INSTRUCTION MANUAL

KELVIN-VARLEY RESISTIVE DIVIDER

MODEL DV4107D

PRIME TECHNOLOGY, INC.
General Resistance Division
Twin Lakes Road/P.O. Box 185
North Branford, CT 06471

COPYRIGHT 1990

TABLE OF CONTENTS

		PAGE
	Limited Warranty	1
I	INTRODUCTION	2
1.1	Description	2
1.2	Schematic	3,4
1.3	Special Features	4,5
1.4	Specifications	5
II	OPERATIONAL GUIDES	6
2.1	Power Limitations	6
2.2	Power Effects	6
2.3	Output Loading	6,7
2.4	Calibration Certificate	8
III	CALIBRATION	9
3.1	Equipment Required	9, 10
3.2	Calibration of Terminal Linearity	11 - 14
3.3	Maintenance	15

LIMITED WARRANTY

General Resistance Div. warrants each instrument to be free from defects in material and workmanship for a period of one year from date of purchase.

The obligation of General Resistance Div. under this Warranty is limited to servicing or adjusting any failed instrument returned, shipped prepaid, to the factory for that purpose.

Units returned under this warranty shall be examined by General Resistance Div. to establish that the failure resulted from defective material and/or workmanship and not as a result of misuse, neglect, or improper operation, which latter failure is not within the meaning of this Warranty.

This Warranty does not cover collateral or consequential damages of any nature.

General Resistance Div. reserves the right to make changes to design at any time without incurring any obligation to install same in units previously purchased.

This Warranty is expressly in lieu of all other obligations or liabilities on the part of General Resistance Div., express or implied, and General Resistance Div. neither assumes nor authorizes any person to assume for them any other liability in connection with the sale of General Resistance Div. products.

TABLE OF CONTENTS

		PAGE
I	INTRODUCTION	2
1.1	Description	2
1.2	Schematic	3,4
1.3	Special Features	4,5
1.4	Specifications	5
II	OPERATIONAL GUIDES	6
2.1	Power Limitations	6
2.2	Power Effects	6
2.3	Output Loading	6,7
2.4	Calibration Certificate	8
III	CALIBRATION	9
3.1	Equipment Required	9, 10
3.2	Calibration of Terminal Linearity	11 - 14
3.3	Maintenance	15

SECTION 1

INTRODUCTION

1.1 DESCRIPTION

The General Resistance Model DV4107D, Figure 1,is a master standard resistive divider. It utilizes the Kelvin-Varley circuit. These hand crafted units are aged and tested over a period of months during which time systematic checks are made to assure their inherent stability. Its ruggedized construction employs military type high reliability epoxy encapsulated resistors with very low and matched temperature coefficient giving resistive tracking to a fraction of a part per million. The high stability assures specified performance even after years of continuous use.

Figure 1, below, is an outline drawing of the divider. Input terminals marked "High" and "Low" are accessible on the left side of the front panel, and output terminals marked "High" and "Low" are available on the right side. Decade dials indicate the output voltage in proportional parts of the input. The output can be read to seven significant digits, the most significant digit being located closest to the input terminals. Connection to the most significant decade is available through use of the input terminals. Pairs of terminals used for testing the other six individual decades are available at the rear of the divider, inside the dust cover.

The model DV4107D is designed to mount in a standard 19 inch rack. The divider is housed in a metal case which provides for electrostatic shielding for the circuitry. The divider can be used for a variety of applications. Most prominent of these are for calibration of potentiometers, dividers and ratio sets. It can also be used in impedance comparators as well as checking unknown voltages and currents. The addition of an accurate voltage reference and null detector facilitates a multitude of potentiometric and ratiometric measurements basic to the laboratory at "state of the art" tolerances.

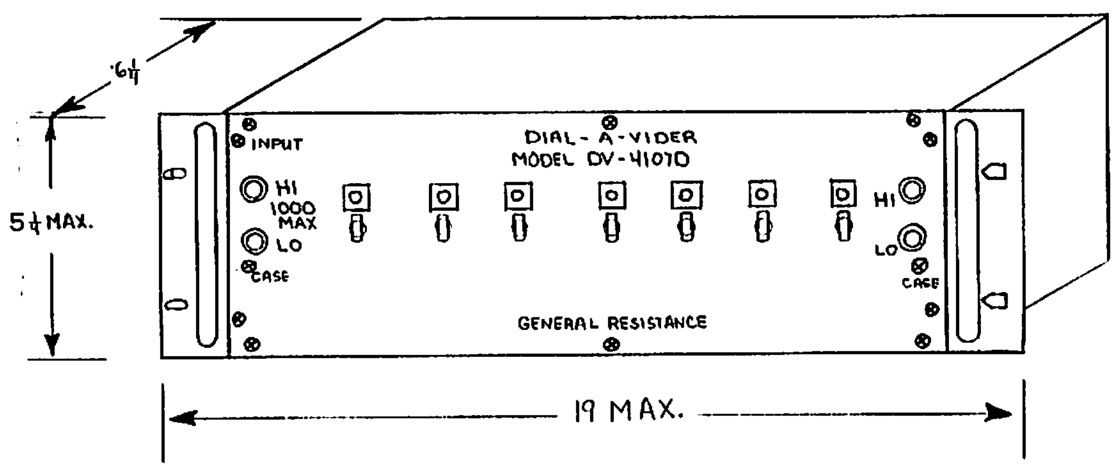


Figure 1

1.2 SCHEMATIC

Figure 2 shows a simplified schematic of the circuit employed. As seen from the schematic each decade contains eleven series resistors with the exception of the least significant decade which contains ten. The most significant decade is arranged so that there are two resistors in parallel for each position, providing improved power handling capability. The reason for eleven resistors in each decade instead of ten is as follows.

If a voltage is spanned by 10 equal resistors, in series, and measurement taps are at each interconnection, assuming there is no leakage resistance or current being drawn from any tap, then the potential difference will be divided into ten equal parts. In the DV4107D, 11 equal resistors in series are used, since two of them are spanned by a moveable rider (two pole switch, Figure 2). The rider terminals, shown as A-B, have a shunt resistor and the next deck connected in parallel, with an equivalent total resistance of 2R. Since switch A-B always spans 2R the result is that the total resistance across the potential difference (Ein) is again that of 10 equal resistors, (10R). (See Figure 2)

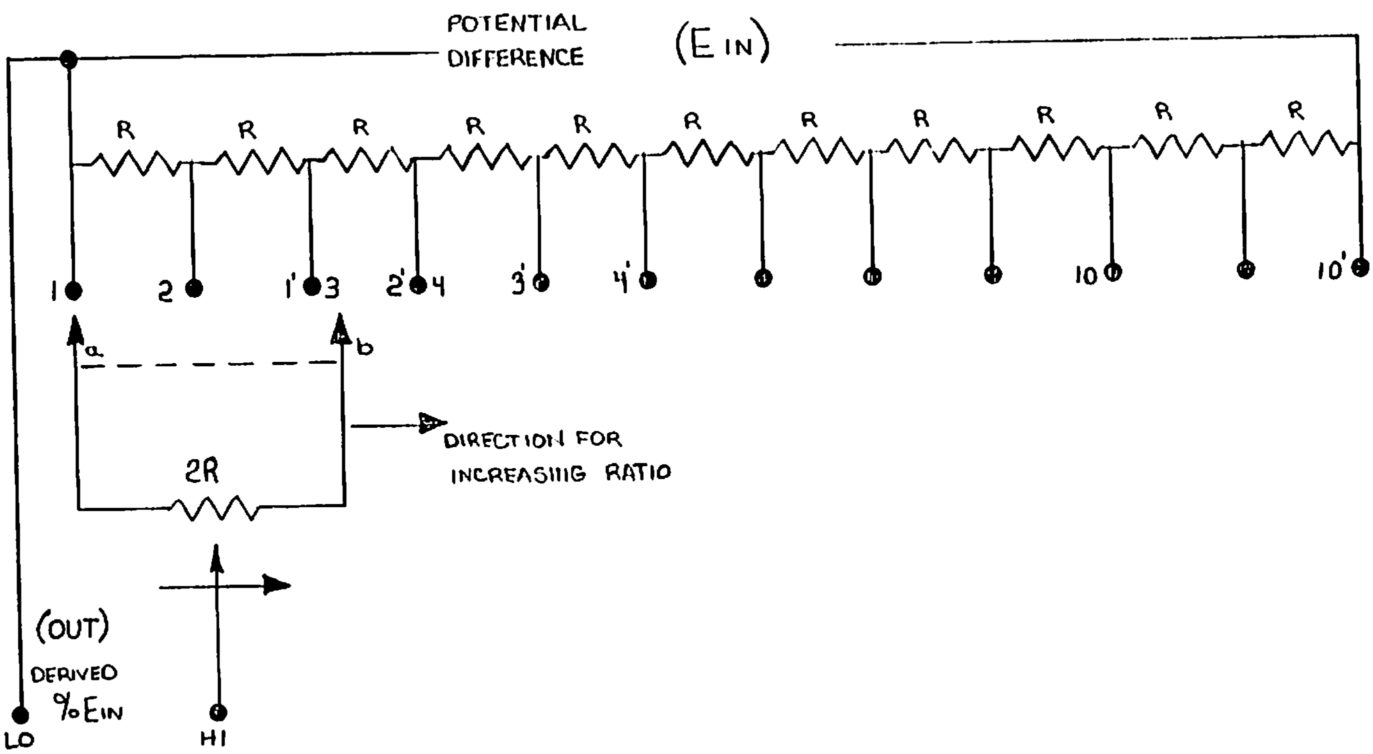


FIGURE 2

Switch segment 'A' can be moved from position 1 to 2 to 3 etc. up to 10 while a mechanical linkage drives switch segment 'B' to 1^1 (while 'A' is at 1) and always to the n^1 of the position selected for segment 'A'. This always parallels 2R with 2R (which reduces to R) and maintains the equivalent of 10 equal parts.

Positioning of switch A-B permits selection of 0,.1,.2,-- .9 times E in (assuming potentiometer 2R at full CCW position). The DV4107D employs this technique in all but the seventh decade which is divided into ten equal parts.

The resistors shown in the schematic (Figure 8) designated R_{S1}, R_{S2}, R_{S3}, R_{S4}, R_{S5} and R_{S6} are employed to shunt their respective decks and the decks equivalent resistance to a value 2R (where R is each resistor in the deck spanned). This technique permits extention of the basic Kelvin-Varley divider to each successive decade without using excessively small values of resistance. The resistors associated with each decade must be closely matched to each other for resistance value and temperature coefficient. Obviously, the resistance match of the most significant decade is more stringent than the rest and the matching becomes less critical as one proceeds towards the least significant decade.

1.3 SPECIAL FEATURES

The following special features are available on the divider:

a. Direct reading in-line numeric display.

b. Terminals in rear are available for absolute measurement and calibration of each decade.

c. Redundant Switching - provides improved reliability, life and performance. Using 4 pairs of contacts in parallel in the first decade and 2 pairs of contacts in parallel in the remaining decks reduces switch contact resistance to increase accuracy. Solid precious metal contacts on all switches provide low contact resistance capabilities and minimize error producing thermal voltages.

d. Power Coefficient - increasing the input voltage increases power dissipation in the resistors. This results in a non-uniform temperature rise* and larger errors due to temperature coefficient mismatch. To reduce the significance of this effect each resistor of the most significant decade actually consists of two resistors in parallel. One of each pair is trimmed with a low value series resistor to match each pair to the other pairs in the first deck.

   This technique provides a lowering of the power coefficient and also makes for easier match of resistance value, yielding divider accuracies substantially improved from specification

*(See Par. 2.2)

requirements. Measurements of power coefficient made on general production units show that the power coefficient is typically in the order of ten times better than the allowable spec requirement of 1 ppm per watt, (approximately 0.1 ppm per watt), measured at midscale.

e. High Reliability, military type encapsulated components, microscopically welded, are power aged and individually tested. These components are then selected for accuracy, stability and temperature coefficient.

1.4 SPECIFICATIONS

Circuit: Kelvin-Varley Resistive Divider
Number of Decades: Seven
Resolution: 10,000,000 divisions, 0.1 ppm steps
Input Resistance: 100,000 ohm, ±.005%
Absolute Linearity: Direct Reading at 25°C
±0.5 parts per million of full scale at mid-scale, improving to zero at end settings.
Terminal Linearity: Same as absolute linearity above, except that the end voltage drops are less than 0.05 parts per million of full scale.
Two-Year Stability: Shall be ±1 part per million of full scale at mid-scale improving to zero at end settings.
Temperature Coefficient: ±0.2 ppm per °C and improved below settings of 0.1.
Power Coefficient: ±1 ppm of full scale/watt at mid-scale, improving to zero at end settings.
Maximum Power Input: 10 watts
Maximum Input Voltage: 1000 Volts D.C.
Breakdown Voltage: 1,000 volts peak between active terminals and case.
Zero Compensation: Common output Terminal compensated for lead and switch resistance so that output at zero setting does not exceed 0.002 ppm of input.
Calibration Facilities: Input Terminals are provided for each individual decade to facilitate calibration against a standard.
Dimensions: 19"W x 5 1/4"H x 7 3/4"D (6 1/4" depth behind panel)
Weight: 8 3/4 lbs.

SECTION 2

OPERATIONAL GUIDES

The Kelvin-Varley divider is primarily used as a Ratiometer or voltage source in null-balancing circuits to check potentiometers, dividers, ratio settings, etc. It cannot be used as a variable resistance because of the circuitry arrangement. From Figure 8 it can be readily seen that input "Low" terminal is not a common connection with output "Low" terminal. Therefore, three terminal resistance ratios are not exactly linearly related to four terminal voltage ratios.

2.1 POWER LIMITATIONS

To avoid damaging the divider do not exceed 1000 VDC on the input circuitry.

2.2 POWER EFFECTS

When using the divider in conjunction with large input voltages allow a short time for temperature stabilization of resistors prior to operation if the first decade is being switched. As a result of the arrangement of the Kelvin-Varley circuit uneven power distribution results from the shunting of two of the eleven resistors of one decade by the next decade. The resistors shunted by the following decade will dissipate 1/4 the wattage of the other components in the string. Since the temperature rise in each resistor is proportional to the power dissipated by it, time for temperature stabilization should be allowed. Redundance in power & low T.C. components in the DV4107D minimize this time and effect.

2.3 OUTPUT LOADING

The output voltage of the divider will change due to output loading. This change may or may not be significant, depending upon how the divider is being used. When used to check potentiometers or dividers where a null detector is used the effect of loading is negligible. When used as a source of voltage the output will depend upon the ratio setting and the output load. The output of the divider can be represented by a Thevenin equivalent generator and output resistance in series.

The Thevenin generator is equal to the unloaded output voltage of the divider. The output resistance varies as the ratio setting. The output resistance is measured in the following manner. Set the divider to the ratio to be used when loaded. Short the input terminals and measure the output resistance between terminals 3 and 4 by a bridge null method or equivalent. Figure 3 shows the equivalent circuit.

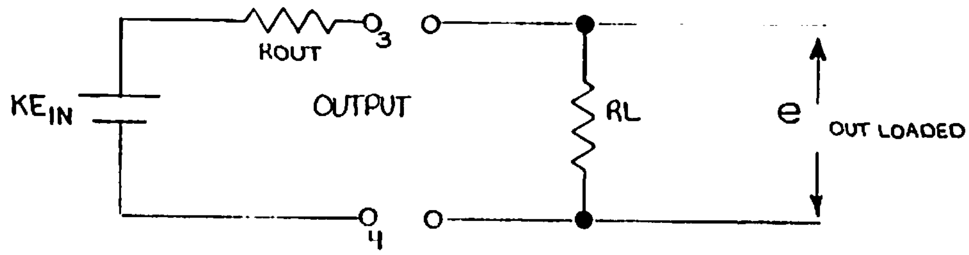


Figure 3

By knowing the value of the load resistance across the output terminals and having measured the output resistance the loaded output voltage can readily be calculated as:

$$e_{out\ loaded} = KEin \times \frac{RL}{RL + Rout}$$

With high impedance loads the effect of output voltage change is negligible compared to the linearity deviation. The unloaded output ratio will be modified by the ratio of

$$\frac{RL}{RL + Rout}$$

for any appreciable loading, and can be expressed in PPM deviation from the unloaded output.

2.4 CALIBRATION CERTIFICATE

A calibration certificate is supplied with each divider certifying actual linearity within ±0.1 PPM. This calibration is used to increase measurement accuracy. These corrections may be used to determine the amount of linearity deviation at any dial setting permitting ratio measurements to ±0.2 PPM certainty. The inherent stability of the DV4107D relative to the accuracy requirements of your applications will determine the required frequency of recalibration.

SECTION 3

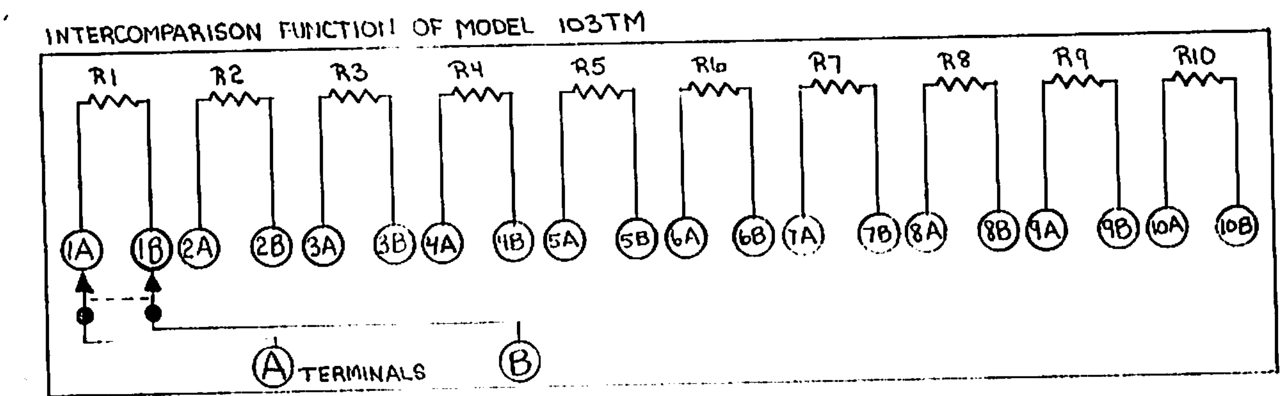
CALIBRATION

Although the DV4107D is a highly stable device, periodic calibration permits one to take advantage of the divider's short term stability. Thus, it may be used to yield a more accurate unit than specification limits. For ultimate accuracy in a specific application the divider should be calibrated at the voltage and temperature conditions of actual use.

3.1 EQUIPMENT REQUIRED

a) A ten step, 100K input resistive divider Transfer Standard (General Resistance Model 103TM, 10K per step), or equal. See Figures 4,5.
b) A DC source capable of delivering 100 volts to a 50K load.
c) Low resistance lead compensating potentiometers (General Resistance Model LRC 201). See Figure 6.
d) A high impedance (1 Megohm or greater) null detector or microvolt meter with a sensitivity of better than 10 microvolts.

Fig 4



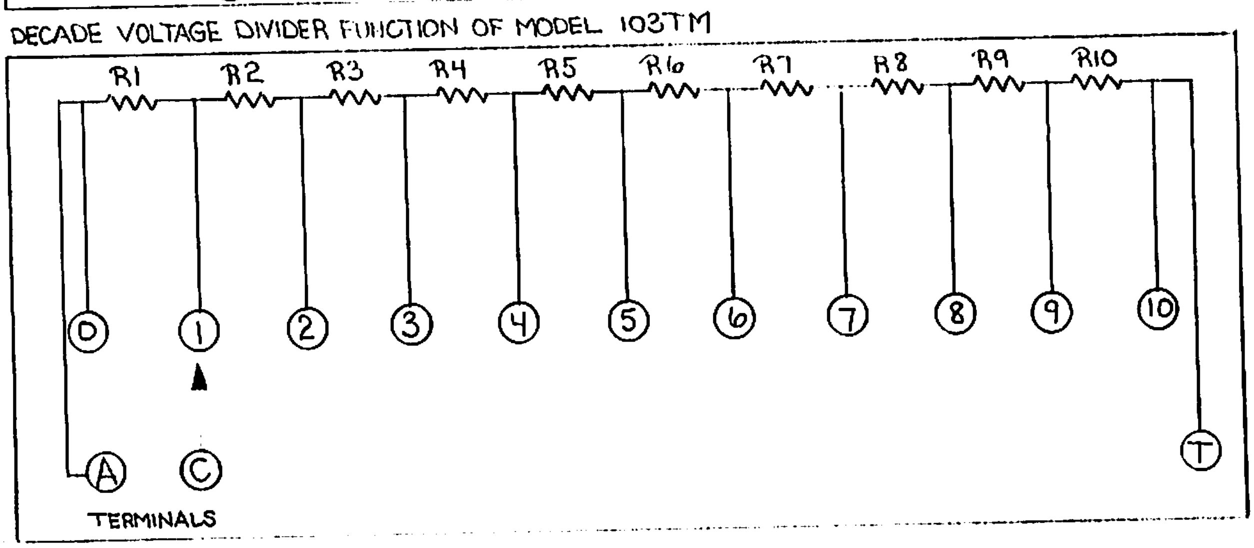


Fig 5

The suggested resistive divider, the General Resistance Model 103TM, will permit making ratio measurements to an uncertainty of ±0.2 parts per million or better. Each Transfer Standard contains ten precision matched laboratory quality resistors in an unusual switching configuration. Two functions are provided which permit matching of the ten resistors against an external standard, and employing the resistors in a ten-step voltage divider whose linearity is easily and accurately calculable from the previously measured resistance values.

The Intercomparison Funtion (Figure 4) illustrates the switching which enables the user to measure,calibrate and compare each of the ten equal resistors aginst a single primary standard. This allows either absolute or relative resistance measurements to be established within a few parts per million.

The Decade Voltage Divider Funtion (Figure 5) permits ratio settings of 0, 0.1, 0.2, ... 1 times the input voltage. These settings can be calculated to an accuracy ten times better than the accuracy improvement occurs as the switch in advanced because of the algebraic addition of errors.

3.2 CALIBRATION OF ABSOLUTE LINEARITY

The procedure for the determination of absolute linearity for the divider is outlined below. Figure 6 shows the test circuit to be used.

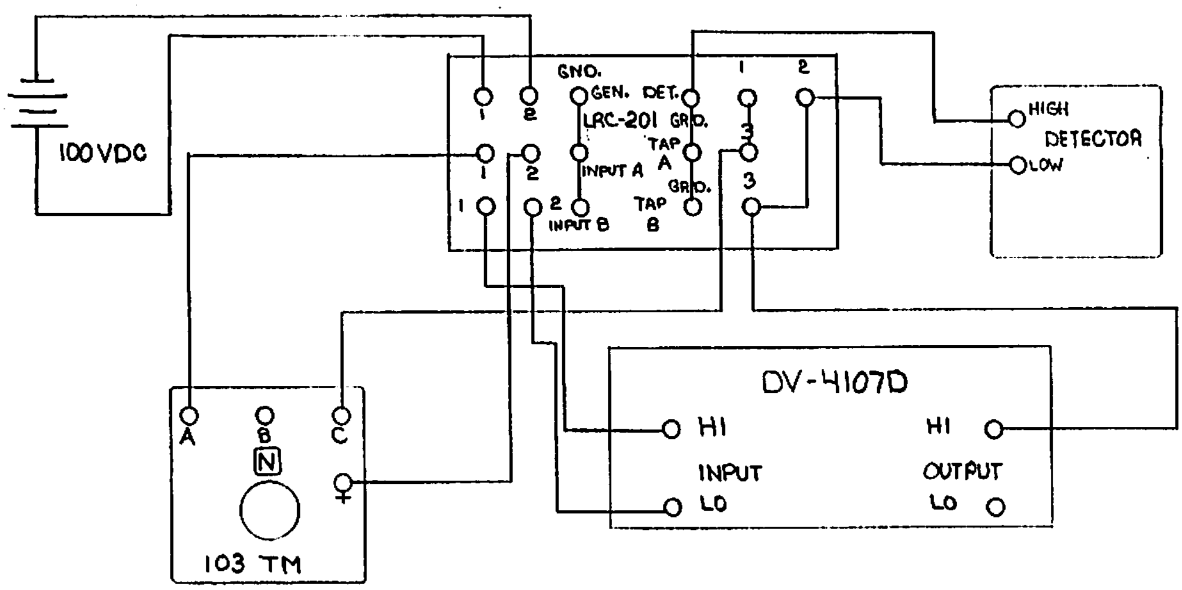


Fig 6

The detector used should be a microvoltmeter with a one meghom minimum input resistance and a sensitivity of at least one microvolt. (Note: for 100 volt input, 1000 microvolt deflection = 10 PPM, 100 microvolt = 1 PPM. Voltmeter should be calibrated so that error represents PPM directly.)

1) Connect equipment as shown in Figure 6.

2) Set the Transfer Standard for N = 0. Adjust the seven digits of the divider to read zero (.0000000). Adjust the balance 2 control on the LRC 201 so that null detector reads zero.

3) Adjust Transfer Standard so that n = 10. Adjust seven digits of divider to read .999999X. Adjust balance 1 control on the LRC 201 so that null detector again reads zero.

4) Adjust Transfer Standard for values of N from 1 to 9. At each value of N adjust output of divider to read .N000000 and .(N-1)99999X. At each voltage divider setting record microvolt deviation of null detector and corresponding error in PPM. Use calibration curve supplied with Transfer Standard to correct errors recorded and list final correction in PPM of input.

Table 1 shown below is typical of the calibration data to be recorded.

TABLE 1 DIAL CALIBRATION

Decade Under Test:__________. Input__________Volts.
Transfer Std__________________. Temp__________°C.

A	B,C	D	E	F	G	H
Trans Std Setting *	Dial Setting	Reading (uv)	Reading (PPM)	Ref Divider Error (PPM)	Dial Error (PPM) (E+F)	$\frac{G}{10^{N-1}}$ Dial Error Referred To Input (PPM)
1	.1000000					
2	.2000000					
3	.3000000					
4	.4000000					
5	.5000000					
6	.6000000					
7	.7000000					
8	.8000000					
9	.9000000					
1	.099999X					
2	.199999X					
3	.299999X					
4	.399999X					
5	.499999X					
6	.599999X					
7	.699999X					
8	.799999X					
9	.899999X					

*The numbers in this column should be divided by 10 when using a standard voltage divider as a transfer standard.

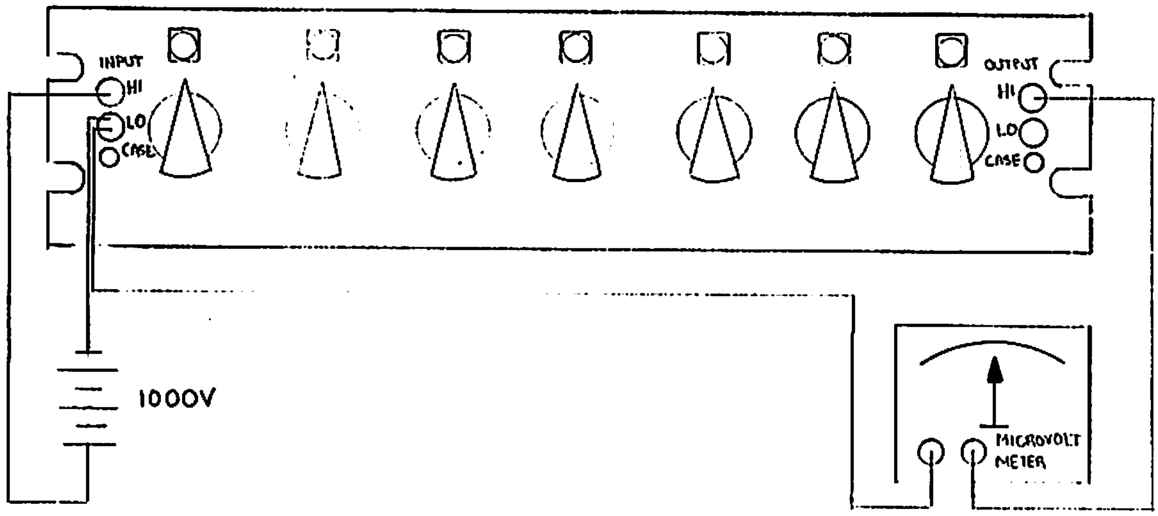


FIG. 7A

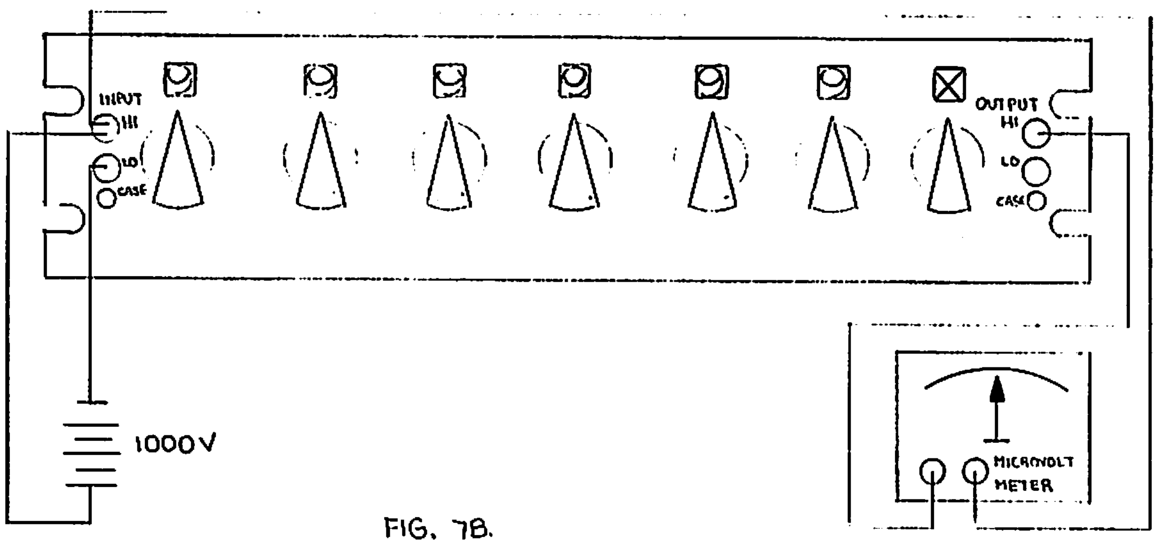


FIG. 7B.

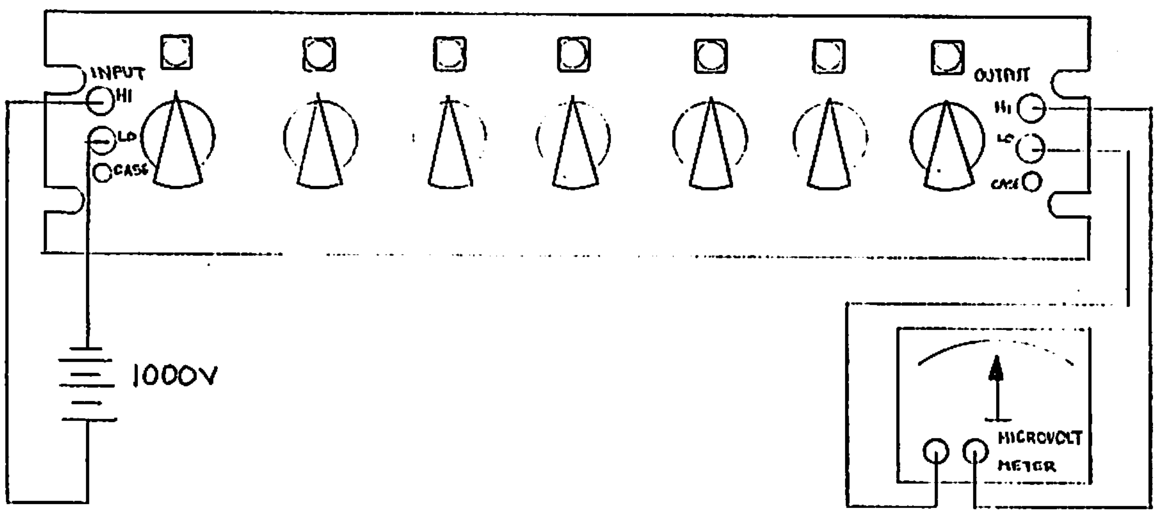


FIG. 7C.

5) Repeat steps 1 through 4 at each decade desired. For calibration purposes it is only necessary to use the first three significant decades since the errors contributed beyond these digits become insignificant in comparison. For decades other than the most significant, terminals are available in the rear of the divider. The most significant digit is located at the right of the front panel when viewed from the rear.

6) The error of each decade at all nine dial settings is obtained by the following steps outlined in Par. 1), 3) and 4). Record the information in the appropriate row and column on a data sheet. (Table 1) Column G is the algebraic sum of columns E and F. Column H represents the error contribution of the specific decade tested related to the total DV4107D error and is in PPM of input. The figure is derived and entered in column H as follows: When the test data sheet represents the first or most significant decade, copy column G directly into column H. When the test data sheet represents the second decade in significance (second from left on front panel when viewed from front), divide column G by 10 and enter the figure in column H. For the third decade, divide column G by 100 and enter in column H. For the fourth decade, divide column G by 1000 etc. It should now be obvious that the contribution of error of each successive decade is diminished by an order of magnitude.

7) Terminal linearity is related to absolute linearity by adding the required High and Low corrections to the absolute linearity. It is only necessary to measure the end corrections to establish the terminal linearity.

a) Connect the test equipment as shown in figure 7A. Set all DV4107D dials to 0.

b) Record the microvoltmeter reading, with normal and reversed battery polarity. Calculate one-half of the algebraic difference of the two readings, which should not exceed 50 microvolts for a 1000 volt input. This is the Low correction.

c) Reconnect the test equipment for measurement of the High end correction, (Figure 7B). Set all DV4107D dials to 9, except for the last (right-hand most) dial, which should be set to X.

d) Record the microvoltmeter reading, with normal and reversed battery polarity. Calculate one-half of the algebraic difference of the two readings, which should not exceed 50 microvolts for a 1000 volt input. This is the High correction.

8) The compensated terminal linearity is related to terminal linearity by the (algebraic) addition of the bootstrap error. This error is less than plus or minus 0.002 ppm of full scale for the DV4107D, and can be ignored in most applications. It can be measured by connecting the equipment as shown (diagram 7C), and with all dials set to 0, recording the microvoltmeter reading for normal and reversed battery polarities. The correction is one-half of the algebraic difference between these two readings and should not exceed 2 microvolts, for a 1000 volt input.

3.3 MAINTENANCE

The only maintenance which will be required is switch lubrication. This should be done only when the switches are subjected to dust. The recommended lubricant is Oak Manufacturing Company's Type #2008 grease. This lubricant should be applied sparingly as a thin film on the rotor blades. Excessive lubricant can be removed with a degreasing agent, such as carbon tetrachloride or methanol, and the switch then allowed to dry. Care should be taken to keep lubricant and degreasing agent from contracting the precision resistors.

All terminals not marked as grounded (GRD) are insulated from the chassis. Leakage resistance between these terminals to ground must be kept high to prevent measurement error. The following procedure is suggested to check for excessive leakage resistance:

1. Interconnect the following terminals:

   Input High, Input Low, Output High and Output Low

2. Connecting the Insulation Resistance Tester, between the interconnected terminals and Case Ground, the measured insulation resistance at 500 VDC must exceed 100,000 Megohms.

If the insulation resistance is lower than 100,000 Megohms, and the unit has been subjected to operation in an unusually humid environment, a "bakeout" at a temperature of less than 150°F is suggested. Retesting after drying out should show that the leakage resistance has been restored to its specified value. If not, degreasing in a clean solvent, such as carbon tetrachloride or methanol, should be attempted. This must be followed by re-lubrication of the switches as previously described.

The front panel binding posts are made of copper, gold plated, to cause minimum thermal emf's. This material is somewhat softer than brass binding posts used where thermal effects are not significant. The top of the post should not be forced open (in a counterclockwise direction), as it will reform the binding post threads and allow the top to come off.