OPERATOR MANUAL

FOR

MODEL GL1050 Series

PRECISION RESISTANCE TRANSFER STANDARD

OMGL1050-3-00
29 June, 2020

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

This manual provides an overview of the GL 1050 Precision Resistance Transfer Standard and contains the necessary information required to perform a calibration or verification test. General product information, product description and performance specifications are also included.

The phone number in the USA and Canada to obtain Product Support, Calibration Service or Replacement Parts is (800) 310-8104.

To contact Guildline Instruments, the following information is provided.

USA and Canada Telephone: (613) 283-3000
USA and Canada Fax: 1-613-283-6082

Outside US and Canada Telephone: + [0] [1] 613 283-3000
Outside US and Canada Fax: + [0] [1] 613 283-6082

You can also contact Guildline Instruments Limited via their Email or Website.

Email is: sales@guildline.com
Website is: www.guildline.com

1.1. Warranty

Guildline Instruments warrants its products to be free of defects in manufacture and normal operation for a period of two (2) years from the date of purchase, except as otherwise specified. This warranty applies only in the country of original purchase and only to the original purchaser, who is also the end user. Equipment, which is defective or fails within the warranty period, will be repaired or replaced at our factory without charge at the discretion of Guildline Instruments.

In addition, systems engineered by Guildline Instruments are warranted to be free of defects in overall system operation for a period of two (2) years from the date of receipt by the original purchaser.

Third party system components purchased by Guildline carry the warranty of the original equipment manufacturer and will be accepted for claim by Guildline Instruments at our factory only after warranty authorization by the original manufacturer.

Limitation of Warranty

Warranty coverage does not apply to equipment which has failed due to misuse, neglect, accident or abnormal conditions of operation or if modifications or repairs have been made without prior authorization of Guildline instruments.

Damage in Shipment to Original Purchase

Instrument(s) should be thoroughly inspected immediately on receipt for visible damage. Any damage should be reported to the carrier and further inspection and operational tests should be carried out if appropriate to determine if there is internal damage. Contact Guildline Instruments before returning for repair. The customer or purchaser must complete all final claims with the carrier.

Regular charges will apply to non-warranty service. External service charges and expenses will be billed at cost plus handling.

1.2. To Obtain Warranty or Calibration and Repair Service

Call for a Return Material Authorization (RMA) number. RMA's are required for all Warranty Returns and/or Calibration and Repair Service Requests. Telephone, Fax and email addresses to contact Guildline are provided previously.

Guildline Instruments will pay for all warranty costs including shipping to the original shipment point. However, if the instrument is purchased within one country and shipped to another, Guildline will only pay for shipping to the original ship to country or customer point.

1.2.1. USA Warranty Return Address

USA Customers should use the following address to return instruments for warranty service or calibration support.

Guildline Instruments Limited
C/O AN Deringer
800 Proctor Avenue
Ogdensburg, NY 13669

Mark on the outside of the box:
RMA # ______________
Model #______________
Serial #______________
The Statement: "Canadian manufactured goods being returned for repair."

1.2.2. Returns All Other Countries

For all other countries, including Canada please ship to:

Guildline Instruments Limited
21 Gilroy Street, PO Box 99
Smiths Falls, ON K7A 4S9

Mark on the outside of the box:
RMA # _____________
Model #_____________
Serial #_____________
The Statement: "Canadian manufactured goods being returned for repair."

1.3. Safety Information

WARNING: During usage and calibration, high voltages or high currents may be present. Use caution when working above 40 Volts DC or currents above 1mA. Such voltages or currents can cause death.

WARNING: <u>GRD input is connected to the chassis and switch handles. The GRD is normally connected to the Ground.</u> Use caution when connecting the GRD to above 40 Volts DC. Such voltages can cause death.

The GL 1050 Precision Resistance Transfer Standard is designed to work within operating specifications. Applying more than the recommended current or voltage will damage the unit.

Inspect the GL 1050 Precision Resistance Transfer Standard for damage such as broken switches or cracked connectors prior to use. If the unit has a burned smell or smoke is visible during use, discontinue use immediately.

If test equipment used with Resistance Standards overloads or trips, this could be a sign that the GL 1050 requires repair.

Inspect all test leads used for damaged insulation or exposed metal. Check all test leads for continuity.

Ensure all test leads are correctly connected prior to applying current or voltage.

Do not use Resistance Standards around explosive gas, vapor or dust.

1.4. Instrument Description

Precision transfer measurements up to 110 MΩ relative to a single 10 kΩ resistance standard can be obtained with the GL 1050 high value 1 MΩ and 10 MΩ resistance standards.

The GL 1050 utilizes a transfer technique that consists of switching resistance sections in parallel, series, or series-parallel sections. An outstanding design feature is a structure in which leakage resistance to ground appears only at the terminals in any resistor configuration. Therefore, leakage can be effectively eliminated in a three-terminal measurement. There are no solid insulation leakage paths to ground other than at the terminal points, regardless of the configuration into which the individual resistance steps may be switched. A unique and outstanding design characteristic of the GL 1050 Precision Resistance Transfer Standard obviates the need to support resistors from a common insulating sheet or from insulators mounted on a common conducting surface. Therefore, resistance accuracies cannot be degraded by leakage paths to ground at random points within the string.

Each active resistance step consists of multiple elements connected in series, plus a fixed trimming element for obtaining precise final value adjustment. The reduced head concentration that results from distributing the dissipated power over multiple elements rather than in a single resistor improves the thermal characteristics of an already low-temperature-coefficient resistance element.

The GL 1050 will also function as a voltage divider. In this mode, the only solid insulation leakage paths to ground are from the three terminals. These leakages will range between 10^{13} and 10^{16} Ω, except under the most adverse environmental conditions.

2. SPECIFICATIONS

Step Size	Adjustment (Initial) Accuracy	Transfer Accuracy [1]	Stability (ppm/year)	Long Term Stability	Temperature Coefficient	Resistance Matching	
						Adjustment	TC
1 MΩ	±20 ppm	±2 ppm	±15 ppm	±30 ppm	±3 ppm/°C	±10 ppm	±3 ppm
10MΩ	±20 ppm	±2 ppm	±15 ppm	±30 ppm	±3 ppm/°C	±10 ppm	±3 ppm

1 – Within 1 °C of measured value (low Power).
2 –Calibrated in air at 23 °C traceable to the SI unit of electric resistance, calibration uncertainties expanded and expressed at the 95 % level of confidence. An ISO/IEC 17025 accredited certificate and report of calibration stating the calibrated value and estimated uncertainty is provided with each resistor.
3 – No oil bath is required for either model to achieve specifications).

General Specifications		
Maximum Power Rating:	1 W/step or 5 W distributed over 10 steps, or maximum voltage of 2.5 kV where this value does not result in power > 1 W per resistor	
Power Coefficient:	<± 0.05 ppm/mW per resistor	
Break Down Voltage:	2,500 peak V between any terminal and case	
Leakage Resistance:	Greater than 10^{13} Ω from terminal to case	
Connection Terminals:	Three gold-plated, 5-way, tellurium-copper binding posts with low thermal emf and low resistance. One shielded UHF terminal labelled COMMON, used when the unit is employed as a precision voltage divider.	
Calibration Data:	Initial Calibration readings are listed on certificate and instrument	
Environmental:	Operating	Storage
Temperature:	23 °C ± 3 °C	0 °C to 50 °C
Humidity:	20 % to 50 % RH	15 % to 80 % RH
Size (Either Model) H x W x D:	17″ x 6.0″ x 5.9″	43 cm x 15.2 cm x 15 cm
Weight (Either Model):	11 lbs	5 kgs

3. RECEIPT AND INSPECTION

3.1. General

Remove the instrument from its shipping container. The instrument was thoroughly tested and inspected before shipment and should be free from any electrical or mechanical damage when received. Nevertheless, you should perform an inspection for physical damage, ensure all items on the packing list are present and test the instrument, electrically, as soon as possible after receipt. Refer to the warranty card at the front of the manual if any damage or deficiencies are found.

3.2. Packaging

We recommend that the shipping container be retained for future storage or transportation of this instrument.

4. OPERATION INSTRUCTIONS

4.1. Using the Calibration Chart

The calibration chart on the end of the enclosure for each GL 1050 gives resistance calibration data for individual resistors and groups of resistors in the GL 1050, in terms of their deviation from the nominal value, expressed in parts per million.

A sample calibration chart is shown in Figure 4-1.

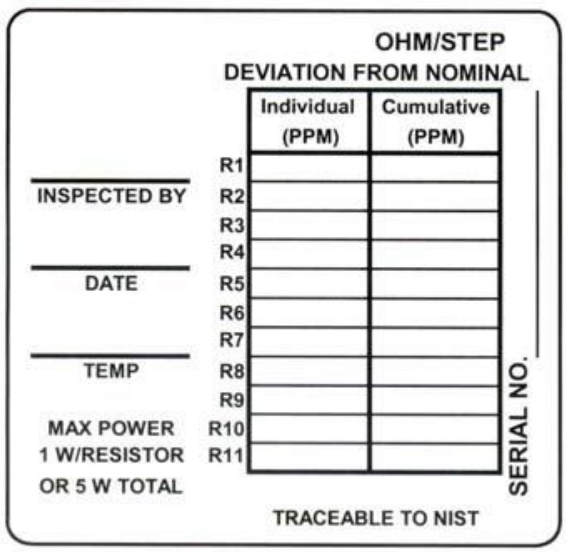


Figure 4-1 : Calibration Chart

The first column gives the measured deviation of each resistor from its nominal value. The second column gives the cumulative average of the deviation figures in the first column, rounded to the same number of significant figures as the first column. For example, to the right of R7, the figure in the first column is the measured deviation of R7 from the nominal, while the figure in the second column is the calculated average deviation of resistors R1 through R7.

The cumulative average deviation in the second column calibrates any series, parallel, or series-parallel connection of the corresponding group of resistors in which the power divides equally among all the resistors in the group. For example, the first nine resistors in a 1-MΩ-per-step box can be connected in series for a nominal value of 9 MΩ, in parallel for 1/9 of a MΩ, or in series-parallel for 1 MΩ; the actual value of each of these three alternate connections will be exactly the same number of parts per million away from the nominal value for that connection. (See paragraph 5.4 for further details on transfer accuracy.)

The calibration chart data supplied initially with each GL 1050 is traceable to a National Metrology Institute with the specified accuracy under the stated laboratory environmental conditions.

4.2. 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 kΩ standard resistors for reference standards. One can then compare by ratio techniques the transfer standards to the reference standards. The technique for transferring from 1 Ω to higher levels (such as 10 kΩ) is described in the Instruction Manual for Model GL 1010N Resistance Transfer Standard.

This is because ten nominally equal resistors in series have ten times the resistance as one, and ten resistors in parallel have one-tenth the resistance of one. Furthermore, 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 5.4.

The Model GL 1050 Precision Resistance Transfer Standards can be used to transfer resistance from 10 kΩ to 100 MΩ using only 1-to-1 comparisons as on a comparison bridge or other ratio technique. The procedure, briefly, is to set a 100 kΩ-per-step transfer standard (such as the Guildline GL 1010N Resistance Transfer Standard or Guildline 9350 Hamon Transfer Standard) for one-tenth the step resistance (10 kΩ) and compare it to the standard resistor. This gives the average deviation of the ten 100 kΩ resistors. The next step is to set the 100 kΩ-per-step transfer standard for ten times the step resistance (1 MΩ) and compare it to a 10 MΩ-per-step transfer standard for ten times the step resistance (1 MΩ) and compare it to a 10 MΩ-per-step transfer standard that is set to one-tenth the step resistance (also 1 MΩ). This gives the average deviation of the ten 1 MΩ resistors, which can be set in series to be 100 MΩ with the same deviation.

Figures 4-2 and 4-3 illustrate switch positions for one-tenth and ten times the nominal value of the transfer standard, in each case using the same resistors. Figure 4-4 illustrates method of switching to connect nine resistors in series-parallel to equal the nominal resistance of one step.

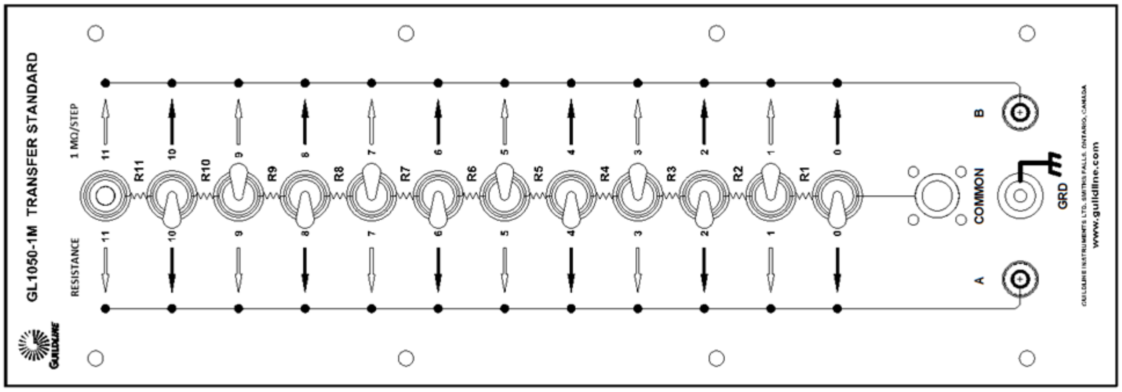


Figure 4-2 : Switch Positions for One-Tenth Nominal Step Resistance

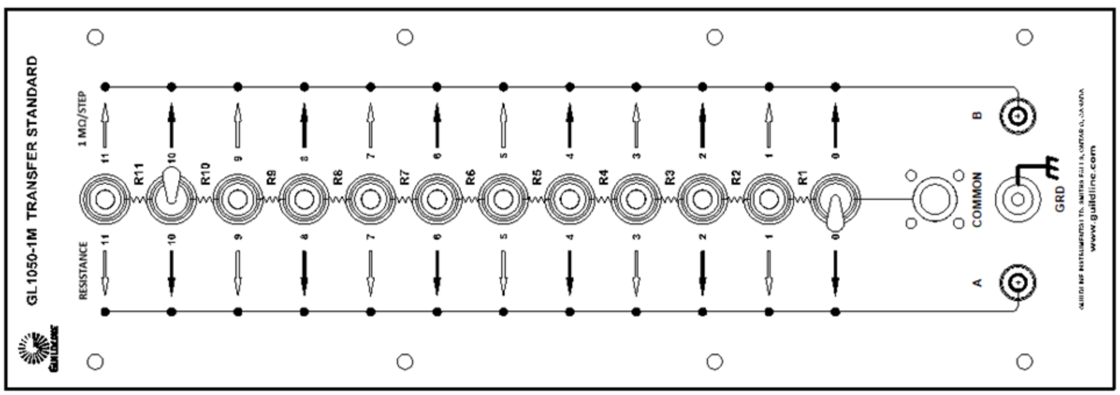


Figure 4-3 : Switch Positions for Ten Times Nominal Step Resistance

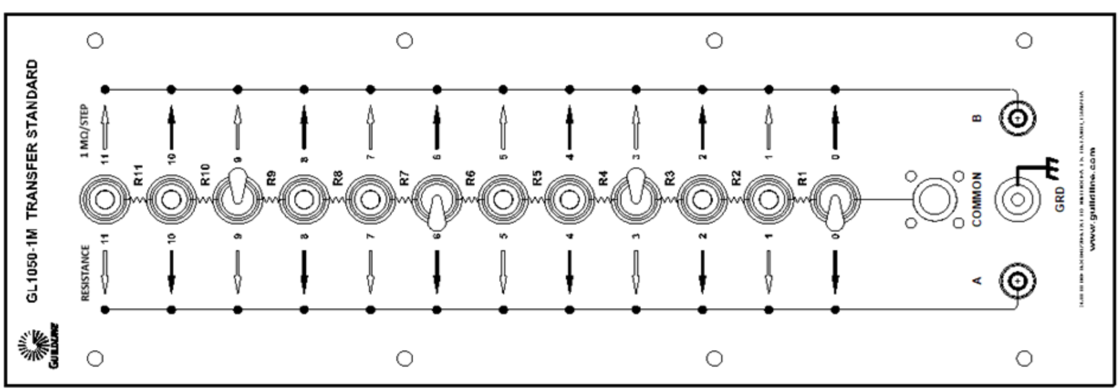


Figure 4-4 : Switch Positions for Series-Parallel Connection Equal to Nominal Value of One Step

4.3. Voltage Divider Operation

The Model GL 1050 Precision Resistance Transfer Standard may be used as a voltage divider. A coaxial fitting, nominally capped, connects to one end of the resistor string, and may be used as either the high or low voltage end of the divider. If it is so used, one of the other terminals, A or B, forms the opposite end of the divider, and the remaining terminal is the tap. Figure 4-5 shows an example of the Model GL 1050 Precision Resistance Transfer Standard connected as a voltage divider.

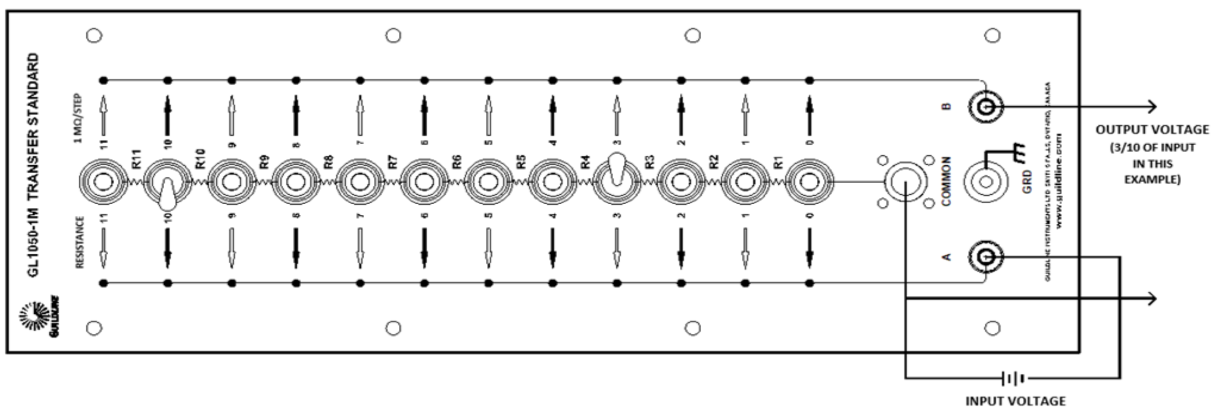


Figure 4-5 : Voltage Divider Connections

5. THEORY

5.1. Three-Terminal Resistance Measurements of Single Resistors

When a resistor is mounted between two terminals on a terminal board made of insulating material, the leakage resistance of the board shunts the resistor. However, when the resistor is mounted between insulators on a metal terminal board (Figure 5-1), the leakage is all to the metal board. A three-terminal measurement using the metal board as the third terminal can give the true value of the resistor with no measurable effect from the leakage.

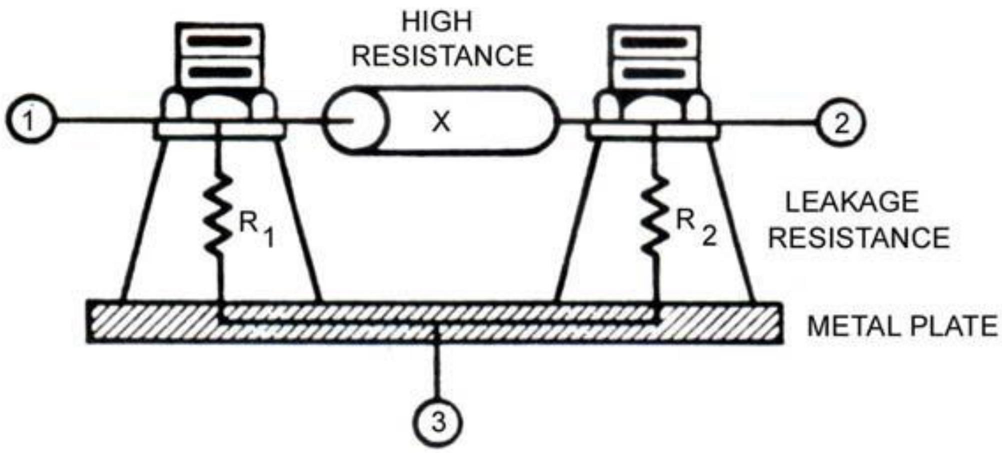


Figure 5-1 : Three-Terminal Resistor

The third terminal (the case of the mounting plate) is connected to a Wheatstone bridge, as shown in Figure 5-2. Note that leakage resistance R2 is now across the detector, and causes no error. R2 is usually larger than the meter resistance and merely reduces the latter's sensitivity slightly.

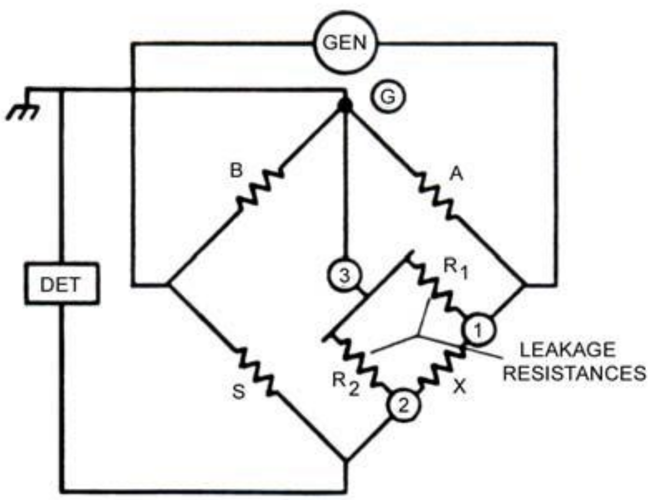


Figure 5-2 : Three-Terminal Measurement Bridge

Leakage resistance R1 is across resistor A and does change its value slightly. With good insulation materials, the resistance of R1 can be made so much higher than that of A that this change can be neglected. Thus, with the three-terminal connection, the resistor can be measured to high accuracy even though its resistance and the leakage resistances are of the same order of magnitude (as might be true on a humid day).

Figure 5-3 shows the method of making three-terminal connections when using the Kelvin bridge circuit. Here both the standard S and the unknown X can be connected as three-terminal resistors. When the resistances of X and S are high, the circuit on the right is a good approximation of the measurement condition. The leakage resistance R2 R3 is across relatively low-resistance bridge arms so that normal leakage values do not give measurement errors.

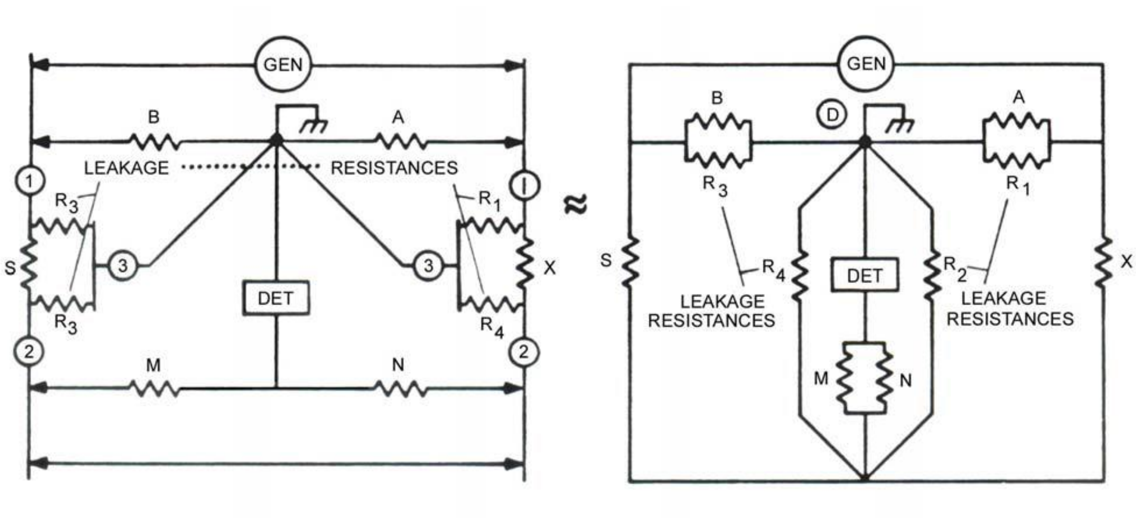


Figure 5-3 : Kelvin Bridge Three-Terminal Connections

5.2. Three-Terminal Resistance Measurements of Series and Parallel Groups of Resistors

When resistors are connected in parallel, the shunting resistance of the insulators holding each resistor is the same value as the resistance shunting each resistor when it is measured individually. Thus the parallel value of the resistors is precisely related to the individual values of the resistors. The errors caused by leakage can be eliminated in the same manner as in the measurement of a single resistor.

Resistors in series, however, have a more serious problem. If a set of resistors, each independently supported, is connected in series, the leakage of the insulators is shunted across different parts of the resistance string. Figure 5-4 illustrates such a series string of resistors. In this case, the resistance of the series string, measured with a bridge of any configuration, will be less than the sum of the resistances measured separately.

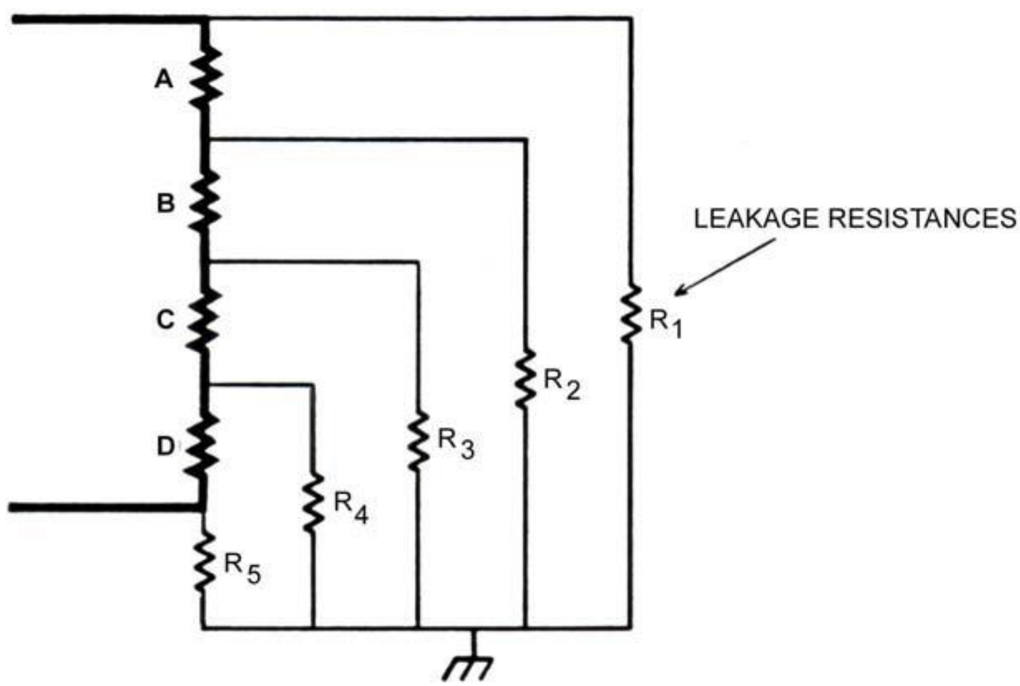


Figure 5-4 : Leakage Resistances with Series Resistors

5.3. Constant Leakage

Such errors are eliminated in the Model GL 1050 Precision Resistance Transfer Standard by special construction. Controlled leakage construction is illustrated in Figure 5-5. The leakage resistance of the insulator that supports each resistor is shunted across each resistor. With this construction, the leakage resistance across each resistor is the same in all series and parallel connections and the same as when the resistor is measured individually. Since this is the case, the accuracy of the transfer of resistance from parallel to series connections is theoretically perfect.

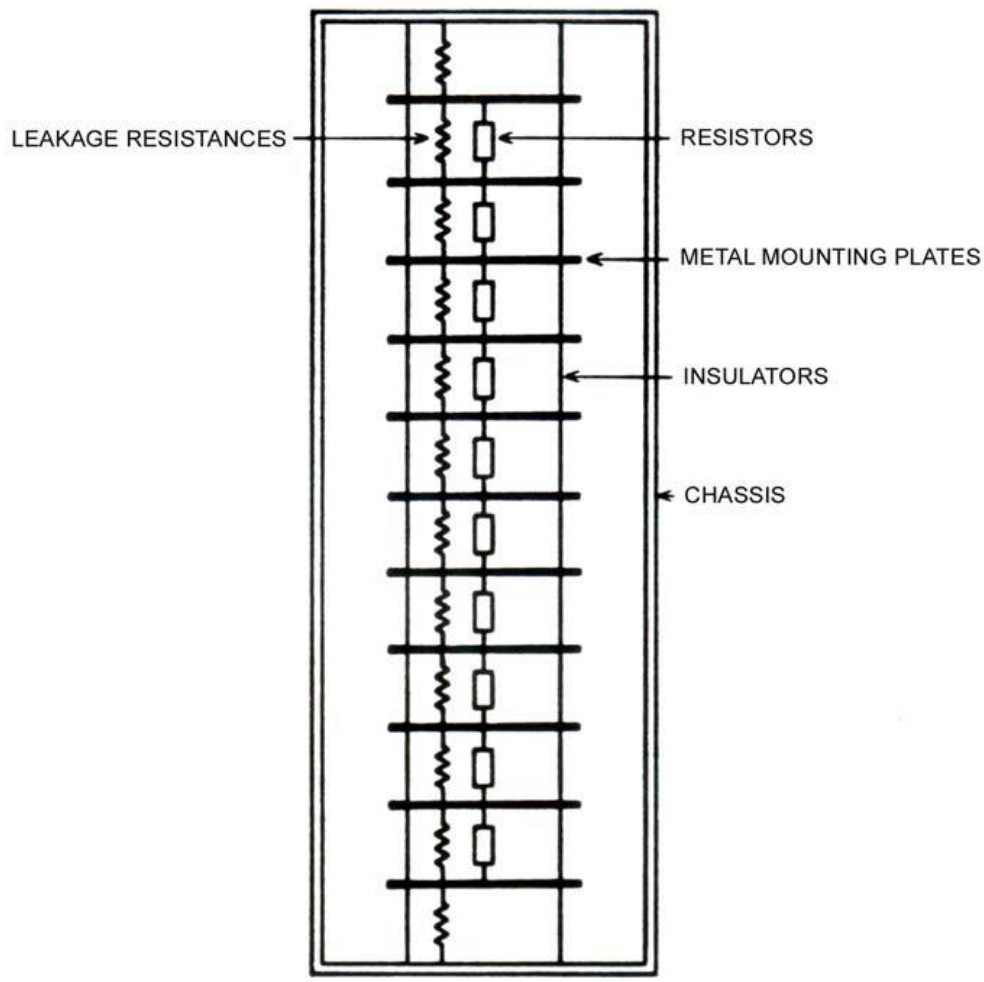


Figure 5-5 : Constant Leakage Construction

It might be noted that the switches that connect the resistors in the Model GL 1050 Precision Resistance Transfer Standard allow no significant leakage since there is no mechanical connection, even though insulation, between the switched bus or the case and the resistor to be contacted unless the switch is operated. Such leakage that does occur is only between the switched bus and the instrument case. It is eliminated as a source of error in three-terminal measurements, as described in Paragraph 5.1.

Figure 5-6 illustrates schematically the Model GL 1050 Precision Resistance Transfer Standard.

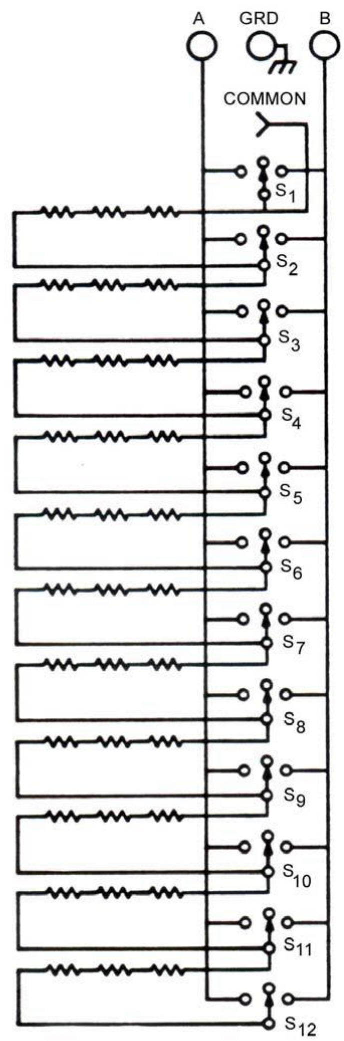


Figure 5-6 : Model GL 1050 Schematic

5.4. 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 dn the deviation from nominal of this nth resistor. The value of the nth resistor will then be Rn = R(1+dn). The value of the ten resistors in series will be:

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

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

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

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

The resistance of the same 10 resistors in parallel will be:

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

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

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

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

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

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

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

The assumption being that $\frac{1}{10}\sum_{n=1}^{10} d^2$ is negligible. Since d_n maximum for the

GL-1050 is less than100 ppm d^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.

5.5. Linearity Deviation

To calibrate a GL1050 as a voltage divider, you need to know between the actual ratio of the output to the input voltages and the settings. This difference is called linearity deviation.

$$L = \frac{E_{out}}{E_{in}} - S$$

L = linearity deviation
E_{in} = actual input voltage
E_{out} = actual output voltage
S = divider setting

Since the voltage and resistance divide proportionately, the linearity deviation can be found by a precision comparison of the resistors in the divider string. By using 10 resistor of the GL 1050 in the divider string, the output can be set to integral multiples of a tenth of the input voltage. The linearity deviation for this divider can be shown as:

$$L = \frac{\sum_{n=1}^{10S} R_n}{\sum_{n=1}^{10} R_n} - S$$

L = linearity deviation

R_n = resistance of the nth resistor

$$\sum_{n=1}^{10S} R_n = \text{resistance from COM to OUT in ohms}$$

$$\sum_{n=1}^{10} R_n = \text{total input resistance in ohms}$$

S = divider setting

If all the resistors in the string were equal, the voltage would also divide equally. To find out how far from the ideal this divider is, each resistor R_n of the string is compared to a standard resistor. To maintain the ultimate in measurement accuracy, three-terminal measurements should be used. The measured resistance deviation is used to calculate the linearity deviation.

$$R_n = R_s (1 + d_n)$$

R_n = resistance of the nth resistor in ohms
R_s = resistance of standard resistor in ohms
d_n = per unit deviation of R_n from R_s

This leads to the following expression for linearity deviation:

$$L = \frac{\sum_{n=1}^{10S} (1 + d_n)}{\sum_{n=1}^{10} (1 + d_n)} - S$$

The precise value of the standard resistor is not important since it is cancelled out of these equations. Thus any one of the resistors in the string can be used as the standard resistor. To simplify calculations of the equation for linearity deviation can be modified by first defining the average deviation as:

$$d_{av}^{10} = 0.1 \sum_{n=1}^{10} d_n$$

And then assuming d_{av}^{10} is much smaller than one.

The equation for deviation can then be expressed as follows:

$$L = 0.1 \sum_{n=1}^{10S} \left(d_n - d_{av}^{10} \right)$$

6. Calibration and Performance Verification

6.1. Introduction

The following section describes the calibration and performance verification procedures for the GL 1050 Transfer Standard Series. Calibration is recommended every 12 months. This procedure should be performed only by those who have the necessary facilities. Calibration should be performed in a controlled laboratory environment.

6.2. Calibration Overview

This calibration procedure covers the entire series of the GL 1050 Transfer Standards.

Please note that the recommended procedure is a fully automated procedure using the Guildline 6625A Resistance Measurement System, Bridgeworks Software and Transfer Software Utility. The procedure is listed in section 6.6.

The BridgeWorks Data Acquisition Software is the accompanying control software for the Guildline 6625A Resistance Measurement System. Using the 6625A System with the computer will increase the functionality of the instrument greatly with respect to operating its components as stand-alone units. Before using the 6622A Resistance Bridge contained in the 6625AF System with the computer, you should ensure that the operation of this software package is well understood. This software was designed with an interface that blends the most common features of a traditional front panel coupled with the familiarity of the Windows™ interface. The control of your Guildline Resistance Measurement System through this software will enable you to automate your measurement process, acquire your data and analyze the results.

6.3. Calibration Interval and Performance

It is recommended that the GL 1050 Transfer Standard Series be calibrated or verified on the manufacturer's recommended 12-month interval. As with all resistance standards, it is highly recommended that past history be used to determine drift rates. Generally, resistance standards will drift in value more significantly in the first 12 months. After the initial 12 months, drift rates typically become smaller for all models.

It is highly recommended that each GL 1050 Transfer Standard Series be calibrated within a highly controlled temperature environment.

Each GL 1050 Transfer Standard is manufactured to provide some of the best (i.e. lowest) uncertainties when compared to other commercially available resistance standards. After recalibration, the user should determine the Resistance Calibration Uncertainties by applying an uncertainty calculation that includes: uncertainties for drift, standards and equipment used, the calibration and laboratory environment, and other uncertainties applicable to that calibration.

Guildline offers ISO/IEC 17025 Accredited DC Resistance Calibration Services from its Smiths Falls, Canada Location. We can provide very good turn-around times with some of the lowest uncertainties available today. GL 1050 Transfer Standard users may find the use of Guildline Calibration Services an excellent convenience as well as a great alternative to maintaining their own calibration facilities to support these standards. US customers can ship to a US address and Guildline makes all of the arrangements for shipping to and from Canada and import and export.

6.4. Equipment and Standards Required for Calibration

The following Resistance Standards and Test Equipment are required for calibration.

Use Standards:

Complete 6625A Resistance Measurement System (See Below for Alternative Acceptable Equipment Models).

Bridgeworks Software with Transfer Standard Utility.

Or (Alternative Standards):

(a) Direct Current Comparator Resistance Bridge (Acceptable Models)
Guildline Instruments 6622A Series DCC Resistance Bridge
Guildline Instruments 6675 or 6675A Series DCC Resistance Bridge
Guildline Instruments Model 9975A Resistance Bridge

(b) Laboratory Grade Primary Resistance Standard (Acceptable Models)
Guildline Instruments 6634A Temperature Stabilized Resistance Standard
Guildline Instruments 6634TS Traveling Standard (Temperature Stabilized)
Guildline Instruments 9334A or 7334 Standards maintained in a Guildline 5030 Air Bath
Guildline Instruments 9330 or 7330 Oil Standards maintained in a Guildline Oil or Fluid Bath

(c) Low Thermal Lead Sets or Low Thermal Wire (Acceptable Models)
Guildine 6622A-12 or 6675A-12 : Precision Lead Set For Resistance Bridge
SCW-30:18AWG : 18 Guage Low Thermal Wire

(d) Optional (For Automation and Connections)

Guildline 6664B/C 4-Wire, 8 or16 Channel Low Thermal Scanner (For Automation)
(Note – the Scanner model must be capable of operating at 1000 V)
Guildline Bridgeworks Software
Digital Thermometer (Acceptable Guildline Models 9535, 9540A, 9540B, 9540 or 5150)

6.5. Transfer Standard Process

The table below contains the switch positions to measure each resistor. All tests are based on a user-defined sample depth, reversal rate and excitation current of an individual element. This test setup is repeated for all the elements in the transfer standard. All resistors in the standard use the same Rs resistor.

Switch / Element	0	1	2	3	4	5	6	7	8	9	10	11
R1	A	B	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
R2	NC	A	B	NC	NC	NC	NC	NC	NC	NC	NC	NC
R3	NC	NC	A	B	NC	NC	NC	NC	NC	NC	NC	NC
R4	NC	NC	NC	A	B	NC	NC	NC	NC	NC	NC	NC
R5	NC	NC	NC	NC	A	B	NC	NC	NC	NC	NC	NC
R6	NC	NC	NC	NC	NC	A	B	NC	NC	NC	NC	NC
R7	NC	NC	NC	NC	NC	NC	A	B	NC	NC	NC	NC
R8	NC	NC	NC	NC	NC	NC	NC	A	B	NC	NC	NC
R9	NC	NC	NC	NC	NC	NC	NC	NC	A	B	NC	NC
R10	NC	NC	NC	NC	NC	NC	NC	NC	NC	A	B	NC
R11	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	A	B

Table 6-1: Switch Positions

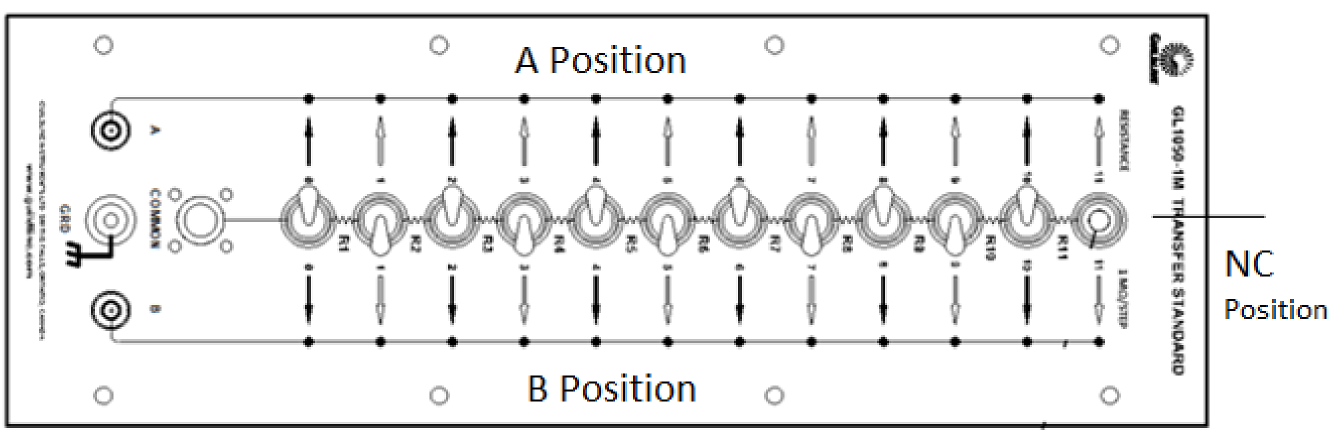


Figure 6-1 : GL1050 with Switch Positions Marks

The resistance element values are calculated by: $R_{element} = Ratio \times R_{ref}$

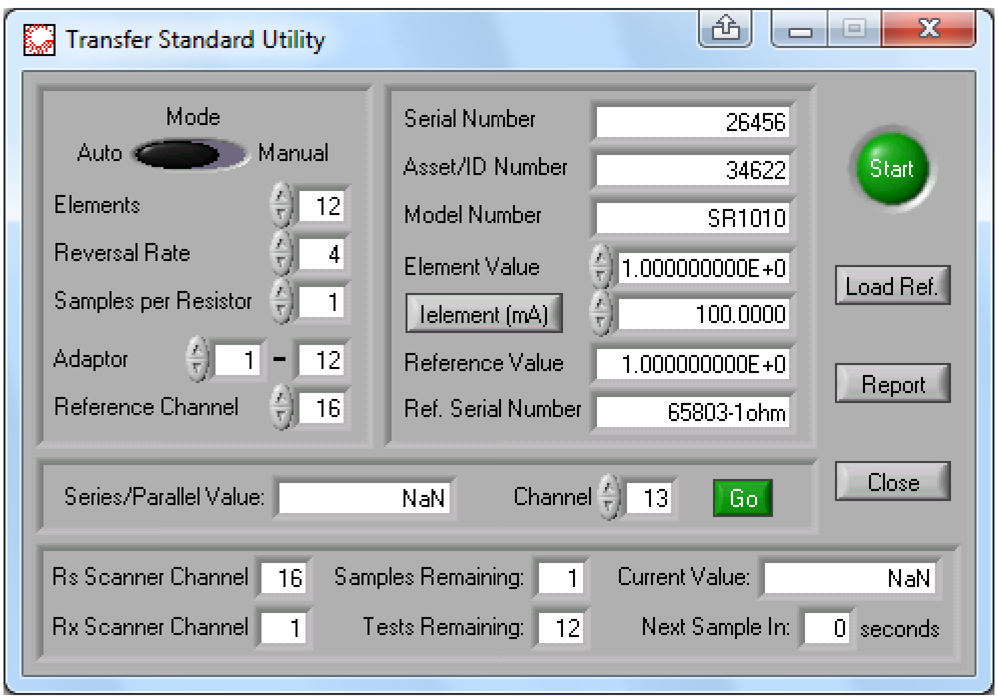
The series resistance is calculated by: $R_{series} = \sum_{1}^{10} R_n$

The parallel resistance is calculated by: $R_{parallel} = 1 \div (\sum_{1}^{10} \frac{1}{R_n})$

As a final test, the Series-Parallel value can be measured for which its value is calculated the same as any single element value and should be approximately that same value as a single element. From this, the Delta Average is calculated

The Delta Average is calculated by: $R_{deltaaverage.} = (9 \times R_{series/\,parallel} + R_{10}) \div 10$

6.6. Transfer Standard Utility



The Transfer Standard utility is a calibration tool that will use the attached scanners to calibrate and verify your GL 1050 or similar type resistor transfer standards. At the launch of the utility, a prompt will remind you of the specific hardware configuration required to execute this test process. The prompt must be acknowledged by the user by clicking the "OK" button to continue.

The “MANUAL” mode is used for transfer standards that include switches, such as GL 1050, ESI SR1050, ESI SR1030, and ESI SR1060.

In “Manual” mode, you will then be prompted before each resistor change to switch the transfer standard to the necessary resistor for that test. If you have selected “Manual” mode, then the single Rx channel required for the transfer standard is displayed. This mode is used for transfer standards that include switches such as GL 1050. While in operation, the status area at the bottom will gauge your progress. After the test’s completion, you can then view and print out your results by clicking the "Report" button. The final report gives you a choice to view the results based on the first ten elements or all twelve. When exiting the Transfer utility, you will be prompted to save this report. At any time, you can stop the test by clicking again on the "Stop" button.

6.6.1. Start/Stop Button

Clicking the green "Start" button will execute the tests and toggle the button to be a red "Stop" button. Clicking the "Stop" button will terminate the test process and toggle it back to a "Start" button. When the test is completed, the "Stop" button will automatically toggle back to a "Start" button.

6.6.2. Mode Switch

The "Mode" switch toggles between a manual or automatic mode of operation. In the automatic mode, this utility utilizes 12 channels of the scanner to calibrate your decade transfer standards that are directly compatible with the GL 1010 or ESI SR 1010 series of resistors. In manual mode, the utility uses only one channel and prompts the user between tests to reconfigure the hardware for the next element. This can be used with GL 1050, ESI™ SR1050 or similar transfer standards.

6.6.3. Reversal Rate Control

The "Reversal Rate" control allows you to select the measurement reversal rate in seconds for all the elements in the transfer standard.

6.6.4. Samples Per Resistor Control

The "Samples per Resistor" control allows you to select the measurement sample depth for all the elements in the transfer standard. The utility automatically takes 10 readings **before** the number entered here to allow for settling. It is suggested to use a sample size that is adequate to calculate a meaningful standard deviation, such as 10 samples. The value **must** be greater than 1 for and standard deviation to be calculated as the initial 10 readings taken are not counted in any report calculations.

6.6.5. Adapter Channels Control

The "Adapter Channels" control allows you to select the channel set that the SR1010 Adapter is connected to while in the "Auto" mode. If you are in "Manual" mode, this is merely the selection of the individual channel used for your transfer standard. You may use any free channel above channel 12.

6.6.6. Reference Channel Control

The "Reference Channel" control allows you to assign the scanner channel in which your reference resistor is connected.

6.6.7. Serial Number Field

The "Serial Number" field is where the serial number can be logged for the transfer standard under test.

6.6.8. Asset/ID Field

The "Asset/ID" field is where the control number can be logged for the transfer standard under test.

6.6.9. Model Number Field

The "Model Number" field is where the model number can be logged for the transfer standard under test.

6.6.10. Element Value Control

The "Element Value" control is where the nominal resistance value for the individual elements of the transfer standard is entered.

6.6.11. Ielement/Velemet Button

The "Ielement (mA)/Velement (V)" button is where you can select the use of voltage or current measurement mode for your transfer standard. See section 4.1 of the BridgeWorks Software Manual for recommendations on setting test currents and voltages.

6.6.11.1. Ielement/Velement Control

The "Ielement (mA)/Velement (V)" control is where the test current value in mA or test voltage in V for the individual element tests of the transfer standard is entered.

6.6.11.2. Reference Value Indicator

The "Reference Value" indicator displays the value of the loaded reference resistor.

6.6.12. Reference Serial Indicator

The "Reference Serial" indicator displays the Serial number of the loaded reference resistor.

6.6.13. Load Ref. Button

Clicking the "Load Ref." button will call a prompt that will guide you in selecting what standard resistor profile you wish to use to calibrate your transfer standard.

6.6.14. Series/Parallel Value Indicator

The "Series/Parallel Value" indicator displays the measured series-parallel value of the transfer standard.

6.6.15. Channel Control

The "Channel" control sets what channel you have configured the series/parallel measurement on.

6.6.16. Go Button

Clicking the "Go" button will initiate the series-parallel measurement for your transfer standard.

6.6.17. Report Button

Clicking the "Report" button will call a prompt that will guide you in selecting what report you wish to view, either current or from stored report data.

6.6.18. Close Button

Clicking the "Close" button will prompt you to save your current data and then exit the Transfer Standard Utility after you have responded to the prompt.

6.6.19. Rs Scanner Channel Indicator

The "Rs Scanner Channel" indicator displays the currently selected Rs scanner channel by BridgeWorks-AF for the current test in the transfer standard calibration process.

6.6.20. Rx Scanner Channel Indicator

The "Rx Scanner Channel" indicator displays the currently selected Rx scanner channel by BridgeWorks-AF for the current test in the transfer standard calibration process.

6.6.21. Samples Remaining Indicator

The "Samples Remaining" indicator displays the number of samples remaining for the current test in the transfer standard calibration process, not including the present sample.

6.6.22. Tests Remaining Indicator

The "Tests Remaining" indicator displays the number of tests remaining in the current transfer standard calibration process, not including the present test.

6.6.23. Current Value Indicator

The "Current Value" indicator displays the last Rx:Rs ratio sample value read in by BridgeWorks-AF for the current test in the transfer standard calibration process.

6.6.24. Next Sample In Indicator

The "Next Sample In" indicator displays the amount of time in seconds before the next sample is expected for the current test in the transfer standard calibration process. Note that this is an estimation made by BridgeWorks-AF, and will differ greatly from the bridge during the rough null stage (first few samples) of any test. For the remainder of that test, it is a good estimate.

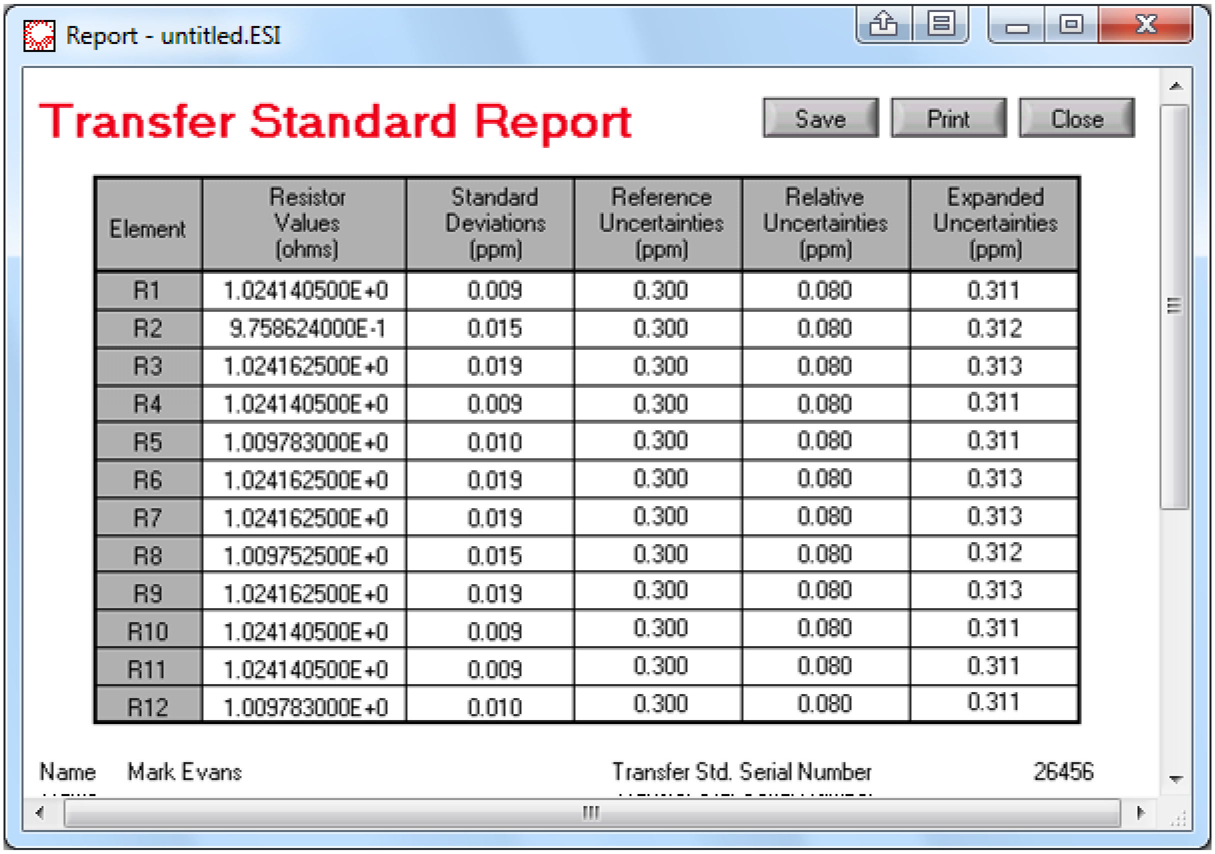
6.6.25. Saving Transfer Standard Report Data

Upon exiting the Transfer Standard Utility window, you will be prompted to save the data currently stored in memory from the utility. At this time, you can select "No" to discard the data or "Yes," where you will then be given a windows file dialogue prompting you for the name you wish to save the data under. The file extension ".ESI" will automatically be added to your saved Transfer Standard file.

6.6.26. Loading/Viewing Transfer Standard Report Data

To load or view a Transfer Standard Report, click on the "Report" button in the Transfer Standard Utility window. You will then be asked to select between viewing the current data or from a saved report file. If you choose current data, then the information that is currently available from the last run test will be loaded. If you choose to load a file, then a standard Windows file dialog will prompt you to select a file with ".ESI" extension. You then find and select the file of choice, highlight it and then click on "Open" to view it. Refer to the Transfer Utility Manual for the Transfer Standard Report itself.

6.7. Transfer Standard Report



Transfer Standard Report

Element	Resistor Values (ohms)	Standard Deviations (ppm)	Reference Uncertainties (ppm)	Relative Uncertainties (ppm)	Expanded Uncertainties (ppm)
R1	1.024140500E+0	0.009	0.300	0.080	0.311
R2	9.758624000E-1	0.015	0.300	0.080	0.312
R3	1.024162500E+0	0.019	0.300	0.080	0.313
R4	1.024140500E+0	0.009	0.300	0.080	0.311
R5	1.009783000E+0	0.010	0.300	0.080	0.311
R6	1.024162500E+0	0.019	0.300	0.080	0.313
R7	1.024162500E+0	0.019	0.300	0.080	0.313
R8	1.009752500E+0	0.015	0.300	0.080	0.312
R9	1.024162500E+0	0.019	0.300	0.080	0.313
R10	1.024140500E+0	0.009	0.300	0.080	0.311
R11	1.024140500E+0	0.009	0.300	0.080	0.311
R12	1.009783000E+0	0.010	0.300	0.080	0.311

Name Mark Evans   Transfer Std. Serial Number 26456

The Transfer Standard Report displays the current or a saved Transfer Standard results in an easy to follow printable report. The report is accessed through the "Report" button on the Transfer Standard Utility window.

6.7.1. Save Button

Clicking the "Save" button will save the displayed report to a file.

6.7.2. Print Button

Clicking the "Print" button will print the report, as shown.

6.7.3. Close Button

Clicking the "Close" button will exit the report window and return you to the Transfer Standard Utility.

6.7.4. Value Indicators

The "Value" indicators are in a table organized by element. These indicators display measured resistances from each of the tests conducted in the Transfer Standard utility.

6.7.5. Standard Deviation (ppm) Indicators

The "Standard Deviation (ppm)" indicators are in a table organized by element. These indicators display measured standard deviation from each of the tests conducted in the Transfer Standard utility.

6.7.6. Reference Uncertainty (ppm) Indicators

The "Reference Uncertainty (ppm)" indicators are in a table organized by element. These indicators display uncertainty from the reference standard contributed for each of the tests conducted in the Transfer Standard utility.

6.7.7. Coefficient Uncertainty (ppm) Indicators

The "Coefficient Uncertainty (ppm)" indicators are in a table organized by element. These indicators display uncertainty from the bridge coefficient contributed for each of the tests conducted in the Transfer Standard utility.

6.7.8. Expanded Uncertainty (ppm) Indicators

The "Expanded Uncertainty (ppm)" indicators are in a table organized by element. These indicators display calculated expanded uncertainty for each of the tests conducted in the Transfer Standard utility.

6.7.9. Name Indicator

The "Name" indicator is where the test technician's name that was entered into the Environment Options is displayed.

6.7.10. Location Indicator

The "Location" indicator is where the company/lab name that was entered into the Environment Options is displayed.

6.7.11. Date Indicator

The "Date" indicator is where the test date and time are shown. This date and time are stamped at test completion into the saved Transfer Standard file.

6.7.12. Series/Parallel Value Indicator

The "Series/Parallel Value" indicator displays the measured series/parallel configuration for elements R1-R10.

6.7.13. Delta Average Indicator

The "Delta Average" indicator displays the calculated delta average for elements R1-R10.

6.7.14. Calculated Series Value (R1-R10) Indicator

The "Calculated Series Value (R1-R10)" indicator displays the calculated series resistance in ohms of the first 10 resistance elements that are being displayed.

6.7.15. Calculated Parallel Value (R1-R10) Indicator

The "Calculated Parallel Value (R1-R10)" indicator displays the calculated parallel resistance in ohms of the first 10 resistance elements that are being displayed.

6.7.16. Mean Resistor Value (R1-R10) Indicator

The "Mean Resistor Value (R1-R10)" indicator displays the calculated average resistance in ohms of the first 10 resistance elements that are being displayed.

6.7.17. Transfer Std. Serial Number Indicator

The "Transfer Std. Serial Number" indicator is where the serial number of the transfer standard that was calibrated using the Transfer Standard utility is displayed.

6.7.18. Transfer Std. Asset/ID Number Indicator

The "Transfer Std. Asset/ID Number" indicator is where the control number of the transfer standard that was calibrated using the Transfer Standard utility is displayed.

6.7.19. Transfer Std. Model Number Indicator

The "Transfer Std. Model Number" indicator is where the model number of the transfer standard that was calibrated using the Transfer Standard utility is displayed.

6.7.20. Reference Serial Number Indicator

The "Reference Serial Number" indicator is where the serial number of the reference standard that was used to calibrate the transfer standard is displayed.

6.7.21. Reference Model Number Indicator

The "Reference Model Number" indicator is where the model number of the transfer standard that was calibrated using the Transfer Standard utility is displayed.

6.7.22. Calculated Series Value (all) Indicator

The "Calculated Series Value (all)" indicator displays the calculated series resistance in ohms of all 12 resistance elements that are being displayed.

6.7.23. Calculated Parallel Value (all) Indicator

The "Calculated Parallel Value (all)" indicator displays the calculated parallel resistance in ohms of all 12 resistance elements that are being displayed.

6.7.24. Mean Resistor Value (all) Indicator

The "Mean Resistor Value (all)" indicator displays the calculated average resistance in ohms of all 12 resistance elements that are being displayed.

6.8. Transfer Standard Procedure

The following steps outline the general procedure for executing a "Transfer Standard" calibration.

Connect the IEEE-488.2 interface connector of the bridge to an IBM-PC compatible computer running WindowsTM and run the BridgeWorks-AF software.

Step 1) Connect the reference resistor leads on the four-wire terminals to any free scanner channels, where C1P1 identifies one current potential pair and C2P2 the other pair.

Step 2) Connect the transfer standard in which you wish to calibrate to any free scanner channel.

Step 3) Open the "Transfer Standard" utility from the "Configuration" menu of the main window.

Step 4) Select the "Mode" in which you would like to conduct this test. The "Manual" mode will require you to manually reconfigure the transfer standard under test for types that are not compatible with the adapter.

Step 5) Next, select the reversal rate and the number of samples you wish to use to test each element of the transfer standard.

Step 6) Now select the channel set or channel that your transfer standard is connected to with the "Adapter Channels" control.

Step 7) Lastly, you will need to enter the serial number, Asset/ID control number and model number into the respective fields to finish describing the details of your transfer standard.

Step 8) Now you will need to load the reference resistor profile by clicking on "Load Ref." button. You will then be greeted by a Windows file dialog that is prompting you to select the reference resistor configuration file.

Step 9) Upon completion of loading the reference resistor file, select the scanner channel that it is physically connected to with the "Reference Channel" control.

Step 10) Now click on the green "Start" button, and the transfer standard calibration will begin.

Step 11) This test will run completely automated using the connected scanners, with the exception of transfer standard reconfiguration only used in "Manual" mode. The status indicators will display the progress of the working set calibration process. You will also be prompted to reconfigure the transfer standard in "Manual" mode as needed. This whole process will take approximately 1/2 to 1 hour for a typical transfer standard.

Step 12) If a series/parallel measurement is desired, configure the GL 1050, SR1050 (or similar) to the series-parallel configuration for elements R1-R10.

Step 13) Connect the GL 1050 to a free scanner channel and configure the software to measure the series/parallel value on that channel.

Step 14) Click on “Go” to initiate the test.

Step 15) Upon completion of the Transfer Standard calibration, click on the "Report" button to see the results. A prompt will follow, asking if you wish to load a saved file or view the current results. You need to select the current to see the test you have just completed.

Step 16) Use the "Print" button if you desire a hard copy report.

Step 17) Close the report window using the "Close" button. This will return you to the utility window.

Step 18) Now exit the utility using its “Close” button. Upon clicking on "Close" in the utility, you will be greeted with a prompt asking if you wish to save the data. It is recommended that you do by selecting "Yes" and typing a filename in the file dialogue that follows. Then click on "Save" in the file dialogue.

Step 19) You will now be back at the main window. If you selected "No" when asked to save, you will go straight back to the main window and will no longer have the opportunity to save the "Transfer Standard" data.