apply a moderate amount of pure petroleum jelly to the contact surface.

The switch decks are carefully lubricated at the time of manufacture and are protected from contamination by the dust cover. They should rarely, if ever, require maintenance. It is recommended that they be cleaned or lubricated *only* if they are not making good electrical contact. In such a case, proceed as follows:

1. Place instrument horizontally on bench, with a sheet of white paper under switch to be cleaned. Spray switch with Freon TF degreaser in aerosol can (Miller Stephenson Co. or equivalent) until no more residue appears on white paper. Drying is not necessary.

2. Lubricate with a low-conductivity oil (Viscosity Oil Co., No. 7069, available from ESI as Part No. 13500). Apply one drop to each rotor tab and one drop to the rotor ring contact using a hypodermic needle. With a small brush, apply a dab of petroleum jelly to each switch bearing and detent mechanism. DO NOT OVERLUBRICATE.

4.4 REPLACING THE DUST COVER

Be sure that the interior of the unit is completely clear of all foreign material.

Slip the dust cover over the unit, being careful not to touch any resistors, and replace the screws.

4.5 REPLACEMENT PARTS LIST

The following parts are listed alphabetically by description. All parts are available from Electro Scientific Industries, Inc.

The Federal Supply Code for Manufacturers (FSCM) for Electro Scientific Industries is 11837.

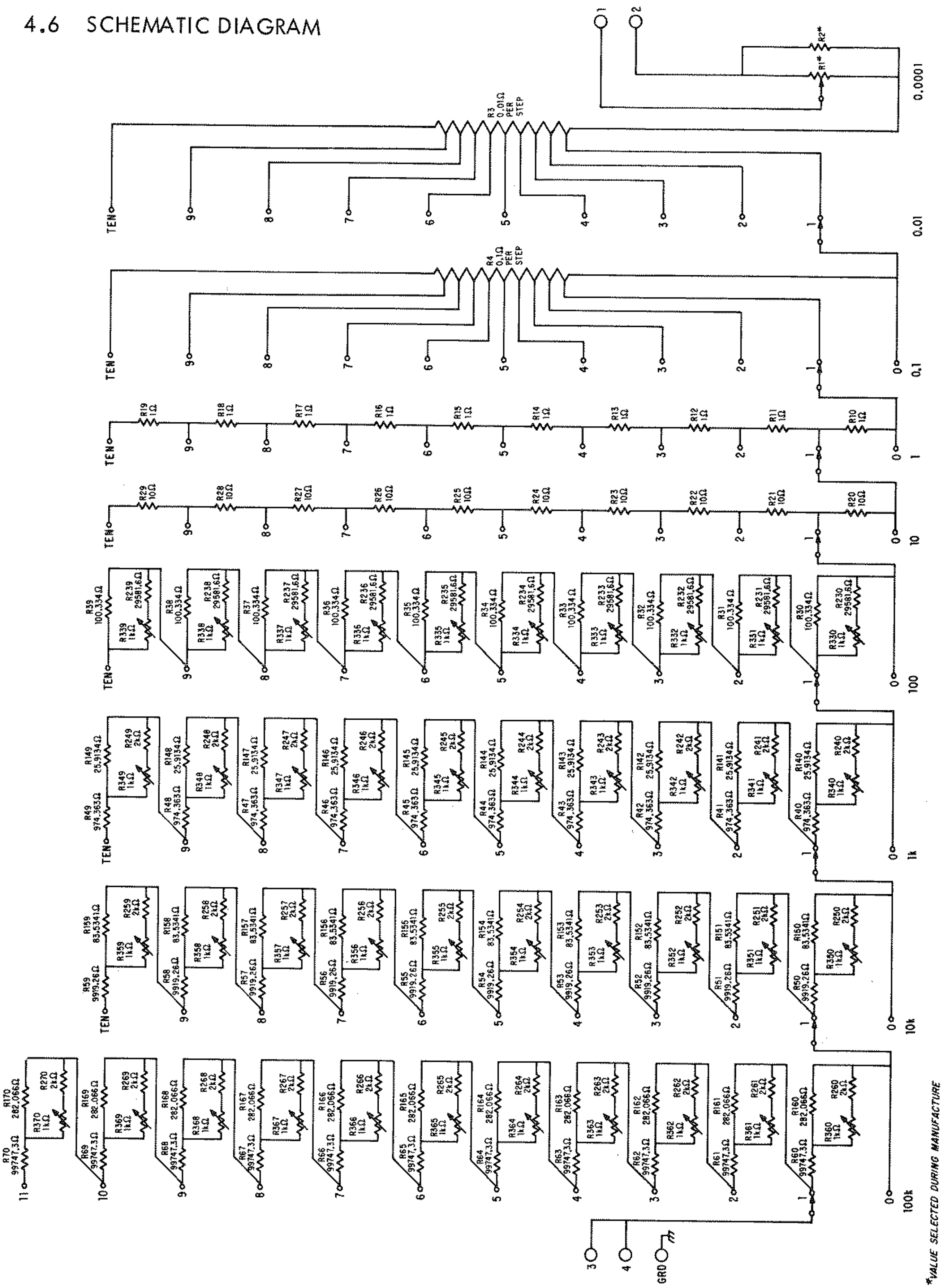
When ordering parts, please include the following information:

Model and serial number of the instrument
ESI part number
Description of part

DESCRIPTION	PART NO.	QTY USED
Cap, Binding Post, Black	1170	4
Cap, Binding Post, Gold	1172	1

Due to the requirement for critical adjustment of high-precision resistors *after* replacement, the Model RS 925D is considered non-repairable in the field. Any unauthorized field repair will void the warranty of the unit.

4.6 SCHEMATIC DIAGRAM



*VALUE SELECTED DURING MANUFACTURE

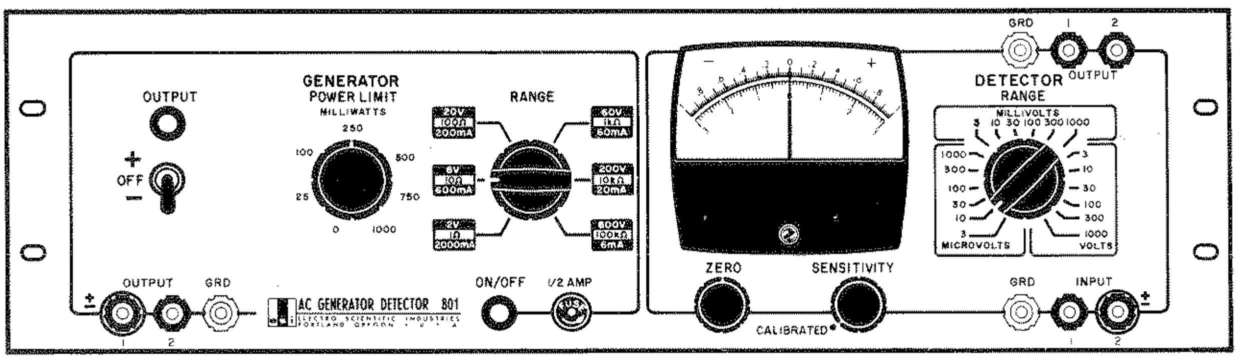
Figure 4-1. Model RS 925D Schematic Diagram

Instruction Manual

MARCH 1970
REPLACES AUGUST 1967

MODEL 801

DC
GENERATOR-DETECTOR



SERIAL NUMBER: ______________

PART NUMBER: 18403

e|s|i ®

Electro Scientific Industries

13900 N. W. SCIENCE PARK DRIVE, PORTLAND, OREGON 97229

The following table lists the most recent revision of each page at the present printing:

PAGES	DATE
Title	3/70
A	3/70
i	2/66
ii	3/70
1-1 thru 1-4	1/66
2-1 thru 2-13	1/66
3-1 thru 3-4	1/66
4-1 thru 4-9	1/66
4-10	2/66
4-11	3/70
4-12	8/67
4-13 thru 4-15	3/70

TABLE OF CONTENTS

The following are registered trademarks of Electro Scientific Industries, Inc.:

ESI® Electro Scientific Industries, Inc.
ESIAC® Algebraic Computer
ESIPOT® Potentiometer
DEKABOX® Decade Resistors and Capacitors
DEKABRIDGE® Bridge Circuit
DEKADIAL® Decade Dials
DEKAMATIC® Automatic Unit
DEKAPOT® Decade Potentiometers
DEKASTAT® Decade Rheostat
DEKAPACITOR® Decade Capacitor
DEKAVIDER® Decade Voltage Divider
KELVIN KLAMPS® Four-Terminal Clamps
KELVIN KLIPS® Four-Terminal Clips
PORTAMETRIC® Portable Measuring Instrument
PVB® Potentiometric Voltmeter Bridge

ACKNOWLEDGMENTS

We wish to thank Hewlett-Packard Company for information concerning theory of operation, maintenance, schematic diagrams, and calibration and adjustment procedures for the detector. In particular, Sections 3.2, 4.2, 4.3, and 4.4 were adapted from the instruction manual for the Hewlett-Packard Model 419A DC Null Detector by permission of Hewlett-Packard.

SECTION I

INTRODUCTION

1.1 DESCRIPTION

The ESI Model 801 is a dc generator and null detector (microvoltmeter). The instrument features double-chassis construction, or guarding, to greatly reduce stray leakage paths to ground. Leakage from the high generator terminal and from the high detector terminals to ground has been virtually eliminated. Insulation of the other terminals is kept to 10^{11} ohms or greater.

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 unique design features of the Model 801 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 801 an ideal generator-detector combination for calibrating precision voltage dividers. A detailed description of this application may be found in ESI's "Design Ideas", volume 1, number 1. See also Section 2.4 of this Manual.

4. The 801 can be used directly to measure extremely low conductance (high resistance). See Section 2.7.

5. The 801 generator can be used separately wherever a variable, guarded, and power-limited dc supply is needed.

6. The 801 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.

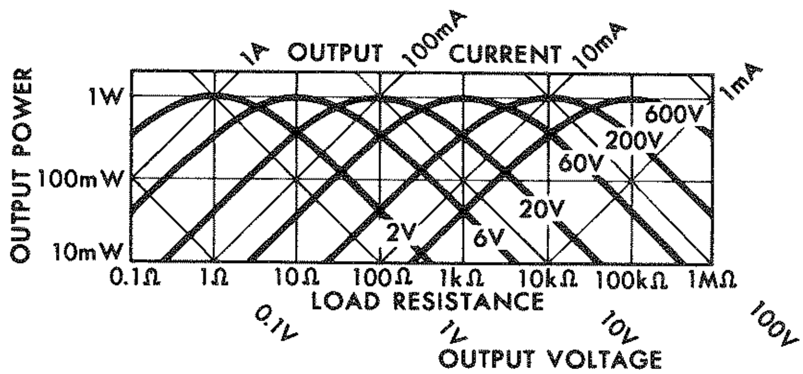


Figure 1.1 Maximum Output of 801 Generator

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

Ranges: Calibrated ±3 microvolts to ±1000 volts dc end scale in 18 zero-center ranges, sensitivity (uncalibrated) can be increased to about 0.75 microvolt end scale.

Accuracy: ±5 percent of end scale, ±0.1 microvolt.

Limits of Zero Control: ±15 microvolts.

Input Resistance: 3-microvolt to 3-millivolt ranges: 100 kilohms.
10-millivolt to 30-millivolt ranges: 1 megohm.
100-millivolt to 300-millivolt ranges: 10 megohms.
1-volt to 1000-volt ranges: 100 megohms.

Response Time: 95 percent of final reading within 4 sec on the 3-microvolt range. 95 percent of final readings within 1.5 sec on the 10-microvolt to 1000-volt ranges.

Superimposed AC Rejection: With frequencies of 60 Hz (cps) or higher (except modulator frequency: 160 to 170 Hz), ac voltages that are 80 dB greater than the end scale will affect the reading less than 2 percent. (AC voltage must be limited to 300 volts rms.)

Noise: Less than 0.1 microvolt peak-to-peak typical. Maximum meter excursion will be 0.2 microvolt peak-to-peak in any ten-second period.

Drift: Less than 0.5 microvolt per day after 30 minutes warm-up.

Gain: 110 dB maximum at recorder output terminals (gain depends on range).

Output: ±1 volt for full scale meter deflection; approximately 750 microamperes maximum.

Overload Protection: 50 volts maximum on 3-microvolt to 3 millivolt ranges; 500 volts maximum on 10-millivolt to 300-millivolt ranges; 1200 volts maximum on 1-volt range and above. Regardless of voltage limitations, the full output of the generator (approximately 600 volts) cannot damage the detector, even on the most sensitive range.

Overload Recovery Time: Meter indicates within 4 seconds for a 10^6 overload with input shorted; less than 15 seconds with input open.

Input Isolation: 10^{11} ohms shunted by 250 picofarads. May be operated more than 600 volts dc or 350 volts ac (rms) above ground.

1.2.3 Physical

Height:	5 1/4 inches	(13.3 cm)
Length:	19 inches	(48.25 cm)
Depth:	11 inches	(25.7 cm)
Weight:	21 pounds	(9.5 kg)

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

SECTION II

OPERATING INSTRUCTIONS

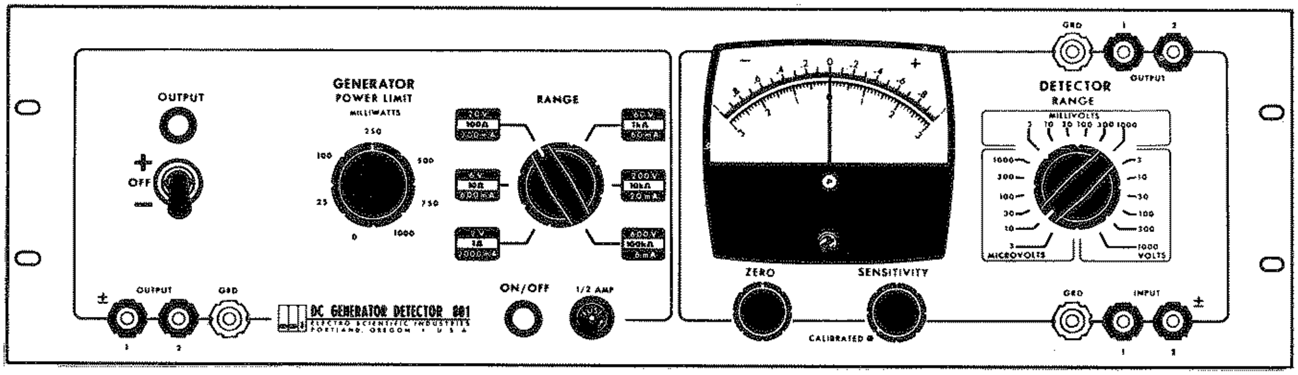


Figure 2.1 Terminals and Controls

2.1 TERMINALS AND CONTROLS

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

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

Detector OUTPUT Terminals: The upper right-hand 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 the sensitivity range of the detector.

Detector SENSITIVITY Control: Continuously varies the detector sensitivity from a minimum at the CALIBRATED position to a maximum of about four times the end-scale sensitivity indicated by the RANGE selector.

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

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

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

ON/OFF Switch: Controls line power to both generator and detector.

2.2 BASIC OPERATING PROCEDURE

This section describes the basic procedure for using the Model 801 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.

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:

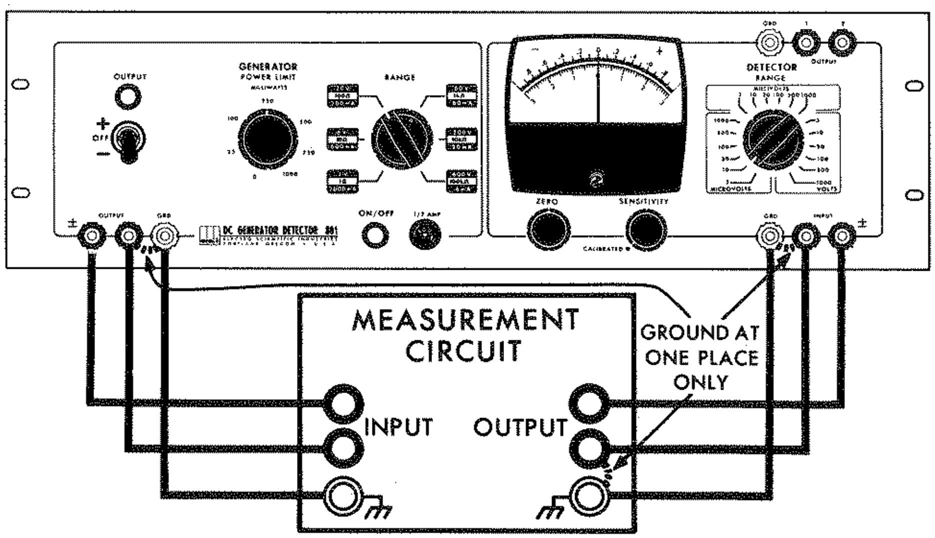


Figure 2.2 Basic Operating Procedure

1. Be sure the generator OUTPUT switch is off, then turn the ON/OFF switch on and allow time for warmup.

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 loop currents between chassis cannot flow through these leads.

3. Set the detector SENSITIVITY control at CALIBRATED.

   This adjusts full scale indication to the range setting.

4. 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 - in order to cancel effects causing zero shift with change in source resistance.

5. 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.

6. 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.

7. 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.

8. 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 of INPUT terminal 2.

9. 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.

10. Change the detector RANGE setting as required for detector sensitivity. Use the SENSITIVITY control to increase the detector sensitivity above the calibrated detector RANGE setting.

    Turn off the generator OUTPUT switch and recheck detector ZERO adjustment each time detector RANGE is changed toward higher sensitivity.

11. 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.

    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 801 FOR BRIDGE MEASUREMENTS

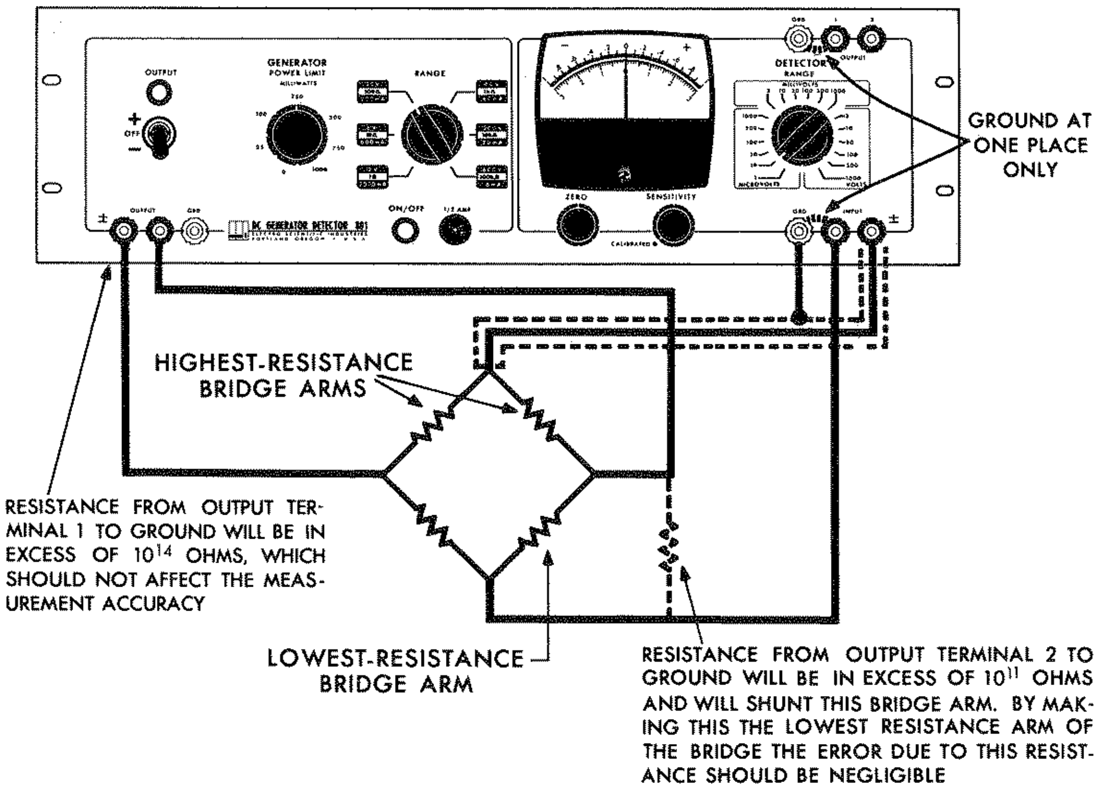


Figure 2.3 Bridge Measurement Connection

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 801 FOR VOLTAGE DIVIDER CALIBRATION

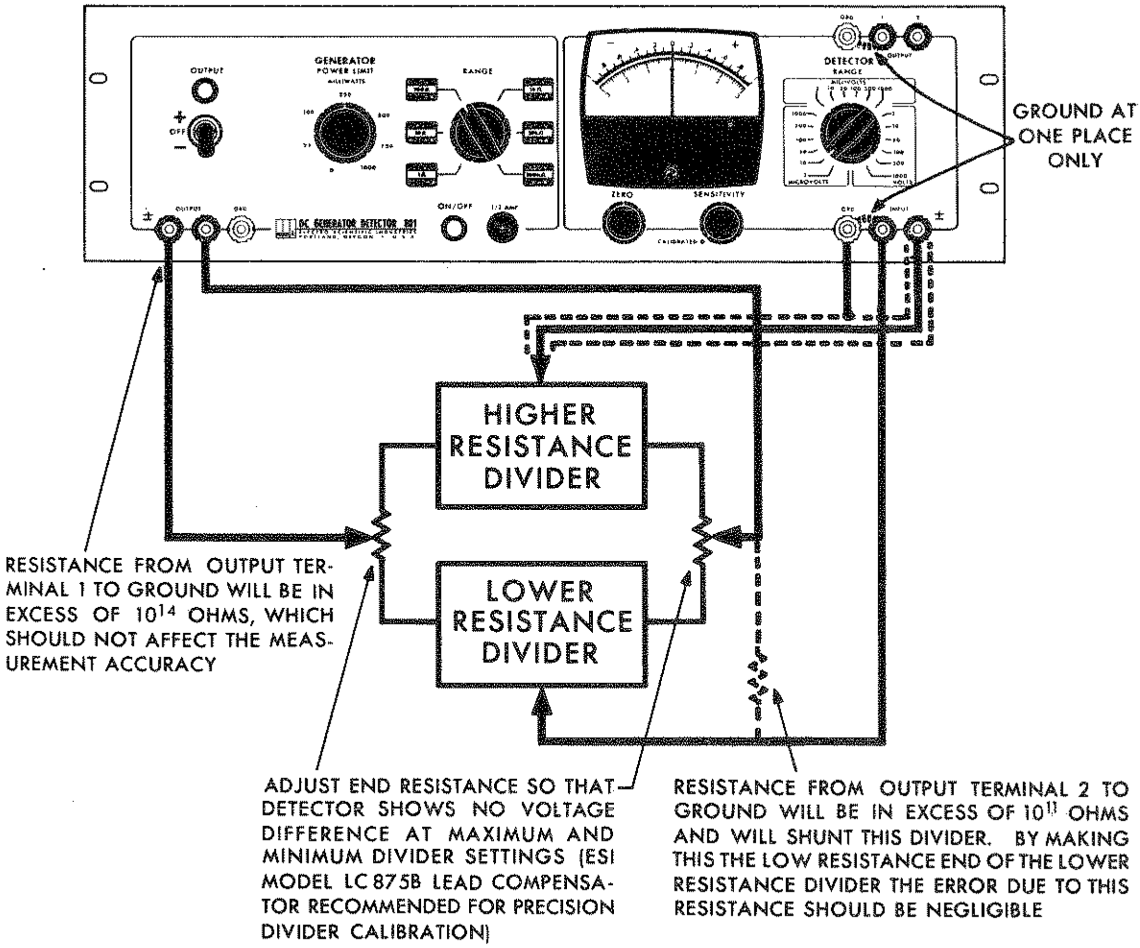


Figure 2.4 Voltage Divider Connection

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 801 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 and SENSITIVITY controls 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.

2.6 USING THE 801 AS AN ULTRA-LOW RESISTANCE OHMMETER

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.

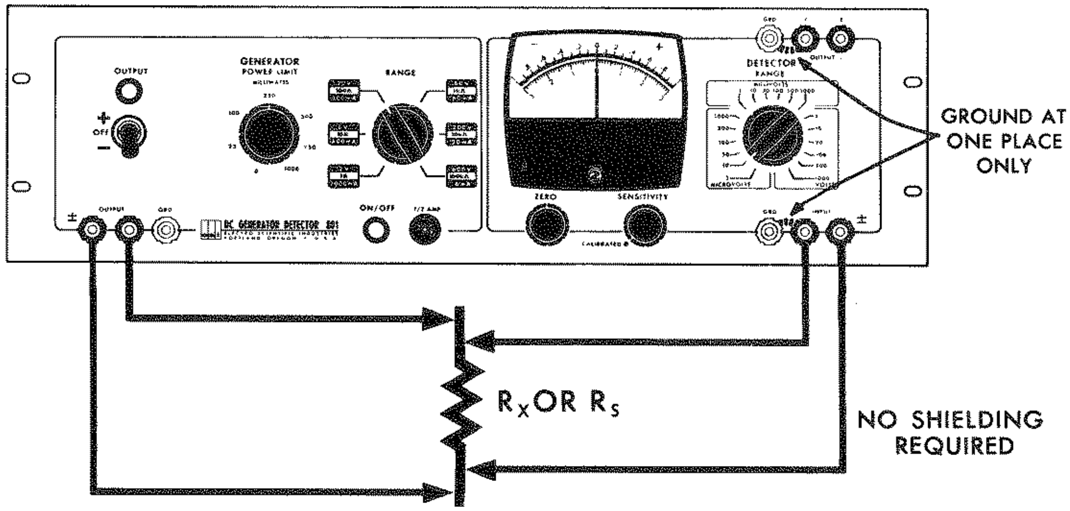


Figure 2.5 Low Resistance Measurement

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

For ±20 percent accuracy:

1. Before connecting the unknown resistance, connect the detector INPUT leads directly to the generator OUTPUT leads.

2. Set the generator RANGE resistance to a value at least 10 times the value of the unknown resistor.

3. Adjust generator POWER LIMIT so that the voltage reading is an exact power of 10. Call this voltage reading E_G.

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, measure the voltage. (Be sure that SENSITIVITY control is set to CALIBRATED.) 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 801 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.

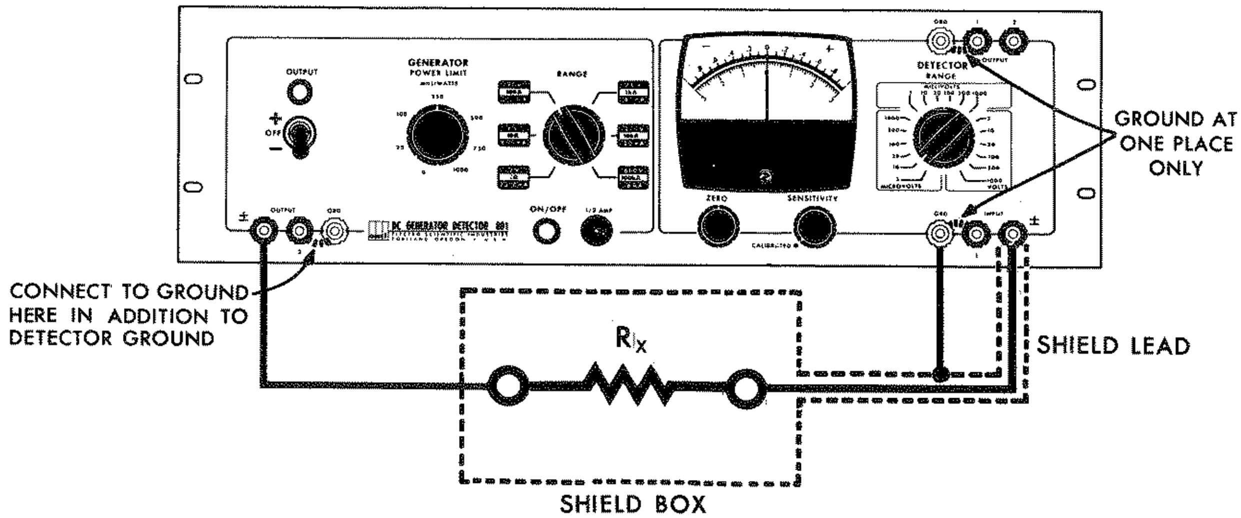


Figure 2.6 High-Resistance Measurement

Follow 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:

3 MICROVOLTS to 3 MILLIVOLTS; 100 kilohms
10 MILLIVOLTS to 30 MILLIVOLTS; 1 megohm
100 MILLIVOLTS to 300 MILLIVOLTS; 10 megohms
1000 MILLIVOLTS to 1000 VOLTS; 100 megohms.)

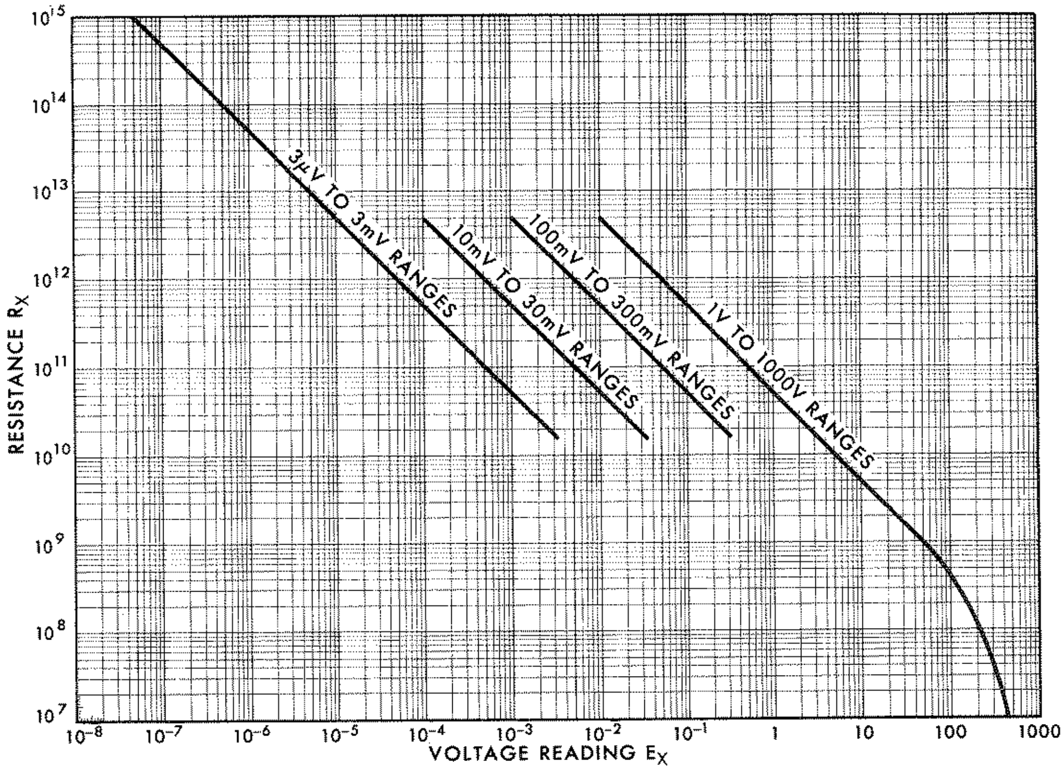


Figure 2.7 Voltage to Resistance Conversion Chart

2.8 USING THE 801 AS A VOLTMETER

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

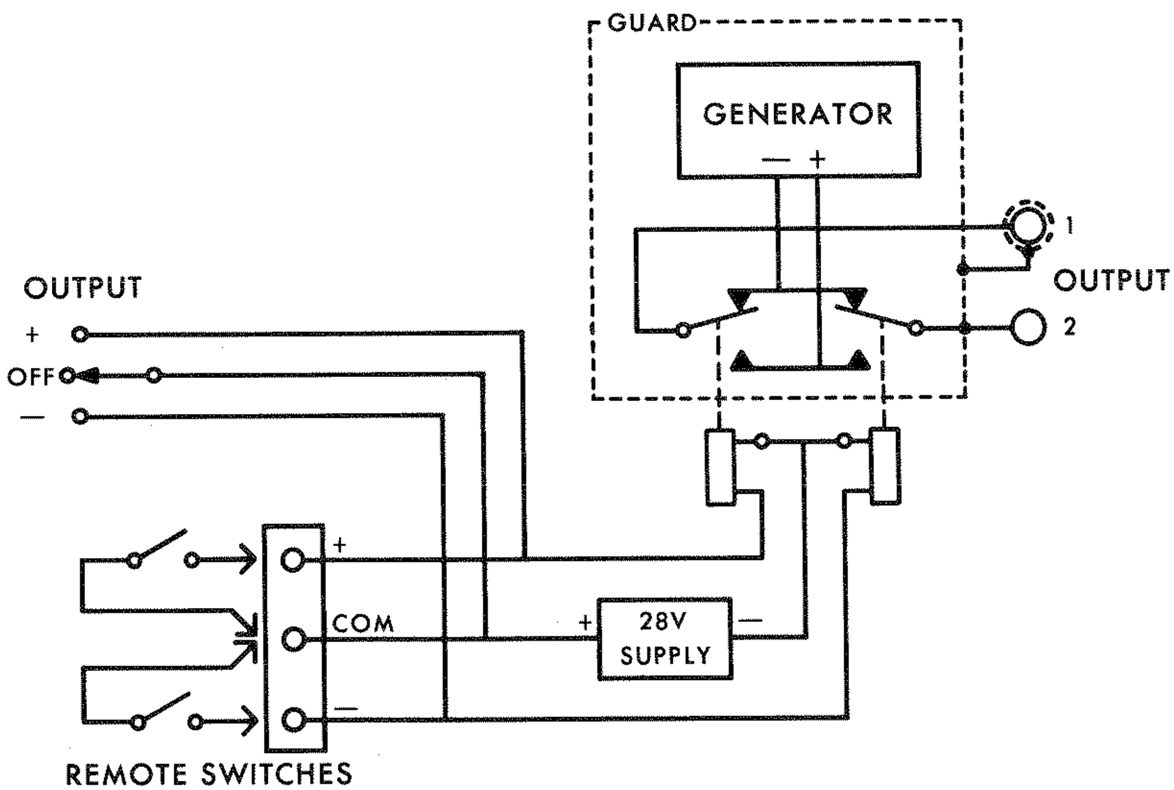


Figure 2.8 Remote Generator Control

2.10 CHANGING THE INPUT LINE VOLTAGE

The Model 801 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.

The setting of this switch at the time of manufacture is noted on the rear of the instrument. 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.

In order to have access to the switch, remove the instrument case (paragraph 4.1.2). 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.

Replace the instrument case after setting the switch, and correct the note attached to the rear of the instrument.

SECTION III

THEORY OF OPERATION

3.1 GENERATOR

The 801 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.

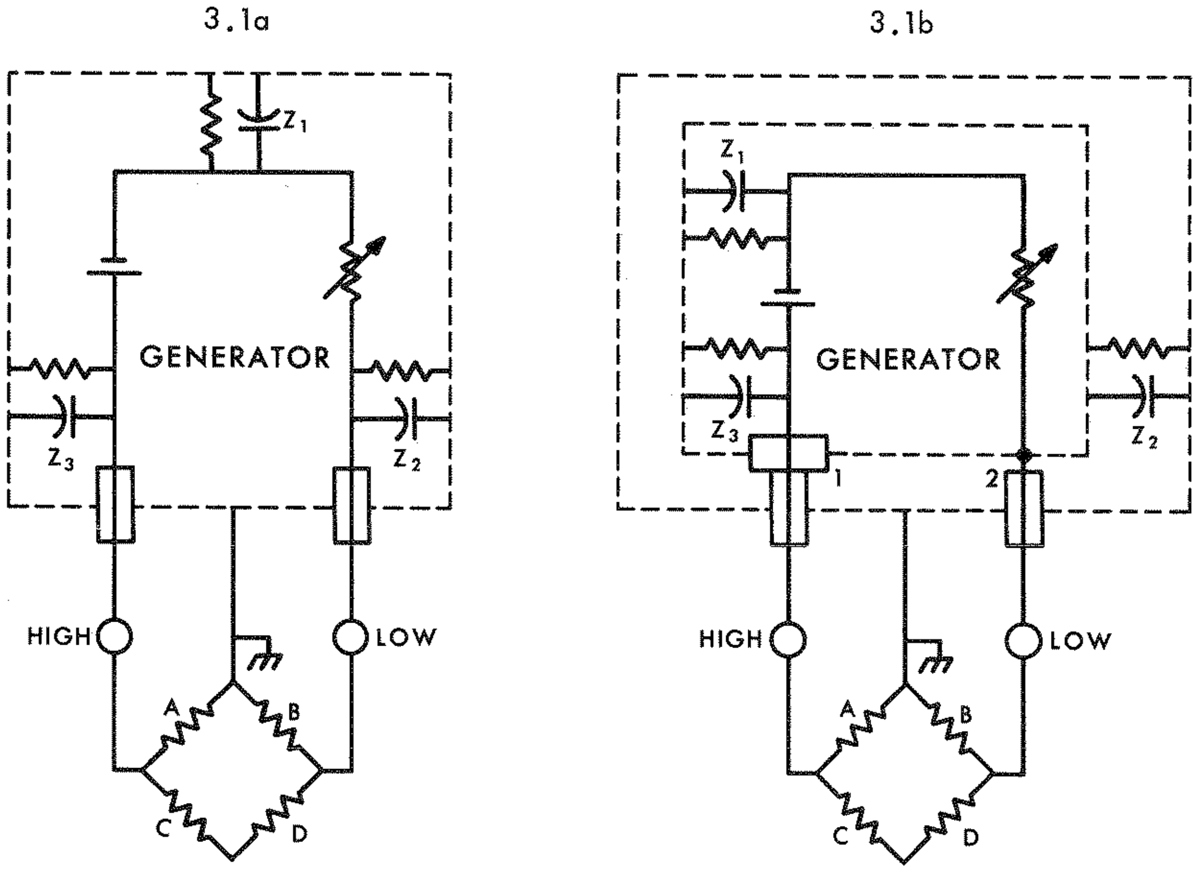


Figure 3.1 Generator Circuits

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 each of arms A and B. Since this leakage is at a higher emf than those at the terminals, it will cause even more error.

The 801 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 in null 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 a 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.

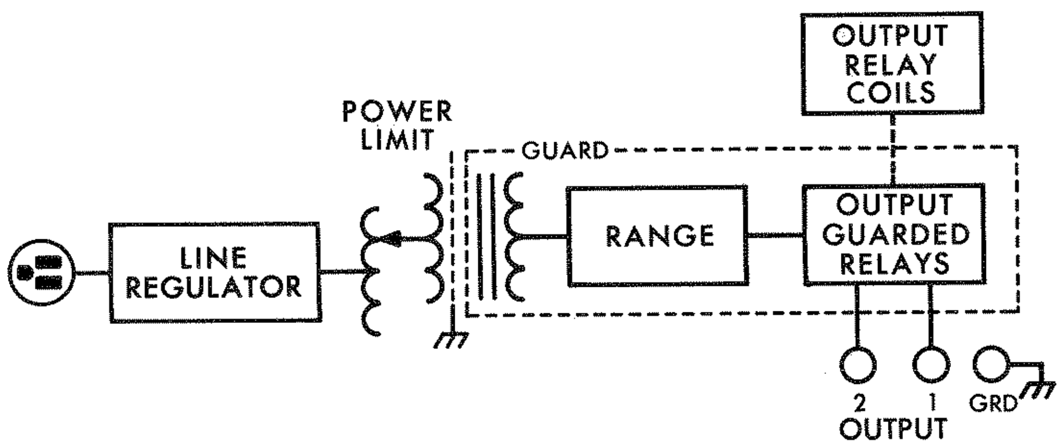


Figure 3.2 Generator Simplified Circuit

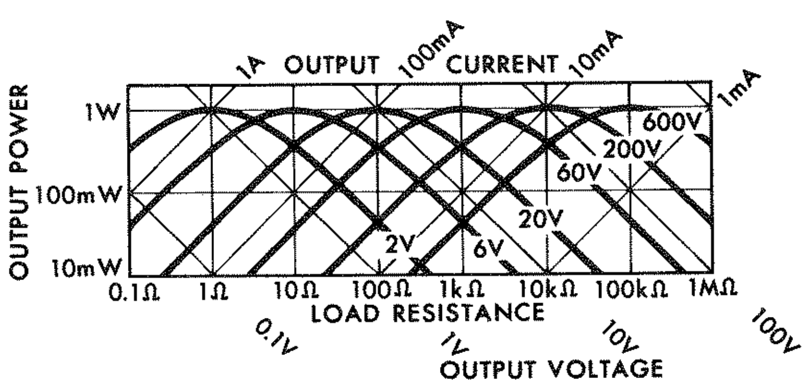


Figure 3.3 Generator Output

3.2 DETECTOR

The detector of the Model 801 is a high-sensitivity solid-state dc voltmeter. It has the following basic circuits: (1) an input attenuator, (2) a modulator and demodulator, (3) an ac amplifier, (4) a dc amplifier, (5) a meter, and (6) a feedback control circuit. Figure 3.4 is a block diagram of the detector.

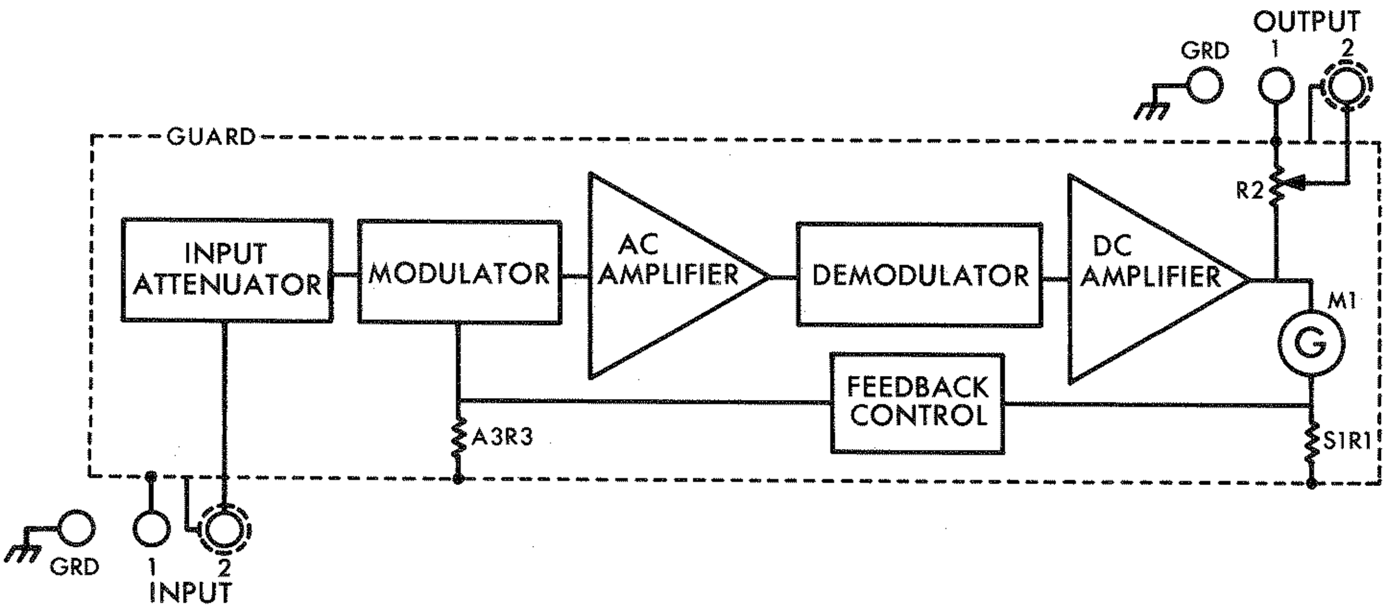


Figure 3.4 Detector Block Diagram

A dc voltage measured by the detector is applied to the input attenuator, which is a resistive divider operated by the RANGE switch. Table 3.1 lists the attenuation factors for each range.

The dc output of the input attenuator is modulated by the modulator, which consists of two photocells that are alternately illuminated by two neon lamps. The output of the modulator is a square wave with an amplitude that is proportional to the amplitude of the dc input voltage.

The square wave output of the modulator is amplified by a six-stage, high-gain ac amplifier. The output of the ac amplifier is applied to the demodulator. The demodulator output is a dc voltage with an amplitude proportional to the square-wave output of the ac amplifier. The output of the demodulator is applied to a three-stage dc voltage and power amplifier. The gain provided by the ac and dc amplifiers is listed for each range in Table 3.1.

The output of the dc amplifier, approximately 1 volt full scale, is applied to the meter and to the OUTPUT terminals on the front of the panel.

The feedback control circuit consists of a resistive voltage divider controlled by the RANGE switch and a SENSITIVITY control. When the SENSITIVITY control is in the CALIBRATED position, it is disconnected, and only the voltage divider has any effect. The feedback provided by the feedback control circuit with SENSITIVITY at CALIBRATED is listed for each range in Table 3.1. Subtracting the feedback from the open-loop gain gives the closed-loop gain. The closed-loop gain, in conjunction with the input attenuation factor provides 18 calibrated full scale ranges from 3 microvolts to 1000 volts. When the SENSITIVITY control is not in the CALIBRATED position, it reduces the feedback and thus increases the closed-loop gain. By thus reducing the feedback, the sensitivity of the detector can be increased to about four times the calibrated sensitivity.

Table 3.1 Amplifier Characteristics

RANGE	ATTENUATION FACTOR	OPEN LOOP GAIN	FEEDBACK
3 μV	1:1	150 dB	40 dB
10 μV	1:1	150 dB	50 dB
30 μV	1:1	150 dB	60 dB
100 μV	1:1	150 dB	70 dB
300 μV	1:1	130 dB	60 dB
1000 μV	1:1	130 dB	70 dB
3 mV	1:1	120 dB	70 dB
10 mV	10:1	120 dB	60 dB
30 mV	10:1	120 dB	70 dB
100 mV	10^2:1	120 dB	60 dB
300 mV	10^2:1	120 dB	70 dB
1000 mV	10^3:1	120 dB	60 dB
3 V	10^3:1	120 dB	70 dB
10 V	10^4:1	120 dB	60 dB
30 V	10^4:1	120 dB	70 dB
100 V	10^5:1	120 dB	60 dB
300 V	10^5:1	120 dB	70 dB
1000 V	10^6:1	120 dB	60 dB

SECTION IV

MAINTENANCE

4.1 PREVENTIVE MAINTENANCE

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

4.1.2 Removing the Case

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.

4.2 PERFORMANCE TESTS

The performance tests presented in this section are front panel procedures designed to compare the Model 801 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 801 is listed in Table 4.1. Equipment having similar characteristics may be substituted for the equipment listed.

Table 4.1 Test Equipment Required

INSTRUMENT TYPE	REQUIRED CHARACTERISTICS	USE	RECOMMENDED MODEL
Potentiometric Voltmeter	DC Voltage Range: 1 μV to 500 V Accuracy: ±0.2%	Accuracy Test, Response Test, and Alignment	ESI Model 300 PVB®

4.2.1 Accuracy Performance Test

The accuracy performance test setup is illustrated in Figure 4.1.

a) Connect test setup illustrated in Figure 4.1a and set potentiometric voltmeter to operate as a voltage source.

b) Make control settings indicated in Step 1 of Table 4.2. If detector reading is not within tolerances listed, perform full-scale calibration procedure (paragraph 4.4.3).

c) Repeat Step b for Steps 1 through 13 in Table 4.2.

d) Connect a wire from generator OUTPUT terminal 1 to detector INPUT terminal 2, and a wire from generator OUTPUT terminal 2 to detector INPUT terminal 1. See Figure 4.1b.

e) Set the potentiometric voltmeter to measure voltage.

f) Make the control settings indicated in Step 14 of Table 4.2 and adjust generator POWER LIMIT and RANGE controls to null the potentiometric voltmeter. If detector reading is not within tolerances listed, perform full-scale calibration procedure (paragraph 4.4.3).

g) Repeat Step f for Steps 14 through 18 in Table 4.2.

Table 4.2 Accuracy Performance Test

STEP	POTENTIOMETRIC VOLTMETER SETTINGS		MODEL 801	
	MULTIPLIER	DECADE DIALS	DETECTOR RANGE	DETECTOR READING
1	VOLTS × 0.01	0.0003	3 μV	2.75 to 3.35
2	VOLTS × 0.1	0.0001	10 μV	9.40 to 10.60
3	VOLTS × 0.1	0.0003	30 μV	2.84 to 3.16
4	VOLTS × 0.1	0.0010	100 μV	9.49 to 10.51
5	VOLTS × 0.1	0.0030	300 μV	2.85 to 3.15
6	VOLTS × 1	0.0010	1000 μV	9.50 to 10.50
7	VOLTS × 1	0.0030	3 mV	2.85 to 3.15
8	VOLTS × 1	0.0100	10 mV	9.50 to 10.50
9	VOLTS × 1	0.0300	30 mV	2.85 to 3.15
10	VOLTS × 1	0.1000	100 mV	9.50 to 10.50
11	VOLTS × 1	0.3000	300 mV	2.85 to 3.15
12	VOLTS × 1	1.0000	1000 mV	9.50 to 10.50
13	VOLTS × 1	3.0000	3 V	2.85 to 3.15
14	VOLTS × 10	1.0000	10 V	9.50 to 10.50
15	VOLTS × 10	3.0000	30 V	2.85 to 3.15
16	VOLTS × 100	1.0000	100 V	9.50 to 10.50
17	VOLTS × 100	3.0000	300 V	2.85 to 3.15
18	VOLTS × 100	5.0000	1000 V	4.50 to 5.50

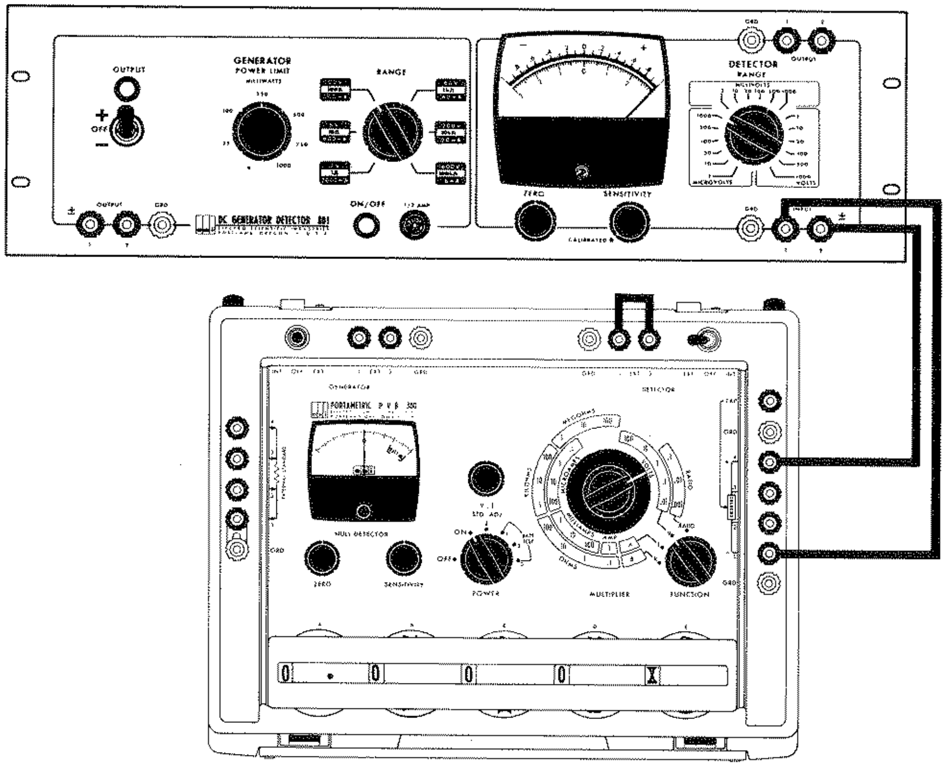


Figure 4.1a Detector Accuracy Test

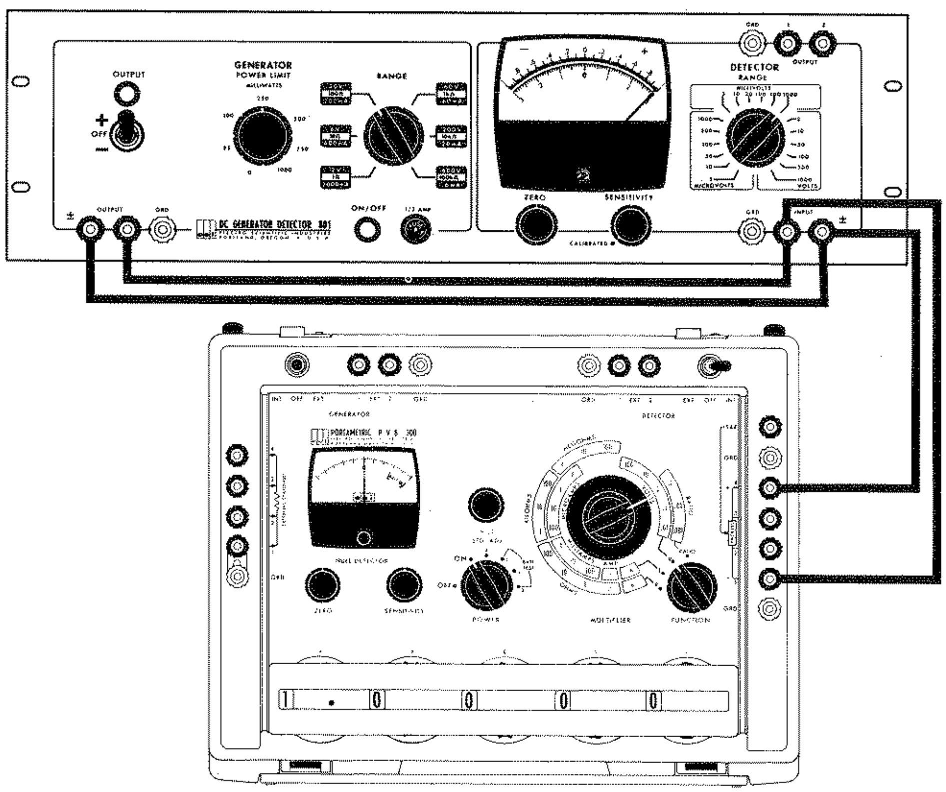


Figure 4.1b Detector Accuracy Test

4.2.2 Noise Performance Test

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

1. Short-circuit detector INPUT terminals.
2. Set detector RANGE control to 3 MICROVOLTS, and SENSITIVITY control to CALIBRATED.
3. Zero the detector.
4. Observe the meter for three successive 10-second periods. For at least one of these periods, the meter pointer should not vary more than 0.15 microvolt peak-to-peak; it should stay within a 3-minor-division interval.

4.2.3 Generator Voltage Check

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

1. Turn instrument on and allow 5 minutes to warm up.
2. Turn OUTPUT switch to OFF.
3. Set generator RANGE control to 1 ohm.
4. Set POLARITY to + .
5. Connect detector INPUT to generator OUTPUT terminals.
6. Set generator POWER LIMIT control to maximum.
7. Read voltage using the detector as a voltmeter.
8. Repeat all steps for all other settings of the generator RANGE control.

The voltages should be:

Range	Voltage
1Ω	1.6 to 2.4 V
10Ω	5.0 to 7.6 V
100Ω	10 to 24 V
1kΩ	50 to 76 V
10kΩ	160 to 240 V
100kΩ	500 to 760 V

4.2.4 Generator Leakage Resistance Check

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

1. Connect jumper strap between detector INPUT terminal 1 and ground.
2. Connect generator OUTPUT terminal 1 to detector INPUT terminal 2 with shielded lead and plug.
3. Cover generator OUTPUT terminal with a grounded shield. Make sure that the shield does not touch the terminal.
4. Set detector SENSITIVITY control to CALIBRATED, and detector RANGE to 1000 MILLIVOLTS.

5. Set generator RANGE to 600 V, turn POWER LIMIT control fully clockwise, and set OUTPUT switch to + .
6. Meter should indicate less than 600 millivolts. (This indicates resistance greater than 10^{11} ohms.)
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.
8. Set detector RANGE to 3 MICROVOLTS and generator RANGE to 600 V.
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.
10. Within 30 seconds, the meter should indicate not more than 0.6 microvolt. (This indicates resistance greater than 10^{14} ohms.)

4.2.5 <u>Detector Leakage Check</u>

To check leakage resistance from each detector terminal to ground:

1. Disconnect any ground strap or jumper between either detector INPUT or OUTPUT terminals and ground.
2. Connect a jumper strap between generator OUTPUT terminal 2 and ground.
3. Connect generator OUTPUT terminal 1 to detector INPUT terminal 2 with a shielded lead and plug.
4. Cover detector INPUT terminal 1 with a grounded shield. Make sure that the shield does not touch the terminal.
5. Set detector SENSITIVITY control to CALIBRATED, and detector RANGE to 1000 MILLIVOLTS.
6. Turn generator RANGE and POWER LIMIT controls fully clockwise, and set OUTPUT switch to + .
7. Meter should indicate less than 600 millivolts. (This indicates resistance greater than 10^{11} ohms.)
8. Set OUTPUT switch to OFF and connect generator OUTPUT terminal 2 to detector INPUT terminal 1 using shielded cable and plug.
9. Set detector RANGE to 3 MICROVOLTS and generator RANGE to 600 V.
10. 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.
11. Within 30 seconds, the meter should indicate not more than 0.6 microvolt. (This indicates resistance greater than 10^{14} ohms.)

4.3 DETECTOR

4.3.1 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 two screws on the rear of the cover and slide the U-shaped cover backward, being careful not to scrape the circuit boards.

4.3.2 Servicing Etched Circuit Boards

CAUTION

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

The Model 801 has etched circuit boards. Use caution when removing them to avoid damaging mounted components. The assembly and Hewlett-Packard or ESI part number are on the circuit board to identify it.

The detector etched circuit boards are a plated-through type. The electrical connection between sides of the board is made by a layer of metal plated through the component holes. When working on these boards, 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 board and pulling up on 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 board 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).

4.4 ADJUSTMENT AND CALIBRATION

4.4.1 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.

4.4.2 Electrical Zero Adjustment

The electrical zero adjustment should be performed when the meter pointer does not indicate zero on the 1000-millivolt range when instrument power has been on for at least one minute. No external equipment is required for this adjustment.

a) Set detector RANGE control to 1000 MILLIVOLTS.

b) Short-circuit INPUT terminals.

c) Remove the case; adjust A1R14 (1 V ZERO) for zero deflection on meter.

4.4.3 Full-Scale Calibration

The full-scale calibration consists of performing the 3 μV, 10 μV, 1 mV and 1 V adjustments.

a) Connect test setup illustrated in Figure 4.1a.

b) Remove the case

c) Set Potentiometric Voltmeter for 3 μV output; adjust A1R41 (3 μV) for full-scale deflection on 3 μV range.

d) Set Potentiometric Voltmeter for 10 μV output; adjust A1R42 (10 μV) for full-scale deflection on 10 μV range.

e) Set Potentiometric Voltmeter for 1 mV output; adjust A1R43 (1 MV) for full-scale deflection on 1000 μV range.

f) Set Potentiometric Voltmeter for 1 V output; adjust A1R44 (1 V) for full-scale deflection on 1000 mV range.

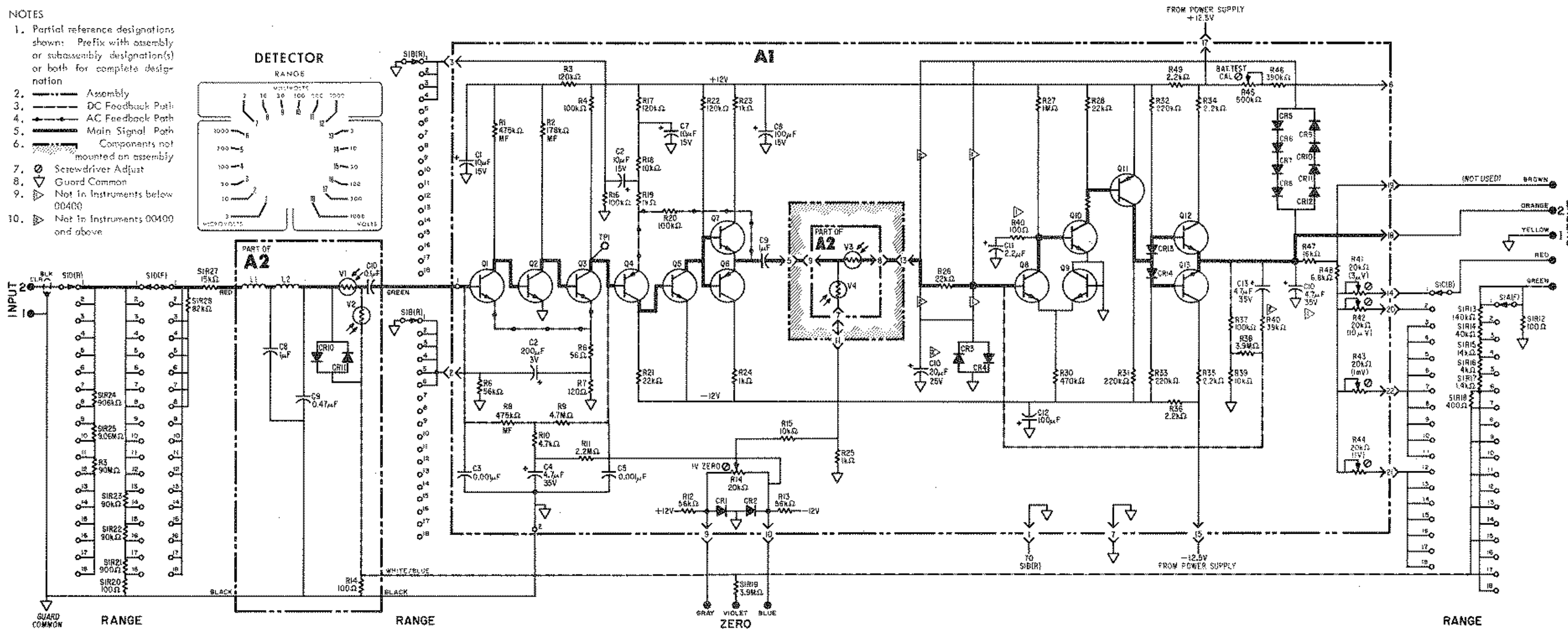
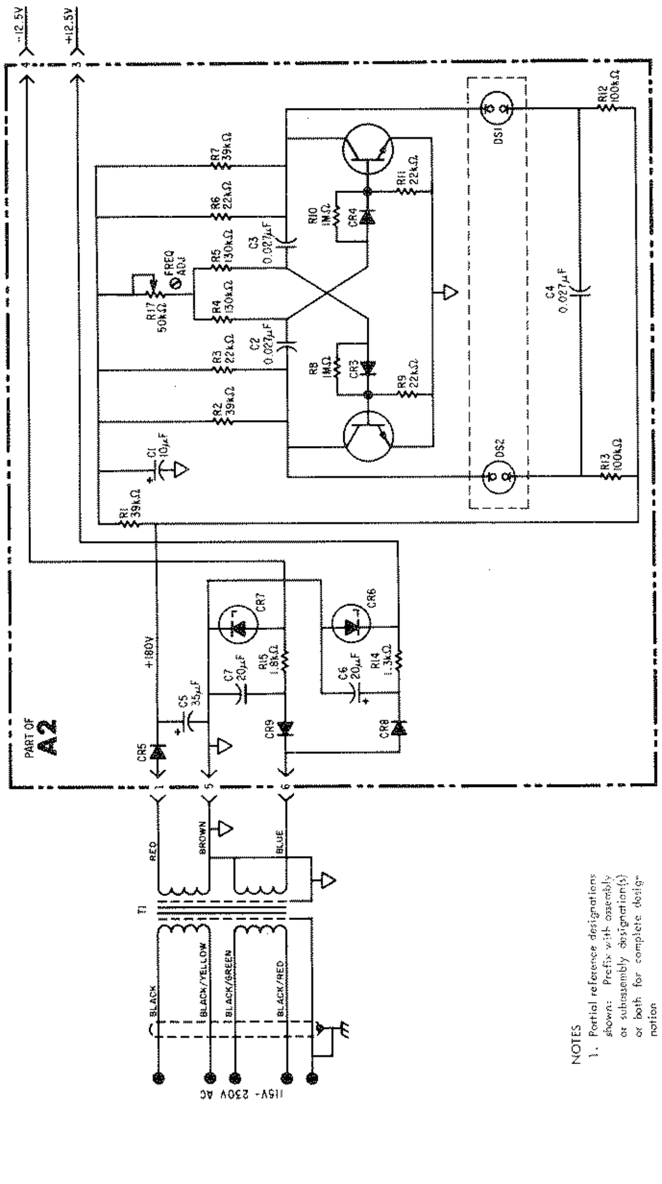


Figure 4.2 Detector, Schematic Diagram



NOTES

1. Partial reference designations shown: Prefix with assembly or subassembly designation(s) or both for complete designation

Figure 4.3 Detector Power Supply and Lamp Driver, Schematic Diagram

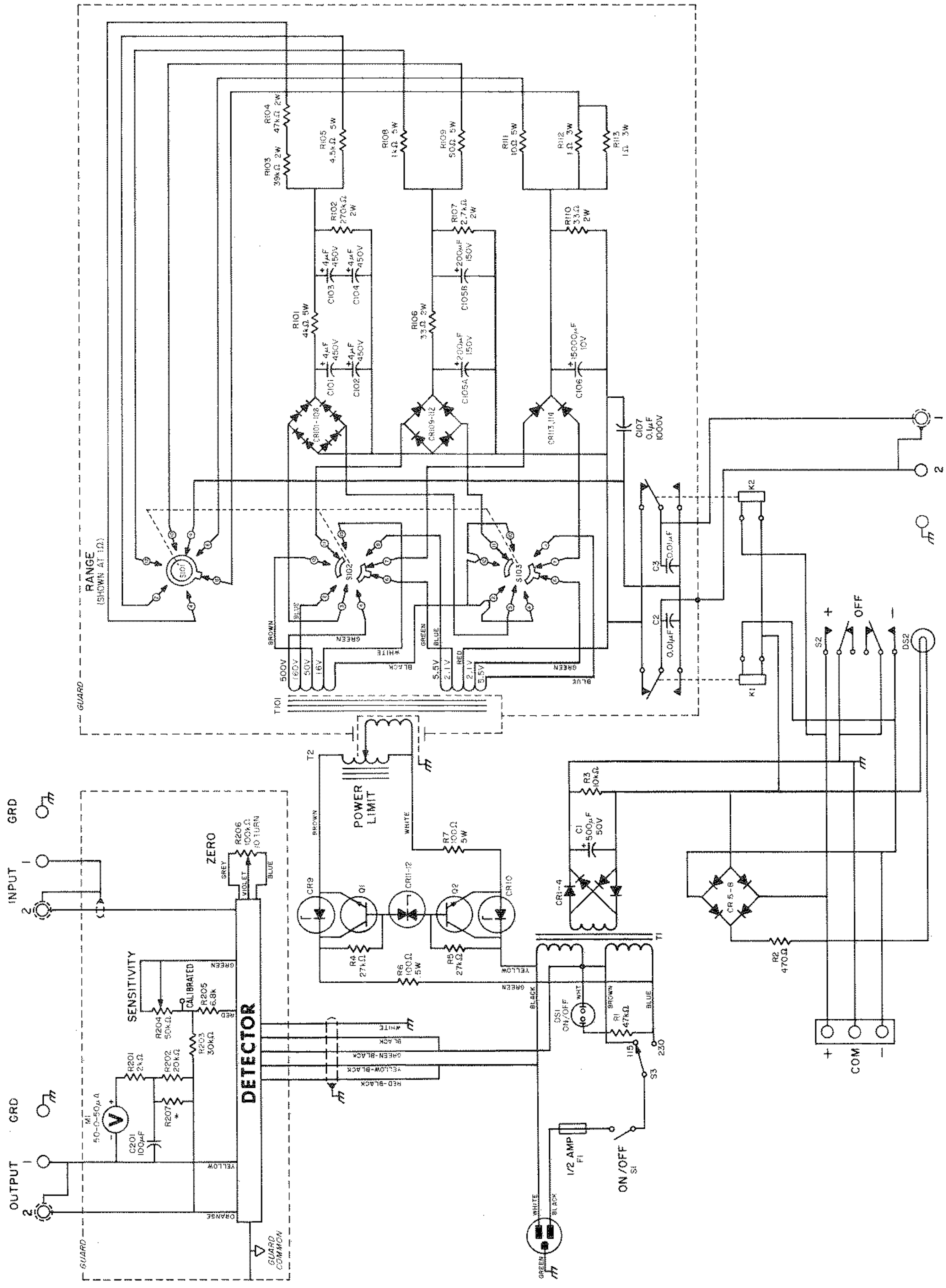


Figure 4.4 Schematic Diagram

4.5 PARTS LIST

The following parts list is in alpha-numerical order of the circuit reference designator. Miscellaneous parts are included at the end of the list. Manufacturer of the part is given in a code number according to the Federal Supply Code for Manufacturers (see list of manufacturers below).

Parts manufactured by Electro Scientific Industries must be ordered from the factory. When ordering, include the following information:

Model and serial number of the instrument
Electro Scientific Industries part number
Circuit reference designator
Description of part

CODE LIST OF MANUFACTURERS

00656	AEROVOX CORP., New Bedford, Massachusetts
01121	ALLEN BRADLEY COMPANY, Milwaukee, Wisconsin
01295	TEXAS INSTRUMENTS, INC., Dallas, Texas
02735	RADIO CORP. OF AMERICA, Somerville, New Jersey
03797	ELDEMA CORP., El Monte, California
04713	MOTOROLA, INC., Phoenix, Arizona
11837	ELECTRO SCIENTIFIC INDUSTRIES, INC., Portland, Oregon
12697	CLAROSTAT MFG. CO., Dover, New Hampshire
14655	CORNELL DUBILIER ELEC. CORP., South Plainfield, New Jersey
28480	HEWLETT-PACKARD COMPANY, Palo Alto, California
37942	P. R. MALLORY & CO., INC., Indianapolis, Indiana
56289	SPRAGUE ELECTRIC COMPANY, North Adams, Massachusetts
58474	SUPERIOR ELECTRIC COMPANY, Bristol, Connecticut
71482	C. P. CLARE, Chicago, Illinois
73138	BECKMAN INSTRUMENTS, INC., Helipot Division, Fullerton, California
73631	CURTIS DEV. & MFG. COMPANY, Milwaukee, Wisconsin
75915	LITTLEFUSE, INC., Des Plaines, Illinois
76487	JAMES MILLEN MFG. CO., INC., Malden, Massachusetts
76854	OAK MANUFACTURING CO., Crystal Lake, Illinois
82389	SWITCHCRAFT, INC., Chicago, Illinois

CKT REF	DESCRIPTION	MFR CODE	MFR PART NUMBER	ESI PART NUMBER	QTY USED
A1	Detector Amplifier Circuit Assembly	28480	00419-66501B	18409	1
A2	Detector Power Supply Circuit Assembly	28480	00419-66503	18408	1
C1	Capacitor, 500µF, 50V (-10% + 75%)	56289	39D507G050GL4	1942	1
C2, 3	Capacitor, 0.01µF, 1000V (±10%)	56289	41C121A1	1918	2
C101-104	Capacitor, 4µF, 450V (-10% + 100%)	00656	1710	2183	4
C105 A,B	Capacitor, 200µF, 150V (-10% + 75%)	14655	BR200-150	2138	2
C106	Capacitor, 18,000µF, (-10% + 75%)	37942	CG193U10D1	8035	1
C107	Capacitor, 0.1µF, 1000V (±10%)	00656	BE10P1	50013	1
C201	Capacitor, 100µF, 12V (-10% + 50%)	56289	TE1135	6157	1
CR1-8, 101-114*	Diode, Type IN4005 or Equal	04713	IN4005	1779	22
CR9, 10	Diode, Zener, 200 volts, 1 watt, 10%				2
CR11,12	Diode, Zener, 160 volts	04713	IN3049B	18453	2

These apply to Figure 4.4 schematic only.

CKT REF	DESCRIPTION	MFR CODE	MFR PART NUMBER	ESI PART NUMBER	QTY USED
DS2	Pilot Light, Generator OUTPUT	03797	CF03-RTS-176	18412	1
F1	Fuse, 1/2A	75915	3AG 1/2	1802	1
K1, 2	Relay, Guarded	71482	A-131142	18439	2
M1	Meter	11837	18410	18410	1
Q1, 2	Transistor, Type 40318 or Equal	02735	40318	18452	2
R206	Potentiometer, 100kΩ, 10 Turn, ZERO	12697	62JA	18414	1
R204	Potentiometer Switch Assembly, 50kΩ, SENSITIVITY	01121	JS-93392	18413	1
R1	Resistor, 47kΩ, 1/2 watt, 10%	01121	EB4731	1958	1
R2	Resistor, 470Ω, 1/2 watt, 10%	01121	GB4711	2056	1
R3	Resistor, 10kΩ, 1/2 watt, 10%	01121	EB1031	1961	1
R4, 5	Resistor, 27kΩ, 1/2 watts, 10%	01121	EB2731	1062	2
R6, 7	Resistor, 100Ω, 5 watts, 10%	12697	BC5E	1990	2
R101	Resistor, 4kΩ, 5 watts, 5%	12697	VC5E	2484	1
R102	Resistor, 270kΩ, 2 watts, 10%	01121	HB2741	1645	1
R103	Resistor, 39kΩ, 2 watts, 10%	01121	HB3931	2469	1
R104	Resistor, 47kΩ, 2 watts, 10%	01121	HB4731	2474	1
R105	Resistor, 4.5kΩ, 5 watts, 5%	12697	VC5E	2070	1
R106, 110	Resistor, 33Ω, 2 watts, 10%	01121	HP3301	2045	2
R107	Resistor, 2.7kΩ, 2 watts, 10%	01121	HB2721	2065	1
R108	Resistor, 1kΩ, 5 watts, 5%	12697	VPR5F-1K	2061	1
R109	Resistor, 50Ω, 5 watts, 5%	12697	VC5E-50Ω	2047	1
R111	Resistor, 10Ω, 5 watts, 5%	12697	VPR5F	2040	1
R112, 113	Resistor, 1Ω, 3 watts, 5%	12697	VC3D	2036	2
R201	Resistor, 2kΩ, 1/2 watt, 1%	00656	CPSX-1/2	2062	1
R202	Resistor, 20kΩ, 1/2 watt, 1%	00656	CPSX-1/2	1987	1
R203	Resistor, 30kΩ, 1/2 watt, 1%	00656	CPSX-1/2	2458	1
R205	Resistor, 6.8kΩ, 1/2 watt, 10%	01121	EB6821	2075	1
S1/DS1	Switch and Pilot Light Assembly ON/OFF	76854	616-26-A16	18418	1
S2	Switch, Lever, Generator OUTPUT	11837	3071	3071	1
S3	Switch, DPDT, (115-230)	82389	H6206LF	18424	1
S101-103	Switch, Generator RANGE	11837	8050	8050	1
T1	Transformer, Relay Supply	11837	18445	18445	1
T2	Variable Autotransformer, POWER LIMIT	58474	10B	8068	1
T101	Transformer, Generator	11837	8091	8091	1
	Barrier Strip, 3 Terminal	73631	GFTC-3	18415	1
	Binding Post, Guarded	11837	1480	1480	3
	Binding Post, 1 Inch Long	11837	1396	1396	6
	Cap, Binding Post, Black	11837	1170	1170	6
	Cap, Binding Post, Gold Plated	11837	1172	1172	6
	Detector Assembly	28480	00419	18411	1
	Dust Cover	11837	18446	18446	1
	Fuseholder	75915	342014	18416	1
	Generator Power Supply Assembly	11837	18420	18420	1
	Knob, Large Bar, Filled	11837	1266	1266	2
	Knob, Large Round, Filled	11837	1271	1271	1
	Knob, Small Round, Filled	11837	1268	1268	1

CKT REF	DESCRIPTION	MFR CODE	MFR PART NUMBER	ESI PART NUMBER	QTY USED
	Panel, Front	11837	18419	18419	1
	Power Cord	11837	2520	2520	1
	Printed Circuit Board Assembly, Capacitor	11837	18870	18870	1
	Printed Circuit Board Assembly, Diode	11837	18435	18435	1
	Printed Circuit Board Assembly, Meter	11837	18449	18449	1
	Printed Circuit Board Assembly, Relay Power	11837	18437	18437	1
	Shaft Coupler, Insulating	76487	39002	8052	2
	Slides	11837	82579	82579	2

Electro Scientific Industries, Inc.

13900 NW Science Park Drive
Portland, Oregon 97229
Phone (503) 641-4141
Telex 36-0273

WARRANTY OF TRACEABILITY

Electro Scientific Industries, Inc. maintains reference standards of measurement which are compared with the U. S. National Standards through frequent tests by the U. S. National Bureau of Standards.

ESI working standards and testing apparatus used are calibrated against the ESI reference standards in a rigorously maintained program of measurement control.

The manufacture and final calibration of all ESI instruments are controlled by use of the ESI reference and working standards and testing apparatus in accordance with established procedures and documented results. (Reference MIL-C-45662)

Final calibration of this instrument was performed with reference to the mean values of the ESI reference standards or to ratio devices that were verified at the time and place of use.

esi® Part No. 1866 5/76

Electro Scientific Industries, Inc.

13900 NW Science Park Drive
Portland, Oregon 97229
Phone (503) 641-4141
Telex 36-0273

WARRANTY OF QUALITY

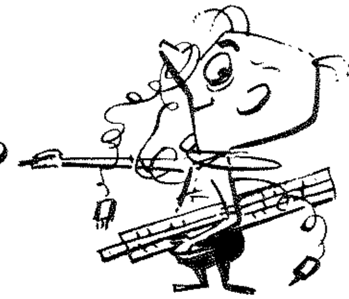
Electro Scientific Industries, Inc. warrants its products to be free from defects in material and workmanship for the following periods:

1. Two years for components and instruments using passive circuitry. One year for repairs of out-of-warranty items.
2. One year for components and instruments using active circuitry (see ESI Metrology Catalog). Six months for repairs of out-of-warranty items.

During the in-warranty periods, we will service or, at our option, replace any device that fails in normal use to meet its published specifications. Batteries, tubes and relays that have given normal service are excepted.

esi Part No. 1867 5/76

Would you like more information?



ESI technical publications are listed on the back of this page. If you would like any of these, simply check the appropriate box and fill in your address below. Also, please add any comments you have concerning the instrument or instruction manual. We value your feedback to help us improve or correct our manuals.

Instrument Description: Model No. ______________ Serial No. ______________
(Please Print)

Name ______________________________ Title ______________

Department ______________________________ Mail Stop ______________

Company ______________________________

Address ______________________________

City ______________ State ______________ Zip Code ________

Comments or corrections ______________________________

____

____

____

____

Mail this page to:

Electro Scientific Industries, Inc.
13900 N.W. Science Park Drive
Portland, Oregon 97229

Attention: Literature Department

esi Part No. 1872A 10/75

- applications data
- technical articles
- engineering bulletins

☐ EB10 — Effects of Output Loading on Resistive Voltage Dividers, *October 1969*

☐ EB15 — Low Input Resistance Voltage Dividers, *February 1970*

☐ EB17 — Accuracy vs. Frequency of Models 290B and 250DE Universal Impedance Bridges, *(revised May 1969)*

☐ EB26 — International System of Units, *August 1969*

☐ EB29 — DC and Low Frequency AC Ratio Measurements, *Dr. Merle L. Morgan, September 1962*

☐ EB30 — Traceability of Resistance Measurement, *Jack Riley, January 1964*

☐ EB34 — Resistance Transfer Technique, *Lawrence H. White, (revised April 1968)*

☐ EB35 — An Improved Technique for Establishing Resistance Ratios, *R. M. Pailthorp and J. C. Riley, November 1962*

☐ EB41 — Derivation of Electrical Units from Fundamental Standards, *R. D. Kuykendall and R. M. Pailthorp, July 1964*

☐ EB44 — DC Measurements Using Ratio Techniques, *Jack C. Riley, September 1965*

☐ TA2 — A Ratio Transformer Bridge for Standardization of Inductors and Capacitors, *D. L. Hillhouse and H. W. Kline, August 1960*

☐ TA6 — The Accuracy of Series and Parallel Connections of Four-Terminal Resistors, *Jack C. Riley, April 1965*

☐ TA8 — AC Measurements Using Ratio Techniques, *Jack C. Riley, May 1965*

☐ TA9 — Strength for the Weak Spot in DC Potentiometry, *George D. Vincent and M. L. Roberts, October 1965*

☐ TA14 — The Advantages of a Ten Kilohm Transportable Resistance Standard, *Robert M. Pailthorp, September 1967*

☐ TA16 — Which Bridge for Precise Resistance Measurements? *Edward J. Swenson and George D. Vincent, December 1967*

☐ TA17 — Experimental Verification of the Five-Terminal, Ten-Kilohm Resistor as a Device for Dissemination of the Ohm, *R. M. Pailthorp and George Vincent, December 1968*

☐ TA22A — Laser Resistance Trimming from the Measurement Point of View, *Arthur G. Albin and Edward J. Swenson, June 1971*

☐ TA23 — Precision Measurement of Resistor Networks, *Robert M. Pailthorp and Jack C. Riley, June 1971*

☐ TA24 — Predictive Adjustment of Tantalum Film Resistors by Anodization, *Donald R. Cutler and Edward J. Swenson, July 1971*

☐ TA25 — Laser Trimming Analysis Using a Resistive Sheet Analogy, *Swenson, Vincent, Riley, December 1972*

☐ TA26 — The Effects of Laser Trimming on Birox and 1100 Series Thick Film Composition, *N. S. Spann, R. Headley, G. D. Vincent and E. J. Swenson, October 1971*

☐ TA27 — Laser Trimming Thin Film Precision Resistor Networks with an Automated System, *Leonhard Groth, January 1974*

☐ TA28 — YAG Laser Trimming of Thick Film Resistors, *Headley, Popowich, Anders January 1974*

☐ TA29 — An Overview of Laser Functional Trimming Techniques, *Gunnar Hurtig III and Edward J. Swenson, August 1974*

☐ TA30 — Measurement Subsystem for an AC Network Laser Trimmer, *R. A. Schomburg, August 1974*

☐ TA31 — A Method of Obtaining Optimum Trimming Performance from a Laser System, *Paul F. Parks and Thomas W. Richardson, October 1974*