

◆ PRECISION INSTRUMENTS FOR TEST AND MEASUREMENT ◆

SR-1050

**High Accuracy
Transfer Standard
User and Service Manual**



WARNING



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

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

HIGH VOLTAGES MAY BE PRESENT AT THE TERMINALS OF THIS INSTRUMENT

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

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

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

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



CAUTION



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

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Chapter 1

INTRODUCTION

1.1 Overview

The **SR-1050** Series (Figure 1-1) is a family of transfer standards suitable for making resistance calibration transfer measurements from 100 k Ω to 100 M Ω , with step sizes of either 1 M Ω or 10 M Ω .

In order to perform calibrations with a high degree of accuracy, reference standards must normally be employed at every range or decade of the measuring or calibration instrumentation. Clearly this can be difficult and costly, since these standards must be highly stable and their values must be known with a high degree of certainty and with a sufficient resolution.

To minimize the cost and difficulty, a more practical means of performing such calibrations is to use transfer standards.

The **SR-1050** Series of transfer standard consists of 11 matched equal value resistors, R , which may be connected in series or parallel combinations to produce a number of values such as $R/10$, $1R$, and $10R$, thereby allowing progressive transfers to higher or lower decades. For lower resistance values (below 100 k Ω), the **SR-1010** Series of transfer standards may be used.

The transfer standard may be calibrated using a single primary standard. This transfer standard may then be used at $R/10$, $1R$, and at $10R$, where R is the step size. It may be used at these three decades with an uncertainty that is equal to the initial calibration uncertainty of the steps plus the transfer uncertainty. For example, if a $1\text{ M}\Omega$ step **SR-1050** unit has a nominal uncertainty of 10 ppm and a transfer accuracy of 2 ppm, then it may be used at $100\text{ k}\Omega$ and $10\text{ M}\Omega$ with an uncertainty of 12 ppm ($10\text{ ppm} + 2\text{ ppm}$). The nominal adjustment error (the difference between actual value and nominal) for all three decades is essentially the same, e.g. if the adjustment error at $1\text{ M}\Omega$ is 10 ppm, then it is also 10 ppm at $100\text{ k}\Omega$ and $10\text{ M}\Omega$, remembering that the transfer accuracy error has to be added at these additional decade settings.

The **SR-1050** standards are constructed using matched low temperature coefficient, hermetically sealed resistors for high stability and imperviousness to moisture. Each resistance step is composed of multiple individual resistors for better power handling, heat distribution, and higher voltage capability. In addition, there is a trimming network that allows precise setting of the resistance step values, and greatly simplifies subsequent calibrations.

The switches are of special low-leakage construction. Switches are placed at every junction and at the two ends of the series string to connect that junction to either of the two binding posts; a center-off setting provides for no connection to that junction. By means of these switches, the resistances may be connected in various series-parallel combinations.

Low-thermal-emf, five-way binding posts are used for connections to the two buses, and a shielded bnc connector provides for connection to one end of the resistor string. A third binding post provides a connection to the metal case; this may be used as a guard.

The unit is housed in a contamination-and-moisture-resistant case. The insulation materials in the instrument are Kel-F plastic and teflon, for the highest possible resistance and low moisture absorption.

Chapter 2

SPECIFICATIONS

For convenience, a calibration chart, shown in Figure 2-1, is affixed to the side of the unit. This gives the individual and progressive cumulative deviations from nominal. These are deviations which may be used for transfers.

For additional convenience to the user, the pertinent specifications are given in an **OPERATING GUIDE** also affixed to the case of the instrument. Figure 2-22 shows a typical example.

2.1 Specifications

Step Size	Adjustment accuracy	Transfer accuracy	Stability ppm/year	Stability long term	Temperature coefficient	Matching	
						Adj. Acc.	TC
1 M Ω	± 20 ppm	± 2 ppm	± 15 ppm	± 30 ppm	± 3 ppm/ $^{\circ}$ C	± 10 ppm	± 3 ppm
10 M Ω	± 20 ppm	± 2 ppm	± 15 ppm	± 30 ppm	± 5 ppm/ $^{\circ}$ C	± 10 ppm	± 3 ppm

Calibration conditions:

23 $^{\circ}$ C, low-power, with meter guard applied to COMMON and ground applied to GND, traceable to SI

Initial calibration data for each resistor is supplied with the instrument.

Leakage resistance:

>10 T Ω from terminal to case

Power coefficient:

< ± 0.05 ppm/mW per resistor

Maximum applied input:

2500 V, or 1 W per resistor, or 10 W for entire unit (whichever applies first)

Breakdown voltage:

3,500 peak between any terminal and case

Connection terminals:

Three gold-plated, 5-way, tellurium-copper binding posts with low thermal emf and low resistance.

One shielded bnc terminal labeled COMMON, used when the unit is employed as a precision voltage divider.

Environmental conditions:

Operating: 10 $^{\circ}$ C to 40 $^{\circ}$ C; <50% RH

Storage: -40 $^{\circ}$ C to 70 $^{\circ}$ C

Dimensions:

35.6 cm W x 16.5 cm H x 10.2 cm D (14" x 6.5" x 4")

Weight:

5 kg (11 lbs)

SR1050-10M			
Deviation from Nominal			
	Individual (ppm)	Cumulative (ppm)	Temperature: 23.5 $^{\circ}$ C
R1	-3.7	-3.7	Date: 15-Feb-2013 Date Due: Model: SR1050-10M Serial Number: 20309831050A BY: CN Traceable to SI
R2	-6.2	-5.0	
R3	-0.9	-3.6	
R4	-18.4	-7.3	
R5	-9.3	-7.7	
R6	0.4	-6.3	
R7	-15.7	-7.7	
R8	-16.1	-8.7	
R9	-5.8	-8.4	
R10	-3.2	-7.9	
R11	-1.1	-7.3	

Figure 2-1: Sample calibration chart

SR-1050 HIGH ACCURACY TRANSFER STANDARD

CONSULT INSTRUCTION MANUAL FOR PROPER INSTRUMENT OPERATION

Step Size	Adjustment accuracy	Transfer accuracy	Stability ppm/year	Stability long term	Temperature coefficient	Matching	
						Adj. Acc.	TC
1 MΩ	±20 ppm	±2 ppm	±15 ppm	±30 ppm	±3 ppm/°C	±10 ppm	±3 ppm
10 MΩ	±20 ppm	±2 ppm	±15 ppm	±30 ppm	±5 ppm/°C	±10 ppm	±3 ppm

	R0	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11
To set standard to R/10	↓	↑	↓	↓	↓	↓	↓	↓	↓	↓	↓	Off
To set standard to 10R	↓	Off	Off	Off	Off	Off	Off	Off	Off	Off	↑	Off
To set standard to 1R	↓	Off	Off	↑	Off	Off	↓	Off	Off	↑	Off	Off

Note: R0 is the left most switch

Connection terminals:

Three gold-plated, 5-way, tellurium-copper binding posts with low thermal emf and low resistance.
One shielded bnc terminal labeled COMMON, used when the unit is employed as a precision voltage divider.

Environmental conditions:

Operating: 10°C to 40°C; <50% RH
Storage: -40°C to 70°C

Calibration conditions:

23°C, low-power, with meter guard applied to COMMON and ground applied to GND, traceable to SI
Initial calibration data for each resistor is supplied with the instrument.

Leakage resistance:

>10 TΩ from terminal to case

Power coefficient:

<±0.05 ppm/mW per resistor

Maximum applied input:

2500 V, or 1 W per resistor, or 10 W for entire unit (whichever applies first)

Breakdown voltage:

3,500 peak between any terminal and case

MODEL: SR-1050-10M

SN: E1-1306210

WARNING



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



Figure 2-2: Typical operating guide

Chapter 3

INSTALLATION

3.1 Initial Inspection

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

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

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

3.2 Installation

For a rack mounted model, installation on a 19 inch rack may be made using the slots in the rack mounting ears. A mounting location that does not expose the unit to excessive heat is recommended.

For bench models, no installation as such is required, because this instrument series is not powered. Since it is a high-accuracy instrument, it is recommended that a bench space be provided that would not expose it to abuse and keep it protected from temperature extremes and contaminants.

3.3 Repackaging for Shipment

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

1. Attach a tag to the instrument identifying the owner and indicate the service or repair to be accomplished. Include the model number, the full serial number of the instrument, the RMA number, and shipping address.
2. Wrap the instrument in heavy paper or plastic.
3. Protect the front panel and any other protrusions with cardboard or foam padding.
4. Place instrument in original container or equally substantial heavy carton.
5. Use packing material around all sides of instrument.
6. Seal with strong tape or strapping.
7. Mark shipping container “DELICATE INSTRUMENT,” “FRAGILE,” etc.

3.4 Storage

If this instrument is to be stored for any extended period of time, it should be sealed in plastic and stored in a dry location. It should not be exposed to temperatures below -10°C or above +50°C. Extended exposure to temperature extremes can result in an irreversible change in resistance and would require recalibration.

Chapter 4

OPERATION

4.1 Inspection and operation

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

An **OPERATING GUIDE** and a **CALIBRATION CHART** are attached to the case of the instrument to provide ready reference to specifications.

4.2 Setting for Various Resistance Combinations

4.2.1 Output terminals

The SR-1050 Series Transfer Standard, may be set into any number of parallel and/or series combinations to produce different resulting net resistances. These combinations are produced at binding post terminals labeled **A** and **B**. See Figure 4-1 below.

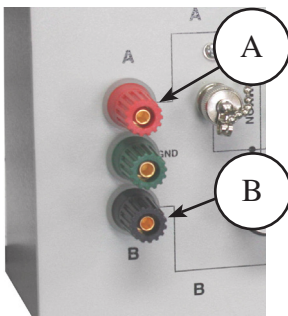


Figure 4-1: A and B binding post terminals

For resistance applications, connect to the **A** and **B** binding posts. A guard shield may be connected to the **GND** binding post.

4.2.2 Controls

Selection of desired resistance is controlled by 12 switches located on the front panel. These switches redirect the electric circuit either through or around internal resistors, and enabling the user to select series and parallel resistance as required. Each switch has three possible positions: **OFF** (no connection), **A** (connection to the **A terminal**), and **B** (connection to the **B terminal**). See Figure 4-2 below.

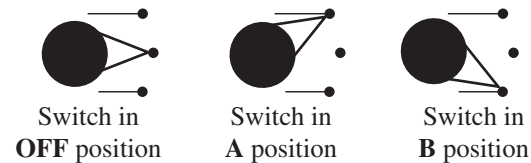


Figure 4-2: Switch positions

4.2.3 Setting resistance

Set the switches as desired to obtain the desired resistance between the **A** and **B** binding posts. For example, for the easiest way to get a value of $1R$ where R is the step size:

1. Set the first switch to **B**.
*This connects the lower end of R_1 to the **B** binding post.*
2. Set the next switch to **A**.

This connects the upper end of R_1 to the **B** binding post. Thus, we now have R_1 connected between the **A** and **B** binding posts for an effective value of $1R$. See Figure 4-3.

Note: Although this is the easiest way to get $1R$, the best method is depicted in Figure 4-5. The advantage of the configuration shown in that figure is that it uses the combined value of nine resistors, and allows the use of the same adjustment error.

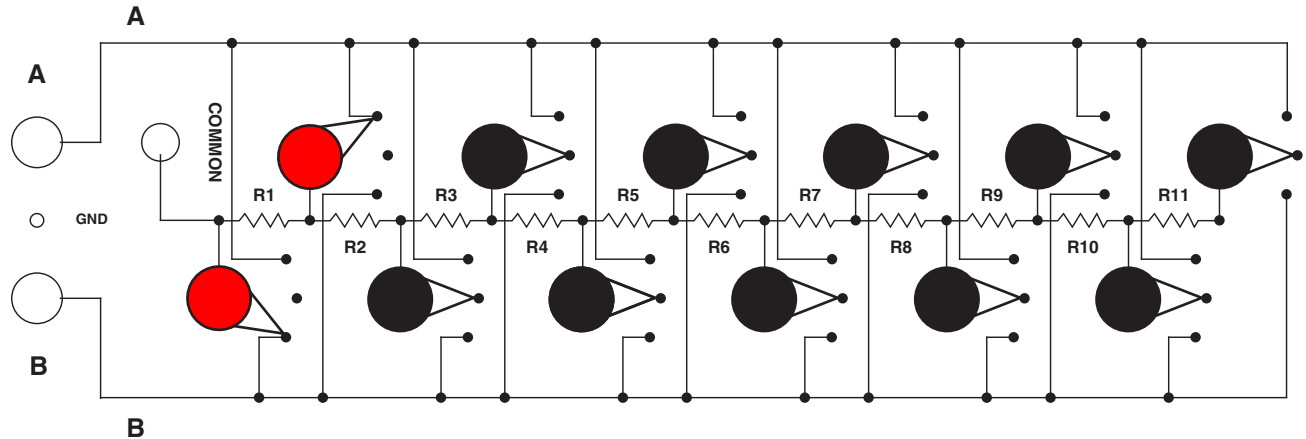


Figure 4-3: Resistance = 1R: single resistor

Using the above method to get the value of 2R:

1. Set the first switch to **B**.
This connects the lower end of R1 to the B binding post.
2. Set the third switch to **A**.

This connects two resistors in series between **A** and **B** for an effective resistance of 2R. See Figure 4-4.

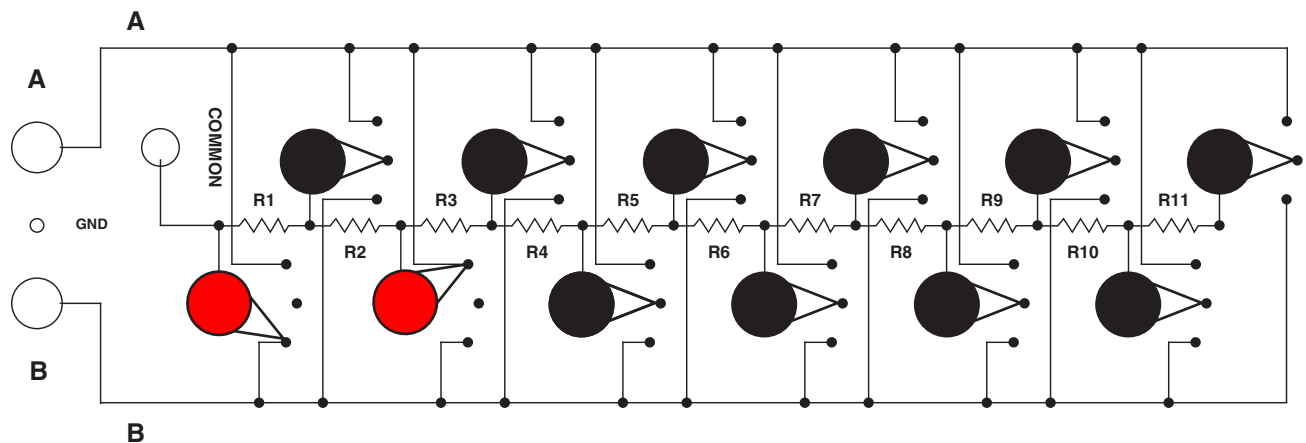


Figure 4-4: Resistance = 2R: two resistors in series

The same method may be applied from 1R to 11R.

More complex resistance settings may be achieved. Below are just some of the examples. Figure

- For a composite value of $1R$ spread over 9 resistors (which allows the use of the same adjustment error), see Figure 4-5.
- For a composite value of $10R$, see Figure 4-6.
- For a composite value of $R/10$, see Figure 4-7.
- For a composite value of $0.4R$, see Figure 4-8.
- For a precision voltage divider with 50% ration, see Figure 4-9.

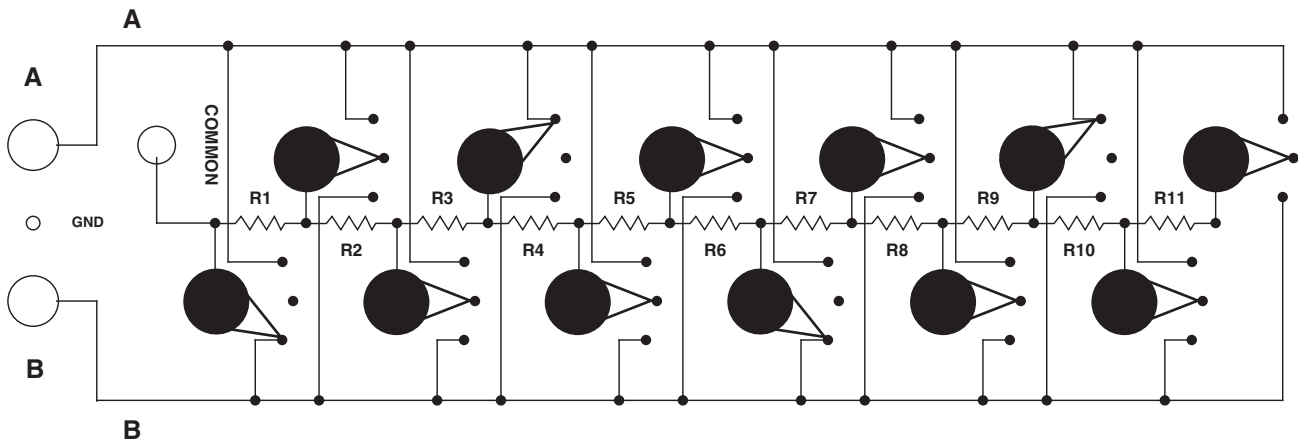


Figure 4-5: Resistance = $1R$: three groups of three, series-parallel

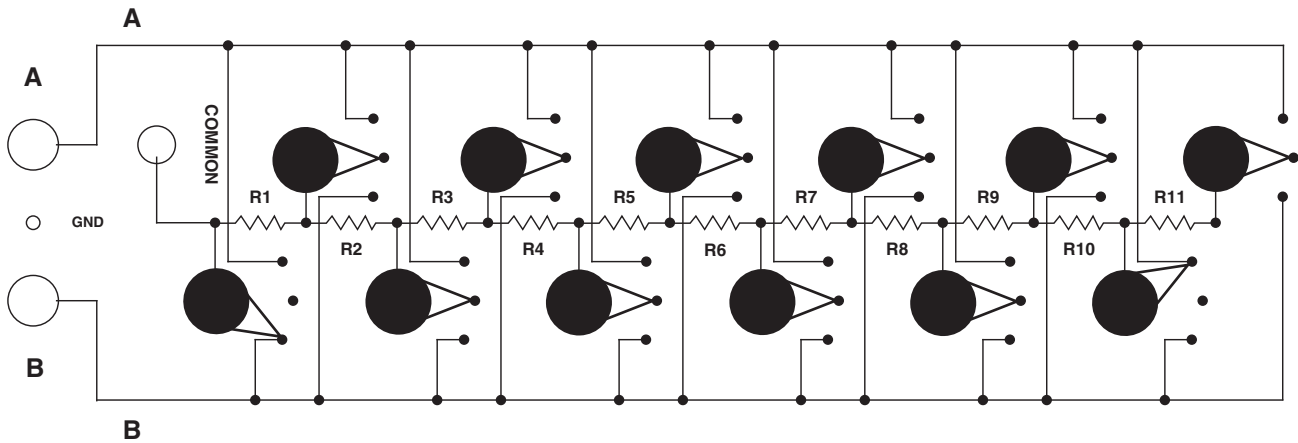


Figure 4-6: Resistance = $10R$: ten resistors in series

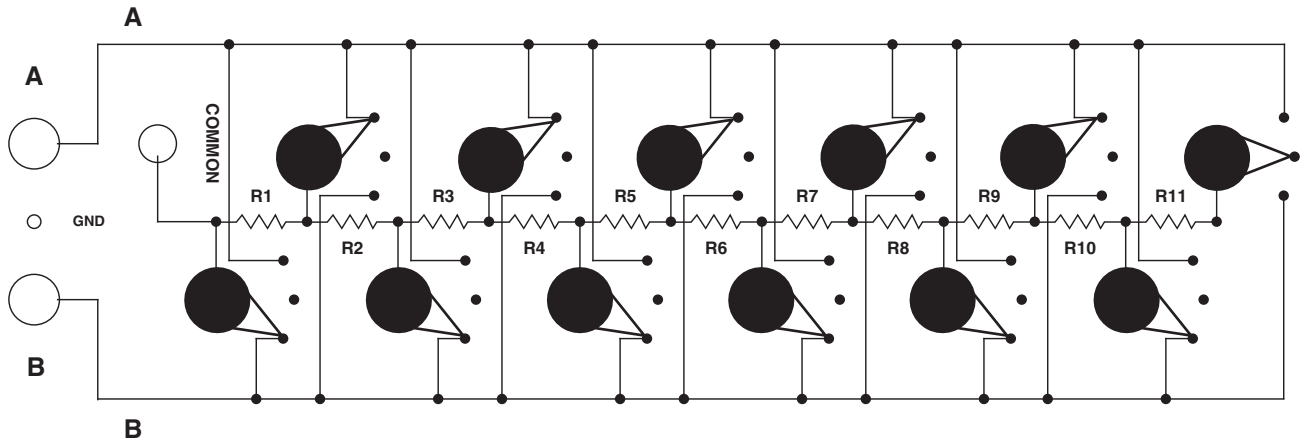


Figure 4-7: Resistance = $R/10$: ten resistors in parallel

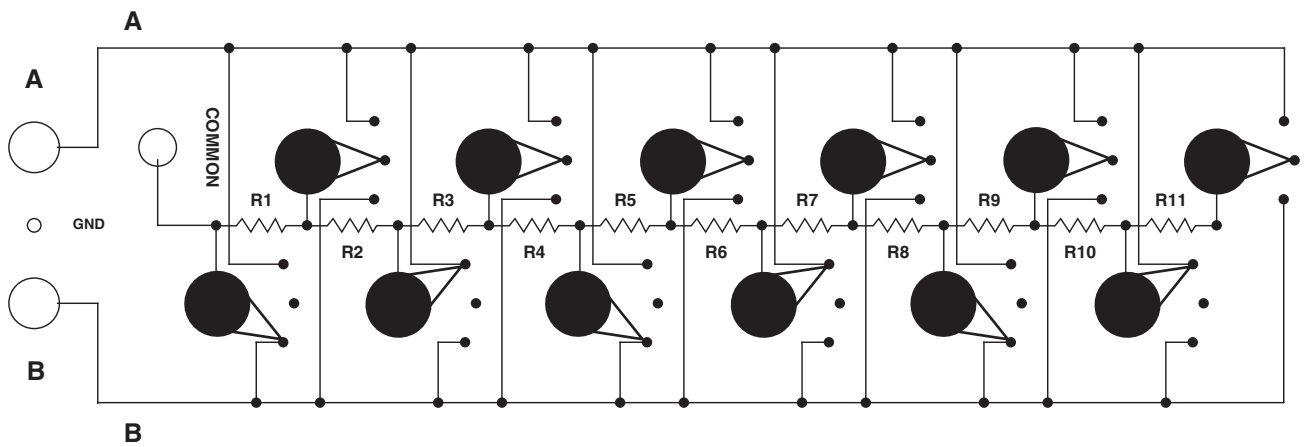


Figure 4-8: Resistance = $0.4R$: 5 groups of 2, in series-parallel

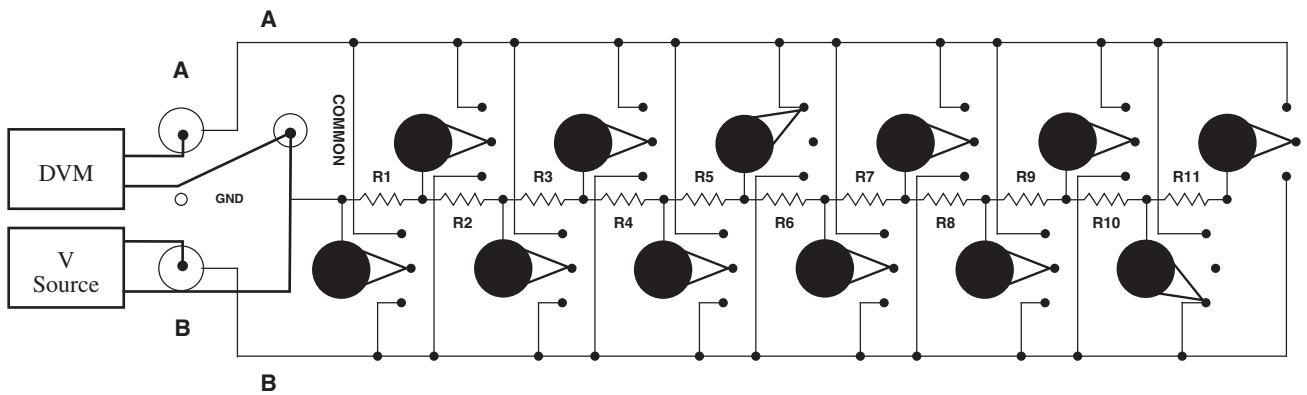



Figure 4-9: Unit configured as a precision voltage divider with 50% ratio (in this example)

4.2.4 Transfer accuracy

The deviations of each individual resistor from its nominal value, as well as the cumulative average deviation of the resistance string is given in a **CALIBRATION CHART** attached to the unit. Figure 4-10 shows a typical chart.

SR1050-10M				
Deviation from Nominal			Temperature: 23.5°C	
	Individual (ppm)	Cumulative (ppm)	Date:	Date Due:
R1	-3.7	-3.7	15-Feb-2013	
R2	-6.2	-5.0		
R3	-0.9	-3.6		
R4	-18.4	-7.3		
R5	-9.3	-7.7		
R6	0.4	-6.3		
R7	-15.7	-7.7		
R8	-16.1	-8.7		
R9	-5.8	-8.4		
R10	-3.2	-7.9		
R11	-1.1	-7.3		

Model: SR1050-10M
Serial Number: 20309831050A
BY: CN
Traceable to SI

Figure 4-10: Sample calibration chart

What is important to note is that any series, parallel, or series-parallel configuration results in the net deviation being essentially equal to the average deviation for that group of resistors regardless of how they are connected, as long as the power applied is divided equally, (or almost equally) among the resistors. This is clearly the case with the R/10 and the 10R configurations, i.e. that they have the same deviations. It is also true with the 9-resistor series-parallel configuration, since the effect of the deviation of the single missing resistor may be safely neglected. This property is very useful since it permits making accurate transfers across three decades with one single unit.

A single high accuracy, high stability standard whose value is traceable to SI may thus be transferred to other values using the **SR-1050** Series in various combinations.

4.2.5 High Accuracy Calibration Transfer

It is desirable to have as few standards that must be calibrated by national laboratories as possible. The best plan in the case of resistance is to have 1 Ω or 10 k Ω standard resistors for reference standards. One can then compare by ratio techniques the transfer standards to the reference standards.

The technique for transferring is based on the fact that ten nominally equal resistors in series have ten times the resistances as one; ten resistors in parallel have one-tenth the resistance of one. The resistance deviation of either the series or parallel case is the same as the average deviation of the ten resistors.

The resistance from 1 Ω to higher levels (such as 10 k Ω) is described in the Instruction Manual for Model SR-1010 Resistance Transfer Standard.

The technique is based on the fact that ten nominally equal resistors in series have ten times the resistances as one; ten resistors in parallel have one-tenth the resistance of one. The resistance deviation of either the series or parallel case is the same as the average deviation of the ten resistors. This is discussed in detail in Section 4.2.6.

The Model SR-1050 Transfer Standards can be used to transfer resistance from 10 k Ω to 100 M Ω using only 1 to 1 comparisons as on a comparison bridge or other ratio technique. The procedure is to set a 100 k Ω per-step transfer standard for one-tenth the step resistance (10 k Ω) and compare it to the standard resistor. This gives the average deviation of the ten 100 k Ω resistors. The next step is to set the 100 k Ω per-step transfer standard for ten times the step resistance (1 M Ω) and compare it to a 10 M Ω per-step transfer standard that is set to one-tenth the step resistance (also 1 M Ω). This gives the average deviation of the ten 1 M Ω resistors which can be set in series to be 100 M Ω with the same deviation.

Figures 4-6 and 4-7 illustrate switch positions for ten times and one-tenth times the nominal value of the transfer standard, in each case using the same ten

resistors. Figure 4-5 illustrates a method of switching to connect the nine resistors in series and parallel to equal the nominal resistance value of one step.

4.2.6 Basic Transfer Accuracy

To make transfer measurements which do not depend on the absolute accuracy of the transfer standard but only on its short term stability, it is necessary to assume that ten resistors in parallel are exactly equal to one one-hundredth of the same ten resistors in series. To see how valid this assumption is let R be the nominal value of the individual resistors and d_n the deviation from nominal of this n th resistor. The value of the n th resistor will then be $R_n = R(1+d_n)$. The value of the ten resistor in series will be:

$$R_s = \sum_{n=1}^{10} R(1+d_n) = 10R \left(1 + \frac{1}{10} \sum_{n=1}^{10} d_n \right)$$

$$d_{av}^{10} = \frac{1}{10} \sum_{n=1}^{10} d_n$$

where

d_{av}^{10} is the average of the deviation d_n for ten resistors.

$$R_s = 10R \left(1 + d_{av}^{10} \right)$$

The resistance of the same ten resistors in parallel will be:

$$R_p = \frac{1}{\sum_{n=1}^{10} \frac{1}{R(1+d_n)}}$$

$$\frac{1}{R(1+d_n)} = \frac{1}{R} (1 - d_n + d_n^2 - d_n^3 \dots)$$

$$R_p = \frac{1}{\sum_{n=1}^{10} \frac{1}{R} (1 - d_n + d_n^2 \dots)}$$

$$R_p = \frac{R}{10} \frac{1}{1 + \frac{1}{10} \sum_{n=1}^{10} (-d_n + d_n^2 \dots)}$$

$$R_p = \frac{R}{10} \left(1 + \frac{1}{10} \sum_{n=1}^{10} d_n - \frac{1}{10} \sum_{n=1}^{10} d_n^2 \dots \right)$$

$$R_p = \frac{R}{10} \left(1 + d_{av}^{10} - \frac{1}{10} \sum_{n=1}^{10} d_n^2 \dots \right)$$

$$R_p \approx \frac{R}{10} \left(1 + d_{av}^{10} \right)$$

The assumption being that $\frac{1}{10} \sum_{n=1}^{10} d_n^2$ is negligible. Since d_n maximum for the SR-1050 is less than 100 ppm d_n^2 will be less than 0.01 ppm, which can be neglected. Thus the original assumption is quite valid. A similar analysis can be made for the series-parallel connection or any other configuration in which the power divides equally among the resistors.

4.2.7 Example transfer

For example, a 100 k Ω standard may be compared with a SR-1050 unit with 1 M Ω steps connected in parallel as shown in Figure 4-7 above, to provide a 100 k Ω resistance. Once a comparison is made, a net deviation of the parallel R/10 combination is obtained.

This average or net deviation remains constant for all combinations. Thereby, the standard is effectively “transferred” with the same deviation plus the transfer accuracy of the unit to another decade, 10R or 10 M Ω in this example. It may also be transferred to the single step R value with the series parallel combination. See Figure 4-5.

This process may be continued with another transfer standard, 10 M Ω steps in this example, which would first be configured in the R/10 mode to produce 1 M Ω to start, and then 10 M Ω and 100 M Ω with the same deviation. The transfer uncertainty should still be added at each transfer.

4.3 Use as a Stand-Alone Standard

Whenever an application requires a resistance standard that has an accuracy that is met by the initial or long term accuracies of the SR-1050 Series, as specified, the SR-1050 unit may be used as a calibration source at any value desired. For example, the SR-1050-1M Ω step unit may be used as a calibration source with an adjustment accuracy of 20 ppm and a stability of 15 ppm/year.

4.4 Use as a Precision Voltage Divider

The SR-1050 unit may be used as a precision voltage divider. See Figure 4-9, reproduced below. For this application:

1. Connect the input voltage low to **COMMON** bnc connector and the high to the B binding post.
2. Obtain the “tap,” or ratio voltage from the **A** binding post to **COMMON**.

4.5 General Considerations for best performance

Since the SR-1050 is a precision *high* resistance unit, any electrical leakage across the terminals will affect performance. To keep the leakage low, keep the unit clean. This is particularly important for the binding post area, including the white insulating washers underneath. Follow the guidelines below to ensure cleanliness and low leakage:

- Keep the unit sealed and in a dry laboratory environment when not in use.
- Do not handle the white insulators under the binding posts with bare hands.
- If necessary, clean the binding post area with rubbing alcohol and a lint-free cloth.

For 10 M Ω step units, allow the measurement to stabilize for as long as one or two minutes to settle to within specifications. This is needed because of the different effects of meter and bridge test currents on the very long resistance wire making up each resistor.

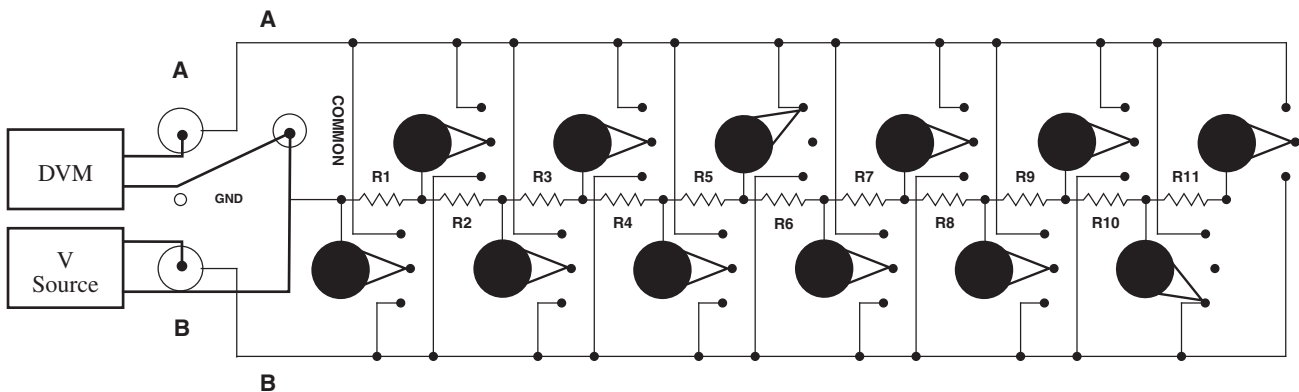


Figure 4-9: Unit configured as a precision voltage divider with 50% ratio (in this example).

Chapter 5

CALIBRATION

5.1 Verification of Performance

5.1.1 Calibration interval

It is recommended that the **SR-1050** Series instruments should be verified for performance at a calibration interval of twelve (12) months. This procedure may be carried out by the user (if a calibration capability is available), by the manufacturer, or by a certified calibration laboratory. If the user should choose to perform this procedure, then the considerations below should be observed.

Note: For **SR-1050** series to be used as transfer standards only, recalibration is not *strictly* required assuming that there has been no drastic change in the deviations of any individual resistors.

5.1.2 General considerations

It is important, whenever calibrating or certifying the **SR-1050** Series Transfer Standards, to be very aware of the capabilities and limitations of the test instruments used. A resistance standard and a DMM with sufficient capability is recommended.

It is important to allow both the testing instrument and the **SR-1050** standard to stabilize for a number of hours at laboratory conditions of temperature and humidity. There should be no temperature gradients across the unit under test.

Proper metrology practices should be followed in performing this verification or calibration. Special care should be exercised for the high resistance values

5.1.3 Calibration procedure

1. Determine the allowable upper and lower limits for each resistance step.
These are the specified long term accuracy limits.
2. Perform measurements under stabilized temperatures and with the SR-1050 instrument case connected to the appropriate measuring instrument guard point.
3. Confirm that the resistances fall within these limits.
If any resistances fall outside these limits, they may be calibrated as described in section 5.2 below.
4. If desired, the new verified values may be entered on a facsimile of the calibration chart in Figure 4-10 and affixed in place of or on top of the existing calibration chart.

5.2 Making adjustments

If any individual resistors requires adjustments, the associated resistor network may be trimmed by adjusting the potentiometer for that resistance.



CAUTION

Don't touch anything inside the unit with bare hands. If it should become necessary to handle any internal component, gloves should be worn.

This procedure should be performed in an environment as free as possible from electrical noise due to the high impedance of these instruments. If this is not possible, or for best results, the effects of such noise may be minimized by the use of a Faraday cage and/or a ground plane.

1. Loosen the four captive screws at the corners of the SR-1050 unit and carefully lift the unit out of the enclosure.
2. Set it on a teflon or styrofoam insulating pad.
3. Connect the DMM across the A and B binding posts with any guard shield connected to the center metal binding post.
4. Set the switches as needed to access each resistor.
5. Locate the trimming potentiometer for each resistor; unlock the potentiometer and adjust to trim the step under test.
6. After making the adjustment, move away from the unit and allow the measurement to settle to its final reading.
This procedure can be time-consuming, requiring several minutes for each step.
7. After Adjustment of all required resistances in the unit, return it to its enclosure and fasten with the four retaining screws.
8. Recheck all 11 values, and repeat the adjustment procedure if necessary