

HARS-X SERIES
High-Accuracy Decade
Resistance Substituter
User and Service Manual



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HARS im/January, 2002



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WARNING



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

ELECTRICAL SHOCK HAZARD. DO NOT OPEN CASE.
REFER SERVICING TO QUALIFIED PERSONNEL.

HIGH VOLTAGE MAY BE PRESENT WITH HIGH VOLTAGE OPTIONS.

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.

REMOVE POWER WHEN HANDLING UNIT.

POST WARNING SIGNS AND KEEP 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.

Chapter 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.

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 m Ω 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 m Ω and a maximum available resistance of over 111 M Ω , 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.

The **HARS** Series may be rack-mounted to serve as components in measurement and control systems.



Figure 1.1. HARS-X Series High Accuracy Resistance Substituter

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 (\pm ppm/year)	Long Term Stability (\pm ppm/3 years)	Temperature Coefficient (\pm ppm/ $^{\circ}$ C)	Max. Power (W/step)	Maximum current (per decade)	Maximum voltage (per step)
1 m Ω	10 m Ω	100	700	50	0.025	5 A	5 mV
10 m Ω	100 m Ω	50	350	20	0.2	4 A	40 mV
100 m Ω	1 Ω	30	50	20	0.25	1.6 A	0.16 V
1 Ω	10 Ω	10	25	20	0.6	0.8 A	0.8 V
10 Ω	100 Ω	10	25	15	0.6	0.25 A	2.5 V
100 Ω	1 k Ω	10	25	5	0.6	80 mA	8 V
1 k Ω	10 k Ω	10	25	5	0.5	23 mA	23 V
10 k Ω	100 k Ω	10	25	5	0.5	7 mA	70 V
100 k Ω	1 M Ω	10	25	5	0.5*	2.3* mA	230 V*
1 M Ω	10 M Ω	10	25	10	0.5*	0.7* mA	700 V*
10 M Ω	100 M Ω	25	40	10	0.1*	0.1* mA	1000 V*

*Subject to maximum of 2000 V.

Accuracy: After subtraction of zero resistance, at 23 $^{\circ}$ C; traceable to NIST.

HARS-X: $\pm(0.01\% + 2 \text{ m}\Omega)$

HARS-A: $\pm(0.05\% + 2 \text{ m}\Omega)$

HARS-Q: $\pm(0.02\% + 2 \text{ m}\Omega)$

Zero Resistance: <1 m Ω per decade, at dc; slightly higher for 7-10 decades.

Maximum Voltage to Case: 2000 V peak.

Switch Type: 11 positions; "0"- "10"; multiple solid silver alloy contacts.

Switch Capacitance: <4 pF per switch, low-loss.

Terminals: Low-thermal-emf beryllium-copper binding posts with standard 3/4 inch spacing, plus shield terminal; connections on the rear of the instrument are available (**RO** option). Single decade units have solder-terminal connections.

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 (1.0 lb)
2-4 decades	37.5 cm W x 8.9 cm H x 10.2 cm D (14.8" x 3.5" x 4")	1.7 kg (3.8 lb)
5 decades		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 19.7 cm D (19.0" x 7.0" x 7.8")	2.6 kg (5.7 lb)
9 decades		5.1 kg (11.2 lb)
10 decades		5.3 kg (11.7 lb)

SINGLE DECADE UNITS

Single-decade units are available with resistance as low as 1 mΩ per step to as high as 10 MΩ per step. These units satisfy many system applications requiring only a single decade while maintaining all the quality features of the **HARS** series.

Each decade is enclosed in an aluminum case which can serve as a shield.

It may be panel mounted and integrated with additional units to form potentiometer circuits or other configurations.

Each unit consists of low-inductance resistors in series, with a high-performance solid-silver-alloy-contact switch.



Single Decade **HARS-X** Unit

ORDERING INFORMATION

Model* (0.01% Accuracy)	Total Res. (Ω)	No. of Decades	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
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

Model* (0.01% Accuracy)	Total Res. (Ω)	No. of Decades	Resolution (Ω)
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

* For less exacting applications, more economical tolerances are available:

- use "A" for "X" in part number for 0.05% basic accuracy, in lieu of .01%
- use "Q" for "X" in part number for 0.02% basic accuracy, in lieu of .01%
- use "B" for "X" in part number for 0.1% basic accuracy, in lieu of .01%

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

Resistor Type: Resistance wire for 0.1 Ω steps and under; wirewound, noninductive for 1 Ω through 1 M Ω steps; resistance film for 10 M Ω steps.

Temperature Coefficient: $\leq \pm 50$ ppm/ $^{\circ}$ C for 1 m Ω steps; $\leq \pm 20$ ppm/ $^{\circ}$ C for 10 m Ω through 1 Ω steps; $\leq \pm 15$ ppm/ $^{\circ}$ C for 10 Ω steps; $\leq \pm 5$ ppm/ $^{\circ}$ C for 100 Ω through 100 k Ω steps; $\leq \pm 10$ ppm/ $^{\circ}$ C for 1 M Ω and 10 M Ω steps.

Accuracy: $\pm(0.01\% + 2 \text{ m}\Omega)$ after subtraction of zero resistance, at 23 $^{\circ}$ C; traceable to NIST.

Switch Type: Multiple solid silver alloy contacts.

Zero Resistance: ≤ 1 m Ω per decade, typical at dc.

Switch Capacitance: Less than 4 pF per switch, low loss.

Power per Step: 25 mW for 1 m Ω steps;

0.2 W for 10 m Ω steps;

0.25 W for 100 m Ω steps;

0.6 W for 1 Ω through 100 Ω steps;

0.5 W for 1 k Ω through 1 M Ω steps;

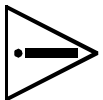
0.1 W for 10 M Ω steps;

subject to a maximum of 2000 V.

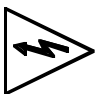
Operation: If switches have not been operated for an extended period, they should be rotated a few times to restore contact resistance to specifications.

MODEL: HARS-X-4-0.1 SN: C1-01191538

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.



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HARSXC1BL07/HARS-X_rev1/1/0-00

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-X** 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 either 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-X** terminals. That would either be the **HARS-X** terminal that is shorted to the case, or the **LOW HARS-X** terminal whenever neither is connected to the case.

3.2.2 Electrical Considerations

In order to make proper use of the full performance capabilities of the **HARS-X** unit, especially if low resistance or low-resistance increments are important, care must be taken in connecting to the terminals of the decade box.

In particular, in order to keep contact resistance to a minimum, the most substantial and secure connection to the binding posts should be made. 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 significant 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.

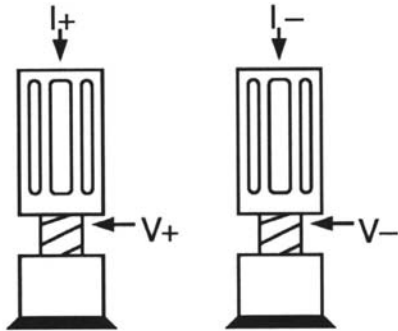


Figure 3.1 Optimal 4-Wire Kelvin Lead Connection

3.2.4 Thermal emf Considerations

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

This emf will not reflect itself if an ac measurement instrument is employed. It will also be eliminated if a meter with so called “True Ohm” capability is used. Otherwise it may represent itself as a false component of the dc resistance measurement.

3.3 Dial Setting

Whenever the dials are used in positions 0-9, the resulting resistance is simply 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	0
10	1	0	0	0	0
0			0	0	
10			1	0	
TOT	3	7	0	1	0

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

10	1	0	0	0	0	0.0
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
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-X** 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 $\pm(100\text{ppm}+2\text{ m}\Omega)$ 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-X** Substituter to stabilize for a number of hours at the nominal operating temperature of 23°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 Procedure

1. Confirm the zero resistance of the unit.
2. Determine the allowable upper and lower limits for each resistance setting of each decade following the specified accuracy. For the **HARS-X** series, these limits for any resistance “R” are $[R\pm(0.0001 R + 2\text{ m}\Omega)]$. For the A, B, or Q series, see specifications.
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 replacement.

4.2 Schematic

Refer to Figure 4.1 for a schematic of the **HARS** decade unit.

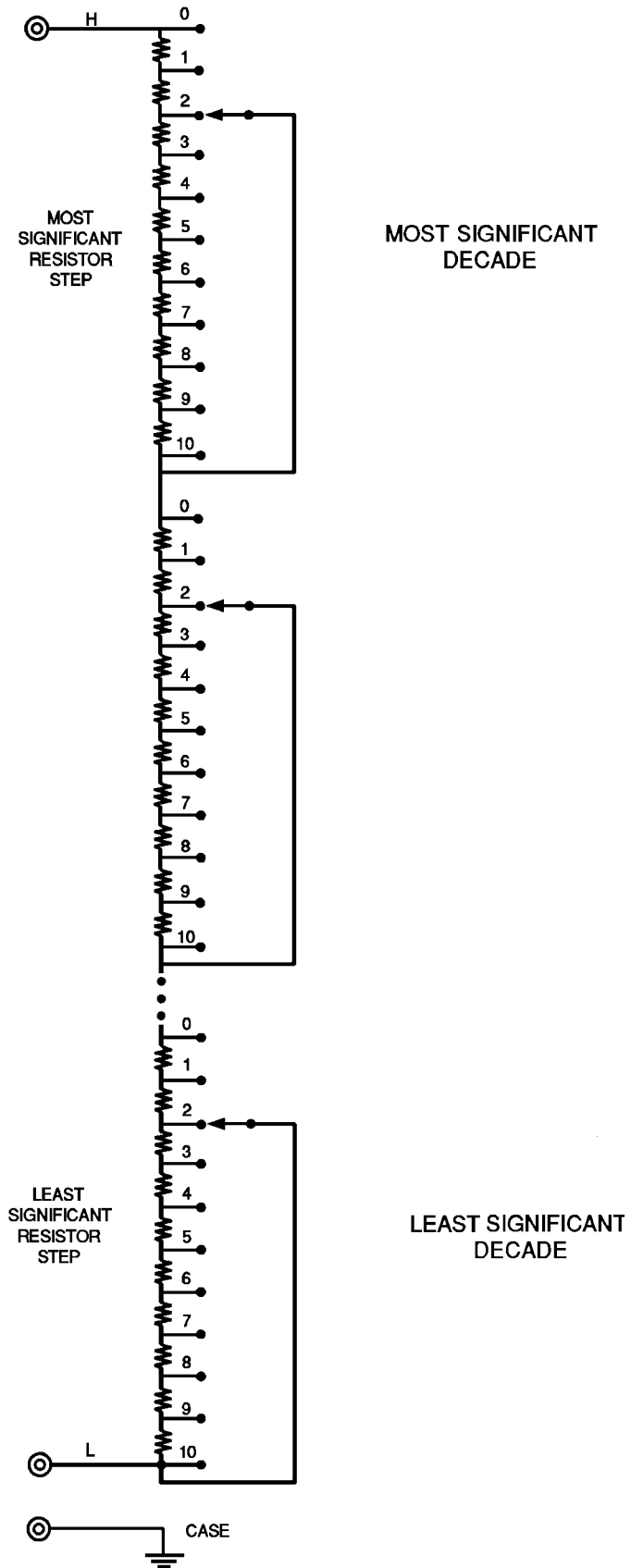


Figure 4.1. HARS Series Schematic Diagram

