♦ PRECISION INSTRUMENTS FOR TEST AND MEASUREMENT ♦

SRL Series

Resistance Standard Operation Manual

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SRL im/January 2010

IET LABS, INC.
534 Main Street, Westbury, NY 11590
www.ietlabs.com
TEL: (516) 334-5959 • (800) 899-8438 • FAX: (516) 334-5988

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WARRANTY

We warrant that this product is free from defects in material and workmanship and, when properly used, will perform in accordance with applicable IET specifications. If within one year after original shipment, it is found not to meet this standard, it will be repaired or, at the option of IET, replaced at no charge when returned to IET. Changes in this product not approved by IET or application of voltages or currents greater than those allowed by the specifications shall void this warranty. IET shall not be liable for any indirect, special, or consequential damages, even if notice has been given to the possibility of such damages.

THIS WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO, ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE.

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.

Contents

Figures and Tables

Chapter 1
INTRODUCTION

1.1 Introduction

The SRL Series (Figure 1.1) are extremely stable, precise, laboratory or portable resistance standards. Their ruggedness and small size plus their virtually zero temperature coefficient makes the SRL Series ideal for any applications outside of laboratory environment within the temperature range of 18°C to 28°C. The temperature chart provided with each unit enhances the accuracy by indicating the deviation from nominal for the operating temperature range in 0.5°C increments. Because of the low temperature coefficient, they require no oil-or-temperature bath.

Figure 1-1: SRL Series Resistance Standard

The SRL series units are available in values ranging from 1 mΩ to 20 TΩ, with custom values available, to satisfy any need. They are built with precision resistors and use no adjustable resistors of any kind.

To further reduce errors caused by temperature changes, the SRL units are built with a temperature coefficient of near zero at 23°C. The binding posts are constructed of low-thermal emf material.

Chapter 2

SPECIFICATIONS

For convenience to the user, the pertinent specifications are given in an **OPERATION GUIDE**, shown in Figures 2-1 and 2-2, affixed to the case of the instrument.

SPECIFICATIONS

Accuracy and other specifications:

See Table 2-1.

Retrace:

1 Ω to 19 MΩ: Permanent shift in resistance value is <2 ppm for 23°C to 0°C to 23°C cycle, and 23°C to 40°C to 23°C cycle

Calibration Report:

Initial SI traceable calibration data provided in 0.5°C increments for temperature range of 18°C to 28°C as shown in Figure 2-2.

Calibration Conditions:

Three of four-wire Kelvin measurements, low power, at 23°C; two wire for 1 MΩ and over. Traceable to SI

Terminals:

Gold-plated, tellurium-copper, low-thermal-emf binding posts on standard 3/4 inch spacing. A **GROUND** terminal is provided on all units.

≤190 kΩ: four 5-way binding posts for 4-terminal measurement

<190 kΩ: two 5-way binding posts

≥100 MΩ: two 5-way binding posts with **GUARD**

Other available terminals:

- DMM direct input compatibles
- bnc, Triax, and custom connectors

Transit Case:

Optional **Model SRC-100** lightweight transit case with handle, suitable for transporting and storing two units. The case provides mechanical protection and insulation from temperature changes during transportation or shipping.

Dimensions:

8.6 cm H x 10.5 cm W x 12.7 cm D (3.4" x 4.15" x 5")

Weight:

0.73 kg (1.6 lb)

SRL-1 Ω STANDARD RESISTOR

Adjustment to Nominal: ±2 ppm
Max. Change from 23°C value (18°C to 28°C): ±3 ppm
Operating Temperature Range: 18°C to 28°C
Max. Voltage: 0.5 V
Max. Current: 500 mA
Stability: 8 ppm per year max; 2 ppm typical.
Retrace: <2 ppm for for max. temp. cycles.

$R_t = R_{23}[1 + \alpha(t - 23) + \beta(t - 23)^2]$; α= -1.6E-07 β= -2.4E-08

Date Calibrated	19-Jun-2001				
Temperature (°C)	23.0°C				
Relative Humidity	N/A				
Resistance R_{23}	1.000 003 3 Ω				
Test Conditions	N/A				
Meas. Uncertainty	N/A				
By	JOS				
Recommended Due	19-Jun-2002				

Model: SRL-1 SN: B2-9240246

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800-899-8438 • 516-334-5959
www.ietlabs.com (FAX) 516-334-5988

Figure 2-1: OPERATION GUIDE affixed to unit

Temperature Calibration Chart

Model: SRL-1

SN: B2-9240246 Report No: 0

Alpha: -1.6E-07 Beta: -2.4E-08

Measured value at 23°C: 1.000 003 3 Ω

Temperature (°C)	Resistance Ω	Deviation from Nominal (ppm)
18.0	1.000 003 5 Ω	3.5
18.5	1.000 003 5 Ω	3.5
19.0	1.000 003 6 Ω	3.6
19.5	1.000 003 6 Ω	3.6
20.0	1.000 003 6 Ω	3.6
20.5	1.000 003 6 Ω	3.6
21.0	1.000 003 5 Ω	3.5
21.5	1.000 003 5 Ω	3.5
22.0	1.000 003 4 Ω	3.4
22.5	1.000 003 4 Ω	3.4
23.0	1.000 003 3 Ω	3.3
23.5	1.000 003 2 Ω	3.2
24.0	1.000 003 1 Ω	3.1
24.5	1.000 003 0 Ω	3.0
25.0	1.000 002 9 Ω	2.9
25.5	1.000 002 7 Ω	2.7
26.0	1.000 002 6 Ω	2.6
26.5	1.000 002 4 Ω	2.4
27.0	1.000 002 3 Ω	2.3
27.5	1.000 002 1 Ω	2.1
28.0	1.000 001 9 Ω	1.9

Date: 19-Jun-2001 Traceable to NIST

By: JOS

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Figure 2-2: Temperature Calibration Chart

Nominal Value	Model Number	Adjustment to Nominal	Calibration Uncertainty	Stability per year		Max Resistance Change 18-28°C from 23 °C	Max Applied Input		
				max	typical		0 ppm change*	<1 ppm change**	<3 ppm change**
1 mΩ	SRL-0.001	±50 ppm	±8 ppm	±50 ppm	-	20 ppm/°C	50 mW	100 mW	200 mW
1.9 mΩ	SRL-0.0019	±50 ppm	±8 ppm	±50 ppm	-	20 ppm/°C	50 mW	100 mW	200 mW
2 mΩ	SRL-0.002	±50 ppm	±8 ppm	±50 ppm	-	20 ppm/°C	50 mW	100 mW	200 mW
10 mΩ	SRL-0.01	±5 ppm	±6 ppm	±15 ppm	-	5 ppm/°C	25 mW	50 mW	200 mW
19 mΩ	SRL-0.019	±5 ppm	±6 ppm	±15 ppm	-	5 ppm/°C	25 mW	50 mW	200 mW
20 mΩ	SRL-0.02	±5 ppm	±6 ppm	±15 ppm	-	5 ppm/°C	25 mW	50 mW	200 mW
100 mΩ	SRL-0.1	±5 ppm	±2 ppm	±12 ppm	-	2 ppm/°C	50 mW	100 mW	250 mW
190 mΩ	SRL-0.19	±5 ppm	±2 ppm	±12 ppm	-	2 ppm/°C	50 mW	100 mW	250 mW
200 mΩ	SRL-0.19	±5 ppm	±2 ppm	±12 ppm	-	2 ppm/°C	50 mW	100 mW	250 mW
1 Ω	SRL-1	±2 ppm	±1 ppm	±8 ppm	±2 ppm	3 ppm tot	175 mW	350 mW	850 mW
1.9 Ω	SRL-1.9	±2 ppm	±1 ppm	±8 ppm	±2 ppm	3 ppm tot	175 mW	350 mW	850 mW
2 Ω	SRL-1.9	±2 ppm	±1 ppm	±8 ppm	±2 ppm	3 ppm tot	175 mW	350 mW	850 mW
10 Ω	SRL-10	±2 ppm	±1 ppm	±8 ppm	±2 ppm	3 ppm tot	100 mW	200 mW	500 mW
19 Ω	SRL-19	±2 ppm	±1 ppm	±8 ppm	±2 ppm	3 ppm tot	100 mW	200 mW	500 mW
20 Ω	SRL-19	±2 ppm	±1 ppm	±8 ppm	±2 ppm	3 ppm tot	100 mW	200 mW	500 mW
25 Ω	SRL-25	±2 ppm	±1 ppm	±8 ppm	±2 ppm	3 ppm tot	100 mW	200 mW	500 mW
30 Ω	SRL-30	±2 ppm	±1 ppm	±8 ppm	±2 ppm	3 ppm tot	100 mW	200 mW	500 mW
50 Ω	SRL-50	±2 ppm	±1 ppm	±8 ppm	±2 ppm	3 ppm tot	100 mW	200 mW	500 mW
100 Ω	SRL-100	±2 ppm	±1 ppm	±6 ppm	±2 ppm	3 ppm tot	100 mW	200 mW	500 mW
190 Ω	SRL-190	±2 ppm	±1 ppm	±6 ppm	±2 ppm	3 ppm tot	100 mW	200 mW	500 mW
200 Ω	SRL-190	±2 ppm	±1 ppm	±6 ppm	±2 ppm	3 ppm tot	100 mW	200 mW	500 mW
350 Ω	SRL-350	±2 ppm	±1 ppm	±6 ppm	±2 ppm	3 ppm tot	100 mW	200 mW	500 mW
400 Ω	SRL-400	±2 ppm	±1 ppm	±6 ppm	±2 ppm	3 ppm tot	100 mW	200 mW	500 mW
1 kΩ	SRL-1K	±2 ppm	±1 ppm	±6 ppm	±1 ppm	3 ppm tot	100 mW	200 mW	500 mW
1.9 kΩ	SRL-1.9K	±2 ppm	±1 ppm	±6 ppm	±1 ppm	2 ppm tot	100 mW	200 mW	500 mW
2 kΩ	SRL-2K	±2 ppm	±1 ppm	±6 ppm	±1 ppm	2 ppm tot	100 mW	200 mW	500 mW
4 kΩ	SRL-4K	±2 ppm	±1 ppm	±4 ppm	±1 ppm	2 ppm tot	100 mW	200 mW	500 mW
10 kΩ	SRL-10K	±2 ppm	±1 ppm	±4 ppm	±1 ppm	1.5 ppm tot	100 mW	200 mW	500 mW
19 kΩ	SRL-19K	±2 ppm	±1 ppm	±4 ppm	±1 ppm	2 ppm tot	100 mW	200 mW	500 mW
20 kΩ	SRL-100K	±2 ppm	±1 ppm	±6 ppm	±2 ppm	2 ppm tot	100 mW	200 mW	500 mW
100 kΩ	SRL-100K	±2 ppm	±1 ppm	±6 ppm	±2 ppm	2 ppm tot	100 mW	200 mW	500 mW
190 kΩ	SRL-190K	±2 ppm	±1 ppm	±8 ppm	±2 ppm	2 ppm tot	100 mW	200 mW	500 mW
200 kΩ	SRL-190K	±2 ppm	±1 ppm	±8 ppm	±2 ppm	2 ppm tot	100 mW	200 mW	500 mW
1 MΩ	SRL-1M	±2 ppm	±2 ppm	±8 ppm	±2 ppm	2 ppm tot	100 mW	200 mW	500 mW
1.9 MΩ	SRL-1.9M	±2 ppm	±2 ppm	±9 ppm	±2 ppm	3 ppm tot	100 mW	200 mW	500 mW
2 MΩ	SRL-1.9M	±2 ppm	±2 ppm	±9 ppm	±2 ppm	3 ppm tot	100 mW	200 mW	500 mW
10 MΩ	SRL-10M	±2 ppm	±2 ppm	±9 ppm	±2 ppm	3 ppm tot	1000 V		
19 MΩ	SRL-19M	±2 ppm	±9 ppm	±10 ppm	±2 ppm	4 ppm tot	1000 V		
20 MΩ	SRL-19M	±2 ppm	±9 ppm	±10 ppm	±2 ppm	4 ppm tot	1000 V		
100 MΩ	SRL-100M	±10 ppm	±9 ppm	±20 ppm	-	5 ppm/°C	1000 V		
190 MΩ	SRL-100M	±10 ppm	±9 ppm	±20 ppm	-	5 ppm/°C	1000 V		
200 MΩ	SRL-100M	±10 ppm	±9 ppm	±20 ppm	-	5 ppm/°C	1000 V		
1 GΩ	SRL-1G	±0.1%	±100 ppm	±200 ppm	±100 ppm	20 ppm/°C	5000 V		
1.9 GΩ	SRL-1G	±0.1%	±100 ppm	±200 ppm	±100 ppm	20 ppm/°C	5000 V		
2 GΩ	SRL-1G	±0.1%	±100 ppm	±200 ppm	±100 ppm	20 ppm/°C	5000 V		
10 GΩ	SRL-10G	±0.1%	±200 ppm	±500 ppm	±300 ppm	25 ppm/°C	5000 V		
19 GΩ	SRL-10G	±0.1%	±200 ppm	±500 ppm	±300 ppm	25 ppm/°C	5000 V		
20 GΩ	SRL-10G	±0.1%	±200 ppm	±500 ppm	±300 ppm	25 ppm/°C	5000 V		
100 GΩ	SRL-100G	±0.2%	±1000 ppm	±500 ppm	±300 ppm	25 ppm/°C	5000 V		
190 GΩ	SRL-100G	±0.2%	±1000 ppm	±500 ppm	±300 ppm	25 ppm/°C	5000 V		
200 GΩ	SRL-100G	±0.2%	±1000 ppm	±500 ppm	±300 ppm	25 ppm/°C	5000 V		
1 TΩ	SRL-1T	±0.5%	±0.25%	±500 ppm	±300 ppm	50 ppm/°C	5000 V		
1.9 TΩ	SRL-1.9T	±0.7%	±0.7%	±1000 ppm	±500 ppm	100 ppm/°C	5000 V		
2 TΩ	SRL-2T	±0.7%	±0.7%	±1000 ppm	±500 ppm	100 ppm/°C	5000 V		
10 TΩ	SRL-10T	±0.7%	±0.7%	±2000 ppm	±1000 ppm	100 ppm/°C	5000 V		
19 TΩ	SRL-19T	±0.7%	±0.7%	±2000 ppm	±1000 ppm	100 ppm/°C	5000 V		
20 TΩ	SRL-10T	±0.7%	±0.7%	±2000 ppm	±1000 ppm	100 ppm/°C	5000 V		

** negligible effect of self-heating; do not exceed voltage limits where given.*

*** non-permanent self-heating change; exceeding this value may cause a permanent change in the resistance.*

Table 2-1: SRL Specifications

Chapter 3

OPERATION

3.1 Initial Inspection and Setup

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

An **OPERATION GUIDE** is attached to the case of the instrument to provide ready reference to specifications.

3.2 Connections

The SRL series has three different types of connections listed below.

3.2.1 Connections for values ≤190 kΩ

Values ≤190 kΩ have four insulated low thermal emf binding posts for four-terminal measurements as shown in Figure 3-1. The fifth binding post is connected to the case. For high-resistance models (e.g. >10 kΩ) two-terminal measurements may be made by shorting **HI** to **HI** and **LO** to **LO**, preferably with shorting links or other substantial means.

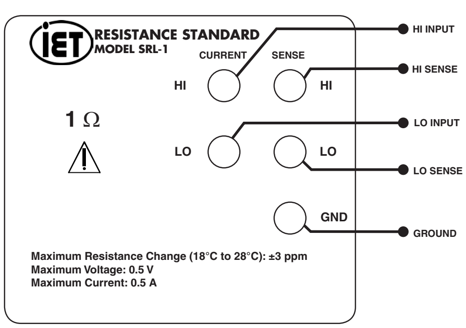


Figure 3-1: Connections for values ≤190 kΩ

Binding Post	Function
CURRENT HI	Current input from source (e.g. ohmmeter)
CURRENT LO	Current return to source (e.g. ohmmeter)
SENSE HI	Measurement point for a four-wire ohmmeter
SENSE LO	Measurement point for a four-wire ohmmeter
GND	Guard or shield

Table 3-1: Connections for values ≤190 kΩ

3.2.2 Connections for values > 190 kΩ and <100 MΩ

Values > 190 kΩ and <100 MΩ have two insulated, low thermal emf binding posts for two-terminal measurements as shown in Figure 3-2. The third binding post is connected to the case.

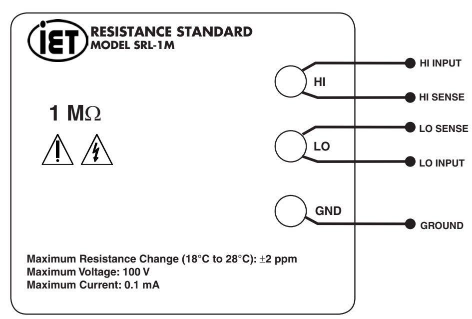


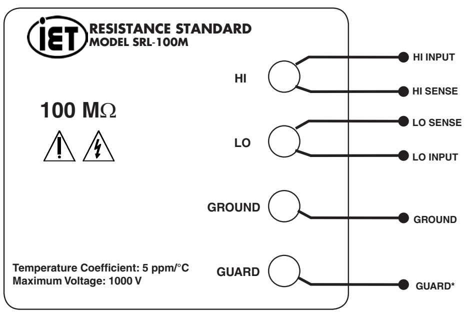
Figure 3-2: Connections for values > 190 kΩ and <100 MΩ

Binding Post	Function
HI	Input from source (e.g. ohmmeter)
SENSE LO	Measurement point
GND	Guard or shield

Table 3-2: Connections for values > 190 kΩ and <100 MΩ

3.2.3 Connections for values ≥100 MΩ

Values ≥100 MΩ have two insulated, low thermal emf binding posts for two-terminal measurements as shown in Figure 3-3. The third binding post, labeled **GROUND**, is connected to the case. The fourth binding post, labeled **GUARD**, is connected to an internal case that contains the resistor.



If no* ***GUARD* *point exists on the measuring instrument, it may be connected to* ***GROUND****.*

Figure 3-3: Connections for values ≥100 MΩ

Binding Post	Function
HI	Input from source (e.g. ohmmeter)
SENSE LO	Measurement point
GROUND	Shield
GUARD	Interrupts leakage from the internal resistor to the case and other components of the unit

Table 3-3: Connections for values ≥100 MΩ

3.3 Thermal emf Considerations

High-quality, gold-plated, tellurium-copper binding posts serve to minimize the thermal emf effects which would artificially reflect a change in dc resistance measurements. All other conductors within the instrument, as well as the solder used, contain no metals or junctions that could contribute to thermal emf problems.

There nevertheless may be some minute thermal emf generated at the test leads where they contact the gold banana jacks. This voltage will also be eliminated if a meter with so called "True Ohm" capability is used. Otherwise the generated emf may represent itself as a false component of the dc resistance measurement.

Always use low emf test leads when working with SRL models. In particular, avoid brass or steel conductors.

3.4 Temperature Coefficient Constants

The change of resistance with temperature for each standard is accurately expressed by the equation:

$R_t = R_{23}[1 + a(t-23) + ß(t-23)^2]$

R_t=Resistance at (°C)

R_{23} = Resistance at 23°C

a = Slope of the curve (ppm/°C) at 23°C

ß = Rate of change of slope of the curve (ppm/°C^2)

The values of a and ß are given with each unit. Experience shows that these values do not change appreciably with time and hence need to be determined only once.

The resistance vs. temperature relationship is shown in Figure 3-4. The value at any temperature may be obtained from the above formula, or the temperature calibration chart shown in Figure 3-5.

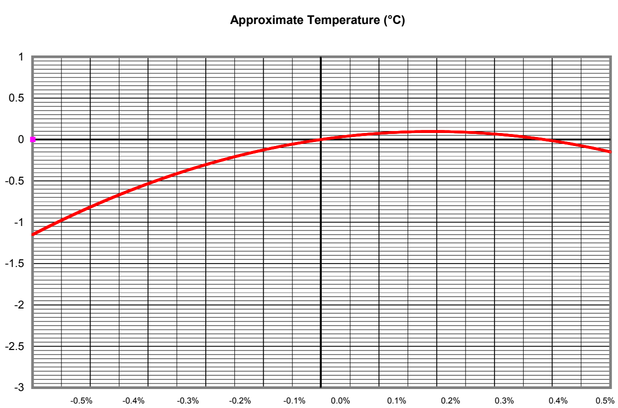


Figure 3-4: Resistance vs. temperature relationship

Temperature Calibration Chart

Model: SRL-1

SN: B2-9240246 Report No: 0

Alpha: -1.6E-07 Beta: -2.4E-08

Measured value at 23°C: 1.000 003 3 Ω

Temperature (°C)	Resistance Ω	Deviation from Nominal (ppm)
18.0	1.000 003 5 Ω	3.5
18.5	1.000 003 5 Ω	3.5
19.0	1.000 003 6 Ω	3.6
19.5	1.000 003 6 Ω	3.6
20.0	1.000 003 6 Ω	3.6
20.5	1.000 003 6 Ω	3.6
21.0	1.000 003 5 Ω	3.5
21.5	1.000 003 5 Ω	3.5
22.0	1.000 003 4 Ω	3.4
22.5	1.000 003 4 Ω	3.4
23.0	1.000 003 3 Ω	3.3
23.5	1.000 003 2 Ω	3.2
24.0	1.000 003 1 Ω	3.1
24.5	1.000 003 0 Ω	3.0
25.0	1.000 002 9 Ω	2.9
25.5	1.000 002 7 Ω	2.7
26.0	1.000 002 6 Ω	2.6
26.5	1.000 002 4 Ω	2.4
27.0	1.000 002 3 Ω	2.3
27.5	1.000 002 1 Ω	2.1
28.0	1.000 001 9 Ω	1.9

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By: JOS

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• (516) 334-5959
• (800) 899-8438

Figure 3-5: Temperature Calibration Chart

3.5 Environmental Conditions

3.5.1 Operating Temperature

For optimal accuracy, SRL Models should be used in an environment of 23°C ±5°C. They should be allowed to stabilize at those temperatures after any significant temperature variation. For determination of accuracy for other temperatures consult the Temperature Calibration Chart provided with each unit. The calculated resistance value is provided between 18°C and 28°C in 0.5°C increments. Figure 2-2 shows an example of this table.

3.5.2 Storage Temperature

The SRL Series should be maintained within the storage temperature range of 0°C to 40°C to retain its accuracy within the specified limits.

3.6 Shipping and Handling

The SRL Series should not be exposed to any excessive shock or temperature extremes. The option SRC-100, a lightweight transit case capable of storing two SRL units, is recommended for shipping or transporting the models.

Chapter 4
MAINTENANCE

4.1 Maintainability and Reliability

It is possible to maintain SRL units indefinitely. They are reliable due to their closed, rugged design and sealed resistors. The units are resistant to electromagnetic interference (EMI) because of their metal enclosure.

4.2 Preventive Maintenance

Keep the SRL units in a clean environment. This will help prevent possible contamination.

The front panel may be cleaned to eliminate any leakage paths from near or around the binding posts. To clean the front panel:

Wipe the front panel clean using alcohol and a lint-free cloth.

4.3 Calibration

The SRL units may be employed as stand-alone instruments or as an integral components of a system. If used as part of a system, they should be calibrated as part of the overall system to provide an optimum system calibration.

If an SRL model is employed as a stand-alone device, the following should be observed:

- Calibration Interval
- General Considerations
- Required Equipment
- Calibration Procedure

4.3.1 Calibration Interval

The recommended SRL Series calibration interval is twelve (12) months.

If the instrument is used to transfer resistance values only, recalibration is not required, assuming that there has been no drastic change of value.

4.3.2 General Considerations

Before starting the calibration procedure, you need to consider the following:

- Calibration environment should be 23°C and less than 50% relative humidity.
- Test instruments should be sufficiently more accurate than the SRL unit, and/or the uncertainty of the measurement instrumentation has to be considered in the calibration Test Uncertainty Ratio (TUR).
- The testing equipment and the SRL unit should stabilize at laboratory conditions for at least 24 hours.
- Kelvin type 4-wire test leads should be used to obtain accurate low resistance measurements.
- Steps should be taken to minimize thermal emf effects, such as using a meter with "True Ohm" capacity.
- Accepted metrology practices should be followed.