User's Guide

Agilent 16441A R-Box

Agilent Technologies

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  Product maintenance agreements and other customer assistance agreements are available for Agilent Technologies products.

  For any assistance, contact your nearest Agilent Technologies Sales Office.

- **Certification**

  Agilent Technologies Inc. certifies that this product met its published specifications at the time of shipment from the factory. Agilent further certifies that its calibration measurements are traceable to the National Institute of Standards and Technology (NIST), to the extent allowed by the Institute's calibration facility, and to the calibration facilities of other International Standards Organization members.

- **Safety Summary**

  The following general safety precautions must be observed during all phases of operation, service, and repair of this instrument. Failure to comply with these precautions or with specific warnings elsewhere in this manual may impair the protections provided by the equipment. In addition, it violates safety standards of design, manufacture, and intended use of the instrument. Agilent Technologies Inc. assumes no liability for customer's failure to comply with these requirements.

- *GROUND THE INSTRUMENT*

  This is Safety Class I instrument. To minimize shock hazard, the instrument chassis and cabinet must be connected to an electrical ground. The power terminal and the power cable must meet International Electrotechnical Commission (IEC) safety standards.

- *DO NOT OPERATE IN AN EXPLOSIVE ATMOSPHERE*

  Do not operate the instrument in the presence of flammable gases or fumes. Operation of any electrical instrument in such an environment constitutes a definite safety hazard.

- *KEEP AWAY FROM LIVE CIRCUITS*

  Operation personnel must not remove instrument covers. Component replacement and internal adjustments must be made by qualified maintenance personnel. Do not replace components with power cable connected. Under certain conditions, dangerous voltages may exist even with the power cable removed. To avoid injuries, always disconnect power and discharge circuits before touching them.

- *DO NOT SERVICE OR ADJUST ALONE*

  Do not attempt internal service or adjustment unless another person, capable of rendering first aid and resuscitation, is present.

- *DO NOT SUBSTITUTE PARTS OR MODIFY INSTRUMENT*

  Because of the danger of introducing additional hazards, do not install substitute parts or perform any unauthorized modification to the instrument. Return the instrument to a Agilent Technologies Sales and Service Office for services and repair to ensure that safety features are maintained.

- *DANGEROUS PROCEDURE WARNINGS*

  Warnings, such as example below, precede potentially dangerous procedures throughout this manual. Instructions contained in the warnings must be followed.

WARNING **Dangerous Voltage, capable of causing death, are present in this instrument. Use extreme caution when handling, testing, and adjusting.**

- **Safety Symbols**

  The general definitions of safety symbols used on equipment or in manuals are listed below.

Instruction manual symbol: the product will be marked with this symbol when it is necessary for the user to refer to the instruction manual in order to protect against damage to the instrument.

Indicates dangerous voltage and potential for electrical shock. Do not touch terminals that have this symbol when instrument is on.

Protective conductor terminal. For protection against electrical shock in case of a fault. Used with field wiring terminals to indicate the terminal which must be connected to ground before operating equipment.

Frame or chassis terminal. A connection to the frame (chassis) of the equipment which normally includes all exposed metal structures.

Indicates earth (ground) terminal.

Alternating current.

Direct current.

ON (Supply).

OFF (Supply).

STANDBY (Supply).

CAT 1

Means INSTALLATION CATEGORY I. Measurement terminals on the rear panel comply with INSTALLATION CATEGORY I.

WARNING

The warning sign denotes a hazard. It calls attention to a procedure, practice, condition or the like, which, if not correctly performed or adhered to, could result in injury or death to personal.

CAUTION

The caution sign denotes a hazard. It calls attention to an operating procedure, practice, condition or the like, which, if not correctly performed or adhered to, could result in damage to or destruction of part or all of the product.

- **Herstellerbescheinigung**

  GEÄUSCHEMISSION

  Lpa < 70 dB

  am Arbeitsplatz

  normaler Betrieb

  nach DIN 45635 T. 19
- **Manufacturer's Declaration**

  ACOUSTIC NOISE EMISSION

  Lpa < 70dB

  operator position

  normal operation

  per ISO 7779

Printing History

Edition 1:	February 1994
Edition 2:	April 1995
Edition 3:	August 1997
Edition 4:	January 2000

User's Guide

Agilent 16441A R-Box is one of the accessories available for Agilent 4155/4156 Semiconductor Parameter Analyzers. The R-Box is used to add a series resistance (0 Ω, 10 kΩ, 100 kΩ, or 1 MΩ) between the 4155/4156's SMU output and your test device (DUT), and is useful for the following measurements:

- negative resistance measurement

  R-Box is effective for the negative resistance measurement, because SMUs *cannot* measure negative resistance.

- breakdown measurement

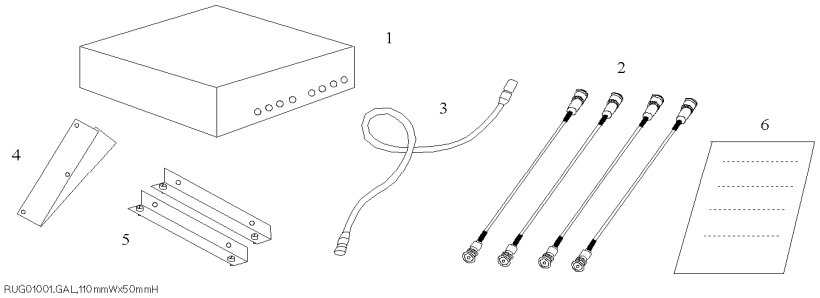
  R-Box is effective for preventing excessive current, thus preventing damage to DUT when sudden voltage change occurs.

This manual consists of the following sections:

- Introduction
- Operation
- Installation
- Maintenance
- Specifications

Introduction

The 16441A R-Box contains the following accessories:



	Description	Agilent Part Number	Quantity
1	R-Box	16441A	1
2	40 cm triaxial cable	04155-61605	4
3	(option 001) 1.5 m control cable	04155-61610	1
	(option 002) 3 m control cable	04155-61609	1
4	plate [a]	16440-60001	2
5	angle [b]	16440-60002	2
6	*User's Guide* (this document)	16441-90000	1

a. Three screws are furnished for each plate.
b. Two screws are furnished for each angle.

NOTE

Inspecting the 16441A upon Receiving

When the 16441A arrives at your site, make sure that nothing is missing or damaged. Unpack the carton, then check the contents. See figure and table shown above.

If anything is missing or damaged, contact your nearest Agilent Technologies sales office.

Operation

The R-Box adds a series resistance between the 4155/4156 Semiconductor Parameter Analyzer and DUT. Available resistance values are 0 Ω, 10 kΩ, 100 kΩ, and 1 MΩ. There is two channels (CH1 and CH2) to connect SMUs.

Switching of resistance is controlled by the 4155/4156. After you set a resistance value on the 4155/4156 setup screen, the R-Box sets the selected resistance value when the 4155/4156 is in the measurement state.

Available Measurement Units

The R-box is effective for the following SMUs:

- SMU1
- SMU2 or SMU5

  If the 4155/4156 is installed with the 41501 PGU/PG Expander which has an HPSMU (High Power SMU), SMU5 is available instead of SMU2.

Measurement Data Compensation

The resistance value is automatically compensated for by the 4155/4156. So, the data displayed on the GRAPH/LIST screen of the 4155/4156 or data used for user function is the compensated data.

If you connect the R-Box to SMUs other than described above, resistance values are not compensated for automatically. You need to compensate for the resistance values manually, such as by using a user function or calculation in IBASIC program.

NOTE

Additional Measurement Channel for Compensation

Be aware that an additional measurement channel is automatically used if *both* the following are true:

- You *force voltage* from channel that is connected to R-Box, and
- You display this voltage variable on the GRAPH/LIST screen, or use voltage variable in user function.

So if both above are true for a channel, and you set another one measurement channel, the 4155/4156 uses two measurement channels automatically.

Additional measurement channel is used for the automatic measurement of the current through R-Box. This is necessary to perform compensation calculation.

Selecting Resistance Value

Install the R-Box as shown in “Installation”, and turn on the 4155/4156. Then do following:

1. Display the CHANNELS: CHANNEL DEFINITION screen of the 4155/4156.
2. Move the field pointer to the SERIES RESISTANCE field. In this field, select:
   - 0 ohm softkey to set 0 Ω resistance
   - 10k ohm softkey to set 10 kΩ resistance
   - 100k ohm softkey to set 100 kΩ resistance
   - 1M ohm softkey to set 1 MΩ resistance

   where, for the following SMUs, select the 0 ohm softkey. Else error occurs.
   - SMU defined as the standby channel:

     If STBY field is ON, the SMU is defined as the standby channel.
   - SMU set to the common mode:

     If MODE field is COMMON, the SMU is set to the common mode.

When the 4155/4156 is in the measurement state, the R-Box sets the selected resistance value. In the other operation state (idle state, standby state, or stress force state), the R-Box sets 0 Ω.

Present resistance setting is also indicated by LEDs on the R-Box front panel.

NOTE **If an emergency occurs**

If an emergency occurs, resistance value is automatically set to 1 MΩ.

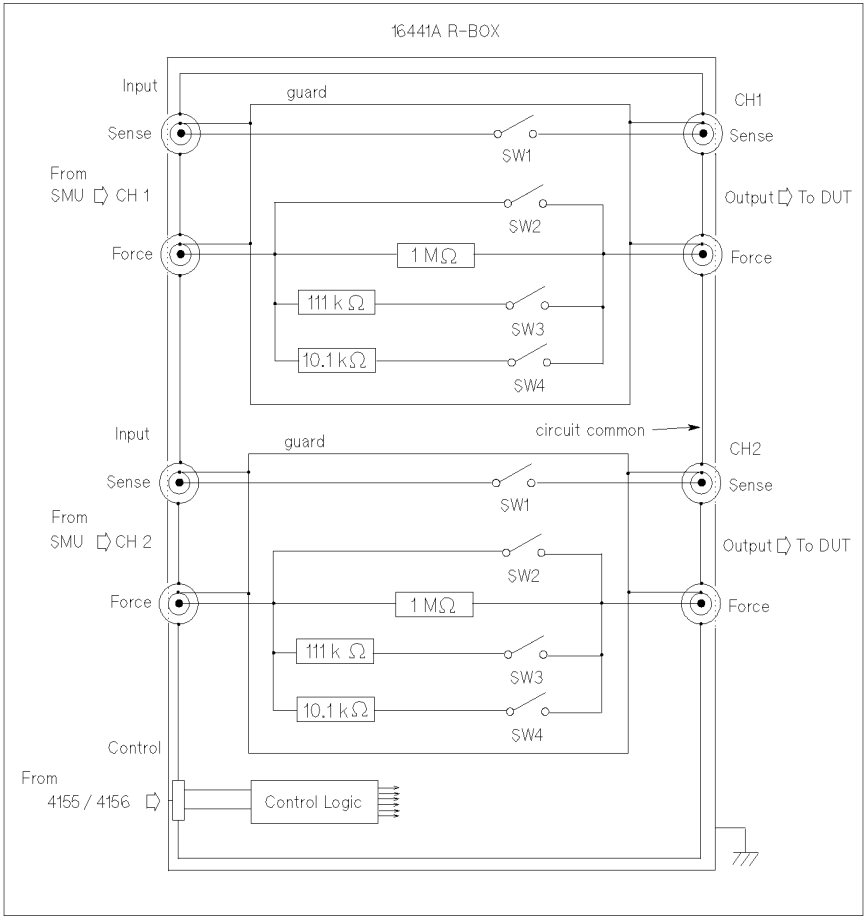
NOTE **Making Kelvin Connection**

The R-Box makes Kelvin connection only when 0 Ω is selected.

For 1 MΩ, 100 kΩ, and 10 kΩ settings, the R-Box always opens the sense line of HRSMU and HPSMU. See “Circuit Diagram” on page 6.

Circuit Diagram

The simplified circuit diagram of the R-Box is shown below.



RUG02001 130h,118w

The table below shows the internal relay positions for each resistance setting.

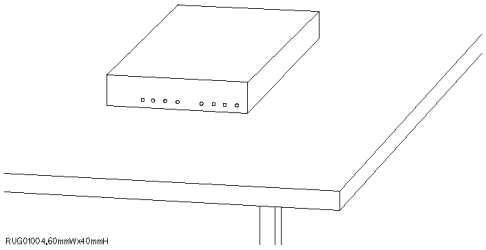
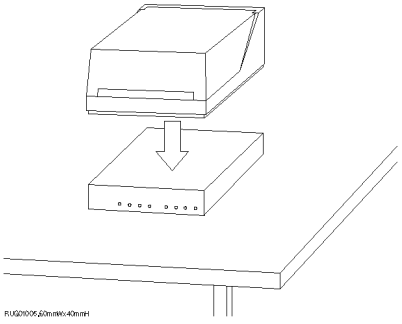
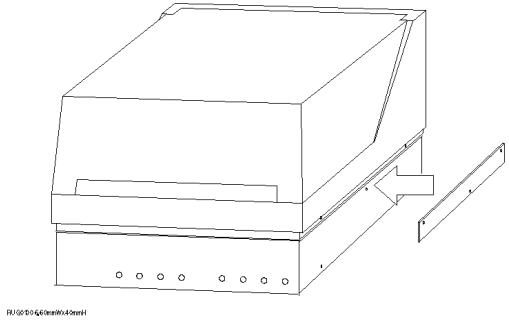
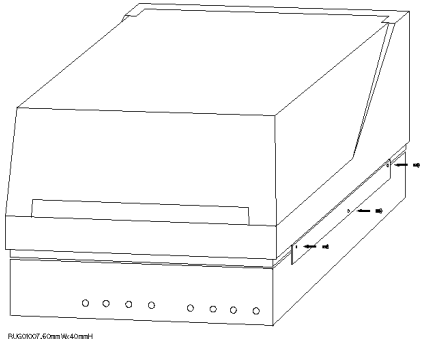
Settings	Relay Switches			
	SW1	SW2	SW3	SW4
0 Ω	ON	ON	OFF	OFF
10 kΩ	OFF	OFF	OFF	ON
100 kΩ	OFF	OFF	ON	OFF
1 MΩ	OFF	OFF	OFF	OFF

Installation

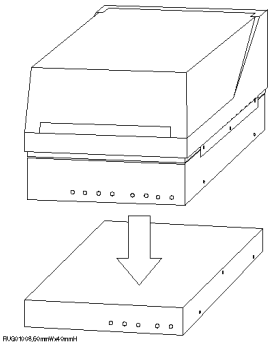
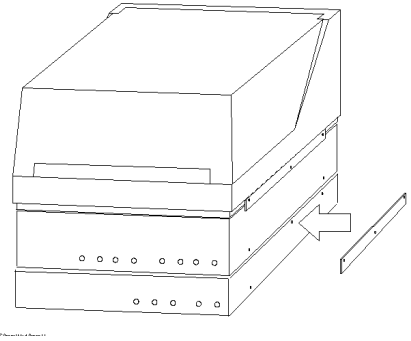
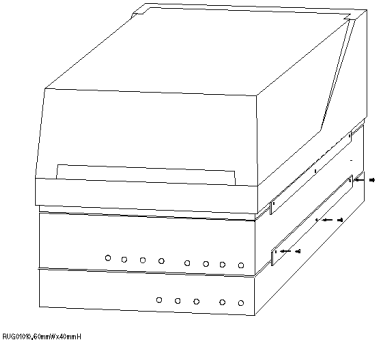
This section describes how to attach the R-Box to Agilent 16442A test fixture or to a shielding box, and how to connect it to the 4155/4156.

To Attach the R-Box to Test Fixture

You can attach your R-Box to Agilent 16442A test fixture as shown below. You need a standard screwdriver.

1. Place the R-Box on your workbench.	2. Place the test fixture on top of the R-Box.
	
3. Position a plate on both sides.	4. Attach each plate using the three flathead screws supplied with the instrument.
	

The following steps apply when using the 16440A selector:

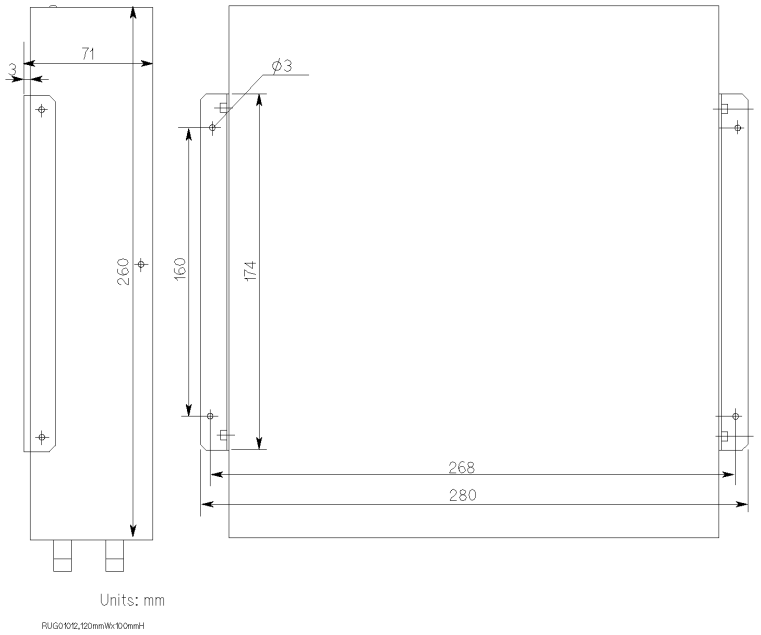
5. Place the selector on your workbench. Place the R-Box and the test fixture on top of the selector.	
6. Position a plate on both sides.	7. Attach each plate using the three flathead screws supplied with the instrument.
	

To attach one more selector, repeat steps 5 to 7 again.

To Attach the R-Box to Shielding Box

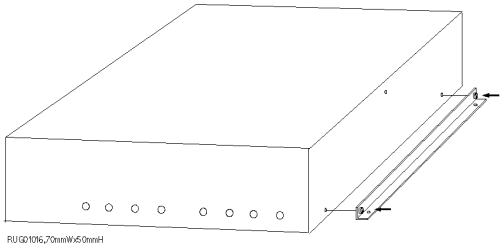
You can attach your R-Box to a shielding box. You need a standard screwdriver.

The following figure shows the spacing of the 16441A screw holes. You need to prepare four screws and nuts to match the screw holes.

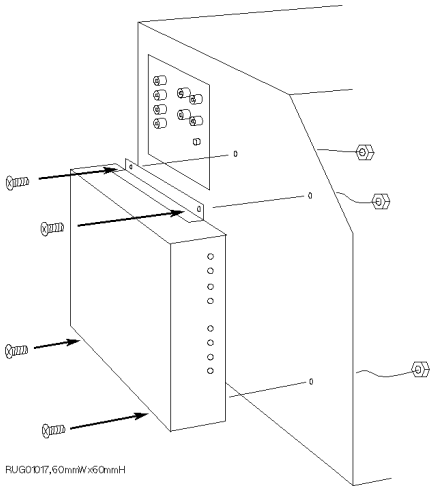


Attach the R-Box to the shielding box as shown below:

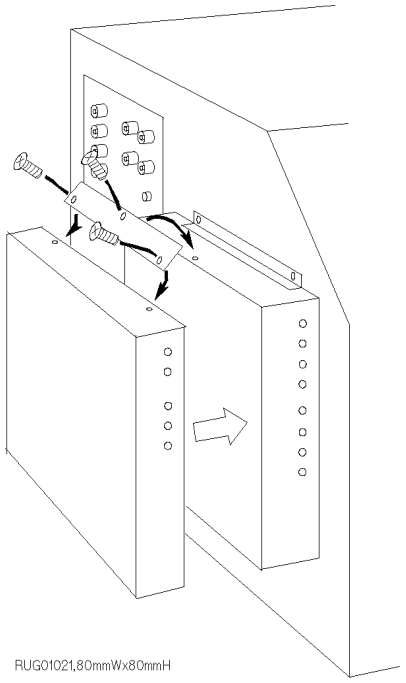
1. Attach an angle bracket to each side of the R-Box, using the screws supplied.



2. Place the R-Box on the side panel of the shielding box.
3. Position four nuts on the inside panel of the shielding box.
4. Attach the angle bracket to the shielding box using four flathead screws.



If you use the 16440A selector, attach the selector to the R-Box as shown below:



Connecting the R-Box to the 4155/4156

Before connecting the R-box to the 4155/4156 and 41501, turn off the instruments.

1. Connect the To R-Box terminal on the 4155/4156 rear panel to the Control terminal on the R-Box rear panel using a 3.0 m or 1.5 m control cable.
2. Connect the instrument measurement terminals to the R-Box input terminals as shown below:

Instrument terminals	R-Box Input	Cable
4155 MPSMU	Input Force	3 m or 1.5 m Triaxial Cable
4156 HRSMU	Input (Force/Sense)	3 m or 1.5 m Kelvin Triaxial Cable
41501 MPSMU	Input Force	3 m or 1.5 m Triaxial Cable
41501 HPSMU	Input (Force/Sense)	3 m or 1.5 m Kelvin Triaxial Cable

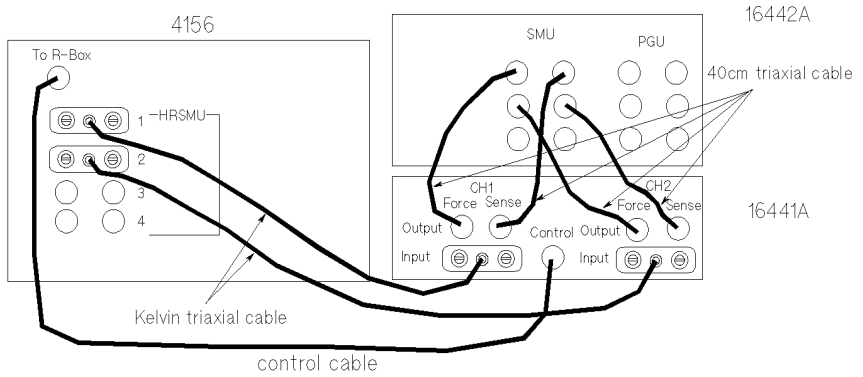
3. Connect the R-Box output terminals to the input terminals of the 16442A test fixture or an connector plate using 40 cm triaxial cables as shown below:

R-Box Output	16442A Input or Connector Plate Input		
Output Force [a]	SMU1, 2, 3, 4, 5, or 6		
Output Force [b]	SMU1	SMU3	SMU5
Output Sense [b]	SMU2	SMU4	SMU6

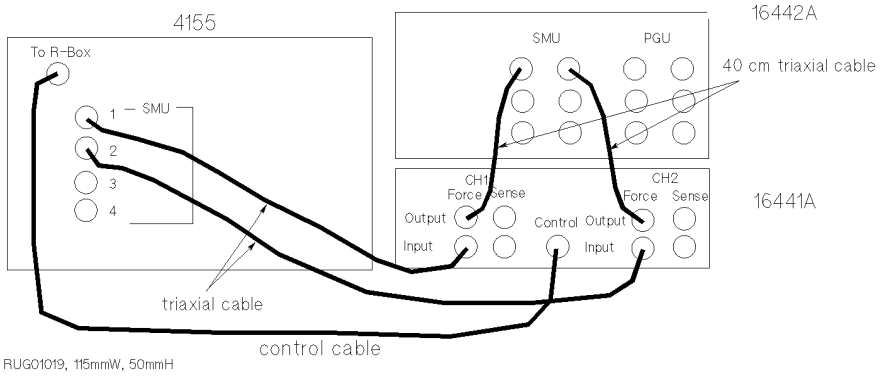
a. For non-Kelvin connection.
b. For the Kelvin connection, two triaxial cables must be used to connect the R-Box and the 16442A, instead of a Kelvin triaxial cable.

When you use the connector plate, use a low-noise coaxial cable (Agilent part number: 8120-3674) from the connector plate to DUT. If you use insufficiently insulated cables, leakage current may occur.

The following figure shows example connections with the 4156.



The following figure shows example connections with the 4155.



Maintenance

This section provides the following maintenance information:

- Cleaning
- Servicing

Cleaning the R-Box

To maintain high performance, the R-Box must be kept clean. Oil, perspiration, hair, dust, and dirt degrade board insulation, which increases leakage current and decreases measurement accuracy.

Agilent Technologies recommend the following cleaning procedure:

1. Make sure that voltage or current is *not* present at any channel.
2. Disconnect all cables from the R-Box.
3. Using lint-free paper, gently wipe the chassis. For any area that will not come clean, dip the lint-free paper into alcohol and wipe the area gently.

Servicing the R-Box

This section provides information for trained service personnel to repair the R-Box.

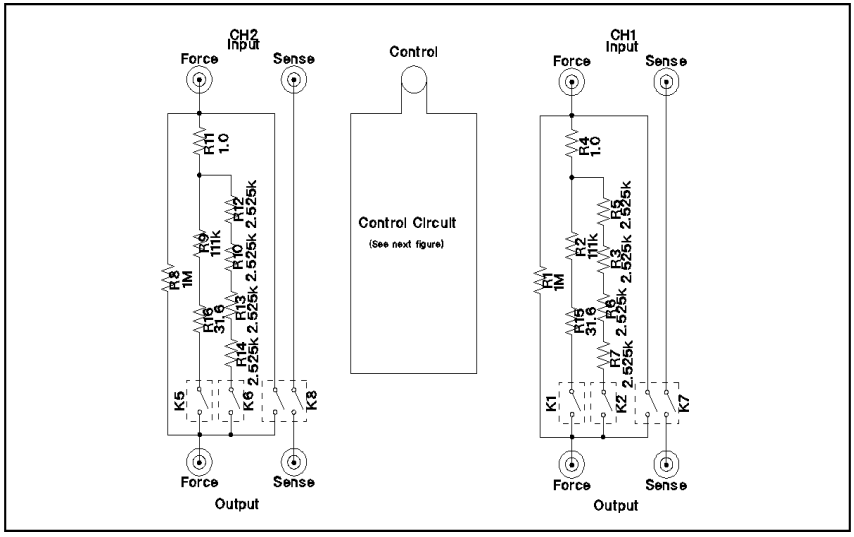
When a replaceable part, which is shown with the Agilent part number in this section, needs to be replaced, order the parts from the nearest Agilent Technologies Sales and Service Office.

WARNING **High voltages may be present in the selector when voltage or current is added to the R-Box. Dangerous voltage may be generated on wires or parts and the danger of electric shock exists.**

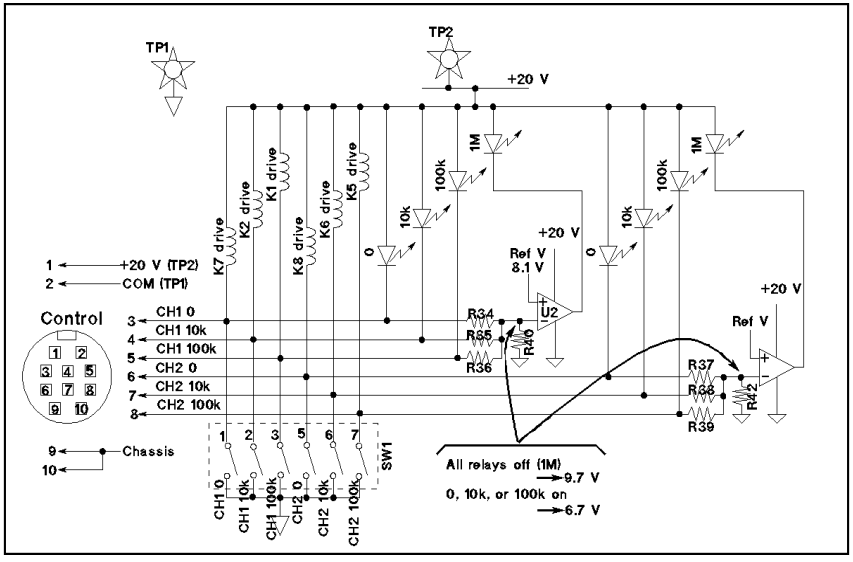
Make sure that terminals are not connected to the instruments before you repair the R-Box.

Circuit Block Diagram

Circuit Block Diagram is shown below:



Control Circuit is shown below:



Performance Verification

This section provides information to verify the performance of the R-Box without the 4155/4156.

For the procedures to verify the performance of the R-Box by using the 4155/4156, refer to the *4155/4156 Service Manual*.

Test Equipments

Digital Multi Meter	Agilent Technologies 3458A or equivalent
Power Supply	can force 20 V and 100 mA.
Connection Cables	04155-61650, 2ea

Test Condition

Temperature 23 ± 3 °C

DMM Condition

- 4 wire ohm measurement
- AUTO RANGE
- Within one year from the last calibration
- Has been warmed up
- NPLC 100
- OCOMP ON
- All other settings are same as PRESET NORM
- Within 24 hours from the last auto-calibration (ACAL)
- The ambient temperature changes is less than ± 1°C from the last ACAL
- Operating temperature is ± 5 of the temperature of calibration (Tcal)

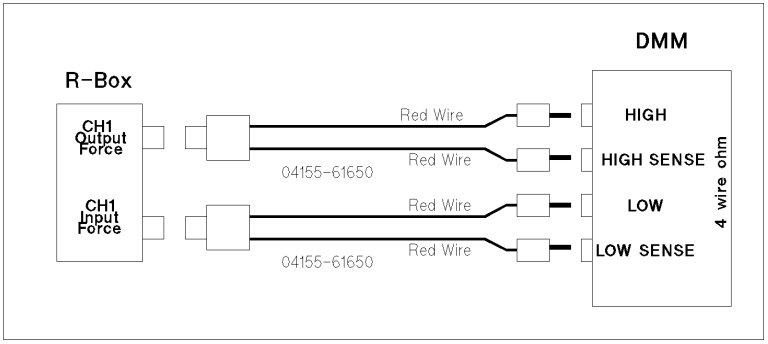
Test Procedure

1. Apply dc voltage to the control circuit of the R-Box by the power supply as follows:

   TP1 0 V

   TP2 +20 V

2. Connect the R-Box and DMM as follows:

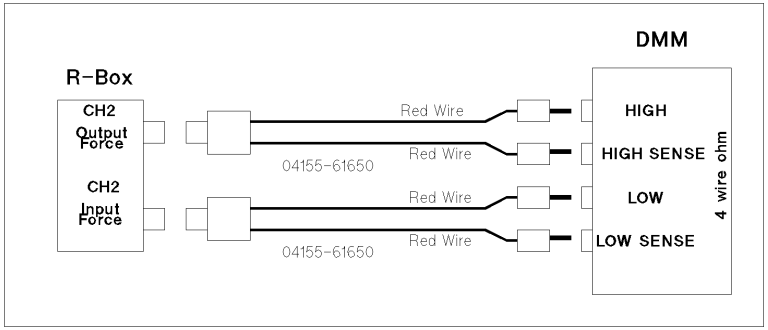


3. Change the setting of the SW1 on the circuit board of the R-Box and verify the resistance value measured by the DMM as follows:

   CH1 Path Test:

Test Path	SW1 Setting						Resistance Value Test Limit (Ω)
	1	2	3	5	6	7	
10kΩ	OFF	ON	OFF	OFF	OFF	OFF	9991.78 to 10008.22
100kΩ	OFF	OFF	ON	OFF	OFF	OFF	99962.8 to 100037.2
1MΩ	OFF	OFF	OFF	OFF	OFF	OFF	998800 to 1001200
0Ω	ON	OFF	OFF	OFF	OFF	OFF	0 to 0.5

4. Change the connection between the R-Box and DMM as follows:

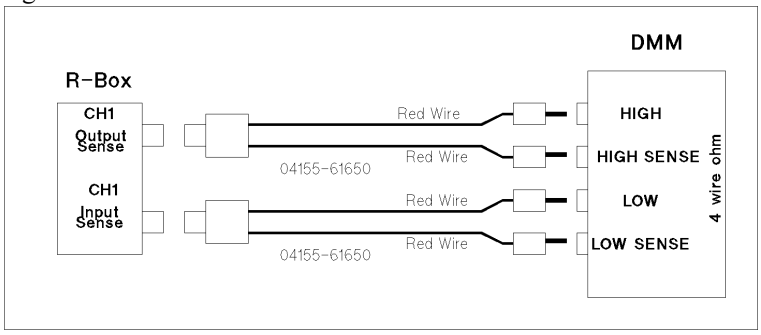


5. Change the setting of the SW1 on the circuit board of the R-Box and measure the resistance value by the DMM to verify the resistor paths as follows:

   CH2 Path Test:

Test Path	SW1 Setting						Resistance Value Test Limit (Ω)
	1	2	3	5	6	7	
10kΩ	OFF	OFF	OFF	OFF	ON	OFF	9991.78 to 10008.22
100kΩ	OFF	OFF	OFF	OFF	OFF	ON	99962.8 to 100037.2
1MΩ	OFF	OFF	OFF	OFF	OFF	OFF	998800 to 1001200
0Ω	OFF	OFF	OFF	ON	OFF	OFF	0 to 0.5

6. Change the connection between the R-Box and DMM as follows:

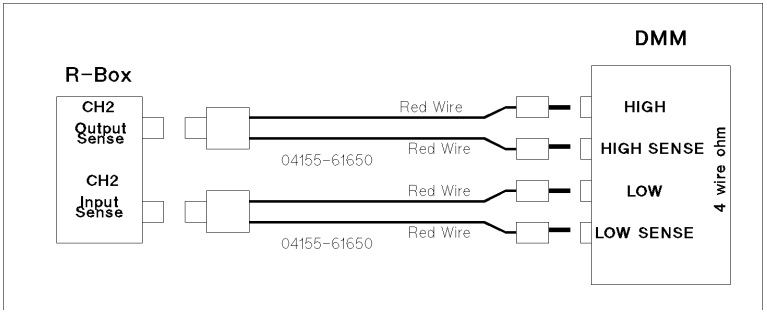


7. Change the setting of the SW1 on the circuit board of the R-Box and measure the resistance value by the DMM to verify the resistor paths as follows:

   Sense Path Test:

Test Path	SW1 Setting						Resistance Value Test Limit (Ω)
	1	2	3	5	6	7	
0Ω	ON	OFF	OFF	OFF	OFF	OFF	0 to 0.5

8. Change the connection between the R-Box and DMM as follows:



9. Change the setting of the SW1 on the circuit board of the R-Box and measure the resistance value by the DMM to verify the resistor paths as follows:

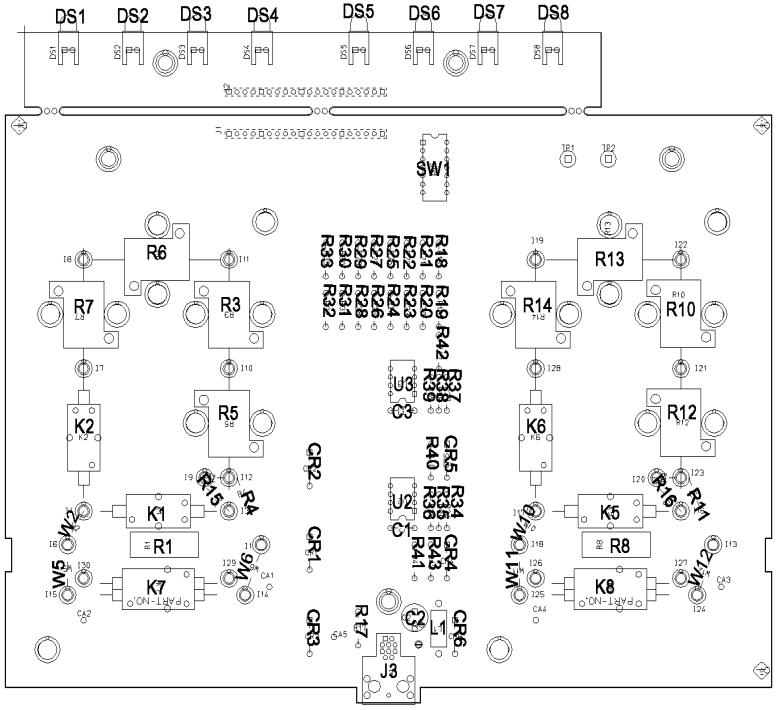
   Sense Path Test:

Test Path	SW1 Setting						Resistance Value Test Limit (Ω)
	1	2	3	5	6	7	
0Ω	OFF	OFF	OFF	ON	OFF	OFF	0 to 0.5

Replaceable Parts

When wiring or soldering, use low hydrochloric acid solder (Agilent part number: 8090-0433) to prevent the flux in the solder from spreading unnecessarily. When soldering, make sure the terminals do not make contact with each other. After soldering, make sure that there are no lint bridges so that leakage current is minimal.

Parts Location on the Circuit Board Assembly:



Reference Designation	Agilent Part Number	Description
R1	0698-2036	Resistor 1MΩ 0.1 % .25 W
R3	0699-3702	Resistor 2.525KΩ 0.02 %
R4	0699-0208	Resistor 1Ω 5 % .25 W
R5	0699-3702	Resistor 2.525KΩ 0.02 %
R6	0699-3702	Resistor 2.525KΩ 0.02 %
R7	0699-3702	Resistor 2.525KΩ 0.02 %
R8	0698-2036	Resistor 1MΩ 0.1 % .25 W
R10	0699-3702	Resistor 2.525KΩ 0.02 %
R11	0699-0208	Resistor 1Ω 5 % .25 W
R12	0699-3702	Resistor 2.525KΩ 0.02 %
R13	0699-3702	Resistor 2.525KΩ 0.02 %
R14	0699-3702	Resistor 2.525KΩ 0.02 %
R15	0757-0180	Resistor 31Ω.6 1 %
R16	0757-0180	Resistor 31Ω.6 1 %
R17	0757-0442	Resistor 10KΩ 1 % .125 W
R18	0757-0418	Resistor 619Ω 1 % .125 W
R19	0757-0418	Resistor 619Ω 1 % .125 W
R20	0757-0418	Resistor 619Ω 1 % .125 W
R21	0757-0418	Resistor 619Ω 1 % .125 W
R22	0757-0418	Resistor 619Ω 1 % .125 W
R23	0757-0418	Resistor 619Ω 1 % .125 W
R24	0757-0418	Resistor 619Ω 1 % .125 W
R25	0757-0418	Resistor 619Ω 1 % .125 W
R26	0757-0418	Resistor 619Ω 1 % .125 W
R27	0757-0418	Resistor 619Ω 1 % .125 W
R28	0757-0418	Resistor 619Ω 1 % .125 W
R29	0757-0418	Resistor 619Ω 1 % .125 W
R30	0757-0418	Resistor 619Ω 1 % .125 W
R31	0757-0418	Resistor 619Ω 1 % .125 W
R32	0757-0418	Resistor 619Ω 1 % .125 W

Reference Designation	Agilent Part Number	Description
R33	0757-0418	Resistor 619Ω 1 % .125 W
R34	0757-0465	Resistor 100KΩ 1 %
R35	0757-0465	Resistor 100KΩ 1 %
R36	0757-0465	Resistor 100KΩ 1 %
R37	0757-0465	Resistor 100KΩ 1 %
R38	0757-0465	Resistor 100KΩ 1 %
R39	0757-0465	Resistor 100KΩ 1 %
R40	0698-3160	Resistor 31.6KΩ 1 %
R41	0698-3160	Resistor 31.6KΩ 1 %
R42	0698-3160	Resistor 31.6KΩ 1 %
R43	0698-3162	Resistor 46.4KΩ 1 %
CR1	1901-0050	Diode
CR2	1901-0050	Diode
CR3	1901-0050	Diode
CR4	1901-0050	Diode
CR5	1901-0050	Diode
CR6	1901-0050	Diode
L1	9140-0210	Inductor 100 µH 5 %
C1	0160-4832	Capacitor 0.01 µF 100 V
C2	0180-3468	Capacitor 47 µF 50 V
C3	0160-4832	Capacitor 0.01 µF 100 V
U2	1826-0065	IC 311
U3	1826-0065	IC 311
K1	0490-1930	Reed Relay
K2	0490-1930	Reed Relay
K5	0490-1930	Reed Relay
K6	0490-1930	Reed Relay
K7	0490-1929	Reed Relay
K8	0490-1930	Reed Relay

Reference Designation	Agilent Part Number	Description
W2	8159-0005	Wire (Resistor 0Ω)
W5	8159-0005	Wire (Resistor 0Ω)
W6	8159-0005	Wire (Resistor 0Ω)
W10	8159-0005	Wire (Resistor 0Ω)
W11	8159-0005	Wire (Resistor 0Ω)
W12	8159-0005	Wire (Resistor 0Ω)
DS1	1990-0967	LED Green
DS2	1990-0967	LED Green
DS3	1990-0967	LED Green
DS4	1990-0967	LED Green
DS5	1990-0967	LED Green
DS6	1990-0967	LED Green
DS7	1990-0967	LED Green
DS8	1990-0967	LED Green
J3	1252-5466	Connector 10 pin Female
SW1	3101-2885	Switch - DIP

Specifications

The "supplemental information" and "typical" entries, in the following specifications are not warranted, but provide useful information about the functions and performance of the instruments.

The following specifications data is specified at 23 ± 5 °C and 50 % relative humidity.

- Function

  Agilent 16441A R-BOX adds a selectable series resistor to the SMU output. You can select the resistor from the setup page, and the voltage drop due to the series resistor is automatically calculated. There are the limitations on measurement with Agilent 4155/4156 Semiconductor Parameter Analyzers and R-Box:

  - If you measure device characteristics including negative resistance over 1 MΩ with the 4155/4156 and R-Box, there is a possibility that they cannot measure it.
  - There is a possibility that the 4155/4156 cannot perform measurement circumstances.

- Resistance value and accuracy

  Number of SMU channels that can add resistor: 2

  Following resistance values are available for each channel (CH1, CH2):

  - 1 MΩ
  - 100 kΩ
  - 10 kΩ
  - 0 Ω

  resistance accuracy 0.3 % between Input and Output terminals
  (at 23 ± 5 °C and 50 % relative humidity)

- Kelvin connection

  Kelvin connection is effective only when 0 Ω is selected.

- Voltage and current range
  - maximum voltage: 200 V
  - maximum current: 1 A (when 0 Ω is selected)
- Accessories (furnished). See “Introduction” for details.
  - Option 001
    - 1.5 m control cable (Agilent part number 04155-61610)
    - 40 cm triaxial cable (Agilent part number 04155-61605)
  - Option 002
    - 3.0 m control cable (Agilent part number 04155-61609)
    - 40 cm triaxial cable (Agilent part number 04155-61605)
- Accessories (optional)
  - 1.5 m Kelvin triaxial cable (Agilent 16493K option 001)
  - 3.0 m Kelvin triaxial cable (Agilent 16493K option 002)
  - 1.5 m triaxial cable (Agilent 16493C option 001)
  - 3.0 m triaxial cable (Agilent 16493C option 002)
- General specifications
  - Environment

Operating temperature	5 °C to 40 °C
Storage temperature	–40 °C to 60 °C
Operating Humidity	15 % to 80 % relative humidity (at no condensation)
Storage Humidity	5 % to 90 % relative humidity at 60 °C

  - Weight

    Approximately 1.6 kg

Supplemental Information

The following reference data is specified at 23 ± 5 °C and 50% relative humidity.

Leakage current less than 100 fA at 100 V

Residual resistance 0.3 Ω typical (when 0 Ω is selected)

Output channel stray capacitance

force to common	0.3 pF typical (at DC, without cable)
force to guard	15 pF typical (when 1 MΩ or 100 kΩ is selected at 1 MHz)
	40 pF typical (when 10 kΩ is selected at 1 MHz)
guard to common	150 pF typical at 1 MHz