FLUKE®

Instruction Manual

Model

720A

Kelvin-Varley Voltage Divider

P/N 294058

MARCH, 1969

Rev. 2 9/20/74

LIMITED WARRANTY

The JOHN FLUKE MFG. CO., INC., warrants each instrument it manufactures to be free from defects in material and workmanship under normal use and service for the period of one year from date of purchase. This warranty extends only to the original purchaser. This warranty shall not apply to fuses, disposable batteries (rechargeable type batteries are warranted for 90 days), or any product or parts which have been subject to misuse, neglect, accident or abnormal conditions of operations.

In the event of failure of a product covered by this warranty, John Fluke Mfg. Co., Inc., will repair and calibrate an instrument returned to an authorized Service Facility within one year of the original purchase; provided the warrantor's examination discloses to its satisfaction that the product was defective. The warrantor may, at its option, replace the product in lieu of repair. With regard to any instrument returned within one year of the original purchase, said repairs or replacement will be made without charge. If the fault has been caused by misuse, neglect, accident or abnormal conditions of operations, repairs will be billed at a nominal cost. In such case, an estimate will be submitted before work is started, if requested.

ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS SHALL BE LIMITED TO A PERIOD OF TWELVE MONTHS FROM THE DATE OF PURCHASE. THE FOREGOING WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTY OF MERCHANTABILITY, FITNESS OR ADEQUACY FOR ANY PARTICULAR PURPOSE OR USE. JOHN FLUKE MFG. CO., INC. SHALL NOT BE LIABLE FOR ANY SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES, WHETHER IN CONTRACT, TORT OR OTHERWISE.

NOTE: Some states do not allow limitations on how long an implied warranty lasts, or the exclusion or limitation of incidental or consequential damages, so the above limitations or exclusion may not apply to you. This warranty gives you specific legal rights, and you may also have other rights which vary from state to state.

If any fault develops, the following steps should be taken:

1. Notify the John Fluke Mfg. Co., Inc. or nearest Service facility, giving full details of the difficulty, and include the Model number, type number, and serial number. On receipt of this information, service data or shipping instructions will be forwarded to you.
2. On receipt of the shipping instructions, forward the instrument, transportation prepaid. Repairs will be made at the Service Facility and the instrument returned, transportation prepaid.

SHIPPING TO MANUFACTURER FOR REPAIR OR ADJUSTMENT

All shipments of John Fluke Mfg. Co., Inc., instruments should be made via United Parcel Service or "Best Way*" prepaid. The instrument should be shipped in the original packing carton; or if it is not available, use any suitable container that is rigid and of adequate size. If a substitute container is used, the instrument should be wrapped in paper and surrounded with at least four inches of excelsior or similar shock-absorbing material.

CLAIM FOR DAMAGE IN SHIPMENT TO ORIGINAL PURCHASER

The instrument should be thoroughly inspected immediately upon original delivery to purchaser. All material in the container should be checked against the enclosed packing list. The manufacturer will not be responsible for shortages against the packing sheet unless notified immediately. If the instrument is damaged in any way, a claim should be filed with the carrier immediately. (To obtain a quotation to repair shipment damage, contact the nearest Fluke Technical Center.) Final claim and negotiations with the carrier must be completed by the customer.

The John Fluke Mfg. Co., Inc. will be happy to answer all application or use questions, which will enhance your use of this instrument. Please address your requests or correspondence to: JOHN FLUKE MFG. CO., INC., P.O. Box 43210, MOUNTLAKE TERRACE, WASHINGTON 98043, Atten: Sales Dept. For European Customers: FLUKE (Nederland) B.V., Zevenheuvelenweg 53, Tilburg, The Netherlands.

* For European customers, Air Freight prepaid.

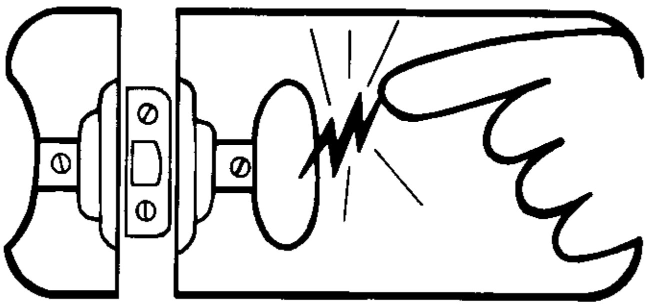
John Fluke Mfg. Co., Inc. • P.O. Box 43210 • Mountlake Terrace, Washington 98043

Rev. 12/77

static awareness

A Message From

John Fluke Mfg. Co., Inc.

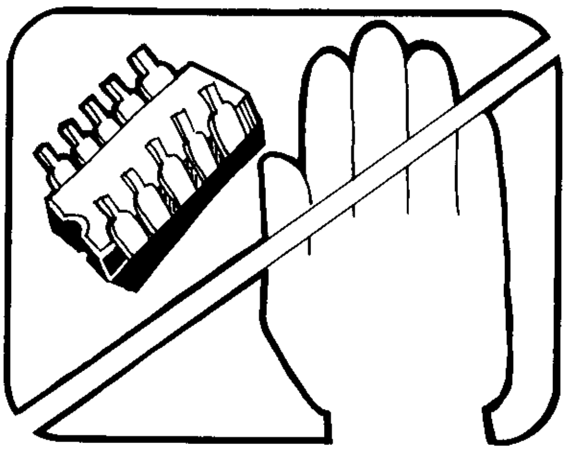


Some semiconductors and custom IC's can be damaged by electrostatic discharge during handling. This notice explains how you can minimize the chances of destroying such devices by:

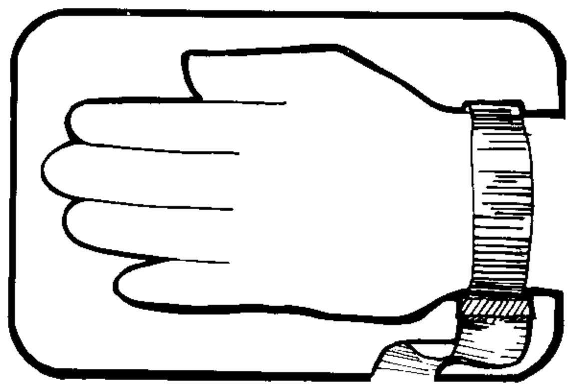
1. Knowing that there is a problem.
2. Learning the guidelines for handling them.
3. Using the procedures, and packaging and bench techniques that are recommended.

The Static Sensitive (S.S.) devices are identified in the Fluke technical manual parts list with the symbol "⊗".

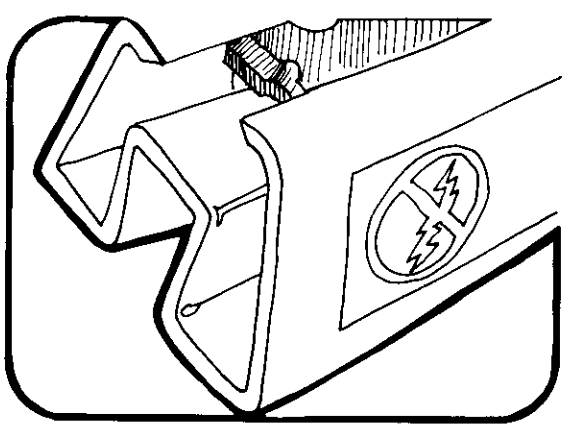
The following practices should be followed to minimize damage to S.S. devices.



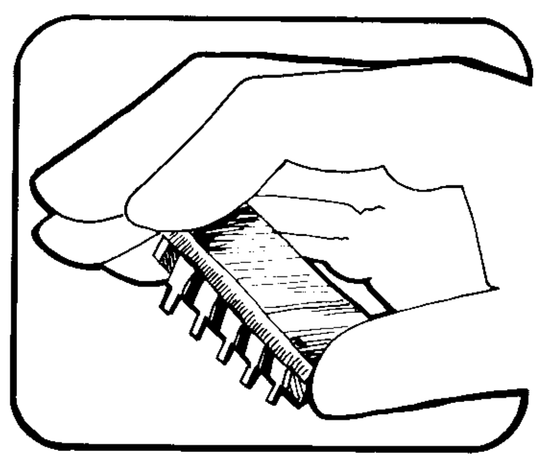
1. MINIMIZE HANDLING



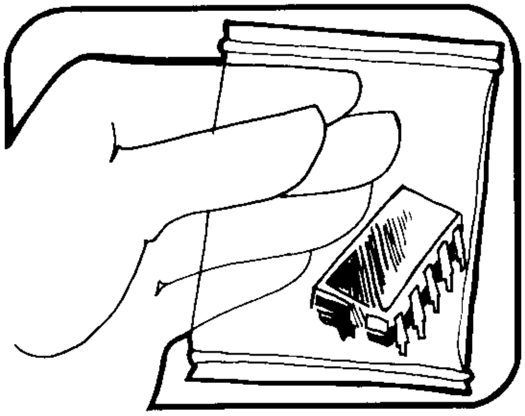
3. DISCHARGE PERSONAL STATIC BEFORE HANDLING DEVICES



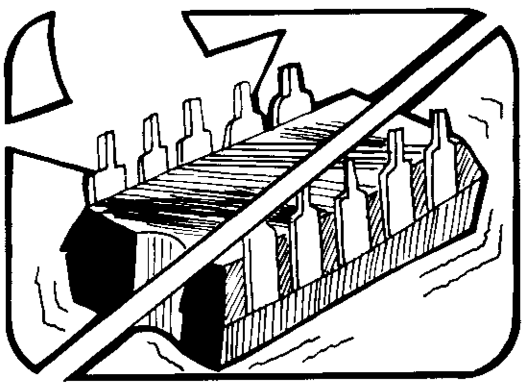
2. KEEP PARTS IN ORIGINAL CONTAINERS UNTIL READY FOR USE.



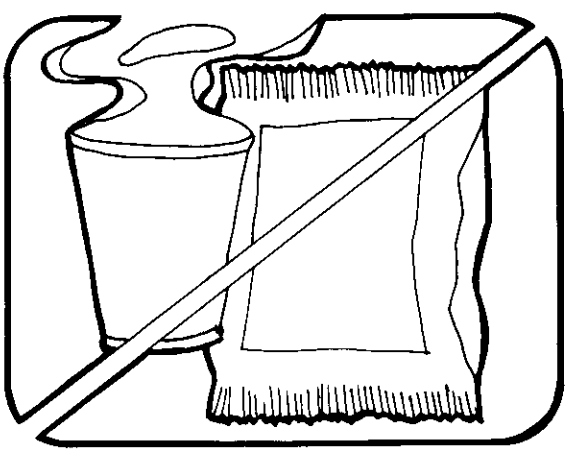
4. HANDLE S.S. DEVICES BY THE BODY



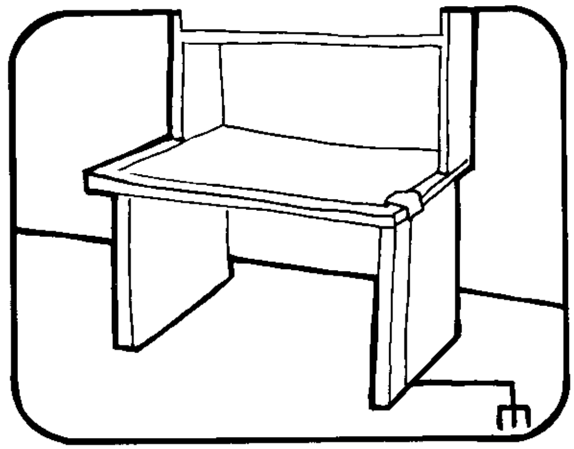
5. USE ANTI-STATIC CONTAINERS FOR HANDLING AND TRANSPORT



6. DO NOT SLIDE S.S. DEVICES OVER ANY SURFACE



7. AVOID PLASTIC, VINYL AND STYROFOAM IN WORK AREA



8. HANDLE S.S. DEVICES ONLY AT A STATIC-FREE WORK STATION

9. ONLY ANTI-STATIC TYPE SOLDER-SUCKERS SHOULD BE USED.

10. ONLY GROUNDED TIP SOLDERING IRONS SHOULD BE USED.

Anti-static bags, for storing S.S. devices or pcbs with these devices on them, can be ordered from the John Fluke Mfg. Co., Inc.. See section 5 in any Fluke technical manual for ordering instructions. Use the following part numbers when ordering these special bags.

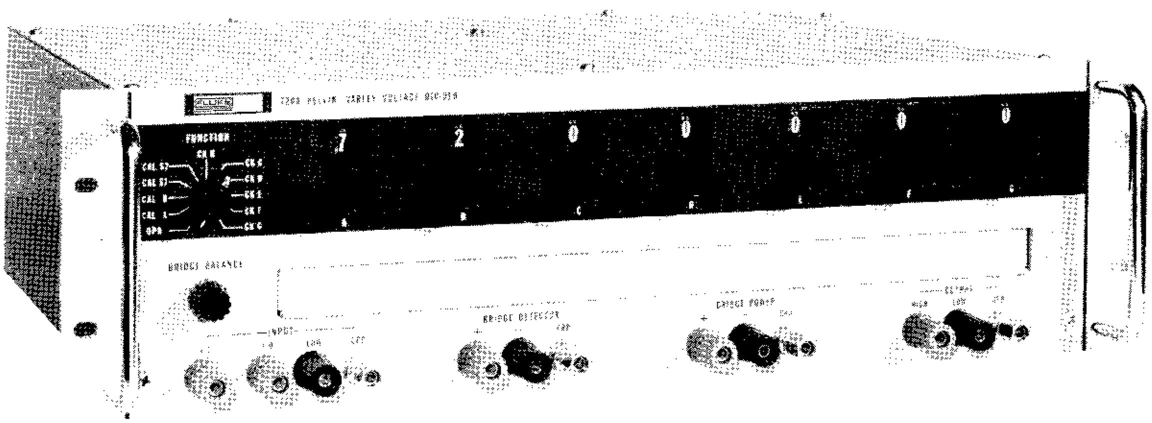
John Fluke Part No.	Bag Size
453522	6" x 8"
453530	8" x 12"
453548	16" x 24"
454025	12" x 15"

Table of Contents

TABLE OF CONTENTS, *continued*

List of Illustrations

LIST OF ILLUSTRATIONS, *continued*



MODEL 720A KELVIN-VARLEY VOLTAGE DIVIDER

Section 1

Introduction & Specifications

1-1. INTRODUCTION

1-2. The Model 720A Kelvin-Varley Voltage Divider is a seven-dial primary ratio standard which meets the most exacting requirements of the standards laboratory. Absolute linearity of 0.1 ppm, temperature coefficient of linearity of 0.1 ppm/°C, and self-calibration make the 720A the most accurate instrument available for the comparison of primary and secondary voltage and resistance standards. The linearity has a small power derating coefficient of 0.2 ppm per watt which is achieved by matching the resistors' temperature coefficients close to zero. This permits operation at up to 1100 volts and 11 watts.

1-3. The Model 720A has two high input terminals. The terminal labeled INPUT 1.0 is for general use in all Kelvin-Varley applications for which direct reading, in ratio, is desired. The terminal labeled INPUT 1.1 is used for voltage measurement applications when both direct reading in voltage and over-ranging are desired. An example of this application is the measurement of standard cell voltages. Use of the 1.1 INPUT at a level of 1.1 volts in this application results in divider resolution of 0.1 microvolt and allows comparison of standard cells to within 1 microvolt.

1-4. Only thoroughly aged resistors of the highest quality are used in the Model 720A Kelvin-Varley Divider. As a result, linearity change per year will not exceed one part per million unless the instrument is subjected to abuse. To assure that the divider remains within its specifications throughout its useful life, adjustments are provided for the resistors of the first three decades. The third decade adjustments normally will be used only during annual calibration. Performing the self calibration procedure sets the adjustments of the first two decades. With reasonable care these adjustments will provide instrument accuracy of 0.1 part per million at the time of adjustment.

1-5. ELECTRICAL SPECIFICATIONS

RATIO RANGE
0 to 1.0 (1.0 INPUT TAP) and 0 to 1.1 (1.1 INPUT TAP).

RESOLUTION
0.1 ppm of input with 7 decades.

ABSOLUTE LINEARITY
(at calibration temperature and without the use of a correction chart)*
±0.1 ppm of input at dial settings of 1.1 to 0.1.
±0.1 $(10S)^{1/3}$ of input at dial settings (S) of 0.1 to 0.
(See Figure 1-1.)

ABSOLUTE LINEARITY STABILITY (without self-calibration)
±1.0 ppm of input/year at dial settings of 1.1 to 0.1.
±1.0 $(10S)^{2/3}$ ppm of input/year at dial settings (S) of 0.1 to 0.
(See Figure 1-2.)

NOTE!

The self-calibration procedure may be used at any time to reset absolute linearity to ±0.1 ppm of input.

TEMPERATURE COEFFICIENT OF LINEARITY
±0.1 ppm of input/°C maximum at dial settings of 1.1 to 0.1.
(See Figure 1-3.)

SHORT-TERM LINEARITY STABILITY
Under typical conditions in a standards laboratory environment (temperature maintained within ±1°C) and with an applied voltage of up to 100 volts, stability of linearity is 0.1 ppm/30 days.

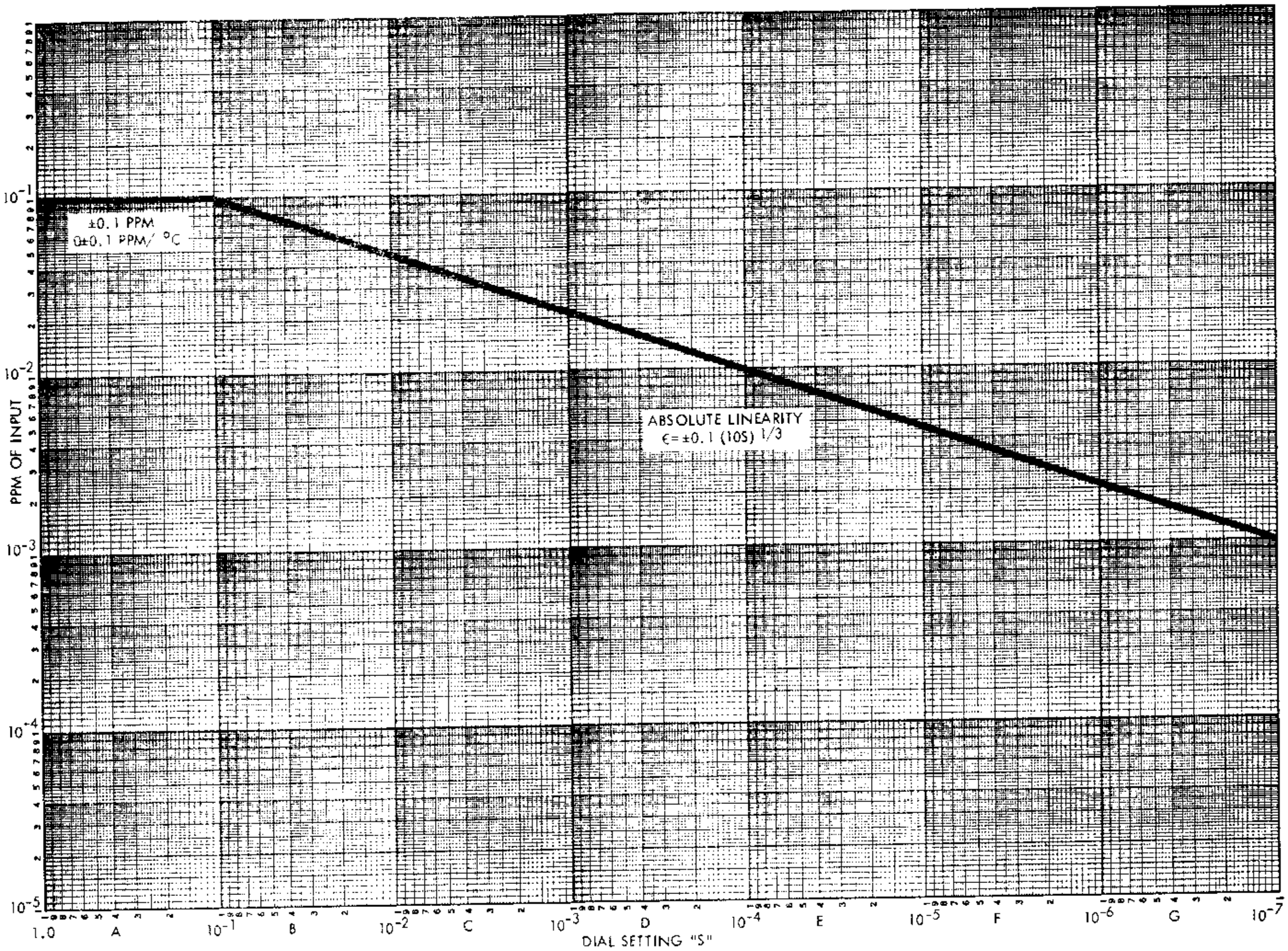


Figure 1-1. ABSOLUTE LINEARITY

POWER COEFFICIENT OF LINEARITY
±0.2 ppm of input/watt maximum at dial settings of 1.1 to 0.1.
±0.2 $(10S)^2$ ppm of input/watt maximum at dial settings (S) of 0.1 to 0.
(See Figure 1-4.)

MAXIMUM END ERRORS

Zero error, at output low	0.004 ppm of input
Zero error, at input low	0.05 ppm of input
Full-scale error	0.05 ppm of input

THERMAL VOLTAGES
±0.5 uv maximum.

MAXIMUM INPUT POWER
10 watts on 1.0 INPUT terminal.
11 watts on 1.1 INPUT terminal.

*Absolute linearity is defined as the linearity between maximum and minimum output voltages.

MAXIMUM INPUT VOLTAGE
1000 volts on 1.0 INPUT terminal.
1100 volts on 1.1 INPUT terminal.

BREAKDOWN VOLTAGE
2000 volts to case at 10,000 feet.
2500 volts to case at sea level.

INPUT RESISTANCE
100 kilohms ±0.005% at 1.0 INPUT terminal at 25°C.
110 kilohms ±0.005% at 1.1 INPUT terminal at 25°C.

TEMPERATURE COEFFICIENT OF INPUT RESISTANCE
±1 ppm/°C maximum.

MAXIMUM OUTPUT RESISTANCE
66 kilohms.

1-6. MECHANICAL AND ENVIRONMENTAL SPECIFICATIONS

OPERATING TEMPERATURE RANGE
0°C to 50°C (32°F to 122°F).

NOTE!

When the Model 720A is used at temperatures below 15°C (59°F) or above 35°C (95°F), the range of the calibration adjustments may be

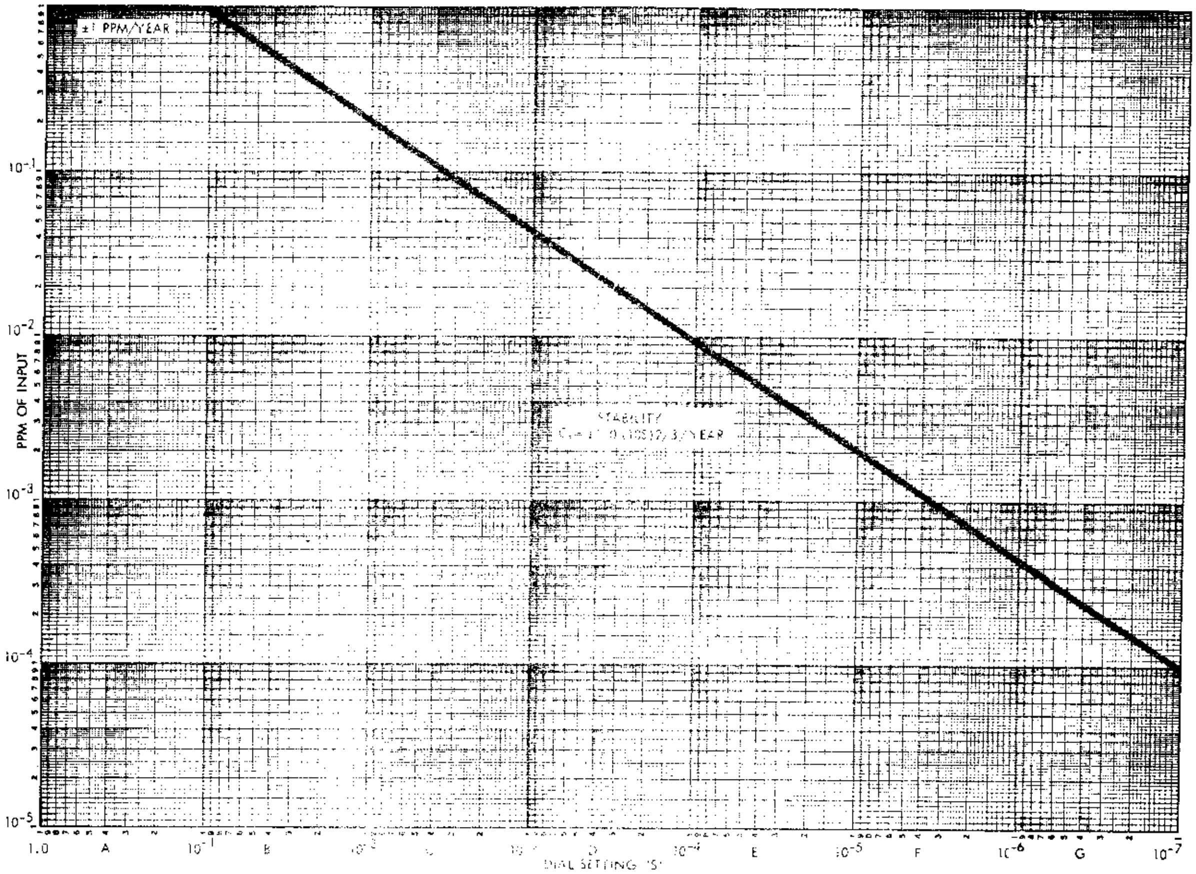


Figure 1-2. STABILITY

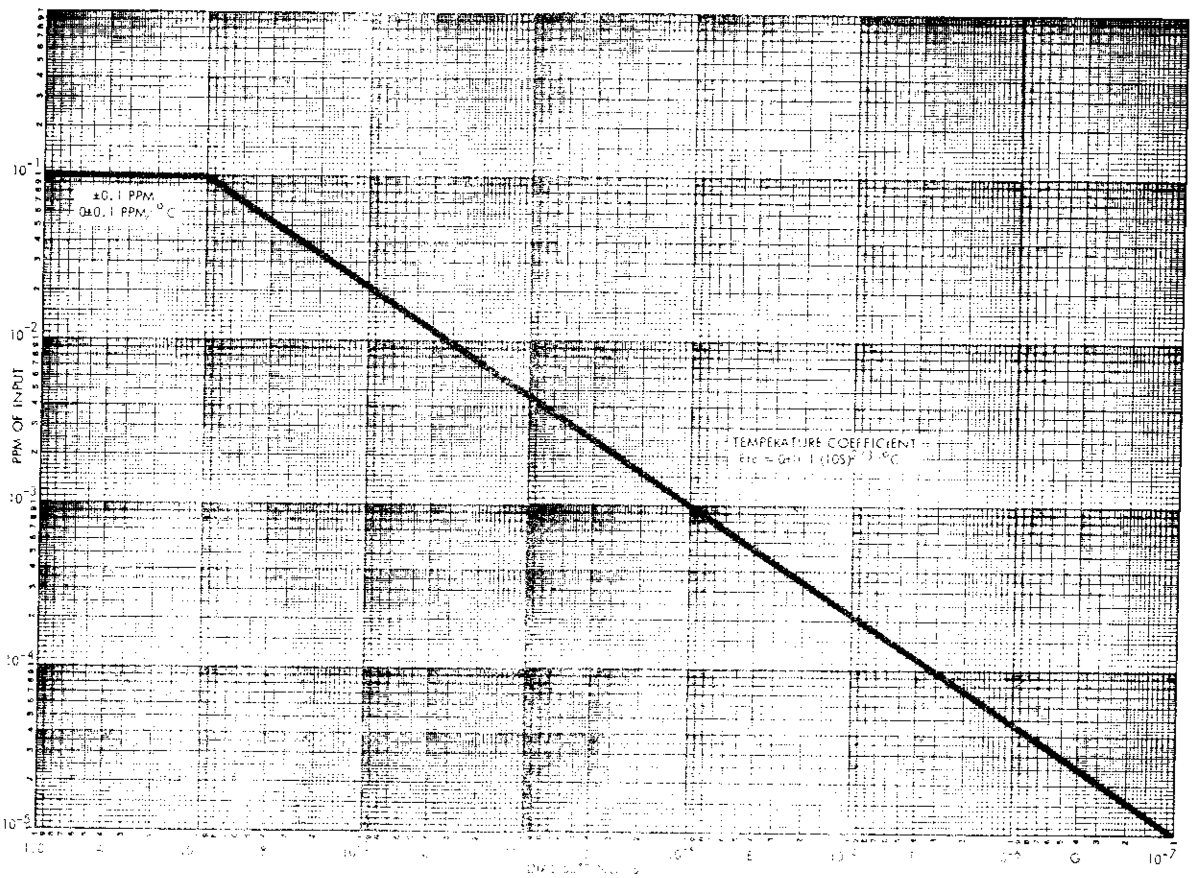


Figure 1-3. TEMPERATURE COEFFICIENT

exceeded and linearity must be derated 0.1 ppm/°C from the calibration temperature.

OPERATING HUMIDITY RANGE
Up to 70% relative humidity at 35°C (95°F): No derating is required.
Up to 80% relative humidity at 35°C (95°F): Linearity derating is 0.1 ppm of input for any relative humidity between 70% and 80%.

STORAGE TEMPERATURE RANGE
-34°C to 70°C (-29°F to 158°F).

SHOCK
Meets requirements of MIL-T-945A and MIL-S-901B, rigidly mounted with slides.

VIBRATION
Meets requirements of MIL-T-945A, rigidly mounted or rack mounted with slides.

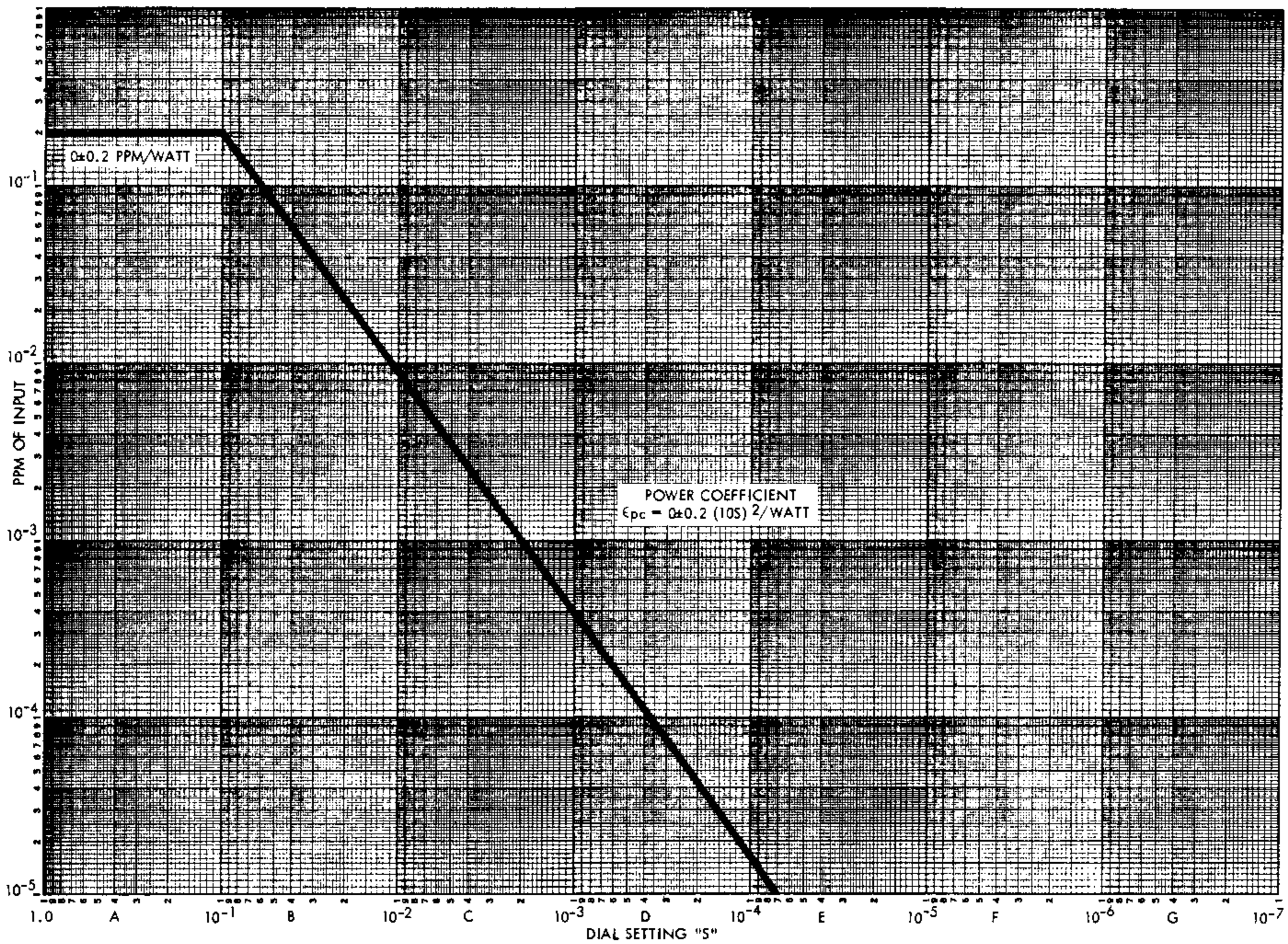


Figure 1-4. POWER COEFFICIENT

Section 2

Operating Instructions

2-1. INTRODUCTION

2-2. Although the Model 720A is a primary ratio standard it has the versatility necessary for use in a wide variety of measurement and control applications. In most applications the divider is used as an element of a system for measuring ratios, voltages, or resistances.

2-3. POWER LIMITATIONS

2-4. It is possible to damage the Model 720A by applying voltages incorrectly to the input terminals or by drawing more than 11 milliamperes from the output tap. The instrument will be damaged if a potential greater than 200 volts is applied between the 1.0 INPUT terminal and the 1.1 INPUT terminal. To prevent damage caused by drawing excessive current from the output tap, either the input or the output can be fused for 11 milliamperes. Another method of protecting the instrument is through the use of a power supply with current limiting capability. The current limit should be set for 11 milliamperes or less.

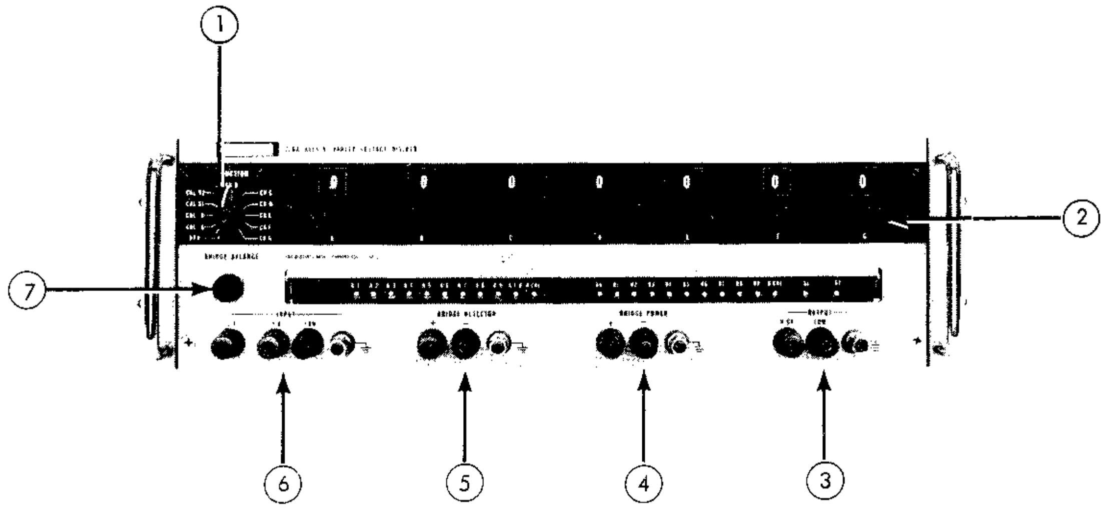
2-5. FUNCTIONS OF CONTROLS AND TERMINALS

2-6. Figure 2-1 shows the controls and terminals of the Model 720A and describes their functions.

2-7. RATIO ERRORS CAUSED BY LOADING OR LEAKAGE

2-8. Measurements of any kind require a knowledge of the errors associated with the equipment used to perform the measurement. Measurement made with the Model 720A are not different.

2-9. One very important source of error in measurements employing the Model 720A is the effect that external load and leakage resistances have on overall accuracy. If excessive current is drawn from the divider output tap because of loading or leakage, linearity errors which far exceed the linearity specifications can result. For this reason, Kelvin-Varley dividers customarily are used in null-balance systems in which minimum current is drawn from the divider output tap.



1	FUNCTION SWITCH	Places instrument in operating mode, or performs internal switching for calibration, or performs internal switching for decade linearity test.
2	DIALS	Decade switches are used to set the ratio of output to input (division ratio).
3	OUTPUT TERMINALS	Provide output voltage of the divider. LOW OUTPUT terminal is connected to LOW INPUT terminal through low compensating resistance.
4	BRIDGE POWER TERMINALS	Used to connect the bridge power for calibration. BRIDGE POWER (-) terminal is used for low input during decade linearity testing.
5	BRIDGE DETECTOR TERMINALS	Used to connect null detector for calibration.
6	INPUT TERMINALS	Used to connect the input voltage across the resistance of the divider.
7	BRIDGE BALANCE CONTROL	Used to balance bridge during self-calibration and calibration.

Figure 2-1. FUNCTIONS OF CONTROLS AND TERMINALS

2-10. Loading Errors

2-11. Figure 2-2 illustrates the Thevinin equivalent for the Model 720A Kelvin-Varley Divider.

To calculate the error in output voltage, as a fraction of the input voltage, the following expressions are given.

$$E_o\,(1 + \epsilon_o) = \frac{S(1+\epsilon)\;E_{IN}\,R_L}{R_L + R_o}$$

but $E_o = SE_{IN}$

therefore $$(1 + \epsilon_o) = \frac{(1+\epsilon)\,R_L}{R_L + R_o}$$

If $R_L \gg R_o$ and $\left(1 + \frac{R_o}{R_L}\right)$ is expanded in series

then

$$(1 + \epsilon_o) = (1 + \epsilon)\left[1 - \frac{R_o}{R_L} + \left(\frac{R_o}{R_L}\right)^2 - \left(\frac{R_o}{R_2}\right)^3 + \ldots\ldots\right]$$

$$\cong (1+\epsilon)\;(1 - \frac{R_o}{R_L})$$

$$\epsilon_o \cong \epsilon - \frac{R_o}{R_L}$$

and $\epsilon_L \cong \frac{R_o}{R_L}$

Converting to errors expressed as a fraction of the input voltage the expression becomes:

$$\epsilon'_o = \epsilon' - \frac{S\,R_o}{R_L}$$

If the 1.1 INPUT terminal is used then:

$$E_o = \frac{S}{1.1}\,E_{IN}$$

and:

$$\epsilon'_o \cong \epsilon' - \frac{SR_o}{1.1\,R_L}$$

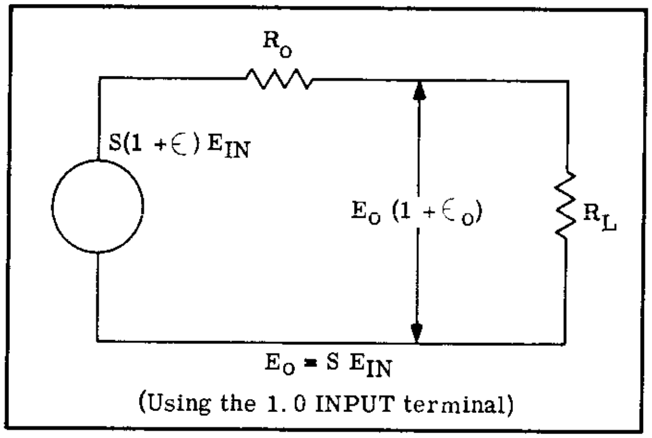


Figure 2-2. THEVININ EQUIVALENT CIRCUIT

2-12. The following list of definitions are given for the terms used in the preceding paragraphs.

a. E_o - Nominal output voltage.

b. E_{IN} - Input voltage.

c. ϵ_o - Error in output voltage as a fraction of output.

d. ϵ - Divider linearity error as a fraction of output.

e. ϵ_L - Loading error as a fraction of output.

f. ϵ'_o - Error in output voltage as a fraction of input.

g. ϵ' - Divider linearity error as a fraction of input.

h. ϵ'_L - Loading error as a fraction of input.

i. S - Divider dial setting.

j. R_o - Divider output resistance.

k. R_L - Load resistance (including leakage resistance from the tap terminal to the divider input terminal).

2-13. Output Resistance Versus Loading

2-14. The graph in Figure 2-3 illustrates the approximate variation of output resistance with the dial setting for both the 1.0 and 1.1 INPUT terminals. This resistance is measured by shorting the input high and input low terminals and measuring the resistance between the output high and low terminals. When computing correction factors for loading of a particular instrument do not use the approximate resistance values given by Figure 2-3. Instead, measure the output resistance at the desired dial setting. The maximum amount of loading which will still be negligible for any dial setting may be calculated as follows:

a. Divider specification = 0.1 ppm of input.

b. Maximum loading error limit = 0.03 ppm of input.

c. $\frac{S\,R_o}{R_L} = \epsilon_L = 0.3 \times 10^{-8}$

d. Maximum R_o = 66 kilohms when S = .454.

e. Minimum $R_L = \frac{S\,R_o}{\epsilon_L} = \frac{(.454)\,(6.6 \times 10^4)}{3 \times 10^{-8}}$

$= 1 \times 10^{12}$ ohms.

2-15. Similar calculations have been made for other dial settings and the results have been plotted in Figure 2-4. The choice of a loading error limit of 0.03 ppm was, of course, arbitrary and should vary over a wide range for different measurement applications. In general, the error should be calculated and allowances made unless the errors are small compared to either the desired measurement accuracies or the divider specifications.

2-16. It should be noted that resistances calculated are the parallel combinations of the load resistor and any leakage resistances which may exist from the tap point (OUTPUT HIGH terminal) to the input terminals of the divider.

2-17. In applications where the load resistance must be supplied with a current, this current may be supplied by either a stable power supply or a second voltage divider in parallel with the measurement divider.

2-18. TEMPERATURE CONTROL

2-19. Because of slight differences in temperature coefficients of the resistors used in the Model 720A, the linearity of the divider will vary with ambient temperature. This change in linearity will never exceed ±0.1 ppm of input per degree centigrade for dial settings above 0.1, and typically will be 0.05 ppm/°C. For measurement applications which require the best possible accuracy, temperature and temperature variations must be considered. The operating temperature should be within 1°C of the self-calibration temperature if at all possible. If the desired operating temperature is

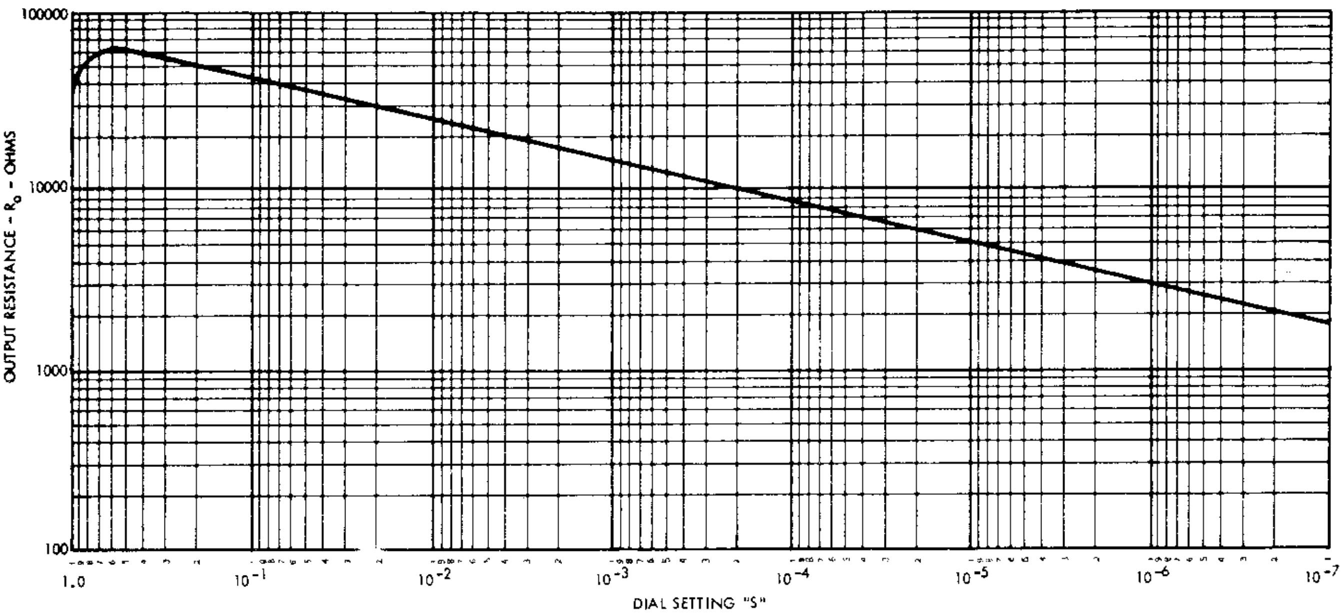


Figure 2-3. APPROXIMATE VARIATION OF OUTPUT RESISTANCE WITH DIAL SETTING

appreciably different from the last calibration temperature, the instrument should be allowed to stabilize at the operating temperature and then the self-calibration procedure should be performed to adjust linearity to 0.1 ppm of input. The Model 720A is factory tested at a temperature of 23 ±1°C.

2-20. POWER COEFFICIENT

2-21. The power coefficient will not exceed 0.2 ppm per watt of input power and typically will be 0.1 ppm per watt or less. With high-voltage applied, self-heating will cause the linearity of the instrument to drift. This drift may continue for as long as four hours after application of the high voltage. Low-voltage, high-accuracy measurements (0.1 ppm) should not be attempted immediately after high-voltage use. Each time the setting of the "A" decade is changed, the power distribution in it is changed because the current through the instrument is divided between the two shunted resistors of the "A" decade and the resistance of the other decades which shunts them. Because of this current division, the two shunted resistors do not become as hot as the other resistors in the "A" decade. The change in current distribution brought about by changing the setting of the "A" decade causes linearity to drift for a few minutes if high voltage is applied.

2-22. END ERRORS

2-23. When the Model 720A is compared to another divider, and a lead compensator such as the Fluke Model 721A is used, absolute linearity may be used directly without correction for end errors. In other applications, the use of a lead compensator is not practical and end error corrections must be applied. Use the following procedure to determine the end error corrections for the Model 720A:

a. Connect the equipment as shown in Figure 2-5 (A).

b. Adjust the input voltage to 1000 volts.

c. With all dials set to zero, measure the voltage between the OUTPUT HIGH terminal and the INPUT LOW terminal. This is the zero error at input low. One microvolt equals 0.001 ppm.

d. Connect the equipment shown in Figure 2-5 (B).

e. Adjust the input voltage to 1000 volts.

f. With all dials set to zero, measure the voltage between the OUTPUT HIGH and OUTPUT LOW terminals. This is the zero error at output low. One microvolt equals 0.001 ppm.

g. Connect the equipment as shown in Figure 2-5 (C).

h. Adjust the input voltage to 1000 volts.

i. With dials set to 999999X, measure the voltage between the OUTPUT HIGH and 1.0 terminals. This is the full-scale error. One microvolt equals 0.001 ppm.

j. Maintain the test set up of Figure 2-5 (C) except move the two leads connected to the 1.0 INPUT terminal to the 1.1 INPUT terminal.

k. Adjust the input voltage to 1000 volts.

l. With all dials set to 1.0 09999X, measure the voltage between the OUTPUT HIGH and 1.1 INPUT terminals. One microvolt equals 0.001 ppm.

2-24. SELF-CALIBRATION PROCEDURE

2-25. Performing this self-calibration procedure adjusts the step resistance and overall resistance of the

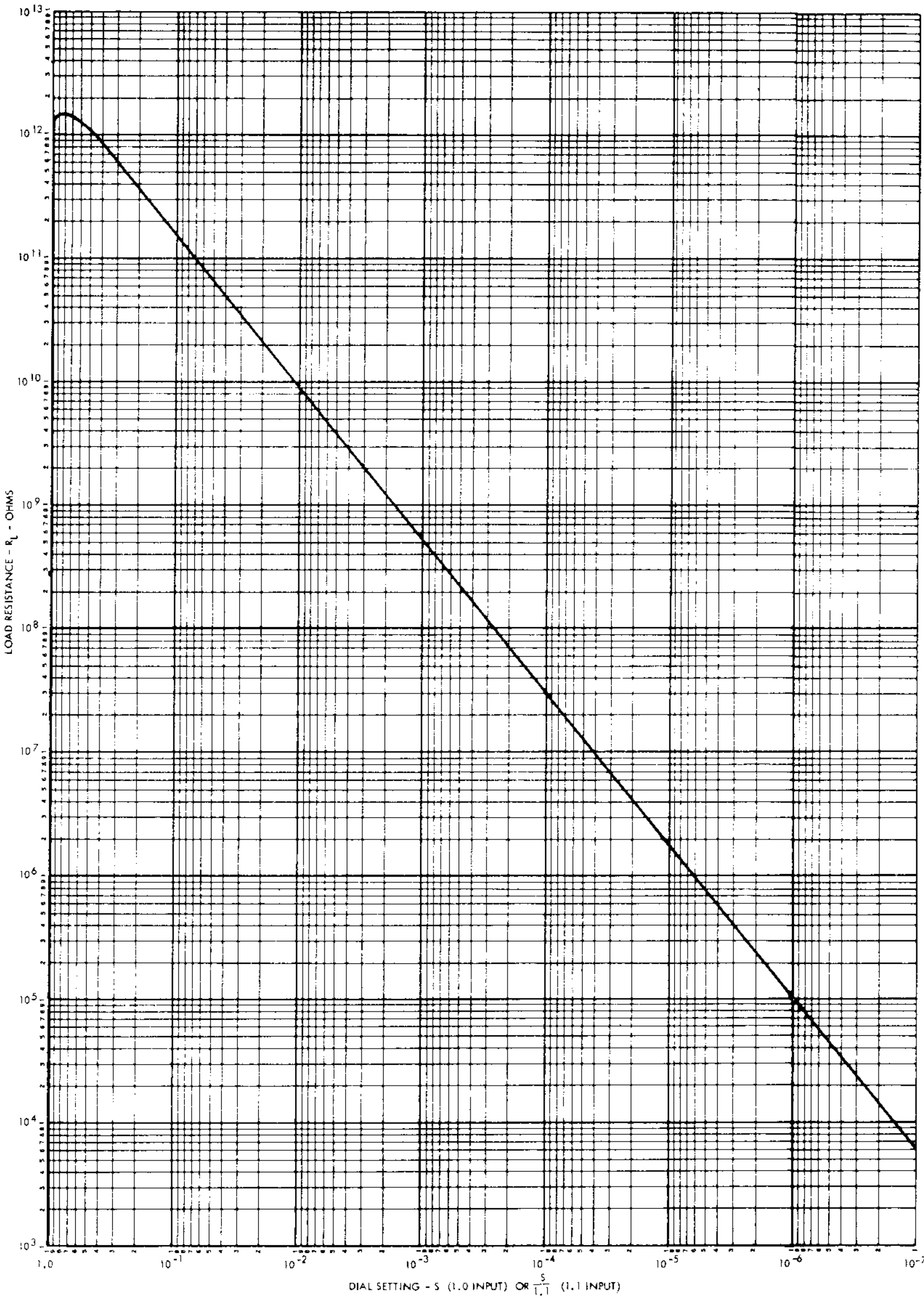


Figure 2-4. APPROXIMATE VARIATION OF MINIMUM LOAD RESISTANCE FOR 0.03 PPM OF INPUT LOADING ERROR

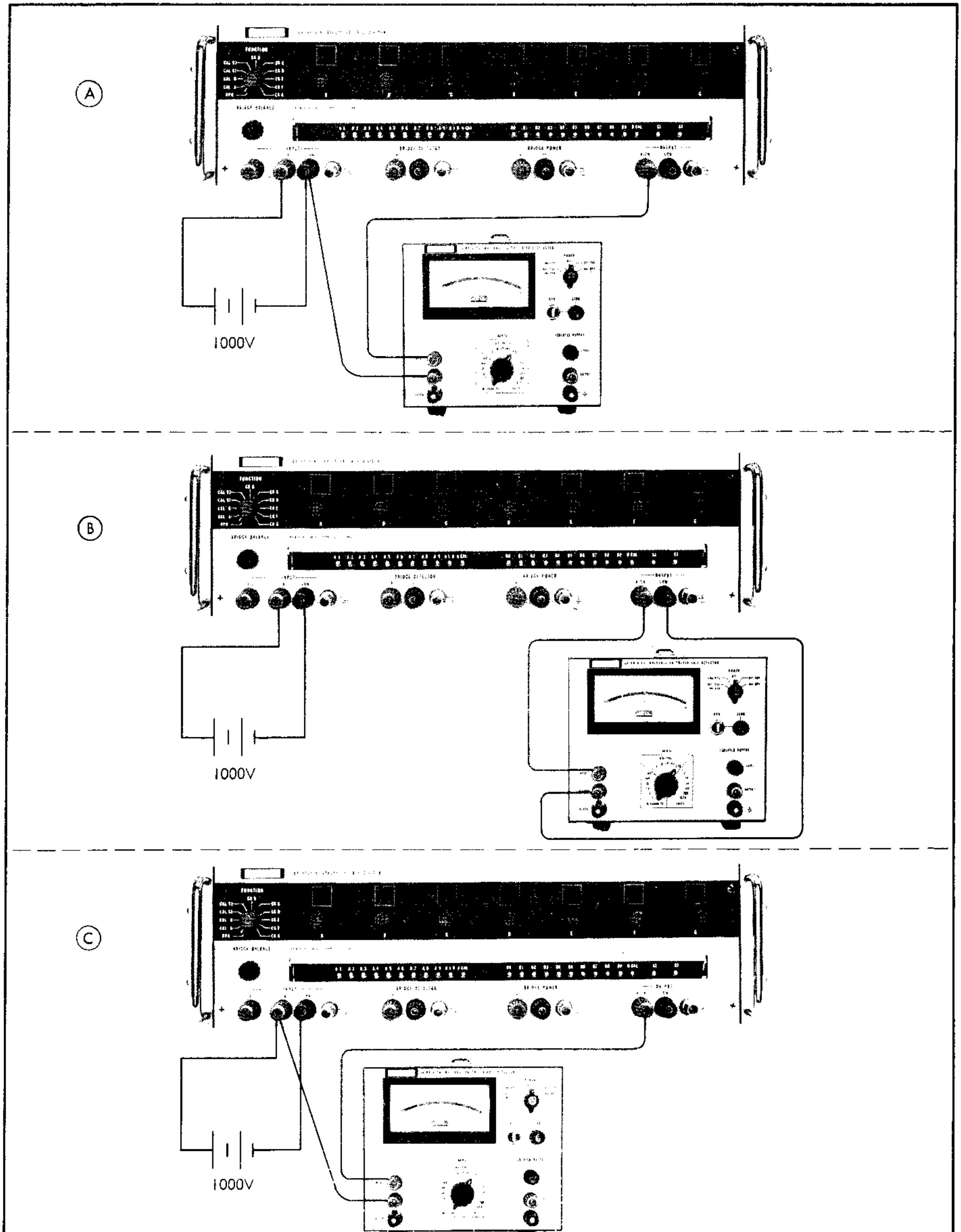


Figure 2-5. CONNECTIONS FOR DETERMINING END ERRORS

first two decades to compensate for any resistance changes caused by temperature changes or aging. Thus, the absolute linearity of the instrument is adjusted to 0.1 ppm of input. The only external test units required are a stable source of 10 volts and 20 volts such as the Fluke Model 412B and a sensitive null detector such as the Fluke Model 845AB. The procedure may be adapted easily to use batteries as the voltage source if a suitable dc power supply is not available. The procedure is as follows:

a. Connect the null detector (845AB) to the BRIDGE DETECTOR binding posts using low thermal leads.

b. On the Model 720A, set the FUNCTION switch to CAL A and the decade readout to .0000000.

c. On the Model 845AB, set the range switch to 10 microvolts; set the OPR ZERO switch to ZERO and adjust for zero meter deflection. Return the OPR-ZERO switch to OPR position.

d. Set the power supply (412B) for 20 volts output and connect it to the BRIDGE POWER binding posts.

e. Adjust the BRIDGE BALANCE control for a null indication on the Model 845AB.

f. Advance the "A" decade to 0.1, and adjust the associated variable resistor (A.1) to produce null, ±0.5 microvolts.

NOTE!

As the procedure is continued, occasionally return the "A" decade switch to zero and recheck bridge balance.

g. In turn, advance the "A" decade one position (A.2 through A CAL) and adjust the associated variable resistor.

h. Return the "A" decade to zero upon completion of the CAL position adjustment.

i. Set the power supply output to 10 volts.

j. Adjust the BRIDGE BALANCE to obtain a null.

k. Set the FUNCTION switch to CAL B, and adjust the associated variable resistor (BO) to produce a null ±1 microvolt.

NOTE!

As the procedure is continued, occasionally return the FUNCTION switch to CAL A and recheck bridge balance.

l. In turn, advance the "B" decade one position (B1 through B CAL) and adjust the associated variable resistor.

m. Return the "B" decade to zero upon completion of the CAL position adjustment.

n. Set the FUNCTION switch to CAL S1 and adjust variable resistor S1 for a null, ±1 microvolt.

o. Set the power supply to 20 volts.

p. Set the "A" decade to .0 and set the FUNCTION switch to CAL A.

q. Adjust the BRIDGE BALANCE control for a null.

r. Set the FUNCTION switch to CAL S2 and adjust variable resistor S2 for a null, ±0.5 microvolt.

s. Set the FUNCTION switch to OPR and disconnect the test units. The self-calibration is complete.

2-26. CHECK POSITIONS OF THE FUNCTION SWITCH

2-27. Check positions (CK B etc.) are provided on the FUNCTION switch to permit checking the linearity of each decade from the front panel. This linearity check is a maintenance procedure. It should not be undertaken as a part of operation.

2-28. APPLICATIONS OF THE MODEL 720A

2-29. The following paragraphs give general instructions and equipment connections for calibrating a voltage divider, measuring unknown voltages, and measuring unknown resistances. Although these are by no means

TYPICAL EQUIPMENT	REQUIRED SPECIFICATIONS
DC Voltage source; John Fluke Mfg. Co. Model 332B or equivalent.	Output voltage from 0 to 1100 volts. Stability of 0.0015% per hour. Output ripple less than 40 uv rms.
DC Null Detector; John Fluke Mfg. Co. Model 845AB or equivalent.	1 uv full-scale sensitivity. 10 megohms input resistance.
Lead compensator; John Fluke Mfg. Co. Model 721A	Resolution of 0.1 milliohm.

Figure 2-6. TYPICAL ASSOCIATED EQUIPMENT FOR VOLTAGE DIVIDER CALIBRATION

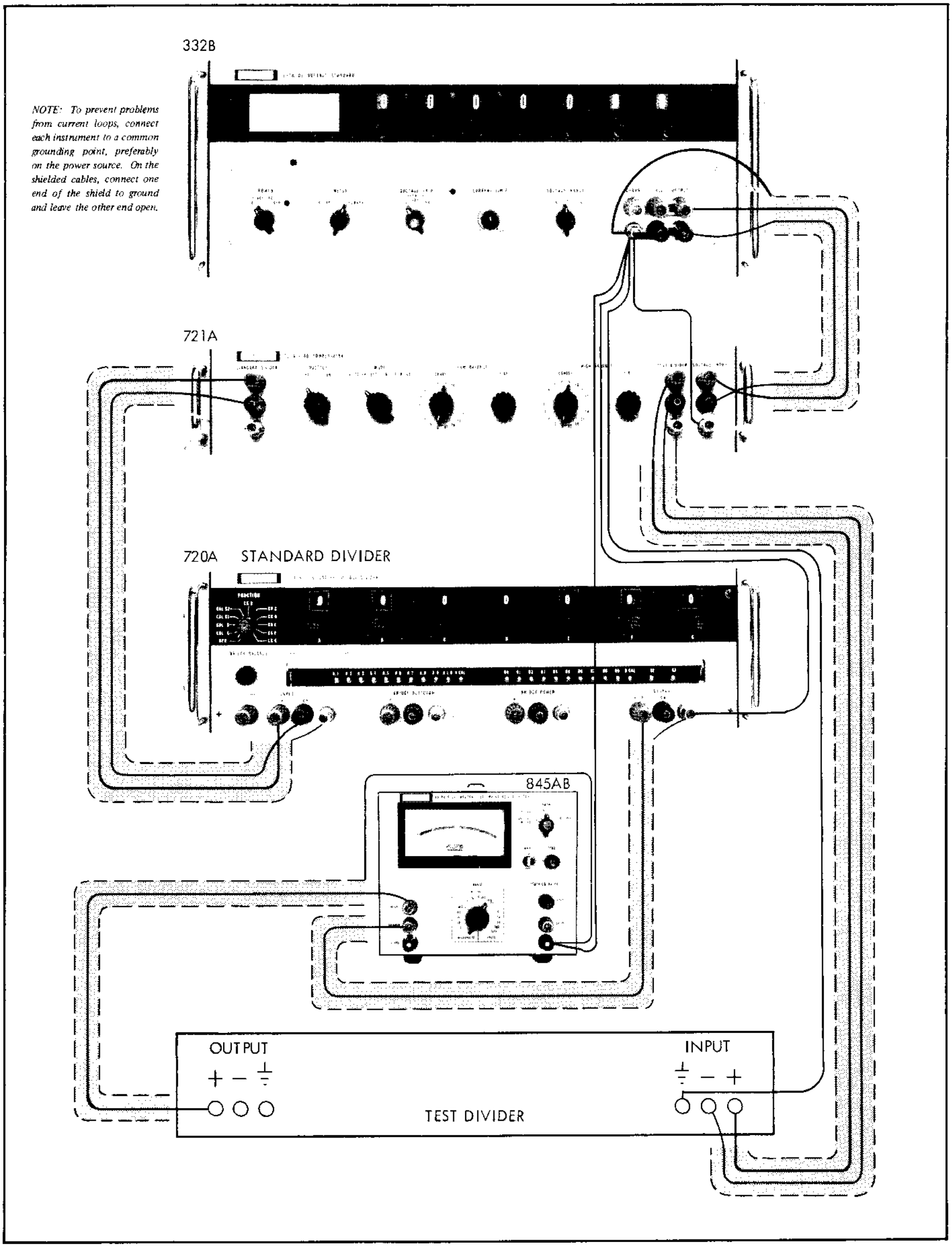


Figure 2-7. EQUIPMENT CONNECTIONS FOR CALIBRATING A VOLTAGE DIVIDER

the only applications of the instrument, they are the most common applications of a high-accuracy Kelvin-Varley divider such as the Model 720A.

2-30. Calibrating a Voltage Divider

2-31. The Model 720A in company with a dc voltage source, a null detector, and a lead compensator can be used to calibrate voltage dividers to an accuracy of 0.1 parts per million of input. Typical associated equipment for this application is listed in Figure 2-6. With this equipment, the full electrical capabilities of the Model 720A Kelvin-Varley Voltage Divider may be realized.

2-32. To calibrate a voltage divider, connect the equipment as shown in Figure 2-7 and proceed as follows:

NOTE!

Figure 2-8 is a schematic diagram of the test setup obtained by interconnecting the equipment as shown in Figure 2-7.

a. Set both dividers to zero.

b. Turn all equipment on and allow it to warm up until it reaches temperature equilibrium.

c. Place the null detector in zero mode, adjust it for zero deflection, and return it to operating mode.

d. Adjust the LOW BALANCE controls of the lead compensator to obtain a zero indication on the null detector.

e. Turn the HIGH BALANCE COARSE control to the same setting as the LOW BALANCE COARSE control.

NOTE!

If the dividers are set from one calibration point to the next while the test setup is energized, the null detector meter will require several seconds to recover between readings. Measurement may be performed more rapidly if the VOLTAGE switch of the lead compensator is turned to OFF before switching. Measurement may be speeded further by turning the ZERO-OPR switch of the null detector to ZERO during switching. This prevents the transient caused by turning the voltage on, from saturating the null detector amplifier.

f. Set both dividers to full scale and adjust the HIGH BALANCE FINE control to obtain a zero indication on the null detector.

g. Set both dividers to zero and re-adjust the LOW BALANCE FINE control if necessary to obtain a zero indication on the null detector.

h. Set both dividers to the first calibration point.

i. Observe the null detector and adjust the Model 720A to obtain a zero indication on the null detector. The difference between the setting of the Model 720A and the nominal value of the calibration point is the error of the divider being calibrated expressed as a decimal fraction of the input.

j. Find the error at each calibration point until the calibration is complete.

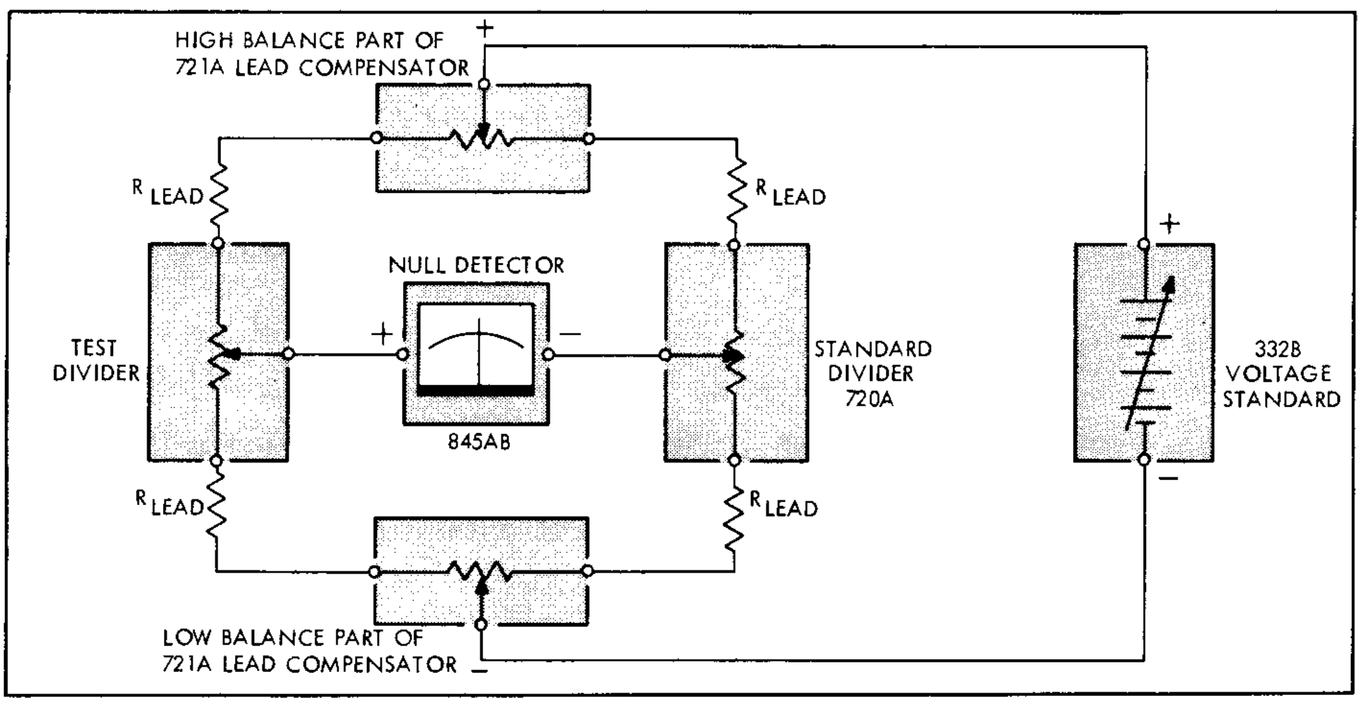


Figure 2-8. SIMPLIFIED SCHEMATIC DIAGRAM OF VOLTAGE DIVIDER CALIBRATION

TYPICAL EQUIPMENT	REQUIRED SPECIFICATIONS
DC Voltage Source; John Fluke Mfg. Co. Model 332B or equivalent.	Output voltage from 0 to 1100 volts. Stability of 0.0015% per hour. Output ripple less than 40 uv rms.
DC Null Detector (2 required); John Fluke Mfg. Co. Model 845AB or equivalent.	1 uv full-scale sensitivity. 10 megohms input resistance.
Standard Cell; Guildline Instruments Model 9152 or equivalent.	At least three saturated cells. Accuracy of 0.0005%.
DC Reference Voltage Divider; John Fluke Mfg. Co. Model 750A or equivalent.	Output accuracy of ±10 ppm. Input and output voltage. Rating of 1100V dc.

Figure 2-9. TYPICAL ASSOCIATED EQUIPMENT FOR MEASURING UNKNOWN VOLTAGES

2-33. Measuring Unknown Voltages

2-34. The Model 720A in company with a stable dc voltage source, two null detectors, a standard cell, and a reference voltage divider may be used to measure an unknown voltage with high accuracy. Typical equipment for this application is listed in Figure 2-9. With this equipment the full electrical capabilities of the Model 720A may be realized.

2-35. To measure an unknown voltage, first connect the equipment as shown in Figure 2-10. The size of wire for leads A and B should be no smaller than No. 24 and the total length should be less than 3 feet. Then measure the approximate voltage by dialing the Model 720A to .0000000 and reading the null detector on the appropriate voltage range. Proceed as follows:

a. Open the standard cell voltage switch on the reference divider and set the standard cell voltage dials to the correct standard cell voltage.

b. Set the reference divider input switch to the first position higher than the voltage to be measured. Set the output switch to the same position.

c. Turn on all equipment and allow it to warm up until it reaches temperature equilibrium.

d. Set the standard cell switch of the reference divider to momentary position and adjust the output of the dc source to obtain a null indication on null detector number 1.

e. Adjust the readout dials of the Model 720A to obtain a null indication on null detector number 2.

f. Calculate the unknown voltage by multiplying the input voltage of the Model 720A by the numerical setting of the readout dials. For example, if the input voltage is 100 volts and the dial setting is .8903174, the unknown voltage is 89.03174 volts.

2-36. Simplified Method of Voltage Measurement

2-37. Voltages under 11 volts may be measured with comparable accuracy by the simpler equipment setup shown in Figure 2-12. This method standardizes the output voltage of the Model 720A by comparing it directly to a known standard cell. When used with an input of 1.1 volts, it is ideally suited to the accurate certification of standard cells. Typical associated equipment for this application is listed in Figure 2-11.

2-38. To measure the unknown voltages, connect the equipment as shown in Figure 2-12 and proceed as follows:

a. Set the dc voltage source for an output of eleven or 1.1 volts depending on the desired range and allow to warm up.

b. Set the readout dials of the Model 720A to the standard cell voltage.

c. Connect the standard cell in place of the unknown voltage and adjust the dc source to obtain a null indication on the null detector.

d. Disconnect the standard cell.

e. Set the readout dials of the Model 720A to the approximate value of the unknown voltage.

f. Connect the unknown voltage.

g. Adjust the readout dials of the Model 720A to obtain a null indication on the null detector.

h. Calculate the unknown voltage by multiplying by 10 or 1 depending on the range. For example, if the readout dials are set at .7500055 and the input is 11 volts, the unknown voltage is 7.500055 volts.

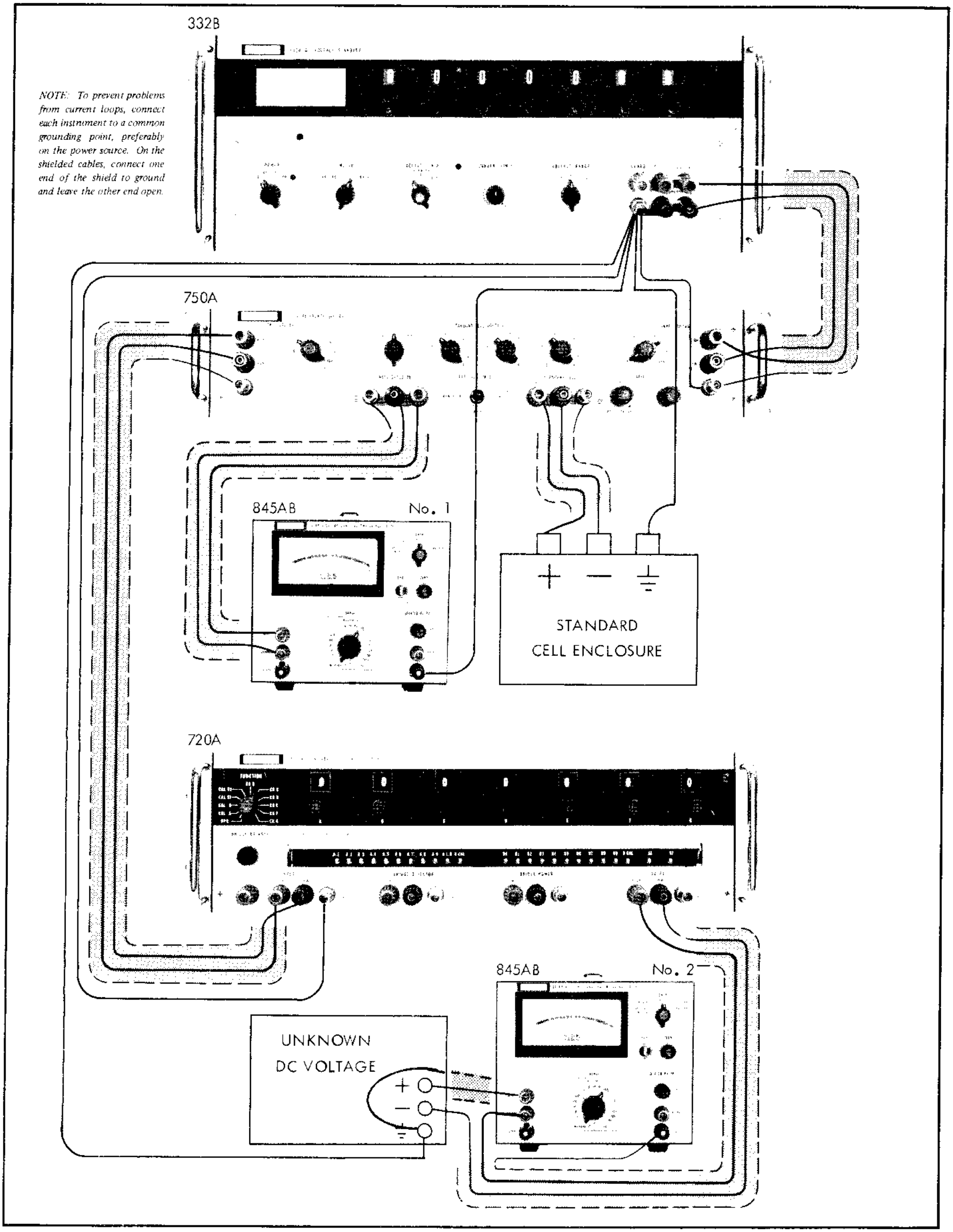


Figure 2-10. EQUIPMENT CONNECTIONS FOR VOLTAGE MEASUREMENTS (Sheet 1 of 2)

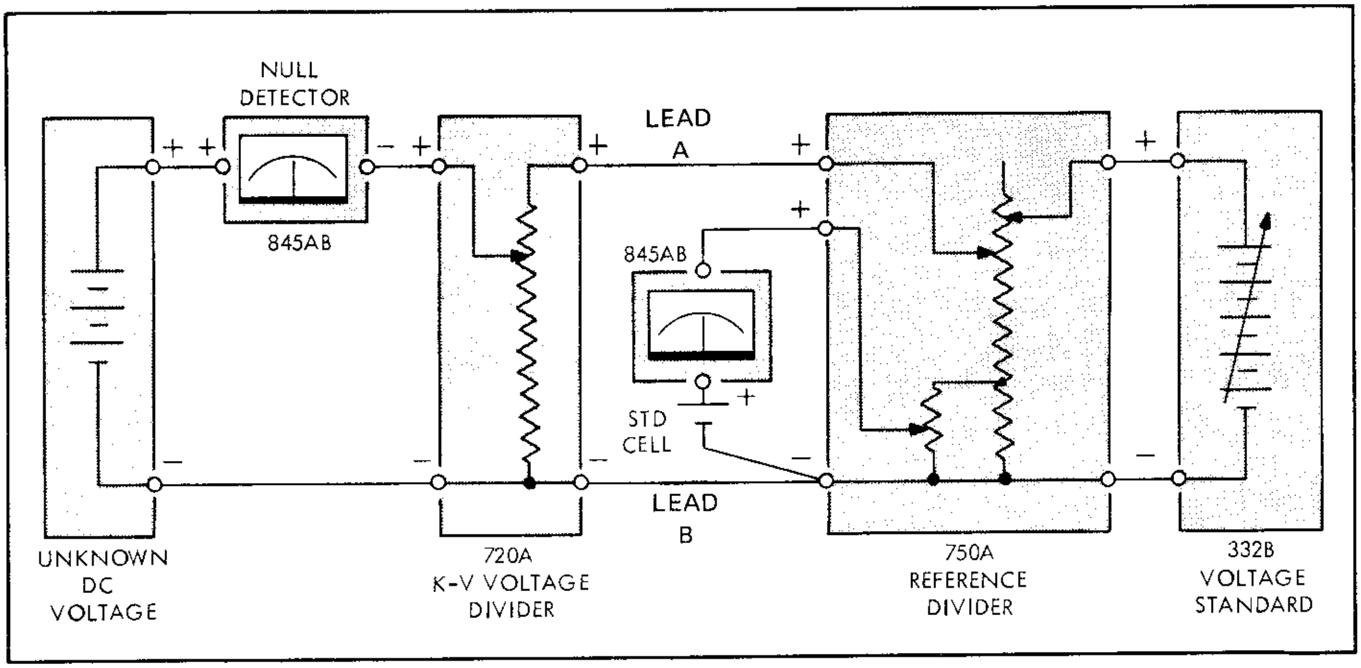


Figure 2-10. EQUIPMENT CONNECTIONS FOR VOLTAGE MEASUREMENTS (Sheet 2 of 2)

2-39. Measuring Unknown Resistance

2-40. The Model 720A may be used in a setup including a null detector, a power supply, and a standard resistor, to measure an unknown resistance with a high degree of accuracy. Typical associated equipment for this application is listed in Figure 2-13. The unknown resistance and the standard resistance should be in the same order of magnitude for the best accuracy.

2-41. To measure an unknown resistance, connect the equipment as shown in Figure 2-14 using shielded leads. Apply the positive lead from the dc voltage source to the 1.0 INPUT terminal of the Model 720A. Proceed as follows:

> P_1, P_2, P_3, and P_4 = decimal ratio set on the readout dials of the Model 720A at points P_1, P_2, P_3, and P_4 respectively.

If Rx + R std is greater than 100 ohms, the use of a lead compensator is desirable. If a lead compensator is used, P_1 can be made equal to 1.0000000 and P_4 can be made equal to .0000000.

$$\frac{Rx}{R\ std} = \frac{1 - P_2}{P_3}$$

If lead resistance between the resistors is made insignificant in addition to using a lead compensator, then $P_2 = P_3$ and the equation may be further simplified to:

$$\frac{Rx}{R\ std} = \frac{1}{P} - 1$$

a. Set the dc voltage source to the desired test voltage.

CAUTION!

Do not exceed the current rating of the standard resistor.

b. Set the readout dials of the Model 720A to zero.

c. Connect the null detector lead to point P_1 and adjust the readout dials of the Model 720A to obtain a null indication. Record the dial reading.

TYPICAL EQUIPMENT	REQUIRED SPECIFICATIONS
DC Voltage Source; John Fluke Mfg. Co. Model 332B or equivalent.	Output voltage from 0 to 1100 volts. Stability of 0.0015% per hour. Output ripple less than 40 uv rms.
DC Null Detector John Fluke Mfg. Co. Model 845AB or equivalent.	1 uv full-scale sensitivity. 10 megohms input resistance.

Figure 2-11. TYPICAL ASSOCIATED EQUIPMENT FOR MEASURING UNKNOWN VOLTAGES

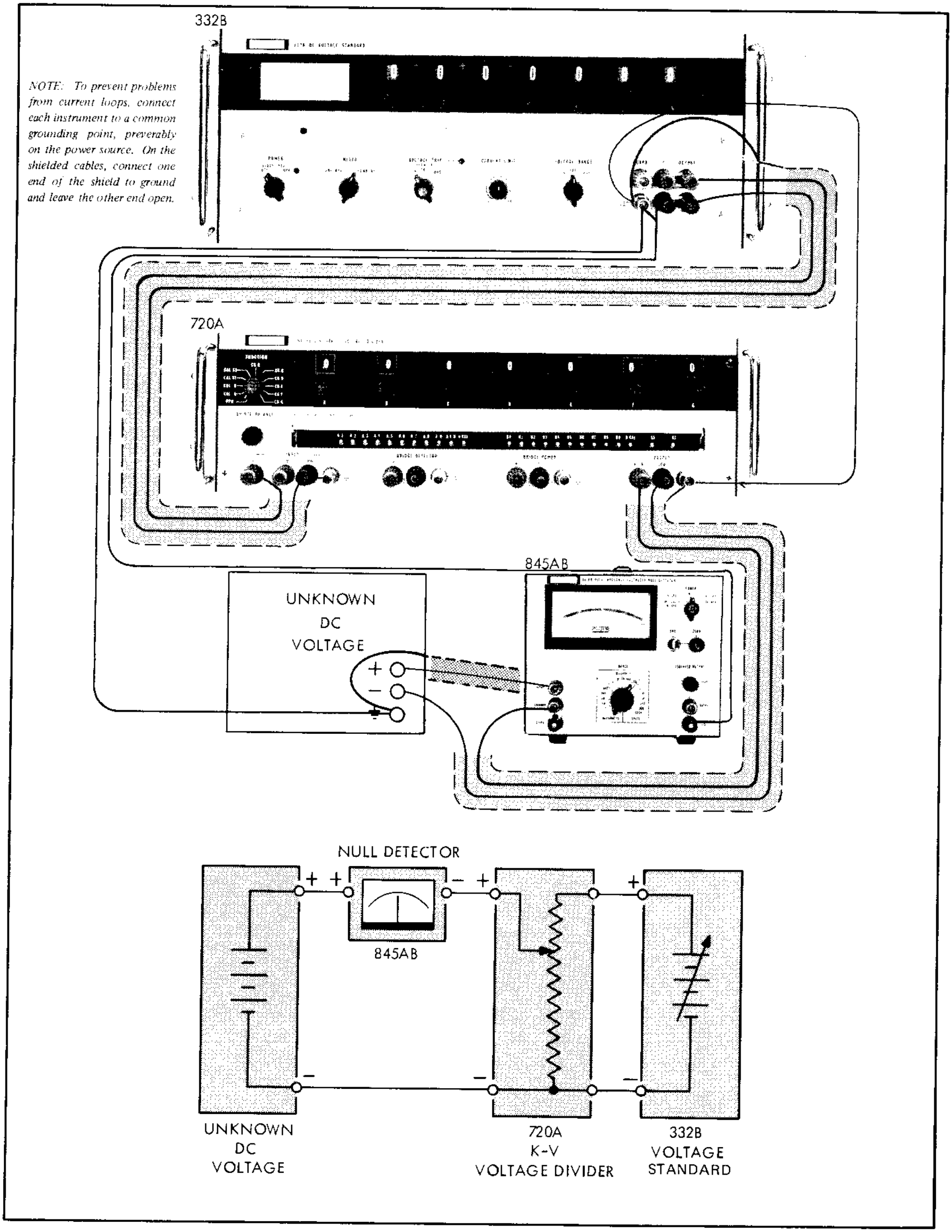


Figure 2-12. EQUIPMENT CONNECTIONS FOR SIMPLIFIED METHOD OF VOLTAGE MEASUREMENT

TYPICAL EQUIPMENT	REQUIRED SPECIFICATIONS
DC Voltage Source; John Fluke Mfg. Co. Model 332B or equivalent.	Output voltage from 0 to 1100 volts. Stability of 0.0015% per hour. Output ripple less than 40 uv rms.
DC Null Detector John Fluke Mfg. Co. Model 845AB or equivalent.	1 uv full-scale sensitivity. 10 megohms input resistance.
Standard resistor.	

Figure 2-13. TYPICAL ASSOCIATED EQUIPMENT FOR MEASURING UNKNOWN RESISTANCE RATIOS

d. Move the null detector lead to point P_2, adjust the readout dials to obtain a null, and record the dial reading.

e. Move the null detector lead to point P_3, adjust the readout dials to obtain a null, and record the reading.

f. Move the null detector lead to point P_4, adjust the dials to obtain a null, and record the dial reading.

g. Calculate the unknown resistance from the following equation.

$$\frac{Rx}{R\ std} = \frac{P_1 - P_2}{P_3 - P_4}$$

where:

Rx = unknown resistance
R std = standard resistance

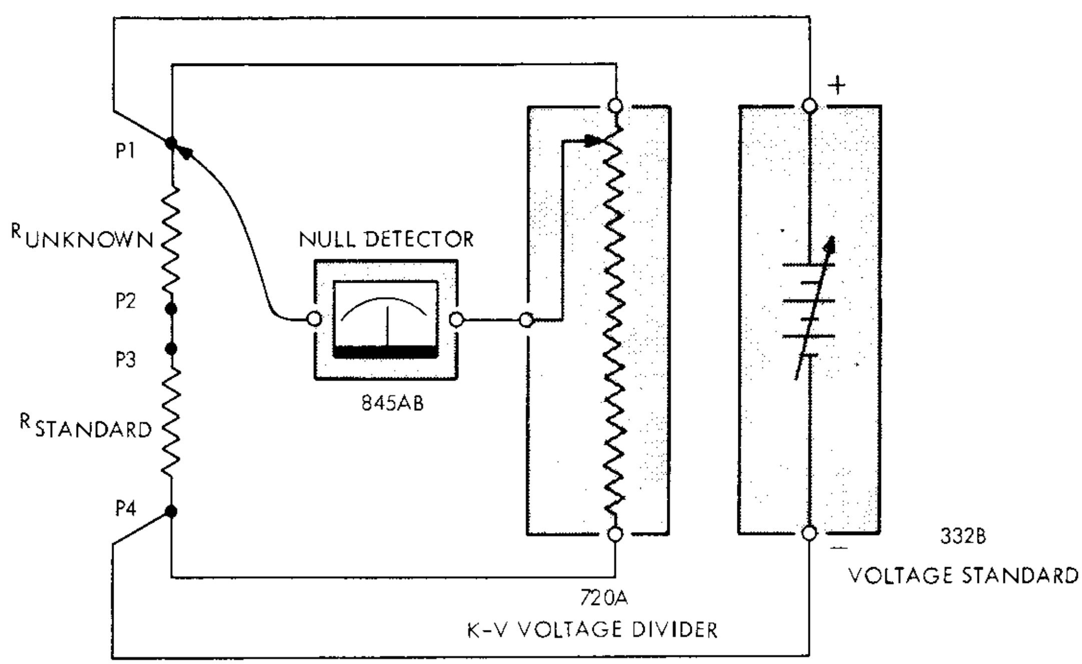


Figure 2-14. EQUIPMENT CONNECTIONS FOR DETERMINING AN UNKNOWN RESISTANCE VALUE (Sheet 1 of 2)

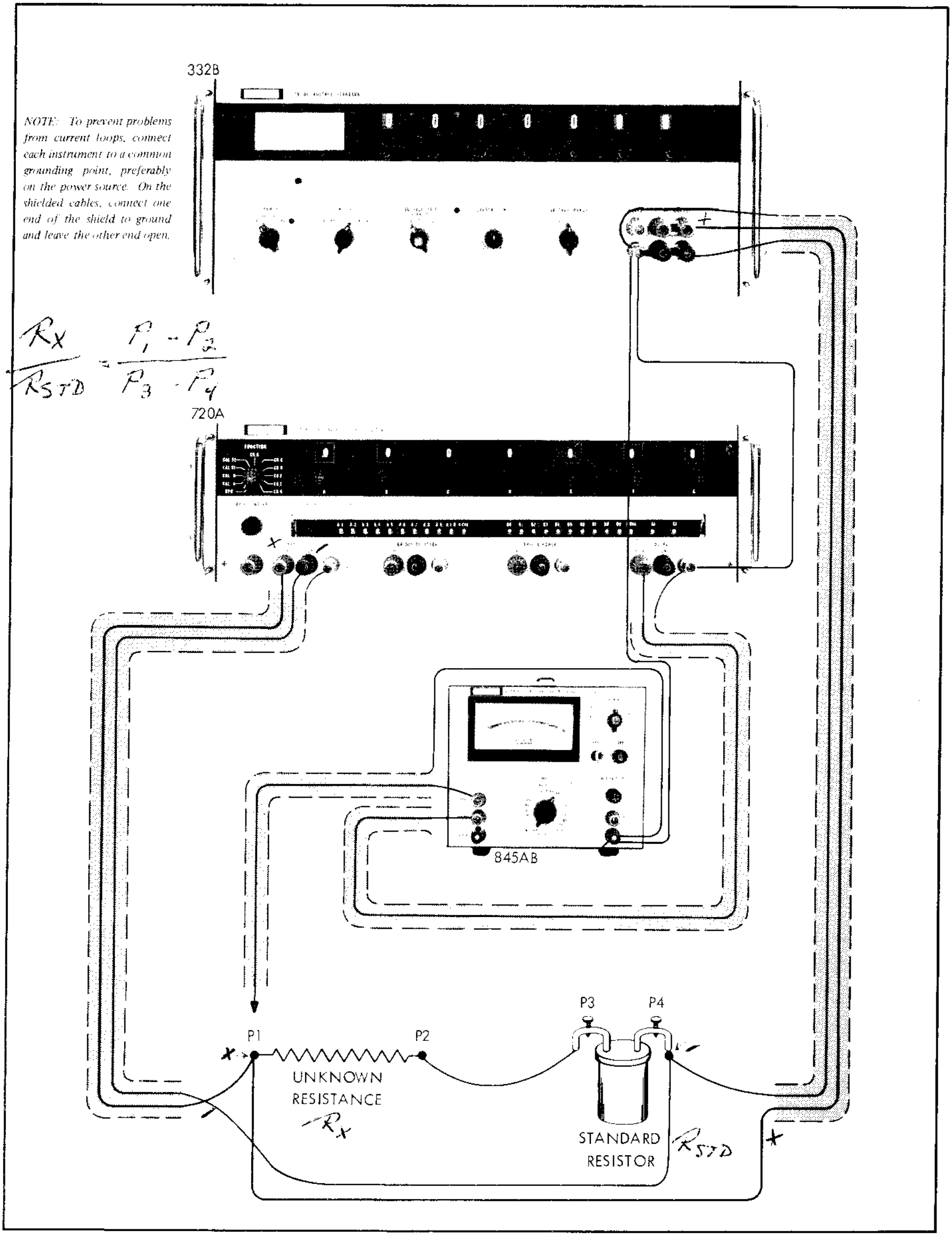


Figure 2-14. EQUIPMENT CONNECTIONS FOR DETERMINING AN UNKNOWN RESISTANCE VALUE (Sheet 2 of 2)

Section 3
Theory of Operation

3-1. INTRODUCTION

3-2. The Kelvin-Varley divider is a resistive circuit used primarily as a ratio standard. It is capable of dividing the input voltage with high resolution, usually to six or seven decimal places, and with high accuracy, usually a few parts per million.

3-3. THE BASIC CIRCUIT

3-4. Figure 3-1 is a simplified schematic diagram of a basic Kelvin-Varley divider. This simplified divider is capable of dividing the input voltage into 10, 000 parts. It consists of four decades or resistive dividers each of which divides its input voltage into 10 equal parts ($10^4 = 10,000$).

3-5. For a decade to divide the voltage across it into 10 equal parts it must consist of 10 equal resistances. Placing the resistance of succeeding decade in parallel with a portion of the resistance of a decade, reduces the effective resistance of that portion. Referring to Figure 3-1, notice that the shunted resistance in the first decade is 20 kilohms and that each of the other steps is 10 kilohms. The 20 kilohms in the first decade is shunted by the 20 kilohms total effective resistance of the second decade resulting in a total effective resistance of 10 kilohms for that step. Thus all steps are kept equal. Each step of the second decade is two kilohms. The four kilohms spanned by the switch contacts is shunted by the four kilohms effective resistance of the third decade. Similarly 800 ohms of the third decade is shunted by the 800 ohms total resistance of the fourth decade.

3-6. CIRCUIT REFINEMENTS

3-7. Although the simplified Kelvin-Varley divider shown in Figure 3-1 shows all of the essential details of the basic circuit, a number of common design refinements should be mentioned. The latter decades may employ step resistors which are all of the same value and a shunt across the entire decade to reduce the effective decade resistance to the proper value. In Figure 3-1, this could be accomplished by using 400 ohm resistors in the fourth decade with a 1000 ohm shunt across the decade to reduce the effective resistance of the decade to 800 ohms. This avoids the necessity of using resistors of very small value in the latter decades. Usually each step of at least the first decade will consist of two equal resistors matched for equal but opposite temperature coefficients. This matching tends to produce a zero temperature coefficient for each step and for the entire decade, which reduces the nonlinearity caused by uneven temperature when power is applied. Some Kelvin-Varley dividers have adjustable trimmer resistors in the first, or even the second and third decades to permit compensation for drift and changes of ambient temperature. Overranging capability is provided in some circuits by adding an additional step of resistance and a 1. 1 input terminal at the upper end of the first decade. In some dividers a small series resistance is added between the lower end of the divider string and the low input terminal to compensate for contact and wiring resistance bringing the low output voltage at zero setting to the same value as the low input voltage. Although these refinements improve the capability of the circuit, it operates in the same manner with them as without them.

3-8. THE MODEL 720A

3-9. The Model 720A is a seven-dial Kelvin-Varley divider with overranging and adjustable trimmers in the first three decades. The low output is compensated by a small resistance in series with the low input terminal. The input resistance (total effective resistance of the first decade is 110 kilohms at the 1. 1 input terminal or 100 kilohms at the 1. 0 input terminal. Resistors of equal value and fixed decade shunts are used in the last four decades to avoid using very small resistance values.

3-10. Design characteristics of the Model 720A which are not commonly found in Kelvin-Varley dividers include adjustable shunts in the first three decades, a built-in Wheatstone bridge, and switching to permit linearity adjustment (self-calibration) from the front panel. In addition, internal switching provides access to the second through the seventh decades so the linearity of any decade may be checked against a 10-step divider from the front panel.

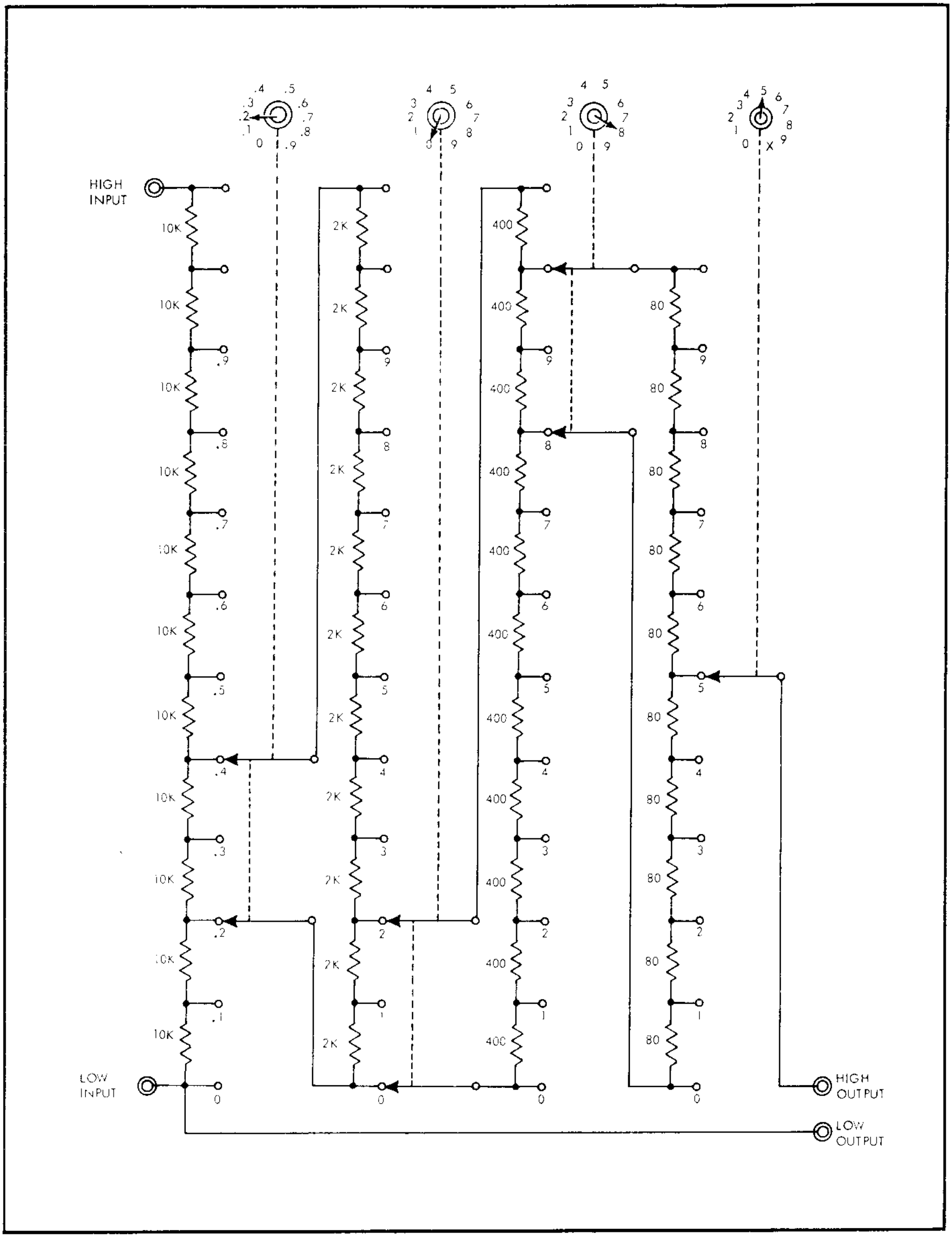


Figure 3-1. SIMPLIFIED SCHEMATIC DIAGRAM OF BASIC KELVIN-VARLEY DIVIDER CIRCUIT

Section 4
Maintenance

4-1. INTRODUCTION

4-2. This section contains the instructions and information required for maintenance of the Model 720A Kelvin–Varley Divider. Instructions are included for preventive maintenance, testing and repair of the instrument. If repair is beyond the capability of the user, it is recommended that the instrument be returned to the manufacturer. All maintenance procedures except the replacement of factory selected resistors and resistors housed in the oil tank are within the capability of a skilled technician if the listed test equipment is available.

4-3. The ratio accuracy of 0.1 ppm of the Model 720A is guaranteed for one year after shipment from the factory provided the instrument is regularly self-calibrated in accordance with paragraph 2-24 and is operated in the same environment in which it is self-calibrated. The instrument also must meet the requirements of the Leakage Resistance Test, paragraph 4-8. In the self-calibration procedure, all resistors on the A and B decades are adjusted to be equal to each other by substituting each in turn into the self-contained resistance bridge. The Linearity Test given in paragraph 4-14 should be performed once each year to verify instrument performance. If testing and calibration are beyond the capability of the user, these services may be obtained from a commercial calibration laboratory or from the manufacturer.

4-4. TEST EQUIPMENT REQUIRED FOR MAINTENANCE

4-5. The test equipment required for maintenance is listed in Figure 4-1. Equivalent or similar units may be substituted for those listed providing they have the required specifications listed in the figure.

4-6. PREVENTIVE MAINTENANCE

4-7. Preventive maintenance of the Model 720A consists of leakage resistance testing, cleaning, switch contact lubrication, and linearity testing. The frequency with which preventive maintenance procedures should be scheduled depends upon the user's requirements and the environment of the instrument. In an air conditioned standards laboratory, there will be little contamination of surfaces within this instrument and therefore testing and cleaning will seldom be required. In a contaminated atmosphere, frequent testing and cleaning may be required to maintain the accuracy of the instrument.

4-8. Leakage Resistance Tests

4-9. The need for cleaning can be determined without removing the cover from the Model 720A by performing

RECOMMENDED EQUIPMENT	SPECIFICATIONS REQUIRED
DC Voltage Source John Fluke Mfg. Co. Model 332B or Model 412B	Source of 0 to 1100 vdc. Accuracy at least 0.25% Stability at least 0.005% per hour.
DC Null Detector John Fluke Mfg. Co. Model 845AB	Sensitivity at least 10 microvolts full scale. 10 Megohm input Resistance.
Lead Compensator John Fluke Mfg. Co. Model 721A	Resolution of 0.1 milliohm. Ratio capability of 110:1
Standard Divider John Fluke Mfg. Co. Model 720A	Ratio accuracy of 0.1 ppm of input.
Standard Divider (11 Steps)	Ratio accuracy of 0.05 ppm of input
Decade Resistance Standard Electro Scientific Industries Model RS925A	4007.6 ohms, 10,000 ohms Accuracy of ±20 ppm

Figure 4-1. TEST EQUIPMENT REQUIRED FOR MAINTENANCE

the simple leakage resistance test described in this paragraph. This test should also be performed after cleaning to assure that all contamination has been removed. To measure leakage resistance, proceed as follows:

a. Place the Model 720A on a sheet of dielectric.

b. Use teflon insulated wire to connect the Model 720A, a 1000-volt source (Model 332B), and a null detector (Model 845AB) as shown in Figure 4-2.

c. Connect a shunt resistor across the input of the null-detector to bring its input resistance to one megohm on the one millivolt range. The value required for the Model 845AB is 1.1 megohms.

d. Turn on the 1000-volt supply and read the null detector. An indication of 1 millivolt corresponds to leakage resistance of 10^{12} ohms. If the indication is more than 1 millivolt, the leakage resistance is too low and corrective measures must be taken. If repeated cleaning fails to correct the problem, troubleshooting must be undertaken.

4-10. CLEANING

4-11. When the Model 720A is properly cared for and kept in a controlled atmosphere, cleaning will seldom be required. However, any contamination, particularly oil, in the instrument can contribute to reduced leakage resistance which will impair accuracy. Special care has been taken in the design and manufacture of the instrument to prevent leakage. The voltage dial switches are supported by Lexan spacers, and the circuit board is coated with a moisture sealant and isolated from the chassis by polyethelene grommets. These insulators and the switches can be contaminated easily by handling or by airborne contaminants. Dust may be removed with dry oil-free air at a pressure of 15 pounds per square inch or less. To remove oil, place the instrument on its side, place paper towels under it and spray with denatured anhydrous ethyl alcohol, Crown SPRA-TOOL No. 8011 or equivalent. When dry, perform switch contact lubrication, paragraph 4-12. After cleaning and drying, the leakage resistance test should be performed to assure that the excessive leakage has been corrected.

4-12. Switch Contact Lubrication

4-13. Corrosion of switch contacts can cause high contact resistance in one or more positions resulting in an impairment of linearity. If evidence of this condition is present and exercising the switch fails to correct it, the switch contact should be lubricated with a special purpose switch lubricant. The product recommended for this purpose is Rykon lubricant No. 2 EP (American Oil Co.) mixed with Tuluol. It should be carefully applied in a very thin film with a camel's hair brush.

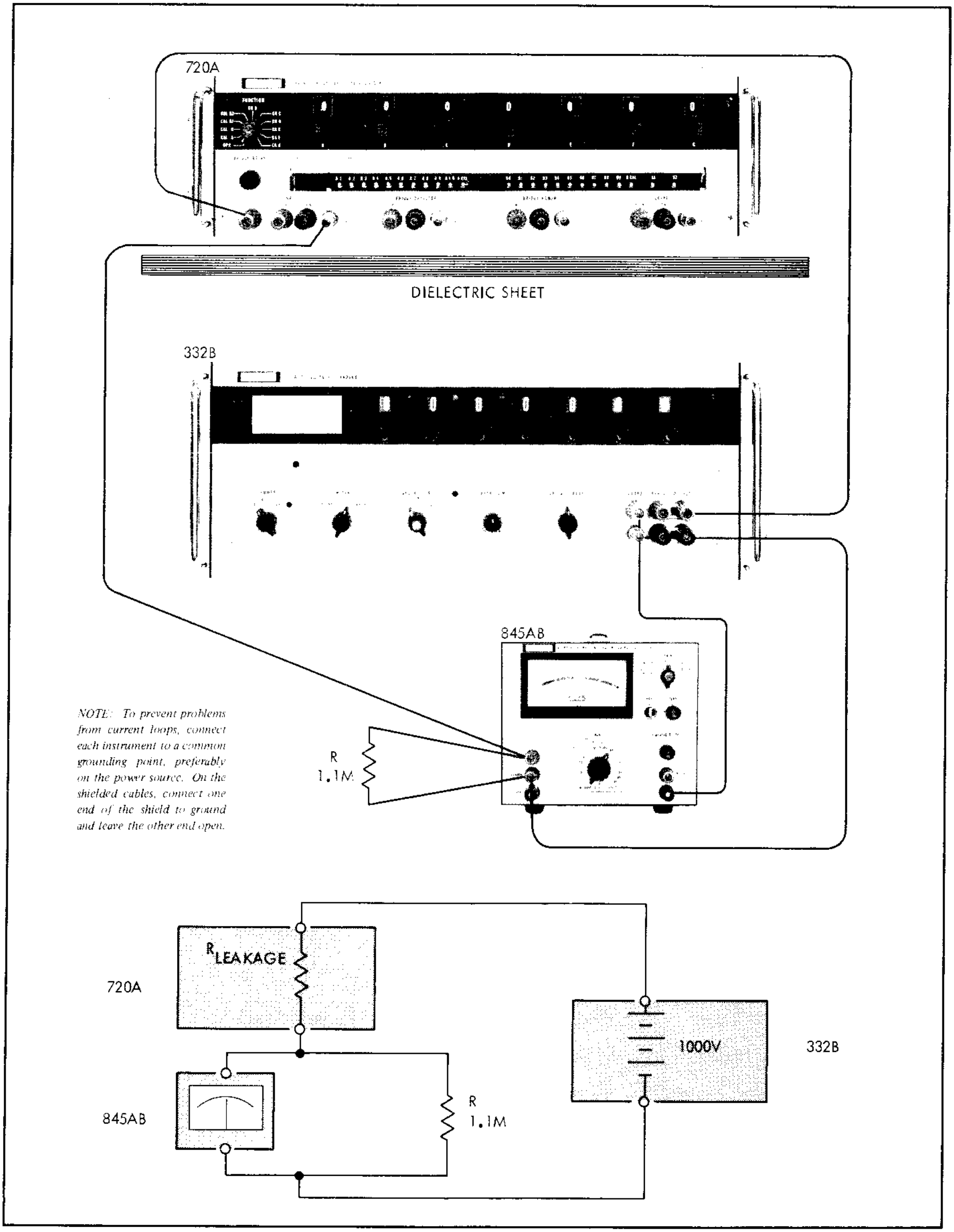
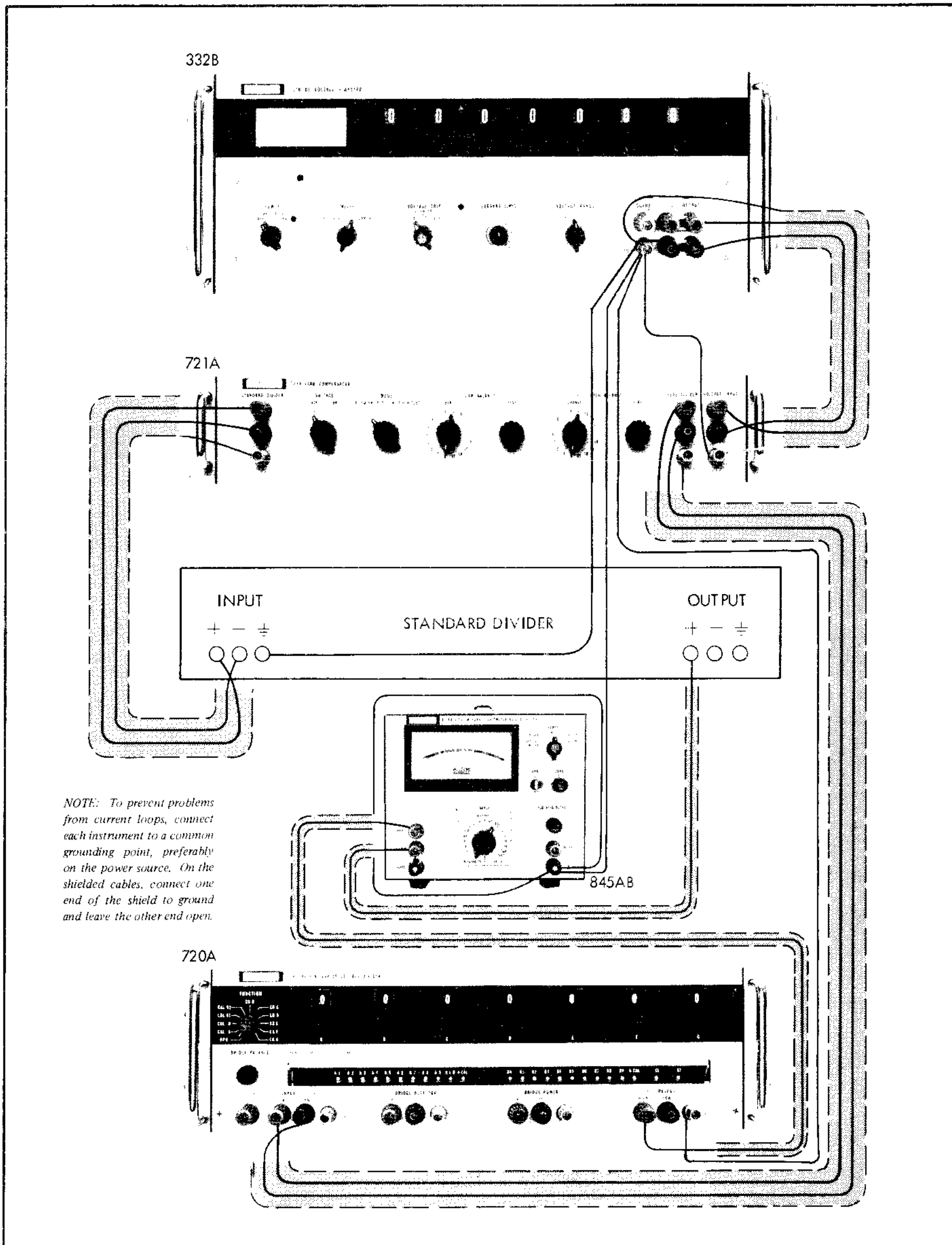


Figure 4-2. EQUIPMENT CONNECTIONS FOR LEAKAGE RESISTANCE TEST



NOTE: To prevent problems from current loops, connect each instrument to a common grounding point, preferably on the power source. On the shielded cables, connect one end of the shield to ground and leave the other end open.

Figure 4-3. EQUIPMENT CONNECTIONS FOR LINEARITY COMPARISON TEST

CAUTION!

Great care should be used to avoid excessive use of contact lubricant on the switches of the Model 720A. The contacts should not be lubricated unless there is evidence of irregular operation.

Before applying the lubricant, clean the switch following the instructions in paragraph 4-10. Only a minute amount of lubricating fluid should be applied. After application, exercise the switch by rotating it through all positions several times.

4-14. Linearity Testing

4-15. The design of the 720A Voltage Divider is such that if the instrument is self-calibrated, if the leakage resistance is low, and if the switch contacts display repeatable contact resistance, the divider will meet its linearity specifications. Because of the extremely tight over-all specification (0.1 PPM of input) very few laboratories will have both the necessary equipment and the required technical skills to prove this. The following linearity test using a second Model 720A as a standard is therefore intended only to indicate gross errors (0.2 PPM of input) in the first decade and to prove specification on the lower decades. The customer who hopes to prove more than this is referred to the following articles and papers:

1. Andrew F. Dunn, "Calibration of a Kelvin-Varley Voltage Divider," National Research Council Report No. 7863.
2. M. L. Morgan and J. C. Riley, "Calibration of a Kelvin-Varley Standard Divider," IRE Trans. on Instrumentation, vol. 1-9, pp 237-243; Sept. 1960.

4-16. To compare divider linearity, connect the equipment as shown in Figure 4-3 and proceed as follows:

NOTE!

Figure 4-4 is a schematic diagram of the test set-up obtained by interconnecting the equipment as shown in Figure 4-3.

a. Self-calibrate the Model 720A. (See paragraph 2-24 in Section II).

b. Set both dividers to zero.

c. Set the voltage source to the desired test voltage, turn on all equipment and allow it to warm up until it reaches temperature equilibrium.

d. Place the null detector in the zero mode, adjust it for zero deflection, and return it to operating mode.

e. Adjust the LOW BALANCE controls of the lead compensator to obtain a zero indication on the null detector.

f. Turn the HIGH BALANCE COARSE control to the same setting as the LOW BALANCE COARSE control.

NOTE!

If the dividers are set from one calibration point to the next while the test setup is energized, the null detector meter will require several seconds to recover between readings. Measurement may

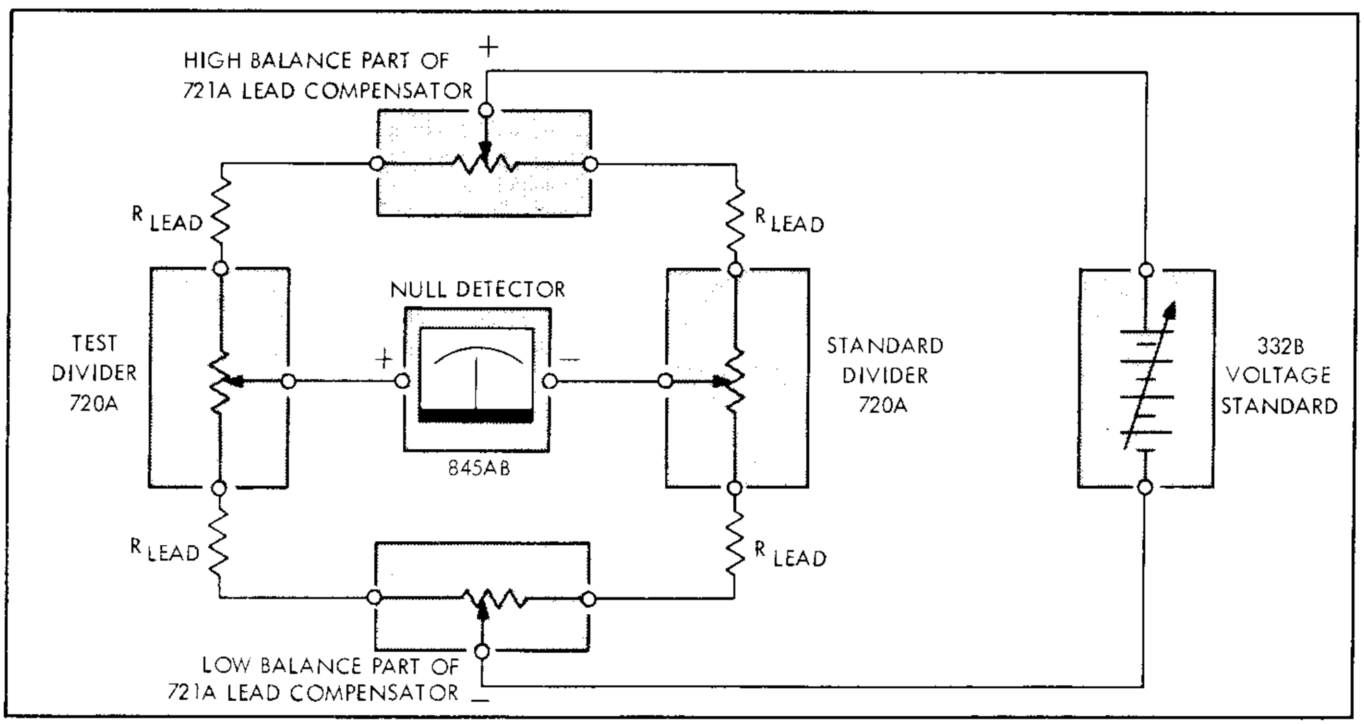


Figure 4-4. SIMPLIFIED SCHEMATIC DIAGRAM OF LINEARITY COMPARISON TEST

be performed more rapidly if the VOLTAGE switch of the lead compensator is turned to OFF before switching. Measurement may be speeded further by turning the ZERO-OPR switch of the null detector to ZERO during switching. This prevents the transient caused by turning the voltage on from saturating the null detector amplifier.

g. Set both dividers to full scale and adjust the HIGH BALANCE FINE control to obtain a zero indication on the null detector.

h. Set both dividers to zero and re-adjust the LOW BALANCE FINE control if necessary to obtain a zero indication on the null detector.

i. Set the null detector to the desired sensitivity.

j. Set both dividers to the first comparison point and adjust the standard divider for a near zero indication on the null detector. The dial settings of the two dividers plus the null detector reading shall agree within a tolerance of 0.2 PPM. This criterion is applicable for input voltages of 100 volts or less.

k. Continue to compare each setting of each decade until the comparison is complete. The following dial setting combinations should be checked on each decade.

0 all zeros	______________
1 all zeros	1 (dial 09 and all 9s except X in last)
2 all zeros	2 (dial 19 and all 9s except X in last)
3 all zeros	3 (dial 29 and all 9s except X in last)
4 all zeros	4 (dial 39 and all 9s except X in last)
5 all zeros	5 (dial 49 and all 9s except X in last)
6 all zeros	6 (dial 59 and all 9s except X in last)
7 all zeros	7 (dial 69 and all 9s except X in last)
8 all zeros	8 (dial 79 and all 9s except X in last)
9 all zeros	9 (dial 89 and all 9s except X in last)
1.0 all zeros	10 (dial 99 and all 9s except X in last)
__________	1.1 (dial 1.09 and all 9s except X in last)

4-17. Decade Linearity Testing

4-18. The CK B through CK G positions of the FUNCTION switch are provided to permit access to the individual decades of the Model 720A under test so that each may be checked against the first decade of the standard divider. To test the linearity of each decade individually, proceed as follows:

a. Change the test setup to that shown in Figure 4-5.

NOTE!

Figure 4-6 is a schematic diagram of the test setup obtained by interconnecting the equipment as shown in Figure 4-5.

b. Turn the FUNCTION switch to CK B.

c. Set the standard divider to zero.

d. Set the divider under test to <u>1.0</u> 000000.

e. Set the voltage source to the desired test voltage.

CAUTION!

Do not exceed the maximum test voltages listed in Figures 4-7 through 4-12.

f. Place the null detector in the zero mode, adjust it for zero deflection, and return it to operating mode.

g. Adjust the LOW BALANCE controls of the lead compensator to obtain a zero indication on the null detector.

h. Turn the HIGH BALANCE COARSE control to the same setting as the LOW BALANCE COARSE control.

NOTE!

If the dividers are set from one calibration point to the next while the test setup is energized, the null detector meter will require several seconds to recover between readings. Measurement may be performed more rapidly if the VOLTAGE switch of the lead compensator is turned to OFF before switching. Measurement may be speeded further by turning the ZERO-OPR switch of the null detector to ZERO during switching. This prevents the transient caused by turning the voltage on, from saturating the null detector amplifier.

i. Set the standard divider to full scale.

j. Set the divider under test to <u>1.0</u> 99999X.

k. Adjust the HIGH BALANCE FINE control to obtain a zero indication on the null detector.

l. Set the divider under test back to <u>1.0</u> 000000 and set the standard divider back to zero.

m. Re-adjust the LOW BALANCE FINE control if necessary to obtain a zero indication on the null detector.

n. Set the null detector for the desired sensitivity and make the linearity measurements given in Figure 4-7. The null detector indications must be

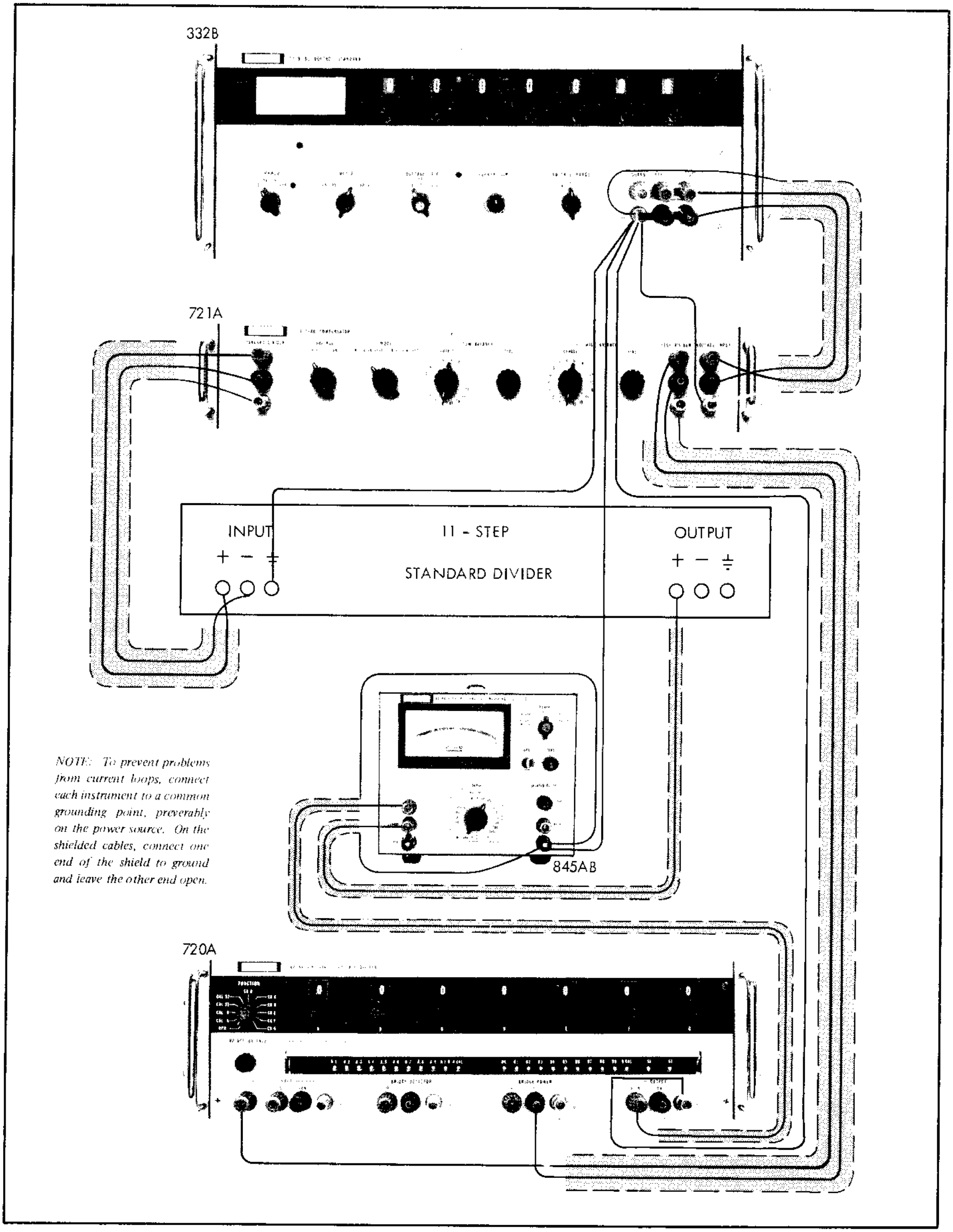


Figure 4-5. EQUIPMENT CONNECTIONS FOR DECADE LINEARITY TEST

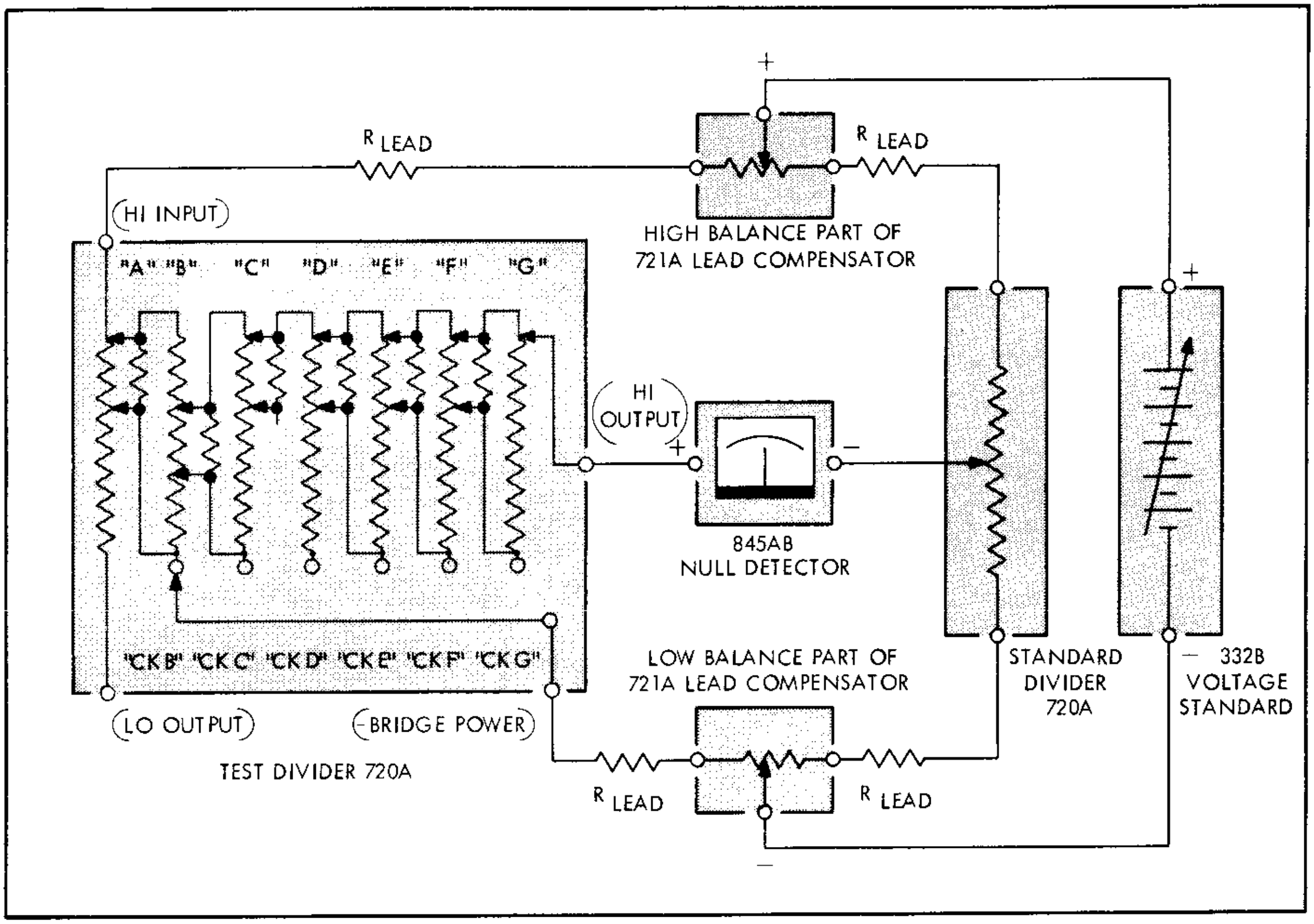


Figure 4-6. SIMPLIFIED SCHEMATIC DIAGRAM OF DECADE LINEARITY TEST

within the limits listed in the Permissible Deviation column.

NOTE!

An indication beyond these limits is a symptom of trouble within the instrument. Refer to the troubleshooting instructions to determine the nature of the fault.

o. Set the voltage source to the desired voltage for testing the "C" decade.

p. Turn the FUNCTION switch to CK C.

q. Set the standard divider to zero.

r. Set the divider under test to 1. 0 900000.

s. Place the null detector in the zero mode, adjust it for zero deflection, and return it to operating mode.

t. Adjust the LOW BALANCE CONTROLS of the lead compensator to obtain a zero indication on the null detector.

u. Turn the HIGH BALANCE COARSE control to the same setting as the LOW BALANCE COARSE control.

v. Set the standard divider to full scale.

w. Set the divider under test to 1. 0 99999X.

x. Adjust the HIGH BALANCE FINE control to obtain a zero indication on the null detector.

y. Set the divider under test back to 1. 0 900000 and set the standard divider back to zero.

z. Re-adjust the LOW BALANCE FINE control if necessary to obtain a zero indication on the null detector.

aa. Set the null detector for the desired sensitivity and make the linearity measurements listed in Figure 4-8.

ab. Set the voltage source to the desired test voltage for testing "D" Decade.

ac. Turn the FUNCTION switch to CK D.

SETTINGS		PERMISSIBLE DEVIATION PPM of INPUT to "B" DECADE	MAX. TEST VOLTAGE
STANDARD DIVIDER	720A		
0	1.0 000000	0	100V
.1	1.0 100000	0.38	
.2	1.0 200000	0.45	
.3	1.0 300000	0.50	
.4	1.0 400000	0.54	
.5	1.0 500000	0.57	
.6	1.0 600000	0.60	
.7	1.0 700000	0.63	
.8	1.0 800000	0.65	
.9	1.0 900000	0.67	
.999999X	1.0 99999X	0	
.9	1.0 89999X	0.67	
.8	1.0 79999X	0.65	
.7	1.0 69999X	0.63	
.6	1.0 59999X	0.60	
.5	1.0 49999X	0.57	
.4	1.0 39999X	0.54	
.3	1.0 29999X	0.50	
.2	1.0 19999X	0.45	
.1	1.0 09999X	0.38	↓

Figure 4-7. "B" DECADE LINEARITY TEST

ad. Set the standard divider to zero.

ae. Set the divider under test to 1.0 990000.

af. Place the null detector in the zero mode, adjust it for zero deflection, and return it to operating mode.

ag. Adjust the LOW BALANCE controls of the lead compensator to obtain a zero indication on the null detector.

ah. Turn the HIGH BALANCE COARSE control to the same setting as the LOW BALANCE COARSE control.

ai. Set the standard divider to full scale.

aj. Set the divider under test to 1.0 99999X.

ak. Adjust the HIGH BALANCE FINE control to obtain a zero indication on the null detector.

al. Set the divider under test back to 1.0 990000 and set the standard divider back to zero.

am. Re-adjust the LOW BALANCE FINE control if necessary to obtain a zero indication on the null detector.

an. Set the null detector for the desired sensitivity and make the linearity measurements given in Figure 4-9. The null detector indications must be within the limits listed in the "permissible deviation" column.

SETTINGS		PERMISSIBLE DEVIATION PPM of INPUT to "C" DECADE	MAX. TEST VOLTAGE
STANDARD DIVIDER	720A		
0	1.0 900000	0	100V
.1	1.0 910000	1.4	
.2	1.0 920000	1.7	
.3	1.0 930000	1.9	
.4	1.0 940000	2.1	
.5	1.0 950000	2.3	
.6	1.0 960000	2.4	
.7	1.0 970000	2.5	
.8	1.0 980000	2.7	
.9	1.0 990000	2.8	
.999999X	1.0 99999X	0	
.9	1.0 98999X	2.8	
.8	1.0 97999X	2.7	
.7	1.0 96999X	2.5	
.6	1.0 95999X	2.4	
.5	1.0 94999X	2.3	
.4	1.0 93999X	2.1	
.3	1.0 92999X	1.9	
.2	1.0 91999X	1.7	
.1	1.0 90999X	1.4	↓

Figure 4-8. "C" DECADE LINEARITY TEST

ao. Turn the FUNCTION switch to CK E.

ap. Set the standard divider to zero.

aq. Set the divider under test to 1.0 999000.

ar. Place the null detector in the zero mode, adjust it for zero deflection, and return it to operating mode.

as. Adjust the LOW BALANCE controls of the lead compensator to obtain a zero indication on the null detector.

at. Turn the HIGH BALANCE COARSE control to the same setting as the LOW BALANCE COARSE control.

au. Set the standard divider to full scale.

av. Set the divider under test to 1.0 99999X.

aw. Adjust the HIGH BALANCE FINE control to obtain a zero indication on the null detector.

ax. Set the divider under test back to 1.0 999000 and set the standard divider back to zero.

SETTINGS		PERMISSIBLE DEVIATION PPM of INPUT to "D" DECADE	MAX. TEST VOLTAGE
STANDARD DIVIDER	720A		
0	1.0 990000	0	10V
.1	1.0 991000	6.0	
.2	1.0 992000	7.5	
.3	1.0 993000	8.6	
.4	1.0 994000	9.5	
.5	1.0 995000	10.2	
.6	1.0 996000	10.8	
.7	1.0 997000	11.4	
.8	1.0 998000	12.0	
.9	1.0 999000	12.5	
.999999X	1.0 99999X	0	
.9	1.0 99899X	12.5	
.8	1.0 99799X	12.0	
.7	1.0 99699X	11.4	
.6	1.0 99599X	10.8	
.5	1.0 99499X	10.2	
.4	1.0 99399X	9.5	
.3	1.0 99299X	8.6	
.2	1.0 99199X	7.5	
.1	1.0 99099X	6.0	

Figure 4-9. "D" DECADE LINEARITY TEST

ay. Re-adjust the LOW BALANCE FINE control if necessary to obtain a zero indication on the null detector.

az. Set the null detector for the desired sensitivity and make the linearity measurement given in Figure 4-10. The null detector indications must be within the limits listed in the "permissible deviation" column.

ba. Turn the FUNCTION switch to CK F.

bb. Set the standard divider to zero.

bc. Set the divider under test 1.0 999900.

bd. Place the null detector in the zero mode, adjust it for zero deflection, and return it to operating mode.

be. Adjust the LOW BALANCE controls of the lead compensator to obtain a zero indication on the null detector.

bf. Turn the HIGH BALANCE COARSE control to the same setting as the LOW BALANCE COARSE control.

bg. Set the standard divider to full scale.

bh. Set the divider under test to 1.0 99999X.

bi. Adjust the HIGH BALANCE FINE control to obtain a zero indication on the null detector.

SETTINGS		PERMISSIBLE DEVIATION PPM of INPUT to "E" DECADE	MAX. TEST VOLTAGE
STANDARD DIVIDER	720A		
0	1.0 999000	0	10V
.1	1.0 999100	28	
.2	1.0 999200	35	
.3	1.0 999300	40	
.4	1.0 999400	44	
.5	1.0 999500	47	
.6	1.0 999600	50	
.7	1.0 999700	53	
.8	1.0 999800	55	
.9	1.0 999900	57	
.999999X	1.0 999990	0	
.9	1.0 99989X	57	
.8	1.0 99979X	55	
.7	1.0 99969X	53	
.6	1.0 99959X	50	
.5	1.0 99949X	47	
.4	1.0 99939X	44	
.3	1.0 99929X	40	
.2	1.0 99919X	35	
.1	1.0 99909X	28	

Figure 4-10. "E" DECADE LINEARITY TEST

bj. Set the divider under test back to 1.0 999900 and set the standard divider back to zero.

bk. Re-adjust the LOW BALANCE FINE control if necessary to obtain zero indication on the null detector.

bl. Set the null detector for the desired sensitivity and make the linearity measurements given in Figure 4-11. The null detector indications must be within the limits listed in the "permissible deviation" column.

bm. Turn the FUNCTION switch to CK G.

bn. Set the standard divider to zero.

bo. Set the divider under test to 1.0 999990.

bp. Place the null detector in the zero mode, adjust it for zero deflection, and return it to operating mode.

bq. Adjust the LOW BALANCE controls of the lead compensator to obtain a zero indication on the null detector.

br. Turn the HIGH BALANCE COARSE control to the same setting as the LOW BALANCE COARSE control.

bs. Set the standard divider to full scale.

bt. Set the divider under test to 1.0 99999X.

SETTINGS		PERMISSIBLE DEVIATION PPM of INPUT to "F" DECADE	MAX. TEST VOLTAGE
STANDARD DIVIDER	720A		
0	1.0 999900	0	10V
.1	1.0 999910	130	
.2	1.0 999920	160	
.3	1.0 999930	180	
.4	1.0 999940	200	
.5	1.0 999950	220	
.6	1.0 999960	230	
.7	1.0 999970	240	
.8	1.0 999980	260	
.9	1.0 999990	270	
.999999X	1.0 99999X	0	
.9	1.0 99998X	270	
.8	1.0 99997X	260	
.7	1.0 99996X	240	
.6	1.0 99995X	230	
.5	1.0 99994X	220	
.4	1.0 99993X	200	
.3	1.0 99992X	180	
.2	1.0 99991X	160	
.1	1.0 99990X	130	

Figure 4-11. "F" DECADE LINEARITY TEST

bu. Adjust the HIGH BALANCE FINE control to obtain a zero indication on the null detector.

bv. Set the divider under test back to 1.0 999990 and set the standard divider back to zero.

bw. Re-adjust the LOW BALANCE FINE control if necessary to obtain a zero indication on the null detector.

bx. Set the null detector for the desired sensitivity and make the linearity measurements given in Figure 4-12. The null detector indications must be within the limits listed in the "permissible deviation" column.

by. Disconnect the test equipment and return the FUNCTION switch to OPR position; the decade linearity tests are complete.

4-19. CALIBRATION

4-20. Calibration of the Model 720A consists of calibrating two standard resistance arms of the internal Wheatstone bridge and calibrating the first three decades. The bridge arms require calibration only if the BRIDGE BALANCE control has insufficient range to balance the bridge during divider calibration.

4-21. Divider Calibration

4-22. This procedure is used to adjust the linearity of the "A", "B" and "C" decades of the Model 720A so

SETTINGS		PERMISSIBLE DEVIATION PPM of INPUT to "G" DECADE	MAX. TEST VOLTAGE
STANDARD DIVIDER	720A		
0	1.0 999990	0	10V
.1	1.0 999991	600	
.2	1.0 999992	750	
.3	1.0 999993	860	
.4	1.0 999994	950	
.5	1.0 999995	1020	
.6	1.0 999996	1080	
.7	1.0 999997	1140	
.8	1.0 999998	1200	
.9	1.0 999999	1250	
.999999X	1.0 99999X	0	

Figure 4-12. "G" DECADE LINEARITY TEST

that any readout setting is accurate within 0.1 ppm of input. This procedure consists of two parts, calibration of the "C" decade and the "S3" shunt, and calibration of the "A" and "B" decades, and their shunts. The latter is the self calibration procedure which is performed from the front panel.

4-23. To calibrate the "C" decade and "S3" shunt proceed as follows:

[redacted]

NOTE!

SEE NOTE ON PG. 4-18 CONCERNING R205

Insure the system has the correct connections and ground as shown in Figure 4-14.

a. Turn the FUNCTION switch to OPR, turn the internal FUNCTION switch to CAL C, exercise the "C" decade switch by turning it twice through all positions, and set the readout to .0000000.

b. Connect the voltage source to the red and the black BRIDGE POWER binding posts.

c. Connect the null detector to the BRIDGE DETECTOR binding posts. The guard terminal of the null detector must be connected to the common terminal.

d. Turn the B decade switch to the blank position and apply 10 volts from the voltage source.

e. Adjust the BRIDGE BALANCE control to obtain a null indication ±10 microvolts.

NOTE!

If the null meter cannot be nulled using the Bridge Balance Control, perform the Bridge Calibration Procedure (paragraph 4-25).

f. Locate the C-0 trimmer (R1130) on the circuit board and sweep it slowly from stop to stop while observing the null detector. If the indication does not change smoothly, sweep it from stop to stop several times.

g. Set the null detector to the 30 microvolt range and adjust the C-0 trimmer to obtain an indication of 0 ±10 microvolts.

h. Observe the null detector and tap the trimmer; the indication should remain within 10 microvolts of zero.

i. Use the following procedure to calibrate the "C" deck switch positions 1 through CAL:

1. Turn the "C" deck switch clockwise to the next position to be calibrated.

2. Observe the null detector and slowly sweep the trimmer corresponding to the switch position (C-1 through C CAL) from stop to stop. If the indication does not change smoothly, sweep the trimmer from stop to stop several times.

3. Observe the null detector and adjust the trimmer to obtain an indication of 0 ±10 microvolts.

4. Observe the null detector and tap the trimmer; the indication should stay within 10 microvolts of the zero.

5. Turn the "C" deck switch away from the position being calibrated, return it and observe the meter. The indication should be within 10 microvolts of zero

NOTE!

If the indication is not within 10 microvolts of zero, exercise the switch and repeat the procedure. If this fails, lubricate the switch as instructed in paragraph 4-12.

6. Proceed to the next position to be calibrated.

j. Return the "C" deck switch to the 0 position.

k. Turn the internal FUNCTION switch to the CAL S3 position.

l. Observe the null detector and slowly sweep the CAL S3 trimmer from stop to stop. If the indication does not change smoothly, sweep it from stop to stop several times.

m. Adjust the CAL S3 trimmer to obtain an indication of 0 ±10 microvolts.

n. Observe the null detector and tap the trimmer. The indication should stay within 10 microvolts of zero.

o. Turn the "C" decade switch away from the 0 positions and return it to zero.. The null detector indication should be within 10 microvolts of zero.

p. Return the internal FUNCTION switch to OPR; Calibration of the "C" decade and S3 shunt is complete.

4–24. To calibrate the "A" and "B" decades, perform the self-calibration procedure using the instructions given in paragraphs 2-24 and 2-25.

4-25. Bridge Calibration

NOTE!

The Bridge Calibration procedure is required only if a null could not be obtained during Divider Calibration with the BRIDGE BALANCE Control.

4-26. 10-KILOHM BRIDGE STANDARD. This procedure is used to adjust the total resistance of the bridge arm used for calibration of the "A" and "B" decades (self-calibration of the instrument) so the bridge can be balanced to measure a nominal 10,000 ohms. If the bridge can be balanced near the center of travel for the BRIDGE BALANCE during self-cal at CAL A - Zero positions the procedure following does not need to be performed. However, if during self-cal in the CAL A - Zero position (See paragraph 2-24) the bridge cannot be balanced using the BRIDGE BALANCE Control, perform the procedure below:

NOTE!

Insure the system has the correct connections and ground as shown in Figure 4-14.

a. Turn the FUNCTION switch to CAL A; turn the internal FUNCTION switch to OPR (Fig. 4-13) and set the readout to .0000000.

b. Connect a 20 volt DC source to the red and the black BRIDGE POWER binding posts.

c. Connect the null detector to the BRIDGE DETECTOR binding posts. The guard terminal of the null detector must be connected to the Common terminal.

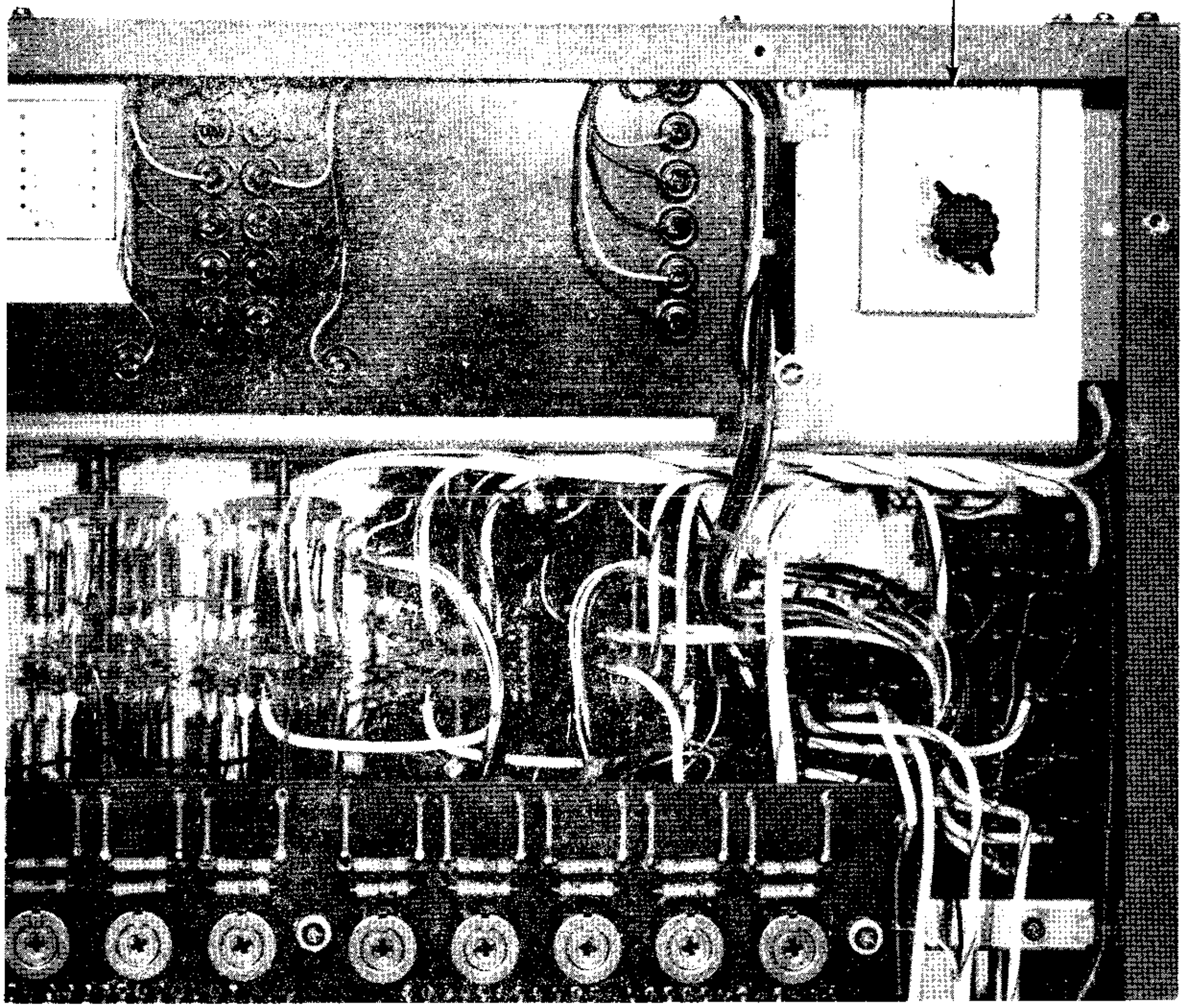


Figure [illegible]. INTERNAL FUNCTION SWITCH

d. Adjust the Bridge Balance control to the center of its travel range.

NOTE

BRIDGE BALANCE [illegible] with both a Fine and Coarse [illegible] control knob.

e. Observe the [illegible] bridge [illegible] the indication [illegible] change [illegible] R203 from stop to stop [illegible]

f. Adjust R203 [illegible] microvolts.

g. Select the one millivolt range on the null detector. Vary the Bridge Balance control while observing the null detector. When the electrical center is obtained, leave the BRIDGE BALANCE control at that position.

h. Re-adjust R203 to obtain an indication of 0 ± 100 microvolts.

i. Calibration of the 10-kilohm bridge standard is complete.

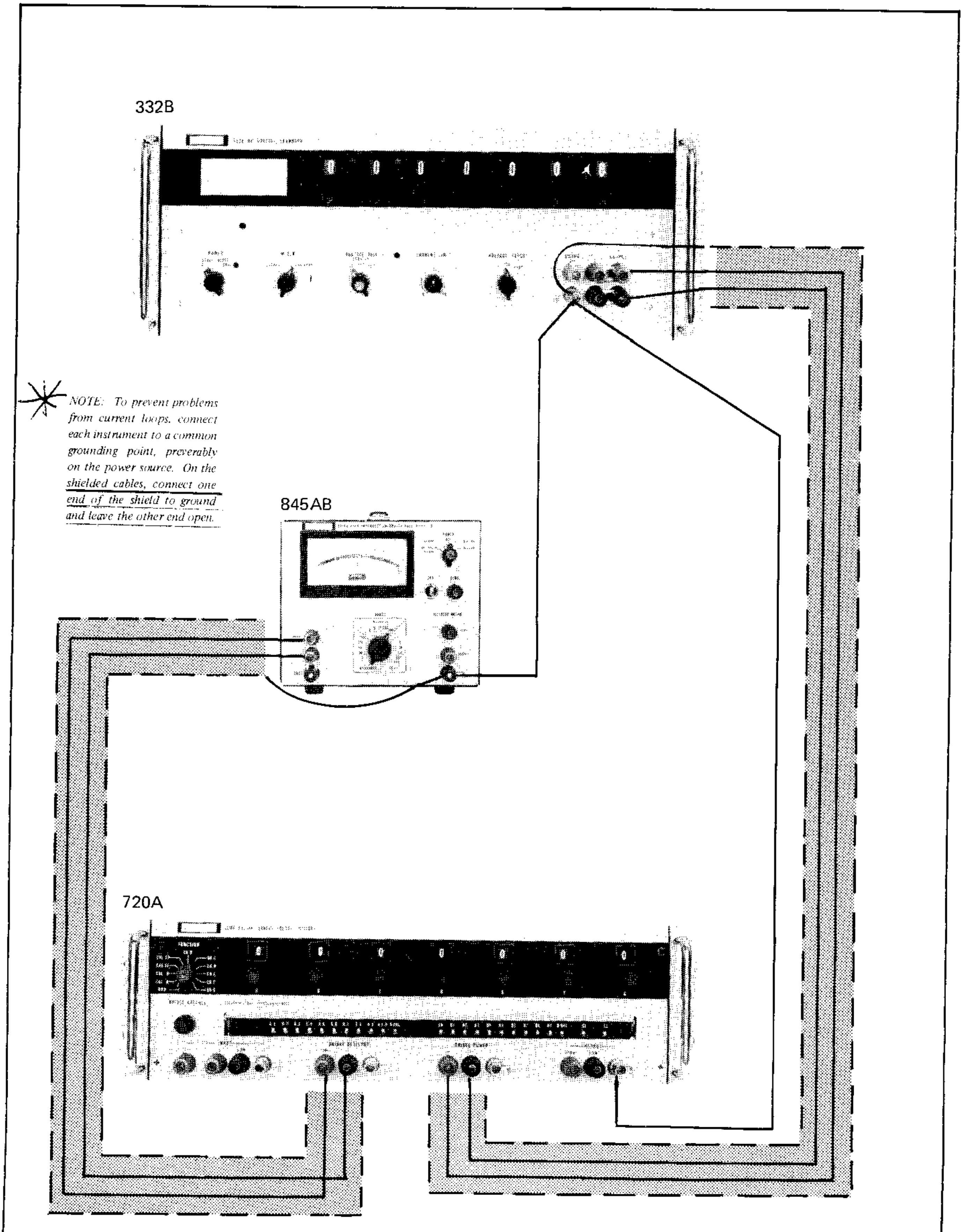


Figure 4-14. EQUIPMENT CONNECTIONS FOR SELF CALIBRATION.

NOTE!

The BRIDGE BALANCE control and R203 are now ready for the self-cal procedures for A and B decades in paragraph 2-24, assuming R312 and its associated trim resistors have not shifted excessively in value. If insufficient trim range remains at A.1, A.2, etc., the 720A should be returned to the factory for repair. Perform the C decade and S3 shunt check in paragraph 4-21 prior to performing the self-cal at A and B decades.

4-27. 4-KILOHM BRIDGE STANDARD. This procedure is used to adjust the total resistance of the bridge arm used for calibration of the third "C" decade so the bridge can be balanced to measure a nominal 4007.6 ohms. Calibration of the "C" decade consists of setting each step on the decade to a nominal 4007.6 ohms. If the bridge can be balanced with the BRIDGE BALANCE control on the front panel during self-cal in the CAL C - Zero position described in paragraph 4-21, this procedure does not need to be performed. To reset the range of the BRIDGE BALANCE, control for balance of the bridge, perform the following procedure:

a. Turn the FUNCTION switch to OPR, and turn the internal FUNCTION switch to CAL C, and set the readout to .0000000.

NOTE!

The internal FUNCTION switch, which is shown in Figure 4-13, is used only for calibration of the "C" decade and the S-3 shunt. It should not be confused with the FUNCTION switch located on the front panel.

b. Connect the voltage source to the red and the black BRIDGE POWER binding posts.

c. Connect the null detector to the BRIDGE DETECTOR binding posts. The guard terminal of the null detector must be connected to the common terminal.

d. Turn the "B" decade switch to the blank position and apply 10 volts from the voltage source.

e. Adjust BRIDGE BALANCE to the mid-position and adjust R1130 (Decade C-0) to mid position

f. Observing the Null Detector sweep R205 (Bridge Circuit Board) thru its range. If the null detector does not show a smooth change, sweep R205 through its range several times.

g. Adjust R205 for 0 ±50 microvolts on the Null Detector.

h. Place the Null Detector on the 300 microvolt range. Observe the range of the BRIDGE BALANCE control on the Null Detector and place the BRIDGE BALANCE control at the electrical center.

i. Adjust R1130 (Decade C-0) for 0 ±10 microvolts.

NOTE!

The BRIDGE BALANCE control, R205 and R1130 are now set to give a nominal 4007.6 ohm reference and the self-cal procedure in paragraph 4-21 will make the other positions of the C Decade the same value. If there is not enough range to trim the remaining positions of the C Decade to this nominal value repeat steps a through i with different settings for R205 and R1130. If calibration still is not possible, return the 720A to the factory for repair.

j. Disconnect the test equipment; calibration of the 4-kilohm bridge standard is complete.

4-28. TROUBLESHOOTING

4-29. Troubles in the Model 720A may be located most easily by performing the decade linearity test described in paragraph 4-15 and analyzing the results. Reference to the schematic diagram will greatly assist in the analysis. Before attempting to locate the trouble, the instrument should first be cleaned following the procedure described in paragraph 4-10 and the leakage resistance should be measured following the procedure described in paragraph 4-8.

4-30. Because of the passive nature of the instrument, troubles will be limited to defective resistors, defective switches, defective wiring, and excessive leakage will usually be corrected by cleaning. If repeated cleaning fails to correct the condition, the instrument should be returned to the factory for repair.

4-31. Not only may resistor defects be isolated to a particular step of a decade by the linearity test, but also the nature of the defect may be determined. A resistor may be shorted, open, over value, or under value. Because the switch contacts span two steps of resistance in all decades except the seventh ("G"), the effect caused directly by a defective resistor will be seen at two adjacent switch positions. In the "D" through "G" decades the linearity test will isolate the defect to a particular resistor. In the "A", "B", and "C", decades each step is made up of several resistors and each resistor in the step will have to be measured to find the defect. In these decades, the variable trimmer resistor in the defective step should be checked by monitoring it and sweeping it from stop to stop several times. If the variation is not smooth, it should be replaced. If one of the resistors in the oil tank or one of the factory selected fixed resistors is found to be defective, the instrument should be returned to the factory for repair.

4-32. A shorted resistor will decrease the overall resistance of the decade thereby increasing the proportional value of all steps except the one containing the shorted resistor. The proportional value of this step will be very low.

4-33. An open resistor in any decade will prevent any output until the switch is advanced so the contacts span the open resistor. At this point the ratio will be high. As the switch is advanced so the contacts no longer span the open resistor, the measured output will be the source voltage. If a decade shunt is open all steps of the decade will be equal but resistance of the decade will be high. This will cause nonlinearity in the preceding decade which may be observed by dialing it upward from zero. Below the midpoint, the output will be high; above the midpoint, the output will be low.

4-34. An over value resistor in any decade will reduce the proportion of all other steps and increase the proportion of the step containing the over value resistor. In all decades except the seventh, this increase will be seen at two adjacent switch positions because the switch contacts span two resistance steps. In the seventh decade, there will be only one over value step. If a decade shunt is over value, all steps of the decade will be equal but the resistance of the decade will be high. This will cause nonlinearity in the preceding decade which may be observed by dialing it upward from zero. Below the midpoint, the output will be high; above the midpoint, the output will be low.

4-35. An under value resistor in any decade will increase the proportion of all other steps and decrease the proportion of the step containing the under value resistor. In all decades except the seventh, this decrease will be seen at two adjacent switch positions. In the seventh decade there will be only one under value step. If a decade shunt is under value, all steps of the decade will be equal but the resistance of the decade will be low. This will cause nonlinearity in the preceding decade which may be observed by dialing it upward from zero. Below the midpoint, the output will be low; above the midpoint, the output will be high.

4-36. A defective switch usually will cause erratic or irregular operation of the decade. A broken contact may cause one step to be missing although all others are of the correct value or it may completely open the divider circuit. When a switch defect is suspected, the switch should be checked for continuity at each position.

4-37. Defective wiring usually will cause one step of a decade to be missing or will completely open the divider circuit. Wiring continuity should be checked to isolate the fault.

4-38. REPAIR

4-39. Any parts of the Model 720A except factory selected resistors and resistors housed in the oil tank may be replaced without difficulty by an experienced electronic maintenance technician. When a switch is replaced all leads should be tagged as they are disconnected to assure that they are correctly connected to the new switch. Care should be exercised in any soldering operation to assure that good electrical contact is made. All parts except precision wirewound resistors may be ordered from the factory by giving only the information specified in paragraph 5-4.

4-40. The precision wirewound resistors used in the Model 720A are selected and matched during manufacture to form a completely matched set. Sufficient information is marked on each of these resistors to permit replacement with a resistor which will match the others in the set. The following information should be given when one of these resistors is ordered from the factory:

a. Serial number of the instrument.

b. Reference designation of the resistor.

c. All markings on the resistor.

If all markings on the defective resistor can not be read, give the following information:

a. Serial number of the instrument.

b. Reference designation of the defective resistor.

c. Reference designation and all part markings of the adjacent resistor on one side.

d. Reference designation and all part markings of the adjacent resistor on the other side.

4-41. SERVICE INFORMATION

4-42. The John Fluke Manufacturing Co., Inc. warrants each instrument manufactured by them for the period of one year upon making delivery of the instrument to you, the original purchaser. Complete warranty page located at the rear of this manual.

4-43. If you should encounter any problem in the operation of your instrument, please feel free to contact your nearest John Fluke Sales Representative or write directly to the John Fluke Manufacturing Co., Inc. with a statement of your problem.

Section 5
List of Replaceable Parts

5-1. INTRODUCTION

5-2. This section contains complete descriptions of those parts one might normally expect to replace during the life of the instrument. The first listing is a breakdown of all of the major assemblies in the instrument. Subsequent listings itemize the components in each assembly. Every listing is accompanied by an illustration identifying each component in the listing. Assemblies and subassemblies are identified by name in the parts list and by a ten digit stock number in the illustrations. Components are identified by the schematic diagram reference designation (e.g. R1, C107 DS1). Parts not appearing on the schematic diagram are numbered consecutively throughout the parts list with a whole number. Flagnotes are used throughout the parts list and refer to ordering explanations. The flagnote explanations appear at the end of the parts list in which they are listed.

5-3. COLUMNAR INFORMATION

a. The REF DESIG column indexes the item description to the associated illustration. In general the reference designations are listed under each assembly in alpha-numeric order. Subassemblies of minor proportions are sometimes listed with the assembly of which they are a part. In this case, the reference designations for the components of the subassembly may appear out of order.

b. The DESCRIPTION column describes the salient characteristics of the component. Indention of the description indicates the relationship to other assemblies, components, etc. In many cases it is necessary to abbreviate in this column. For abbreviations and symbols used, see the following page.

c. The ten-digit part number by which the item is identified at the John Fluke Mfg. Co. is listed in the STOCK NO. column. Use this number when ordering parts from the factory or authorized representatives.

d. The Federal Supply Code for the item manufacturer is listed in the MFR column. An abbreviated list of Federal Supply Codes is included in the Appendix.

e. The part number which uniquely identifies the item to the original manufacturer is listed in the MFR PART NO column. If a component must be ordered by description, the type number is listed.

f. The TOT QTY column lists the total quantity of the item used in the instrument. Second and subsequent listing of the same item are referenced to the first listing with the abbreviation REF. In the case of optional subassemblies, plug ins, etc. that are not always part of the instrument, the TOT QTY column lists the total quantity of the item in that particular assembly.

g. Entries in the REC QTY column indicate the recommended number of spare parts necessary to support one to five instruments for a period of two years. This list presumes an availability of common electronic parts at the maintenance site. For maintenance for one year or more at an isolated site, it is recommended that at least one of every part in the instrument be stocked.

h. The USE CODE column identifies certain parts which have been added, deleted or modified during the production of the instrument. Each part for which a Use Code has been assigned may be identified with a particular instrument serial number by consulting the Serial Number Effectivity List. As Use Codes are added to the list, the TOT QTY column listings are changed to reflect the most current information. Sometimes when a part is changed, the new part can and should be used as a replacement for the original part. In this event a parenthetical note is added in the DESCRIPTION column.

5-4. HOW TO OBTAIN PARTS

5-5. Standard components have been used wherever possible. Standard components may be ordered directly from the manufacturer by using the manufacturer's part number, or parts may be ordered from the John Fluke Mfg. Co. factory or authorized representative by using the Fluke part number. In the event the part you order has been replaced by a new or improved part, the replacement will be accompanied by an explanatory note and installation instructions, if necessary.

5-6. You can insure prompt and efficient handling of your order to the John Fluke Mfg. Co. if you include the following information:

a. Quantity.

b. FLUKE Stock Number.

c. Description.

d. Reference Designation.

e. Instrument model and serial number.

Example; 2 each, 4805-177105, Transistors, 2N3565, Q107-108 for 845AR, s/n 168.

If you must order structural parts not listed in the parts list, describe the part as completely as possible. A sketch of the part showing its location to other parts of the instrument is usually most helpful.

5-8. SERIAL NUMBER EFFECTIVITY

5-9. A Use Code column is provided to identify certain parts that have been added, deleted, or modified during production of the Model 720A. Each part for which a use code has been assigned may be identified with a particular instrument serial number by consulting the Use Code Effectivity List below. All parts with no code are used on all instruments with serial numbers above 123. New codes will be added as required by instrument changes.

USE CODE	EFFECTIVITY
No Code	Model 720A, serial number 123 and on.
A	Model 720A, serial number 536 and on.

REF DESIG	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
	KELVIN-VARLEY VOLTAGE DIVIDER Figure 5-1	720A					
	Front Panel Assembly (See Figure 5-2)						
	Trimmer P/C Assembly (See Figure 5-3)	1702-210716 (720A-4001)	89536	1702-210716	1		
	Bridge P/C Assembly (See Figure 5-4)	1702-200295 (720A-4002)	89536	1702-200295	1		
	Resistor Can Assembly If a resistor in this assembly requires replacement, the entire instrument must be returned to the factory for repair and recalibration.	3158-217612 (720A-4018)	89536	3158-217612	1		
S1	Switch, "A" DECADE, rotary, 3p, 12 pos, 3 sect	5105-220012	89536	5105-220012	1		
	"B" Decade Switch Assembly (See Figure 5-5)	5110-217307 (720A-4004)	89536	5110-217307	1		
	"C" Decade Switch Assembly (See Figure 5-6)	5110-217315 (720A-4005)	89536	5110-217315	1		
	"D", "E", "F" and "G" Decades Switch Assy. (See Figure 5-7)	5110-217323 (720A-4006)	89536	5110-217323	1		
S8	Switch, FUNCTION, 5p, 11 pos, 5 sect	5105-220020	89536	5105-220020	1		
S9	Switch, INTERNAL FUNCTION, 4p, 3 pos, 2 sect	5107-218560	89536	5107-218560	1		
1	Bushing, dial	2502-130435	89536	2502-130435	7		
1	Bushing, dial	3153-130252	89536	3153-130252	7		A
2	Coupler, switch (not illustrated)	2402-200592	89536	2402-200592	7		
3	Cover, bottom (not illustrated)	3156-217117	89536	3156-217117	1		
4	Cover, internal function switch	3156-217521	89536	3156-217521	1		
5	Cover, top (not illustrated)	3156-217125	89536	3156-217125	1		
6	Detent, switch	5108-218578	89536	5108-218578	6		
7	Detent, internal function switch (not illustrated)	5108-218552	89536	5108-218552	1		
8	Dial, 0.0 - 1.0 Cal	2403-208611	89536	2403-208611	1		
9	Dial, 0 - Cal	2403-208595	89536	2403-208595	2		
10	Dial, 0 - X	2403-208603	89536	2403-208603	1		
11	Dial, 0 - 9	2403-208587	89536	2403-208587	3		
12	Foot, rubber (not illustrated)	2819-103309	77969	9102-W	4		
13	Heat sink, resistor	3156-217463	89536	3156-217463	1		
14	Knob, INTERNAL FUNCTION	2405-170050	89536	2405-170050	1		
15	Panel, rear	3156-217075	89536	3156-217075	1		

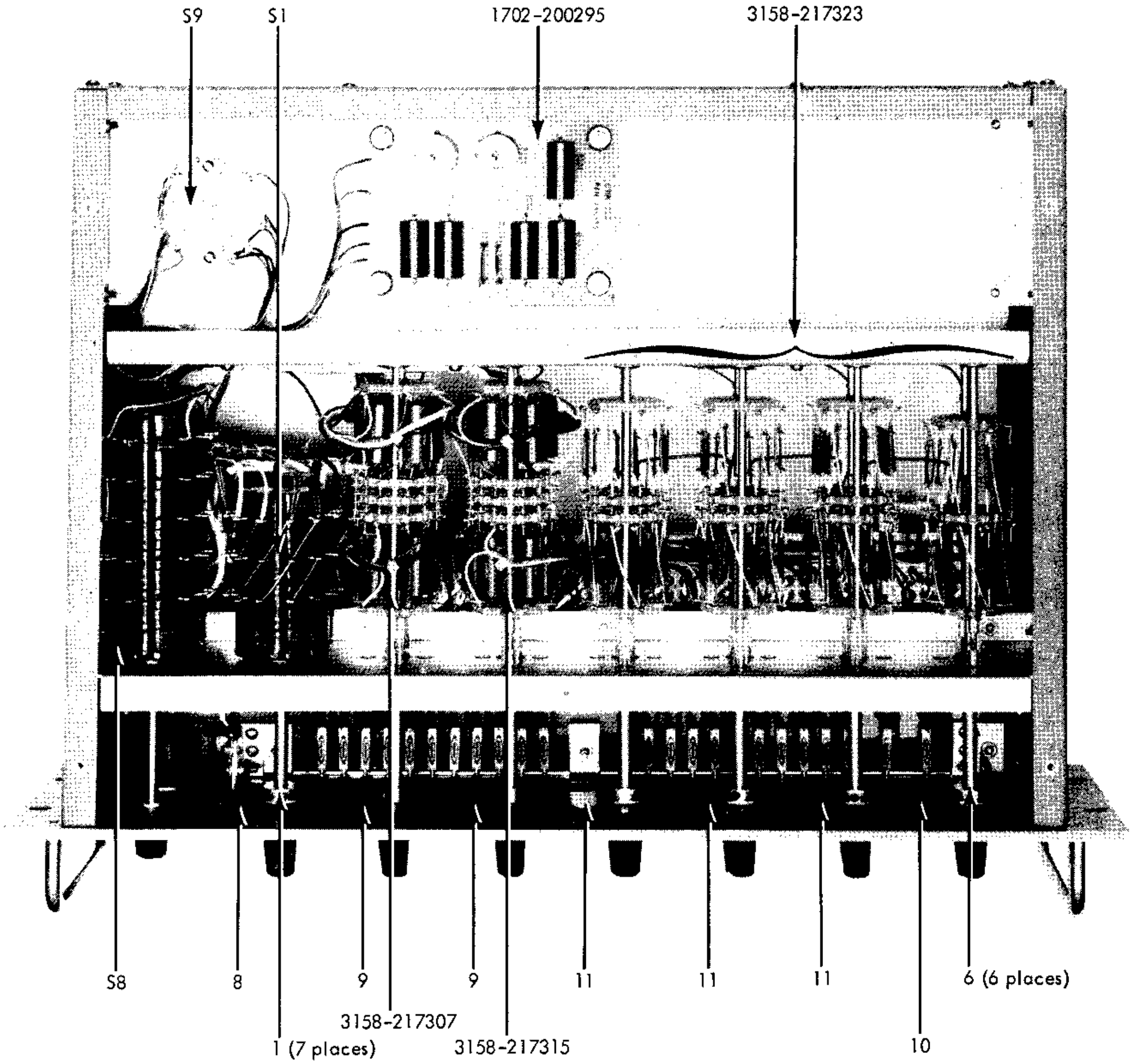


Figure 5-1. 720A KELVIN-VARLEY VOLTAGE DIVIDER (Sheet 1 of 2)

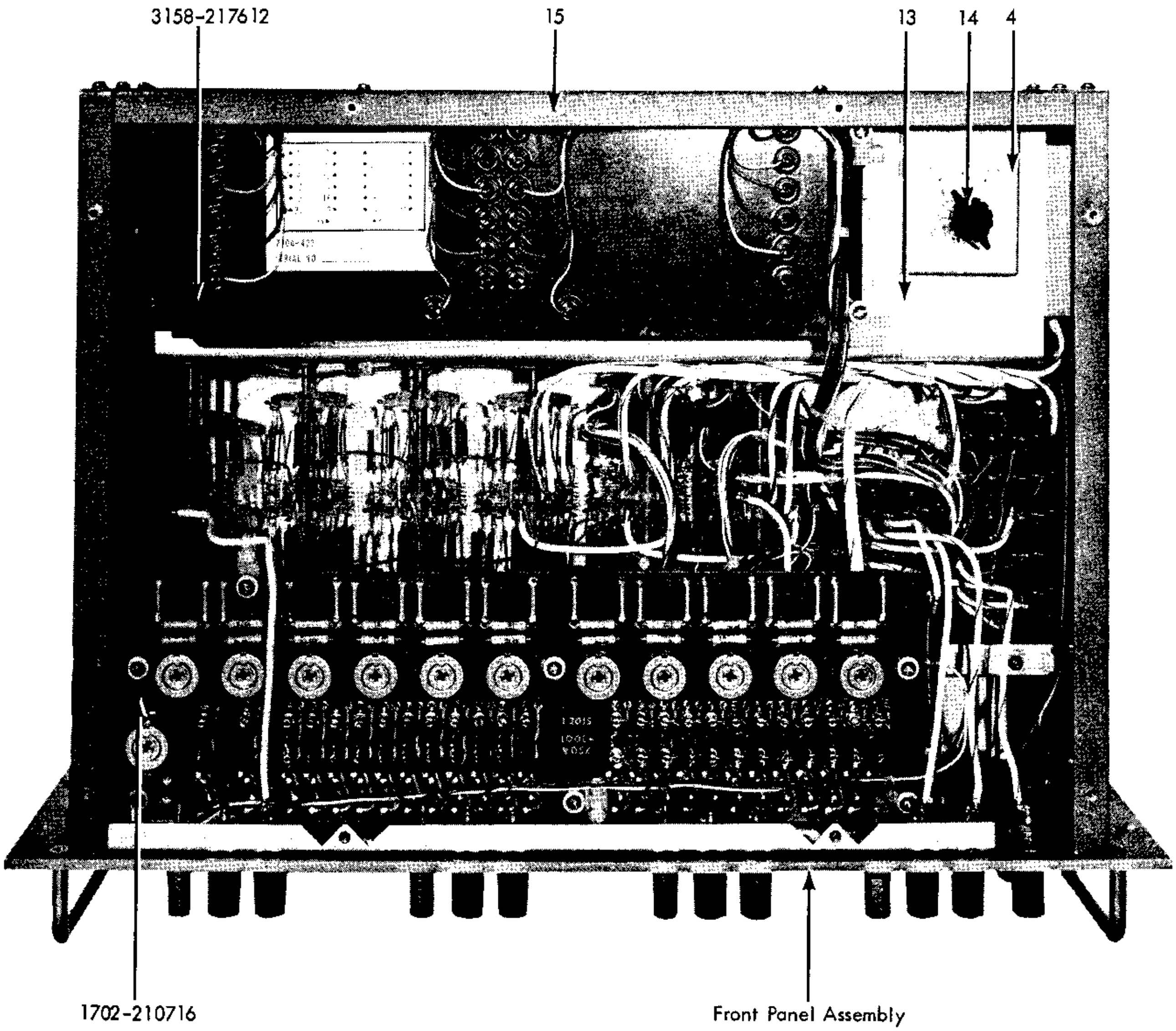


Figure 5-1. 720A KELVIN-VARLEY VOLTAGE DIVIDER (Sheet 2 of 2)

REF DESIG	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
	FRONT PANEL ASSEMBLY - Figure 5-2						
J1	Binding post, red, 1.1 INPUT	2811-149856	58474	BHB-10208-G22	5		
J2	Binding post, red, 1.0 INPUT	2811-149856	58474	BHB-10208-G22	REF		
J3	Binding post, black, LOW INPUT	2811-149864	58474	BHB-10208-G21	4		
J4	Binding post, GROUND INPUT	2811-155911	58474	GP30NC	4		
J5	Binding post, red, HIGH OUTPUT	2811-149856	58474	BHB-10208-G22	REF		
J6	Binding post, black, LOW OUTPUT	2811-149864	58474	BHB-10208-G21	REF		
J7	Binding post, GROUND OUTPUT	2811-155911	58474	GP30NC	REF		
J8	Binding post, black, - BRIDGE DETECTOR	2811-149864	58474	BHB-10208-G21	REF		
J9	Binding post, red, + BRIDGE DETECTOR	2811-149856	58474	BHB-10208-G22	REF		
J10	Binding post, GROUND BRIDGE DETECTOR	2811-155911	58474	GP30NC	REF		
J11	Binding post, red, + BRIDGE POWER	2811-149856	58474	BHB-10208-G22	REF		
J12	Binding post, black, - BRIDGE POWER	2811-149864	58474	BHB-10208-G21	REF		
J13	Binding post, GROUND BRIDGE POWER	2811-155911	58474	GP30NC	REF		
R1	Res, var, ww, 5k ±3%, 3w, BRIDGE BALANCE (not illustrated)	4702-215319	89536	4702-215319	1		
16	Cover, calibration access	3156-217083	89536	3156-217083	1		
17	Handle, chrome-plated brass	2404-101683	15849	1010-13	2		
18	Knob, A through G	2405-158949	89536	2405-158949	7		
19	Knob, BRIDGE BALANCE	2405-158956	89536	2405-158956	1		
20	Knob, FUNCTION	2405-190249	89536	2405-190249	1		
21	Panel, front	1406-217042	89536	1406-217042	1		

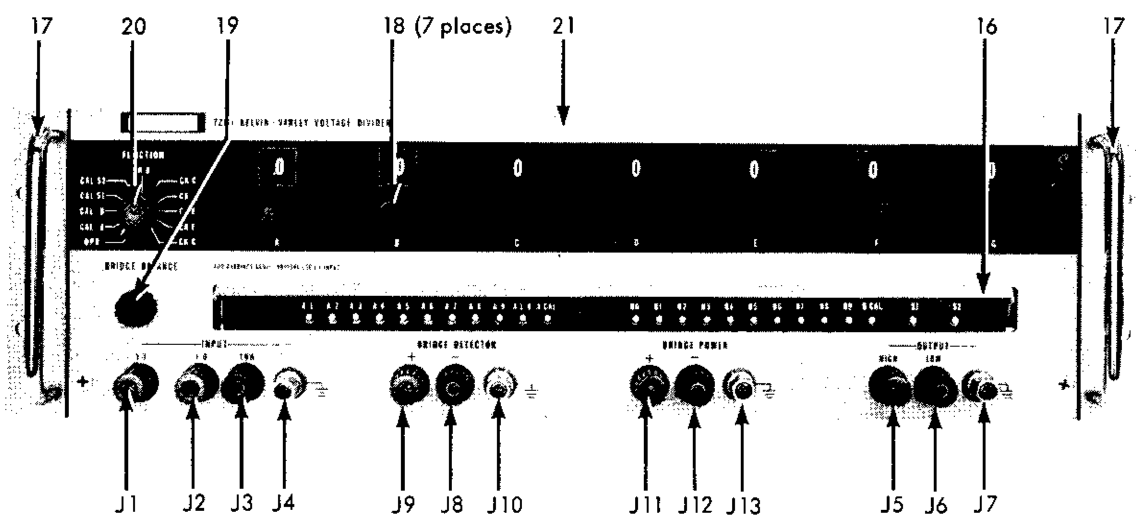


Figure 5-2. FRONT PANEL ASSEMBLY

REF DESIG	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
	TRIMMER P/C ASSEMBLY - Figure 5-3	1702-210716 (720A-4001)	89536	1702-210716	REF		
R1001	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	24		
R1002	Res, met flm, 8.45k ±1%, 1/2w	4705-159475	12400	Type CEC-TO	12		
R1003	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	23	1	
R1004	Res, ww, factory selected	[1]					
R1005	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		
R1006	Res, met flm, 8.45k ±1%, 1/2w	4705-159475	12400	Type CEC-TO	REF		
R1007	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	REF		
R1008	Res, ww, factory selected	[1]					
R1009	Res, var, ww, 5k +10%, 1w	4702-215269	02660	3800P-502	REF		
R1010	Res, met flm, 8.45k ±1%, 1/2w	4702-159475	12400	Type CEC-TO	REF		
R1011	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	REF		
R1012	Res, ww, factory selected	[1]					
R1013	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		
R1014	Res, met flm, 8.45k ±1%, 1/2w	4705-159475	12400	Type CEC-TO	REF		
R1015	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	REF		
R1016	Res, ww, factory selected	[1]					
R1017	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		
R1018	Res, met flm, 8.45k ±1%, 1/2w	4705-159475	12400	Type CEC-TO	REF		
R1019	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	REF		
R1020	Res, ww, factory selected	[1]					
R1021	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		
R1022	Res, met flm, 8.45k ±1%, 1/2w	4705-159475	12400	Type CEC-TO	REF		
R1023	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	REF		
R1024	Res, ww, factory selected	[1]					
R1025	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		
R1026	Res, met flm, 8.45k ±1%, 1/2w	4705-159475	12400	Type CEC-TO	REF		
R1027	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	REF		
R1028	Res, ww, factory selected	[1]					
R1029	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		
R1030	Res, met flm, 8.45k ±1%, 1/2w	4705-159475	12400	Type CEC-TO	REF		
R1031	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	REF		
R1032	Res, ww, factory selected	[1]					
R1033	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		
R1034	Res, met flm, 8.45k ±1%, 1/2w	4705-159475	12400	Type CEC-TO	REF		
R1035	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	REF		
R1036	Res, ww, factory selected	[1]					
R1037	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		
R1038	Res, met flm, 8.45k ±1%, 1/2w	4705-159475	12400	Type CEC-TO	REF		
R1039	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	REF		
R1040	Res, ww, factory selected	[1]					
R1041	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		
R1042	Res, met flm, 8.45k ±1%, 1/2w	4705-159475	12400	Type CEC-TO	REF		
R1043	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	REF		
R1044	Res, ww, factory selected	[1]					
R1045	Res, ww, 100Ω ±0.5%, 1/2w	4707-155846	89536	4707-155846	REF		
R1046	Res, ww, factory selected	[1]					
R1047	Res, ww, factory selected	[1]					
R1048	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		

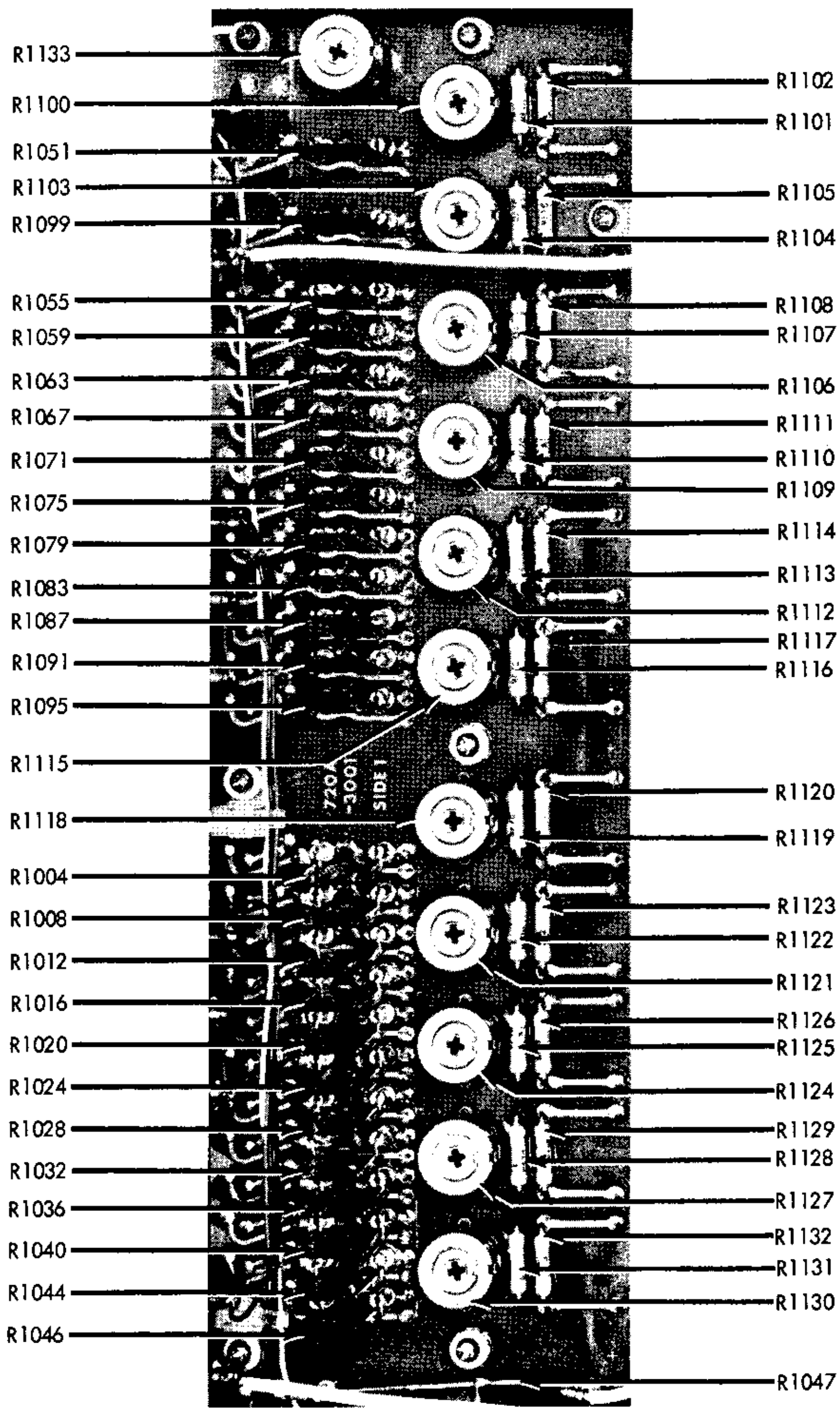


Figure 5-3. TRIMMER P/C ASSEMBLY (Sheet 1 of 2)

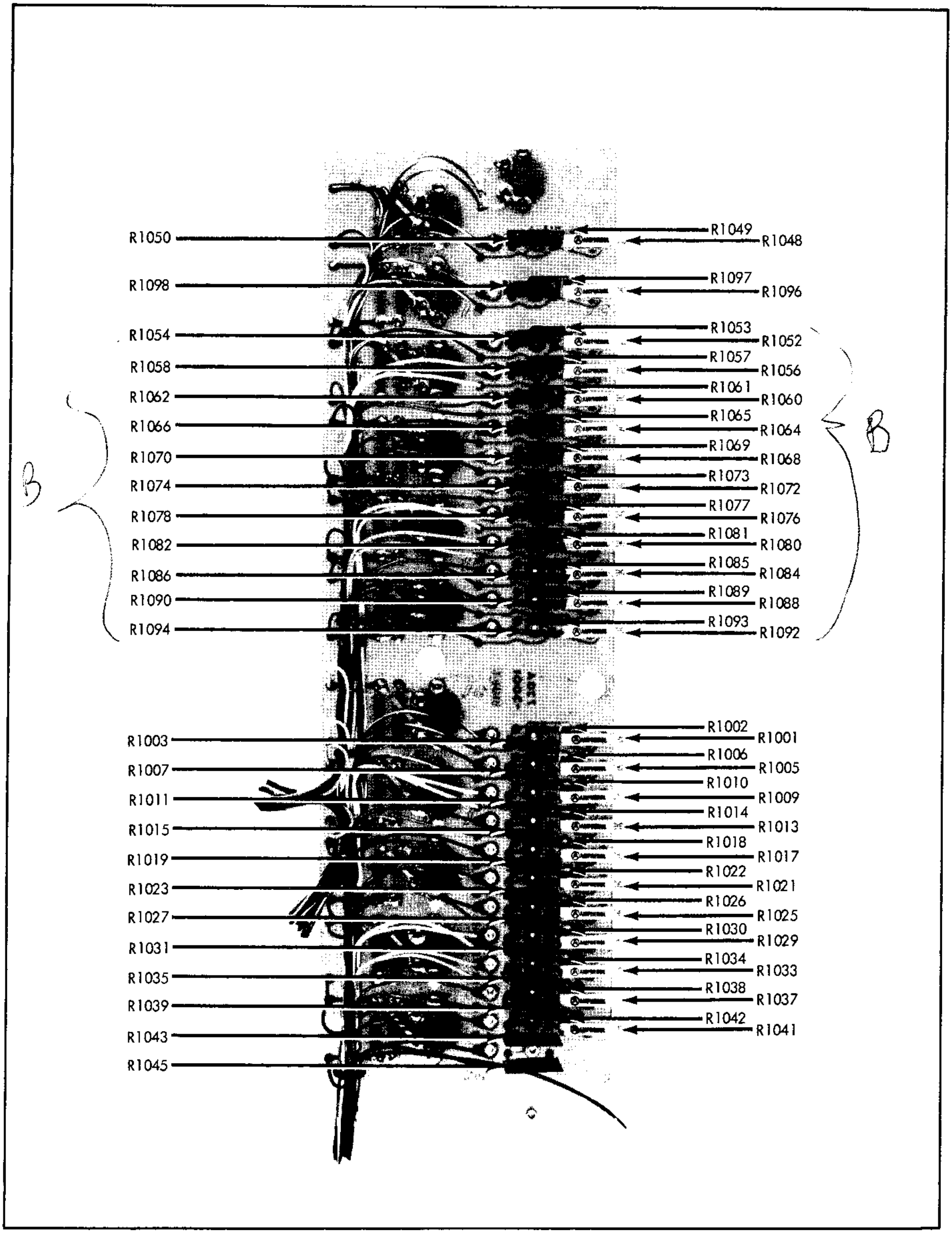


Figure 5-3. TRIMMER P/C ASSEMBLY (Sheet 2 of 2)

REF DESIG	DESCRIPTION	[illegible]	[illegible]	[illegible]	[illegible]	REC QTY	USE CODE
R1049	Res, met flm, 8.45k ±1% [illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
R1050	Res, ww, 250Ω ±0.5%, [illegible]	[illegible]		[illegible]			
R1051	Res, ww, factory selected						
R1052	Res, var, ww, 5k ±10%, [illegible]	[illegible]	[illegible]	[illegible]	REF		
R1053	Res, met flm, 4.75k ±1%, [illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
R1054	Res, ww, 100Ω ±0.5%, [illegible]	[illegible]	[illegible]	[illegible]	REF		
R1055	Res, ww, factory selected						
R1056	Res, var, ww, 5k ±10% [illegible]	[illegible]	[illegible]	[illegible]	REF		
R1057	Res, met flm, 4.75k ±1%, [illegible]	[illegible]	[illegible]	[illegible]	REF		
R1058	Res, ww, 100Ω ±0.5% [illegible]	[illegible]	[illegible]	[illegible]	REF		
R1059	Res, ww, factory selected						
R1060	Res, var, ww, 5k ±10% [illegible]	[illegible]		[illegible]			
R1061	Res, met flm, 4.75k ±1% [illegible]	[illegible]	[illegible]	[illegible]	REF		
R1062	Res, ww, 100Ω ±0.5%, [illegible]	[illegible]		[illegible]			
R1063	Res, ww, factory selected						
R1064	Res, var, ww, 5k ±10% [illegible]	[illegible]	[illegible]	[illegible]	REF		
R1065	Res, met flm, 4.75k ±1% [illegible]	[illegible]					
R1066	Res, ww, 100Ω ±0.5%, [illegible]	[illegible]	[illegible]	[illegible]	REF		
R1067	Res, ww, factory selected						
R1068	Res, var, ww, 5k ±10% [illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
R1069	Res, met flm, 4.75k [illegible]	[illegible]	[illegible]	[illegible]	REF		
R1070	Res, ww, 100Ω ±0.5% [illegible]	[illegible]		[illegible]	REF		
R1071	Res, ww, factory selected						
R1072	Res, var, ww, 5k ±10% [illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
R1073	Res, met flm, 4.75k [illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
R1074	Res, ww, 100Ω ±0.5% [illegible]	[illegible]					
R1075	Res, ww, factory sele[illegible]						
R1076	Res, var, ww, 5k ±1[illegible]	[illegible]					
R1077	Res, met flm, 4.75k [illegible] 1/2w	[illegible]	[illegible]	[illegible]	[illegible]		
R1078	Res, ww, 100Ω ±0.5%, [illegible]	[illegible]	[illegible]	[illegible]	REF		
R1079	Res, ww, factory sele[illegible]						
R1080	Res, var, ww, 5k ±10% [illegible]	[illegible]					
R1081	Res, met flm, 4.75k [illegible] 1/2w	[illegible]		Type [illegible]	REF		
R1082	Res, ww, 100Ω ±0.5%, 1/2w	4707-[illegible]	[illegible]	[illegible]	REF		
R1083	Res, ww, factory selected	▷					
R1084	Res, var, ww, 5k ±10%, 1w	4702-215269	02660	3800P-502	REF		
R1085	Res, met flm, 4.75k ±1%, 1/2w	4705-192500	12400	Type CEC-TO	REF		
R1086	Res, ww, 100Ω ±0.5% [illegible]	[illegible]	[illegible]	[illegible]	REF		
R1087	Res, ww, factory selected	▷					
R1088	Res, var, ww, 5k ±10[illegible]	4702-215269	02660	3800P-502	REF		
R1089	Res, met flm, 4.75k ±1%, 1/2w	4705-192500	[illegible]	Type CEC-TO	[illegible]		
R1090	Res, ww, 100Ω ±0.5[illegible]	4707-[illegible]	[illegible]	[illegible]	[illegible]		
R1091	Res, ww, factory sele[illegible]						
R1092	Res, var, ww, 5k ±[illegible]	[illegible]	[illegible]	[illegible]	REF		
R1093	Res, met flm, 4.75k [illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
R1094	Res, ww, 100Ω ±0.5[illegible]			[illegible]	[illegible]		
R1095	Res, ww, factory se[illegible]						
R1096	Res, var, ww, 5k [illegible]	[illegible]		[illegible]	[illegible]		
R1097	Res, met flm, 4.75[illegible]	[illegible]					
R1098	Res, ww, 400Ω ±0.5[illegible]	[illegible]					

REF DESIG	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
R1099	Res, ww, factory selected	[1]					
R1100	Res, var, ww, 25Ω ±10%, 1 1/4w	4702-161703	71450	Type 110	11		
R1101	Res, met flm, 23.2Ω ±1%, 1/2w	4705-200790	12400	Type CEC-TO	11		
R1102	Res, met flm, 10Ω ±1%, 1/2w	4705-151043	12400	Type CEC-TO	11		
R1103	Res, var, ww, 25Ω ±10%, 1 1/4w	4702-161703	71450	Type 110	REF		
R1104	Res, met flm, 23.2Ω ±1%, 1/2w	4705-200790	12400	Type CEC-TO	REF		
R1105	Res, met flm, 10Ω ±1%, 1/2w	4705-151043	12400	Type CEC-TO	REF		
R1106	Res, var, ww, 25Ω ±10%, 1 1/4w	4702-161703	71450	Type 110	REF		
R1107	Res, met flm, 23.2Ω ±1%, 1/2w	4705-200790	12400	Type CEC-TO	REF		
R1108	Res, met flm, 10Ω ±1%, 1/2w	4705-151043	12400	Type CEC-TO	REF		
R1109	Res, var, ww, 25Ω ±10%, 1 1/4w	4702-161703	71450	Type 110	REF		
R1110	Res, met flm, 23.2Ω ±1%, 1/2w	4705-200790	12400	Type CEC-TO	REF		
R1111	Res, met flm, 10Ω ±1%, 1/2w	4705-151043	12400	Type CEC-TO	REF		
R1112	Res, var, ww, 25Ω ±10%, 1 1/4w	4702-161703	71450	Type 110	REF		
R1113	Res, met flm, 23.2Ω ±1%, 1/2w	4705-200790	12400	Type CEC-TO	REF		
R1114	Res, met flm, 10Ω ±1%, 1/2w	4705-151043	12400	Type CEC-TO	REF		
R1115	Res, var, ww, 25Ω ±10%, 1 1/4w	4702-161703	71450	Type 110	REF		
R1116	Res, met flm, 23.2Ω ±1%, 1/2w	4705-200790	12400	Type CEC-TO	REF		
R1117	Res, met flm, 10Ω ±1%, 1/2w	4705-151043	12400	Type CEC-TO	REF		
R1118	Res, var, ww, 25Ω ±10%, 1 1/4w	4702-161703	71450	Type 110	REF		
R1119	Res, met flm, 23.2Ω ±1%, 1/2w	4705-200790	12400	Type CEC-TO	REF		
R1120	Res, met flm, 10Ω ±1%, 1/2w	4705-151043	12400	Type CEC-TO	REF		
R1121	Res, var, ww, 25Ω ±10%, 1 1/4w	4702-161703	71450	Type 110	REF		
R1122	Res, met flm, 23.2Ω ±1%, 1/2w	4705-200790	12400	Type CEC-TO	REF		
R1123	Res, met flm, 10Ω ±1%, 1/2w	4705-151043	12400	Type CEC-TO	REF		
R1124	Res, var, ww, 25Ω ±10%, 1 1/4w	4702-161703	71450	Type 110	REF		
R1125	Res, met flm, 23.2Ω ±1%, 1/2w	4705-200790	12400	Type CEC-TO	REF		
R1126	Res, met flm, 10Ω ±1%, 1/2w	4705-151043	12400	Type CEC-TO	REF		
R1127	Res, var, ww, 25Ω ±10%, 1 1/4w	4702-161703	71450	Type 110	REF		
R1128	Res, met flm, 23.2Ω ±1%, 1/2w	4705-200790	12400	Type CEC-TO	REF		
R1129	Res, met flm, 10Ω ±1%, 1/2w	4705-151043	12400	Type CEC-TO	REF		
R1130	Res, var, ww, 25Ω ±10%, 1 1/4w	4702-161703	71450	Type 110	REF		
R1131	Res, met flm, 23.2Ω ±1%, 1/2w	4705-200790	12400	Type CEC-TO	REF		
R1132	Res, met flm, 10Ω ±1%, 1/2w	4705-151043	12400	Type CEC-TO	REF		
R1133	Res, var, ww, 150Ω ±20%, 1 1/4w	4702-163642	71450	Type 110	1		

[1] These resistors are factory selected. Replace with exact value. When ordering, include model, serial number, reference designation and all information stamped on the resistor.

REF DESIG	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
	BRIDGE P/C ASSEMBLY - Figure 5-4	1702-200295 (720A-4002)	89536	1702-200295	REF		
R201	Res, ww, 39.536k, matched set	[2]					
R202	Res, ww, 39.536k, matched set	[2]					
R203	Res, var, ww, 100Ω ±20%, 1 1/4w	4702-112797	71450	Type 110	2		
R204	Res, ww, 15.814k ±0.02%, 1w	4707-200550	89536	4707-200550	1	1	
R205	Res, var, ww, 100Ω ±20%, 1 1/4w	4702-112797	71450	Type 110	REF		
R206	Res, ww, 4.873k, matched set	[3]					
R207	Res, ww, 4.873k, matched set	[3]					
R208	Res, met flm, 15k ±1%, 1/2w	4705-151498	12400	Type CEC-TO	1		
R209	Res, ww, 250Ω ±0.5%, 1/2w	4707-199893	89536	4707-199893	1	1	

[2] These resistors are factory matched. If replacement is required, an entire set, part number 4710-217679, must be ordered.

[3] These resistors are factory matched. If replacement is required, an entire set, part number 4710-217687, must be ordered.

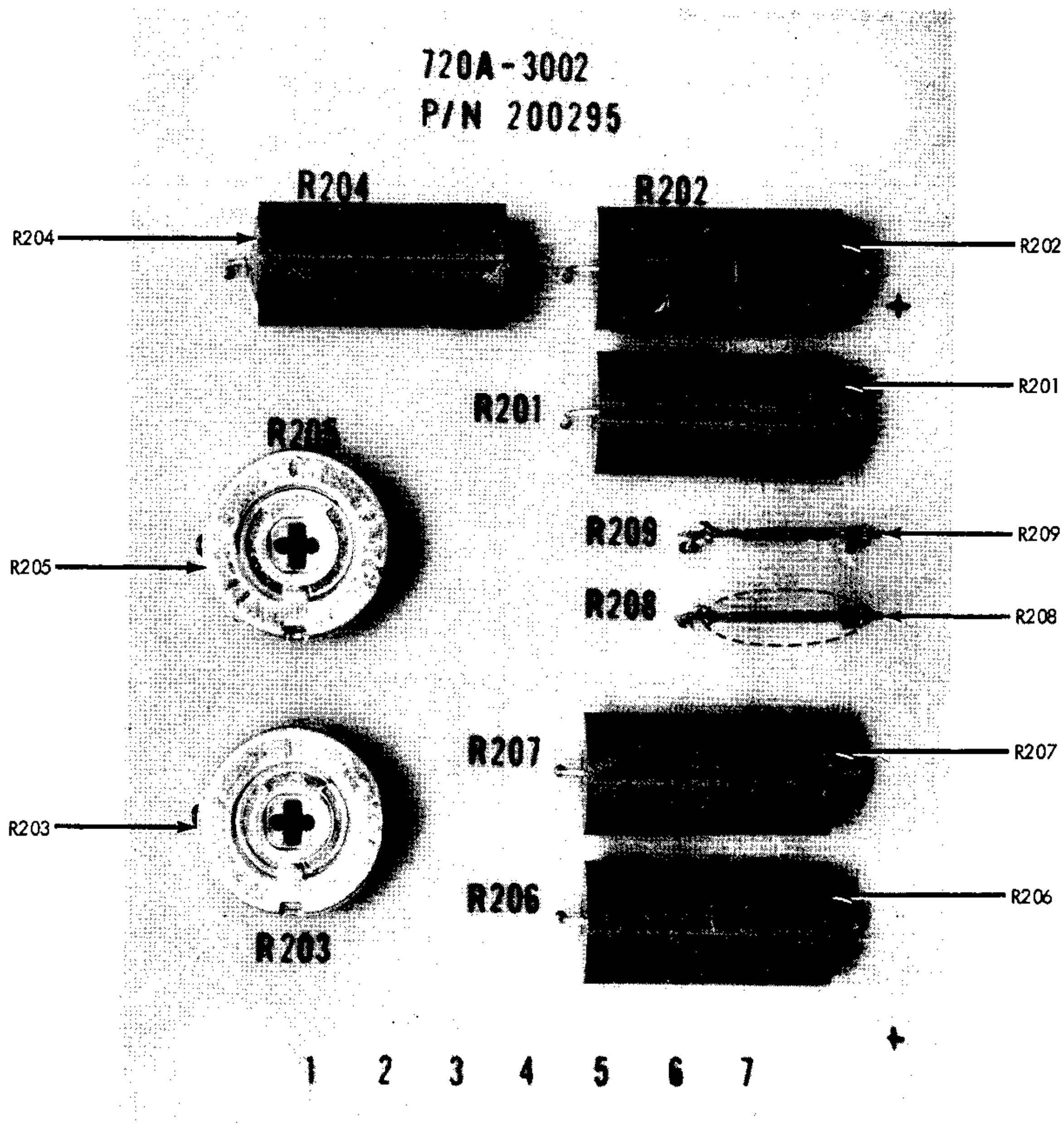


Figure 5-4. BRIDGE P/C ASSEMBLY

REF DESIG	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
	"B" DECADE SWITCH ASSEMBLY Figure 5-5	5110-217307 (720A-4004)	89536	5110-217307	REF		
R401 thru R411	Res, ww, 9.898k, matched set	4					
R412	Res, ww, 39.536k ±0.01%, 1w	4707-199810	89536	4707-199810	1	1	
S2	Switch, "B", rotary, 3p, 11 pos, 5 sect	5107-218602	89536	5107-218602	2		

4 These resistors are a factory matched set, part number 4710-217646. If replacement of one or more resistors in the set is required, include all information stamped on the resistor along with the information described in paragraph 5-6. Should the information on the resistor not be discernible, include all of the above information about the adjacent resistors.

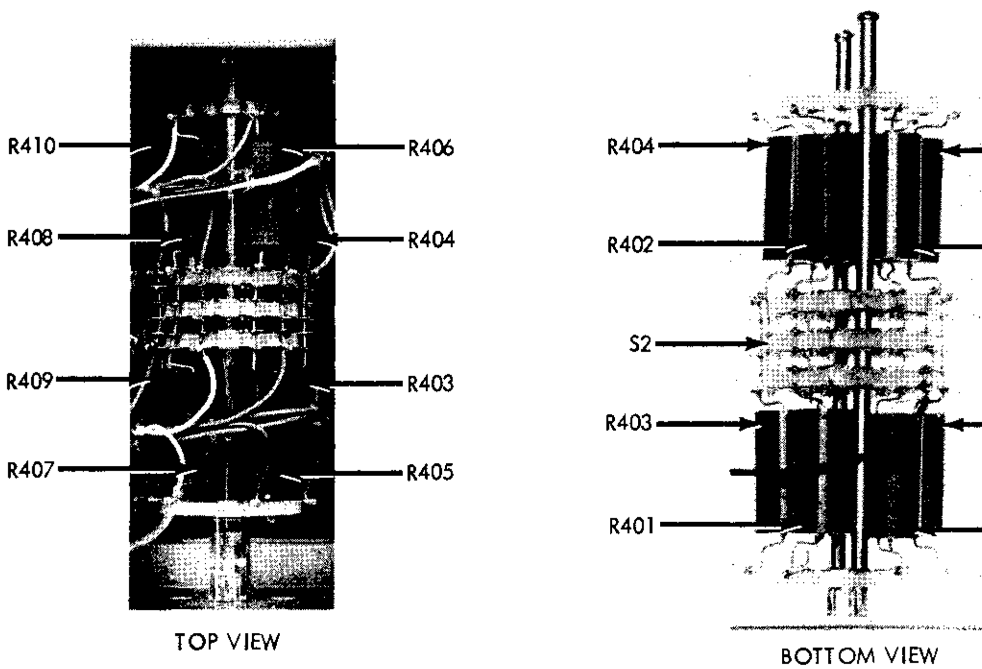


Figure 5-5. "B" DECADE SWITCH ASSEMBLY

REF DESIG	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
	"C" DECADE SWITCH ASSEMBLY Figure 5-6	5110-217315 (720A-4005)	89536	5110-217315	REF		
R501 thru R511	Res, ww, 4k, matched set	[5]					
R512	Res, ww, 40.31k ±0.02%, 1w	4707-199836	89536	4707-199836	1	1	
S3	Switch, "C", rotary, 3p, 11 pos, 5 sect	5107-218602	89536	5107-218602	REF		

[5] These resistors are a factory matched set, part number 4710-217653. If replacement of one or more resistors in the set is required, include all information stamped on the resistor along with the information described in paragraph 5-6. Should the information on the resistor not be discernible, include all of the above information about the adjacent resistors.

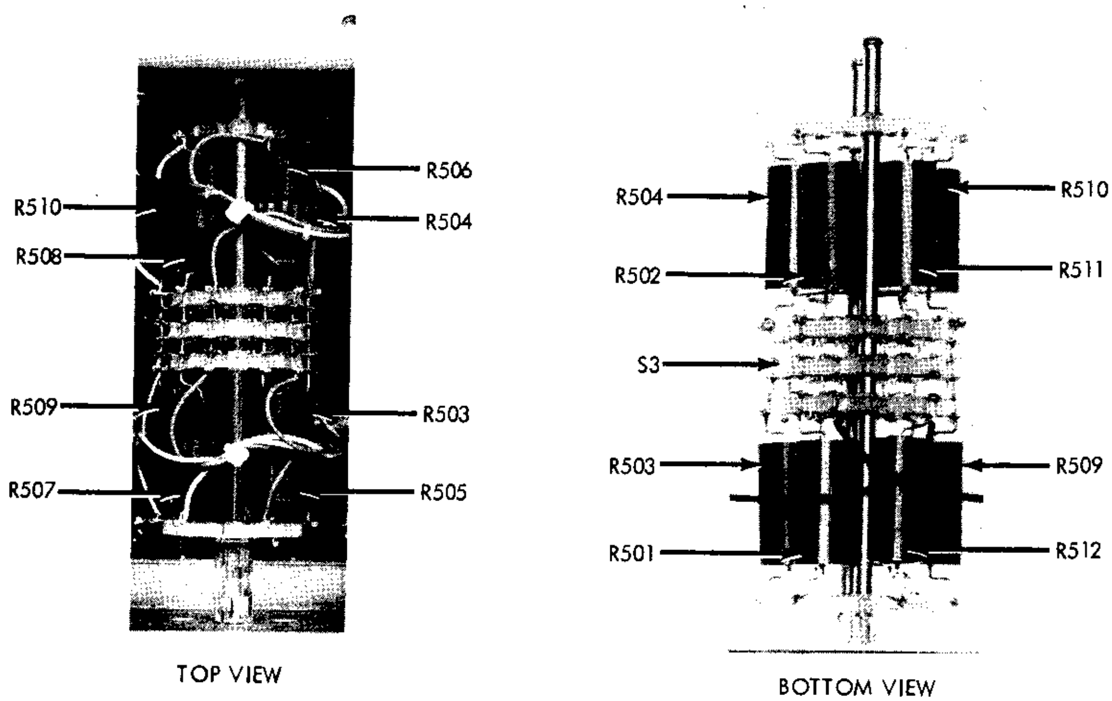


Figure 5-6. "C" DECADE SWITCH ASSEMBLY

REF DESIG	DESCRIPTION	STOCK NO	MFR	MFR PART NO	TOT QTY	REC QTY	USE CODE
	"D","E","F", AND "G" DECADES SWITCH ASSEMBLY - Figure 5-7	5110-217323 (720A-4006)	89536	5110-217323	REF		
R601 thru R611	Res, ww, 1k, matched set	[6]					
R612	Res, ww, 2.5k, matched set	[6]					
R701 thru R711	Res, ww, 1k, matched set	[6]					
R712	Res, ww, 2.5k, matched set	[6]					
R801 thru R811	Res, ww, 1k, matched set	[6]					
R812	Res, ww, 2.5k, matched set	[6]					
R901 thru R910	Res, ww, 1k, matched set	[6]					
S4	Switch, "D", rotary, 2p, 10 pos, 4 sect	5107-218594	89536	5107-218594	3		
S5	Switch, "E", rotary, 2p, 10 pos, 4 sect	5107-218594	89536	5107-218594	REF		
S6	Switch, "F", rotary, 2p, 10 pos, 4 sect	5107-218594	89536	5107-218594	REF		
S7	Switch, "G", rotary, 1p, 11 pos, 3 sect	5107-218586	89536	5107-218586	1		

[6] These resistors are a factory matched set, part number 4710-217661. If replacement of one or more resistors in the set is required, include all information stamped on the resistor along with the information described in paragraph 5-6. Should the information on the resistor not be discernible, include all of the above information about the adjacent resistors.

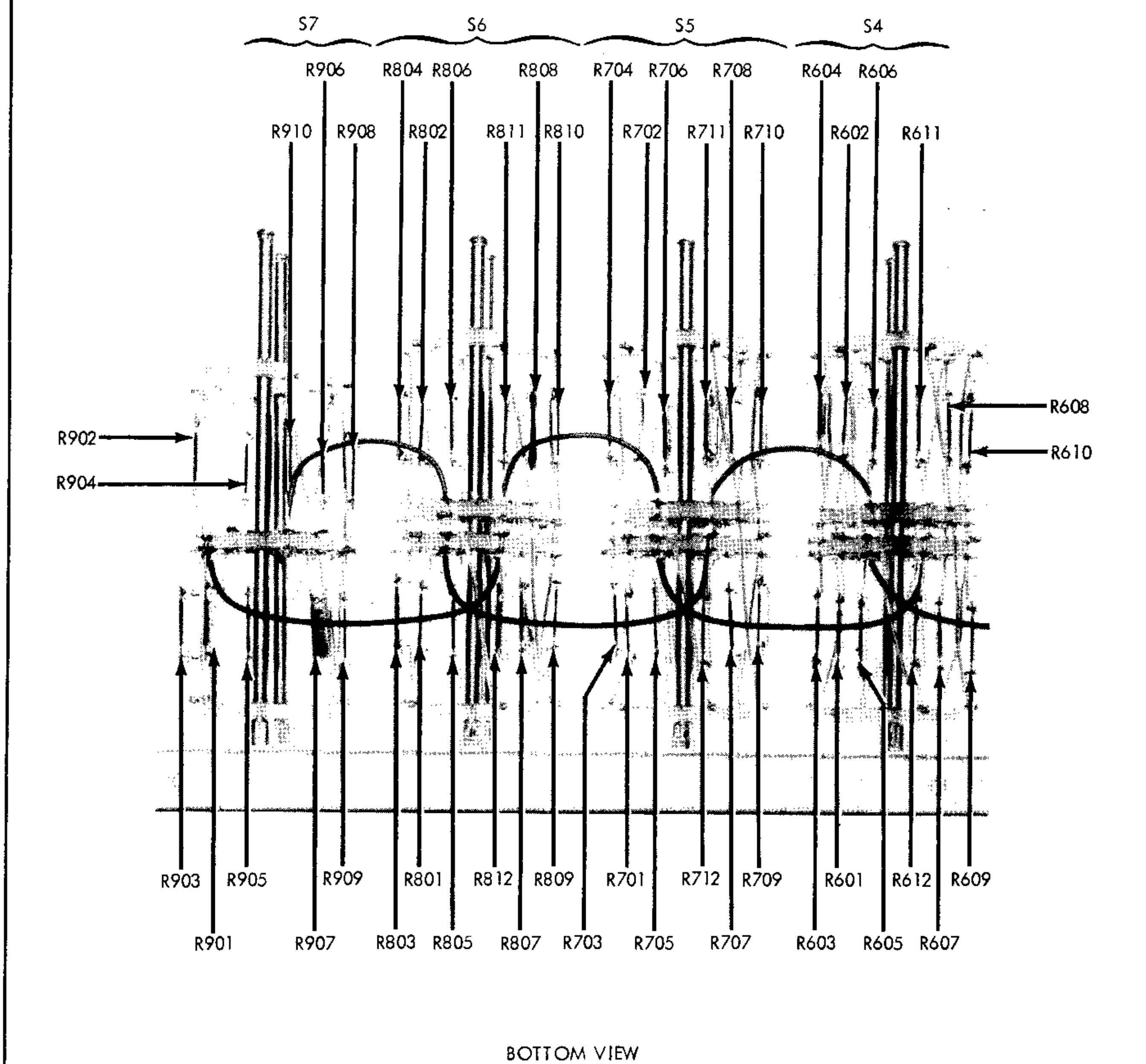


Figure 5-7. "D", "E", "F" AND "G" DECADES SWITCH ASSEMBLY

Section 7
General Information

7-1. This section of the manual contains generalized user information as well as supplemental information to the List of Replaceable Parts contained in Section 5. The following information is presented in this section:

List of Abbreviations
Federal Supply Codes for Manufacturers
Fluke Technical Service Centers — U.S. and Canada
Sales and Service Locations — International
Sales Representatives — U.S. and Canada

List of Abbreviations and Symbols

A or amp	ampere
ac	alternating current
af	audio frequency
a/d	analog-to-digital
assy	assembly
AWG	american wire gauge
B	bel
bcd	binary coded decimal
°C	Celsius
cap	capacitor
ccw	counterclockwise
cer	ceramic
cermet	ceramic to metal (seal)
ckt	circuit
cm	centimeter
cmrr	common mode rejection ratio
comp	composition
cont	continue
crt	cathode-ray tube
cw	clockwise
d/a	digital-to-analog
dac	digital-to-analog converter
dB	decibel
dc	direct current
dmm	digital multimeter
dvm	digital voltmeter
elect	electrolytic
ext	external
F	farad
°F	Fahrenheit
FET	Field-effect transistor
ff	flip-flop
freq	frequency
FSN	federal stock number
g	gram
G	giga (10^9)
gd	guard
Ge	germanium
GHz	gigahertz
gmv	guaranteed minimum value
gnd	ground
H	henry
hd	heavy duty
hf	high frequency
Hz	hertz
IC	integrated circuit
if	intermediate frequency
in	inch(es)
intl	internal
I/O	input/output
k	kilo (10^3)
kHz	kilohertz
kΩ	kilohm(s)
kV	kilovolt(s)
lf	low frequency
LED	light-emitting diode
LSB	least significant bit
LSD	least significant digit
M	mega (10^6)
m	milli (10^{-3})
mA	milliampere(s)
max	maximum
mf	metal film
MHz	megahertz
min	minimum
mm	millimeter
ms	millisecond
MSB	most significant bit
MSD	most significant digit
MTBF	mean time between failures
MTTR	mean time to repair
mV	millivolt(s)
mv	multivibrator
MΩ	megohm(s)
n	nano (10^{-9})
na	not applicable
NC	normally closed
(−) or neg	negative
NO	normally open
ns	nanosecond
opnl ampl	operational amplifier
p	pico (10^{-12})
para	paragraph
pcb	printed circuit board
pF	picofarad
pn	part number
(+) or pos	positive
pot	potentiometer
p-p	peak-to-peak
ppm	parts per million
PROM	programmable read-only memory
psi	pound-force per square inch
RAM	random-access memory
rf	radio frequency
rms	root mean square
ROM	read-only memory
s or sec	second (time)
scope	oscilloscope
SH	shield
Si	silicon
serno	serial number
sr	shift register
Ta	tantalum
tb	terminal board
tc	temperature coefficient or temperature compensating
tcxo	temperature compensated crystal oscillator
tp	test point
u or μ	micro (10^{-6})
uhf	ultra high frequency
us or μs	microsecond(s) (10^{-6})
uut	unit under test
V	volt
v	voltage
var	variable
vco	voltage controlled oscillator
vhf	very high frequency
vlf	very low frequency
W	watt(s)
ww	wire wound
xfmr	transformer
xstr	transistor
xtal	crystal
xtlo	crystal oscillator
Ω	ohm(s)
μ	micro (10^{-6})

Federal Supply Codes for Manufacturers (Continued)

00213
Nytronics Comp. Group Inc.
Subsidiary of Nytronics Inc.
Formerly Sage Electronics
Rochester, New York

00327
Welwyn International, Inc.
Westlake, Ohio

00656
Aerovox Corp.
New Bedford, Massachusetts

00686
Film Capacitors, Inc.
Passaic, New Jersey

00779
AMP Inc.
Harrisberg, Pennsylvania

01121
Allen-Bradley Co.
Milwaukee, Wisconsin

01281
TRW Electronic Comp.
Semiconductor Operations
Lawndale, California

01295
Texas Instruments, Inc.
Semiconductor Group
Dallas, Texas

01537
Motorola Communications &
Electronics Inc.
Franklin Park, Illinois

01686
RCL Electronics Inc.
Manchester, New Hampshire

01730
Replaced by 73586

01884 - use 56289
Sprague Electric Co.
Dearborn Electronic Div.
Lockwood, Florida

02114
Ferroxcube Corp.
Saugerties, New York

02131
General Instrument Corp.
Harris ASW Div.
Westwood, Maine

02395
Rason Mfg. Co.
Brooklyn, New York

02533
Snelgrove, C.R. Co., Ltd.
Don Mills, Ontario, Canada
M3B 1M2

02606
Fenwal Labs
Div. of Travenal Labs.
Morton Grove, Illinois

02660
Bunker Ramo Corp., Conn Div.
Formerly Amphenol-Borg
Electric Corp.
Broadview, Illinois

02799
Areo Capacitors, Inc.
Chatsworth, California

03508
General Electric Co.
Semiconductor Products
Syracuse, New York

03614
Replaced by 71400

03651
Replaced by 44655

03797
Eldema Div.
Genisco Technology Corp.
Compton, California

03877
Transistron Electronic Corp.
Wakefield, Massachusetts

03888
KDI Pyrofilm Corp.
Whippany, New Jersey

03911
Clairex Electronics Div.
Clairex Corp.
Mt. Vernon, New York

03980
Muirhead Inc.
Mountainside, New Jersey

04009
Arrow Hart Inc.
Hartford, Connecticut

04062
Replaced by 72136

04202
Replaced by 81312

04217
Essex International Inc.
Wire & Cable Div.
Anaheim, California

04221
Aemco, Div. of
Midtex Inc.
Mankato, Minnesota

04222
AVX Ceramics Div.
AVX Corp.
Myrtle Beach, Florida

04423
Telonic Industries
Laguna Beach, California

04645
Replaced by 75376

04713
Motorola Inc. Semiconductor
Products
Phoenix, Arizona

04946
Standard Wire & Cable
Los Angeles, California

05082
Replaced by 94988

05236
Jonathan Mfg. Co.
Fullerton, California

05245
Components Corp. now
Corcom, Inc.
Chicago, Illinois

05277
Westinghouse Electric Corp.
Semiconductor Div.
Youngwood, Pennsylvania

05278
Replaced by 43543

05279
Southwest Machine &
Plastic Co.
Glendora, California

05397
Union Carbide Corp.
Materials Systems Div.
New York, New York

05571 - use 56289
Sprague Electric Co.
Pacific Div.
Los Angeles, California

05574
Viking Industries
Chatsworth, California

05704
Replaced by 16258

05820
Wakefield Engineering Inc.
Wakefield, Massachusetts

06001
General Electric Co.
Electronic Capacitor &
Battery Products Dept.
Columbia, South Carolina

06136
Replaced by 63743

06383
Panduit Corp.
Tinley Park, Illinois

06473
Bunker Ramo Corp.
Amphenol SAMS Div.
Chatsworth, California

06555
Beede Electrical Instrument Co.
Penacook, New Hampshire

06739
Electron Corp.
Littleton, Colorado

06743
Clevite Corp.
Cleveland, Ohio

06751
Components, Inc. Semcor Div.
Phoenix, Arizona

06860
Gould Automotive Div.
City of Industry, California

06961
Vernitron Corp., Piezo
Electric Div.
Formerly Clevite Corp., Piezo
Electric Div.
Bedford, Ohio

06980
Eimac Div.
Varian Associates
San Carlos, California

07047
Ross Milton, Co., The
South Hampton, Pennsylvania

07115
Replaced by 14674

07138
Westinghouse Electric Corp.,
Electronic Tube Division
Horsehead, New York

07233
TRW Electronic Components
Cinch Graphic
City of Industry, California

07256
Silicon Transistor Corp.
Div. of BBF Group Inc.
Chelmsford, MA

07261
Aumet Corp.
Culver City, California

07263
Fairchild Semiconductor
Div. of Fairchild Camera
& Instrument Corp.
Mountain View, California

07344
Bircher Co., Inc.
Rochester, New York

07597
Burndy Corp.
Tape/Cable Div.
Rochester, New York

07792
Lerma Engineering Corp.
Northampton, Massachusetts

07910
Teledyne Semiconductor
Formerly Continental Device
Hawthorne, California

07933 - use 49956
Raytheon Co.
Semiconductor Div. HQ
Mountain View, California

08225
Industro Transistor Corp.
Long Island City, New York

08261
Spectra Strip Corp.
Garden Grove, California

08530
Reliance Mica Corp.
Brooklyn, New York

08806
General Electric Co.
Miniature Lamp Products Dept.
Cleveland, Ohio

08863
Nylomatic Corp.
Norrisville, Pennsylvania

08988 - use 53085
Skottie Electronics Inc.
Archbald, Pennsylvania

09214
G.E. Co. Semi-Conductor
Products Dept.
Power Semi-Conductor
Products OPN Sec.
Auburn, New York

09353
C and K Components
Watertown, Massachusetts

09423
Scientific Components, Inc.
Santa Barbara, California

09922
Burndy Corp.
Norwalk, Connecticut

09969
Dale Electronics Inc.
Yankton, S. Dakota

10059
Barker Engineering Corp.
Formerly Amerace, Amerace
ESNA Corp.
Kenilworth, New Jersey

11236
CTS of Berne
Berne, Indiana

11237
CTS Keene Inc.
Paso Robles, California

11358
CBS Electronic Div.
Columbia Broadcasting System
Newburyport, MN

11403
Best Products Co.
Chicago, Illinois

11503
Keystone Columbia Inc.
Warren, Michigan

11532
Teledyne Relays
Hawthorne, California

11711
General Instrument Corp
Rectifier Division
Hickville, New York

11726
Qualidyne Corp.
Santa Clara, California

12014
Chicago Rivet & Machine Co.
Bellwood, Illinois

12040
National Semiconductor Corp.
Danburry, Connecticut

12060
Diodes, Inc.
Chatsworth, California

12136
Philadelphia Handle Co.
Camden, New Jersey

12300
Potter-Brumfield Division
AMF Canada LTD.
Guelph, Onatrio, Canada

12323
Presin Co., Inc.
Shelton, Connecticut

12327
Freeway Corp. formerly
Freeway Washer & Stamping Co.
Cleveland, Ohio

12443
Budd Co. The, Polychem Products
Plastic Products Div.
Bridgeport, PA

12615
U.S. Terminals Inc.
Cincinnati, Ohio

12617
Hamlin Inc.
Lake Mills, Wisconsin

12697
Clarostat Mfg. Co.
Dover, New Hampshire

12749
James Electronics
Chicago, Illinois

12856
Micrometals
Sierra Madre, California

12954
Dickson Electronics Corp.
Scottsdale, Arizona

12969
Unitrode Corp.
Watertown, Massachusetts

13103
Thermalloy Co., Inc.
Dallas, Texas

13327
Solitron Devices Inc.
Tappan, New York

13511
Amphenol Cadre Div.
Bunker-Ramo Corp.
Los Gatos, California

13606 - use 56289
Sprague Electric Co.
Transistor Div.
Concord, New Hampshire

13839
Replaced by 23732

14099
Semtech Corp.
Newbury Park, California

14140
Edison Electronic Div.
Mc Gray-Edison Co.
Manchester, New Hampshire

14193
Cal-R-Inc. formerly
California Resistor, Corp.
Santa Monica, California

14298
American Components, Inc.
an Insilco Co.
Conshohocken, Pennsylvania

14655
Cornell-Dublier Electronics
Division of Federal Pacific
Electric Co. Govt. Control Dept.
Newark, New Jersey

14752
Electro Cube Inc.
San Gabriel, California

14869
Replaced by 96853

14936
General Instrument Corp.
Semi Conductor Products Group
Hicksville, New York

15636
Elec-Trol Inc.
Saugus, California

15801
Fenwal Electronics Inc.
Div. of Kidde Walter and Co., Inc.
Framingham, Massachusetts

15818
Teledyne Semiconductors, formerly
Amelco Semiconductor
Mountain View, California

15849
Litton Systems Inc. Useco Div.
formerly Useco Inc.
Van Nuys, California

15898
International Business
Machines Corp.
Essex Junction, Vermont

15909
Replaced by 14140

16258
Space-Lok Inc.
Burbank, California

16299
Corning Glass
Electronic Components Div.
Raleigh, North Carolina

16332
Replaced by 28478

16473
Cambridge Scientific Ind.
Div. of Chemed Corporation
Cambridge, Maryland

16742
Paramount Plastics Fabricators, Inc.
Downey, California

16758
Delco Electronics
Div. of General Motors Corp.
Kokomo, Indiana

17001
Replaced by 71468

17069
Circuit Structures Lab.
Burbank, California

17338
High Pressure Eng. Co., Inc.
Oklahoma City, Oklahoma

17545
Atlantic Semiconductors, Inc.
Asbury Park, New Jersey

17856
Siliconix, Inc.
Santa Clara, California

17870
Replaced by 14140

18178
Vactec Inc.
Maryland Heights, Missouri

18324
Signetics Corp.
Sunnyvale, California

18612
Vishay Resistor Products Div.
Vishay Intertechnology Inc.
Malvern, Pennsylvania

18736
Voltronics Corp.
Hanover, New Jersey

18927
G T E Sylvania Inc.
Precision Material Group
Parts Division
Titusville, Pennsylvania

19451
Perine Machinery & Supply Co.
Seattle, Washington

19701
Electro-Midland Corp.
Mepco-Electra Inc.
Mineral Wells, Texas

20584
Enochs Mfg. Inc.
Indianapolis, Indiana

20891
Self-Organizing Systems, Inc.
Dallas, Texas

21604
Buckeye Stamping Co.
Columbus, Ohio

21845
Solitron Devices Inc.
Transistor Division
Riveria Beach, Florida

22767
ITT Semiconductors
Palo Alto, California

23050
Product Comp. Corp.
Mount Vernon, New York

23732
Tracor Inc.
Rockville, Maryland

23880
Stanford Applied Engrng.
Santa Clara, California

23936
Pamotor Div., Wm. J. Purdy Co.
Burlingame, California

24248
Replaced by 94222

24355
Analog Devices Inc.
Norwood, Massachusetts

24655
General Radio
Concord, Massachusetts

24759
Lenox-Fugle Electronics Inc.
South Plainfield, New Jersey

25088
Siemen Corp.
Isilen, New Jersey

25403
Amperex Electronic Corp.
Semiconductor &
Micro-Circuits Div.
Slatersville, Rhode Island

27014
National Semiconductor Corp.
Santa Clara, California

27264
Molex Products
Downers Grove, Illinois

28213
Minnesota Mining & Mfg. Co.
Consumer Products Div.
St. Paul, Minnesota

28425
Serv-/-Link formerly
Bohannan Industries
Fort Worth, Texas

28478
Deltrol Controls Div.
Deltrol Corporation
Milwaukee, Wisconsin

28480
Hewlett Packard Co. Corporate H.Q.
Palo Alto, California

28520
Heyman Mfg. Co.
Kenilworth, New Jersey

29083
Monsanto, Co., Inc.
Santa Clara, California

29604
Stackpole Components Co.
Raleigh, North Carolina

30148
A B Enterprise Inc.
Ahoskie, North Carolina

30323
Illinois Tool Works, Inc.
Chicago, Illinois

31091
Optimax Inc.
Colmar, Pennsylvania

32539
Mura Corp.
Great Neck, New York

32767
Griffith Plastic Corp.
Burlingame, California

32879
Advanced Mechanical Components
Northridge, California

32897
Erie Technological Products, Inc.
Frequency Control Div.
Carlisle, Pennsylvania

32997
Bourns Inc.
Trimpot Products Division
Riverside, California

33173
General Electric Co.
Products Dept.
Owensboro, Kentucky

34333
Silicon General
Westminister, California

34335
Advanced Micro Devices
Sunnyvale, California

34802
Electromotive Inc.
Kenilworth, New Jersey

37942
Mallory, P.R. & Co., Inc.
Indianapolis, Indiana

42498
National Radio
Melrose, Massachusetts

43543
Nytronics Inc.
Transformer Co. Div.
Geneva, New York

44655
Ohmite Mfg. Co.
Skokie, Illinois

49671
RCA Corp.
New York, New York

49956
Raytheon Company
Lexington, Massachusetts

50088
Mostek Corp.
Carrollton, Texas

50579
Litronix Inc.
Cupertino, California

51605
Scientific Components Inc.
Linden, New Jersey

53021
Sangamo Electric Co.
Springfield, Illinois

54294
Cutler-Hammer Inc. formerly
Shallcross, A Cutter-Hammer Co.
Selma, North Carolina

55026
Simpson Electric Co.
Div. of Am. Gage and Mach. Co.
Elgin, Illinois

56289
Sprague Electric Co.
North Adams, Massachusetts

58474
Superior Electric Co.
Bristol, Connecticut

60399
Torin Corp. formerly
Torrington Mfg. Co.
Torrington, Connecticut

63743
Ward Leonard Electric Co., Inc.
Mount Vernon, New York

64834
West Mfg. Co.
San Francisco, Californai

65092
Weston Instruments Inc.
Newark, New Jersey

66150
Winslow Tele-Tronics Inc.
Eaton Town, New Jersey

70485
Atlantic India Rubber Works
Chicago, Illinois

70563
Amperite Company
Union City, New Jersey

70903
Belden Corp.
Geneva, Illinois

71002
Birnbach Radio Co., Inc.
Freeport, LI New York

71400
Bussmann Mfg.
Div. of McGraw-Edison Co.
Saint Louis, Missouri

71450
CTS Corp.
Elkhart, Indiana

71468
ITT Cannon Electric Inc.
Santa Ana, California

71482
Clare, C.P. & Co.
Chicago, Illinois

71590
Centrelab Electronics
Div. of Globe Union Inc.
Milwaukee, Wisconsin

71707
Coto Coil Co., Inc.
Providence, Rhode Island

71744
Chicago Miniature Lamp Works
Chicago, Illinois

71785
TRW Electronics Components
Cinch Connector Operations Div.
Elk Grove Village, Chicago, Illinois

72005
Driver, Wilber B., Co.
Newark, New Jersey

72092
Replaced by 06980

72136
Electro Motive Mfg. Co.
Williamantic, Connecticut

72259
Nytronics Inc.
Pelham Manor, New Jersey

72619
Dialight Div.
Amperex Electronic Corp.
Brooklyn, New York

72653
G.C. Electronics
Div. of Hydrometals, Inc.
Brooklyn, New York

72665
Replaced by 90303

72794
Dzus Fastener Co., Inc.
West Islip, New York

72928
Gulton Ind. Inc.
Gudeman Div.
Chicago, Illinois

72982
Erie Tech. Products Inc.
Erie, Pennsylvania

73138
Beckman Instruments Inc.
Helipot Division
Fullerton, California

73293
Hughes Aircraft Co.
Electron Dynamics Div.
Torrence, California

73445
Amperex Electronic Corp.
Hicksville, LI, New York

73559
Carling Electric Inc.
West Hartford, Connecticut

73586
Circle F Industries
Trenton, New Jersey

73734
Federal Screw Products, Inc.
Chicago, Illinois

73743
Fischer Special Mfg. Co.
Cincinnati, Ohio

73899
JFD Electronics Co.
Components Corp
Brooklyn, New York

73949
Guardian Electric Mfg. Co.
Chicago, Illinois

74199
Quan Nichols Co.
Chicago, Illinois

74217
Radio Switch Corp.
Marlboro, New Jersey

74276
Signalite Div.
General Instrument Corp.
Neptune, New Jersey

74306
Piezo Crystal Co.
Carlisle, Pennsylvania

74542
Hoyt Elect. Instr. Works
Penacook, New Hampshire

74970
Johnson E.F., Co.
Waseca, Minnesota

75042
TRW Electronics Components
IRC Fixed Resistors
Philadelphia, Pennsylvania

75376
Kurz-Kasch Inc.
Dayton, Ohio

75378
CTS Knights Inc.
Sandwich, Illinois

75382
Kulka Electric Corp.
Mount Vernon, New York

75915
Littlefuse Inc.
Des Plaines, Illinois

76854
Oak Industries Inc.
Switch Div.
Crystal Lake, Illinois

77342
AMF Inc.
Potter & Brumfield Div.
Princeton, Indiana

77638
General Instrument Corp.
Rectifier Division
Brooklyn, New York

77969
Rubbercraft Corp. of CA. LTD.
Torrance, California

78189
Shakeproof
Div. of Illinois Tool Works Inc.
Elgin, Illinois

78277
Sigma Instruments, Inc.
South Braintree, Massachusetts

78488
Stackpole Carbon Co.
Saint Marys, Pennsylvania

78553
Eaton Corp. Engineered
Fastener Div.
Tinnerman Plant
Cleveland, Ohio

79136
Waldes Kohinoor Inc.
Long Island City, New York

79497
Western Rubber Company
Goshen, Indiana

79963
Zierick Mfg. Corp.
Mt. Kisko, New York

80031
Electro-Midland Corp., Mepco Div.
A North American Phillips Co.
Morristown, New Jersey

80145
LFE Corp., Process Control Div.
formerly API Instrument Co.
Chesterland, Ohio

80183 - use 56289
Sprague Products
North Adams, Massachusetts

80294
Bourns Inc., Instrument Div.
Riverside, California

80583
Hammarlund Mfg. Co., Inc.
Red Bank, New Jersey

80640
Stevens, Arnold Inc.
South Boston, Massachusetts

81073
Grayhill, Inc.
La Grange, Illinois

81312
Winchester Electronics
Div. of Litton Industries Inc.
Oakville, Connecticut

81439
Therm-O-Disc Inc.
Mansfield, Ohio

81483
International Rectifier Corp.
Los Angeles, California

81590
Korry Mfg. Co.
Seattle, Washington

81741
Chicago Lock Co.
Chicago, Illinois

82305
Palmer Electronics Corp.
South Gate, California

82389
Switchcraft Inc.
Chicago, Illinois

Federal Supply Codes for Manufacturers (Concluded)

82415
North American Phillips
Controls Corp.
Frederick, Maryland

82872
Roanwell Corp.
New York, New York

82877
Rotron Inc.
Woodstock, New York

82879
ITT Royal Electric Div.
Pawtucket, Rhode Island

83003
Varo Inc.
Garland, Texas

83058
Carr Co., The United Can Div.
of TRW
Cambridge, Massachusetts

83298
Bendix Corp.
Electric Power Division
Eatontown, New Jersey

83330
Smith, Herman H., Inc.
Brooklyn, New York

83478
Rubbercraft Corp. of America, Inc.
West Haven, Connecticut

83594
Burroughs Corp.
Electronic Components Div.
Plainfield, New Jersey

83740
Union Carbide Corp.
Battery Products Div.
formerly Consumer Products Div.
New York, New York

84171
Arco Electronics
Great Neck, New York

84411
TRW Electronic Components
TRW Capacitors
Ogallala, Nebraska

84613
Fuse Indicator Corp.
Rockville, Maryland

84682
Essex International Inc.
Industrial Wire Div.
Peabody, Massachusetts

86577
Precision Metal Products,
of Malden Inc.
Stoneham, Massachusetts

86684
Radio Corp. of America
Electronic Components Div.
Harrison, New Jersey

86928
Seastrom Mfg. Co., Inc.
Glendale, California

87034
Illuminated Products Inc.
Subsidiary of Oak Industries Inc.
Anahiem, California

88219
Gould Inc.
Industrial Div.
Trenton, New Jersey

88245
Litton Systems Inc.
Useco Div.
Van Nuys, California

88419
Cornell-Dubilier Electronic Div.
Federal Pacific Co.
Fuquay-Varian, North Carolina

88486
Plastic Wire & Cable
Jewitt City, Connecticut

88690
Replaced by 04217

89536
Fluke, John Mfg. Co., Inc.
Seattle, Washington

89730
G.E. Co., Newark Lamp Works
Newark, New Jersey

90201
Mallory Capacitor Co. Div of
P.R. Mallory Co., Inc.
Indianapolis, Indiana

90211 - use 56365
Square D Co.
Chicago, Illinois

90215
Best Stamp & Mfg. Co.
Kansas City, Missouri

90303
Mallory Battery Co.
Div. of Mallory Co., Inc.
Tarrytown, New York

91094
Essex International Inc.
Suglex/IWP Div.
Newmarket, New Hampshire

91293
Johanson Mfg. Co.
Boonton, New Jersey

91407
Replaced by 58474

91502
Associated Machine
Santa Clara, California

91506
Augat Inc.
Attleboro, Massachusetts

91637
Dale Electronics Inc.
Columbus, Nebraska

91662
Elco Corp.
Willow Grove, Pennsylvania

91737 - use 71468
Gremar Mfg. Co., Inc.
ITT Cannon/Gremar
Santa Ana, California

91802
Industrial Devices, Inc.
Edgewater, New Jersey

91833
Keystone Electronics Corp.
New York, New York

91836
King's Electronics Co., Inc.
Tuckahoe, New York

91929
Honeywell Inc.
Micro Switch Div.
Freeport, Illinois

91934
Miller Electric Co., Inc.
Div of Aunet
Woonsocket, Rhode Island

92194
Alpha Wire Corp.
Elizabeth, New Jersey

93332
Sylvania Electric Products
Semiconductor Products Div.
Woburn, Massachusetts

94145
Replaced by 49956

94154 - use 94988
Wagner Electric Corp.
Tung-Sol Div.
Newark, New Jersey

94222
Southco Inc. formerly
South Chester Corp.
Lester, Pennsylvania

95146
Alco Electronic Products Inc.
Lawrence, Massachusetts

95263
Leecraft Mfg. Co.
Long Island City, New York

95264
Replaced by 98278

95275
Vitramon Inc.
Bridgeport, Connecticut

95303
RCA Corp.
Receiving Tube Div.
Cincinnati, Ohio

95348
Gordo's Corp.
Bloomfield, New Jersey

95354
Methode Mfg. Corp.
Rolling Meadows, Illinois

95712
Bendix Corp.
Electrical Components Div.
Microwave Devices Plant
Franklin, Indiana

95987
Weckesser Co. Inc.
Chicago, Illinois

96733
San Fernando Electric Mfg. Co.
San Fernando, California

96853
Gulton Industries Inc.
Measurement and Controls Div.
formerly Rustrak Instruments Co.
Manchester, New Hampshire

96881
Thomson Industries, Inc.
Manhasset, New York

97540
Master Mobile Mounts
Div. of Whitehall Electronics Corp.
Ft. Meyers, Florida

97913
Industrial Electronic Hdware Corp.
New York, New York

97945
Penwalt Corp.
SS White Industrial Products Div.
Piscataway, New Jersey

97966
Replaced by 11358

98094
Replaced by 49956

98159
Rubber-Teck, Inc.
Gardena, California

98278
Malco A Microdot Co., Inc.
Connector & Cable Div.
Pasadena, California

98291
Sealectro Corp.
Mamaroneck, New York

98388
Royal Industries
Products Div.
San Diego, California

98743
Replaced by 12749

98925
Replaced by 14433

99120
Plastic Capacitors, Inc.
Chicago, Illinois

99217
Bell Industries Elect. Comp. Div.
formerly Southern Elect. Div.
Burbank, California

99392
STM
Oakland, California

99515
ITT Jennings Monrovia Plant
Div. of ITT Jennings formerly
Marshall Industries Capacitor Div.
Monrovia, California

99779 - use 29587
Bunker-Ramo Corp.
Barnes Div.
Landsdowne, Pennsylvania

99800
American Precision Industries Inc.
Delevan Division
East Aurora, New York

99942
Centrelab Semiconductor
Centrelab Electronics Div. of
Globe-Union Inc.
El Monte, California

Toyo Electronics
(R-Ohm Corp.)
Irvine, California

National Connector
Minneapolis, Minnesota

Fluke Technical Service Centers — U.S. and Canada

United States

CALIFORNIA
Burbank
Fluke Technical Center
2020 N. Lincoln St.
Zip: 91504
Tel. (213) 849-4641

Santa Clara
Fluke Technical Center
2300 Walsh Avenue
Zip: 95050
Tel. (408) 985-1200

COLORADO
Denver
Fluke Technical Center
1980 S. Quebec St.
Unit 4
Zip: 80231
Tel. (303) 750-1228

FLORIDA
Orlando
Fluke Technical Center
940 N. Fern Creek Ave.
Zip: 32803
Tel. (305) 896-2296

ILLINOIS
Rolling Meadows
Fluke Technical Center
1400 Hicks Road
Zip: 60008
Tel. (312) 398-5800

MARYLAND
Kensington
Fluke Technical Center
11501 Huff Court
Zip: 20795
Tel. (301) 881-6155

MASSACHUSETTS
Waltham
Fluke Technical Center
244 Second Ave.
Zip: 02154
Tel. (617) 890-1604

MINNESOTA
Minneapolis
Fluke Technical Center
10800 Lyndale Ave. So.
Zip: 55420
Tel. (612) 884-4541

NEW JERSEY
Clifton
Fluke Technical Center
460 Colfax Ave.
Zip: 07013
Tel. (201) 778-1339

NORTH CAROLINA
Greensboro
Fluke Technical Center
1310 Beaman Place
Zip: 27408
Tel. (919) 273-1918

TEXAS
Dallas
Fluke Technical Center
14400 Midway Road
Zip: 75240
Tel. (214) 233-9945

WASHINGTON
Mountlake Terrace
John Fluke Mfg. Co., Inc.
21707 66th Ave. W. Suite 1
Zip: 98043
Tel. (206) 774-2206

Canada

ALBERTA
Calgary
Allan Crawford Assoc. Ltd.
Fluke Technical Center
14-2280 39th N.E.
Zip: T2E 6P7
Tel. (403) 276-9658

ONTARIO
Mississauga
Allan Crawford Assoc. Ltd.
Fluke Technical Center
6503 Northam Drive
Zip: L4V 1J5
Tel. (416) 678-1500

QUEBEC
Longueuil
Allan Crawford Assoc. Ltd.
Fluke Technical Center
1330 Marie Victorin Blvd. E.
Zip: J4G 1A2
Tel. (514) 670-1212

Sales and Service Locations — International

Supplied and supported by Fluke (Nederland) B.V., P.O. Box 5053, Zevenheuvelenweg 53, Tilburg, Netherlands.

EUROPE

AUSTRIA
*Walter Rekirsch Elektronische
Gerate GmbH & Co. Vertrieb KG
Liechtensteinstrasse 97/6
A-1090 Vienna, Austria
Tel. (222) 347646-0

BELGIUM
*C. N. Rood S/A
37 Place de Jamblinne de Meux
B-1040 Brussels, Belgium
Tel. (02) 27352135

CYPRUS
Chris Radiovision Ltd.
P.O. Box 1989
Nicosia, Cyprus
Tel. 66121

DENMARK
*Tage Olsen A/S
Ballerup Byveg 222
DK-2750 Ballerup
Tel. (01) 2-65 81 11

FINLAND
*Oy Findip AB
Teollisuustie 7
02700 Kauniainen
Helsinki, Finland
Tel. (080) 502255

FRANCE
*M. B. Electronique S.A.
Rue Fourney
ZAC de BUC
B. P. No. 31
78530 BUC, France
Tel. (01) 9563130

GERMAN FEDERAL REPUBLIC
*Fluke (Deutschland) GmbH
4-Dusseldorf
Meineckestrasse 53
West Germany
Tel. 211-450831

*Fluke (Deutschland) GmbH
8000 Munich 80
Vertriesburo Bayern
Rosenheimer Strasse 139
West Germany
Tel. 089-404061

GREECE
*Hellenic Scientific
Representations Ltd.
11 Vrassida Street
Athens 612, Greece
Tel. (021) 7792320

ITALY
*Sistrel S.p.A.
Via Giuseppe Armellini No. 39
00143 Rome, Italy
Tel. (06) 5915551

*Sistrel S.p.A.
Via Timavo 66
20099 Sesto S. Giovanni (Milan)
Italy
Tel. (02) 2476693

NETHERLANDS
*C.N. Rood, B.V.
Cort van der Lindenstraat 11-13
Rijswijk ZH2280AA
Netherlands
Tel. (070) 996360

NORWAY
*Morgenstierne & Co. A/A
Konghellegate 3
P.O. Box 6688, Rodelokka
Oslo 5, Norway
Tel. (02) 356110

PORTUGAL
*Equipamentos
De Laboratorio Ltda.
P.O. Box 1100
Lisbon 1, Portugal
Tel. (019) 976551

SPAIN
*Hispano Electronica S.A.
Poligono Industrial Urtinsa
Apartado de Correos 48
Alcorcon (Madrid), Spain
Tel. 09-341-6194108

SWEDEN
*Teleinstrument AB
P.O. Box 490
S-162 Vallingby-4
Sweden
Tel. (08) 380370

SWITZERLAND
*Traco Electronic AG
Jenatschstrasse 1
8002 Zurich, Switzerland
Tel. (01) 2010711

TURKEY
*Erkman Electronik Aletler
Necatibey Cad 92/2
Karakoy/Istanbul
Turkey
Tel. 441546

UNITED KINGDOM
*Fluke International Corp.
Colonial Way
Watford Herts WD2 4TT, England
Tel. (0923) 40511

MIDDLE EAST

EGYPT
Lotus Engineering Organisation
P.O. Box 1252
Cairo, Egypt
Tel. 71617

IRAN
*Irantronics Company Ltd.
20 Salm Road, Roosevelt Ave.
Tehran, Iran
Tel. 828294

ISRAEL
*R.D.T. Electronics
Engineering Ltd.
46, Sokolov Street
Ramat Hasharon 47235, Israel
Tel. 482311

JORDAN
Trading & Agricultural
Development Co.
P.O. Box 567
Amman, Jordan
Tel. 23052

KUWAIT
Tareq Company
P.O. Box Safat 20506
Kuwait, Arabian Gulf
Tel. 436100

LEBANON
Mabek
P.O. Box 11-3823
Beirut, Lebanon
Tel. 252631

MOROCCO
Mainvest
Residence Moulay Ismail
Bat.C Boulevard
Moulay Slimane, Rabat, Morocco
Tel. 276-64

SAUDI ARABIA
Electronic Equipment
Marketing Est.
P.O. Box 3750
Riyadh, Saudi Arabia
Tel. 32700

SYRIA
Mabek Electronics
C/O Messers G. Ghazzi
P.O. Box 4238
Damascus, Syria

Customers in the following countries: Bulgaria, Czechoslovakia, Hungary, Poland, Romania, U.S.S.R. and Yugoslavia. Contact: Amtest Associates Ltd., P.O. Box 55, Addlestone, Surrey, KT 15 1DU, England, Tel. (0932) 52121

? ? ?

***Technical Service Available**

Supplied and supported by Fluke International Corporation, P.o. Box 43210, Mountlake Terrace, WA 98043

ARGENTINA
*Coasin S.A.
Virrey del Pino 4071
Buenos Aires, Argentina
Tel. 523185

AUSTRALIA
*Elmeasco Instruments Pty. Ltd.
P.O. Box 30
Concord, N.S.W.
Australia 2137
Tel. (02) 736-2888

Elmeasco Instruments Pty. Ltd.
P.O. Box 107
Mt. Waverly, VIC 3149
Australia
Tel. 233-4044

BANGLADESH
Kabir Brothers Ltd.
97 - Gulshan Ave., Gulshan
G.P.O. Box 693
Dacca-12, Bangladesh
Tel. 303104

BOLIVIA
Coasin Bolivia S.R.L.
Casilla 7295
La Paz, Bolivia
Tel. 40962

BRAZIL
*Arotec S.A.
Industrial e Comercio
Av. Pacaembu 811
Sao Paulo S.P., Brazil
Tel. (67) 2393

*Arotec S.A.
Av. Rio Branco, 277
Grupo 1309
Rio de Janeiro - R. J., Brazil

CHILE
*Intronica Chile Ltda.
Casilla 16228
Manuel Montt 024-Of. D
Santiago 9, Chile
Tel. 44940

COLOMBIA
Coasin Ltda.
Carrera 13, No. 37-37, Of. 407
Ap. Aereo 29583
Bogota DE, Colombia
Tel. 285-0230

ECUADOR
*Proteco Coasin CIA, Ltda.
Edifica "Jerico"
Ave. 12 de Octubre
No. 2285 y Ave. Orellana
(Planta Baja)
Quito, Ecuador
Tel. 529-684

HONG KONG
*Gilman & Co., Ltd.
P.O. Box 56
Hong Kong
Tel. 794266

ICELAND
Kristjan O. Skagfjord Ltd.
P.O. Box 906
Reykjavik, Iceland
Tel. 24120

INDIA
*Hinditron Services Pvt. Ltd.
69/A.L. Jagmohandas Marg
Bombay 400 006, India
Tel. 365344

*Hinditron Services Pvt. Ltd.
412 Raj Mahal Vilas Extn.
Bangalore 560 006, India
Tel. 33139

INDONESIA
*P.T. DWI Tunggal Jaya Sakti
Sangga Buana Bldg., 1st Floor
J1 Senen Raya 44, P.O. Box 4435
Jakarta, Indonesia
Tel. 367390

P.T. DWI Tunggal Jaya Sakti
Jalan Sasakgantung 45
Bandung, Indonesia

JAPAN
Panetron Division
Tokyo Electron Ltd.
1 Higashikata-machi
Midori-ku
Yokohama 226, Japan
Tel. (045) 471-8811

*John Fluke Mfg. Co., Inc.
1 Higashikata-machi
Midori-ku
Yokohama 226, Japan
Tel. (045) 473-5425
Tlx: 3823-666 FLUKJP J

KENYA
Adcom Limited Inc.
P.O. Box 30070
Nairobi, Kenya
East Africa
Tel. 331955

KOREA
*Electro-Science Korea Co.
C.P.O. Box 8446
Rm. 1201 Bowon Bldg.
490 Chongro-5Ka
Chongro-ku
Seoul, Korea
Tel. 261-7702

MALAYSIA
O'Connor's (Pte) Ltd.
P.O. Box 1197
Kota Kinabalu, Sabah
East Malaysia
Tel. 54082

O'Connor's (Pte) Ltd.
P.O. Box 91
Petaling Jaya, Selangor
West Malaysia
Tel. 51563

MEXICO
*C.J. Christensen S.A. de C.V.
Instrumentos Electronicos
de Medicion
Melchor Ocampo 150-8
Mexico 4, D.F., Mexico
Tel. (905) 535-2258

NEW ZEALAND
*W & K McLean Ltd.
P.O. Box 3097
Auckland, New Zealand
Tel. 587-037

NIGERIA
Mofat Engineering Co., Ltd.
P.O. Box 6369
Lagos, Nigeria

PAKISTAN
Pak International Operations
505 Muhammadi House
McLeod Road
P.O. Box 5323
Karachi, Pakistan
Tel. 221127

PERU
*Importaciones
y Representaciones
Electronicas S.A.
Avda, Franklin D. Roosevelt 105
Lima 1, Peru
Tel. 288650

SINGAPORE
*O'Connor's (Pte) Ltd.
98 Pasir Panjang Road
Singapore 5, Singapore
Tel. 637944

SOUTH AFRICA
*Fluke S.A. (Pty) Ltd.
P.O. Box 39797
Bramley 2018
Republic of South Africa
Tel. (011) 786-3170

TAIWAN
CCT Associates, Inc.
P.O. Box 24209
Taipei, Taiwan
Republic of China
Tel. (02) 391-6894

THAILAND
Dynamic Supply
Engineering R.O.P.
No. 56 Ekamai, Sukhumvit 63
Bankok 11, Thailand
Tel. 914434

URUGUAY
Coasin Uruguaya S.R.L.
Cerrito 617-4° Piso
Montevideo, Uruguay
Tel. 917978

VENEZUELA
*Coasin C.A.
APDO Postal 50939
Sabana Grande No. 1
Caracas 105, Venezuela
Tel. 782-9109

*Technical Service Available

Sales Offices — U.S. and Canada

John Fluke Mfg. Co., Inc.
P.O. Box 43210, Mountlake Terrace, WA 98043
Tel. (206) 774-2211 Toll Free: (800) 426-0361 TWX: 910-449-2850 TLX: 32-0013 Cable: Fluke

United States

AK, Anchorage
Harry Lang & Associates
1406 W. 47th Ave.
Anchorage, AK 99503
(907) 279-5741

AL, Huntsville
John Fluke Mfg. Co., Inc.
3322 S.Memorial Parkway
Huntsville, AL 35807
(205) 881-6220

AZ, Phoenix
John Fluke Mfg. Co., Inc.
7319 E. Stetson Drive
Scottsdale, AZ 85251
(602) 994-3883

CA, Burbank
John Fluke Mfg. Co., Inc.
2020 N. Lincoln Blvd.
Burbank, CA 91504
(213) 849-7181

CA, Santa Clara
John Fluke Mfg. Co., Inc.
2300 Walsh Ave.
Santa Clara, CA 95050
(408) 244-1505

CA, Tustin
John Fluke Mfg. Co., Inc.
15441 Red Hill Ave, Unit B
Tustin, CA 92680
(714) 752-6200

CO, Denver
Barnhill Three, Inc.
1980 S. Quebec St., Unit 4
Denver, CO 80231
(303) 750-1222

CT, Hartford
John Fluke Mfg. Co., Inc.
124 Hebron Ave.
Glastonbury, CT 06033
(203) 633-0777

FL, Orlando
John Fluke Mfg. Co., Inc.
940 N. Fern Creek Ave.
Orlando, FL 32803
(305) 896-4881

HI, Honolulu
EMC Corporation
2979 Ualena St.
Honolulu, HI 96819
(808) 847-1138

IL, Chicago
John Fluke Mfg. Co., Inc.
1400 Hicks Road
Rolling Meadows, IL 60008
(312) 398-0850

IN, Indianapolis
John Fluke Mfg. Co., Inc.
5610 Crawfordsville Rd.
Suite 802
Indianapolis, IN 46224
(317) 244-2456

MA, Waltham
John Fluke Mfg. Co., Inc.
244 Second Avenue
Waltham, MA 02154
(617) 890-1600

MD, Baltimore
John Fluke Mfg. Co., Inc.
11501 Huff Court
Kensington, MD 20795
(301) 881-3370
(301) 792-7060 (Baltimore)

MI, Detroit
John Fluke Mfg. Co., Inc.,
13955 Farmington Rd.
Livonia, MI 48154
(313) 522-9140

MN, Minneapolis
John Fluke Mfg. Co., Inc.
10800 Lyndale Ave. S.
Minneapolis, MN 55420
(612) 884-4336

MO, Kansas City
John Fluke Mfg. Co., Inc.
4406 Chouteau Traffic Way
Kansas City, MO 64117
(816) 454-5836

MO, St. Louis
John Fluke Mfg. Co., Inc.
300 Brooks Dr., Suite 100
Hazelwood, MO 63042
(314) 731-3388

NC,, Greensboro
John Fluke Mfg. Co., Inc.
1310 Beaman Place
Greensboro, NC 27408
(919) 273-1918

NJ, Clifton
John Fluke Mfg. Co., Inc.
460 Colfax Avenue
Clifton, NJ 07013
(201) 778-4040
(516) 935-6672 (Long Island)

NM, Albuquerque
Barnhill Three, Inc.
1410 D Wyoming N.E.
Albuquerque, NM 87112
(505) 299-7658

NY, Rochester
John Fluke Mfg. Co., Inc.
4515 Culver Road
Rochester, NY 14622
(716) 266-1400

OH, Cleveland
John Fluke Mfg. Co., Inc.
7830 Freeway Circle
Middleburg Heights, OH 44130
(216) 234-4540

OH, Dayton
John Fluke Mfg. Co., Inc.
4756 Fishburg Rd.
Dayton, OH 45424
(513) 233-2238

PA, Philadelphia
John Fluke Mfg. Co., Inc.
1010 West 8th Ave., Suite H
King of Prussia, PA 19406
(215) 265-4040

TX, Austin
John Fluke Mfg. Co., Inc.
111 W. Anderson Lane
Suite 213
Austin ,TX 78752
(512) 458-6279

TX, Dallas
John Fluke Mfg. Co., Inc.
14400 Midway Road
Dallas, TX 75240
(214) 233-9990

TX, Houston
John Fluke Mfg. Co., Inc.
1014 Wirt Road, Suite 270
Houston, TX 77055
(713) 683-7913
(512) 222-2726 (San Antonio)

UT, Salt Lake City
Barnhill Three, Inc.
54 West 2100 South
Suite 3
Salt Lake City, UT 84115
(801) 484-4496

WA, Seattle
John Fluke Mfg. Co., Inc.
691 Strander Blvd.
Seattle, WA 98168
(206) 575-3765

Canada

ALB, Calgary
Allan Crawford Assoc., Ltd.
2280 - 39th N.E.
Calgary, ALB T2E 6P7
(403) 276-9658

BC, North Vancouver
Allan Crawford Assoc., Ltd.
3795 William Street
Burnaby, BC Y5C 3H3
(604) 294-1326

NS, Halifax
Allan Crawford Assoc., Ltd.
Suite 201, Townsend Pl.
800 Windmill Road
Burnside Industrial Park
Dartmouth, NS B3B 1L1
(902) 469-7865

ONT, Ottawa
Allan Crawford Assoc., Ltd.
1299 Richmond Road
Ottawa, ONT K2B 7Y4
(613) 829-9651

ONT, Toronto
Allan Crawford Assoc., Ltd.
6503 Northam Drive
Mississauga, ONT L4V 1J5
(416) 678-1500

QUE, Montreal
Allan Crawford Assoc., Ltd.
1330 Marie Victorin Blvd. E.
Longueuil, QUE J4G 1A2
(514) 670-1212

For Canadian areas not listed, contact the office nearest you or Allan Crawford Assoc. Ltd., Mississauga (Toronto), Ontario.

For more information on Fluke products or Sales Offices you may dial (800) 426-0361 toll free in most of U.S. From Alaska, Hawaii, Washington, or Canada phone (206) 774-2481. From other countries phone (206) 774-2398.