HARS-X and X2

High Accuracy Resistance Substituter

User and Service Manual

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HARS-X im/October 2018

IET LABS, INC.
www.ietlabs.com
Email: info@ietlabs.com
TEL: (516) 334-5959 • FAX: (516) 334-5988

www.ietlabs.com
Email: info@ietlabs.com
TEL: (516) 334-5959 • FAX: (516) 334-5988

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.

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Chapter 1

INTRODUCTION

1.1 Introduction

The High-Accuracy Resistance Substituter (**HARS**) series of resistance decade substituters is a family of instruments providing a very broad choice of high-performance resistance sources. Any number of decades from one to eleven is available in a choice of accuracies. See Figures 1-1 and 1-2.

The **HARS** substituter is a precision resistance source with excellent characteristics of stability, temperature coefficient, power coefficient, and frequency response.

The **HARS** Series employs very-low-resistance switches with silver-alloy contacts. A special design keeps zero resistance to less than 1 mΩ per decade. Self cleaning keeps the silver contacts from becoming tarnished when unused, or when only low currents are passed through them. This is most often the case when only minute test currents are drawn by digital multimeters or other test instruments. Contact resistance is stable and remains low and repeatable.

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 employed, contain no metals or junctions that could contribute to thermal emf problems.

The standard models offer a choice of one through eleven decades. The panels are clearly labeled showing the step size and maximum voltage and current limitations for each decade.

With a resolution as low as 1 mΩ and a maximum available resistance of over 111 MΩ, the **HARS** series may be used for exacting precision measurement applications requiring high accuracy, good stability, and low zero-resistance. They can be used as components of dc and ac bridges, for calibration, as transfer standards, and as RTD simulators.

Single-decade units may be panel-mounted and combined with additional units to form potentiometer circuits or other configurations.

The larger units may be rack-mounted to serve as components in measurement and control systems.

Figure 1-1. HARS Series High Accuracy Resistance Substituter

Figure 1-2. Single-Decade HARS Unit.

Chapter 2

SPECIFICATIONS

For convenience to the user, the pertinent specifications are given in an **OPERATING GUIDE** affixed to the case of the instrument. Figure 2.1 shows a typical example.

SPECIFICATIONS

Resistance per step	Total decade resistance	Stability (±ppm/yr)	Long-term stability (±ppm/3 yrs)	Temperature coefficient (±ppm/°C)	Resistor type	HARS-X			HARS-X2		
						Max current	Max voltage (per step)	Max power (per step)	Max current	Max voltage (per step)	Max power (per step)
1 mΩ	10 mΩ	50	75	50	Resistance wire	8.0 A	5 mV	0.04 W	9.0 A	9 mV	0.08 W
10 mΩ	100 mΩ	50	75	20		4.0 A	40 mV	0.16 W	6.3 A	63 mV	0.4 W
100 mΩ	1 Ω	50	75	20		1.6 A	0.16 V	0.25 W	2.2 A	0.3 V	0.5 W
1 Ω	10 Ω	20	25	20	Wirewound, non-inductive	0.8 A	0.8 V	0.6 W	1.1 A	1.1 V	1.2 W
10 Ω	100 Ω	20	25	15		0.25 A	2.5 V	0.6 W	0.35 A	3.5 V	1.2 W
100 Ω	1 kΩ	20	25	5		80 mA	8 V	0.6 W	110 mA	11 V	1.2 W
1 kΩ	10 kΩ	20	25	5		23 mA	23 V	0.5 W	35 mA	35 V	1.2 W
10 kΩ	100 kΩ	20	25	5		7 mA	70 V	0.5 W	11 mA	110 V	1.2 W
100 kΩ	1 MΩ	20	25	5		2.3 mA*	230 V*	0.5 W*	3 mA*	500 V*	1 W*
1 MΩ	10 MΩ	20	25	5		0.7 mA*	700 V*	0.5 W*	1 mA*	1000 V*	1 W*
10 MΩ	100 MΩ	50	100	10	Metal oxide film	0.1 mA*	1000 V*	0.1 W*	0.1 mA*	1000 V*	0.1 W*

**Subject to maximum of 2000 V to case*

Accuracy:
≤1 MΩ steps: ±(0.01% + 2 mΩ)
10 MΩ steps: ±0.03%
After subtraction of zero-resistance, at 23°C; traceable to SI

Zero resistance:
≤1 MΩ steps: ≤1 mΩ per decade
10 MΩ steps: ≤3 mΩ

Switch type:
Multiple solid silver alloy contacts, continuous rotation

Switch capacitance:
<1 pF between contacts

Operation:
If switches have not been operated for an extended period of time, they should be rotated a few times in both directions to restore contact resistance to specifications.

Environmental conditions:
Operating conditions: +10 to +40°C, <80% RH
Storage conditions: -20 to +65°C

Terminals:
3 Low-thermal-emf tellurium-copper binding posts with standard 3/4 inch spacing, plus shield terminal; connections on the rear of the instrument are available (RO option). -K Option: Kelvin connection is available as an option with 5 binding posts

ORDERING INFORMATION

Model*	Total resistance (Ω)	No of Dials	Resolution (Ω)
HARS-X-1-0.001	0.01	1	0.001
HARS-X-1-0.01	0.1	1	0.01
HARS-X-1-0.1	1	1	0.1
HARS-X-1-1	10	1	1
HARS-X-1-10	100	1	10
HARS-X-1-100	1 k	1	100
HARS-X-1-1K	10 k	1	1 k
HARS-X-1-10K	100 k	1	10 k
HARS-X-1-100K	1 M	1	100 k
HARS-X-1-1M	10 M	1	1 M
HARS-X-1-10M	100 M	1	10 M
HARS-X-2-0.001	0.11	2	0.001
HARS-X-2-0.01	1.1	2	0.01
HARS-X-2-0.1	11	2	0.1
HARS-X-2-1	110	2	1
HARS-X-2-10	1.1 k	2	10
HARS-X-2-100	11 k	2	100
HARS-X-2-1K	110 k	2	1 k
HARS-X-2-10K	1.1 M	2	10 k
HARS-X-2-100K	11 M	2	100 k
HARS-X-2-1M	110 M	2	1 M
HARS-X-3-0.001	1.11	3	0.001
HARS-X-3-0.01	11.1	3	0.01
HARS-X-3-0.1	111	3	0.1
HARS-X-3-1	1.11 k	3	1
HARS-X-3-10	11.1 k	3	10
HARS-X-3-100	111 k	3	100
HARS-X-3-1K	1.11 M	3	1 k
HARS-X-3-10K	11.1 M	3	10 k
HARS-X-3-100K	111 M	3	100 k

Model*	Total resistance (Ω)	No of Dials	Resolution (Ω)
HARS-X-4-0.001	11.11	4	0.001
HARS-X-4-0.01	111.1	4	0.01
HARS-X-4-0.1	1.111 k	4	0.1
HARS-X-4-1	11.11 k	4	1
HARS-X-4-10	111.1 k	4	10
HARS-X-4-100	1.111 M	4	100
HARS-X-4-1K	11.11 M	4	1 k
HARS-X-4-10K	111.1 M	4	10 k
HARS-X-5-0.001	111.11	5	0.001
HARS-X-5-0.01	1.1111 k	5	0.01
HARS-X-5-0.1	11.111 k	5	0.1
HARS-X-5-1	111.11 k	5	1
HARS-X-5-10	1.1111 M	5	10
HARS-X-5-100	11.111 M	5	100
HARS-X-5-1K	111.11 M	5	1 k
HARS-X-6-0.001	1.111 11 k	6	0.001
HARS-X-6-0.01	11.1111 k	6	0.01
HARS-X-6-0.1	111.111 k	6	0.1
HARS-X-6-1	1.111 11 M	6	1
HARS-X-6-10	11.1111 M	6	10
HARS-X-6-100	111.111 M	6	100
HARS-X-7-0.001	11.111 11 k	7	0.001
HARS-X-7-0.01	111.1111 k	7	0.01
HARS-X-7-0.1	1.111 111 M	7	0.1
HARS-X-7-1	11.111 11 M	7	1
HARS-X-7-10	111.1111 M	7	10
HARS-X-8-0.001	111.111 11 k	8	0.001
HARS-X-8-0.01	1.111 111 1 M	8	0.01
HARS-X-8-0.1	11.111 111 M	8	0.1
HARS-X-8-1	111.111 11 M	8	1
HARS-X-9-0.001	1.111 111 11 M	9	0.001
HARS-X-9-0.01	11.111 111 1 M	9	0.01
HARS-X-9-0.1	111.111 111 M	9	0.1
HARS-X-10-0.001	11.111 111 11 M	10	0.001
HARS-X-10-0.01	111.111 111 1 M	10	0.01
HARS-X-11-0.001	111.111 111 11 M	11	0.001

* Use "**X2**" for higher power model

Mechanical:

Model	Dimensions	Weight
1 decade	7.7 cm W x 7.7 cm H x 8.4 cm D (3" x 3" x 3.3")	0.45 kg (1 lb)
2-3 decade	31 cm W x 8.9 cm H x 10.2 cm D (12.2" x 3.5" x 4")	1.7 kg (3.8 lb)
4-5 decade	37.5 cm W x 8.9 cm H x 10.2 cm D (14.75" x 3.5" x 4")	2.0 kg (4.3 lb)
6 decades	43.9 cm W x 8.9 cm H x 10.2 cm D (17.3" x 3.5" x 4")	2.2 kg (4.8 lb)
7 decades		2.4 kg (5.3 lb)
8 decades	48.3 cm W x 17.8 cm H x 17.8 cm D (19" x 7" x 7")	3.4 kg (7.5 lb)
9 decades		3.5 kg (7.7 lb)
10 decades		3.6 kg (7.9 lb)
11 decades		3.7 kg (8.1 lb)

OPTIONS

- **RM** Rack mountable case for standard 19" rack
- **K** Kelvin type 4-terminal binding posts
- **RO** Rear output binding posts

HARS-X SERIES HIGH ACCURACY DECADE RESISTANCE SUBSTITUTER

CONSULT INSTRUCTION MANUAL FOR PROPER INSTRUMENT OPERATION

Resistance per step	Total deacde resistance	Max current	Max voltage	Power per/step (W)	Stability (±ppm/yr)	Long-term stability (±ppm/3 yrs)	Temp. coeffieient (±ppm/°C)	Resistor type
1 mΩ	10 mΩ	8 A	5 mV	0.4	50	75	50	Resistance Wire
10 mΩ	100 mΩ	4 A	40 mV	0.16	50	75	20	
100 mΩ	1 Ω	1.6 A	0.16 V	0.25	50	75	20	
1 Ω	10 Ω	.8 A	0.8 V	0.6	20	25	20	Wirewound, non-inductive
10 Ω	100 Ω	.25 A	2.5 V	0.6	20	25	15	
100 Ω	1 kΩ	80 mA	8 V	0.6	20	25	5	
1 kΩ	10 kΩ	23 mA	23 V	0.5	20	25	5	
10 kΩ	100 kΩ	7 mA	70 V	0.5	20	25	5	
100 kΩ	1 MΩ	2.3 mA*	230 V*	0.5*	20	25	5	
1 MΩ	10 MΩ	0.7 mA*	700 V*	0.5*	20	25	10	
10 MΩ	100 MΩ	0.1 mA*	1000 V*	0.1*	50	100	10	Metal oxide film

***Subject to maximum of 2000 V to case**

Accuracy:
≤1 MΩ steps: ±(0.01% + 2 mΩ)
10 MΩ steps: ±0.03%
After subtraction of zero resistance, at 23°C; traceable to SI

Zero Resistance:
≤1 MΩ steps: ≤1 mΩ per decade
10 MΩ steps: approx. 3 mΩ

Switch Type:
Multiple solid silver alloy contacts, continuous rotation

Switch Capacitance:
<1 pF between contacts

Operating Conditions:
+10 to + 40°C, <80% RH

Operation:
If switches have not been operated for an extended period, they should be rotated a few times to restore contact resistance to specifications.

MODEL: HARS-X-6-0.01 **SN: C3-09404334**

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.

IET LABS, INC. • 534 Main Street, Westbury, NY 11590 • (800) 899-8438 • (516) 334-5959 • Fax: (516) 334-5988
CAGE CODE: 62015 **www.ietlabs.com**

HARSXCLBL/p1/HARS-X gen'l/55%/03-02-2010

Figure 2-1. Typical Operating Guide Affixed to Unit

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

3.2 Connection

3.2.1 General Considerations

The **HARS** Series Decade unit provides three terminals labeled **H** (high), **L** (low), and **G** (ground). The **H** and **L** terminals are connected to the ends of the resistance being set; the **G** terminal is connected to the case. The **G** terminal may be used as a guard or shield terminal. It may also be connected (using a shorting link) to the **L** terminal to allow two-terminal as opposed to three-terminal measurements.

In order to make the most stable measurements, determine which is the more sensitive of the two user leads, i.e. the one going into a higher impedance. This lead should be connected to the more protected one of the two **HARS** terminals. That would either be the **HARS** terminal that is shorted to the case, or the **LOW HARS** terminal whenever neither is connected to the case.

If switches have not been operated for an extended period, they should be rotated a few times to restore contact resistance to specifications.

3.2.2 Electrical Considerations

In order to make proper use of the full performance capabilities of the **HARS** unit, especially if low resistance or low-resistance increments are important, take care when connecting to the terminals of the decade box. In particular, in order to keep contact resistance to a minimum, take the most substantial and secure connection to the binding posts. They accept banana plugs, telephone tips, spade lugs, alligator clips, and bare wire. The largest or heaviest mating connection should be made, and, where applicable, the binding posts should be securely tightened.

These considerations may be relaxed whenever single milliohms are considered insignificant for the task being performed.

3.2.3 Four-Wire Kelvin Lead Connections

Whenever possible, 4-wire Kelvin leads, the ideal connection, should be employed. Such a connection minimizes the effects of contact resistance and approaches ideal performance.

If the four terminals are available as clamps similar to alligator clips, they may be connected to the necks of the binding posts. If the four terminals are available separately, the optimal connection is shown in Figure 3.1, where the current leads are introduced into the top of the binding posts, and the voltage leads at the necks.

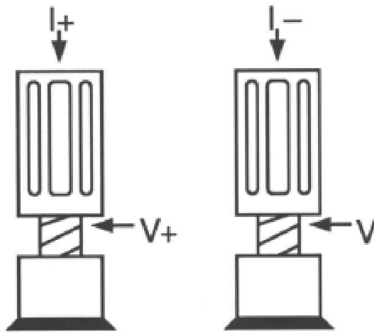

Figure 3-1 Optimal 4-Wire Kelvin Lead Connection

3.2.4 Thermal emf Considerations

The highest-quality low-emf components are used in the **HARS** Series. There nevertheless may be some minute thermal emf generated at the test leads where they contact the gold-plated binding posts.

This emf will not reflect itself if an ac measurement instrument is employed. It will also be eliminated if a meter with a “True Ohm” capability is used. Otherwise it may represent itself as a false component of the dc resistance measurement. It is also possible to take a second measurement with the leads reversed and average the reading.

3.3 Dial Setting

Whenever the dials are used in positions 0-9, the resulting resistance is read directly. Both the decimal point and the steps are clearly marked on the panel.

For additional flexibility and range, each decade provides a “10” position setting. This “10” position on any one decade equals the “1” position on the next higher decade. It adds about 11% to the nominal total decade resistance.

To determine the resistance obtained when one or more “10” settings are used, simply add “1” to the next higher decade. For example, a setting of 3-6-10-0-10 Ω becomes:

3	3 0 0 0 0
6	6 0 0 0
10	1 0 0 0
0	0 0
10	1 0
TOT	**3 7 0 1 0**

and a setting of 10-10-10-l0-10.10 Ω becomes:

10	1 0 0 0 0 0.0
10	1 0 0 0 0.0
10	1 0 0 0.0
10	1 0 0.0
10	1 0.0
.10	1.0
TOT	**1 1 1 1 1 1.0**

3.4 Environmental Conditions

For optimal accuracy, the decade box should be used in an environment of 23°C. It should be allowed to stabilize at that temperature after any significant temperature variation.

Humidity should be maintained at laboratory conditions. This is especially important if high resistances are involved.

Chapter 4

MAINTENANCE

4.1 Verification of Performance

4.1.1 Calibration Interval

The **HARS** 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 IET Labs, or by a certified calibration laboratory.

If the user should choose to perform this procedure, then the considerations below should be observed.

4.1.2 General Considerations

It is important, whenever testing the **HARS** Series Decade Units, to be very aware of the capabilities and limitations of the test instruments used. A resistance bridge may be employed, and there are direct-reading resistance meters or digital multimeters available that can verify the accuracy of these units, especially when used in conjunction with standards that can serve to confirm or improve the accuracy of the testing instrument

Such test instruments must be significantly more accurate than ±(l00ppm+2 mΩ) for all applicable ranges, allowing for a band of uncertainty of the instrument itself. A number of commercial bridges and meters exist that can perform this task; consult IET Labs.

It is important to allow both the testing instrument and the **HARS** Substituter to stabilize for a number of hours at the nominal operating temperature of 23^{O}C, and at nominal laboratory conditions of humidity. There should be no temperature gradients across the unit under test.

Substantial Kelvin-type 4-wire test terminals should be used to obtain accurate low-resistance readings. It is convenient, once the zero resistance has been determined, to subtract it from the remaining measurements. This can be automatically done in many instruments which have an offset subtraction capability.

4.1.3 Calibration Procedure

1. Confirm the zero resistance of the unit.
2. Determine the allowable upper and lower limits for each resistance setting of each decade based on the specified accuracy.

   For the HARS series, these limits for any resistance "R" are [R±(0.0001 R + 2 mΩ)].
3. Confirm that the resistances fall within these limits after subtraction of the zero resistance.
4. If any resistances fall outside these limits, the associated switch assembly may require service or replacement.

4.2 Schematic

Refer to Figure 4-1 for a schematic of the **HARS** decade unit.

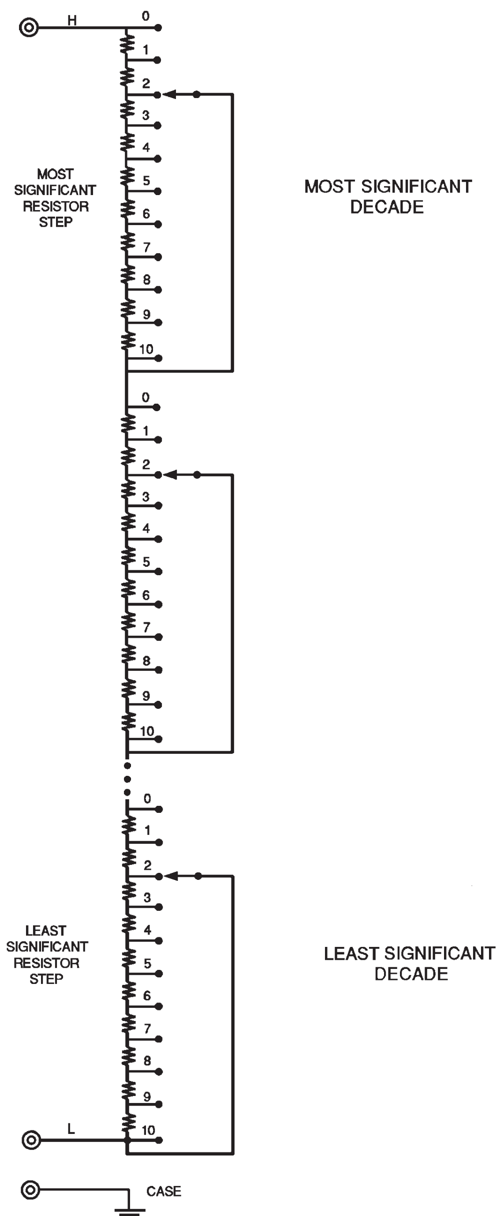

Figure 4-1. HARS Series Schematic Diagram

4.3 Replaceable Parts List

Table 4.2: Replacement List

Model Ref	IET Pt No	Description
1	BP-1000-RD	Binding Post, Red
2	BP-1000-BK	Binding Post, Black
3	BP-1000-GN	Binding Post, Green
4	HARS-X-4300-KNB	Knob Assembly
Not Shown	HARS-X-3100	Foot
Not Shown	HARS-4100-X-.001	1 mΩ/step Decade Switch Assembly
Not Shown	HARS-4100-X-0.01	10 mΩ/step Decade Switch Assembly
Not Shown	HARS-4100-X-0.1	100 mΩ/step Decade Switch Assembly
Not Shown	HARS-4100-X-1	1 Ω/step Decade Switch Assembly
Not Shown	HARS-4100-X-10	10 Ω/step Decade Switch Assembly
Not Shown	HARS-4100-X-100	100 Ω/step Decade Switch Assembly
Not Shown	HARS-4100-X-1k	1 kΩ/step Decade Switch Assembly
Not Shown	HARS-4100-X-10k	10 kΩ/step Decade Switch Assembly
Not Shown	HARS-4100-X-100k	100 kΩ/step Decade Switch Assembly
Not Shown	HARS-4100-X-1M	1 MΩ/step Decade Switch Assembly
Not Shown	HARS-4100-X-10M	10 MΩ/step Decade Switch Assembly

* Use "**X2**" for higher power model, for example HARS-4100-X2-100 for 100 Ω/step Decade X2 Switch Assembly

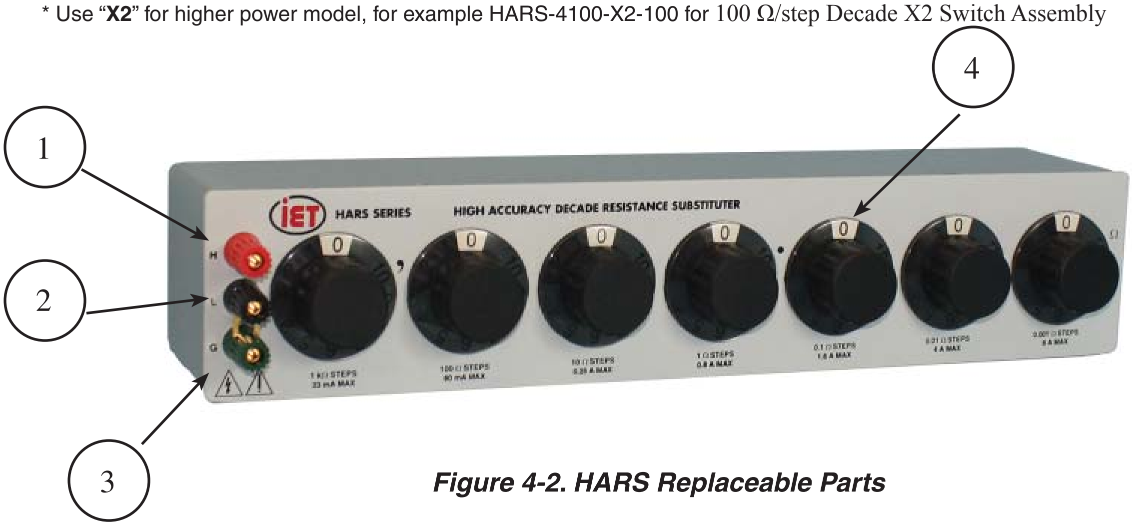

Figure 4-2. HARS Replaceable Parts