HIOKI

INSTRUCTION MANUAL

3541

RESISTANCE HiTESTER

HIOKI E. E. CORPORATION

Introduction

Thank you for purchasing the HIOKI “Model 3541 RESISTANCE HiTESTER". To obtain maximum performance from the instrument, please read this manual carefully, and keep it handy for future reference.

Inspection

Confirming package contents

When you receive the instrument, inspect it carefully to ensure that no damage occurred during shipping. In particular, check the accessories, panel switches, and connectors. If damage is evident, or if it fails to operate according to the specifications, contact your dealer or Hioki representative.

Instrument 3541 RESISTANCE HiTESTER

Accessories

- 9287-10 CLIP TYPE LEAD 1
- 9451 TEMPERATURE PROBE.....1
- Instruction Manual.....1
- Power Cord (2-line + ground).....1
- EXT I/O Male Connector 1

Shipping precautions

Use the original packing materials when transporting the instrument, if possible.

Options

Test-Lead-Related (Page 194)

- 9452 CLIP TYPE LEAD
- 9453 FOUR TERMINAL LEAD
- 9455 PIN TYPE LEAD (for ultra precision)
- 9461 PIN TYPE LEAD
- 9467 LARGE CLIP TYPE LEAD
- 9454 ZERO ADJUSTMENT BOARD
- 9300 CONNECTION CABLE

Interface Cable

- 9637 RS-232C CABLE (9-pin to 9-pin/cross cable)
- 9638 RS-232C CABLE (9-pin to 25-pin/cross cable)
- 9151-02 GP-IB CONNECTOR CABLE (2 m)
- 9151-04 GP-IB CONNECTOR CABLE (4 m)

Printer-Related

- 9670 PRINTER (BL-80RS II, made by SANEI ELECTRIC INC.)
- 9671 AC ADAPTER (for the 9670, BL-100W, made by SANEI ELECTRIC INC.)
- 9672 BATTERY PACK (for the 9670)
- 9673 BATTERY CHARGER (for the 9672)
- 9237 RECORDING PAPER (80 mm x 25 m, 4 rolls, for the 9670)
- 9638 RS-232C CABLE (for 3541-9670)

Safety Information

⚠WARNING

This instrument is designed to comply with IEC 61010 Safety Standards, and has been thoroughly tested for safety prior to shipment. However, mishandling during use could result in injury or death, as well as damage to the instrument. Be certain that you understand the instructions and precautions in the manual before use. We disclaim any responsibility for accidents or injuries not resulting directly from product defects.

This manual contains information and warnings essential for safe operation of the instrument and for maintaining it in safe operating condition. Before using it, be sure to carefully read the following safety precautions.

Safety Symbols

⚠	In the manual, the ⚠ symbol indicates particularly important information that the user should read before using the instrument.
	The ⚠ symbol printed on the instrument indicates that the user should refer to a corresponding topic in the manual (marked with the ⚠ symbol) before using the relevant function.
~	Indicates AC (Alternating Current).
I	Indicates the ON side of the power switch.
O	Indicates the OFF side of the power switch.

The following symbols in this manual indicate the relative importance of cautions and warnings.

⚠WARNING	Indicates that incorrect operation presents a significant hazard that could result in serious injury or death to the user.
⚠CAUTION	Indicates that incorrect operation presents a possibility of injury to the user or damage to the instrument.
NOTE	Indicates advisory items related to performance or correct operation of the instrument.

Other Symbols

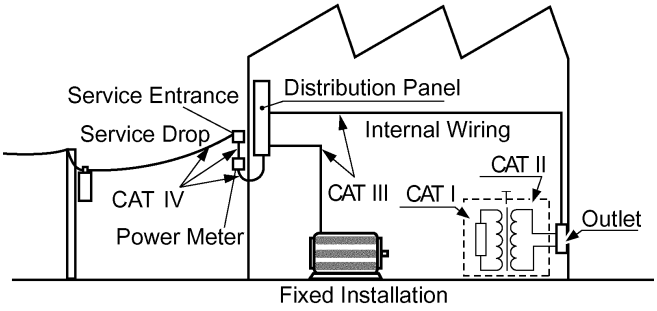
⊘	Indicates a prohibited action.
❖	Indicates the location of reference information.
? →	Indicates quick references for operation and remedies for troubleshooting.
*	Indicates that descriptive information is provided below.

Measurement categories (Overvoltage categories)

To ensure safe operation of measurement instruments, IEC 61010 establishes safety standards for various electrical environments, categorized as CAT I to CAT IV, and called measurement categories. These are defined as follows.

CAT I	Secondary electrical circuits connected to an AC electrical outlet through a transformer or similar device.
CAT II	Primary electrical circuits in equipment connected to an AC electrical outlet by a power cord (portable tools, household appliances, etc.)
CAT III	Primary electrical circuits of heavy equipment (fixed installations) connected directly to the distribution panel, and feeders from the distribution panel to outlets.
CAT IV	The circuit from the service drop to the service entrance, and to the power meter and primary overcurrent protection device (distribution panel).

Higher-numbered categories correspond to electrical environments with greater momentary energy. So a measurement device designed for CAT III environments can endure greater momentary energy than a device designed for CAT II.
Using a measurement instrument in an environment designated with a higher-numbered category than that for which the instrument is rated could result in a severe accident, and must be carefully avoided.
Never use a CAT I measuring instrument in CAT II, III, or IV environments.
The measurement categories comply with the Overvoltage Categories of the IEC60664 Standards.



Accuracy

We define measurement tolerances in terms of f.s. (full scale), rdg. (reading) and dgt. (digit) values, with the following meanings:

f.s.	(maximum display value or scale length) The maximum displayable value or scale length. This is usually the name of the currently selected range.
rdg.	(reading, displayed or indicated value) The value currently being measured and indicated on the measuring instrument.
dgt.	(resolution) The smallest displayable unit on a digital measuring instrument, i.e., the input value that causes the digital display to show a "1" as the least-significant digit.

Operating Precautions

Follow these precautions to ensure safe operation and to obtain the full benefits of the various functions.

Before Use

- Before using the instrument the first time, verify that it operates normally to ensure that the no damage occurred during storage or shipping. If you find any damage, contact your dealer or Hioki representative.
- Before using the instrument, make sure that the insulation on the probes and cables is undamaged and that no bare conductors are improperly exposed. Using the instrument in such conditions could cause an electric shock, so contact your dealer or Hioki representative for replacements.

Handling the Instrument

⚠WARNING

- **Do not allow the instrument to get wet, and do not take measurements with wet hands. This may cause an electric shock.**
- **Never modify the instrument. Only Hioki service engineers should disassemble or repair the instrument. Failure to observe these precautions may result in fire, electric shock, or injury.**
- **Do not use the instrument where it may be exposed to corrosive or combustible gases. The instrument may be damaged or cause an explosion.**

⚠CAUTION

To avoid damage to the instrument, protect it from physical shock when transporting and handling. Be especially careful to avoid physical shock from dropping.

Handling the Cords and Probes

⚠CAUTION

- Avoid stepping on or pinching cables, which could damage the cable insulation.
- To avoid breaking the cables and test leads, do not bend or pull them.
- To avoid damaging the power cord, grasp the plug, not the cord, when unplugging it from the power outlet.
- The sensor used in the temperature probe is a thin, precision platinum film. Be aware that excessive voltage pulses or static discharges can destroy the film.
- Avoid subjecting the temperature probe tip to physical shock, and avoid sharp bends in the leads. These may damage the probe or break a wire.
- When measuring high temperatures, do not let the handle of the temperature probe or the compensation lead wire exceed the temperature range.

NOTE

- Use only the specified test leads and cables. Using a non-specified cable may result in incorrect measurements due to poor connection or other reasons.
- To avoid measurement errors, be sure to wipe the temperature probe plug, if necessary, to keep it clean.

Instrument Installation and Operating Environment

⚠CAUTION

- Do not install the instrument upside-down, or stand it on its side.
- Do not store or use the instrument where it could be exposed to direct sunlight, high temperature or humidity, or condensation. Under such conditions, the instrument may be damaged and insulation may deteriorate so that it no longer meets specifications.
- This instrument is designed for use indoors. It can be operated at temperatures between 0 and 40°C without degrading safety.
- This instrument is not designed to be entirely water- or dust-proof. Do not use it in an especially dusty environment, nor where it might be splashed with liquid. This may cause damage.
- Do not use the instrument near a source of strong electromagnetic radiation, or near a highly electrically charged object. These may cause a malfunction.

NOTE

- Correct measurement may be impossible in the presence of strong magnetic fields, such as near transformers and high-current conductors, or in the presence of strong electromagnetic fields such as near radio transmitters.
- In an electrically noisy environment, noise may impinge upon the measured object, resulting in unstable measurements. The instrument should not be used in such places.

Before Connecting and Powering On

WARNING

Power and Grounding

- **Before turning the instrument on, make sure the supply voltage matches that indicated on the its power connector. Connection to an improper supply voltage may damage the instrument and present an electrical hazard.**
- **To avoid electrical accidents and to maintain the safety specifications of this instrument, connect the power cord only to a 3-contact (two-conductor + ground) outlet.**

Connections

To avoid electric shock or damage to the equipment, always observe the following precautions when connecting to external terminals or connectors.

- **Always turn off the power to the instrument and to any devices to be connected before making connections.**
- **Be careful to avoid exceeding the ratings of external terminals and connectors.**
- **During operation, a wire becoming dislocated and contacting another conductive object can be serious hazard. Make sure that connections are secure and use screws to secure the external connectors.**

NOTE

To suppress noise, the instrument needs to be set to match the frequency of the power source.
Before operating, set the instrument to the frequency of your commercial power. If the line frequency is not set properly, measurements will be unstable.
❖ 2.8 Selecting the Line Frequency (Page 26)

Measurement Precautions

⚠WARNING

Observe the following to avoid electric shock and damage to the instrument.

- **Do not apply voltage to the input terminals (INPUT A and INPUT B). Also, to avoid electrical accidents, only take measurements after turning off the power to the circuit being measured.**
- **Do not allow voltage of 2 V DC or more to be applied to the TC SENSOR jack.**

⚠CAUTION

- Never attempt to measure at a point where voltage is present.
  In particular, be careful to avoid damaging the instrument from inductor discharge when attempting to measure a transformer or motor immediately after a temperature increase test or withstand-voltage test.
- The input terminals incorporate a circuit protection fuse.
  Measurement is not possible when the fuse is blown.
- In the 20 mΩ and 200 mΩ ranges (1 A measurement current), the test object can be loaded with one watt or more. Also, in the 100 kΩ range and above, 10 volts or more may be applied. Therefore, when measuring delicate components, use the Low-Power Resistance Measurement mode.
- Allowable input voltage from an analog thermometer is 0 to 2 V (between terminal contacts). Do not apply voltage exceeding this range.
- Battery internal resistance cannot be measured with this instrument. It will sustain damage. To measure battery internal resistance, we recommend the HIOKI 3550, 3551 and 3555 BATTERY HiTESTERs or the 3560 AC mΩ HiTESTER.

NOTE

- To ensure certified measurement accuracy, allow at least 60 minutes warm-up. Within the 30- to 60-minute warm-up period, please double specified accuracy values. After warm-up, be sure to execute self-calibration.
  ❖ 5.8 Self-Calibration (Page 68)
- This instrument internally stores (backs up) all settings (except measurement values), such as measurement range, comparator settings and etc., but only when no operation is performed for a certain time. Therefore, to preserve settings, do not turn the power off for a short time (about five seconds) after changing a setting. However, measurement settings made through the RS-232C or GP-IB interface and measurement settings loaded by LOAD signals of the external I/O terminal are not memorized.
- The direct current that this instrument uses for measuring is affected by thermoelectromotive force, which can cause measurement aberrations. In such cases, use the Offset Voltage Compensation function.
  ❖ 5.7 Offset Voltage Compensation (OVC) (Page 66)
  ❖ Appendix 4 Effect of Thermoelectromotive Force (Page 183)
- When measuring objects with a large inductance (L-content) such as power transformers, the measured value may be unstable. In such cases, contact your dealer or Hioki representative.

Using the Temperature Probe

- Holding the temperature probe in a bare hand can cause enough noise pickup to destabilize measurements.
- Temperature Correction does not work if the temperature probe is allowed to touch the test object. Only the ambient temperature of the immediate locale should be used.
- Before measuring, install the temperature probe and allow at least 60 minutes warm-up before measurement. Unless the test object and temperature probe used for temperature correction measurement have been allowed to completely stabilize at ambient temperature, large measurement errors may occur.
- Unless the temperature probe is inserted all the way into the TC SENSOR jack on the rear panel of the instrument, large measurement errors may occur.

Chapter 1 Overview

1.1 Product Overview

The 3541 employs a four-terminal measurement method that is ideal for measuring the resistance of motor and transformer windings, relay/switch and connector contacts, PCB patterns, chip inductor DC resistance and for ohmmeter shipping inspection tests. The instrument includes functions for temperature correction, comparator decisions and data output, making it particularly suitable for production and inspection lines, as well as for system applications.

1.2 Features

High Precision, Fine Resolution and Fast Resistance Measurement

The 4-terminal method enables precise, fast measurement of resistances as small as 0.1 μΩ.
In addition, resistance measurements can be made as in as little as 0.6 ms.

Offset Voltage Compensation

Removes the effects of thermoelectromotive force on measurements.

Low-Power Measurement Function

Minimizes stress on test objects.

Multipolar Connector

A multipolar connector (INPUT B) shielded from thermoelectromotive force is provided to facilitate fast measurements.

Broad Temperature Correction Support

By connecting a temperature probe, temperature correction of resistance measurements is available for practically any temperature and thermal coefficient. A thermometer with analog output can be used in place of the supplied 9451 TEMPERATURE PROBE.

Temperature Conversion

The temperature increase (Δt) of a test object can be obtained by conversion of its measured resistance.

Statistical Calculation Functions

Maximum value (Max), minimum value (Min), mean value (Average), overall standard deviation (σ), and process capability indices (Cp and Cpk) can be calculated.

Comparator and BIN Functions

The Comparator function provides product pass/fail decisions. And the BIN function provides classification into up to ten categories.

Save and Load up to 30 Sets of Measurement Setting States

Store up to 30 sets of measurement settings such as comparator tables, measurement ranges and sampling rates for later recall.

External I/O

Various trigger inputs and comparator, BIN and BCD outputs are provided to support production line applications.

Equipped with GP-IB and RS-232C Standard Interfaces

Full remote control is available through the GP-IB and RS-232C interfaces.

Prints Measurement Values and Calculation Results (Printer Optional)

Connect the optional HIOKI 9670 PRINTER to print out measurement values and statistical calculation results.

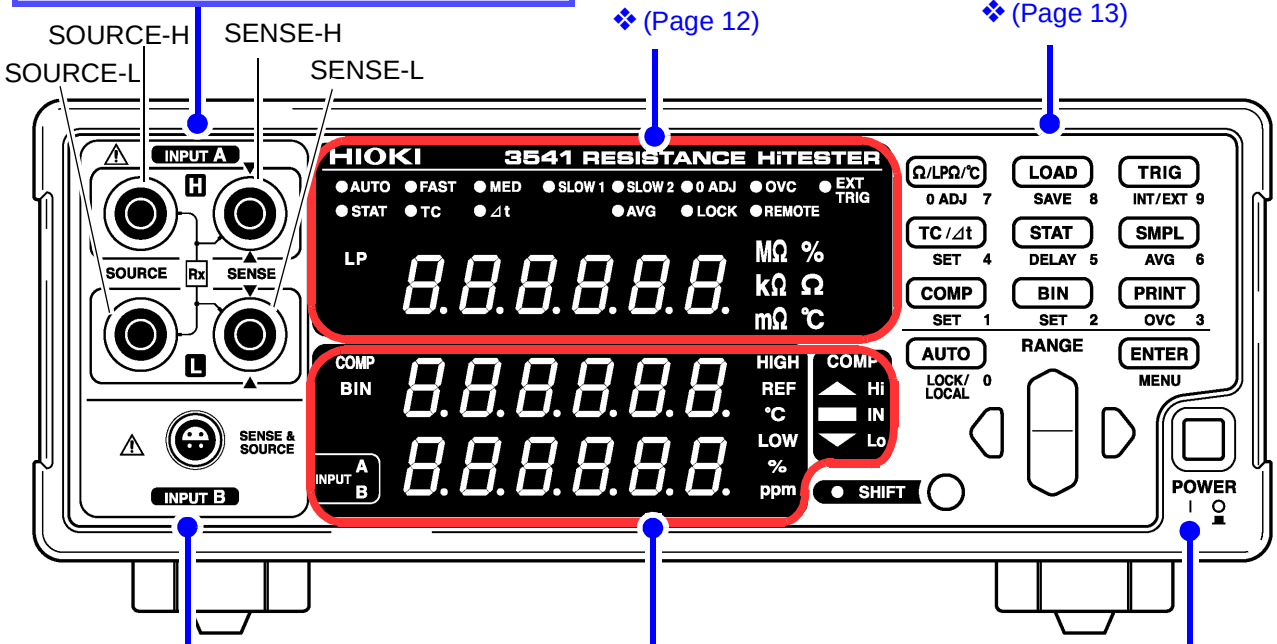
1.3 Names and Functions of Parts

Front Panel

Input Terminals INPUT A
Connect the supplied 9287-10 CLIP TYPE LEAD or optional measurement leads.

Display
Main Display
❖ (Page 12)

Operating Keys
❖ (Page 13)



Input Terminals INPUT B
Connect a multipolar plug.
❖ Connections: (Page 19)

Display
Sub Display
❖ (Page 12)

POWER Switch
Turns the instrument on and off.
○ : Power OFF
| : Power ON

❖ (Page 24)

Main Display

Displays the current measurement function, measured value (while measuring) or setting item (while setting).

(Upper row)

AUTO Lit when measuring with Auto-Ranging.

FAST, MED, SLOW1, SLOW2 The selected sampling rate is lit.

0 ADJ Lit when measuring in a range for which zero-adjustment has been performed.

OVC Lit when measuring with the Offset Voltage Compensation function enabled.

EXT TRIG Lit when the manual trigger mode is enabled.

(Lower row)

STAT Lit when the Statistical Calculation function is enabled.

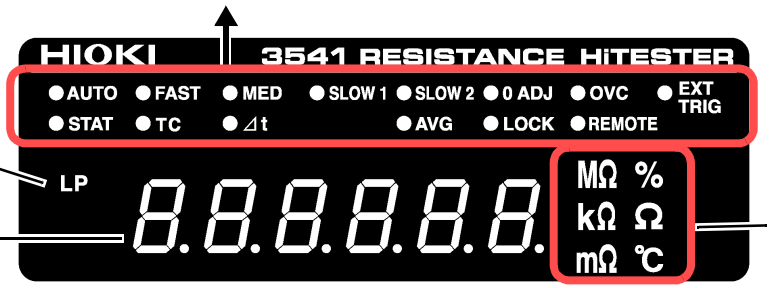
TC Lit when the Temperature Correction function is enabled.

Δt Lit when the Temperature Conversion function is enabled.

AVG Lit when measuring with the Averaging setting enabled.

LOCK Lit when the keys are locked.

REMOTE Lit during communications.



LP
Indicates Low-Power measurement mode.

Shows measured value or setting item.

Units of displayed measurement

Sub Display

Upper and lower thresholds and other settings are displayed (when set).

COMP
While measuring, indicates the Comparator function is enabled.

BIN
While measuring, indicates the BIN function is enabled.

INPUT
Indicates the selected measurement terminals.

HIGH / LOW Indicates that absolute value comparator operation is enabled (while measuring), and also when setting.

REF / % Indicates that relative value comparator operation is enabled (while measuring), and also when setting.

°C / ppm Indicates that the temperature correction or compensation value is displayed (while measuring), and also when setting.

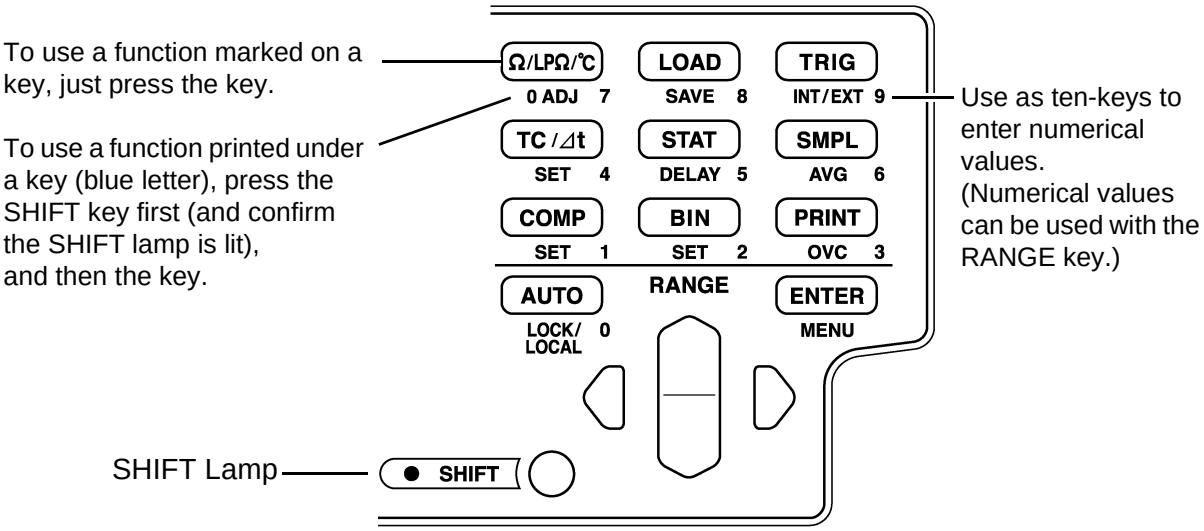
Shows Comparator Decision Result.

Hi Indicates that the measured value is above the upper threshold.

IN Indicates that the measured value is between the upper and lower thresholds.

Lo Indicates that the measured value is below the lower threshold.

Operating Keys



[ ]: Enabled after pressing the SHIFT key (SHIFT lamp lit).

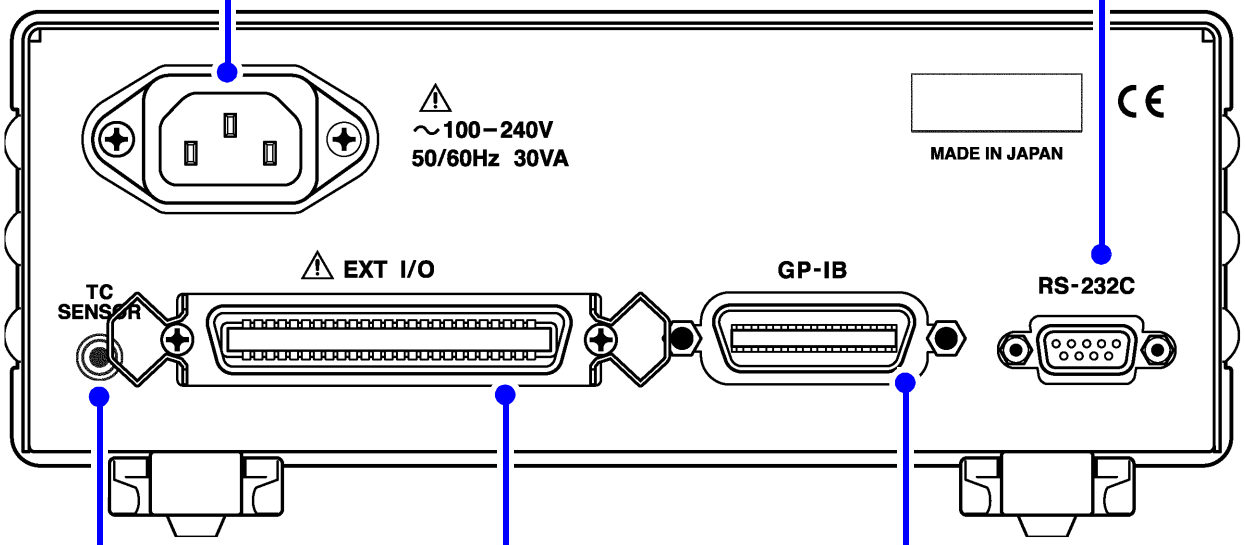
Operating Key	Description
Ω/LPΩ/°C	Select the measurement function (4-terminal resistance, low-power 4-terminal resistance or temperature measurement).
[0 ADJ]	Executes zero-adjustment.
LOAD	Loads saved settings.
[SAVE]	Saves settings.
TRIG	Use for manual triggering.
[INT/EXT]	Selects internal/external triggering.
TC/Δt	Switches Temperature Correction or Temperature Conversion on and off.
[SET]	Sets parameters for Temperature Correction or Temperature Conversion.
STAT	Displays and sets statistical calculation results.
[DELAY]	Sets the trigger delay.
SMPL	Selects the sampling rate.
[AVG]	Activates Averaging function settings.
COMP	Switches the Comparator function on and off.
[SET]	Activates Comparator function setting.
BIN	Switches the BIN function on and off.
[SET]	Activates BIN function setting.

Operating Key	Description
PRINT	Sends measurement values and statistical calculation results to the printer.
[OVC]	Switches the Offset Voltage Compensation function on and off.
AUTO	Switches between automatic and manual range selection.
[LOCAL/ LOCK]	LOCAL: Reverts from the communications state. LOCK: Switches the Key-Lock function on and off.
ENTER	Applies settings.
[MENU]	Selects various items. (Selects temperature correction/ conversion, calibration on/off, key beeper on/off, interface, line frequency and setting/system reset) ❖ (Page 15)
RANGE	Up/Down:Changes setting value or numerical value, and range selection. Left/Right: Moves the setting item or digit.
SHIFT	• Enables the functions of the operating keys marked in blue. The lamp is lit when the SHIFT state is active. • Cancels settings in various setting displays. (Returns to the Measurement display without applying settings.) However, this does not apply to Menu display.

Rear Panel

Power Inlet
Connect the supplied power cord here.
❖ (Page 18)

RS-232C Connector
Connection for the printer or RS-232C interface.
❖ Printer (Page 94), RS-232C (Page 103), Temperature HiTester (Page 23)



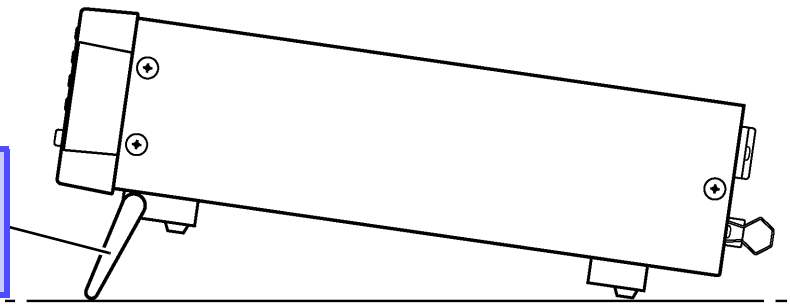
TC SENSOR Jack
Connect the 9451 TEMPERATURE PROBE or an analog-output thermometer here.
❖ (Page 21, 22)

EXT I/O Connector
Connect here to control operation externally.
❖ (Page 81)

GP-IB Connector
Connect here to use the GP-IB interface.
❖ (Page 103)

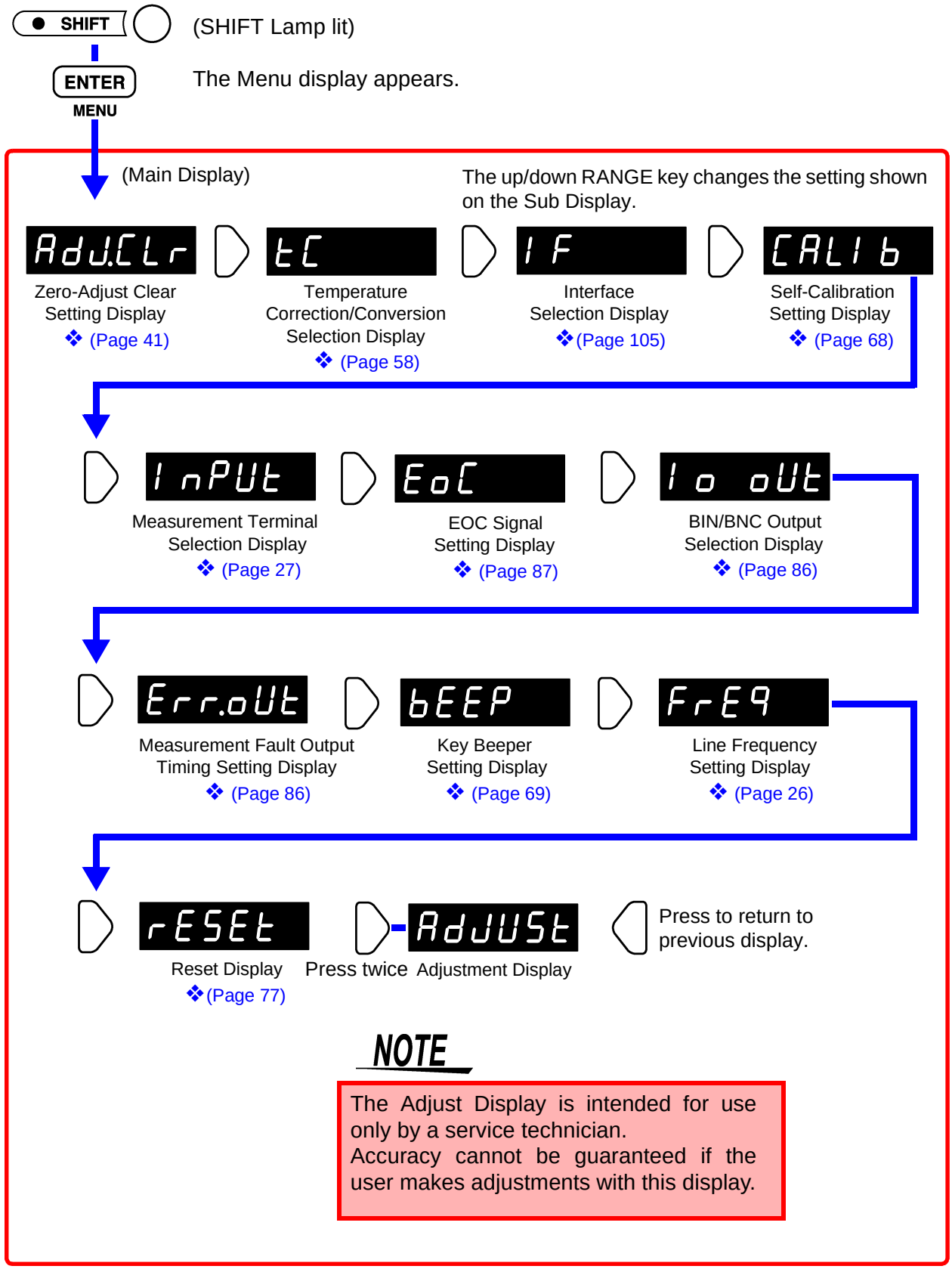
Side View

Stand
Can be opened to tilt the front panel upwards.



⚠CAUTION Do not apply heavy downward pressure with the stand extended. The stand could be damaged.

Menu Display Sequence



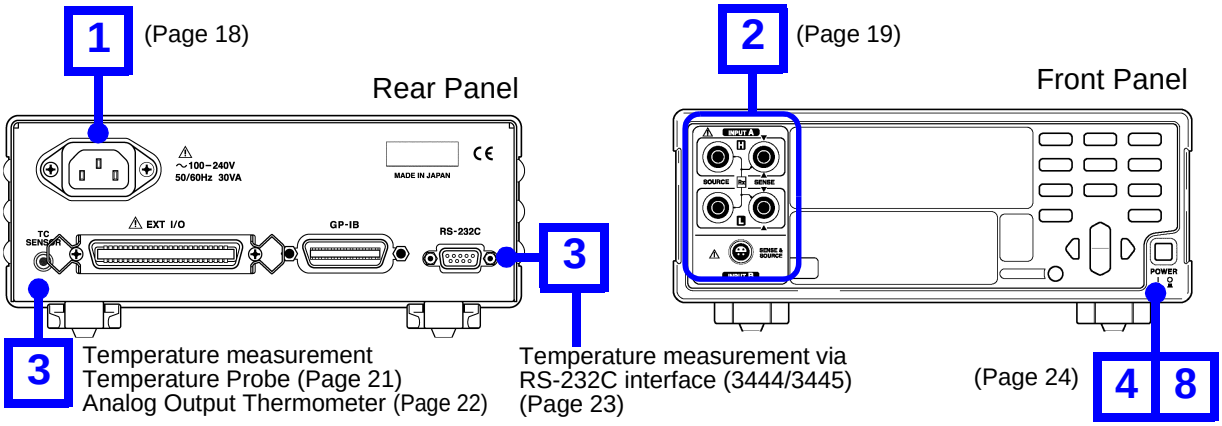
NOTE

The Adjust Display is intended for use only by a service technician.
Accuracy cannot be guaranteed if the user makes adjustments with this display.

NOTE Settings made from the Menu Display are saved internally when you press ENTER or SHIFT to return to the Measurement Display.

Measurement Preparations Chapter 2

2.1 Procedure



1 Connecting the power cord.

↓

2 Connect the test leads to the instrument.

↓

3 (If Temperature Correction is needed)
Connect the temperature probe, an analog temperature probe, or 3444/ 3445.

↓

4 Turn the power on.

↓

5 Select the line frequency. (Page 26)

↓

6 Select the measurement terminals. (Page 27)

↓

7 Set measurement settings, and measure.
Measurement Example (Page 29)
Settings (Pages 37 and 45)

↓

8 Turn the power off.

2.2 Connecting the Power Cord

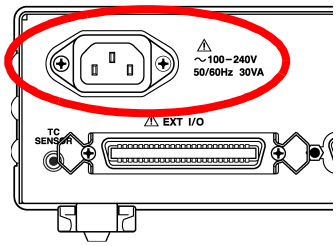
WARNING

- **Before turning the instrument on, make sure the supply voltage matches that indicated on the its power connector. Connection to an improper supply voltage may damage the instrument and present an electrical hazard.**
- **To avoid electrical accidents and to maintain the safety specifications of this instrument, connect the power cord only to a 3-contact (two-conductor + ground) outlet.**

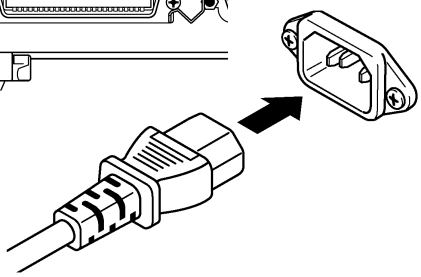
CAUTION

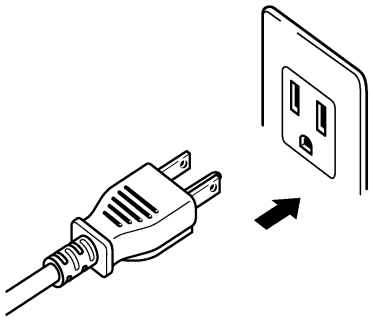
To avoid damaging the power cord, grasp the plug, not the cord, when unplugging it from the power outlet.

Connecting the Power Cord



Rear Panel





1. Confirm that the instrument's Power switch is OFF.

2. Check that the power supply voltage is correct, and connect the power cord to the power inlet socket on the rear of the instrument.

3. Plug the power cord into the AC outlet.

2.3 Connecting the Test Leads

This instrument is equipped with an input with four separate banana-jack terminals (INPUT A) and another input with a multipolar socket (INPUT B). The supplied Model 9287-10 CLIP TYPE LEAD and Hioki's various optional measurement leads connect to the INPUT A terminals.

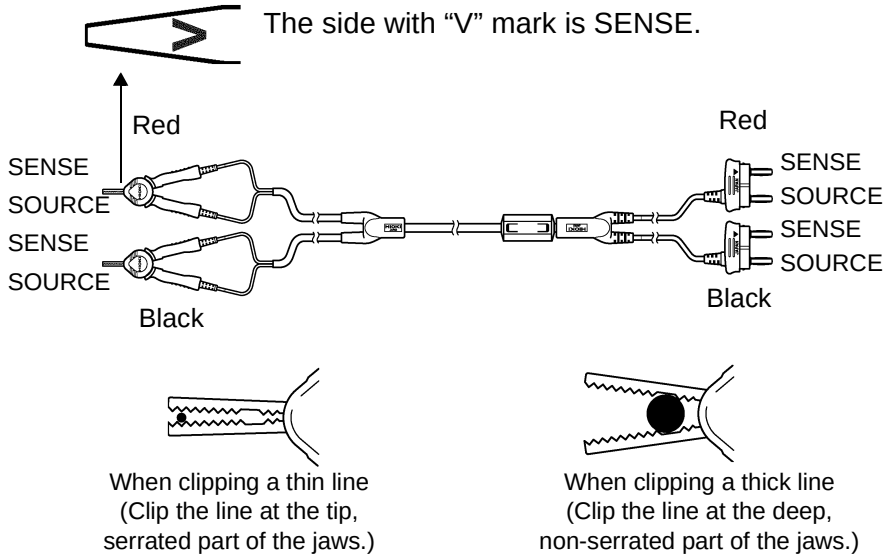
❖ Appendix 9 Test Lead Options (page 194)

For high-resistance and low-power measurements, the high noise immunity of INPUT B offers advantages for high speed measurements.

❖ 2.9 Selecting the Measurement Terminals (page 27)

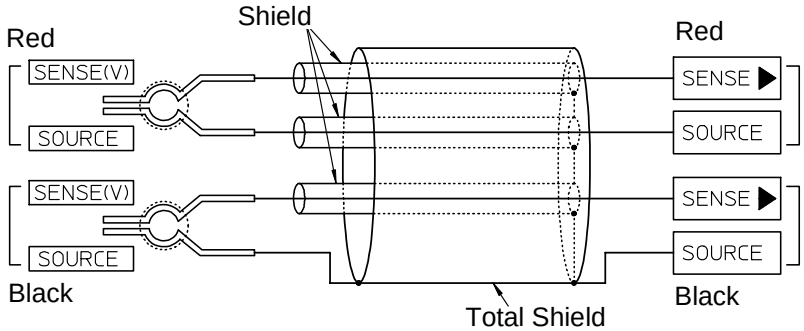
About Test Leads

(Example: Model 9287-10 CLIP TYPE LEAD)



Making your own cable

The cable of our test leads is shielded.
When making your own cable, please bear in mind the following.



Connect the shield to the SOURCE-L lead.
Cable length must not exceed 5 m. (Conductor resistance should be no more than 100 mΩ/m)
However, for the 20 mΩ and 200 mΩ ranges (1 A measurement current), resistance should be no more than 300 mΩ per circuit.

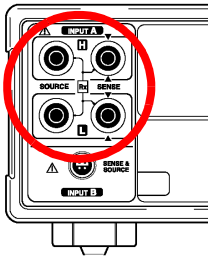
NOTE

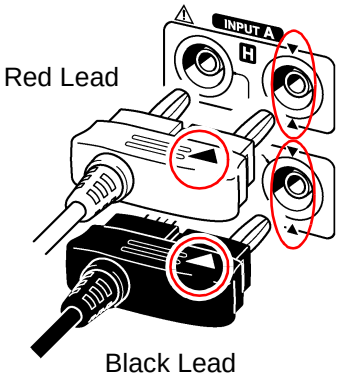
When using the 9287-10 without the clip, be careful not to allow the shielding wire to contact the conductor of SOURCE-Hi, SENSE-Hi, or SENSE-Lo conductor.

Connecting to the terminals

INPUT A Connection Method

Front Panel





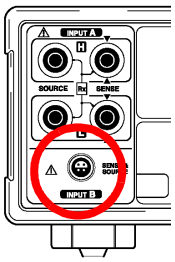
Example: 9287-10 CLIP TYPE LEAD

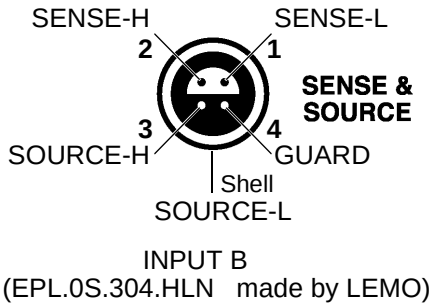
Connect four-terminal test leads such as the 9287-10 CLIP TYPE LEAD to INPUT A.

Plug the ▲ mark on the red lead into the red ▲ marked jack on the instrument, and plug the ▲ mark on the black lead into the black ▲ marked jack on the instrument.

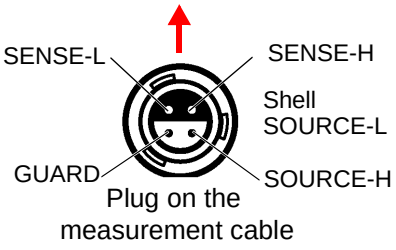
INPUT B Connection Method

Front Panel





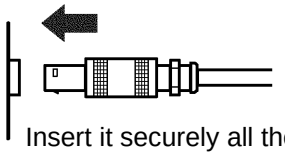
INPUT B
(EPL.0S.304.HLN made by LEMO)



Plug on the measurement cable

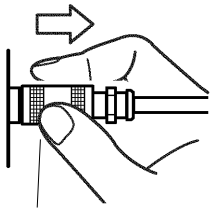
Make sure the plug on the test lead cable is properly oriented, and connect it to the INPUT B socket.

To Insert



Insert it securely all the way in

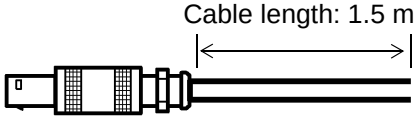
To Remove



Pull while holding as shown
(Lock release)

9300 CONNECTION CABLE

Cable length: 1.5 m

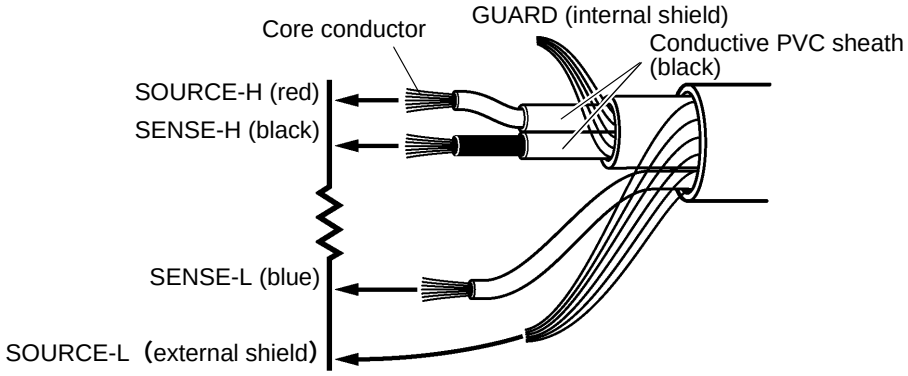


Pin no.	Terminals	Wires
2	SENSE-H	Black 26AWG
1	SENSE-L	Blue 26AWG
3	SOURCE-H	Red 26AWG
Shell	SOURCE-L	External shielded conductor
4	GUARD	Internal shielded conductor

⚠CAUTION

The cable connector (for INPUT B) is a locking type.
Always grasp the plug when removing the cable. Pulling on the cable will damage the connector.

9300 CONNECTION CABLE



NOTE

To suppress noise pick-up from cable friction, the SOURCE-H (red) and SENSE-H (black) leads are shielded in a conductive black PVC sheath.

- **Be careful to avoid touching the core conductors and conductive black PVC sheath during measurement.**
- **Also be careful to avoid touching the SENSE-H, SENSE-L, SOURCE-H, SOURCE-L and GUARD conductors.**
  Touching any of these can interfere with proper measurement.
- Do not connect the GUARD to anything.

2.4 Connecting the Temperature Probe

⚠WARNING

Do not apply voltage to the TC SENSOR jack, to avoid electric shock accidents or damage to the instrument.

⚠CAUTION

To avoid damage to the instrument or temperature probe, observe the following precautions:

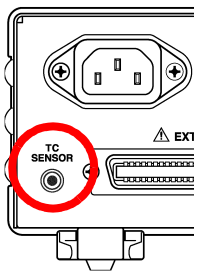
- Turn the instrument off before plugging or unplugging the temperature probe.
- The temperature probe is not waterproof. Do not submerse it in water or other liquid.

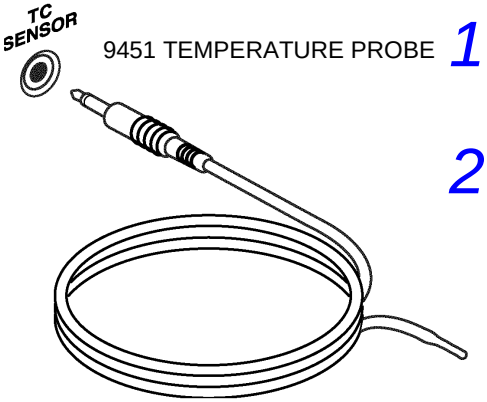
NOTE

To avoid measurement errors, be sure to wipe the temperature probe plug, if necessary, to keep it clean.

9451 TEMPERATURE PROBE Connection

Rear Panel





1. Confirm that the instrument power is turned OFF.
2. Plug the 9451 TEMPERATURE PROBE into the TC SENSOR jack on the rear panel.

Insert the plug securely all the way into the jack.

2.5 Connecting an Analog Output Thermometer

To measure temperature, connect the analog output thermometer to the instrument.
The connection requires a standard 3.5-mm monaural mini-phone plug.

The following TEMPERATURE HiTESTERs are available from Hioki:

- The Model 3444 TEMPERATURE HiTESTER (for long-focus, narrow-visual-field measurements) + 3909 INTERFACE PACK
- The Model 3445 TEMPERATURE HiTESTER (for short-focus, microscopic surface measurements) + 3909 INTERFACE PACK

⚠WARNING

Note that thermometer circuit is grounded. To avoid electric shock accidents or damage to the instrument, do not connect an analog output thermometer to the TC SENSOR jack that has any potential offset from ground.

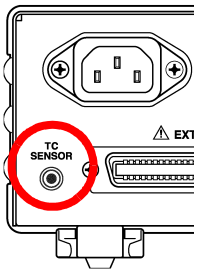
⚠CAUTION

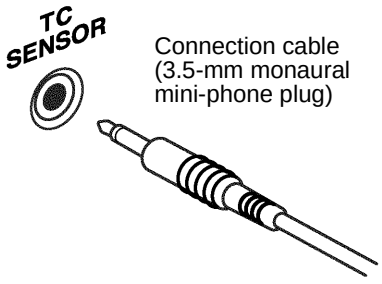
Note the following precautions to avoid damaging the instrument:

- Before connecting a thermometer to the instrument, confirm that any power to the instrument and thermometer is turned OFF.
- Allowable input voltage from an analog thermometer is 0 to 2 V (between terminal contacts). Do not apply voltage exceeding this range.
- With thermometers providing 4 to 20 mA output, connect a shunt resistance of about 100 Ω before connecting, and convert the resulting voltage.

Analog Output Thermometer Connection Method

Rear Panel





Insert the plug securely all the way into the jack.

1. Confirm that the instrument power is turned OFF.
2. Connect the thermometer's analog output connector to the TC SENSOR jack on the rear panel, using a generic connection cable (3.5-mm monaural mini-phone plug).

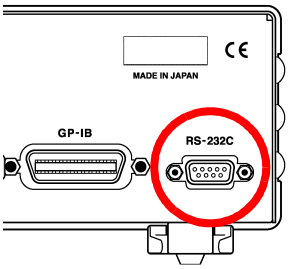
2.6 Connecting the Temperature HiTester via RS-232C

Using the RS-232C interface, you can connect the HIOKI 3444/ 3445 TEMPERATURE HiTESTERs to the unit for temperature measurement. The connection requires the 9637 RS-232C CABLE (option).

- The Model 3444 TEMPERATURE HiTESTER (for long-focus, narrow-visual-field measurements) + 3909 INTERFACE PACK
- The Model 3445 TEMPERATURE HiTESTER (for short-focus, microscopic surface measurements) + 3909 INTERFACE PACK

Connection Method

Rear panel



1. Confirm that power to the 3541 is turned OFF.
2. Connect the TEMPERATURE HiTESTER (3444 or 3445) to the 3909 INTERFACE PACK, using the cable supplied with the 3909.
3. Connect the 3909 INTERFACE PACK to the RS-232C connector of the 3541, using the 9637 RS-232C CABLE.

2.7 Turning the Power On and Off

Before Turning the Power On

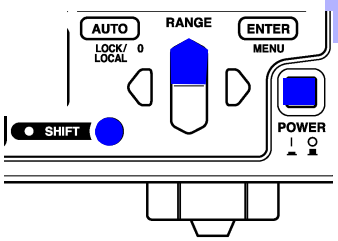
Upon turning the power on, you can select either 1 A (the default selection) or 100 mA as the measurement current for the 200 mΩ range (with software version 1.13 or later).
The measurement current is remembered even after turning the power off.

Turning the Power On

Power ON

When you don't need to change the measurement current for the 200 mΩ range (1 A measurement current):

Turn the POWER switch ON (I).



When you need to change the measurement current for the 200 mΩ range to 100 mA (first time only):

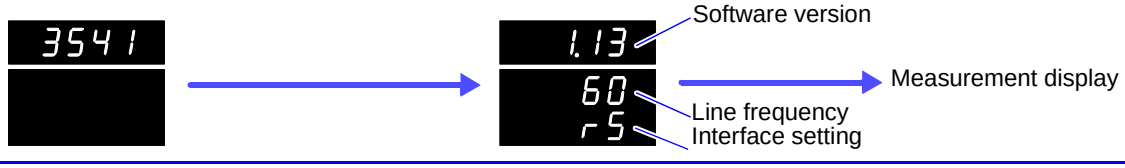
Turn the POWER switch ON (I) while holding down the SHIFT key and RANGE (up) key.

To return the measurement current to 1 A:
Turn the POWER switch ON (I) again while holding down the SHIFT key and RANGE (up) key, or use the Reset function. During power-on, the software version, line frequency setting, and interface setting appear briefly, and then the measurement display appears.

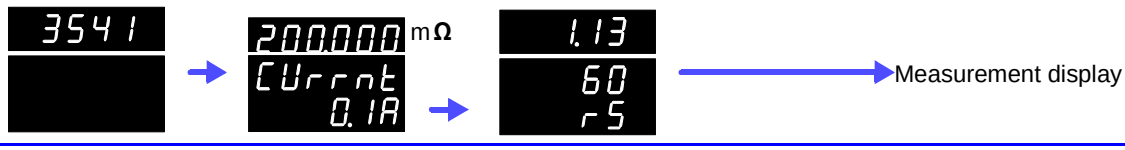
❖ 5.14 Reset Function (page 77)

After turning the power on, the following is displayed and the instrument enters the measurement state.

200mΩRange/Measurement Current 1 A Setting



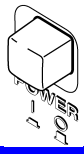
200mΩRange/100 mA Measurement Current Setting



- Measurement conditions are restored to the state that existed when the power was last turned off (from backup). To preserve changes to settings, wait a few moments (about five seconds after changing the settings) before turning the power off. However, note that measurement settings made through the RS-232C or GP-IB interface and measurement settings loaded through the external I/O LOAD terminal are not remembered.
- Before starting to measure, allow 60 minutes for warm-up. Within the 30- to 60-minute warm-up period, please note that specified accuracy values are doubled. After warm-up, be sure to perform self-calibration.

❖ 5.8 Self-Calibration (page 68)

Turning the Power Off



Power OFF ○ Turn the POWER switch OFF(○).

2.8 Selecting the Line Frequency

1 SHIFT + ENTER (MENU)

(SHIFT Lamp lit)

The Menu display appears.

2

Select the Line Frequency setting display.
(Refer to the Menu displays (Page 15))

(Main Display)

3

Select the frequency of the AC mains supply being used.

(Sub Display)

50 ..... 50 Hz
60 ..... 60 Hz

To select the measurement terminals immediately after selecting the line frequency, press ◁ to view the Measurement Terminal Selection display. (2.9 Selecting the Measurement Terminals (page 27) Step 3)

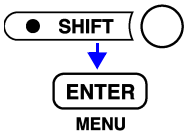
4 ENTER (MENU)

Applies settings and returns to the Measurement display.

NOTE

To suppress noise, the instrument needs to be set to match the frequency of the AC power source.
Before operating, set the instrument to the frequency of your commercial mains power. If the line frequency is not set properly, measurements will be unstable.

2.9 Selecting the Measurement Terminals

1 

(SHIFT Lamp lit)

The Menu display appears.

When continuing setting from Line Frequency Selection, skip this step.

2 

Select the Measurement Terminal selection display.
(Refer to the Menu displays (Page 15))

(Main Display)

When setting immediately after Line Frequency setting, press  .

3 

Select the measurement terminals to be used.

(Sub Display)

A..... INPUT A (with four separate banana jack terminals)
b..... INPUT B (multipolar connector)

4 

Applies settings and returns to the Measurement display.

Do not connect test leads to both INPUT A and INPUT B.
SENSE-L and SOURCE -L are always connected. Note that multiple measurements cannot be performed simultaneously.

About Input Terminal Usage

The factory-default input terminal selection is INPUT A, the four (banana jack) terminals, enabling use of Hioki's various test-lead options.

INPUT A

A 10 nF capacitor is connected between the H-L terminals of INPUT A. This capacitance is intended to improve the stability of high-resistance measurements and measurements of inductive loads. However, this also slows the response time for high-resistance measurements.

The approximate response time required to display about 95% of the resistance of a test object is:

$$\text{Response time [s]} = 3 \times \text{Resistance [}\Omega\text{]} \times 10 \times 10^{-9}\text{ [F]}$$

Even with the 10 nF capacitor, stability cannot be assured with all inductive loads. Inductance of 10 H or more may cause instability. In such cases, connect a 0.1-μF or larger capacitor between H and L, or contact your supplier or Hioki representative for other solutions.

For fast response with high-resistance measurements, use INPUT B (the multipolar connector), which has no 10-nF capacitor. However, because INPUT B has no (10 nF) capacitor, measurements may be unstable with some inductive test objects.

INPUT B

INPUT B offers the advantages of being less affected by thermoelectromotive force than the four separate terminals of INPUT A, and is more suitable for high-speed measurements due to the shielding. When you need to take measurements faster than once per PLC (power line cycle) without OVC (Offset Voltage Compensation), use INPUT B.

Chapter 3 Measurement

Before starting measurement, please read Safety Information (Page 2) and Chapter 2 Measurement Preparations (Page 17).

3.1 Resistance Measurement

The following example describes the resistance measurement process.

Example: Measuring a 10 mΩ shunt resistance

Required items:	10 mΩ shunt resistance 9287-10 CLIP TYPE LEAD
Measurement conditions:	Sampling ..... SLOW2 Zero adjust ..... Enabled Offset Voltage Compensation ..... Enabled Range ..... 20 mΩ

Preparations

1 Connect the 9287-10 CLIP TYPE LEAD to the instrument, and turn it on.

❖ 2.3 Connecting the Test Leads (Page 19)

2 Select the appropriate line frequency and measurement terminals.

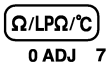
❖ 2.8 Selecting the Line Frequency (Page 26)

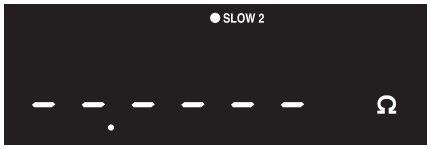
Instrument Settings

Before setting, confirm that the SHIFT lamp is not lit.

1 Select the Resistance Measurement function.

❖ 4.1 Selecting Measurement Functions (Page 37)



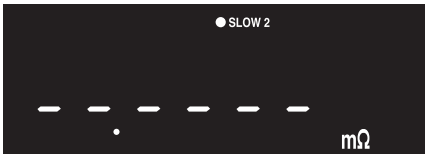


(Main Display)

The Resistance Measurement display appears.
(Ω unit indicator lit, LP off)

2 Set the measurement range to 20 mΩ.

❖ 4.2 Measurement Range Setting (Page 38)



(Main Display)

The position of the decimal and the unit indicator change with each key-press.
(mΩ lit, AUTO off)

3 Set the sampling rate to SLOW2.

❖ 4.4 Sampling Rate Setting (Page 42)

(Main Display)
The lit position moves with each key-press.
(**SLOW2** lit)

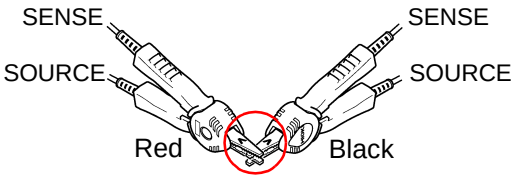
4 Enable Offset Voltage Compensation.

❖ 5.7 Offset Voltage Compensation (OVC) (Page 66)

(Main Display)
(**OVC** lit)

5 Execute zero-adjust.

❖ 4.3 Zero-Adjust Function (Page 40)



Short together the 9287-10 CLIP TYPE LEAD.

Bring the "V" marks together at the same position.

(Main Display)
Accept the currently displayed value as the zero-adjust value.
(**0ADJ** lit)

Applying Temperature Correction

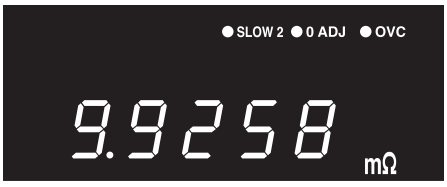
❖ 3.2 Temperature Measurement (Temperature Correction & Conversion) (Page 32),
5.4 Temperature Correction Function (TC) (Page 58)

Applying Temperature Conversion

❖ 3.2 Temperature Measurement (Temperature Correction & Conversion) (Page 32),
5.5 Temperature Conversion Function (Dt) (Page 60)

Measurement

Connect the 9287-10 CLIP TYPE LEAD to the shunt resistance, and read the value.



NOTE

- In the 20 mΩ and 200 mΩ ranges (1 A measurement current), the sample can consume one watt or more. Also, in the 100 kΩ range and above, up to 10 volts may be applied. Therefore, when measuring delicate components, use the Low-Power Resistance Measurement mode.
- In the following cases, the measured value may be displayed with a "-" sign.
  - If SOURCE or SENSE leads are reversed.
  - If zero-adjust is performed by two-terminal measurement, and contact resistance later decreases.
  - If the thermoelectromotive force changes, or the offset voltage of the instrument changes.

3.2 Temperature Measurement (Temperature Correction & Conversion)

Temperature Correction Using the temperature at time of measurement, temperature correction is applied to convert the measured resistance value to the value it would have at a specified reference temperature.

❖ 5.4 Temperature Correction Function (TC) (Page 58)

Temperature Conversion Temperature increase is derived by the temperature conversion principle.

❖ 5.5 Temperature Conversion Function (Dt) (Page 60)
❖ Appendix 3 Temperature Conversion Function (Dt) (Page 182)

Temperature Measurement with the 9451 TEMPERATURE PROBE

Preparations

1 Connect the test leads and the 9451 TEMPERATURE PROBE to the instrument, and turn it on.

❖ 2.3 Connecting the Test Leads (Page 19),
2.4 Connecting the Temperature Probe (Page 21)

2 Select the appropriate line frequency and measurement terminals.

❖ 2.8 Selecting the Line Frequency (Page 26),
2.9 Selecting the Measurement Terminals (Page 27)

Instrument Settings

Before setting, confirm that the SHIFT lamp is not lit.

1 Select the Temperature Measurement function.

❖ 4.1 Selecting Measurement Functions (Page 37)

Ω/LPΩ/℃ (0 ADJ 7)

(Main Display) The Temperature Measurement display appears. (°C unit indicator lit) The current temperature appears.

2 Select Pt for the temperature sensor type.

SHIFT

TC/⊿t (SET 4)

(Main Display) The temperature sensor type selection display appears.

(Sub Display) Select Pt.

ENTER (MENU) Apply settings and return to the Measurement display.

Temperature Measurement

Place the 9451 TEMPERATURE PROBE near the point to measure, and read the temperature.

(Main Display) Read the current temperature.

Temperature Correction & Conversion Settings

Select resistance or low power measurement, and select temperature correction or conversion.

- ❖ For temperature correction: 5.4 Temperature Correction Function (TC) (Page 58)
- ❖ For temperature conversion: 5.5 Temperature Conversion Function (Dt) (Page 60)

Measurement

Connect the test leads to the sample, and measure.

TC /⊿t
SET 4

With temperature correction: The corrected resistance value at the specified reference temperature is displayed.

With temperature conversion: The temperature increase ⊿t relative to ambient temperature is displayed.

About the temperature probe

NOTE

- If the temperature probe is held in the bare hand, body temperature will interfere with temperature measurement.
- The temperature probe is not waterproof.Do not submerse it in water or other liquid.
- If the temperature probe is not inserted all the way into the TC SENSOR jack on the rear panel, large measurement errors may occur.

If the OF indicator appears with temperature measurement	Check whether the temperature probe is connected properly. If it is not, temperature cannot be measured.
If the tC SnS error indicator appears with resistance measurement	Check whether the temperature probe is connected properly. If it is not, the TC/⊿t function is not usable.

Temperature Measurement with Analog Input (Radiation Thermometer)

Preparations

1 Connect the test leads and the analog output thermometer (radiation thermometer) to the instrument, and turn it on.

❖ 2.3 Connecting the Test Leads (Page 19),
2.4 Connecting the Temperature Probe (Page 21)

2 Select the appropriate line frequency and measurement terminals.

❖ 2.8 Selecting the Line Frequency (Page 26),
2.9 Selecting the Measurement Terminals (Page 27)

Instrument Settings

Before setting, confirm that the SHIFT lamp is not lit.

1 Select the Temperature Measurement function.

❖ 4.1 Selecting Measurement Functions (Page 37)

Ω/LPΩ/℃ (0 ADJ 7)

(Main Display) The Temperature Measurement display appears. (°C unit indicator lit)
The current temperature appears.

2 Select Analog (“AnLG.In”) for the temperature sensor type.

SHIFT

TC /⊿t (SET 4)

(Main Display) The temperature sensor type selection display appears.

(Sub Display) Select the Analog Input temperature sensor type.

ENTER (MENU) Apply settings.

3 Set the reference voltage and reference temperature.

Or ten-keys

(Main Display) Set Reference Voltage 1 (V_1) and Reference Temperature 1(T_1).

(Sub Display)
Reference Voltage 1 (V_1):
Setting range = 00.00 to 02.00 V
(In this example, 00.00 [V])
Reference Temperature 1 (T_1):
Setting range = -99.9 to 999.9°C
(In this example, 0000.0 [°C])

ENTER (MENU)

Apply the settings.
The setting display appears for Reference Voltage 2 and Reference Temperature 2.

Or ten-keys

(Main Display) Set Reference Voltage 2 (V_2) and Reference Temperature 2(T_2).

(Sub Display)
Reference Voltage 2 (V_2):
Setting range = 00.00 to 02.00 V
(In this example, 01.00 [V])
Reference Temperature 2 (T_2):
Setting range = -99.9 to 999.9°C
(In this example, 0100.0 [°C])

ENTER (MENU)

Apply settings and return to the Measurement display.

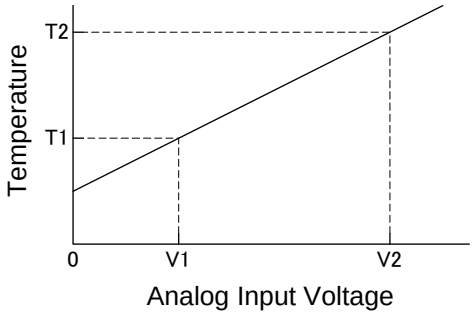
Measurement

Read the value. 

(Main Display)

The displayed value is calculated by the following expression.

$$\frac{T_2 - T_1}{V_2 - V_1} \cdot (\text{Input Voltage}) + \frac{T_1 V_2 - T_2 V_1}{V_2 - V_1}$$



Temperature measurement via RS-232C interface (using the 3444/3445 TEMPERATURE HiTESTER+ 3909 INTERFACE PACK)

Preparations

1 **Connect the test leads and the 3444/ 3445TEMPERATURE HiTESTER to the instrument, and turn it on.**

❖ 2.3 Connecting the Test Leads (Page 19),
2.6 Connecting the Temperature HiTester via RS-232C (Page 23)

2 **Select the appropriate line frequency and measurement terminals.**

❖ 2.8 Selecting the Line Frequency (Page 26),
2.9 Selecting the Measurement Terminals (Page 27)

Instrument Settings

Before setting, confirm that the SHIFT lamp is not lit.

1 **Select the Temperature Measurement function.**

❖ 4.1 Selecting Measurement Functions (Page 37)

Ω/LPΩ/℃
0 ADJ 7

(Main Display)

The Temperature Measurement display appears.
(°C unit indicator lit)
The current temperature appears.

2 **Select rS for the temperature sensor type.**

SHIFT

TC /Δt
SET 4

(Main Display)

(Sub Display)

The temperature sensor type selection display appears.

Select rS.
The 3444/ 3445 will be switched ON automatically.

ENTER
MENU

Apply settings and return to the Measurement display.

Temperature Measurement

Read the value.

(Main Display)

NOTE

- Temperature measurement via the RS-232C interface is possible only with the 3444/3445 TEMPERATURE HiTESTERs.
- When you set the temperature sensor type to "rS", power to the 3444/ 3445 will be switched ON automatically.
- If the 3444/3445 is not connected correctly or if it is not switched ON, the indication "OF" will be shown.
- While carrying out temperature measurement via the RS-232C interface, the RS-232C/GP-IB communication and printing functions are not available.

Basic Function Settings Chapter 4

4.1 Selecting Measurement Functions

Settings

Select the Resistance, Low-Power Resistance or Temperature measurement function.

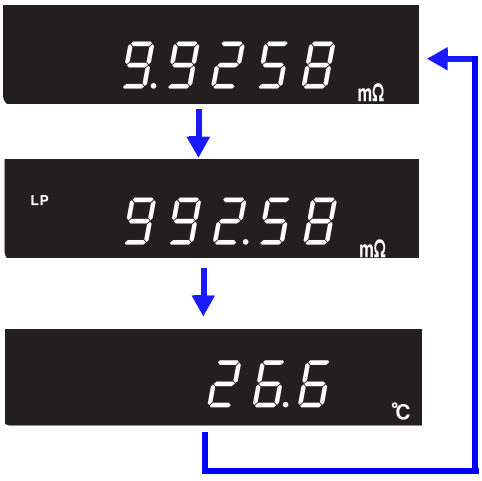
Switching the Measurement Function

1 Confirm the SHIFT lamp is not lit.

2 Ω/LPΩ/℃ (0 ADJ 7)

Switches the displayed measurement function.
Each key-press switches the measurement function.

(Main Display)



Resistance Measurement display (Ω unit indicator lit, LP indicator off)

Low-Power Resistance Measurement display (Ω unit indicator lit, **LP** indicator lit)

Temperature Measurement display (℃ unit indicator lit)

If the OF indicator appears with temperature measurement.

❖ If the temperature sensor is set to Pt: 3.2 Temperature Measurement (Temperature Correction & Conversion) (Page 32)
Check whether the temperature probe is connected properly.
If it is not, temperature cannot be measured.

4.2 Measurement Range Setting

Settings

Select the measurement range. Auto-ranging (the AUTO range) can also be selected.

Manual Range Setting

Select the range to use. (AUTO off)
The decimal point location and unit indicator change with each key-press.

Auto-Ranging

Press this while a manual range is selected. (**AUTO** lights)
The optimum measurement range is automatically selected.

Switching from Auto-ranging back to Manual range selection

Press the **AUTO** key again. The range can now be changed manually.

- Temperature measurement has only one range. The range cannot be changed.
- When measuring certain motor, transformer or coil components, the auto range setting may not stabilize. In such cases, either specify the range manually or lengthen the delay time.

❖ 5.11.2 Trigger Delay and Measurement Fault Detection Time (Page 72)

- In the low resistance ranges (200 Ω and below) a relatively high load is placed on the sample. In the 20 mΩ and 200 mΩ ranges (1 A measurement current), up to about one watt may be applied. Therefore, confirm the measurement range before connecting to delicate samples.
- When measuring delicate samples, use the Low Power measurement mode.
- Refer to 9.2 Accuracy; Resistance Measurement Function (Page 172), Low Power Resistance Measurement Function (Page 173) for information on range accuracy.

Range	Displayed Values	Resistance Measurement Function		Low Power Resistance Measurement Function	
		Measurement Current	Open-Terminal Voltage	Measurement Current	Open-Terminal Voltage*1
20mΩ	20.0000 mΩ	1 A ±5%	5 Vmax	————	————
200mΩ*2	200.000 mΩ	1 A ±5%	5 Vmax	————	————
2Ω	2000.00 mΩ	100 mA ±5%	2.6 Vmax	10 mA ±5%	60 mVmax
20Ω	20.0000 Ω	10 mA ±5%	2.6 Vmax	1 mA ±5%	60 mVmax
200Ω	200.000 Ω	10 mA ±5%	2.6 Vmax	100 μA ±5%	60 mVmax
2kΩ	2000.00 Ω	1 mA ±5%	2.6 Vmax	10 μA ±5%	60 mVmax
20kΩ	20.0000 kΩ	100 μA ±5%	2.6 Vmax	————	————
100kΩ	110.000 kΩ	100 μA ±5%	13 Vmax	————	————
1MΩ	1100.00 kΩ	10 μA ±5%	13 Vmax	————	————
10MΩ	11.0000 MΩ	1 μA ±5%	13 Vmax	————	————
100MΩ	110.000 MΩ	100 nA ±5%	13 Vmax	————	————

*1 When using external triggering, open-terminal voltage is limited to 20 mV maximum from when INDEX goes High until the next trigger input.

*2 100 mA measurement current and 2.6 V open-terminal voltage can be selected for the 200 mΩ range during power-up or by remote command.

❖2.7 Turning the Power On and Off (Page 24)

4.3 Zero-Adjust Function

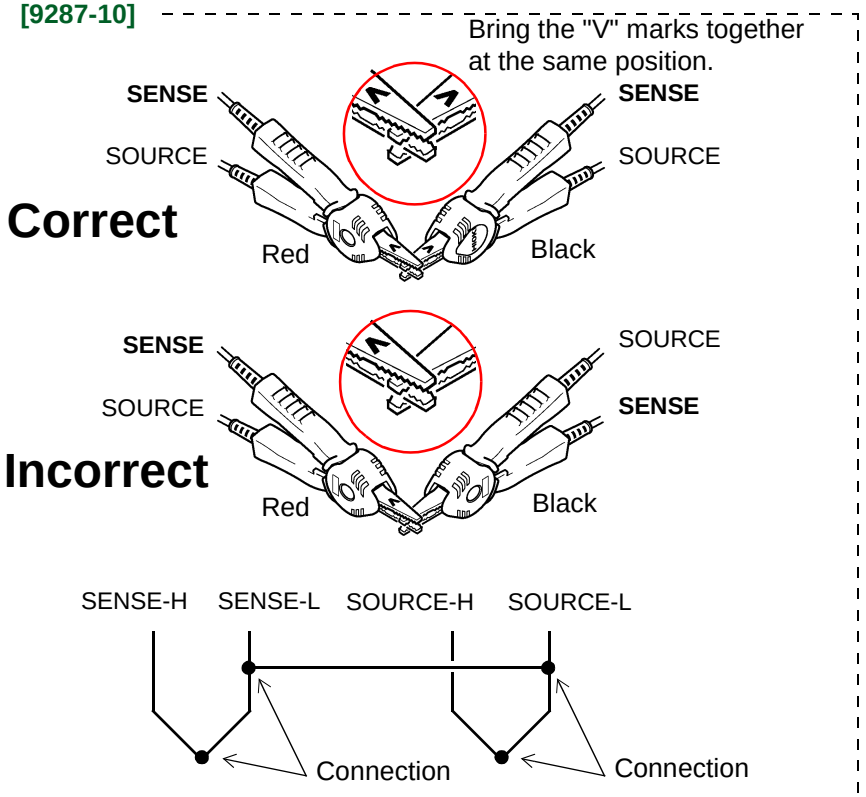
Settings

To nullify the instrument's offset voltage and effects of thermoelectromotive force, perform zero adjustment before measuring. Specified measurement accuracy applies only after zero adjustment has been performed.

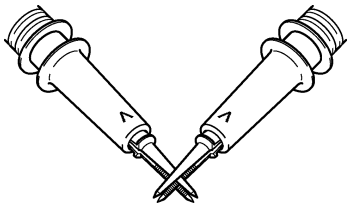
Executing Zero Adjustment

1 Short the test leads together. Proper zero adjustment is not possible with incorrect wiring.

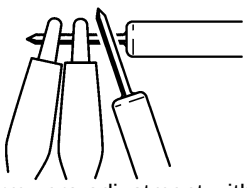
[9287-10]



[9452] (Option)

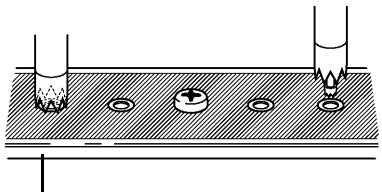


[9453] (Option)



Perform zero adjustment with the alligator clips and lead rods placed as above.

[9465] (Option)



9454 ZERO ADJUST BOARD (Option)

Contacts with SENSE
Contacts with SOURCE

2 SHIFT → Ω/LPΩ/℃ (0 ADJ 7) (SHIFT Lamp lit)

Zero-adjust display appears. (**0ADJ** lit)

(Main Display)

Zero adjustment is performed.

After measurement, the measured value of the compensation applied by the zero-adjust function is displayed.
The range of zero adjustment is up to 1,000 dgt.

NOTE

- Zero adjustment should be executed in each range to be used. When auto-ranging is selected, zero adjustment is executed in all ranges.
- When zero adjustment is executed with auto-ranging, correct zero adjustment may not be possible if the Delay time is too short. In this case, execute zero adjustment manually, or lengthen the Delay time.

❖ 5.11.2 Trigger Delay and Measurement Fault Detection Time (Page 72)

- Zero adjustment values are retained internally even when the instrument is turned off.
- Zero adjustment can be performed even when the 0ADJ pin of the EXT I/O connector is shorted to ground.
- Always perform zero adjustment after switching the Offset Voltage Compensation (OVC) function ON or OFF.

Clearing Zero Adjustment

1 SHIFT → ENTER (MENU) (SHIFT Lamp lit)

The Menu display appears.

(Main Display)

(Sub Display) flashing

2 ENTER (MENU)

The zero-adjust value is cleared.(0ADJ off)

(Main Display)

If OF is displayed

Appears when the value is outside of the following range.
The measurement value minus the zero-adjust value must be greater or equal to -2000 dgt and less than or equal to +200000dgt (20 mΩ to 20 kΩ), +110000dgt (100 kΩ to 100 MΩ)

If Err02 is displayed

The measurement value when attempting zero adjustment was more than 1000 dgt, or a measurement fault condition exists.
The zero adjust function is canceled, so repeat the operation after correcting the cause of the error.

4.4 Sampling Rate Setting

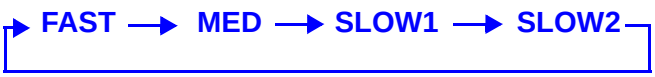
Settings

The sampling rate can be selected from FAST, MEDIUM, SLOW1 and SLOW2. Slower sampling rates generally provide greater measurement precision.

Selecting the Sampling Rate

SMPL
AVG 6

The sampling rate changes as follows with each key-press.



NOTE

- When AUTO self-calibration is enabled and FAST or MED sampling is selected, self-calibration is performed for about 55 ms once every 30 minutes.
  ❖ 5.8 Self-Calibration (Page 68)
- With FAST sampling selected, measurements can be easily affected by the external environment, so countermeasures such as shielding of the sample and test leads are recommended. Shields should be connected to the SOURCE-L side.

4.5 Measurement Fault Detection Function

If a measurement does not execute properly, a measurement fault is indicated on the display.
In addition, a measurement fault signal (ERR) is output at the EXT I/O connector.
❖ Chapter 6 External Control (Page 81)

- **OF Over indication**
  If the measurement value exceeds the prescribed range, "OF" (or "-OF") will appear on the Main Display.
  In the case of over indication, the abnormal measurement signal ("ERR") is not output, and the comparator judges the measurement to be High.

  Example :The range is set to 20 mΩ, and the measurement is 21 mΩ.

- **ErrCur Constant current fault**
  This instrument sends a constant current from the source terminal to the sample. If a constant current cannot be output from the source terminal, "ErrCur" will appear on the Main Display.
  If this error occurs, check the measurement range, the measurement lead connections, and probe contact.

  Example 1:The probe is open.
  Example 2:The source wire is badly connected or disconnected.
  Example 3:The measurement range is set 2 Ω, and the measurement is 100 Ω.
  (The standard is: open-circuit voltage / measurement current. If the measurement current is 1 A, the conductor resistance plus the resistance of the sample should equal less than approximately 500 mΩ.)
  Example 4:The 9300 connection cable is being used and the measurement terminal is INPUT A.
  Example 5:The circuit protection fuse is disconnected. (Repair is required if "ErrCur" remains even after the probe of the connected measurement lead is short-circuited.)
  ❖ 2.9 Selecting the Measurement Terminals (Page 27)

- **ErrHi Sense-Hi bad connection**
  This instrument uses sense terminals to measure the voltage between terminals on a sample.
  If there is a bad connection on the Sense-Hi wire, "ErrHi" will appear on the main display. If this error occurs, check the measurement lead connections and probe contact.
  A bad connection is detected when the resistance between SOURCE-H and SENSE-H reaches approximately 50 Ω.
  Alternatively, "ErrHi" will also be displayed if the circuit protection fuse is disconnected. (Repair is required if "ErrHi" remains even after the probe of the connected measurement lead is short-circuited.)

- **ErrLo Sense-Lo bad connection**
  If there is a bad connection on the Sense-Lo wire, "ErrLo" will appear on the main display. A bad connection is detected when the resistance between SOURCE-L and SENSE-L reaches approximately 35 Ω.

- **“- - - - - - “**
  If more than one of the above errors ("OF", "ErrCur", "ErrHi" or "ErrLo") occurs simultaneously, “- - - - - -” will appear on the Main Display.

NOTE

- If the measurement lead capacltance is 1 nF or greater, measurement abnormalities may not be detectable.
- It takes at least about 500 μs from probe contact with a test object for measurement to stabilize. To detect measurement faults accurately, you must start detection within the response time before starting internal measurement (with INDEX = Lo(OFF)).
  Because the response time depends on the test object, this instrument lets you set a measurement fault detection time. (The time before starting internal measurement)
  See 5.11.2 Trigger Delay and Measurement Fault Detection Time (Page 72), for how to set the detection time.
- If the delay time is set to 0.000 s, you cannot detect measurement faults before starting measurement. Therefore, you should set a delay time of at least 1 ms for secure measurement.
- Over display (OF) occurs as a result of the following factors.

Display	Condition
OF	• When the measured value before temperature correction exceeds the current measurement range. • When the result of temperature correction calculation or Δt exceeds 999,999 dgt. • When the result of relative value calculation is larger than +99.999%. • When the temperature sensor (with the Pt setting selected) is open-circuit.
-OF	• When the measurement value before temperature correction is smaller than -2000 dgt. • When the result temperature correction calculation or Δt exceeds -99,999 dgt. • When the result of relative value calculation is smaller than -99.999%.

Applied Function Settings Chapter 5

5.1 Comparator Measurement Function

Function Description

The comparator function compares measured values to preset upper and lower thresholds, judges the measurements according to their relative levels within the preset range, and indicates the results of the comparisons.
Comparator results can be indicated by the Hi, IN and Lo LEDs, beeper sound and signal output at the EXT I/O connector.

❖ For details about comparator signal outputs at the EXT I/O connector, refer to Chapter 6 External Control (Page 81).

Setting upper and lower thresholds to judge measured values (Comparator Measurement Function)

Example:Within the 2 kΩ range, set the upper threshold to 1 kΩ and the lower threshold to 800 Ω, and judge whether measured values exceed the upper or lower threshold.

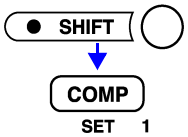
1 (COMP off) Confirm that the Comparator Measurement function is OFF.

2 

Select the appropriate range.

(Main Display)

In this case, select the 2 kΩ range. (2000.00 Ω)

3 

(SHIFT Lamp lit)
The Comparator Beeper setting display appears. (**COMP** lit)

(Main Display)

4 

Select whether and how the beeper should sound according to decision results.

(Main Display)

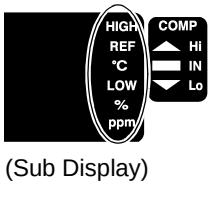
In this case, select **HL**.

oFF..... no beeps sound.
In ..... Beeps when the decision result is IN.
HL..... Beeps when the decision result is Hi or Lo.

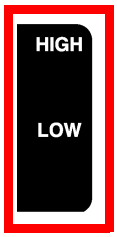
5

Switches to selection of the comparison method for the comparator.

Select the comparison method for the comparator. Each key-press changes the displayed selection.



(Sub Display)



Compare with upper/low thresholds

Compare with reference value/ tolerance

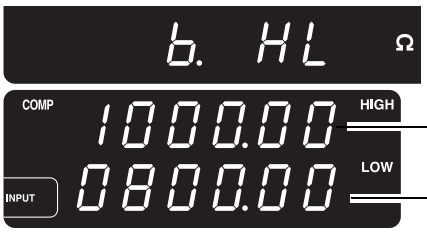
In this case, select **HIGH**/**LOW**.

6

Switches the display to upper/lower threshold setting.

Or ten-keys

Set the upper and lower thresholds.



(Main Display)

(Sub Display)

Upper threshold

Lower threshold

In this case, set the upper threshold to 1000 Ω and the lower threshold to 800 Ω.

Using the RANGE keys:

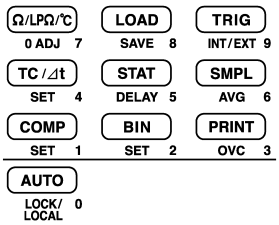
Select a digit to change by moving the blinking location, then select the new numerical value.

Select a digit

Select numerical value

Using the ten-keys:

Press the numeric keys corresponding to the digits to be entered.



7

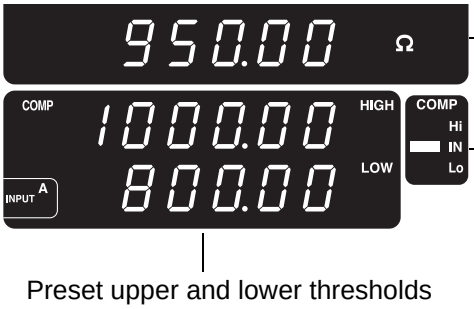
ENTER
MENU

Applies setting and returns to the Measurement display.
The comparator function is enabled.

To cancel the settings: SHIFT

8 COMP SET 1

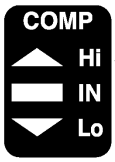
Connect to a test object, and judge the measured value.
The measured value appears on the Main Display, and the decision result is indicated in the decision result section of the Sub Display.



Measured value

Decision result
(IN = within range of upper/ lower thresholds)

Preset upper and lower thresholds



Upper threshold < Measured value
Upper threshold ≥ Measured value ≥ Lower threshold
Measured value < Lower threshold

NOTE

Upper and lower thresholds are stored as the actual entered digits, independent of measurement function and range.
When the measurement function or range is changed, the absolute value represented by the entered digits changes accordingly.

Example: To set the lower threshold to 3.8 Ω in the 20 Ω range, enter 038000. If you now switch to the 200 Ω range, the lower threshold becomes 38Ω.

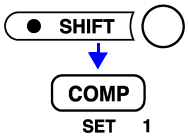
Judging measured values by setting a reference value and tolerance (Comparator Measurement Function)

Example: In the 20Ω range, set a reference value of 15Ω with 5% tolerance, so that when a measured value is judged to be within the specified tolerance, the beeper sounds.

1 (COMP off) Confirm that the Comparator Measurement function is OFF.

2 Select the appropriate range.

(Main Display) In this case, set to 20 Ω. (20.0000 Ω)

3 

(SHIFT Lamp lit)
The Comparator Beeper setting display appears. (**COMP** lit)

(Main Display)

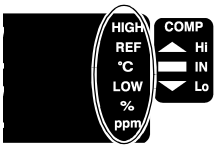
4 Select whether and how the beeper should sound according to decision results.

(Main Display) In this case, select **In**.

oFF..... no beeps sound.
In..... Beeps when the decision result is IN.
HL..... Beeps when the decision result is Hi or Lo.

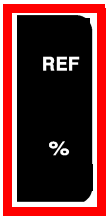
5 Switches to comparison method selection for the comparator.

Select the comparison method for the comparator. Each key-press changes the displayed selection.



(Sub Display)

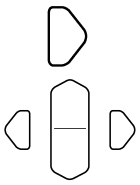
Compare with upper/low thresholds



Compare with reference value/ tolerance

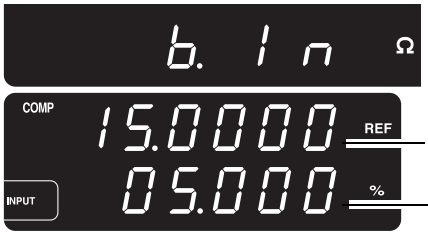
In this case, select **REF/%**.

6



Or ten-keys

Switches to reference/tolerance (%) setting display. Set the reference value and tolerance.



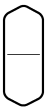
In this case, set the reference value to 15 Ω and the tolerance to 5%.

$$\frac{\text{Measured Resistance - Reference value}}{\text{Reference value}} \times 100$$

Using the RANGE keys:

Select a digit to change by moving the blinking location, then select the new numerical value.

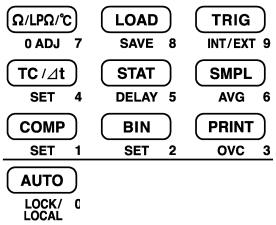
Select a digit



Select numerical value

Using the ten-keys:

Press the numeric keys corresponding to the digits to be entered.



7

ENTER
MENU

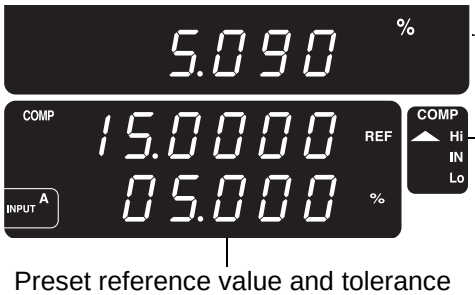
Applies setting and returns to the Measurement display.
The comparator function is enabled.

To cancel the settings: SHIFT ○

8

COMP
SET 1

Connect to a test object, and judge the measured value.
The relative value appears on the Main Display, and the decision result is indicated in the decision result section of the Sub Display.



Relative value

Decision result
(Hi = exceeds tolerance of reference)

Preset reference value and tolerance

$$\text{Relative value} = \frac{\text{Measured Resistance - Reference value}}{\text{Reference value}} \times 100$$

Set tolerance around reference value < Measured value
Set tolerance around reference value = Measured value
Set tolerance around reference value > Measured value

Executing Comparator Measurements

COMP
SET 1

COMP lit

The comparator measurement function is enabled.
Pressing the COMP key executes comparator decision according to the settings

Disabling the Comparator Measurement Function

COMP
SET 1

COMP off
The comparator measurement function is disabled.

NOTE

- Comparator and BIN measurements cannot be executed simultaneously.
- Auto-ranging is not available for comparator measurements. If auto-ranging is on when the comparator function is enabled, auto-ranging is disabled.
- To avoid operating errors, only the following keys are enabled when the comparator is being used:
  SAVE (SHIFT+LOAD), LOAD, STAT, TRIG (for external trigger), and PRINT (when a printer is connected)
  The comparator function must be disabled in order to change the threshold values.
  ❖ 5.15 Valid Functions for Each State (Page 79)
- +OF is judged to be Hi, and -OF is judged to be Lo. No decision occurs in the event of a measurement fault.
- If temperature correction is enabled and the temperature probe is improperly connected, or if the measured temperature is OF or -OF, no decision occurs.
- When comparing by reference value/tolerance, upper and lower thresholds are calculated internally for comparison with measured resistance.

$$\text{Upper threshold} = \text{Reference value} \times \frac{100 + \text{Tolerance [\%]}}{100}$$

$$\text{Lower threshold} = \text{Reference value} \times \frac{100 - \text{Tolerance [\%]}}{100}$$

  Therefore, even if the relative display value is the same as a decision threshold, it may be judged Hi or Lo.
  Example: If the reference value is set to 90.000 Ω and the tolerance is set to 0.012%, the upper threshold is 90.010 Ω. At this time, a measurement of 90.011 Ω will be displayed as 0.012%, but because it exceeds the upper threshold, it is judged as Hi.
- If power is turned off while the setting display is active, settings are ignored, and revert to their former values. If you want to apply the displayed settings, press the ENTER key.

5.2 BIN Measurement Function

Function Description

BIN Measurement compares a measured value with up to ten sets of upper and lower thresholds (BIN0 to BIN9) in one operation, and display the results.
Decision results are output at the EXT I/O connector.

❖ For details about BIN signal outputs at the EXT I/O connector, refer to 6.2 Signal Descriptions (Page 82).

To perform BIN measurement, first select the range, then set the upper and lower thresholds or the reference value/tolerance for each BIN No..

Setting upper and lower thresholds to judge measured values (BIN Measurement Function)

Example: In the 2 kΩ range, set up two decision states using different upper/lower thresholds (BIN0: Upper threshold 1 kΩ/Lower threshold 800 Ω and BIN2: Upper threshold 900 Ω/ Lower threshold 700 Ω), and judge measurements.

1 (BIN off)

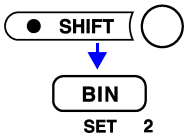
Confirm that the BIN Measurement function is OFF.

2

Select the appropriate range.

(Main Display) In this case, set to 2 kΩ. (2000.00 Ω)

3

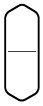


(SHIFT Lamp lit)
The Bin No. setting display appears. (**BIN** lit)

(Main Display) First set the conditions for BIN0, then set the conditions for BIN2.

BIN No. BIN No. enabled/disabled

4



Select the BIN No. (BIN No. = 0 to 9)

(Main Display) In this case, select **0**.

5

Select whether this BIN No. is to be enabled or disabled.

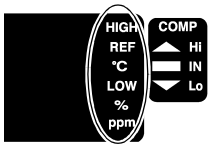
(Main Display) In this case, select **on**.

- - ..... BIN measurement for this BIN No. is disabled.
on ..... BIN measurement for this BIN No. is enabled.

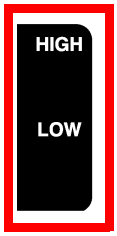
6

Switches to comparison method selection for measurements.

Select the comparison method. Each key-press changes the displayed selection.



(Sub Display)



Compare with upper/low thresholds

Compare with reference value/ tolerance

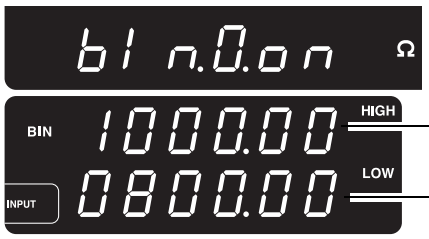
In this case, select **HIGH**/**LOW**.

7

Switches the display to upper/lower threshold setting

Or ten-keys

Set the upper and lower thresholds.



(Main Display)

(Sub Display)

Upper threshold

Lower threshold

In this case, set the upper threshold to **1000** Ω and the lower threshold to **800** Ω.

Using the RANGE keys:

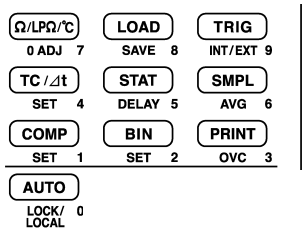
Select a digit to change by moving the blinking location, then select the new numerical value.

Select a digit

Select numerical value

Using the ten-keys:

Press the numeric keys corresponding to the digits to be entered.



8

Returns to the Main Display of this BIN No.

Repeat Steps 3 to 7 for each BIN No.

In this case, select BIN2 as shown at the left.

BIN2
Upper threshold: 900 Ω
Lower threshold: 700 Ω

9

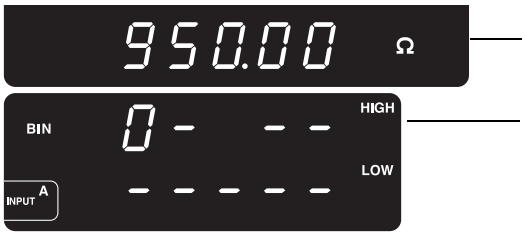
ENTER
MENU

Applies setting and returns to the Measurement display.
The BIN function is enabled.

To cancel the settings: ● SHIFT ○

10 BIN SET 2

Connect to a test object, and judge the measured value.
The measured value appears on the Main Display, and the decision result appears on the Sub Display.



Measured value

Decision result
(BIN0: in range, BIN2: out of range)

❖ Interpreting decision results:(Page 56)

NOTE

Upper and lower thresholds are stored as the actual entered digits, independent of measurement function and range.
When the measurement function or range is changed, the absolute value represented by the entered digits changes accordingly.

Example: To set the lower threshold to 3.8 Ω in the 20 Ω range, enter 038000. If you now switch to the 200 Ω range, the lower threshold becomes 38 Ω.

Judging measured values by setting a reference value and tolerance (BIN Measurement Function)

Example: In the 20Ω range, set up two comparisons using a reference value and tolerance for each (BIN0:Reference value 15 Ω/tolerance: 5%, BIN2:Reference value 15 Ω/tolerance: 2%).

1 (BIN off)

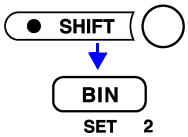
Confirm that the BIN Measurement function is OFF.

2

Select the appropriate range.

(Main Display) In this case, select the 20 Ω range. (20.0000 Ω)

3



(SHIFT Lamp lit)
The Bin No. setting display appears. (**BIN** lit)

(Main Display)

BIN No. BIN No. enabled/disabled

4

Select the BIN No. (BIN No. = 0 to 9)

(Main Display) In this case, select **0**.

5

Select whether this BIN No. is to be enabled or disabled.

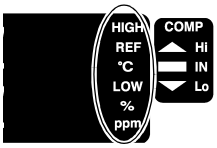
(Main Display) In this case, select **on**.

- - ..... BIN measurement for this BIN No. is disabled.
on ..... BIN measurement for this BIN No. is enabled.

6

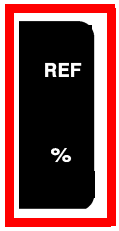
Switches to comparison method selection for measurements.

Select the comparison method. Each key-press changes the displayed selection.



(Sub Display)

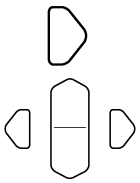
Compare with upper/low thresholds



Compare with reference value/ tolerance

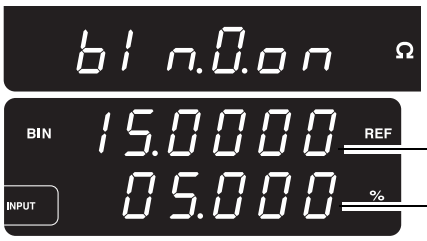
In this case, select **REF/%**.

7



Or ten-keys

Switches to reference/tolerance (%) setting display. Set the reference value and tolerance.



(Main Display)

(Sub Display)

In this case, set the reference value to **15** Ω and the tolerance to **5**%.

Reference value

Tolerance

$$\frac{\text{Measured Resistance - Reference value}}{\text{Reference value}} \times 100$$

Using the RANGE keys:

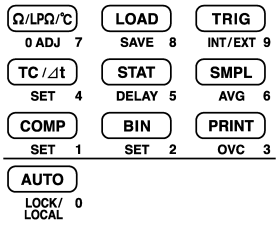
Select a digit to change by moving the blinking location, then select the new numerical value.

Select a digit

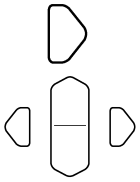
Select numerical value

Using the ten-keys:

Press the numeric keys corresponding to the digits to be entered.



8



Returns to the Main Display of this BIN No.

Repeat Steps 3 to 7 for each BIN No.
In this case, select as follows.

In this case, select BIN2 as shown at the left.

BIN2
Reference value: 15 Ω
Tolerance: 2%

9

Applies setting and returns to the Measurement display.
The BIN function is enabled.

To cancel the settings: 

However, when changing the BIN number, the settings are retained.

10

Connect to a test object, and judge the measured value.
The absolute value appears on the Main Display, and the decision result appears on the Sub Display.

Absolute value

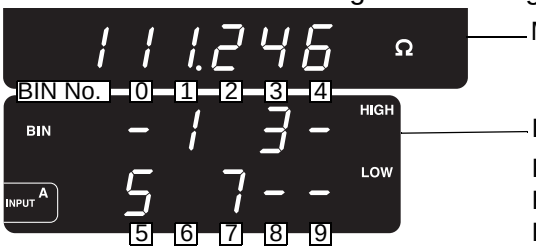
Decision result
(BIN0: in range, BIN2: in range)

❖ Interpreting decision results:(Page 56)

Executing BIN Measurements

BIN
SET 2

(**BIN** lit)
The BIN measurement function is enabled. Pressing the BIN key executes decision according to the setting conditions.



Measured value

Decision results of each BIN.
PASS: BIN Nos. 1, 3, 5, 7
FAIL: BIN Nos. 2, 6
Disabled: BIN Nos. 0, 4, 8, 9

- Numerals (0 to 9): Numbers of the BINs that PASS
  (Measured value is within the range of the conditions set for the displayed BIN No.)
- No Display: FAIL
  (Measured value is outside of the range of the conditions set for the non-displayed BIN No.)
- –: Disabled (no decision)
  (Displayed when the BIN No. setting is OFF on the Main Display)

Disabling the BIN Measurement function

BIN
SET 2

(BIN off)
Disables the BIN Measurement function.

NOTE

- BIN and Comparator measurements cannot be performed simultaneously.
- When BCD output is enabled, BIN measurement results cannot be output as External I/O signals.
  ❖ BIN No. Output/BCD Signal Selection (Page 86)
- To avoid operating errors, only the following keys are enabled when the BIN function is in use:
  SAVE (SHIFT+LOAD), LOAD, STAT, TRIG (for external trigger), and PRINT (when a printer is connected)
  ❖ 5.15 Valid Functions for Each State (Page 79)
- If power is turned off while the setting display is active, settings are ignored, and revert to their former values. If you want to apply the displayed settings, press the ENTER key.
- If auto-ranging is on when BIN measurement is enabled, auto-ranging is disabled.
- No decision occurs in the event of a measurement fault.

5.3 Averaging Function

Function Description

The Averaging Function averages measurement values for output. This function can minimize instability of displayed values.
The number of samples to average can be set from 2 to 100.

Setting the Number of Samples to Average

1 SHIFT → SMPL (AVG 6)

(SHIFT Lamp lit)
The Averaging Function setting display appears.

(Main Display)

2 Select **ON**.

(Sub Display)

3 The number of samples to average setting blinks.

(Sub Display)

4 Or ten-keys — Select the number of samples to average.

5 ENTER (MENU) — The Average Measurement display appears. (**AVG** lit)

Disabling the Averaging Function

1 SHIFT → SMPL (AVG 6)

(SHIFT Lamp lit)
The Averaging Function setting display appears.

(Main Display)

2 Select **OFF**.

(Sub Display)

3 ENTER (MENU) — The Averaging Function is disabled. (AVG off)

NOTE

- When the internal trigger is used for continuous measurement (free-run), the display shows the moving average (default setting). Otherwise, the display shows the integrating average.
  - ❖ Trigger setting: 5.11 Trigger Function (Page 70)
  - ❖ Averaging method (Page 169)
- When FAST sampling rate is used and measurement current is small (approx. 100 µA or less), power line noise may cause instability in measurement values. In such cases, even increasing the number of samples to average may not provide significant improvement. To suppress the noise, thoroughly shield the test object and leads, or change to MEDIUM, SLOW1 or SLOW2 sampling rate.

5.4 Temperature Correction Function (TC)

Function Description

The principle of temperature correction (Appendix 2 Temperature Correction Function (TC) (Page 180)) is used to convert the resistance measured at ambient temperature to its equivalent resistance at a reference temperature for display.
Be sure to read the following before connecting a temperature sensor to the TC SENSOR terminal on the rear panel.

❖ 2.4 Connecting the Temperature Probe (Page 21)
❖ 2.5 Connecting an Analog Output Thermometer (Page 22)

Selecting the Temperature Correction Function

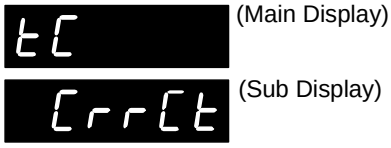
1 SHIFT → ENTER (MENU)

(SHIFT Lamp lit)

The Menu display appears.

2

The TC/Δt selection display appears. (Refer to the Menu display (Page 15))



(Main Display)
(Sub Display)

Select **CrrCt** (Temperature Correction).

3 ENTER (MENU)

Applies setting and returns to the Measurement display.

Making Temperature Correction Settings (Reference Temperature and Temperature Coefficient)

1 SHIFT → TC/Δt (SET 4)

(SHIFT Lamp lit)
The Temperature Correction setting display appears.

(Main Display)

2

Or ten-keys

Set the reference temperature and temperature coefficient.

(Sub Display)
Reference temperature (-10.0 to 99.9°C)
Temperature Coefficient (-99999 to 99999 ppm)

3 ENTER (MENU)

Applies setting and returns to the Measurement display. (**TC** lit)
At this time, the value of resistance adjusted by the temperature correction with the current settings is displayed.

To cancel the settings: SHIFT

Enabling/Disabling Temperature Correction

TC /⊿t
SET 4

TC lit .....Temperature Correction enabled
TC off .....Temperature Correction disabled

An error appears when you press the TC/Δt key

The 9451 TEMPERATURE PROBE may not be connected, or may be connected incorrectly. If Temperature Correction cannot be enabled, check the connections of the temperature probe.

NOTE

- Temperature Correction does not work if the temperature probe is allowed to touch the test object. Only the ambient temperature of the immediate locale should be used.
- Install the temperature probe and allow at least 60 minutes warm-up before measurement. Unless the test object and temperature probe used for temperature correction measurement have been allowed to completely stabilize at ambient temperature, large measurement errors may occur.
- If the temperature probe is not inserted all the way into the TC SENSOR jack on the rear of the instrument, large measurement errors may occur.

5.5 Temperature Conversion Function (Δt)

Function Description

The temperature conversion principle (Appendix 3 Temperature Conversion Function (Dt) (Page 182)) is used to derive temperature increase over time.

NOTE

When using the Temperature Conversion function, the following functions are not available:
Comparator, BIN and Statistical Calculation functions

The Temperature Conversion function is disabled at the factory before shipping.
Use the following procedure to enable the Temperature Conversion function. In this case, the Temperature Correction function is disabled.

Selecting the Temperature Conversion Function

1 SHIFT → ENTER (MENU)

(SHIFT Lamp lit)

The Menu display appears.

2

The TC/Δt selection display appears. (Refer to the Menu display (Page 15))

(Main Display)

(Sub Display)

Select **Conv** (Temperature Conversion).

3 ENTER (MENU)

Applies setting and returns to the Measurement display.

Setting the Conversion Constant

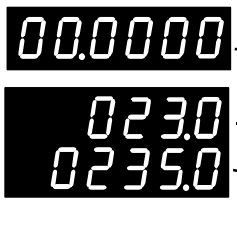
1 SHIFT → TC /⊿t (SET 4)

(SHIFT Lamp lit)

The constant setting display appears.

2 Or ten-keys

Set the reciprocal (k) of the temperature coefficient at 0°C, initial resistance (R1) and initial temperature (t1).



k Reference Value
Recommended by IEC60034 as follows:

- Copper: k = 235
- Aluminum: k = 225

❖ Reference (Page 181)

3 ENTER (MENU)

Applies setting and returns to the Measurement display.

To cancel the settings: SHIFT

Enabling/Disabling Temperature Conversion

TC /⊿t (SET 4)

⊿t lit.....Temperature Conversion enabled.
⊿t off.....Temperature Conversion disabled.

5.6 Statistical Calculation Functions

Function Description

The mean, maximum, minimum, overall standard deviation, standard deviation of sample and process capability indices are calculated and displayed for up to 30,000 measurement values.

The calculation formulas are as follows:

Mean

$$\bar{x} = \frac{\sum x}{n}$$

Overall standard deviation

$$\sigma = \sqrt{\frac{\sum x^2 - n\bar{x}^2}{n}} \quad (= \sigma_n)$$

Standard deviation of sample

$$s = \sqrt{\frac{\sum x^2 - n\bar{x}^2}{n-1}} \quad (= \sigma_{n-1})$$

Process capability index (dispersion)

$$Cp = \frac{|Hi - Lo|}{6\sigma_{n-1}}$$

Process capability index (bias)

$$CpK = \frac{|Hi - Lo| - |Hi + Lo - 2\bar{x}|}{6\sigma_{n-1}}$$

- In these formulas, n represents the number of valid data samples.
- Hi and Lo are the upper and lower thresholds of the comparator.
- The process capability indices represent the quality achievement capability created by a process, which is the breadth of the dispersion and bias of the process' quality. Generally, depending on the values of Cp and CpK, process capability is evaluated as follows:
  Cp, CpK>1.33..... Process capability is ideal
  1.33 ≥ Cp, CpK>1.00..... Process capability is adequate
  1.00 ≥ Cp, CpK..... Process capability is inadequate

NOTE

- When only one valid data sample exists, standard deviation of sample and process capability indices are not displayed.
- When σ_{n-1} is 0, Cp and Cpk are 99.99.
- The upper limit of Cp and CpK is 99.99. Values of Cp and CpK>99.99 are displayed as 99.99.
- When the BIN function is enabled, Cp and CpK are calculated using the upper and lower thresholds of the comparator.
- Negative values of CpK are handled as CpK=0.
- Values measured by the Temperature Conversion function (Δt) cannot be used in statistical calculations.
- Changing settings for the Comparator, BIN or Temperature Correction functions while performing statistical calculations invalidates calculation results.

Enabling/Disabling the Statistical Calculation Function

1 STAT DELAY 5

The Statistical Calculation display appears.

(Main Display)

(Sub Display)

2 ◁ ▷

The function enable/disable display appears.

(Sub Display)

Enable or disable the calculation function on the Sub Display.
on ..... enables the calculation function (ON).
oFF ..... disables the calculation function (OFF).

3 ENTER MENU

Applies setting and returns to the Measurement display.

To cancel the settings: ● SHIFT ◯

NOTE

- Statistical Calculation function setting (ON, OFF) is not available when the Comparator or BIN function is enabled.
- If Statistical Calculation is turned off and then back on without first clearing calculation results, it resumes calculating from the point when it was turned off.
- The Statistical Calculation function slows measurements when it is ON.

Clearing Statistical Calculation Results

1 STAT DELAY 5

The Statistical Calculation display appears.

(Main Display)

(Sub Display)

2 ◁

The Clearing screen will appear.

(Sub Display)

3 ENTER MENU

Clears statistical calculation results.

Automatic Clearing of Statistical Calculation Results after Printing

The 3541 can be set to automatically clear statistical calculation results after results are output to the printer.

1 STAT (DELAY 5)

The Statistical Calculation display appears.

(Main Display)

(Sub Display)

2 ◁

Bring up Auto Clearing After Printing in the Setup screen.

(Sub Display)

▽

Turn Automatic Clearing After Printing on or off.

on.....Automatically clears statistical calculation results after they are output to the printer.

oFF.....Does not clear the results themselves.

3 ENTER (MENU)

Applies setting and returns to the Measurement display.

To cancel the settings: ● SHIFT ◯

Importing Data

TRIG (INT/EXT 9)

Pressing the TRIG key while Statistical Calculation is ON executes one of the following operations:

- External Trigger: Takes one measurement and performs statistical calculation on the result
- Internal Trigger: Performs statistical calculation on the value displayed immediately after pressing

NOTE

- ∗TRG command executes the same operation.
- Grounding the $\overline{\text{TRIG}}$ terminal of the EXT I/O connector executes the same operation.

Confirming Statistical Calculation Results

1 STAT (DELAY 5)

The Statistical Calculation display appears.

2

The indication on the display changes as follows with each key-press.

(Sub Display)
Total data count → Mean (indicated as "Average") → Maximum → Minimum → Overall standard deviation → Standard deviation of sample → Process capability indices → ON/OFF setting → Auto Clearing After Printing setup → Clear setup

Total data count

Mean

Valid data Mean

Maximum

Maximum
Data Sample No.

Minimum

Maximum
Data Sample No.

Overall standard deviation

Standard deviation of sample

Process capability indices

Cp
Cpk

ON/OFF setting

Auto Clearing After Printing setup

Clear setup

NOTE

- No calculation results can be displayed when there are no valid data samples.
- When only one valid data sample exists, standard deviation of sample and process capability indices cannot be displayed.

Sending Statistical Calculation Results to the Printer

PRINT (OVC 3)

With the statistical calculation results displayed, press the PRINT key. The statistical calculation results are output to the optional printer.

❖ Chapter 7 Printer (Optional) (Page 93)

5.7 Offset Voltage Compensation (OVC)

Function Description

This function automatically compensates for the effects of thermoelectromotive force (Appendix 4 Effect of Thermoelectromotive Force (Page 183)) and internal offset voltage of the instrument.

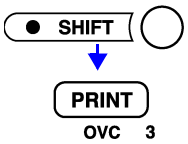
- **With the 2 Ω or higher range and the 200 mΩ range (100 mA measurement current)**
  Displays the true measurement value as follows by measuring R_{ON} with measurement current on, then R_{OFF} with measurement current off.

  $$R_{ON} - R_{OFF}$$

- **With the 20 mΩ and 200 mΩ ranges (1 A measurement current)**
  Displays the true measurement value as follows depending on measurement R_P(>0) with current flow in the positive direction and measurement R_N(<0) with current flow in the negative direction.

  $$\frac{R_P - R_N}{2}$$

Enabling/Disabling Offset Voltage Compensation



(SHIFT Lamp lit)
OVC lit..... Offset Voltage Compensation enabled
OVC off ..... Offset Voltage Compensation disabled

NOTE

- When the thermal capacity of the test object is small, the Offset Voltage Compensation function may be ineffective.
- When the test object is inductive, some delay is necessary after switching current on or off before starting measurement.
  To ensure that inductance does not affect the measurement, the delay setting should aim for about 10 times the value calculated according to the following formula (see also 5.11.2 Trigger Delay and Measurement Fault Detection Time (Page 72)). However, auto delay sets about 100 ms delay presuming that R and L have similar values.

$$t = -\frac{L}{R}\ln\left(1-\frac{IR}{V_O}\right)$$

  L..... Inductance of test object
  R ..... Resistance of test object + test leads + contacts
  I..... Measurement current (refer to 9.2 Accuracy (Page 172))
  V_O ..... Open-terminal voltage (refer to 9.2 Accuracy (Page 172))
- The setting is ignored in the 100 kΩ range and higher.
- Even when a test object is purely resistive, a delay of about 1 to 10 ms is required. To adjust the delay, begin with a longer delay than necessary, then gradually shorten it while watching the measured value.
- If using the Zero-Adjust function, execute it after making any changes to Offset Voltage Compensation.
- When Offset Voltage Compensation is enabled (OVC lit) measurement time is increased.

❖ 6.3 Timing Chart; Measurement Time (Page 90)

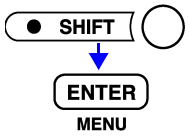
5.8 Self-Calibration

Function Description

To enhance measurement precision, this instrument performs self-calibration to compensate for internal circuit offset voltage and gain drift.
With SLOW1 and SLOW2 sampling, self-calibration is performed once for each measurement. The settings here do not apply when SLOW1 or SLOW2 is selected.
With FAST and MEDIUM sampling, to increase measurement speed, self-calibration is performed only with the timing specified as follows.

- **Self-calibration: Auto**
  Self-calibration is performed for about 55 ms once every 30 minutes.
- **Self-calibration: Manual**
  Self-calibration is performed when the CAL terminal of the EXT I/O connector is connected to GND.
  Self-calibration should always be performed after warm-up.

Setting Auto or Manual Self-Calibration (FAST or MEDIUM)

1 

(SHIFT Lamp lit)

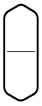
The Menu display appears.

2 

The self-calibration setting display appears.
(Refer to the Menu display (Page 15))

(Main Display)

(Sub Display)



Select Auto or Manual on the Sub Display.
AUto..... Auto self-calibration
In..... Manual self-calibration

3 

Applies setting and returns to the Measurement display.

Self-calibration is performed in the following cases regardless of the above settings:

- When the range is changed
- When the sampling rate is changed
- When a Load operation (refer to 5.13 Panel Load Function (Page 76)) is executed
- When a reset is performed
- When the measurement function is changed.

To obtain the specified accuracy, perform self-calibration in the following cases:

- After warm-up
- When the ambient temperature changes by 2°C or more

Triggers occurring during self-calibration are delayed so that the corresponding measurement occurs only after self-calibration has finished. When using an external trigger, measurement may occur at unintended times, in which case we suggest selecting Manual self-calibration.

5.9 Key Beeper Setting

Function Description

Select whether a beep sounds when an operating key on the front of the instrument is pressed.

Setting the Key Beeper ON/OFF

1 SHIFT → ENTER (MENU)

(SHIFT Lamp lit)

The Menu display appears.

2

The key beeper setting display appears.
(Refer to the Menu display (Page 15))

(Main Display)

(Sub Display)

The current setting of the key beeper blinks.

Select the key beeper state on the Sub Display.
on ..... Key beeper enabled
oFF ..... Key beeper disabled

3 ENTER (MENU)

Applies setting and returns to the Measurement display.

5.10 Key-Lock Function

Function Description

Executing Key-Lock disables the operating keys on the front of the instrument. This function can be useful for protecting settings.

Enabling/Disabling Key-Lock

1

Set the appropriate measurement conditions.

2 SHIFT

(SHIFT Lamp lit)

AUTO (LOCK/ LOCAL 0)

LOCK lit ..... Key-Lock is enabled.
LOCK off ..... Key-Lock is disabled.

NOTE

- Even if the power supply is interrupted, the Key-Lock function is not canceled.
- When Key-Lock is enabled while using an external trigger, the TRIG key remains operational.

5.11 Trigger Function

5.11.1 Trigger Source

Function Description

Two trigger sources are available: internal and external.

- **Internal Trigger**
  Trigger signals are automatically generated internally.
  When using the internal trigger source, measurement current flows continuously.
- **External Trigger**
  Trigger signals are provided externally or manually.

Selecting an Internal or External Trigger Source

Press when **EXT.TRIG** is lit.
(SHIFT Lamp lit)

EXT.TRIG off ..... Internal triggering is selected.

EXT.TRIG lit ..... External triggering is selected.

Measurement with External Triggering

External triggering can be provided in three ways:

- **By key operation**
  Pressing the **TRIG** key triggers one measurement.
- **By External I/O input**
  Grounding the TRIG terminal of the rear panel EXT I/O connector triggers one measurement.
  ❖ 6.2 Signal Descriptions (Page 82)
- **Sending a trigger command via the interface:**
  Sending the "*TRG" command via the interface triggers one measurement.

NOTE

- When the Internal Trigger source is enabled, the EXT I/O signal and the "∗TRG" command are ignored.
- When using external triggering, current flows while measuring with the Low-Power Resistance function in all ranges, and with the Resistance Measurement function, in the 20 mΩ to 20 Ω ranges.
  ❖ 6.3 Timing Chart (Page 88)
- The response time depends on the test object, so some Delay should always be set. Initially set a long Delay, then while watching the measured value, shorten it gradually.
  ❖ 5.11.2 Trigger Delay and Measurement Fault Detection Time (Page 72)
- Normally, the "continuous measurement" condition occurs when operating from the front panel. When internal triggering is selected, the "Free-Run" condition causes continuous triggering. When external triggering is selected, each trigger causes one measurement.
  Continuous measurement can be disabled by setting via RS-232C or GP-IB. When continuous measurement is disabled, triggering is received only according to the timing specified by the host (PC or sequencer).
  ❖ About trigger commands: (7) Triggering (Page 147)
  ❖ 8.7 Basic Data Importing Methods (Page 155)

5.11.2 Trigger Delay and Measurement Fault Detection Time

Function Description

Trigger delay

Set the delay between trigger signal input and the start of measurement.
By using this function, even when a trigger is input immediately upon connecting to a test object, measurement can be delayed to allow conditions to stabilize.
Two types of trigger delay are available:

- **Auto Delay**
  The delay is set automatically for each range. (see Table below)
- **Manual Delay**
  Set the delay time independently.
  The trigger delay can be set with 1 ms resolution from 0.000 to 9.999 s.

Measurement Fault Detection Time

Set the measurement fault detection time before starting measurement (with INDEX = Lo(OFF) set inside this instrument). Any measurement faults that may occur during measurement will be detected.
Although this detection time is normally set to AUTO, you can set the measurement fault detection time to the response time from probe contact with the test object to when measurement is stabilized for more accurate detection of measurement faults.

❖ About Measurement Fault Detection Time (Page 74)

- Auto setting
  The measurement fault detection time (i.e., response time before measurement) is set automatically.
  20 mΩ to 200 Ω ranges, LP function: 0.833 ms
  2 kΩ to 100 MΩ ranges: 0.500 ms
- Manual setting
  The measurement fault detection time is set manually.
  The detection time can be set from 0.000 to 9.998 s with 1-ms resolution. Note that the time cannot be set equal to or greater than the delay time.

NOTE

If the delay time is set to 0.000 s, measurement faults cannot be detected during this period. Therefore, you should set a delay time of at least 1 ms for secure measurement.

Auto Delay Times

		Range [Ω]	20 m	200 m	2	20	200	2 k	20 k	100 k	1 M	10 M	100 M
Resistance Measurement	Delay [ms]	OVC OFF	30	30	3	3	3	3	3	10	100	500	1000
		OVC ON	100	100	100	100	100	100	100	–	–	–	–
Low-Power Resistance Measurement	Delay [ms]	OVC OFF	–	–	3	3	3	15	–	–	–	–	–
		OVC ON	–	–	100	100	100	100	–	–	–	–	–

OVC: Offset Voltage Compensation

Setting Trigger Delay and Measurement Fault Detection Time

1 SHIFT → STAT (DELAY 5)

(SHIFT Lamp lit)

The Trigger Delay setting display appears.

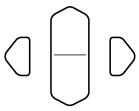
(Main Display)

(Sub Display)

The current trigger delay setting blinks.

2 

Select auto or manual delay on the Sub Display.
AUto .... Auto Delay→ **to step 4**
SEt..... Manual Delay→**to following steps**

3  Or ten-keys

(When SET is selected)
The numbers indicating the trigger delay blink.
Set the trigger delay.

4 ENTER (MENU)

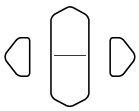
Applies setting and the Measurement fault detection time setting display appears.

(Main Display)

(Sub Display)

5 

Select Auto or Manual setting of the measurement fault detection time on the Sub Display.
AUto..... Auto setting of measurement fault detection time→**to step7**
SEt ..... Manual setting of measurement fault detection time
→**to following steps**

6  Or ten-keys

(When SET is selected)
The numbers indicating the measurement fault detection time blink.
Set the measurement fault detection time.

7 ENTER (MENU)

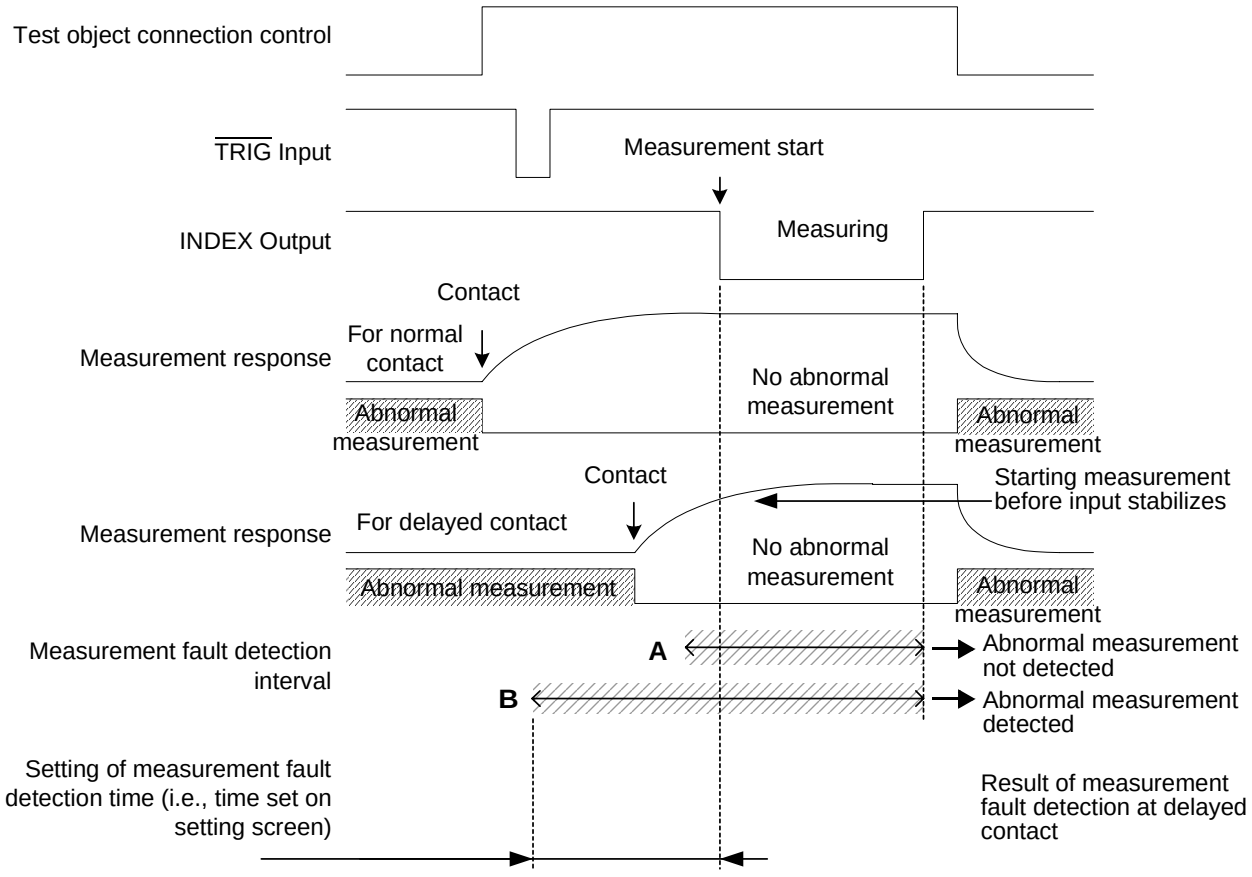
Applies setting and returns to the Measurement display.

To cancel the settings: SHIFT

About Measurement Fault Detection Time

The measurement fault detection function detects measurement leads improperly connected to the test object, and disconnected measurement cables. Unless the connection is secure within a certain time (= response time) before starting measurement, values entered during measurement are not stabilized, resulting in inaccurate measurement values being obtained.
Therefore, measurement faults are detected more securely by starting detection at the beginning of the response time before measurement starts, and continuing until measurement ends.

The following figure shows normal probe contact with a test object and a case of contact delayed (due to, e.g., mechanical fault).
The figure shows that by setting the measurement fault detection time properly, poor measurement due to delayed contact can be detected as a measurement fault.



If actual probe contact to a test object is delayed under probe connection control, input will not stabilize during measurement because the response time is insufficient for starting measurement.
In such case, the measurement values will be inaccurate.

- When setting measurement fault detection interval A, no measurement fault is detected because no measurement faults occur during this interval.
  Indication on the instrument: An inaccurate measurement value is displayed.
- When setting measurement fault detection interval B, a measurement fault that occurs during the first half of this interval is detected.
  Indication on the instrument: A measurement fault error is displayed.

5.12 Panel Save Function

Function Description

The current measurement setting state is stored (saved) in non-volatile memory.
Up to 30 sets of measurement states can be saved.
The measurement settings (state) at the time this function is executed are saved.
Saved measurement states can be reloaded using the Panel Load function, described later.

Saving the Measurement Setting State

1 SHIFT → LOAD SAVE 8

(SHIFT Lamp lit)

The Panel Saving display appears. The panel number blinks.

(Main Display)
Panel No.

2 Or ten-keys

Select the panel number to save.

(Main Display) (To save measurement settings as Panel No. 3)

3 ENTER MENU

Saves the measurement setting state and returns to the Measurement display.

To cancel the setting: SHIFT

Returns to the Measurement display without saving settings.

NOTE

- If you select a Panel number that was previously saved and press the ENTER key, the contents are overwritten.
- The Key-Lock state can be saved only by the :SYSTem:SAVE remote command.

Saved Items

- Measurement rate
- Function
- Range setting
- Comparator settings
- BIN settings
- Internal/External trigger setting
- Delay setting
- Measurement fault detection time setting
- Zero-Adjust setting
- Averaging setting
- TC setting
- Δt setting
- OVC setting
- Self-calibration setting
- External I/O BIN/BCD selection
- SYNC/ASYNC Measurement Fault output setting
- Key-Lock

5.13 Panel Load Function

Function Description

Loads the measurement settings saved by the Panel Save function from internal non-volatile memory.

Loading Saved Measurement Settings

1 LOAD / SAVE 8

The Panel Loading display appears. The panel number blinks.

(Main Display)
Panel No.

2 Or ten-keys

Select the panel number to load.

(Main Display)

(To load measurement settings from Panel No.3)

3 ENTER / MENU

Loads the measurement setting state and returns to the Measurement display.

To cancel loading: ● SHIFT ◯

Returns to the Measurement display without loading the measurement setting state.

NOTE

- If an unsaved Panel No. is selected, a warning beep sounds when you press ENTER.
- When selecting a Panel No. with the up/down RANGE keys, only the numbers of previously saved panels appear.
- Loading can also be executed using the TRIG signal and the LOAD0 to LOAD4 pins of the EXT I/O interface.
  ❖ Chapter 6 External Control; Input Signals (Page 83)
- Zero-adjust values are also loaded, so be sure to perform a panel save after zero adjustment.

5.14 Reset Function

Function Description

Two Reset methods are available:

- **Reset**
  Re-initializes all measurement settings except for Panel Save data to their factory defaults.
- **System Reset**
  Re-initializes all measurement settings, including Panel Save data, to their factory defaults.

Executing Reset or System Reset

1 SHIFT → ENTER (MENU)

(SHIFT Lamp lit)

The Menu display appears.

2

The Reset display appears. (Refer to the Menu display (Page 15))

(Main Display)

(Sub Display)

3

Select the Reset method on the Sub Display.
SEt..... Reset (initializes measurement settings other than those stored with Panel Save)
SYS..... System Reset (initialize all measurement settings)

4

ENTER blinks.

(Sub Display)

5 ENTER (MENU)

Executes the Reset.

To cancel: SHIFT
Returns to the Measurement display without resetting.

NOTE

System Reset also initializes Panel Save data.

Initial Factory Default Settings

Description	Default	Description	Default
Measurement Function	Resistance	Trigger Source	Internal trigger
Resistance Measurement Range	AUTO	Line Frequency	60 Hz
LP Resistance Measurement Range	AUTO	Key Beeper	ON
Zero-Adjust	OFF	Key-Lock	OFF
Zero-Adjust Value	0	Comparator	OFF
Temperature Correction/ Conversion	Temperature Correction	Comparator Mode	Hi/Lo
TC/Δ t	OFF	Comparator Upper Threshold	0
Temperature Correction Ref Temp.	20°C	Comparator Lower Threshold	0
Temperature Correction Coefficient	3930 ppm	Comparator Beeper	HL
Temperature Conversion Initial Resistance	0 mΩ	BIN	OFF
Temperature Conversion Initial Temperature	23°C	BIN Enable/Disable	All Disabled
Temperature Conversion Constant	235°C	BIN Mode	All Hi/Lo
Statistical Calculation Functions	OFF	BIN Upper Threshold	All 0
Delay	AUTO	BIN Lower Threshold	All 0
Delay Time	0.000 s	Interface	RS-232C
Measurement fault detection	AUTO		
Measurement fault detection time setting	0.000s		
Sampling Rate	SLOW2	Print interval	0
Averaging Function	OFF	BIN/BCD Output	BIN Output
Average Times	2	Error Output	Async
Offset Voltage Compensation	OFF	Input Terminals	A
Self-Calibration	AUTO	Temperature Sensor Pt/ Analog /RS-232C	Pt
Continuous Measurement	ON	Analog Temperature Measurement Constants	T1: 0°C T2: 500°C V1: 0 V V2: 1 V
		200 mΩ range measurement current	1 A

5.15 Valid Functions for Each State

● = Valid, – = Invalid, * = Fixed Setting

Function	State: Resistance Measurement	Temperature Measurement	Comparator ON	BIN ON	TC ON	Δt ON	Auto-Ranging	0-Adjust	External Trigger	Delay	Averaging	Statistical Calculation
Function selection	●	●	*	*	●	●	●	●	●	●	●	●
Load/Save	●	●	●	●	●	●	●	●	●	●	●	●
Trigger selection	●	–	*	*	●	●	●	●	●	●	●	●
TC/Δt ON/OFF	●	–	*	*	●	●	●	●	●	●	●	●
TC/Δt Setting	●	–	*	*	●	●	●	●	●	●	●	●
Statistical Calculation	●	–	* *1	* *1	●	–	●	●	●	●	●	●
Sampling	●	–	*	*	●	●	●	●	●	●	●	●
Averaging setting	●	–	*	*	●	●	●	●	●	●	●	●
Comparator ON/OFF	●	–	●	–	●	–	●*3	●	●	●	●	●
Comparator setting	●	–	*	–	●	–	●	●	●	●	●	●
BIN ON/OFF	●	–	–	*	●	–	●*3	●	●	●	●	●
BIN setting	●	–	–	*	●	–	●	●	●	●	●	●
Print	●	●	●	●	●	●	●	●	●	●	●	●
Auto-Ranging	●	–	–	–	●	●	●	●	●	●	●	●
Range selection	●	–	*	*	●	●	●	●	●	●	●	●
0-Adjust execution	●	–	*	*	●	●	●	●	●	●	●	●
Delay setting	●	–	*	*	●	●	●	●	●	●	●	●
OVC ON/OFF	●	–	*	*	●	●	●	●	●	●	●	●
Key-Lock	●	●	●	●	●	●	●	●	●	●	●	●
Zero-Adjust Clear	●	●	* *2	* *2	●	●	●	●	●	●	●	●
TC/Δt selection	●	●	* *2	* *2	●	●	●	●	●	●	●	●
Interface setting	●	●	* *2	* *2	●	●	●	●	●	●	●	●
AUTO/MANU Calibration	●	●	* *2	* *2	●	●	●	●	●	●	●	●
External I/O BIN/BCD	●	●	* *2	* *2	●	●	●	●	●	●	●	●
Err Output Sync/Async	●	●	* *2	* *2	●	●	●	●	●	●	●	●
Key Click Sound	●	●	* *2	* *2	●	●	●	●	●	●	●	●
Line Frequency	●	●	* *2	* *2	●	●	●	●	●	●	●	●
Adjustment	●	●	* *2	* *2	●	●	●	●	●	●	●	●

*1: Display-only
*2: Does not appear on menu display
*3: Auto-Ranging is OFF

External Control Chapter 6

6.1 External Control and the External Input/Output (EXT I/O) Connector

WARNING

To avoid electrical hazards, observe the following cautions:

- **Turn off power to all devices before making connections. Make sure connections are secure so that no wires can become loose during operation and contact conductive parts such as the chassis or test leads.**
- **Note that INT.GND is grounded. Therefore, if the controller has electric potential relative to ground, a short-circuit hazard exists which may cause an accident.**

CAUTION

To avoid damage to the instrument, observe the following cautions:

- Do not apply voltage or current to the EXT I/O terminals that exceeds their ratings.
- When driving relays, be sure to install diodes to absorb counter-electromotive force.
- Be careful not to short-circuit INT.VCC to INT.GND.
- Always provide protective grounding for devices to be connected to external input and output terminals.

External Control Input Functions

- External trigger input ($\overline{\text{TRIG}}$)
- Select Panel No. to load ($\overline{\text{LOAD0}}$ to $\overline{\text{LOAD4}}$)
- Zero-adjust signal input ($\overline{\text{0ADJ}}$)
- Print Signal input ($\overline{\text{PRINT}}$)
- Self-calibration signal input ($\overline{\text{CAL}}$)

External Output Terminal Functions

- End-of-Conversion signal output (EOC)
- Reference signal output (INDEX)
- Measurement Fault signal output (ERR)
- Comparator decision signal output (Hi, IN, Lo)
- BIN signal outputs (BIN0 to BIN9)*1
- BCD output (BCD1-0 to BCD6-3)*1
- General-purpose outputs (OUT0 to OUT7)*2

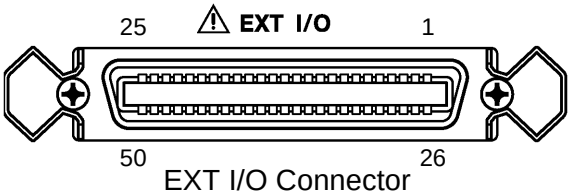
*1: BIN outputs and BCD outputs cannot both be used simultaneously.
*2: General-purpose outputs (OUT0 to OUT7) are not available when the BCD outputs are selected.

Connector Type 57RE-40500-730B (D29) (manufactured by DDK)

Mating Connector 57-30500 (manufactured by DDK) or equivalent

6.2 Signal Descriptions

Pinout



EXT I/O Connector

Pin	I/O	Signal name	Pin	I/O	Signal name
1	IN	$\overline{\text{LOAD0}}$	26	IN	$\overline{\text{LOAD1}}$
2	IN	$\overline{\text{LOAD2}}$	27	IN	$\overline{\text{LOAD3}}$
3	IN	$\overline{\text{LOAD4}}$	28	IN	$\overline{\text{0ADJ}}$
4	IN	$\overline{\text{TRIG}}$ ($\overline{\text{IN0}}$)	29	IN	$\overline{\text{CAL}}$
5	IN	$\overline{\text{PRINT}}$ ($\overline{\text{IN1}}$)	30	–	Unused
6		INT.GND	31		INT.GND
7		INT.GND	32		INT.GND
8		INT.GND	33		INT.GND
9		INT.VCC	34		INT.VCC
10		INT.VCC	35		INT.VCC
11	OUT	ERR	36	OUT	INDEX
12	OUT	EOC	37	OUT	Hi
13	OUT	IN	38	OUT	Lo
14	OUT	BIN0 (BCD1-0)	39	OUT	BIN1 (BCD1-1)
15	OUT	BIN2 (BCD1-2)	40	OUT	BIN3 (BCD1-3)
16	OUT	BIN4 (BCD2-0)	41	OUT	BIN5 (BCD2-1)
17	OUT	BIN6 (BCD2-2)	42	OUT	BIN7 (BCD2-3)
18	OUT	BIN8 (BCD3-0)	43	OUT	BIN9 (BCD3-1)
19	OUT	OB (BCD3-2)	44	OUT	(BCD3-3)
20	OUT	(BCD4-0)	45	OUT	(BCD4-1)
21	OUT	(BCD4-2)	46	OUT	(BCD4-3)
22	OUT	OUT0 (BCD5-0)	47	OUT	OUT1 (BCD5-1)
23	OUT	OUT2 (BCD5-2)	48	OUT	OUT3 (BCD5-3)
24	OUT	OUT4 (BCD6-0)	49	OUT	OUT5 (BCD6-1)
25	OUT	OUT6 (BCD6-2)	50	OUT	OUT7 (BCD6-3)

Input Signals

$\overline{\text{LOAD0}}$ to $\overline{\text{LOAD4}}$

Select a Panel No. to load and apply a $\overline{\text{TRIG}}$ signal to load the selected Panel No. and measure. $\overline{\text{LOAD0}}$ is the LSB, and $\overline{\text{LOAD4}}$ is the MSB.

$\overline{\text{LOAD4}}$	$\overline{\text{LOAD3}}$	$\overline{\text{LOAD2}}$	$\overline{\text{LOAD1}}$	$\overline{\text{LOAD0}}$	Panel No.
0	0	0	0	0	*
0	0	0	0	1	30
0	0	0	1	0	29
0	0	0	1	1	28
0	0	1	0	0	27
0	0	1	0	1	26
0	0	1	1	0	25
0	0	1	1	1	24
0	1	0	0	0	23
0	1	0	0	1	22
0	1	0	1	0	21
0	1	0	1	1	20
0	1	1	0	0	19
0	1	1	0	1	18
0	1	1	1	0	17
0	1	1	1	1	16
1	0	0	0	0	15
1	0	0	0	1	14
1	0	0	1	0	13
1	0	0	1	1	12
1	0	1	0	0	11
1	0	1	0	1	10
1	0	1	1	0	9
1	0	1	1	1	8
1	1	0	0	0	7
1	1	0	0	1	6
1	1	0	1	0	5
1	1	0	1	1	4
1	1	1	0	0	3
1	1	1	0	1	2
1	1	1	1	0	1
1	1	1	1	1	*

0: $\overline{\text{LOAD}}$ terminal shorted to GND

1: $\overline{\text{LOAD}}$ terminal open or connected to 5 V

*: When a trigger signal is applied with $\overline{\text{LOAD0}}$ to $\overline{\text{LOAD4}}$ set to all 1's or all 0's, no Panel Load occurs.

At least 70 ms is required for the settings to change after executing a Panel Load (the actual time depends on the particular function, range and sampling rate).
When set to external trigger mode, one measurement is taken upon load completion.

$\overline{\text{TRIG}}$

When the external trigger, one measurement is taken each time the $\overline{\text{TRIG}}$ signal transitions from High to Low.
In the following cases, the $\overline{\text{TRIG}}$ signal is ignored:

- When using the internal trigger source
- When the Measurement display is not the active display
- When executing Panel Load in Remote state

$\overline{\text{0ADJ}}$

Zero adjustment executes once when the $\overline{\text{0ADJ}}$ signal transitions from High to Low.

$\overline{\text{PRINT}}$

The current measurement value prints when the $\overline{\text{PRINT}}$ signal transitions from High to Low.

$\overline{IN0}$, $\overline{IN1}$

When not using the TRIG and PRINT functions, they can be monitored as general-purpose input terminals with the :IO:IN? command.

❖ 8.6.2 Device-Specific Commands; (6) External I/O (Page 146)

$\overline{CAL}$

When manual self-calibration is selected with FAST or MEDIUM sampling rate, self-calibration begins when the $\overline{CAL}$ signal transitions from High to Low.
Self-calibration requires about 55 ms to complete.
When the SLOW1 or SLOW2 sampling rate is selected, the $\overline{CAL}$ signal is ignored.

❖ 5.8 Self-Calibration (Page 68)

Output Signals

ERR

Indicates a measurement fault.
The Synchronous ERR output setting causes ERR output to be synchronous with EOC output, while with the Asynchronous ERR output setting causes ERR output to follow actual (asynchronous) contact of the probes with the test object.
When simultaneous comparator decision result and ERR output is desired, set the ERR output to Synchronous.

❖ 4.5 Measurement Fault Detection Function (Page 43)
❖ Measurement Fault Output Signal (ERR) Setting (Page 86)

INDEX

The INDEX signal is output during the Trigger Wait, Delay, Self-Calibration and Calculation states.
This signal is not output while measuring the resistance of test objects.
This signal transitions from Off to On to indicate that the test object can be removed.

EOC

This signal indicates the end of a measurement (End-Of-Conversion).

Hi, IN, Lo

These are the results of comparator decision.

BIN0 to BIN9, OB (Out of BINs)

This output indicates the BIN No. that was judged to be IN by the BIN measurement function.
If the decision does not apply to any BIN, the OB signal is output.
When BCD outputs are selected, the BIN signals are not available.

❖ BIN No. Output/BCD Signal Selection (Page 86)

OUT0 to OUT7

The output signals are controlled by the :IO:OUT command.

❖ 8.6.2 Device-Specific Commands; (6) External I/O (Page 146)

BCD1-0 to BCD6-3

These are BCD outputs. BCD1 is the lower digit, and BCD6 the upper digit.
BCDx-0 is the LSB, and BCDx-3 is the MSB.
When BIN outputs are selected, the BCD signals are not available.
Minus signs are not output. Also, temperature measurements are not output as BCD.

❖ BIN No. Output/BCD Signal Selection (Page 86)

INT.GND , INT.VCC

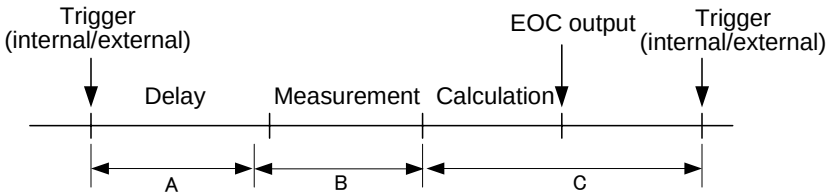
These are outputs of the instrument's internal 5 VDC and GND.

NOTE

- I/O signals should not be used while measurement settings have been changed.
- When the external trigger is selected, the EOC signal and INDEX signal are not output until the first measurement is completed after the power is turned on.
- If it is not necessary to change the measurement conditions, set LOAD0 through LOAD4 to either Hi or Lo.

ERR Output

When ERR output is set to Synchronous, errors are detected during the measurement period and measurement fault detection time setting period. Timing for the Asynchronous ERR setting is as follows:



- Delay (excluding measurement fault detection function) (A): any measurement fault is ignored
- Measurement fault detection time + measurement (B): the ERR is output immediately upon detection of a fault
- After measurement until the next trigger (C): ERR is output for measurement faults lasting at least 5 ms
  Or, the fault is canceled by a valid measurement of at least 5 ms

However, when measuring large inductances, the ERR signal may be output for a period of (C).

❖ 4.5 Measurement Fault Detection Function (Page 43)
❖ 5.11.2 Trigger Delay and Measurement Fault Detection Time (Page 72)

Instrument Settings

Measurement Fault Output Signal (ERR) Setting

1 SHIFT / ENTER MENU

(SHIFT Lamp lit)

The Menu display appears.

2

Select the ERR Output Selection display.
(Refer to the Menu displays (Page 15))

(Main Display)

(Sub Display)

3

Select the type of signal to be output on the Sub Display.
SynC ....Synchronous output (synchronized with EOC output)
ASynC .Asynchronous output (not synchronized with EOC output)

4 ENTER MENU

Applies settings and returns to the Measurement display.

BIN No. Output/BCD Signal Selection

1 SHIFT / ENTER MENU

(SHIFT Lamp lit)

The Menu display appears.

2

Select the BIN/BCD Selection display.
(Refer to the Menu displays (Page 15))

(Main Display)

(Sub Display)

3

Select the signal output type on the Sub Display.
bIn.....Bin Output (when a BIN No. signal is output), or general-purpose output (OUT0 to OUT7)
bCd .....BCD output (when a BCD signal is output)

4 ENTER MENU

Applies settings and returns to the Measurement display.

Setting the EOC Signal

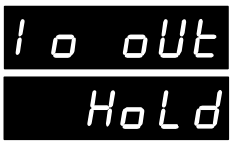
1 SHIFT → ENTER (MENU)

(SHIFT Lamp lit)

The Menu display appears.

2

Select the EOC-signal setup screen.
(Refer to the Menu displays (Page 15))



(Main Display)

(Sub Display)

3

Choose the output method for the EOC signal.

HoLd.... Holds the EOC signal after measurement. → Go to Step 5.

PULSE. Outputs the specified pulse after measurement. → Go to the next step.

4

Or ten-keys

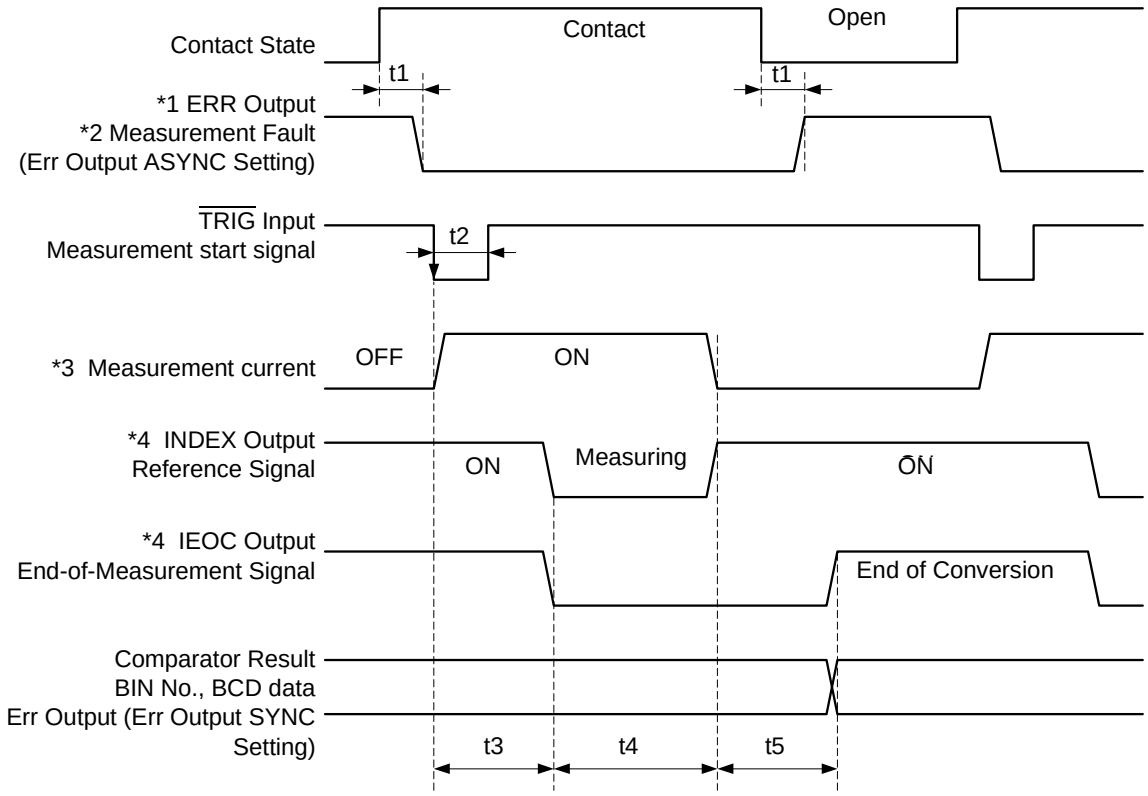
(When PULSE is selected)
The number representing the pulse width of the EOC signal will start blinking. Set the pulse width in ms.

5 ENTER (MENU)

Applies settings and returns to the Measurement display.

6.3 Timing Chart

External Trigger Timing Chart



*1: For details, see “ ERR Output (Page 85).”

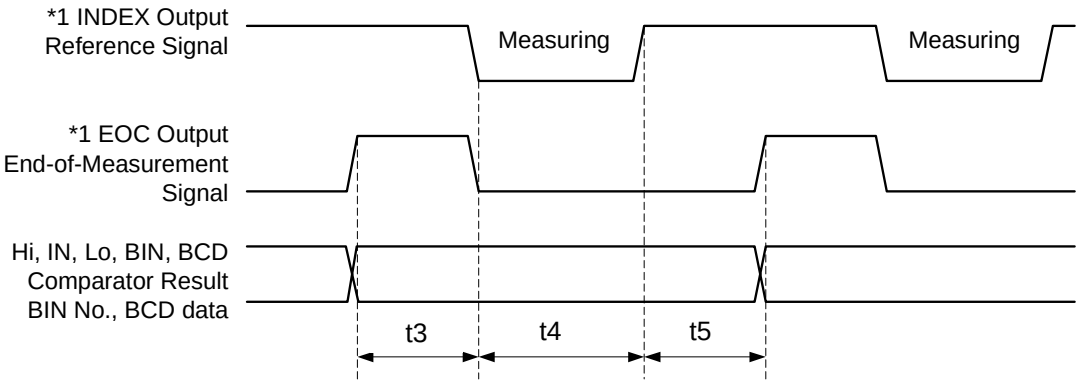
*2: Only in the 2Ω to 100 MΩ ranges.
In the 20 mΩ and 200 mΩ ranges or with the LP function in all ranges, and if the Err (measurement error signal) output is set to Asynchronous, measurement errors are not detected when the measurement current is OFF.
If Err output is set to Synchronous, as with comparator results, measurement error detection results can be obtained when finished measuring.

❖ Measurement Fault Output Signal (ERR) Setting (Page 86)

*3: However, in the 200 Ω or higher resistance ranges, current flows continuously.

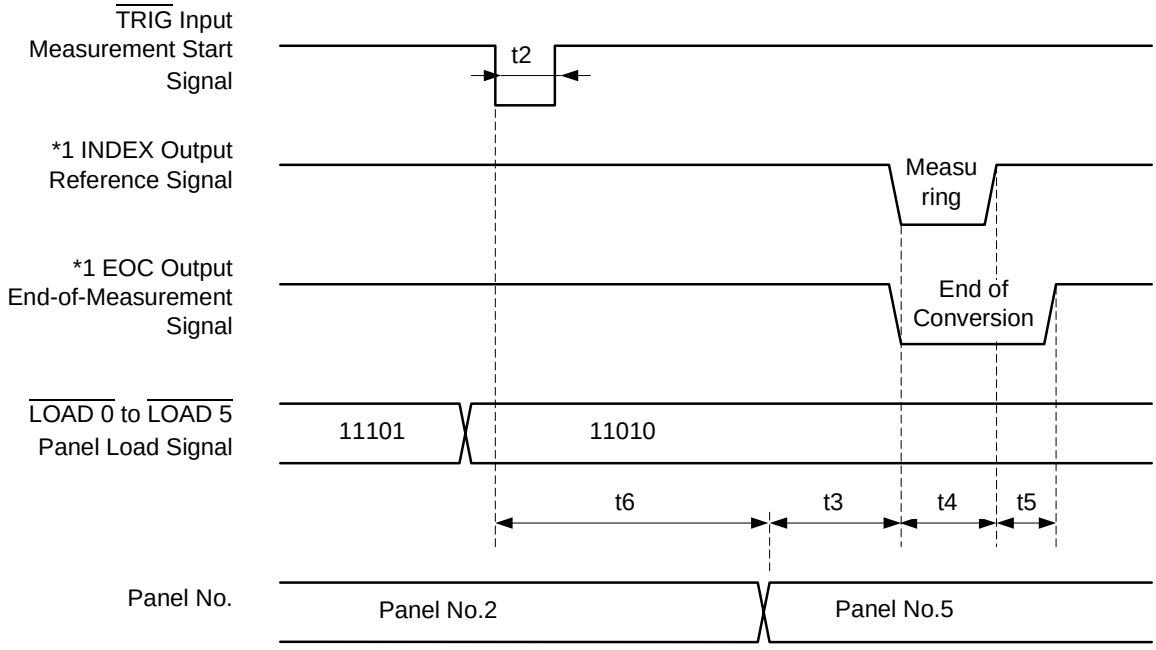
*4: When the EOC signal is set to PULSE, the signal will remain on only for the specified period upon completion of conversion.

Internal Trigger Timing Chart



*1: When the EOC signal is set to PULSE, the signal will remain on only for the specified period upon completion of conversion.

Panel Load Timing Chart (When the External Trigger)



*1: When the EOC signal is set to PULSE, the signal will remain on only for the specified period upon completion of conversion.

Description			Time Offset Voltage Compensation (OVC) OFF	Offset Voltage Compensation (OVC) ON
t1	ERR Output response time*1		100 µs	100 µs
t2	Measurement trigger pulse width		100 µs min	100 µs min
t3	Delay time		per setting ❖ 5.11.2 Trigger Delay and Measurement Fault Detection Time (Page 72)	per setting ❖ 5.11.2 Trigger Delay and Measurement Fault Detection Time (Page 72)
t4	Measurement time*2	FAST MEDIUM SLOW1 SLOW2	300 µs 20 ms (50 Hz) 16.7 ms (60 Hz) 100 ms 400 ms	600 µs + t3 40 ms + t3 (50 Hz) 33.3 ms + t3 (60 Hz) 200 ms + t3 800 ms + 7 x t3
t5	Calculation time*3	FAST, MEDIUM SLOW1, 2	0.3 ms 55 ms (50 Hz line frequency setting)/ 49 ms (60 Hz line frequency setting)	0.3 ms 55 ms (50 Hz line frequency setting)/ 49 ms (60 Hz line frequency setting)
t6	Load time		70 ms min,190 ms max	70 ms min,190 ms max

*1: For details, see “ ERR Output (Page 85).”

*2: About t4 measurement time

- Even when Averaging is enabled, in the free-run state the moving average is calculated, so measurement time t4 is unchanged.
- Non-free-run calculation (:INITiate:CONTinuous ON;:TRIGger:SOURce IMMediate) times t4 are as follows: (n = samples to average)

			Offset Voltage Compensation (OVC) OFF	Offset Voltage Compensation (OVC) ON
t4	Measurement Time	FAST MEDIUM SLOW1 SLOW2	0.33 ms x n+80 µs 20 ms x n (50 Hz) 16.7 ms x n (60 Hz) 100 ms x n 400 ms x n	0.67 ms x n + t3 + 80 µs 40 ms x n + t3 (50 Hz) 33.3 ms x n + t3 (60 Hz) 200 ms x n + (2n-1)t3 800 ms x n + (8n-1)t3

*3: About t5 calculation time

In the following cases, add the indicated times to calculation time t5:

When the BIN Measurement function is enabled	0.08 ms
When the Temperature Correction function is enabled	0.22 ms
When the Statistical Calculation function is enabled	0.3 ms
When BCD external I/O is selected	0.08 ms
When the reference value/tolerance method of comparator decision is selected	0.15 ms
When the measured value is printed	0.5 ms

❖ 5.3 Averaging Function (Page 57)
❖ 5.11 Trigger Function (Page 70)

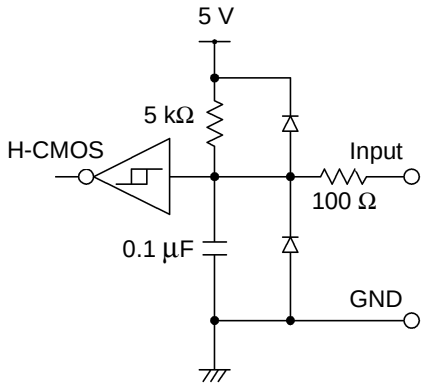
6.4 Internal Circuitry

External Control and External Output Terminal Ratings

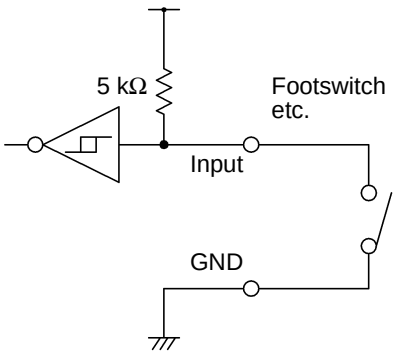
	I/O type	Logic	Electrical specification
Output	Open collector		35 VDC, 50 mA DC max.
Input	C-MOS	Inverse logic	H: 3.8 to 5.0 V, L: 0 to 1.2 V
INT.DCV	Internal power output		5 VDC ±10%, 200 mA max.

External Control Terminals

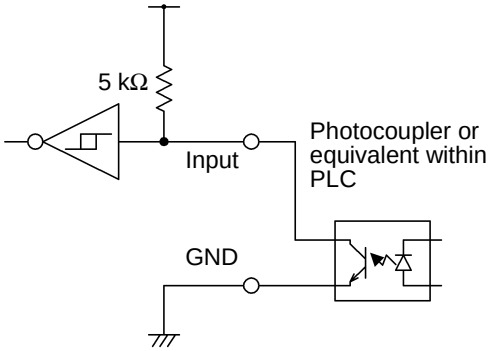
Circuit Diagram



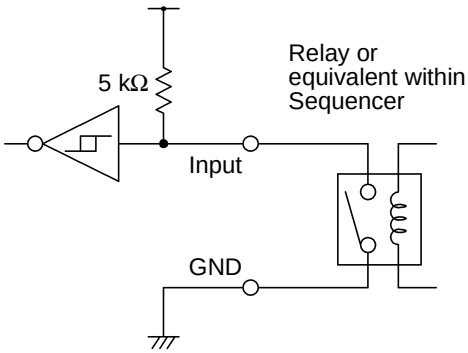
Application Examples



Switch Connection



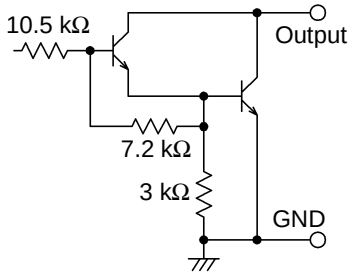
Photocoupler Connection



Relay Connection

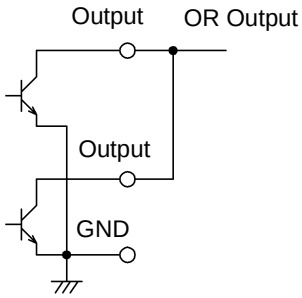
External Output Terminals

Circuit Diagram

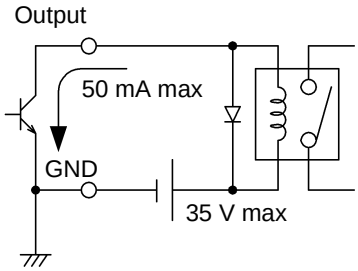


Open-Collector Output

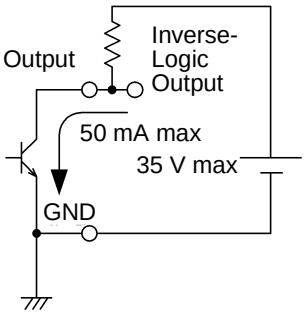
Application Examples



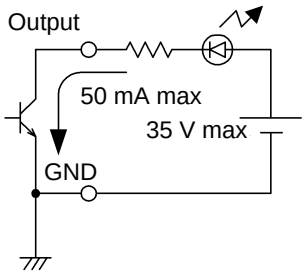
Wired-OR



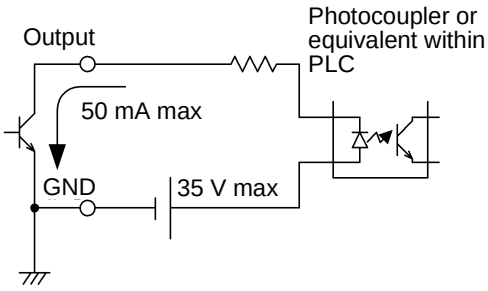
Relay Connection



Inverse-Logic Output Connection



LED Connection



Photocoupler Connection

Printer (Optional) Chapter 7

7.1 About Printing

The following items can be printed using the optional Model 9670 PRINTER, 9638 RS-232C CABLE, 9671 AC ADAPTER and 9237 RECORDING PAPER:

- Measurement values and decision results
- Statistical calculation results

The following items are required to use the 9670 PRINTER.

- Model 9670 PRINTER (Sanei Electric Model BL-80RSII, supplied with a roll of thermal paper)
- Model 9671 AC ADAPTER (Sanei Electric Model BL-100W)
- Model 9237 RECORDING PAPER (thermal paper 80 x 25 m, 4 rolls)
- Model 9638 RS-232C CABLE

To use the printer with a battery:

- Model 9672 BATTERY PACK (Sanei Electric UR-100 or UR-121)
- Model 9673 BATTERY CHARGER (Sanei Electric NC-LSC01)

NOTE

- The default communication speed setting of the 9670 printer is 9600 bps.
  When using with the 3541, follow the instructions in the 9670 user manual to set the communication speed to 19200 bps.
- The 9670 PRINTER does not include a charging function for the 9672 BATTERY PACK. Use the 9673 BATTERY CHARGER to charge it.
- Read the manuals supplied with the printer and battery charger for the operating procedures.
- As much as possible, avoid printing in hot and humid environments. Otherwise, printer life may be severely shortened.
- Please use only the specified recording paper. Using non-specified paper may not only result in faulty printing, but printing may become impossible.
- If the recording paper is skewed on the roller, paper jams may result.
- Printing is not possible if the front and back of the recording paper are reversed.

7.2 Printer Connection

WARNING

Because electric shock and instrument damage hazards are present, always follow the steps below when connecting the printer.

- **Always turn off the instrument and the printer before connecting.**
- **A serious hazard can occur if a wire becomes dislocated and contacts another conductor during operation. Make certain connections are secure.**

CAUTION

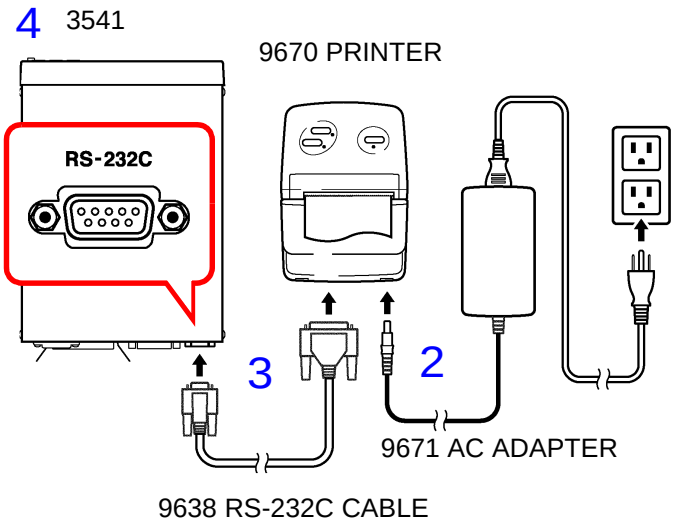
- To avoid damaging the instrument and printer, do not connect and disconnect the connectors when the power is on.
- If using a cable other than the 9638 RS-232C CABLE, the connector at the instrument end should be a molded type. The metal type (with hooks preventing the surface from being flat) will not fit due to the instrument's design.

NOTE

The requirements for a printer to be connected to the instrument are as follows.
Confirm compatibility and make the appropriate settings on the printer before connecting it to the instrument.

- Interface RS-232C
- Characters per line ..... At least 40
- Communication speed..... 19200 bps
- Data bits 8
- Parity ..... none
- Stop bits..... 1
- Flow control ..... none

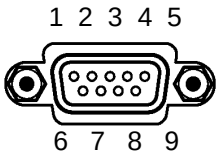
Connecting the 9670 PRINTER to the Instrument



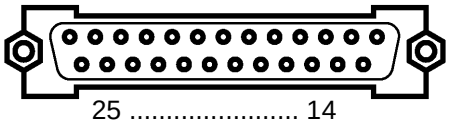
1. Confirm that the instrument and 9670 PRINTER are turned off.
2. Connect the 9671 AC ADAPTER to the 9670 PRINTER, and insert the power plug into an outlet.
3. Connect the 9638 RS-232C CABLE to the RS-232C connectors on the instrument and printer.
4. Turn the instrument and printer on.

For battery operation, use a fully charged Model 9672 BATTERY PACK.
❖ Charging the Battery Pack (Page 97)

Connector Pinouts



3541 (9-pin) Connector

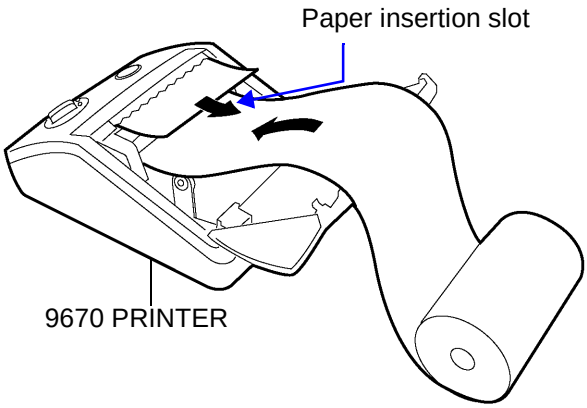


9670 (25-pin) Connector

Function	Signal Name	Pin
Receive Data	RxD	2
Transmit Data	TxD	3
Signal or Common Ground	GND	5

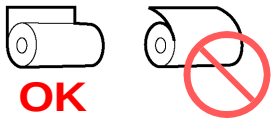
Pin	Signal Name	Function
2	TxD	Transmit Data
3	RxD	Receive Data
7	GND	Signal or Common Ground
4	RTS	Request to Send
5	CTS	Clear to Send

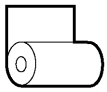
Loading Recording Paper



Load the recording paper into the 9670 PRINTER.

Note the paper orientation!

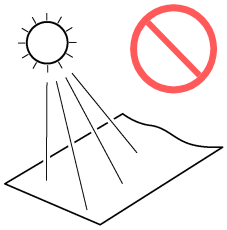




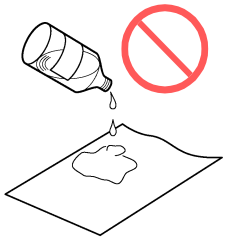
Cut the paper horizontally.

Handling and Storing Recording Paper

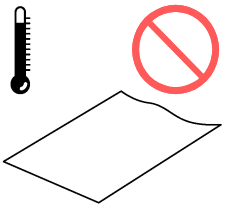
The recording paper is thermally and chemically sensitized. Observe the following precautions to avoid paper discoloration and fading.



Avoid exposure to direct sunlight.

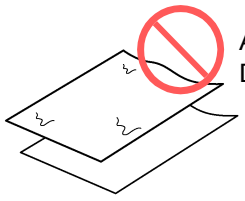


Avoid exposure to volatile organic solvents like alcohol, ethers and ketones.



Do not store thermal paper above 40°C or 90% RH.

Avoid contact with adhesive tapes like soft vinyl chloride and cellophane tape.

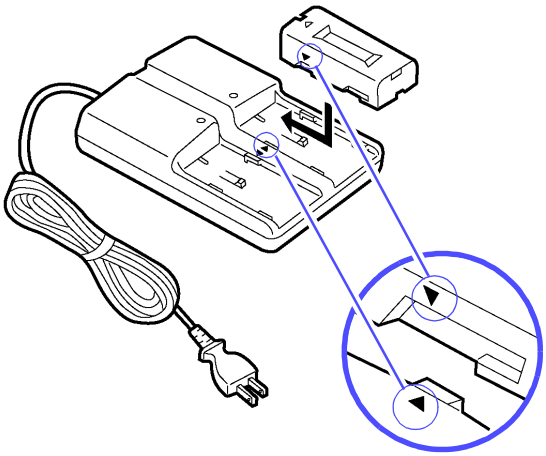


Avoid stacking with wet Diazo copy paper.

NOTE

- Store thermal paper where its temperature will not exceed 40°C.
- The paper will deteriorate if exposed to light for a long time, so do not remove rolls from their wrappers until ready to use.
- Make photocopies of recording printouts that are to be handled or stored for legal purposes.

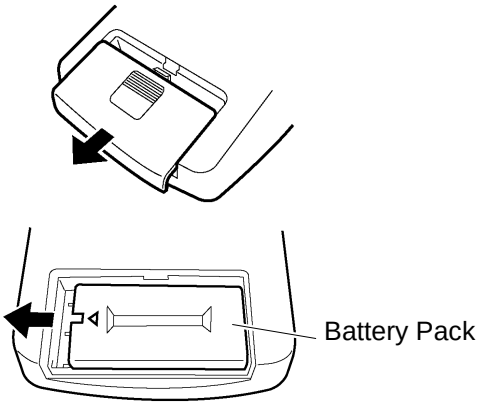
Charging the Battery Pack



1. Plug the charger power cord into an outlet.
2. Insert the battery pack by sliding it in the direction indicated by the arrow.

Align the ▲ marks on the battery pack and charger

Installing the Battery Pack in the Printer



1. Remove the battery compartment cover by sliding it in the direction indicated by the arrow.
2. Install the battery pack with its arrow pointing as shown at the left.

7.3 Interface Selection

Set the Instrument Interface selection to Printer

1 SHIFT → ENTER (MENU)

(SHIFT Lamp lit)

The Menu display appears.

2

Select the Interface Selection display.
(Refer to the Menu displays (Page 15))

(Main Display)

(Sub Display)

Print interval

Select Printer on the Sub Display.
rS..... RS-232C
GP-Ib.... GP-IB
Prn ..... Printer

3

Or ten-keys

Set the print interval time.
0000 ..... Interval printing is OFF. (Printing is carried out once when PRINT key is pressed.)
0001 - 3600 ... Sets the print interval time in seconds.

4 ENTER (MENU)

Applies settings and returns to the Measurement display.

NOTE

While carrying out temperature measurement via the RS-232C interface, the printing functions are not available.

❖ Temperature measurement via RS-232C interface (using the 3444/3445 TEMPERATURE HiTESTER+ 3909 INTERFACE PACK) (Page 35)

7.4 Setting of the 9670 PRINTER

Turn the 9670 PRINTER on while holding the **FEED** button.
Then press **SELECT** to set as needed according to print results.

The settings are as follows:

International char = Japan
Print mode = Graphic
Character set = 24Dot ANK Gothic type
Select switch = Enabled (ON)
Baud rate =19200 bps
Bit length = 8 bits
Parity = None
Data control = SBUSY
Paper selection = Normal paper
Upright/inverted = Upright printing
Auto power off = Enabled (ON) [as needed]
Battery mode = Disabled (OFF) [as needed]

7.5 Printing

Printing Measured Values and Decision Results

From the Measurement display, press the PRINT key or ground the PRINT pin in the EXT I/O connector to print the measured value and decision result.

NOTE

- When using the external trigger, if you want to print after a triggered measurement finishes, connect the EOC signal of the External I/O to the PRINT signal.
- To print all measurements continuously, connect the EOC signal to the PRINT signal and enable the internal trigger.
- When the statistical calculation function is on and the internal trigger is selected, the TRIG key or TRIG signal will trigger statistical calculation and printing of the current measurement value.

Interval printing

This function allows you to automatically print out measurement results at preset intervals. The print interval time must be set from the Interface Selection display.

❖ 7.3 Interface Selection (Page 98)

The setting range is 1 to 3600 seconds.
When the print interval time is set to "0", interval printing is disabled, and only normal printing is carried out.

Operation when interval printing is selected

1. Start printing by pressing the PRINT key or sending the PRINT signal via EXT I/O.
2. Elapsed time (hours/minutes/seconds)*1 and measurement values are printed automatically at intervals corresponding to the preset interval time.
3. Stop printing by pressing the PRINT key or sending the PRINT signal via EXT I/O again.

*1 When the printed elapsed time reaches 100 hours, it resets to 00:00:00 and continues from zero.
(Example)
After 99 hours, 59 minutes and 50 seconds: 99:59:50
After 100 hours, 2 minutes and 30 seconds: 00:02:30

Printing Statistical Calculation Results

From the Statistical Calculation display, press the PRINT key to print statistical calculation results. If no valid data exists, only the data count is printed. When only one valid data sample exists, standard deviation of sample and process capability indices cannot be printed.

❖ 5.6 Statistical Calculation Functions (Page 62)

Example Printouts

Resistance measurements

```
  38.418mOhm
   38.55mOhm
  0.0403 Ohm
    0.06 Ohm
-  0.498kOhm
 19.9950kOhm
 10.0117MOhm
```

With the Comparator ON

```
 109.558MOhm Hi
 109.542MOhm IN
 109.546MOhm Lo
   O.F.      Hi
-  O.F.      Lo
```

With the REF/% comparator function

```
  11.222 %   Hi
-  0.100 %   IN
- 90.805 %   Lo
```

With BIN ON

```
 1200.06 Ohm 0
 1200.16 Ohm     45
 1200.19 Ohm       6
 1200.12 Ohm   23
 1200.26 Ohm          9
```

With ΔT ON

```
   119.1 C
-   63.8 C
```

With erroneous measurement values

```
   O.F.
-  O.F.
 Invalid
 CurrErr
 Sens Hi
 Sens Lo
```

Temperature measurements

```
   0.7 C
   7.2 C
  73.7 C
-  0.8 C
-  7.3 C
- 75.5 C
```

Interval print

```
00:00:00   431.95mOhm
00:00:01   431.95mOhm
00:00:02   431.95mOhm
00:00:03   431.95mOhm
00:00:04   431.94mOhm
00:00:05   431.95mOhm
```

Statistical Calculations (Comparator ON)

```
Number        11
Valid         10
Average  1200.16 Ohm
Max      1200.20 Ohm(     9)
Min      1200.13 Ohm(     1)
Sn        24.104mOhm
Sn-1      25.408mOhm
Cp           0.19
CpK          0.03

Comp Hi       4
Comp IN       6
Comp Lo       0
```

Statistical Calculations (BIN ON)

```
Number        12
Valid         11
Average  1209.25 Ohm
Max      1300.15 Ohm(    12)
Min      1200.10 Ohm(     9)
Sn        28.744 Ohm
Sn-1      30.147 Ohm
Cp           0.00
CpK          0.00

 1200.06 Ohm to 1200.08 Ohm       0
 1200.08 Ohm to 1200.10 Ohm       1
 1200.10 Ohm to 1200.12 Ohm       1
 1200.12 Ohm to 1200.14 Ohm       2
 1200.14 Ohm to 1200.16 Ohm       1
 1200.16 Ohm to 1200.18 Ohm       3
 1200.18 Ohm to 1200.20 Ohm       5
 1200.20 Ohm to 1200.22 Ohm       2
 1200.22 Ohm to 1200.24 Ohm       0
 1200.24 Ohm to 1200.26 Ohm       0
         Out of BIN               1
          Invalid                 1
```

NOTE

When the measurement value is shown as “Invalid” upon printout, the display of the 3541 will show “------.”
“Valid” indicated that the statistical calculation result accurately reflects the result data excluding measurement error and OF data.

RS-232C/GP-IB Interfaces

Chapter 8

This chapter describes the GP-IB and RS-232C interfaces, using the following symbols to indicate which information pertains to each interface. Sections with neither of these symbols pertain to both interfaces.

GP-IB : GP-IB only

RS-232C : RS-232C only

Before Use

- Always make use of the connector screws to affix the GP-IB or RS-232C connectors.
- When issuing commands that contain data, make certain that the data is provided in the specified format.

8.1 Overview and Features

All instrument functions other than power on/off switching can be controlled via GP-IB/RS-232C interfaces.

RS-232C

- Resetting is supported.

GP-IB

- Resetting is supported.
- IEEE 488.2-1987 Common (essential) Commands are supported.
- Complies with the following standard:
  Applicable standard IEEE 488.1-1987*1
- This instrument is designed with reference to the following standard:
  Reference standard IEEE 488.2-1987*2
- If the output queue becomes full, a query error is generated and the output queue is cleared. Therefore, clearing the output queue and query error output from the deadlocked condition*3 as defined in IEEE 488.2 is not supported.

NOTE

While carrying out temperature measurement via the RS-232C interface, the RS-232C/GP-IB communication functions are not available.

❖ Temperature measurement via RS-232C interface (using the 3444/3445 TEMPERATURE HiTESTER+ 3909 INTERFACE PACK) (Page 35)

*1. ANSI/IEEE Standard 488.1-1987, IEEE Standard Digital Interface for Programmable Instrumentation.
*2. ANSI/IEEE Standard 488.2-1987, IEEE Standard Codes, Formats, Protocols, and Common Commands.
*3. The situation in which the input buffer and the output queue become full, so that processing cannot continue.

8.2 Specifications

8.2.1 RS-232C Specifications

RS-232C

Transfer method	Communications: Full duplex Synchronization: Start-stop synchronization	
Baud rate	9600 bps	
Data length	8 bit	
Parity	none	
Stop bit	1 bit	
Message terminator (delimiter)	Receiving: CR+LF, CR Transmitting: CR+LF	
Flow control	none	
Electrical specification	Input voltage levels	5 to 15 V : ON -15 to -5 V: OFF
	Output voltage levels	5 to 9 V : ON -9 to -5 V : OFF
Connector	RS-232C Interface Connector Pinout (Male 9-pin D-sub, with #4-40 attachment screws) The I/O connector is a DTE (Data Terminal Equipment) configuration Recommended cables: • Model 9637 RS-232C CABLE (for PC/AT-compatibles) • Model 9638 RS-232C CABLE (for PC98-series) ❖ 8.3.1 Attaching the Connector (Page 103)	

8.2.2 GP-IB Specifications

GP-IB

Interface Functions

SH1	All Source Handshake functions are supported.
AH1	All Acceptor Handshake functions are supported.
T6	Basic talker functions are supported. Serial poll function are supported. No talk-only mode. The talker cancel function with MLA (My Listen Address) is supported.
L4	Basic listener functions are supported. No listen-only mode. The listener cancel function with MTA (My Talk Address) is supported.
SR1	All Service Request functions are supported.
RL1	All Remote/Local functions are supported.
PP0	No Parallel Poll function.
DC1	All Device Clear functions are supported.
DT1	All Device Trigger functions are supported.
C0	No Controller functions are supported.

Operating Code: ASCII codes

8.3 Connections and Protocol Selection

8.3.1 Attaching the Connector

⚠WARNING

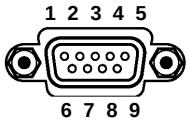
- **Always turn both devices OFF when connecting and disconnecting an interface connector. Otherwise, an electric shock accident may occur.**
- **To avoid damage to the product, do not short-circuit the terminal and do not input voltage to the terminal.**

⚠CAUTION

After connecting, always tighten the connector screws. If the connector is not secured, operation may fail to meet specifications, and damage could result.

RS-232C

RS-232C Connector



Male 9-pin D-sub
#4-40 attaching screws

Connect the RS-232C cable.

To connect the instrument to a controller (DTE), use a crossover cable compatible with the connectors on both the instrument and the controller.

The I/O connector is a DTE (Data Terminal Equipment) configuration. This instrument uses only pins 2, 3 and 5. The other pins are unconnected.

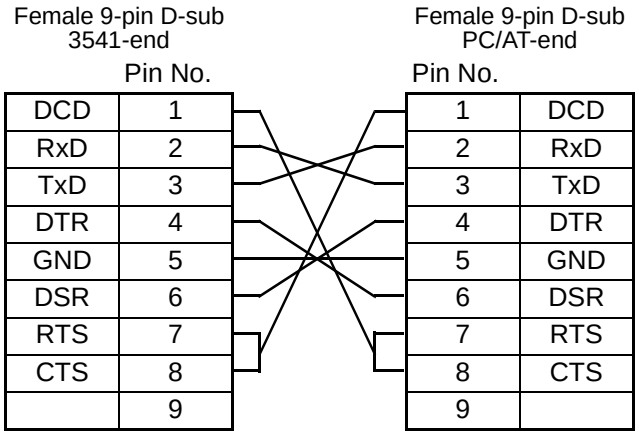
Pin No.	Mutual connection circuit name		CCITT	EIA	JIS	Signal Name
			Circuit No.	Code Addr.	Code Addr.	
1	unused					
2	Receive Data	Receive Data	104	BB	RD	RxD
3	Transmit Data	Send Data	103	BA	SD	TxD
4	Data Terminal Ready	Data Terminal Ready	108/2	CD	ER	DTR
5	Signal Ground	Signal Ground	102	AB	SG	GND
6	unused					
7	Request to Send	Request to Send	105	CA	RS	RTS
8	Clear to Send	Clear to Send	106	CB	CS	CTS
9	unused					

RS-232C

Connecting to a PC/AT-Compatible (DOS/V) Machine

Use a **crossover cable** with **female 9-pin D-sub** connectors.

Crossover Wiring



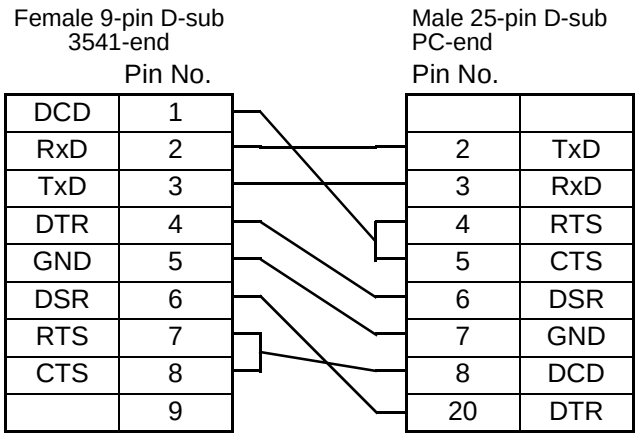
Recommended cable:

HIOKI
9637 RS-232C CABLE (1.8 m)

Connecting to an NEC PC9801 or PC9821 Series Desktop PC (excluding NX)

Use a **crossover cable** with **a female 9-pin D-sub** and **a male 25-pin D-sub** connector.
As the figure shows, RTS and CTS pins are shorted together and crossed to DCD in the other connector.

Crossover Wiring



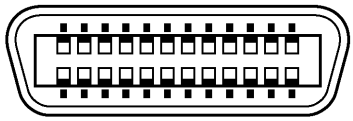
Recommended cable:

HIOKI
9638 RS-232C CABLE (1.8 m)

Note that the combination of a dual male 25-pin D-sub cable and a 9- to 25-pin adapter cannot be used.

GP-IB

GP-IB Connector



Connecting a GP-IB cable.

Recommended cable:
9151-02 GP-IB CONNECTOR CABLE (2 m)
9151-04 GP-IB CONNECTOR CABLE (4 m)

8.3.2 Communications Protocol Selection

Selecting the Interface

1 SHIFT → ENTER (MENU)

(SHIFT Lamp lit)

The Menu display appears.

2

Select the Interface Selection display.
(Refer to the Menu displays (Page 15))

(Main Display)

(Sub Display)

Select RS-232C or GP-IB on the Sub Display.
rS RS-232C
GP-Ib ... GP-IB
Prn ..... Printer

When selecting **GP-IB**, also set the Address and Message Terminator.

(Sub Display)

Message Terminator setting (LF/CRLF)

Address setting (0 to 30)

Selects the item to set

Setting

3 ENTER (MENU)

Applies settings and returns to the Measurement display.

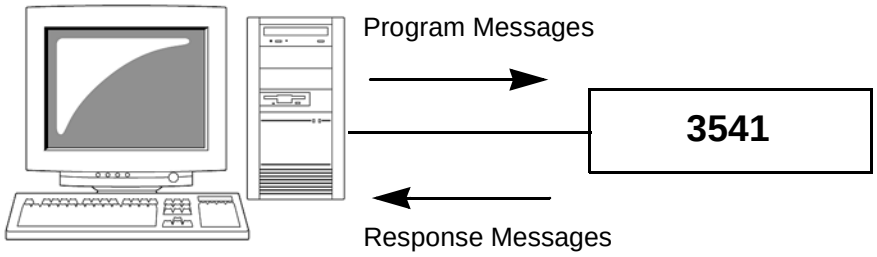
NOTE

While carrying out temperature measurement via the RS-232C interface, the RS-232C/GP-IB communication functions are not available.

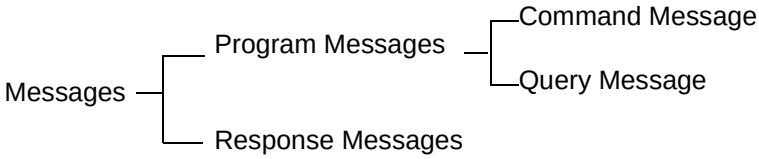
❖ Temperature measurement via RS-232C interface (using the 3444/3445 TEMPERATURE HiTESTER+ 3909 INTERFACE PACK) (Page 35)

8.4 Communication Methods

Various messages are supported for controlling the instrument through the interfaces.
Messages can be either program messages, sent from the PC to the instrument, or response messages, sent from the instrument to the PC.



Message types are further categorized as follows:



8.4.1 Message Format

Program Messages

Program messages can be either Command Messages or Query Messages.

- **Command Messages**
  Instructions to control the instrument, such as to change settings or reset

  Example: (instruction to set the measurement range)

  ```
  :RESISTANCE:RANGE 100E3
  ```

  Header portion — Space — Data portion

- **Query Messages**
  Requests for responses relating to results of operation or measurement, or the state of instrument settings.

  Example: (request for the current measurement range)

  ```
  :RESISTANCE:RANGE?
  ```

  Header portion — Question Mark

❖ For details:Headers (Page 107), Separators (Page 108), Data Formats (Page 109)

Response Messages

When a query message is received, its syntax is checked and a response message is generated.
The ":SYSTem:HEADer" command determines whether headers are prefixed to response messages.

Header ON `:RESISTANCE:RANGE 110.000E+03`
Header OFF `110.000E+03`
(the current resistance measurement range is 100 kΩ)

At power-on, Header OFF is selected.
If an error occurs when a query message is received, no response message is generated for that query.
No header is applied to commands used only for queries, such as `:FETCH?` and `:CALCulate:LIMit:RESult?`.

Command Syntax

Command names are chosen to mnemonically represent their function, and can be abbreviated. The full command name is called the "long form", and the abbreviated name is called the "short form".
The command references in this manual indicate the short form in upper-case letters, extended to the long form in lower case letters, although the commands are not case-sensitive in actual usage.

`FUNCTION`	OK (long form)
`FUNC`	OK (short form)
`FUNCT`	Error
`FUN`	Error

Response messages generated by the instrument are in long form and in upper case letters.

Headers

Headers must always be prefixed to program messages.

(1) Command Program Headers

There are three types of commands: Simple, Compound and Standard.

- **Headers for Simple Commands**
  This header type is a sequence of letters and digits
  `:ESE 0`
- **Headers for Compound Commands**
  These headers consist of multiple simple command type headers separated by colons "`:`"
  `:SAMPle:RATE`
- **Headers for Standard Commands**
  This header type begins with an asterisk "`*`",
  indicating that it is a standard command defined by IEEE 488.2.
  `*RST`

(2) Query Program Header

These commands are used to interrogate the instrument about the results of operations, measured values and the current states of instrument settings.
As shown by the following examples, a query is formed by appending a question mark "`?`" after a program header.

```
:FETCh?
:MEASure:RESistance?
```

Message Terminators

This instrument recognizes the following message terminators:

GP-IB
- LF
- CR+LF
- EOI
- LF with EOI

RS-232C
- CR
- CR+LF

From the instrument's interface settings, the following can be selected as the terminator for response messages.

GP-IB
- LF with EOI (initial setting)
- LF with CR and EOI

RS-232C
- CR + LF (initial setting)

❖ Interface setting: 8.3.2 Communications Protocol Selection (Page 105)

Separators

(1) Message Unit Separator

Multiple message can be written in one line by separating them with semicolons ";".

```
:SYSTEM:LFREQUENCY 60;*IDN?
```

- When messages are combined in this way and if one command contains an error, all subsequent messages up to the next terminator will be ignored.
- A query error occurs if a query command is combined with an immediately following semicolon and subsequent command.

(2) Header Separator

In a message consisting of both a header and data, the header is separated from the data by a space " "(ASCII code 20H).

```
:SYSTEM:OVC V
```

(3) Data Separator

In a message containing multiple data items, commas are required to separate the data items from one another.

```
:CALCULATE:BIN:UPPER 3,100000
```

Data Formats

The instrument uses character data and decimal numeric data, depending on the command.

(1) Character Data

Character data always begins with an alphabetic character, and subsequent characters may be either alphabetic or numeric. Character data is not case-sensitive, although response messages from the instrument are only upper case.

```
:SYSTEM:OVC ON
```

(2) Decimal Numeric Data

Three formats are used for numeric data, identified as NR1, NR2 and NR3. Numeric values may be signed or unsigned. Unsigned numeric values are handled as positive values.
Values exceeding the precision handled by the instrument are rounded to the nearest valid digit.

- NR1 Integer data (e.g.: +12, -23, 34)
- NR2 Fixed-point data(e.g.: +1.23, -23.45, 3.456)
- NR3 Floating-point exponential representation data (e.g.: +1.0E-2, -2.3E+4)

The term "NRf format" includes all three of the above numeric decimal formats.
The instrument accepts NRf format data.

The format of response data is specified for each command, and the data is sent in that format.

```
:ESR0 106
:FETCH? +106.571
```

GP-IB

The instrument does not fully support IEEE 488.2. As much as possible, please use the data formats shown in the Reference section. Also, be careful to avoid constructing single commands that could overflow the input buffer or output queue.

Compound Command Header Omission

When several commands having a common header are combined to form a compound command (e.g., **:CALCulate: LIMit:UPPer** and **:CALCulate:LIMit:LOWer**), if they are written together in sequence, the common portion (here, **:CALCulate:LIMit**) can be omitted after its initial occurrence.
This common portion is called the "current path" (analogous to the path concept in computer file storage), and until it is cleared, the interpretation of subsequent commands presumes that they share the same common portion.

This usage of the current path is shown in the following example:

Full expression

```
:CALCulate:LIMit:UPPer 110000;:CALCulate:LIMit:LOWer 90000
```

Compacted expression

```
:CALCulate:LIMit:UPPer 110000;LOWer 90000
```

This portion becomes the current path, and can be omitted from the messages immediately following.

The current path is cleared when the power is turned on, when reset by key input, by a colon ":" at the start of a command, and when a message terminator is detected.
Standard command messages can be executed regardless of the current path.
They have no effect upon the current path.

A colon ":" is not required at the start of the header of a Simple or Compound command. However, to avoid confusion with abbreviated forms and operating mistakes, we recommend always placing a colon at the start of a header.
In this instrument, the current path is as follows
(for both GP-IB and RS-232C):

```
:CALCulate:LIMit:
```

8.4.2 Output Queue and Input Buffer

Output Queue

Response messages are stored in the output queue until read by the controller. The output queue is also cleared in the following circumstances:

- Power on
- Device clear
- Power on
- Query Error

The output queue capacity of the instrument is 64 bytes. If response messages overflow the buffer, a query error is generated and the output queue is cleared.
Also, with GP-IB, if a new message is received while data remains in the output queue, the output queue is cleared and a query error is generated.

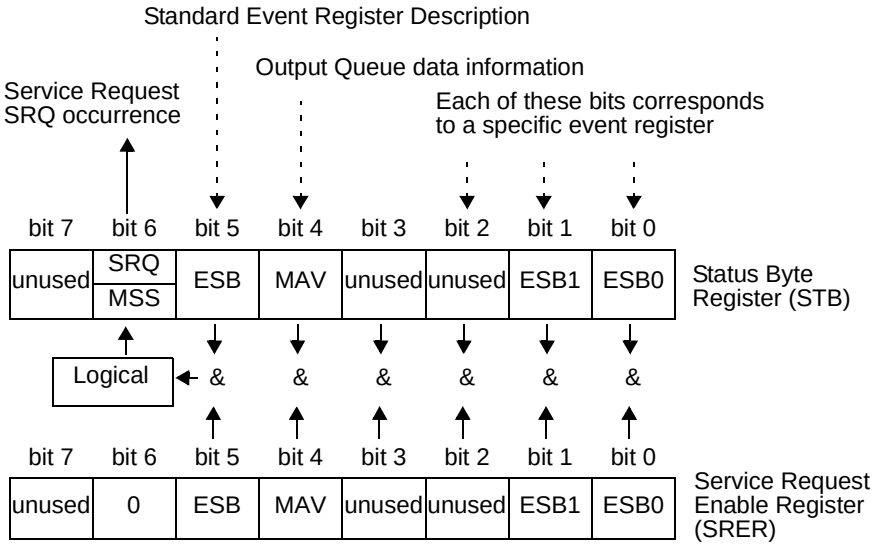
Input Buffer

The input buffer capacity of the instrument is 256 bytes.
If 256 bytes are allowed to accumulate in this buffer so that it becomes full, the GP-IB interface bus enters the waiting state until space is cleared in the buffer.
The RS-232C interface will not accept data beyond 256 bytes.

Ensure that the no command ever exceeds 256 bytes.

8.4.3 Status Byte Register

This instrument implements the status model defined by IEEE 488.2 with regard to the serial poll function using the service request line.
The term "event" refers to any occurrence that generates a service request.



Overview of Service Request Occurrence

The Status Byte Register contains information about the event registers and the output queue. Required items are selected from this information by masking with the Service Request Enable Register. When any bit selected by the mask is set, bit 6 (MSS; the Master Summary Status) of the Status Byte Register is also set, which generates an SRQ (Service Request) message and dispatches a service request.

Status Byte Register (STB)

During serial polling, the contents of the 8-bit Status Byte Register are sent from the instrument to the controller.
When any Status Byte Register bit enabled by the Service Request Enable Register has switched from 0 to 1, the MSS bit becomes 1. Consequently, the SRQ bit is set to 1, and a service request is dispatched.

The SRQ bit is always synchronous with service requests, and is read and simultaneously cleared during serial polling. Although the MSS bit is only read by an **`*STB?`** query, it is not cleared until a clear event is initiated by the **`*CLS`** command.

Bit 7	unused
Bit 6 SRQ MSS	 Set to 1 when a service request is dispatched. This is the logical sum of the other bits of the Status Byte Register.
Bit 5 ESB	Standard Event Status (logical sum) bit This is logical sum of the Standard Event Status Register.
Bit 4 MAV	Message available Indicates that a message is present in the output queue.
Bit 3	unused
Bit 2	unused
Bit 1 ESB1	Event Status (logical sum) bit 1 This is the logical sum of Event Status Register 1.
Bit 0 ESB0	Event Status (logical sum) bit 0 This is the logical sum of Event Status Register 0.

Service Request Enable Register (SRER)

This register masks the Status Byte Register. Setting a bit of this register to 1 enables the corresponding bit of the Status Byte Register to be used.

8.4.4 Event Registers

Standard Event Status Register (SESR)

The Standard Event Status Register is an 8-bit register.
If any bit in the Standard Event Status Register is set to 1 (after masking by the Standard Event Status Enable Register), bit 5 (ESB) of the Status Byte Register is set to 1.

❖ Standard Event Status Register (SESR) and Standard Event Status Enable Register (SESER) (Page 115)

The Standard Event Status Register is cleared in the following situations:

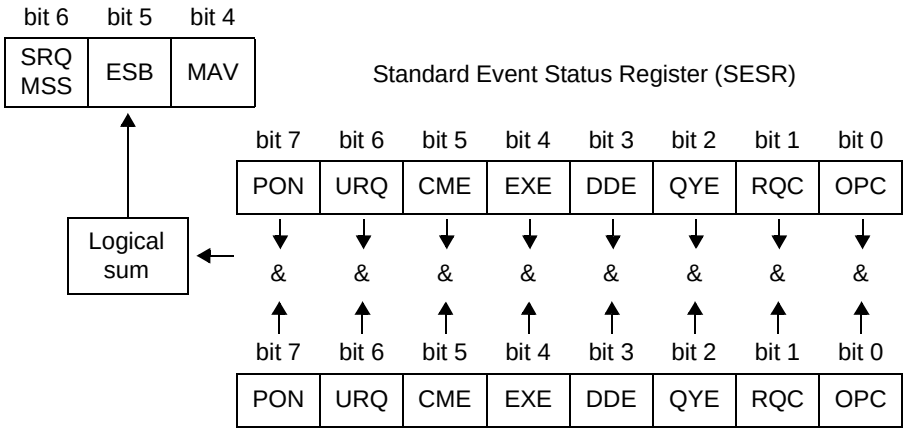
- When a ***CLS** command is executed
- When an event register query (*****ESR?) is executed
- When the instrument is powered on

Bit 7	PON	Power-On Flag Set to 1 when the power is turned on, or upon recovery from an outage.
Bit 6		User Request unused
Bit 5	CME	Command error. (The command to the message terminator is ignored.) This bit is set to 1 when a received command contains a syntactic or semantic error: • Program header error • Incorrect number of data parameters • Invalid parameter format • Received a command not supported by the instrument
Bit 4	EXE	Execution Error This bit is set to 1 when a received command cannot be executed for some reason. • The specified data value is outside of the set range • The specified setting data cannot be set • Execution is prevented by some other operation being performed
Bit 3	DDE	Device-Dependent Error This bit is set to 1 when a command cannot be executed due to some reason other than a command error, a query error or an execution error. • Execution is impossible due to an internal instrument fault
Bit 2	QYE	Query Error (the output queue is cleared) This bit is set to 1 when a query error is detected by the output queue control. • When an attempt has been made to read an empty output queue (GP-IB only) • When the data overflows the output queue • When data in the output queue has been lost
Bit 1		unused
Bit 0	OPC	Operation Complete (GP-IB only) This bit is set to 1 in response to an ∗OPC command. • It indicates the completion of operations of all messages up to the ∗OPC command

Standard Event Status Enable Register (SESER)

Setting any bit of the Standard Event Status Enable Register to 1 enables access to the corresponding bit of the Standard Event Status Register.

Standard Event Status Register (SESR) and Standard Event Status Enable Register (SESER)



Device-Specific Event Status Registers (ESR0 and ESR1)

This instrument provides two event status registers for controlling events.
Each event register is an 8-bit register.
When any bit in one of these event status registers enabled by its corresponding event status enable register is set to 1, the following happens:

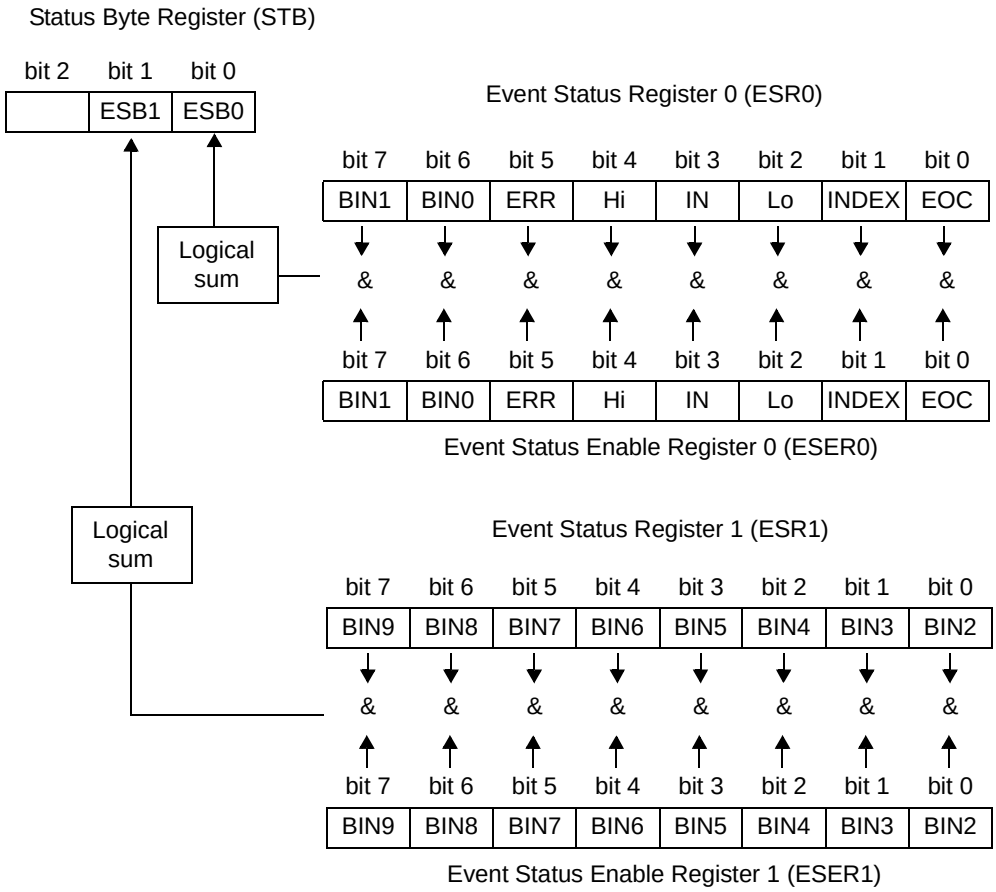
- For Event Status Register 0, bit 0 (ESB0) of the Status Byte Register is set to 1.
- For Event Status Register 1, bit 1 (ESB1) of the Status Byte Register is set to 1.

Event Status Registers 0 and 1 are cleared in the following situations:

- When a **`*CLS`** command is executed
- When an Event Status Register query (**`:ESR0?`** or **`:ESR1?`**) is executed
- When the instrument is powered on

	Event Status Register 0 (ESR0)		Event Status Register 1 (ESR1)	
Bit 7	BIN1	BIN1	BIN9	BIN9
Bit 6	BIN0	BIN0	BIN8	BIN8
Bit 5	ERR	Measurement Fault	BIN7	BIN7
Bit 4	Hi	High Comparator Result	BIN6	BIN6
Bit 3	IN	IN Comparator Result	BIN5	BIN5
Bit 2	Lo	Low Comparator Result	BIN4	BIN4
Bit 1	INDEX	End of Measurement	BIN3	BIN3
Bit 0	EOC	End of Conversion	BIN2	BIN2

Event Status Registers 0 (ESR0) and 1 (ESR1), and Event Status Enable Registers 0 (ESER0) and 1 (ESER1)



Register Reading and Writing

Register	Read	Write
Status Byte Register	∗STB?	–
Service Request Enable Register	∗SRE?	∗SRE
Standard Event Status Register	∗ESR?	–
Standard Event Status Enable Register	∗ESE?	∗ESE
Event Status Register 0	:ESR0?	–
Event Status Enable Register 0	:ESE0?	:ESE0
Event Status Register 1	:ESR1?	–
Event Status Enable Register 1	:ESE1?	:ESE1

GP-IB Commands

The following commands can be used for performing interface functions.

Command	Description	
GTL	Go To Local	Cancels the Remote state and enters the Local state.
LLO	Local Lock Out	Disables all keys, including the LOCAL key.
DCL	Device CLear	Clears the input buffer and the output queue.
SDC	Selected Device Clear	Clears the input buffer and the output queue.
GET	Group Execute Trigger	When an external trigger occurs, processes one sample.

8.4.5 Initialization Items

● = initialized, — = not initialized

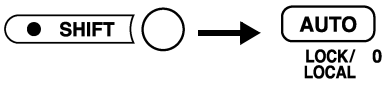
Item \ Initialization Method	At Power-on	∗RST Command	Device Clear	∗CLS Command
Device-specific functions (Range, etc.)	–	●	–	–
Output Queue	●	–	●	–
Input buffer	●	–	●	–
Status Byte Register	●	–	– *1	● *2
Event registers	● *3	–	–	●
Enable register	●	–	–	–
Current path	●	–	●	–
Headers on/off	●	●	–	–

*1 Only the MAV bit (bit 4) is cleared.
*2 All bits except the MAV bit are cleared.
*3 Except the PON bit (bit 7).

8.4.6 Local Function

During communications, **REMOTE** is lit to indicate the remote control state.

To cancel the Remote state



REMOTE off

NOTE If the Local Lock Out (Page 116) GP-IB command has been issued, the Remote state cannot be canceled.

8.5 Message List

Commands specific to RS-232C or GP-IB are identified by RS-232C or GP-IB, respectively.

NOTE

- Any spelling mistake in a message results in a command error.
- < > = contents of the data portion.
  [Numeric data values are indicated by format as (NR1), (NR2) and (NR3), representing integer, fixed-point and floating point decimal data values respectively, or as (NRf), representing any of these formats]
- [ ]: optional

8.5.1 Standard Commands

Command	Data Formats (Response data if a Query)	Description	Error	Ref page
∗CLS		Clears the event registers and the Status Byte Register	*1	126
∗ESE	0 to 255 (NR1)	Sets the contents of the Standard Event Status Enable Register	*3	127
∗ESE?	0 to 255 (NR1)	Queries the Standard Event Status Enable Register	*2	127
∗ESR?	0 to 255 (NR1)	Queries the Standard Event Status Register	*2	127
∗IDN?	<Manufacturer's name>,<Model name>,0,<Software version>	Queries the Device ID.	*2	125
∗OPC	————————	Requests an SRQ after execution completion	*1	126
∗OPC?	1	Queries execution completion	*2	126
∗RST	————————	Initializes the device	*1	125
∗SRE	0 to 255 (NR1)	Sets the Service Request Enable Register	*3	128
∗SRE?	0 to 255 (NR1)	Queries the contents of the Service Request Enable Register	*2	128
∗STB?	0 to 255 (NR1)	Queries the Status Byte Register	*2	128
∗TRG	————————	Executes one sampling	*1,4	128
∗TST?	0 to 3 (NR1)	Initiates a self-test and queries the result	*2	125
∗WAI	————————	Wait for operations to finish	*1	126

Error description (an error occurs when executing messages in the following cases):

*1 Command Error.....When data is present after the command
*2 Query Error.....When the response message exceeds 64 bytes
*3 Execution Error.....When invalid character or numeric data is present
*4 Execution Error..... When the command is executed in internal trigger mode

8.5.2 Device-Specific Commands

Message ([ ] = optional)	Data Contents ( ) = response data	Description	Ref page
Event registers			
:ESE0	0 to 255	Sets Event Status Enable Register 0	129
:ESE0?	(0 to 255)	Queries Event Status Enable Register 0	129
:ESR0?	(0 to 255)	Queries Event Status Register 0	129
:ESE1	0 to 255	Sets Event Status Enable Register 1	129
:ESE1?	(0 to 255)	Queries Event Status Enable Register 1	129
:ESR1?	(0 to 255)	Queries Event Status Register 1	129
Measurement functions			
[:SENSe:]FUNCtion	RESistance, LPResistance or TEMPerature	Function settings	130
[:SENSe:]FUNCtion?	(RESISTANCE, LPRESISTANCE or TEMPERATURE)	Function queries	130
Measurement range			
[:SENSe:]LPResistance:RANGe	0 to 2000	Sets Low-Power Resistance measurement range	130
[:SENSe:]LPResistance:RANGe?	(2000.00E-3 to 2000.00E+0)	Queries the Low-Power Resistance measurement range setting	130
[:SENSe:]LPResistance:RANGe:AUTO	1, 0, ON or OFF	Sets AUTO-ranging for Low-Power Resistance measurement	131
[:SENSe:]LPResistance:RANGe:AUTO?	(ON or OFF)	Queries the AUTO-ranging Low-Power Resistance measurement setting	131
[:SENSe:]RESistance:RANGe	0 to 110E+6	Sets the Resistance measurement range	131
[:SENSe:]RESistance:RANGe?	(20.0000E-3 to 110.000E+6)	Queries the Resistance measurement range	131
[:SENSe:]RESistance:RANGe:AUTO	1, 0, ON or OFF	Sets AUTO-ranging Resistance measurement	131
[:SENSe:]RESistance:RANGe:AUTO?	(ON or OFF)	Queries the AUTO-ranging resistance measurement setting	131
Measurement current selection for 200 mΩ range (with software version 1.13 or later)			
:SYSTem:CURRent	1A / 0.1A	Sets measurement current for the 200mΩ range	132
:SYSTem:CURRent?	(1A / 0.1A)	Queries measurement current setting for the 200 mΩ range	132
Zero-adjust			
:ADJust?	(0 or 1)	Execute Zero-Adjustment	132
:ADJust:CLEAr		Cancels zero-adjustment	132
Measurement terminals			
[:SENSe:]TERMinal	A or B	Selects the Measurement Terminals	132
[:SENSe:]TERMinal?	(A or B)	Queries the Measurement Terminal selection	132
Sampling rate			
:SAMPle:RATE	FAST, MEDium, SLOW1 or SLOW2	Sets the Sampling Rate	132

Message ([ ] = optional)	Data Contents ( ) = response data	Description	Ref page
:SAMPle:RATE?	(FAST, MEDIUM, SLOW1 or SLOW2)	Queries the Sampling Rate setting	132
Temperature correction			
:CALCulate:TCORrect:STATe	1, 0, ON or OFF	Set Temperature Correction execution	133
:CALCulate:TCORrect:STATe?	(ON or OFF)	Queries the Temperature Correction execution setting	133
:CALCulate:TCORrect:PARameter	<Reference Temp.>, <Temp. Coefficient>	Sets the Temperature Correction constant	133
:CALCulate:TCORrect:PARameter?	(<Reference Temp.>, <Temp. Coefficient>)	Queries the Temperature Correction constant setting	133
Temperature conversion (Δt)			
:CALCulate:TCONversion:DELTa:STATe	1, 0, ON or OFF	Set Temperature Conversion execution	134
:CALCulate:TCONversion:DELTa:STATe?	(ON or OFF)	Queries the Temperature Conversion execution setting	134
:CALCulate:TCONversion:DELTa:PARameter	<Initial Resistance>,<Initial Temp.>,<Constant>	Sets the Temperature Conversion constant	134
:CALCulate:TCONversion:DELTa:PARameter?	(<Initial Resistance>, <Initial Temp.>,<Constant>)	Queries the Temperature Conversion constant setting	134
Averaging function			
:CALCulate:AVERage	2 to 100	Sets the no. of samples to average	135
:CALCulate:AVERage?	(2 to 100)	Queries the no. of samples to average setting	135
:CALCulate:AVERage:STATe	1, 0, ON or OFF	Sets Averaging function execution	134
:CALCulate:AVERage:STATe?	(ON or OFF)	Queries the Averaging function execution setting	134
Statistical functions			
:CALCulate:STATistics:STATe	1, 0, ON or OFF	Sets Statistical Calculation function execution	135
:CALCulate:STATistics:STATe?	(ON or OFF)	Queries the Statistical Calculation function execution setting	135
:CALCulate:STATistics:CLEAr		Clears Statistical Calculation results	135
:CALCulate:STATistics:NUMBer?	(<Total data count>, <Valid data count>)	Queries the data count	135
:CALCulate:STATistics:MEAN?	(<Mean>)	Queries the mean value	135
:CALCulate:STATistics:MAXimum?	(<Maximum value>, <Data no.>)	Queries the maximum value	135
:CALCulate:STATistics:MINimum?	(<Minimum value>, <Data no.>)	Queries the minimum value	136
:CALCulate:STATistics:LIMit?	(<Hi count>,<IN count>, <Lo count>, <Measurement fault count>)	Queries comparator results	136
:CALCulate:STATistics:BIN?	(<BIN0 count>,...,<BIN9 count>,<OUT count>, <Measurement fault count>)	Queries BIN results	136
:CALCulate:STATistics:DEViation?	(<σn>,<σn-1>)	Queries standard deviation	136
:CALCulate:STATistics:CP?	(<Cp>,<Cpk>)	Queries the Process Capability Indices	136
Comparator			
:CALCulate:LIMit:STATe	1, 0, ON or OFF	Sets comparator execution	137

Message ([ ] = optional)	Data Contents ( ) = response data	Description	Ref page
:CALCulate:LIMit:STATe?	(ON or OFF)	Queries the comparator execution setting	137
:CALCulate:LIMit:BEEPer	OFF, HI or IN	Sets the beep sound	137
:CALCulate:LIMit:BEEPer?	(OFF, HI or IN)	Queries the beep sound setting	137
:CALCulate:LIMit:MODE	HL or REF	Selects the decision mode	137
:CALCulate:LIMit:MODE?	(HL or REF)	Queries the decision mode setting	137
:CALCulate:LIMit:UPPer	<Upper threshold>	Sets the upper threshold	137
:CALCulate:LIMit:UPPer?	(<Upper threshold>)	Queries the upper threshold setting	137
:CALCulate:LIMit:LOWer	<Lower threshold>	Sets the lower threshold	137
:CALCulate:LIMit:LOWer?	(<Lower threshold>)	Queries the lower threshold setting	137
:CALCulate:LIMit:REFerence	<Reference Resistance>	Sets the reference resistance	138
:CALCulate:LIMit:REFerence?	(<Reference resistance>)	Queries the reference resistance setting	138
:CALCulate:LIMit:PERCent	<Tolerance (%)>	Sets the decision tolerance	138
:CALCulate:LIMit:PERCent?	(<Tolerance (%)>)	Queries the decision tolerance setting	138
:CALCulate:LIMit:RESult?	(HI, IN, LO, OFF or ERR)	Queries the decision result	138
Setting and querying BIN measurements			
:CALCulate:BIN:STATe	1, 0, ON or OFF	Sets BIN measurement execution	138
:CALCulate:BIN:STATe?	(ON or OFF)	Queries the BIN execution state setting	138
:CALCulate:BIN:ENABle	< Enable Mask>	Sets the enable mask	139
:CALCulate:BIN:ENABle?	(<Enable Mask>)	Queries the Enable Mask setting	139
:CALCulate:BIN:MODE	<BIN No.>,<HL or REF>	Sets the decision mode	139
:CALCulate:BIN:MODE?	<BIN No.>,(<HL or REF>)	Queries the decision mode setting	139
:CALCulate:BIN:UPPer	<BIN No.>,<Upper threshold>	Sets the upper threshold	139
:CALCulate:BIN:UPPer?	<BIN No.>,(<Upper threshold>)	Queries the upper threshold setting	139
:CALCulate:BIN:LOWer	<BIN No.>,<Lower threshold>	Sets the lower threshold	139
:CALCulate:BIN:LOWer?	<BIN No.>,(<Lower threshold>)	Queries the lower threshold setting	139
:CALCulate:BIN:REFerence	<BIN No.>,<Reference resistance>	Sets the reference resistance	140
:CALCulate:BIN:REFerence?	<BIN No.> (<Reference resistance>)	Queries the reference resistance setting	140
:CALCulate:BIN:PERCent	<BIN No.>,<Tolerance (%)>	Sets the decision tolerance	140
:CALCulate:BIN:PERCent?	<BIN No.>,(<Tolerance (%)>)	Queries the decision tolerance setting	140
:CALCulate:BIN:RESult?	0 to 1023	Sets the upper threshold	140
Offset voltage compensation function			
:SYSTem:OVC	1, 0, ON or OFF	Set Offset Voltage Compensation function execution	140
:SYSTem:OVC?	(ON or OFF)	Query Offset Voltage Compensation function execution	140
Temperature measurement (analog input)			
:SYSTem:TEMPerature:SENSor	PT or ANALog	Selects the temperature sensor type	141
:SYSTem:TEMPerature:SENSor?	(PT or ANALOG)	Queries the temperature sensor type selection	141

Message ([ ] = optional)	Data Contents ( ) = response data	Description	Ref page
:SYSTem:TEMPerature:PARameter	<V1>,<T1>,<V2>,<T2>	Sets the analog input scaling constants	141
:SYSTem:TEMPerature:PARameter?	(<V1>,<T1>,<V2>, <T2>)	Queries the analog input scaling constant settings	141
Measurement fault detection time			
:SYSTem:FDETect:AUTO		Sets the measurement fault detection.	142
:SYSTem:FDETect:AUTO?		Queries the measurement fault detection setting.	142
:SYSTem:FDETect	0 to 9.998	Sets the measurement fault detection time.	142
:SYSTem:FDETect?	(0 to 9.998)	Queries the measurement fault detection time.	142
Format for Measurement fault data (with software version 1.13 or later)			
:SYSTem:FORMat	CF / NORMal	Sets the format for measurement fault data	142
:SYSTem:FORMat?	(CF / NORMAL)	Queries the format for measurement fault data	142
Self-Calibration			
:SYSTem:CALibration		Execute Self-Calibration	143
:SYSTem:CALibration:AUTO	1, 0, ON or OFF	Sets automatic self-calibration	143
:SYSTem:CALibration:AUTO?	(ON or OFF)	Queries the automatic self-calibration setting	143
Key Beeper			
:SYSTem:BEEPer:STATe	1, 0, ON or OFF	Sets the key beeper	143
:SYSTem:BEEPer:STATe?	(ON or OFF)	Queries the key beeper setting	143
Line Frequency			
:SYSTem:LFRequency	50 or 60	Selects the AC line frequency	143
:SYSTem:LFRequency?	(50 or 60)	Queries the AC line frequency selection	143
Key-Lock			
:SYSTem:KLOCk	1, 0, ON or OFF	Sets the key-lock	144
:SYSTem:KLOCk?	(ON or OFF)	Queries the key-lock setting	144
Saving and Loading Measurement Setting States			
:SYSTem:SAVE	<Table No.>	Saves the measurement setting state	144
:SYSTem:LOAD	<Table No.>	Loads a measurement setting state	144
Header Present			
:SYSTem:HEADer	1, 0, ON or OFF	Sets header present	144
:SYSTem:HEADer?	(ON or OFF)	Queries the header present setting	144
ERR Output			
:SYSTem:ERRor	SYNChronous or ASYNchronous	Sets error output timing	144
:SYSTem:ERRor?	(SYNCHRONOUS or ASYNCHRONOUS)	Queries the error output timing setting	144

Message ([ ] = optional)	Data Contents ( ) = response data	Description	Ref page
External I/O Output			
:SYSTem:EXTernalout	BIN or BCD	Selects BIN or BCD	145
:SYSTem:EXTernalout?	(BIN or BCD)	Queries the external I/O output selection	145
Delimiter (Terminator)			
:SYSTem:TERMinator GP-IB	0 or 1	Sets the command delimiter	145
:SYSTem:TERMinator? GP-IB	(0 or 1)	Queries the command delimiter setting	145
System Reset			
:SYSTem:RESet		Executes a system reset, including saved measurement setting state data	145
External I/O			
:IO:OUT	0 to 255	External I/O Output	146
:IO:IN?	(0 to 3)	External I/O Input	146
Trigger			
:INITiate:CONTinuous	1, 0, ON or OFF	Sets continuous measurement	149
:INITiate:CONTinuous?	(ON or OFF)	Queries the continuous measurement setting	149
:INITiate[:IMMediate]		Trigger wait setting	149
:TRIGger:SOURce	IMMediate or EXTernal	Sets the trigger source	150
:TRIGger:SOURce?	(IMMEDIATE or EXTERNAL)	Queries the trigger source setting	150
:TRIGger:DELay	<Delay>	Sets the trigger delay	150
:TRIGger:DELay?	(0 to 9.999)	Queries the trigger delay setting	150
:TRIGger:DELay:AUTO	1, 0, ON or OFF	Sets automatic trigger delay	150
:TRIGger:DELay:AUTO?	(ON or OFF)	Queries the automatic trigger delay setting	150
Reading Measured Values			
:FETCh?		Reads the Most Recent Measurement	152
:READ?		Waits for trigger and reads the measured value	152
:MEASure:LPResistance?	<[Expected measure-ment value] >	Presets a specified low-power resistance range, and measures	153
:MEASure:RESistance?	<[Expected measure-ment value] >	Presets a specified resistance range, and measures	153
:MEASure:TEMPerature?		Reads the Temperature Measurement	152
Memory Function (software version 1.13 or later)			
:MEMory:STATe	1/ 0/ ON/ OFF	Changes the Memory function execution setting	154
:MEMory:STATe?	(ON/ OFF)	Queries the Memory function execution setting	154
:MEMory:CLEAr		Clears memory data	154
:MEMory:COUNt?	(0 to 10)	Queries the number of measurements stored in memory	154
:MEMory:DATA?	<Memory no> , <Measurement value>	Reads the measurements stored in memory	154

8.6 Message Reference

< >: Indicates the contents (character or numeric parameters) of the data portion of a message.
Character parameters are returned as all capital letters.

Numeric Parameters:
- NRf Number format may be any of NR1, NR2 and NR3
- NR1 Integer data (e.g.: +12, -23, 34)
- NR2 Fixed-point data(e.g.: +1.23, -23.45, 3.456)
- NR3 Floating-point exponential representation data (e.g.: +1.0E-2, -2.3E+4)

Shows the command description.

Shows the message syntax.
Explains the command data or response message.

Describes the message.

Shows an example of an actual command application.
(Normally described with HEADER ON, (except the HEADER command itself).)

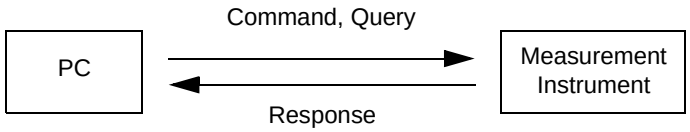
Read/Write the Standard Event Status Enable Register (SESER)

Syntax
Command: ∗**ESE** <0 to 255(NR1)>
Query: ∗**ESE?**
Response: <0 to 255(NR1)>

Description
Command: The SESER mask is set to the numerical value 0 to 255.
The initial value (at power-on) is 0.
Query: The contents of the SESER, as set by the *ESE command, are returned as an NR1 value (0 to 255).

128	64	32	16	8	4	2	1
bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
PON	URQ	CME	EXE	DDE	QYE	RQC	OPC

Example
Command: ***ESE 36**
(Sets bits 5 and 2 of SESER)



8.6.1 Standard Commands

Messages specific to the RS-232C or GP-IB interface are identified by their corresponding symbols.

(1) System Data Command

Queries device ID.

Syntax Query ∗**IDN?**
Response <Manufacturer's name>,<Model name>,0,<Software version>

Example Response `HIOKI,3541,0,V1.00`
The Device ID is HIOKI 3541, 0, software version 1.00.

Note The response message has no header.

(2) Internal Operation Command

Initialize Device

Syntax Command ∗**RST**

Description Command Resets instrument settings (other than saved data) to factory defaults. Operation returns to the initial display after initialization.

Note
- The communications state is not initialized.
- To initialize saved data as well, send the :SYSTem:RESet command.

Execute Self-Test and Query the Result

Syntax Query ∗**TST?**
Response <0 to 3 (NR1)>
0: No Errors
1: RAM Error
2: EEPROM Error
3: RAM and EEPROM Errors

Description Perform instrument self-test and return the result as numerical value 0 to 3.

Example Query `*TST?`
Response `1`
A RAM Error occurred.

(3) Synchronization Commands

Set the OPC bit of SESR When Finished All Pending Operations

Syntax Command ∗**OPC**

Description Sets OPC bit 0 of the Standard Event Status Register (SESR) when all prior commands have finished processing.

Example `A;B;*OPC;C`

The OPC bit of the SESR is set after commands A and B have finished processing.

Respond with ASCII "1" When Finished All Pending Operations

Syntax Query ∗**OPC?**

Response `1`

Description Responds with ASCII "1" when all prior commands have finished processing.

Wait for Pending Commands to Finish

Syntax Command ∗**WAI**

Description The instrument waits until all prior commands finish before executing any subsequent commands.

Note The `*WAI` command is supported because it is defined in IEEE 488.2-1987, but because all Model 3541 device-specific commands are sequential types, this command has no actual affect.

(4) Status and Event Control Commands

Clear the Status Byte and Related Queues (Except the Output Queue)

Syntax Command ∗**CLS**

Description Clears the event registers corresponding to each bit of the Status Byte Register. Also clears the Status Byte Register.

Note RS-232C The output queue is unaffected.

GP-IB The output queue, the various enable registers and MAV bit 4 of the Status Byte Register are unaffected.

Read/Write the Standard Event Status Enable Register (SESER)

Syntax

Command ∗**ESE 0** <0 to 255 (NR1)>

Query ∗**ESE?**
Response <0 to 255 (NR1)>

Description

Command The SESER mask is set to the numerical value 0 to 255.
The initial value (at power-on) is 0.

Query The contents of the SESER, as set by the *ESE command, are returned as an NR1 value (0 to 255).

128	64	32	16	8	4	2	1
bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
PON	URQ	CME	EXE	DDE	QYE	RQC	OPC

Example

Command **`*ESE 36`**

(Sets bits 5 and 2 of SESER)

Read and Clear the Standard Event Status Register (SESR)

Syntax

Query ∗**ESR?**
Response <0 to 255 (NR1)>

Description

Returns the contents of the SESR as an NR1 value from 0 to 255, then clears register contents.

The response message has no header.

RS-232C

128	64	32	16	8	4	2	1
bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
PON	unused	CME	EXE	DDE	QYE	unused	unused

GP-IB

128	64	32	16	8	4	2	1
bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
PON	URQ	CME	EXE	DDE	QYE	RQC	OPC

Example

`32`

Bit 5 of the SESR was set to 1.

Write and Read the Service Request Enable Register (SRER)

Syntax

Command ∗**SRE** <0 to 255 (NR1)>

Query ∗**SRE?**
Response <0 to 255 (NR1)>

Description

Command The SRER mask is set to the numerical value 0 to 255.
Although NRf numerical values are accepted, values to the right of the decimal are rounded to the nearest integer.
Bit 6 and unused bits 2, 3 and 7 are ignored.
The data is initialized to zero at power-on.

Query The contents of the SRER, as set by the ∗SRE command, are returned as an NR1 value (0 to 255). Bit 6 and unused bits 2, 3 and 7 always return as zero.

128 bit 7	64 bit 6	32 bit 5	16 bit 4	8 bit 3	4 bit 2	2 bit 1	1 bit 0
unused	0	ESB	MAV	unused	unused	ESE1	ESE0

Example

Command `*SRE 33`
Set SRER bits 0 and 5 to 1.

Query `*SRE?`
Response `33`
SRER bits 0 and 5 have been set to 1.

Read the Status Byte and MSS Bit

Syntax

Query ∗**STB?**
Response <0 to 255 (NR1)>

Description

The contents of the STB are returned as an NR1 value (0 to 255).
The response message has no header.

128 bit 7	64 bit 6	32 bit 5	16 bit 4	8 bit 3	4 bit 2	2 bit 1	1 bit 0
unused	MSS	ESB	MAV	unused	unused	ESE1	ESE0

Example

Query `*STB?`
Response `16`
STB bit 4 has been set to 1.

Request a Sample

Syntax

Command ∗**TRG**

Description

Performs one measurement when external triggering is enabled.
When Statistical Calculation is ON, imports calculation data.

Example

```
:TRIGger:SOURce EXTernal;*TRG
```

8.6.2 Device-Specific Commands

(1) Event Status Register

Set and Query Device-Specific Event Status Enable Registers ESER0 and ESER1

ESER0

Syntax

Command **:ESE0** <0 to 255 (NR1)>

Query **:ESE0?**
Response <0 to 255 (NR1)>

Description

Command Sets the mask pattern in Event Status Enable Register 0 (ESER0) for the Event Status Register.

128	64	32	16	8	4	2	1
bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
BIN1	BIN0	ERR	Hi	IN	Lo	INDEX	EOC

Note Data initializes to zero at power-on.

ESER1

Syntax

Command **:ESE0** <0 to 255 (NR1)>

Query **:ESE1?**
Response <0 to 255 (NR1)>

Description

Command Sets the mask pattern in Event Status Enable Register 1 (ESER1) for the Event Status Register.

128	64	32	16	8	4	2	1
bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
BIN9	BIN8	BIN7	BIN6	BIN5	BIN4	BIN3	BIN2

Note Data initializes to zero at power-on.

Read Device-Specific Event Status Registers ESR0 and ESR1

Syntax

Query **:ESR0?**
:ESR1?
Response <0 to 255 (NR1)>

Note Executing ESR0? clears the contents of ESR0.
Executing ESR1? clears the contents of ESR1.

(2) Measurement-Related

Select and Query the Function Setting

Syntax

Command **[:SENSe:]FUNCtion** <RESistance, LPResistance or TEMPerature>

Query **[:SENSe:]FUNCtion?**
Response
RESISTANCE .....Resistance measurement function
LPRESISTANCE.....Low-Power Resistance measurement function
TEMPERATURE .....Temperature measurement function

Example

Command **FUNC LPR**

Selects the Low-Power Resistance measurement function.

Query **FUNC?**
Response **RESISTANCE**

The Resistance measurement function has been selected.

Note

- [:SENSe:] may be omitted.
- The following HIOKI 3227 command can be used, but the format of the response message is different.
  :FUNCtion RESIstance

Set and Query the Range Setting

Low-Power Resistance Measurement Range

Syntax

Command **[:SENSe:]LPResistance:RANGe** <Expected measurement value>

<Expected measurement value> = 0 to 2000

Query **[:SENSe:]LPResistance:RANGe?**
Response
<Measurement Range (NR3)>

<Measurement Range (NR3)> = 2000.00E-3, 20.0000E+0, 200.000E+0 or 2000.00E+0

Description

Command Enter the expected measurement value. The instrument is set to the most suitable range for measuring the given numerical value data.

Query Queries the measurement range setting.

Example

Query **LPR:RANG?**
Response **20.0000E+0**

Low-Power Resistance measurement has been set to the 20Ω range.

Resistance Measurement Range

Command **[:SENSe:]RESistance:RANGe** <Expected measurement value>
<Expected measurement value> = 0 to 110E+6

Query **[:SENSe:]RESistance:RANGe?**
Response <Measurement Range (NR3)>
<Measurement Range (NR3)> = 20.0000E-3, 200.000E-3, 2000.00E-3, 20.0000E+0, 200.000E+0, 2000.00E+0, 20.0000E+3, 110.000E+3, 1100.00E+3, 11.0000E+6 or 110.0000E+6

Description

Command: Enter the expected measurement value. The instrument is set to the most suitable range for measuring the given numerical value data.

Query: Queries the measurement range setting.

Example

Command
```
RES:RANG 123
```
Sets the Resistance function to the 200Ω range.

Note

The following HIOKI 3227 command can be used, but the format of the response message is different.
:RESIstance:RANGe

Set and Query the Auto-Ranging Setting

Low-Power Resistance Measurement Range

Syntax

Command **[:SENSe:]LPResistance:RANGe:AUTO** <1, 0, ON or OFF>

Query **[:SENSe:]LPResistance:RANGe:AUTO?**
Response <ON or OFF>

Example

Command
```
LPR:RANG:AUTO ON
```

Resistance Measurement Range

Syntax

Command **[:SENSe:]RESistance:RANGe:AUTO** <1, 0, ON or OFF>

Query **[:SENSe:]RESistance:RANGe:AUTO?**
Response <ON or OFF>

Example

Query
```
RES:RANG:AUTO?
```
Response
```
OFF
```

Note

The following HIOKI 3227 command can be used, but the format of the response message is different.
:RESIstance:AUTO

Sets measurement current for the 200 mΩ range (software version 1.13 or later)

Syntax

Command **[:SYSTem:]CURRent** <1 A/ 0.1 A>

Query **[:SYSTem:]CURRent?**
Response <1A/0.1A>

1 A ..... 1 A setting
0.1 A... 100 mA setting

Example

Command `:SYST:CURR 0.1A`

Execute and Clear Zero-Adjustment

Clear Zero-Adjustment

Syntax

Command **:ADJust:CLEAr**

Execute Zero-Adjustment

Syntax

Query **:ADJust?**
Response <0 or 1>

0 ..... Indicates zero-adjustment succeeded.
1 ..... Indicates the offset resistance exceeded 1,000 dgt during zero-adjustment.

Select and Query the Measurement Terminal Setting

Syntax

Command **[:SENSe:]TERMinal** <A or B>

Query **[:SENSe:]TERMinal?**
Response <A or B>

A..... INPUT A is enabled.
B..... INPUT B is enabled.

Example

Command `TERM B`

Query `TERM?`
Response `B`

(3) Sampling

Select and Query the Sampling Rate setting

Syntax

Command **:SAMPle:RATE** <FAST, MEDium, SLOW1 or SLOW2>

Query **:SAMPle:RATE?**
Response <FAST, MEDIUM, SLOW1 or SLOW2>

Example

Command `:SAMP:RATE MED`

Select and Query the Sampling Rate setting

Query `:SAMP:RATE?`
Response `MEDIUM`

Note The following HIOKI 3227 commands can be used, but the response for both SLOW1 and SLOW2 settings is SLOW. Measurement and response times are both different from the Model 3227.

:SAMPle

Sending the :SAMPle SLOW command sets this instrument to SLOW1 sampling rate.

(4) Calculation

Set and Query the Temperature Correction Settings

Temperature Correction (TC) State

Syntax Command **:CALCulate:TCORrect:STATe** <1, 0, ON or OFF>

Query **:CALCulate:TCORrect:STATe?**
Response <ON or OFF>

Example Command `:CALC:TCOR:STAT ON`

Query `:CALC:TCOR:STAT?`
Response `OFF`

Temperature Correction (TC) Settings

Syntax Command **:CALCulate:TCORrect:PARameter** <Reference Temp.>,<Temp. Coefficient>

Query **:CALCulate:TCORrect:PARameter?**
Response <Reference Temp.>,<Temp. Coefficient>
<Reference temperature > = -10.0 to 99.9 (NR3) [°C]
<Temp. Coefficient> = = -99999 to 99999 (NR1) [ppm/°C]

Example Command `:CALC:TCOR:PAR 20,3930`

Query `:CALC:TCOR:PAR?`
Response `70.0E+0,4500`

Note When the Temperature Correction function is enabled, the Temperature Conversion function is disabled.

The units of the Reference Temperature are °C, and the units of the Temperature Coefficient are ppm/°C.

The following HIOKI 3227 command can be used, but the format of the response message is different.

:TC

:TC?

:TCSET

:TCSET?

Set and Query Temperature Conversion (Δt) Settings

Temperature Conversion (Δt) State

Syntax

Command **:CALCulate:TCONversion:DELTa:STATe** <1, 0, ON or OFF>

Query **:CALCulate:TCONversion:DELTa:STATe?**
Response <ON or OFF>

Example

Command `:CALC:TCON:DELT:STAT ON`

Query `:CALC:TCON:DELT:STAT?`
Response `ON`

Temperature Conversion (Δt) Settings

Syntax

Command **:CALCulate:TCONversion:DELTa:PARameter** <Initial resistance>,<Initial temperature>,<Constant>

Query **:CALCulate:TCONversion:DELTa:PARameter?**
Response <Initial Resistance>,<Initial Temp.>,<Constant>

<Initial resistance> = 0 to 110.000E+6 (NR3)
<Reference temperature > = -10.0 to 99.9 (NR3)
<Constant> = -999.9 to999.9 (NR2)

Example

Command `:CALC:TCON:DELT:PAR 100,20,235`

Query `:CALC:TCON:DELT:PAR?`
Response `100.000E+0,20.0E+0,235.0`

Note

When the Temperature Conversion function is enabled, the Temperature Correction function is disabled.

The unit of initial resistance is Ω.

The unit of initial temperature and constant is °C.

Set and Query the Averaging Function Setting

Averaging Function State

Syntax

Command **:CALCulate:AVERage:STATe** <1, 0, ON or OFF>

Query **:CALCulate:AVERage:STATe?**
Response <ON or OFF>

Example

Command `:CALC:AVER:STAT ON`

Query `:CALC:AVER:STAT?`
Response `OFF`

No. of samples to average

Syntax
Command **:CALCulate:AVERage** <Averaging Samples>
Query **:CALCulate:AVERage?**
Response <Averaging samples>
<Averaging samples> = 2 to 100 (NR1)

Example
Command `:CALC:AVER 10`
Query `:CALC:AVER?`
Response `50`

Clear and Query the Statistical Calculation State

Statistical Calculation State

Syntax
Command **:CALCulate:STATistics:STATe** <1, 0, ON or OFF>
Query **:CALCulate:STATistics:STATe?**
Response <ON or OFF>

Example
Command `:CALC:STAT:STAT ON`
Query `:CALC:STAT:STAT?`
Response `ON`

Clear Statistical Calculation Results

Syntax
Command **:CALCulate:STATistics:CLEAr**

Queries the data count

Syntax
Query **:CALCulate:STATistics:NUMBer?**
Response <Total data count (NR1)>,<Valid data count (NR1)>)
0 to 30000

Example
Query `:CALC:STAT:NUMB?`
Response `23456,23449`

Query the Mean value

Syntax
Query **:CALCulate:STATistics:MEAN?**
Response <Mean (NR3)>

Query the Maximum value

Syntax
Query **:CALCulate:STATistics:MAXimum?**
Response <Maximum value (NR3)>,<Data No. of Maximum value (NR1)>

Example
Query `:CALC:STAT:MAX?`
Response `12.4859E+3,1124`

Query the Minimum value

Syntax
Query: **:CALCulate:STATistics:MINimum?**
Response: <Minimum value (NR3)>,<Data No. of Minimum value (NR1)>

Query Comparator results

Syntax
Query: **:CALCulate:STATistics:LIMit?**
Response: <Hi (NR1) count>,<IN count (NR1)>,<Lo count (NR1)>,<Measurement fault count (NR1)>

Example
Query: `:CALC:STAT:LIM?`
Response: `1516,9310,737,16`

Query BIN Measurement results

Syntax
Query: **:CALCulate:STATistics:BIN?**
Response: <BIN0 count (NR1)>,....,<BIN9 count (NR1)>,<OUT count (NR1)>,<No. of Meas. Faults (NR1)>

Example
Query: `:CALC:STAT:BIN?`
Response: `53,16,70,53,57,28,30,77,1,76,81,3`

Query Standard Deviation

Syntax
Query: **:CALCulate:STATistics:DEViation?**
Response: <σn (NR3)>,<σn-1>

Example
Query: `:CALC:STAT:DEV?`
Response: `0.0159E-3,0.0161E-3`

Query the Process Capability Indices

Syntax
Query: **:CALCulate:STATistics:CP?**
Response: <Cp (NR2)>,<Cpk (NR2)>

Example
Query: `:CALC:STAT:CP?`
Response: `0.86,0.14`

Note

- A data sample can be taken by the following methods:
  1. Press the TRIG key
  2. Apply a signal to the TRIG terminal of the External I/O
  3. Send a ∗TRG command
- The :CALCulate:STATistics:STATe command does not clear calculation results.
- When the valid data count is 0, σn-1 returns 0.
- When cleared, the Statistical Calculation function is not turned OFF.
- The upper limit of Cp and CpK is 99.99. When Cp or Cpk >99.99, its value is returned as 99.99.

Set and Query Comparator Settings

Comparator State

Syntax
Command: **:CALCulate:LIMit:STATe** <1, 0, ON or OFF>
Query: **:CALCulate:LIMit:STATe?**
Response: <ON or OFF>

Example
Command: `:CALC:LIM:STAT ON`

Beeper State

Syntax
Command: **:CALCulate:LIMit:BEEPer** <OFF, HL or IN>
Query: **:CALCulate:LIMit:BEEPer?**
Response: <OFF, HL or IN>

Example
Command: `:CALC:LIM:BEEP HL`

Note
The following HIOKI 3227 command can be used, but the format of the response message is different.
:CSET:BEEPer

Decision Mode Setting

Syntax
Command: **:CALCulate:LIMit:MODE** <HL or REF>
Query: **:CALCulate:LIMit:MODE?**
Response: <HL or REF>
HL = Decision by preset upper and lower thresholds.
REF = Decision by a reference value and tolerance.

Example
Command: `:CALC:LIM:MODE REF`

Note
The following HIOKI 3227 command can be used, but the format of the response message is different.
:CSET:CMODe

Upper Threshold Setting

Syntax
Command: **:CALCulate:LIMit:UPPer** <Upper threshold>
Query: **:CALCulate:LIMit:UPPer?**
Response: <Upper threshold>
<Upper threshold> = 0 to 999999 (NR1)

Example
Command: `:CALC:LIM:UPP 005971`

Lower Threshold Setting

Syntax
Command: **:CALCulate:LIMit:LOWer** <Lower threshold>
Query: **:CALCulate:LIMit:LOWer?**
Response: <Lower threshold>
<Lower threshold> = 0 to 999999 (NR1)

Note (For both Upper and Lower thresholds)

- Upper and Lower thresholds are specified as integer values. To specify 0.567 Ω in the 2Ω range, send the following command:
  :CALCulate:LIMit:UPPer 56700 (or 056700)
- The following HIOKI 3227 command can be used, but the format of the response message is different.
  :CSET:PARAmeter

Reference Resistance Setting

Syntax

Command **:CALCulate:LIMit:REFerence** <Reference Resistance>

Query **:CALCulate:LIMit:REFerence?**
Response <Reference Resistance>

<Reference Resistance> = 0 to 999999 (NR1)

Example

Command `:CALC:LIM:REF 141000`

Note

Reference Resistance is specified as an integer value.2. To specify 0.567 Ω in the 2Ω range, send the following command:
:CALCulate:LIMit:REFerence 56700

Decision Tolerance Setting

Syntax

Command **:CALCulate:LIMit:PERCent** <Tolerance (%)>

Query **:CALCulate:LIMit:PERCent?**
Response <Tolerance (%)>

<Tolerance (%)> = 0 to 99.999 (NR2)

Example

Command `:CALC:LIM:PERC 10.000`

Note

The following HIOKI 3227 command can be used, but the format of the response message is different.
:CSET:PARAmeter

Comparator Result

Syntax

Query **:CALCulate:LIMit:RESult?**
Response <HI, IN, LO, OFF or ERR>

Example

Query `:CALC:LIM:RES?`
Response `HI`

Setting and Querying BIN Measurements

BIN Measurement State

Syntax

Command **:CALCulate:BIN:STATe** <1, 0, ON or OFF>

Query **:CALCulate:BIN:STATe?**
Response <ON or OFF>

Example

Command `:CALC:BIN:STAT ON`

Enable Mask Setting

Syntax

Command **:CALCulate:BIN:ENABle** <Enable Mask>

Query Response **:CALCulate:BIN:ENABle?**
<Enable Mask>
<Enable Mask> = 0 to 1023 (base-10)
Set the bit corresponding to each BIN to be enabled for BIN measurement.

bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
BIN9	BIN8	BIN7	BIN6	BIN5	BIN4	BIN3	BIN2	BIN1	BIN0

Example

Command **`:CALC:BIN:ENAB 15`**
Enables BIN0 to BIN3.

Decision Mode Setting

Syntax

Command **:CALCulate:BIN:MODE** <BIN No.>,<HL or REF>

Query Response **:CALCulate:BIN:MODE?** <BIN No.>
<HL or REF>
<BIN No.> = 0 to 9
<HL or REF> =
HL ..... Compare with upper/lower thresholds.
REF.... Compare with reference value and tolerance.

Example

Command **`:CALC:BIN:MODE 3,HL`**

Upper Threshold Setting

Syntax

Command **:CALCulate:BIN:UPPer?** <BIN No.>,<Upper threshold>

Query Response **:CALCulate:BIN:UPPer?** <BIN No.>
<Upper threshold>
<BIN No.> = 0 to 9
<Upper threshold> = 0 to 999999 (NR1)

Lower Threshold Setting

Syntax

Command **:CALCulate:BIN:LOWer** <BIN No.>,<Lower threshold>

Query Response **:CALCulate:BIN:LOWer?** <BIN No.>
<Lower threshold>
<BIN No.> = 0 to 9
<Lower threshold> = 0 to 999999 (NR1)

Example

Command **`:CALC:BIN:LOW 0,117832`**

Note

Upper and Lower thresholds are specified as integer values.
To specify 0.567 Ω in the 2Ω range, send the command as follows:
:CALCulate:BIN:UPPer 3,56700 (or 056700)

Reference Resistance Setting

Syntax

Command **:CALCulate:BIN:REFerence** <BIN No.>,<Reference Resistance>

Query Response **:CALCulate:BIN:REFerence?** <BIN No.>
<Reference Resistance>
<BIN No.> = 0 to 9
<Reference Resistance> = 0 to 999999 (NR1)

Note Reference Resistance is specified as an integer value.
To specify 0.567 Ω in the 2Ω range, send the command as follows:
:CALCulate:BIN:REFerence 5,56700

Decision Tolerance Setting

Syntax

Command **:CALCulate:BIN:PERCent** <BIN No.>,<Tolerance (%)>

Query Response **:CALCulate:BIN:PERCent?** <BIN No.>
<Tolerance (%)>
<BIN No.> = 0 to 9
<Tolerance (%)> = 0 to 99.999 (NR2)

Query the Decision Result

Syntax

Query Response **:CALCulate:BIN:RESult?**
<NR1>
<NR1> = 0 to 1023
The bit corresponding to each BIN with a PASS decision is set to 1.

bit 9	bit 8	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
BIN9	BIN8	BIN7	BIN6	BIN5	BIN4	BIN3	BIN2	BIN1	BIN0

Example

Query `:CALC:BIN:RES?`
Response `128`
BIN7 was judged PASS.

(5) System

Offset Voltage Compensation State

Syntax

Command **:SYSTem:OVC** <1, 0, ON or OFF>

Query Response **:SYSTem:OVC?**
<ON or OFF>

Example

Command `:SYST:OVC ON`

Query Response `:SYST:OVC?`
`OFF`

Note Settings in the 110 KΩ range and higher are ignored.

Temperature Measurement Settings (Analog Input)

Temperature Sensor Selection

Syntax

Command **:SYSTem:TEMPerature:SENSor** <PT or ANALog>

Query **:SYSTem:TEMPerature:SENSor?**
Response <PT or ANALOG>

PT .....The 9451 TEMPERATURE PROBE is used as the temperature sensor

ANALOG ....An analog output thermometer is used as the temperature sensor

Example

Command `:SYST:TEMP:SENS ANAL`

Query `:SYST:TEMP:SENS?`
Response `PT`

Note For some commands, RS-232C cannot be selected as input for temperature measurement. In such a case, use the menu screens on the 3541 unit to make the setting.

❖ Temperature measurement via RS-232C interface (using the 3444/3445 TEMPERATURE HiTESTER+ 3909 INTERFACE PACK) (Page 35)

Analog Input Parameter Settings

Syntax

Command **:SYSTem:TEMPerature:PARameter** <V1>,<T1>,<V2>,<T2>

Query **:SYSTem:TEMPerature:PARameter?**
Response <V1>,<T1>,<V2>,<T2>

<V1> = 0 to 2.00 (NR2)..... Reference Voltage 1 [V]

<T1> = -99.9 to 999.9 (NR2)..... Reference Temperature 1 [°C]

<V2> = 0 to 2.00 (NR2)..... Reference Voltage 2 [V]

<T1> = -99.9 to 999.9 (NR2)..... Reference Temperature 2 [°C]

Example

Command `:SYST:TEMP:PAR 0,-10,2,100`

Query `:SYST:TEMP:PAR?`
Response `0.00,0.00,1.00,100.0`

0 V displays as 0°C, and 1 V displays as 100°C.

Measurement Fault Detection Time Settings

Measurement Fault Detection Time Auto Settings

Syntax

Command **:SYSTem:FDETect:AUTO** <1, 0, ON or OFF>

Query **:SYSTem:FDETect:AUTO?**
Response <ON or OFF>

ON..... Measurement fault detection time setting: AUTO

OFF ..... Measurement fault detection time setting: OFF

Example

Command `:SYST:FDET:AUTO ON`

Query `:SYST:FDET:AUTO?`
Response `ON`

Measurement Fault Detection Time Settings

Syntax

Command **:SYSTem:FDETect** <Measurement fault detection time>

Query **:SYSTem:FDETect?**
Response <Measurement fault detection time> (NR2)

<Measurement fault detection time> = 0 to 9.998 (NR2)[second]
Do not set a detection time equal to or greater than the delay time.

Example

Command `:SYST:FDET 0.010`

Query `:SYST:FDET?`
Response `0.010`

Format for Measurement fault data (with software version 1.13 or later)

You can change the format for constant-current faults (Err.Cur) to the following.

- Err.Cur is handled in the same manner as Overflow (OF) display.
- During BIN output selection, pin 44 (BCD3-3) is output as an Err.Cur signal.
- When an Err.HI/Lo and an Err.Cur occur at the same time, the Err.Hi/Lo format is used.

Syntax

Command **:SYSTem:FORMat** <CF / NORMal >

Query **:SYSTem:FORMat?**
Response <CF/ NORMAL>

CF ..... Err.Cur is handled in the same manner as overflow display

NORMAL.... Err.Cur is handled as a measurement fault, and comparator decisions are not made.

Example

Command `:SYST:FORM CF`

Self-Calibration State and Setting

Execute Self-Calibration

Syntax Command **:SYSTem:CALibration**

Set Self-Calibration Execution State

Command **:SYSTem:CALibration:AUTO** <1, 0, ON or OFF>

Query **:SYSTem:CALibration:AUTO?**
Response <ON or OFF>

ON ..... AUTO Self-Calibration selected
OFF ..... MANUAL Self-Calibration selected

Example Command `:SYST:CAL:AUTO OFF`

Query `:SYST:CAL:AUTO?`
Response `ON`

Note Even when AUTO is selected, Self-Calibration can be manually performed at any time by sending the SYSTem:CALibration command.

Set and Query the Key Beeper Setting

Syntax Command **:SYSTem:BEEPer:STATe** <1, 0, ON or OFF>

Query **:SYSTem:BEEPer:STATe?**
Response <ON or OFF>

Example Command `:SYST:BEEP:STAT ON`

Query `:SYST:BEEP:STAT?`
Response `ON`

Select and Query the Line Frequency Setting

Syntax Command **:SYSTem:LFRequency** <50 or 60>

Query **:SYSTem:LFRequency?**
Response <50 or 60>

Example Command `:SYST:LFR 50`

Query `:SYST:LFR?`
Response `60`

Note The following HIOKI 3227 command can be used, but the format of the response message is different.

:FREQuency

Set and Query the Key-Lock State

Syntax
Command **:SYSTem:KLOCk** <1, 0, ON or OFF>
Query **:SYSTem:KLOCk?**
Response <ON or OFF>

Example
Command
```
:SYST:KLOC ON
```
Query
```
:SYST:KLOC?
```
Response
```
OFF
```

Save and Load Measurement Setting States

Syntax
Command **:SYSTem:SAVE** <Table No. 1 to 30>
:SYSTem:LOAD <Table No. 1 to 30>

Example
Command
```
:SYST:SAVE 10
:SYST:LOAD 5
```

Set and Query the Header Present Setting

Syntax
Command **:SYSTem:HEADer** <1, 0, ON or OFF>
Query **:SYSTem:HEADer?**
Response <ON or OFF>

Example
Command
```
:SYST:HEAD ON
```
Query
```
:SYST:HEAD?
```
Response
```
OFF
:SYSTEM:HEADER ON
```

Note The following HIOKI 3227 command can be used, but the format of the response message is different.
HEADer

Select the ERR Output Setting

Syntax
Command **:SYSTem:ERRor** <SYNChronous or ASYNchronous>
Query **:SYSTem:ERRor?**
Response <SYNChronous or ASYNchronous>
SYNCHRONOUS.....Synchronize with EOC output
ASYNCHRONOUS ....Asynchronous with EOC output

Example
Command
```
:SYST:ERR SYNC
```
Query
```
:SYST:ERR?
```
Response
```
ASYNCHRONOUS
```

BCD Output Setting

Syntax

Command **:SYSTem:EXTernalout** <BIN or BCD>

Query **:SYSTem:EXTernalout?**
Response <BIN or BCD>

Example

Command `:SYST:EXT BCD`

Query `:SYST:EXT?`
Response `BIN`

Note

- BIN output is disabled when BCD output is selected.
- BCD output is disabled when BIN output is selected.

Delimiter Setting

GP-IB

Syntax

Command **:SYSTem:TERMinator** <0 or 1>

Query **:SYSTem:TERMinator?**
Response <0 or 1>

0..... LF+EOI
1..... CR,LF+EOI

Example

Command `:SYST:TERM 1`

Query `:SYST:TERM?`
Response `0`

Note

- At power-on, this is set to 0 (LF+EOI).
- The RS-232C delimiter is fixed as CR + LF.

System Reset

Syntax

Command **:SYSTem:RESet**

Description

Command Returns all settings, including any saved data, to factory default settings.

Example

Command `:SYST:RES`

Note

If you want to preserve saved data, use the `*RST` command instead.

(6) External I/O

External I/O Output

Syntax Command **:IO:OUT** <Output Data 0 to 255>

Description Command Any 8-bit data value can be output from the EXT I/O connector when the BIN is selected as the BIN/BCD output setting for External I/O.

bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0	
OUT7	OUT6	OUT5	OUT4	OUT3	OUT2	OUT1	OUT0	
50	25	49	24	48	23	47	22	Pin No.

❖ 6.2 Signal Descriptions (Page 82)

Note An execution error occurs if BCD is selected as the BIN/BCD output setting for External I/O.

External I/O Input

Syntax Query **:IO:IN?**
Response 0 to 3 (NR1)

Description Query Reads at the leading edge (ON) of the EXT I/O $\overline{\text{TRIG}}$ and $\overline{\text{PRINT}}$ terminals, and then clears.

A bit is set when the leading edge (short between each signal terminal and the GND terminal) is detected, and is cleared when read by this query command.

TRIG key input is detected in the same way as the $\overline{\text{TRIG}}$ terminal signal.

bit 0: EXT I/O $\overline{\text{TRIG}}$ (leading edge), TRIG key input

bit 1: EXT I/O $\overline{\text{PRINT}}$ (leading edge)

❖ 6.2 Signal Descriptions (Page 82)

(7) Triggering

Triggering System Description

Triggering operates as follows depending on the continuous measurement setting (:INITIATE:CONTINUOUS) and the trigger source setting (:TRIGGER:SOURCE).

❖ 8.7 Basic Data Importing Methods (Page 155)

		Continuous Measurement (**:INITIATE:CONTINUOUS**)	
		ON	**OFF**[*1]
Trigger Source (**:TRIGGER:SOURCE**)	**IMMEDIATE** (EXT.TRIG off)	Free-Run state. Measurement continues automatically. ❖ (Page 148)-1	Trigger by **:INITIATE** (or **:READ?**) command. ❖ (Page 148)-2
	EXTERNAL[*2] (EXT.TRIG lit)	Trigger by TRIG terminal, TRIG key or ∗TRG command. After measurement, enters the trigger wait state. ❖ (Page 148)-3	Issue **:INITIATE** (or **:READ?**) command to wait for trigger. Trigger by TRIG terminal, TRIG key or ∗TRG command. ❖ (Page 148)-4

*1 **:INITIATE:CONTINUOUS OFF**
Can only be set by Remote command.
If this has been set to OFF when operation is returned to the Local state or power is turned off, the following state occurs when power is turned back on.
:INITIATE:CONTINUOUS ON

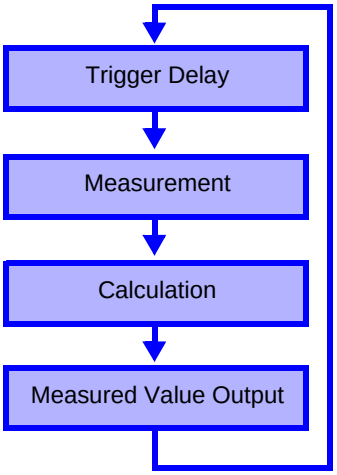
❖ 8.4.6 Local Function (Page 117)

*2 **:TRIGGER:SOURCE EXTERNAL**
Current flows only while measuring in all ranges of the Low-Power Resistance function, and in the 20 mΩ to 20 Ω ranges of the Resistance Measurement function.

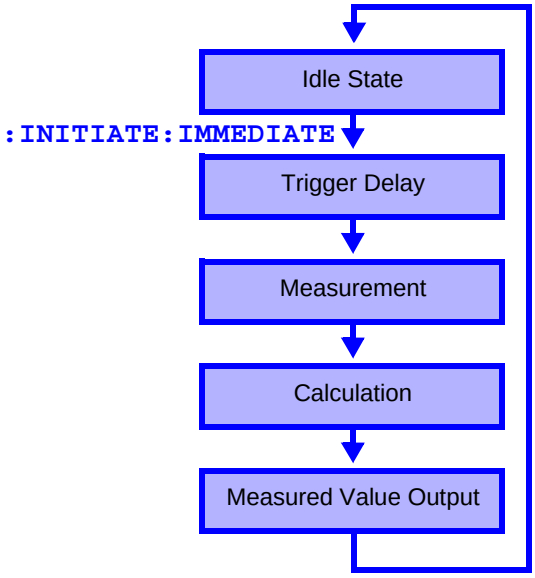
❖ 6.3 Timing Chart (Page 88)

Measurement Flow

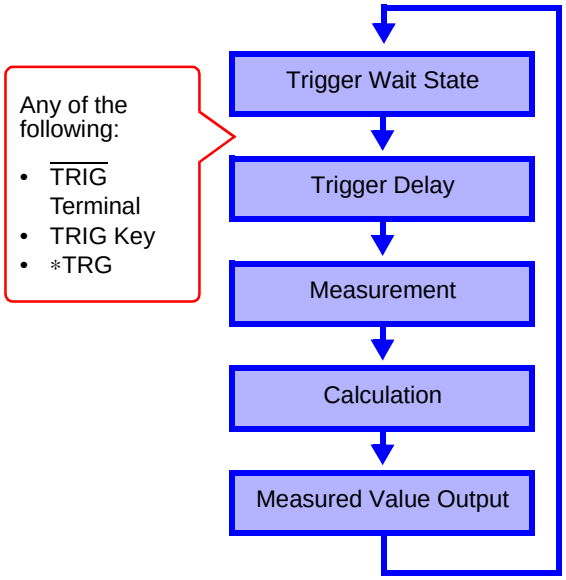
1 `:INITIATE:CONTINUOUS ON`
`:TRIGGER:SOURCE IMMEDIATE`



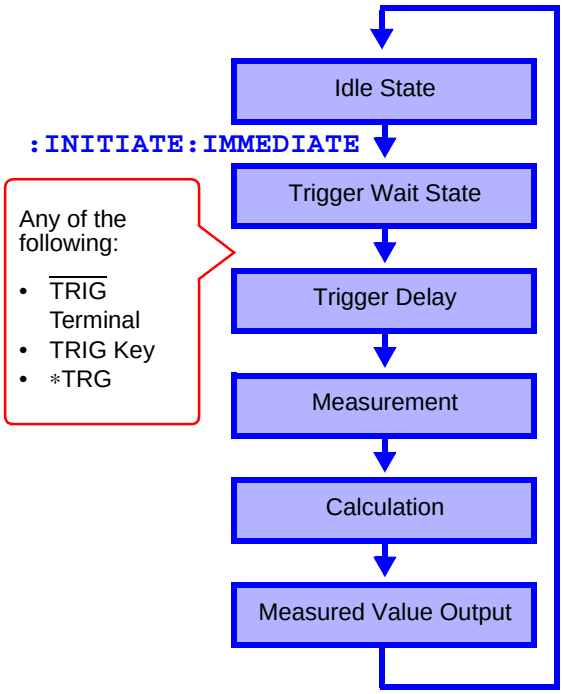
2 `:INITIATE:CONTINUOUS OFF`
`:TRIGGER:SOURCE IMMEDIATE`



3 `:INITIATE:CONTINUOUS ON`
`:TRIGGER:SOURCE EXTERNAL`



4 `:INITIATE:CONTINUOUS OFF`
`:TRIGGER:SOURCE EXTERNAL`



Continuous Measurement Setting

Syntax

Command **:INITiate:CONTinuous** <1, 0, ON or OFF>

Query **:INITiate:CONTinuous?**
Response <ON or OFF>

ON ..... Continuous Measurement Enabled
OFF..... Continuous Measurement Disabled

Example

Command `:INIT:CONT OFF`

Query `:INIT:CONT?`
Response `ON`

Note

- Continuous Measurement Enabled:
  After measurement, enters the Trigger Wait State. When the trigger source setting is IMMediate, the next trigger occurs immediately (the Free-Run State).
- Continuous Measurement Disabled:
  After measurement, enters the Idle State instead of the Trigger Wait State.
- Triggering is ignored in the Idle State. Executing :INITiate[:IMMediate] enables the Trigger Wait State.
- The following commands do not apply to temperature measurement.
  :INITiate:CONTinuous
- Continuous measurement is enabled upon exit from the Remote State.

Trigger Wait Setting

Syntax

Command **:INITiate[:IMMediate]**

Description

Switches triggering from the Idle State to the Trigger Wait State.

Example

Disable continuous measurement, and read one value for each trigger event

Sending
`:TRIG:SOUR IMM`.... Trigger immediately when entering Trigger Wait State
`:INIT:CONT OFF`.... Disables continuous measurement
`:INIT`..... Enable Trigger Wait Trigger immediately upon :TRIG:SOUR IMM
`:FETC?` ..... Fetch measured value

Reading
`2.16414E+3` ..... Measured value is 2.16414kΩ

Error

- An execution error occurs when continuous measurement is enabled (:INITIATE:CONTINUOUS ON).

Note

- When the trigger source is IMMediate, triggering occurs immediately before entering the Idle State.
- When the trigger source is EXTernal, the Trigger Wait State is enabled to wait for an external trigger, and when a trigger occurs, one measurement is taken before entering the Idle State.
- The following commands do not apply to temperature measurement.
  :INITiate[:IMMediate]

Trigger Source Setting

Syntax

Command **:TRIGger:SOURce** <IMMediate or EXTernal>

Query **:TRIGger:SOURce?**
Response <IMMEDIATE or EXTERNAL>

IMMEDIATE .... Internal triggering

EXTERNAL ..... External trigger source. Triggering by TRIG key, TRIG terminal or ∗TRG command.

Example

Command `:TRIG:SOUR IMM`

Query `:TRIG:SOUR?`
Response `IMMEDIATE`

Note

- The following commands do not apply to temperature measurement.
  :TRIGger:SOURce
- The HOLD command for the HIOKI 3227 is the same as the `:TRIGger:SOURce EXTernal` command.

Trigger Delay Setting

Setting the Trigger Delay Time

Syntax

Command **:TRIGger:DELay** <Delay>

Query **:TRIGger:DELay?**
Response <Delay>

Delay [s] .... 0 to 9.999 (NR2)

Example

Query `:TRIG:DEL?`
Response `0.010`

Setting Automatic Trigger Delay

Syntax

Command **:TRIGger:DELay:AUTO** <1, 0, ON or OFF>

Query **:TRIGger:DELay:AUTO?**
Response <ON or OFF>

Example

Cancel automatic triggering and set a trigger delay of 0.01 s.

Sending
```
:TRIG:DEL:AUTO OFF
:TRIG:DEL 10E-3
```

Query `:TRIG:DEL:AUTO?`
Response `ON`

Note

- The following commands do not apply to temperature measurement.
  :TRIGger:DELay
  :TRIGger:DELay:AUTO
- When Auto Delay is enabled (:TRIGger:DELay:AUTO ON), the Delay setting is ignored.

(8) Reading Measured Values

Measurement Value Formats

Resistance Measurement Absolute Value Indication

Measurement Range	Measured Value	±OF	Measurement Fault
20mΩ	±□□.□□□□E-3	±10.0000E+8	+10.0000E+9
200mΩ	±□□□.□□□E-3	±100.000E+7	+100.000E+8
2Ω	±□□□□.□□E-3	±1000.00E+6	+1000.00E+7
20Ω	±□□.□□□□E+0	±10.0000E+8	+10.0000E+9
200Ω	±□□□.□□□E+0	±100.000E+7	+100.000E+8
2kΩ	±□□□□.□□E+0	±1000.00E+6	+1000.00E+7
20kΩ	±□□.□□□□E+3	±10.0000E+8	+10.0000E+9
100kΩ	±□□□.□□□E+3	±100.000E+7	+100.000E+8
1MΩ	±□□□□.□□E+3	±1000.00E+6	+1000.00E+7
10MΩ	±□□.□□□□E+6	±10.0000E+8	+10.0000E+9
100MΩ	±□□□.□□□E+6	±100.000E+7	+100.000E+8

Resistance Measurement Relative Value Indication

	Measured Value	±OF	Measurement Fault
	±□□□.□□□E+0	±100.000E+7	+100.000E+8

Temperature Conversion Indication

	Measured Value	±OF	Measurement Fault
	±□□□□□.□E+0	±10000.0E+5	+10000.0E+6

Temperature Indication

	Measured Value	±OF
	±□□□.□E+0	±100.0E+7

Note For positive measurements, the sign position is blank (ASCII code 20H).

Reading the Most Recent Measurement

Syntax Query **:FETCh?**

Description Reads the most recent measurement. No trigger occurs.

Example
Query `:FETC?`
Response `17.0216E-3`

Note The following HIOKI 3227 command can be used, but the format of the response message is different.
:MEASure:RESIstance?
However, the long-form :MEASURE:RESISTANCE? command operates the same as the :MEASure:RESistance? command of this model.
❖ Measure in a Specifying Range and Function (Ω, LPΩ) (Page 153)

Reading the Temperature Measurement

Syntax Query **:MEASure:TEMPerature?**

Description Reads the most recently measured temperature value.
The temperature measurement can be read regardless of the current resistance function.

Example
Query `:MEAS:TEMP?`
Response `25.1.0000E+0`

Measuring (Awaiting Triggers and Reading Measurements)

Syntax Query **:READ?**

Description Switches from the Idle State to the Trigger Wait State, then reads the next measured value. With auto-ranging enabled, the most suitable range is selected before measurement.

Trigger Source	Operation
IMMediate	Triggers and reads measured value.
EXTernal	After triggering by the TRIG terminal (External I/O), ∗TRG command or TRIG key, reads the measured value.

Error
- This command causes an execution error if issued during the Continuous Measurement state (after :INITIATE:CONTINUOUS ON).
- This command causes an execution error if issued during the Trigger Wait State.

Note
- The next command does not execute until measurement is finished.
- With external triggering using the ∗TRG command, after sending the ∗TRG command and waiting for a time equivalent to the sampling rate, specify the Talker. (only with the GP-IB interface setting)

Measure in a Specifying Range and Function (Ω, LPΩ)

Syntax

Query **:MEASure:LPResistance?** <Expected measurement value>
<Expected measurement value> = 0 to 2E+3

:MEASure:RESistance? <Expected measurement value>
<Expected measurement value> = 0 to 110E+6

Description

If an expected measurement value is provided, the instrument selects the most suitable range for measuring. If the data value is omitted, auto-ranging is selected.

The MEASURE command operates as follows:
1. Triggering is set to disable continuous measurement.
2. Internal triggering is enabled.
3. The specified function is selected.
4. The specified range is selected.
5. One trigger executes.
6. The measured value is read.

The MEASURE command causes the following commands to execute internally.

:FUNC <Function>
<Function>**:RANG** <Expected measurement value>
(If an <Expected measurement value> is not present,
<Function>**:RANG:AUTO ON**)
:INIT:CONT OFF
:TRIG:SOUR IMM
:READ?

Example

Query **:MEAS:RES?**
Response **5.1124E+3**

Query **:MEAS:LPR?**
Response **104.140E+0**

Note

When measuring inductive objects such as transformers or coils, measurement data may be returned before the value has stabilized with auto-ranging. In such cases, specify the measurement range or use the trigger delay function.

Memory Functions (software version 1.13 or later)

You can save and load up to ten measurement data entries.

Memory Function State

Syntax
Command **:MEMory:STATe** <1, 0, ON or OFF>
Query **:MEMory:STATe?**
Response <ON or OFF>

Clear Memory Data

Syntax
Command **:MEMory:CLEAr**

Retrieve the Memory Data Count

Syntax
Command **:MEMory:COUNt?**
Response <Memory data count >
<Memory data cou > = 0 to 10(NR1)

Read Memory Data

Syntax
Command **:MEMory:DATA?**
Response <Memory no(NR1)> , <Measurement value(NR3) >
<Memory no(NR1)> , <Measurement value(NR3) >
<Memory no(NR1)> , <Measurement value(NR3) >
.
.
END

Example
Command **:MEM:STAT ON**
Command **:MEM:CLEA**

External trigger input
External trigger input
External trigger input

Query **:MEM:COUN?**
Response **3**
Query **:MEM:DATA?**
Response **1, 1897.50E-3**
2, 1000.00E+6
3, 1897.48E-3
END

Note
- Each memory data entry ends with a terminator.
- Memory data is available only by remote command.
- Memorize measurement values with the TRIG terminal, TRIG key, or *TRG command.
- If the memory function is enabled, the AUTO range function is disabled.
- Once 10 measurement values are memorized, no new measurement value can be memorized until the memory contents are cleared.

8.7 Basic Data Importing Methods

Flexible data importing is available depending on the application.

Free-Run Data Importing

Initial Setup
:INITiate:CONTinuous ON (enable continuous measurement)
:TRIGger:SOURce IMM (internal triggering)

Importing
:FETCh?
Imports the most recent measurement

Importing by Host Triggering

Initial Setup
:INITiate:CONTinuous OFF (disable continuous measurement)
:TRIGger:SOURce IMM (internal triggering)

Importing
:READ?
A trigger occurs, and a measurement is taken and the result is transferred.

Importing Data by TRIG Key or TRIG Terminal

Initial Setup
:INITiate:CONTinuous OFF (disable continuous measurement)
:TRIGger:SOURce EXT (external triggering)

Importing
:READ?
When triggered by the TRIG key or TRIG terminal, a measurement is taken and the result is transferred.

8.8 Sample Programs

These sample programs are written in Microsoft Visual Basic 5.0 and 6.0.

- The following are used for communication:
  For RS-232C communication: MSComm from Visual Basic Professional
  For GP-IB communication: National Instruments GP-IB Board, Driver and Module for Visual Basic
- During communications, the terminator setting is supposed to be as follows:
  RS-232C: CR+LF
  GP-IB: LF

Visual Basic is a registered trademark of Microsoft Corporation.

RS-232C Communications

(Using Microsoft Visual Basic Professional MSComm)

(1) Simple Resistance Measurement

Imports measured values 10 times, and saves measurements in a text file.

```
Private Sub MeasureSubRS()
Dim recvstr As String                          'Receiving char string
Dim i As Integer

MSComm1.Settings = "9600,n,8,1"                'Comm port setting
MSComm1.PortOpen = True                        'Open a port
Open App.Path & "\data.csv" For Output As #1   'Open a text file for saving

MSComm1.Output = ":TRIG:SOUR IMM" & vbCrLf     'Select internal triggering
MSComm1.Output = ":INIT:CONT ON" & vbCrLf      'Continuous measurement ON
For i = 1 To 10
   MSComm1.Output = ":FETCH?" & vbCrLf         'Send ":FETCH?" to import the most recent
                                               measurement
   recvstr = ""                                'From here on, continue receiving until an LF code
                                               occurs
   While Right(recvstr, 1) <> Chr(10)
      recvstr = recvstr + MSComm1.Input
      DoEvents
   Wend
   recvstr = Left(recvstr, Len(recvstr) - 2)   'Delete the terminator (CR+LF)
   Print #1, Str(i) & "," & recvstr            'Write to the file
Next

Close #1
MSComm1.PortOpen = False
End Sub
```

(2) Measure Resistance by PC Key

Measures and imports by key input on the PC, and saves measurements in a text file.

```
Private Sub MeasureReadSubRS()
Dim recvstr As String                                   'Receiving char string
Dim i As Integer

MSComm1.Settings = "9600,n,8,1"                         'Comm port setting
MSComm1.PortOpen = True                                 'Open a port
Open App.Path & "\data.csv" For Output As #1            'Open a text file for saving

MSComm1.Output = ":TRIG:SOUR IMM" & vbCrLf              'Select internal triggering
MSComm1.Output = ":INIT:CONT OFF" & vbCrLf              'Continuous measurement OFF
For i = 1 To 10
   'Wait for PC key input
   'Create a key input check routine to set InputKey() = True when a key is pressed
   Do While 1
      If InputKey() = True Then Exit Do
      DoEvents
   Loop

   'After confirming key input, measure once, and read the measured value
   MSComm1.Output = ":READ?" & vbCrLf                   'Send ":READ?" to measure and import the
                                                        measurement
   recvstr = ""                                         'From here on, continue receiving until an LF code
                                                        occurs
   While Right(recvstr, 1) <> Chr(10)
      recvstr = recvstr + MSComm1.Input
      DoEvents
   Wend
   recvstr = Left(recvstr, Len(recvstr) - 2)            'Delete the terminator (CR+LF)
   Print #1, Str(i) & "," & recvstr                     'Write to the file
Next

Close #1
MSComm1.PortOpen = False
End Sub
```

(3) External Trigger Measurement 1

Measure and import according to external triggering of the 3541 (TRIG key or EXT I/O TRIG terminal input), or by PC key input, and save measurements in a text file.

```
Private Sub MeasureTrigSubRS()
Dim recvstr As String                                   'Receiving char string
Dim i As Integer

MSComm1.Settings = "9600,n,8,1"                         'Comm port setting
MSComm1.PortOpen = True                                 'Open a port
Open App.Path & "\data.csv" For Output As #1            'Open a text file for saving

MSComm1.Output = ":TRIG:SOUR EXT" & vbCrLf              'Select external triggering
MSComm1.Output = ":INIT:CONT OFF" & vbCrLf              'Continuous measurement OFF
For i = 1 To 10
   MSComm1.Output = ":READ?" & vbCrLf                   'Send ":READ?" to measure and import the
                                                        measurement

   recvstr = ""                                         'From here on, continue receiving until an LF code
                                                        occurs
   While Right(recvstr, 1) <> Chr(10)
      recvstr = recvstr + MSComm1.Input
      DoEvents

      'To execute trigger measurement when a PC key is pressed,
      'Create a key input check routine to set InputKey() = True when a key is pressed
      If InputKey() = True Then
         MSComm1.Output = "*TRG" & vbCrLf               'When key input occurs, send "*TRG" to trigger
                                                        measurement
      End If
   Wend
   recvstr = Left(recvstr, Len(recvstr) - 2)            'Delete the terminator (CR+LF)
   Print #1, Str(i) & "," & recvstr                     'Write to the file
Next

Close #1
MSComm1.PortOpen = False
End Sub
```

(4) External Trigger Measurement 2

Measure and import according to external triggering of the 3541 (TRIG key or EXT I/O TRIG terminal input), and save measurements in a text file.
(The 3541 imports the most recent measurement by trigger input timing with the continuous measurement state)

```
Private Sub MeasureTrig2SubRS()
Dim recvstr As String                                   'Receiving char string
Dim i As Integer

MSComm1.Settings = "9600,n,8,1"                         'Comm port setting
MSComm1.PortOpen = True                                 'Open a port
Open App.Path & "\data.csv" For Output As #1            'Open a text file for saving

MSComm1.Output = ":TRIG:SOUR IMM" & vbCrLf              'Select internal triggering
MSComm1.Output = ":INIT:CONT ON" & vbCrLf               'Continuous measurement ON

'Clear confirmation of  External I/O TRIG input
MSComm1.Output = ":IO:IN?" & vbCrLf
recvstr = ""
While Right(recvstr, 1) <> Chr(10)
   recvstr = recvstr + MSComm1.Input
   DoEvents
Wend

For i = 1 To 10
   'Wait for External I/O TRIG input
   Do While 1
      MSComm1.Output = ":IO:IN?" & vbCrLf
      recvstr = ""
      While Right(recvstr, 1) <> Chr(10)
         recvstr = recvstr + MSComm1.Input
         DoEvents
      Wend
      If Left(recvstr, 1) = "1" Then Exit Do
      DoEvents
   Loop

   MSComm1.Output = ":FETCH?" & vbCrLf                  'Send ":FETCH?" to import the most recent
                                                        measurement

   recvstr = ""                                         'From here on, continue receiving until an LF code
                                                        occurs
   While Right(recvstr, 1) <> Chr(10)
      recvstr = recvstr + MSComm1.Input
      DoEvents
   Wend
   recvstr = Left(recvstr, Len(recvstr) - 2)            'Delete the terminator (CR+LF)
   Print #1, Str(i) & "," & recvstr                     'Write to the file
Next

Close #1
MSComm1.PortOpen = False
End Sub
```

(5) Set Measurement State

Sets up the measurement setting state.

```
'Function: Resistance Measurement
'Range: 200 mΩ
'Sampling: SLOW2
'Triggering: Internal
'Comparator: ON, HI/LO Mode, Beeper HL, Upper Threshold 200000, Lower Threshold 100000
Private Sub SettingsSubRS()
MSComm1.Settings = "9600,n,8,1"                    'Comm port setting
MSComm1.PortOpen = True                            'Open a port

MSComm1.Output = ":FUNC RES" & vbCrLf              'Select Resistance function
MSComm1.Output = ":RES:RANG 200E-3" & vbCrLf       'Select 200 mΩ range
MSComm1.Output = ":SAMP:RATE SLOW2" & vbCrLf       'Select SLOW2 sampling
MSComm1.Output = ":TRIG:SOUR IMM" & vbCrLf         'Select internal triggering
MSComm1.Output = ":INIT:CONT ON" & vbCrLf          'Continuous measurement ON
MSComm1.Output = ":CALC:LIM:MODE HL" & vbCrLf      'From here on, comparator settings
MSComm1.Output = ":CALC:LIM:BEEP HL" & vbCrLf
MSComm1.Output = ":CALC:LIM:UPP 200000" & vbCrLf
MSComm1.Output = ":CALC:LIM:LOW 100000" & vbCrLf
MSComm1.Output = ":CALC:LIM:STAT ON" & vbCrLf      'Comparator ON

MSComm1.PortOpen = False
End Sub
```

GP-IB Communications

(Using National Instruments GP-IB Board)

(1) Simple Resistance Measurement

Imports measured values 10 times, and saves measurements in a text file.

```
Private Sub MeasureSub()
Dim buffer As String * 13                    'Receiving butter
Dim recvstr As String                        'Receiving char string
Dim pad As Integer                           'Controller access
Dim gpibad As Integer                        'Device Address
Dim timeout As Integer                       'Timeout period
Dim ud As Integer                            'State (unused)
Dim i As Integer

pad = 0                                      'Board Address 0
gpibad = 1                                   '3541 Address 1
timeout = T10s                               'Timeout about 10s

Call ibfind("gpib0", 0)                      'Initialize GP-IB
Call ibdev(pad, gpibad, 0, timeout, 1, 0, ud)
Call SendIFC(pad)
Open App.Path & "\data.csv" For Output As #1 'Open a text file for saving

Call Send(pad, gpibad, ":TRIG:SOUR IMM", NLend)  'Select internal triggering
Call Send(pad, gpibad, ":INIT:CONT ON", NLend)   'Continuous measurement ON
For i = 1 To 10
   Call Send(pad, gpibad, ":FETCH?", NLend)      'Send ":FETCH?" to import the most recent
                                                 measurement
   Call Receive(pad, gpibad, buffer, STOPend)    'Receive
   recvstr = Left(buffer, InStr(1, buffer, Chr(10)) - 1)
   Print #1, Str(i) & "," & recvstr              'Write to the file
Next

Close #1
Call ibonl(pad, 0)
End Sub
```

(2) Measure Resistance by PC Key

Measures and imports by key input on the PC, and saves measurements in a text file.

```
Private Sub MeasureReadSub()
Dim buffer As String * 13                          'Receiving butter
Dim recvstr As String                              'Receiving char string
Dim pad As Integer                                 'Controller access
Dim gpibad As Integer                              'Device Address
Dim timeout As Integer                             'Timeout period
Dim ud As Integer                                  'State (unused)
Dim i As Integer

pad = 0                                            'Board Address 0
gpibad = 1                                         '3541 Address 1
timeout = T10s                                     'Timeout about 10s

Call ibfind("gpib0", 0)                            'Initialize GP-IB
Call ibdev(pad, gpibad, 0, timeout, 1, 0, ud)
Call SendIFC(pad)
Open App.Path & "\data.csv" For Output As #1       'Open a text file for saving

Call Send(pad, gpibad, ":TRIG:SOUR IMM", NLend)    'Select internal triggering
Call Send(pad, gpibad, ":INIT:CONT OFF", NLend)    'Continuous measurement OFF
For i = 1 To 10
   'Wait for PC key input
   'Create a key input check routine to set InputKey() = True when a key is pressed
   Do While 1
      If InputKey() = True Then Exit Do
      DoEvents
   Loop

   'After confirming key input, measure once, and read the measured value
   Call Send(pad, gpibad, ":READ?", NLend)         'Send ":READ?" to measure and import the
                                                   measurement
   Call Receive(pad, gpibad, buffer, STOPend)      'Receive
   recvstr = Left(buffer, InStr(1, buffer, Chr(10)) - 1)
   Print #1, Str(i) & "," & recvstr                'Write to the file
Next

Close #1
Call ibonl(pad, 0)
End Sub
```

(3) External Trigger Measurement 1

Measure and import according to external triggering of the 3541 (TRIG key or EXT I/O TRIG terminal input), and save measurements in a text file.

```
Private Sub MeasureTrigSub()
Dim buffer As String * 13                    'Receiving butter
Dim recvstr As String                        'Receiving char string
Dim pad As Integer                           'Controller access
Dim gpibad As Integer                        'Device Address
Dim timeout As Integer                       'Timeout period
Dim ud As Integer                            'State (unused)
Dim i As Integer

pad = 0                                      'Board Address 0
gpibad = 1                                   '3541 Address 1
timeout = T100s                              'Timeout 100s (because of external trigger wait state)

Call ibfind("gpib0", 0)                      'Initialize GP-IB
Call ibdev(pad, gpibad, 0, timeout, 1, 0, ud)
Call SendIFC(pad)
Open App.Path & "\data.csv" For Output As #1 'Open a text file for saving

Call Send(pad, gpibad, ":TRIG:SOUR EXT", NLend)  'Select external triggering
Call Send(pad, gpibad, ":INIT:CONT OFF", NLend)  'Continuous measurement OFF
For i = 1 To 10
   Call Send(pad, gpibad, ":READ?", NLend)   'Send ":READ?" to measure and import the
                                             measurement
   Call Receive(pad, gpibad, buffer, STOPend)  'Receive
   recvstr = Left(buffer, InStr(1, buffer, Chr(10)) - 1)
   Print #1, Str(i) & "," & recvstr          'Write to the file
Next

Close #1
Call ibonl(pad, 0)
End Sub
```

(4) External Trigger Measurement 2

Measure and import according to external triggering of the 3541 (TRIG key or EXT I/O TRIG terminal input), and save measurements in a text file.
(The 3541 imports the most recent measurement by trigger input timing with the continuous measurement state)

```
Private Sub MeasureTrig2Sub()
Dim buffer As String * 13                    'Receiving butter
Dim recvstr As String                        'Receiving char string
Dim pad As Integer                           'Controller access
Dim gpibad As Integer                        'Device Address
Dim timeout As Integer                       'Timeout period
Dim ud As Integer                            'State (unused)
Dim i As Integer

pad = 0                                      'Board Address 0
gpibad = 1                                   '3541 Address 1
timeout = T100s                              'Timeout 100s (because of external trigger wait state)

Call ibfind("gpib0", 0)                      'Initialize GP-IB
Call ibdev(pad, gpibad, 0, timeout, 1, 0, ud)
Call SendIFC(pad)
Open App.Path & "\data.csv" For Output As #1 'Open a text file for saving

Call Send(pad, gpibad, ":TRIG:SOUR IMM", NLend)  'Select internal triggering
Call Send(pad, gpibad, ":INIT:CONT ON", NLend)   'Continuous measurement ON

'Clear confirmation of  External I/O TRIG input
Call Send(pad, gpibad, ":IO:IN?", NLend)
Call Receive(pad, gpibad, buffer, STOPend)
recvstr = Left(buffer, InStr(1, buffer, Chr(10)) - 1)
For i = 1 To 10
   'Wait for External I/O TRIG input
   Do While 1
      Call Send(pad, gpibad, ":IO:IN?", NLend)
      Call Receive(pad, gpibad, buffer, STOPend)
      If Left(buffer, 1) = "1" Then Exit Do
      DoEvents
   Loop

   Call Send(pad, gpibad, ":FETCH?", NLend)  'Send ":FETCH?" to import the most recent
                                             measurement
   Call Receive(pad, gpibad, buffer, STOPend) 'Receive
   recvstr = Left(buffer, InStr(1, buffer, Chr(10)) - 1)
   Print #1, Str(i) & "," & recvstr           'Write to the file
Next

Close #1
Call ibonl(pad, 0)
End Sub
```

(5) Set Measurement State

Sets up the measurement setting state.

```
'Function: Resistance Measurement
'Range: 200 mΩ
'Sampling: SLOW2
'Triggering: Internal
'Comparator: ON, HI/LO Mode, Beeper HL, Upper Threshold 200000, Lower Threshold 100000
Private Sub SettingsSub()
Dim pad As Integer                                      'Controller access
Dim gpibad As Integer                                   'Device Address
Dim timeout As Integer                                  'Timeout period
Dim ud As Integer                                       'State (unused)

pad = 0                                                 'Board Address 0
gpibad = 1                                              '3541 Address 1
timeout = T10s                                          'Timeout about 10s

Call ibfind("gpib0", 0)                                 'Initialize GP-IB
Call ibdev(pad, gpibad, 0, timeout, 1, 0, ud)
Call SendIFC(pad)

Call Send(pad, gpibad, ":FUNC RES", NLend)              'Select Resistance function
Call Send(pad, gpibad, ":RES:RANG 200E-3", NLend)       'Select 200 mΩ range
Call Send(pad, gpibad, ":SAMP:RATE SLOW2", NLend)       'Select SLOW2 sampling
Call Send(pad, gpibad, ":TRIG:SOUR IMM", NLend)         'Select internal triggering
Call Send(pad, gpibad, ":INIT:CONT OFF", NLend)         'Continuous measurement OFF
Call Send(pad, gpibad, ":CALC:LIM:MODE HL", NLend)      'From here on, comparator settings
Call Send(pad, gpibad, ":CALC:LIM:BEEP HL", NLend)
Call Send(pad, gpibad, ":CALC:LIM:UPP 200000", NLend)
Call Send(pad, gpibad, ":CALC:LIM:LOW 100000", NLend)
Call Send(pad, gpibad, ":CALC:LIM:STAT ON", NLend)      'Comparator ON

Call ibonl(pad, 0)
End Sub
```

Specifications Chapter 9

9.1 General Specifications

Measurement functions	Four-terminal resistance measurement	0.1 μΩ (20 mΩ range) to 110.000 MΩ
	Low-power four-terminal resistance measurement	10 μΩ (2 Ω range) to 2.00000 kΩ
	Temperature measurement (Pt)	-10.0 to 99.9°C
	Temperature measurement (analog input)	0 to 2 V
	Temperature measurement (3444/3445+3909 via RS-232C)	-50.0°C to 500.0°C
Range switching function	Auto-ranging (AUTO indicator) and Manual setting	
Temperature correction function	Reference temperature setting range	-10 to +99.9°C
	Temperature coefficient setting range	-99999 to +99999 ppm
	Displayed values	-99,999 to +999,999 dgt
	Correction formula $R_{t0} = \frac{R_t}{1+\alpha_{t0}\times(t-t_0)}$	R_t Actual measured resistance..... [Ω] R_{t0} Corrected resistance ..... [Ω] t_0 Reference temp. ..... [°C] t Ambient temperature ..... [°C] α_{t0} Temperature coefficient at t_0... [1/°C]
Temperature conversion function	Display	Temp. increase Δt
	Cold-state winding resistance setting range (R_1)	00.0000 mΩ to 110.000 MΩ
	Cold-state temperature setting range (t_1)	-10.0 to 99.9°C
	Reciprocal temp. coefficient setting range (k)	-999.9 to +999.9
	Conversion formula $\Delta t = \frac{R_2}{R_1}(k+t_1)-(k+t_a)$	Δt Temperature increase.....[°C] t_1 Winding temp. (cool state) when measuring initial resistance R1.....[°C] t_a Ambient temp. at final measurement .....[°C] R_1 Winding resistance at temp. t1 (cool state)[Ω] R_2 Winding resistance at final measurement .[Ω] k Reciprocal of temp. coefficient of conductor material at 0°C .....[°C]

Zero-Adjust function	Zero-Adjust range		1,000 dgt in each range
Sampling rate	SLOW2, SLOW1, MEDIUM or FAST		
Self-Calibration Function Function (MEDIUM and FAST sampling) (Occurs at power-on, and after switching measurement settings)	AUTO	MEDIUM and FAST	Self-calibration occurs every 30 minutes
		SLOW2 and SLOW1	Self-calibration occurs at every sample
	MANUAL	MEDIUM and FAST	Self-calibration upon input from EXT I/O terminal
		SLOW2 and SLOW1	Self-calibration occurs at every sample
Measurement fault detection	Function		Open-circuit SOURCE and SENSE wiring and constant-current faults can always be observed. ERR output is present at the EXT I/O terminal when a measurement fault is detected ErrCurr is displayed when the SOURCE line is open ErrHi is displayed when the SENSE-H line is open ErrLo is displayed when the SENSE-L line is open
	Output timing		SYNC or ASYNC SYNC: Synchronous with EOC output ASYNC: Asynchronous with EOC output
Overflow detection function	OF or -OF appears when input exceeds the specified display range		
Offset Voltage Compensation function	ON or OFF		
Trigger function	Internal trigger		Triggering occurs internally when a measurement is finished
	External trigger		EXT.TRIG appears Triggering occurs by any of the following: TRIG key, EXT I/O $\overline{\text{TRIG}}$ terminal, ∗TRG or GET command
	When :INITIATE:CONTINUOUS is OFF, an :INITIATE command must be sent before triggering.		

Delay function

AUTO or MANUAL

AUTO

Normal resistance measurement (Offset Voltage Compensation OFF)

Range [Ω]	20 m	200 m	2	20	200	2 k	20 k	100 k	1 M	10 M	100 M
Delay [ms]	30	30	3	3	3	3	3	10	100	500	1000

Normal resistance measurement (Offset Voltage Compensation ON)

Range [Ω]	20 m	200 m	2	20	200	2 k	20 k
Delay [ms]	100	100	100	100	100	100	100

Low-Power mode (Offset Voltage Compensation OFF)

Range [Ω]	2	20	200	2 k
Delay [ms]	3	3	3	15

Low-Power mode (Offset Voltage Compensation ON)

Range [Ω]	2	20	200	2 k
Delay [ms]	100	100	100	100

MANUAL Delay: 0.000 to 9.999s

Measurement fault detection time setting	AUTO/MANUAL		
	AUTO	20 mΩ to 200 Ω ranges, LP function all ranges	833 µs
		2 kΩ to 100 MΩ ranges	500 µs
	MANUAL	0.000 to 9.998s	

Averaging

No. of samples to average	2 to 100, OFF
Averaging method	Integrating average However, with external triggering and continuous measurement ON (Free-Run), the default averaging method is Moving Average

Average (of measurements D1 to D6) with Averaging Samples set to 2.

	1st Sample	2nd Sample	3rd Sample
Free-Run (Moving Avg.)	(D1+D2)/2	(D2+D3)/2	(D3+D4)/2
Non-Free-Run (integrating Avg.)	(D1+D2)/2	(D3+D4)/2	(D5+D6)/2

Statistical calculation

Setting	ON or OFF
Calculations	Total Data Count, Mean, Minimum Value (serial no.), Maximum Value (serial no.), Standard Deviation of Sample, Overall Standard Deviation, Process Capability Indices
Data importing	Statistical calculation occurs by any of the following: TRIG key, EXT I/O $\overline{\text{TRIG}}$ terminal, ∗TRG or GET command
Data count	Up to 30000

Key-Lock function

ON or OFF

Remote/Local function

Operation: When RS-232C or GP-IB communication is enabled, REMOTE is lit.
Pressing the SHIFT →AUTO keys switches from Remote to Local operation

Line frequency setting

50 or 60 Hz

SAVE/LOAD

Storage capacity: (No. of sets of settings) 30

Saved settings:

- Measurement functions
- Resistance Measurement Range
- Low-Power Resistance Measurement Range
- Zero-Adjust ON/OFF
- Zero-Adjust Value
- Temp. Correction Function ON/OFF
- Reference Temperature
- Temperature Coefficient
- Temp. Conversion Function ON/OFF
- Initial Resistance
- Initial Temperature
- Constant
- Statistical Calculation ON/OFF
- Sampling rate
- Self-Calibration AUTO/MANUAL
- Offset Voltage Compensation ON/OFF
- Trigger Setting INT/EXT
- Delay AUTO/MANUAL
- Delay (time value)
- Measurement fault detection time
- Averaging ON/OFF
- No. of samples to average
- Key-Lock
- Comparator ON/OFF
- Comparator Beeper
- Comparator Thresholds
- Comparator Comparison Method
- BIN ON/OFF
- Each BIN No. ON/OFF
- BIN Thresholds
- BIN Comparison Method
- External I/O BIN/BCD

Comparator	Decision	Hi	Display Value > Upper Threshold, or OF
		IN	Upper Threshold≥ Display Value ≥ Lower Threshold
		Lo	Lower Threshold > Display Value, or -OF
	Absolute value decision	Display	Absolute Value
		Upper/Lower Threshold range: 0 to 999,999 dgt	
	Relative value decision	Display	{(Measured Resistance) – (Reference Value)} / (Reference Value) -99.999% to 99.999%
		Reference Value setting: 0 to 999,999 dgt	
		Tolerance (%) setting: 00.000 to 99.999%	
	Beeper	OFF, IN, Hi/Lo	
BIN measurements	Decision	IN	Upper Threshold ≥ Display Value ≥ Lower Threshold
	Absolute value decision	Display	Absolute Value
		Upper/Lower Threshold range: 0 to 999,999 dgt	
	Relative value decision	Display	Absolute Value
		Reference Value setting:0 to 999,999 dgt	
		Tolerance (%) setting: 00.000 to 99.999%	
	BINs	10	
Reset function	Reset	Returns all settings except SAVE data to factory defaults	
	System Reset (Remote Command only)	Returns all settings including SAVE data to factory defaults	

Operating temperature and humidity	0 to 40°C, 80% RH or less (non-condensating)
Storage temperature and humidity	-10 to 50°C, 80% RH or less (non-condensating)
Temperature and humidity range for guaranteed accuracy	23 ±5°C, 80% RH or less (non-condensating)
Period of guaranteed accuracy	1 year
Operating environment	Indoors, Up to 2000 m (6562 ft) ASL
Rated supply voltage	100 to 240 V AC (with allowance for ±10% variation in line voltage)
Rated supply frequency	50/ 60 Hz
Power consumption	30 VA
Dielectric strength	1.39 kV AC for 15s, Cutoff current 10 mA, between all power terminals and protective ground
Dimensions	Approx. 215W x 80H x 295D mm (8.46”W x 3.15”H x11.61”D) (sans protrusions)
Mass	Approx. 2.6 kg (91.7oz.)
Applicable Standards	
Safety	EN61010-1 Pollution degree 2
EMC	EN61326 EN61000-3-2 EN61000-3-3 Effect of radiated radio-frequency electromagnetic field: 1%f.s. at 3 V/m Effect of conducted radio-frequency electromagnetic field: 0.5%f.s. at 3V
Accessories	9287-10 CLIP TYPE LEAD ..... 1 9451 TEMPERATURE PROBE ..... 1 Instruction Manual ..... 1 Power Cord (2-line + ground) ..... 1 EXT I/O Male Connector 1
Options	9452 CLIP TYPE LEAD 9453 FOUR TERMINAL LEAD 9454 ZERO ADJUSTMENT BOARD 9455 PIN TYPE LEAD (for ultra precision) 9461 PIN TYPE LEAD 9467 LARGE CLIP TYPE LEAD 9300 CONNECTION CABLE 9637 RS-232C CABLE (9-pin to 9-pin, crossover) 9638 RS-232C CABLE (9-pin to 25-pin, crossover) 9151-02 GP-IB CONNECTOR CABLE (2 m) 9151-04 GP-IB CONNECTOR CABLE (4 m) 9670 PRINTER (Sanei Electric Model BL-80RS II) 9671 AC ADAPTER (for 9670, Sanei Electric Model BL-100W) 9672 BATTERY PACK (for 9670) 9673 BATTERY CHARGER (for 9672) 9237 RECORDING PAPER (80 mm x 25 m, 4 rolls, for 9670) 9638 RS-232C CABLE (for 3541-9670)

9.2 Accuracy

Resistance Measurement

- After zero adjustment, No temperature correction, Offset voltage compensation OFF
- Add temperature coefficient ±(1/10 of measurement accuracy) °C from 0 to 18 and from 28 to 40°C
- Warm-up time is 60 minutes (accuracy specifications are double from 30 to 60 min)
- For FAST and MEDIUM sampling, execute self-calibration after warm-up. Temperature variation after warm-up should be within ±2°C.
- Add the value calculated below to the rdg error for resistance measurement accuracy when temperature correction is enabled:

$$\frac{-100\,\alpha_{t0}\Delta t}{1+\alpha_{t0}\times(t+\Delta t-t_0)}\ [\%]$$

t_0	Reference temp.	[°C]
t	Ambient temp.	[°C]
Δt	Temp. measurement accuracy	
α_{t0}	Temp. coefficient at t_0	[1/°C]

- Open-terminal voltage specifications in the following table may be momentarily exceeded when the probe is removed from the test object.

Resistance Measurement Function

1-year accuracy (23 ±5°C) (rdg = read value, f.s. = max. value, dgt. = resolution, ppm: parts per million)

Range *1	Displayed Values		SLOW2 *2	SLOW1	MEDIUM	FAST	Measurement Current	Open-Terminal Voltage
			±(ppm of rdg. + ppm of f.s.)					
20 mΩ	20.0000 to -0.2000	mΩ	1000+150 (1000+10)	1000+170 (1000+10)	1000+200 (1000+10)	1000+250 (1000+40)	1 A ±5%	5 Vmax
200 mΩ	200.000 to -02.000	mΩ	1000+60 (1000+10)	1000+80 (1000+10)	1000+120 (1000+10)	1000+170 (1000+20)	1 A ±5%	5 Vmax
200 mΩ *3	200.000 to -02.000	mΩ	500+100 (500+10)	500+120 (500+10)	500+150 (500+20)	500+200 (500+80)	100 mA ±5%	2.6 Vmax
2 Ω	2000.00 to -020.00	mΩ	140+40 (140+10)	140+60 (140+10)	140+100 (140+10)	140+150 (140+40)	100 mA ±5%	2.6 Vmax
20 Ω	20.0000 to -0.2000	Ω	100+40 (100+10)	100+60 (100+10)	100+100 (100+10)	100+150 (100+40)	10 mA ±5%	2.6 Vmax
200 Ω	200.000 to -02.000	Ω	80+15 (80+10)	80+30 (80+10)	80+40 (80+10)	80+100 (80+40)	10 mA ±5%	2.6 Vmax
2 kΩ	2000.00 to -020.00	Ω	70+15 (70+10)	70+30 (70+10)	70+40 (70+10)	70+100 (70+100)	1 mA ±5%	2.6 Vmax
20 kΩ	20.0000 to -0.2000	kΩ	70+15 (70+10)	70+30 (70+10)	70+40 (70+10)	70+100 (70+100)	100 µA ±5%	2.6 Vmax
100 kΩ	110.000 to -02.000	kΩ	70+30	70+60	70+80	70+200	100 µA ±5%	13 Vmax
1 MΩ	1100.00 to -020.00	kΩ	80+30	80+60	80+80	150+100	10 µA ±5%	13 Vmax
10 MΩ	11.0000 to -0.2000	MΩ	400+60	400+90	400+140	3000+200	1 µA ±5%	13 Vmax
100 MΩ	110.000 to -02.000	MΩ	2000+200	2000+230	2000+250	30000(3%) +300	100 nA ±5%	13 Vmax

*1: 100 kΩ range and above are calculated as f.s. = 100,000 dgt.
*2: The lower values in ( ) are with Offset voltage compensation ON
*3: The 200 mΩ range with 100 mA measurement current can be selected during power-up or by remote command.

Low Power Resistance Measurement Function

1-year accuracy (23 ±5°C) (rdg = read value, f.s. = max. value, dgt. = resolution, ppm: parts per million)

Range	Displayed Values		SLOW2 *3	SLOW1	MEDIUM	FAST	Measurement Current	Open-Terminal Voltage *4
			±(ppm of rdg. + ppm of f.s.)					
2 Ω	2000.00 to -020.00	mΩ	110+100 (110+10)	110+120 (110+10)	110+150 (110+20)	110+200 (110+80)	10 mA ±5%	60 mVmax
20 Ω	20.0000 to -0.2000	Ω	110+100 (110+10)	110+120 (110+10)	110+150 (110+20)	110+200 (110+80)	1 mA ±5%	60 mVmax
200 Ω	200.000 to -02.000	Ω	110+100 (110+10)	110+120 (110+10)	110+150 (110+20)	110+200 (110+80)	100 µA ±5%	60 mVmax
2 kΩ	2000.00 to -020.00	Ω	110+100 (110+10)	110+120 (110+10)	110+150 (110+20)	200+200 (200+80)	10 µA ±5%	60 mVmax

*3: The lower values in ( ) are with Offset voltage compensation ON
*4: When using external triggering, open-terminal voltage is limited to 20 mV maximum from when INDEX goes High until the next trigger input.

Temperature Measurement

Pt Sensor

Temperature Sensor
HIOKI 9451 (PT500 (at 25°C))

Accuracy

Range of Guaranteed Accuracy	-10.0 to 39.9°C	40.0 to 99.9°C
Resolution	0.1°C	0.1°C
6-Month Accuracy	±0.30% rdg ±0.5.0°C*1	±0.30% rdg ±1.0°C*1
1-Year Accuracy	±0.45% rdg ±0.8.0°C*1	±0.45% rdg ±1.5.0°C*1

*1: Accuracy is in combination with 9451 TEMPERATURE PROBE.
Accuracy of instrument alone is ±0.2°C for 6 months (±0.3°C for 1 year).
Add temperature coefficient ±0.02/°C to above accuracy for ambient temperature ranges 0 to 18 and 28 to 40°C.

Temperature measurement (analog input)

Accuracy

1-Year

Input Range	0 to 2 V
Display	-99.9°C to 999.9°C
Resolution	1 mV or better
Accuracy	±1% rdg ±3 mV *2

*2: Temperature accuracy conversion method (Only 3541 instrument)

$$1\% \times (T_R - T_{0V}) + 0.3\% \times (T_{1V} - T_{0V})$$

T_{1V}... temperature @ 1-V input
T_{0V} ... temperature @ 0-V input
T_R..... current temperature

Add temperature coefficient (±0.1% rdg ±0.3 mV)/°C to above accuracy for ambient temperature ranges 0 to 18 and 28 to 40°C.

Sampling

Resistance and Low-Power Resistance Measurement

During measurement

(Trigger to EOC=ON)

[ms]

Line Frequency	SLOW2	SLOW1	MEDIUM	FAST
50 Hz	455±10	155±5	21±1	0.60±0.3
60 Hz	449±10	149±5	17±1	0.60±0.3

- DELAY = 0 ms, OVC = OFF, TC = OFF, Statistical Calculation = OFF, Comparator = Hi/Lo
- With FAST and MEDIUM sampling settings, AUTO self-calibration (if enabled) occurs for 55 ±10 ms every 30 minutes.

During importing

(from INDEX=OFF to INDEX=ON)

[ms]

Line Frequency	SLOW2	SLOW1	MEDIUM	FAST
50 Hz	400±10	100±5	20.0±1	0.30±0.1
60 Hz	400±10	100±5	16.7±1	0.30±0.1

Temperature Measurement

Sampling Rate: 400 ±10 ms

Maintenance and Service Chapter 10

10.1 Inspection, Repair and Cleaning

⚠CAUTION

Calibration and repair of this instrument should be performed only under the supervision of qualified technicians knowledgeable about the dangers involved.

NOTE

- If damage is suspected, check the "Troubleshooting" section before contacting your dealer or Hioki representative.
- If no measurement value is displayed even when the probes are shorted together, an internal fuse may have blown.
  Blown internal fuses are not user-replaceable, so if this occurs, please contact your dealer or Hioki representative.

Transporting

Pack the instrument so that it will not sustain damage during shipping, and include a description of existing damage. We cannot accept responsibility for damage incurred during shipping.

Before returning for repair

Symptom	Check Items	Countermeasure
The display does not appear when you turn the power on.	Is the power cord disconnected?	Reconnect the power cord.
Keys do not operate.	Is the unit in the key-locked state?	Disable the key-lock state. ❖ 5.10 Key-Lock Function (page 69)
	Is the instrument being remotely controlled externally using GP-IB?	Set GP-IB to local.
	Is the instrument being remotely controlled externally using RS-232C?	Set RS-232C to local.
An error is displayed.		❖ 10.2 Error Display (page 176)
Operation is abnormal.		External electrical noise may occasionally cause malfunctions. If operation seems abnormal, try executing a Reset. ❖ 5.14 Reset Function (page 77)

Cleaning

NOTE

To clean the instrument, wipe it gently with a soft cloth moistened with water or mild detergent. Never use solvents such as benzene, alcohol, acetone, ether, ketones, thinners or gasoline, as they can deform and discolor the case.

10.2 Error Display

Display		Description
Err02	Zero-Adjust Range Error	The value before zero-adjustment exceeded 1,000 dgt.
Err10	Execution Error	The data portion of a remote command is invalid.
Err11	Command Error	The command portion of a remote command is invalid.
Err80	Manual Adjustment Range Error	The valid adjustment range was exceeded during adjustment.
Err90	ROM Error	An internal program error occurred. Repair is required.
Err91	RAM Error	An internal RAM error occurred. Repair is required.
Err92	EEPROM (Adjustment Data) Error	Adjustment data is corrupted. Repair is required.
Err95	Resistance A/D Communications Error	The A/D converter used for resistance measurement is damaged. Repair is required.
Err96	Temperature A/D Communications Error	The A/D converter used for temperature measurement is damaged. Repair is required.
ErrCur	Constant-Current Fault	• The SOURCE terminal is not in contact with a test circuit. • The resistance of the test circuit greatly exceeds the measurement range. • High resistance between the test circuit and the SOURCE terminal impedes the flow of measurement current. • High lead resistance (or an open circuit) on the SOURCE line impedes the flow of measurement current. • The circuit protection fuse is blown. (In this case, repair is required.)

ErrHi	SENSE-H Open Circuit	• The SENSE-H terminal is not in contact with the test circuit. • Resistance between the test circuit and the SENSE-H terminal is high. • Lead resistance on the SENSE-H line is high (or the line is open). • The circuit protection fuse is blown. (In this case, repair is required.)
ErrLo	SENSE-L Open Circuit	• The SENSE-L terminal is not in contact with the test circuit. • Resistance between the test circuit and the SENSE-L terminal is high. • Lead resistance on the SENSE-L line is high (or the line is open).
- - - - -	Constant-Current Fault, SENSE-H Open Circuit and SENSE-L Open Circuit are occurring simultaneously.	
Error tC SnS	Temperature Sensor Error	The temperature probe is not connected. Please connect the temperature probe when performing temperature correction or temperature conversion.

Appendix

Appendix 1 Four-Terminal (Voltage-Drop) Method

The Four-Terminal method is essential for measuring very small resistance values.
With two-terminal measurements (Fig. 1), the resistance of the test leads is included in the measured resistance, resulting in measurement errors.
The four-terminal method (Fig. 2) consists of current source terminals to provide constant current, and voltage detection terminals to detect voltage drop.
Because of the high input impedance of the voltmeter, measurement requires practically no current flow through the leads connecting the voltage detection terminals to the test object, practically eliminating the effects of lead and contact resistance on the measurement.

Two-Terminal Measurement Method

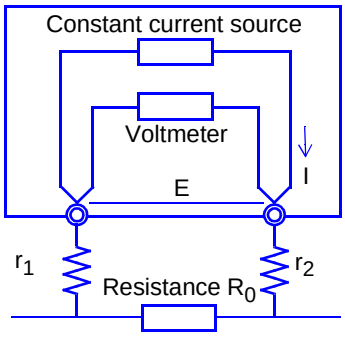


Figure 1.

Measurement current I flows through test object resistance R_0 as well as lead resistances r_1 and r_2.
The voltage to be measured is obtained by $E = I(r_1+R_0+r_2)$, which includes lead resistances r_1 and r_2.

Four-Terminal Measurement Method

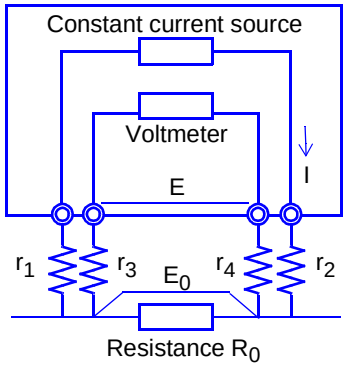


Figure 2.

All of measurement current I flows through test object resistance R_0. So the voltage drop across r_3 and r_4 is practically nil, and voltage E across the measurement terminals and voltage E_0 across test object resistance R_0 are essentially equal, allowing test object resistance to be measured without being affected by r_1 to r_4.

Appendix 2 Temperature Correction Function (TC)

Temperature correction employs the temperature coefficient of a material to convert its resistance measured at one temperature to the value it would have at any other temperature, for display. Because resistance is fundamentally temperature-dependent, measuring it without considering the temperature can provide meaningless results.

Resistances R_t and R_{t0} below are the resistance values of the test object (having resistance temperature coefficient at t_0°C of α_{t0}) at t°C and t_0°C.

$$R_t = R_{t0} \times \{1 + \alpha_{t0} \times (t - t_0)\}$$

R_t	Actual measured resistance [Ω]
R_{t0}	Corrected resistance [Ω]
t_0	Reference temperature [°C]
t	Ambient temperature [°C]
α_{t0}	Temperature coefficient at t_0 [1/°C]

Example If a copper test object (with resistance temperature coefficient of 3930 ppm) measures 100 Ω at 30°C, its resistance at 20°C is calculated as follows:

$$R_{t0} = \frac{R_1}{1 + \alpha_{t0} \times (t - t_0)}$$

$$= \frac{100}{1 + (3930 \times 10^{-6}) \times (30 - 20)}$$

$$= 96.22$$

Refer to the following for temperature correction settings and execution method:

❖ Making Temperature Correction Settings (Reference Temperature and Temperature Coefficient) (Page 58)
❖ Enabling/Disabling Temperature Correction (Page 59)
❖ Reference (Page 181)

NOTE

- The temperature probe detects only ambient temperature; not surface temperature.
- Before measuring, allow the instrument and temperature probe to warm up completely, place the temperature probe as close to the test object as possible, and allow sufficient time for them to stabilize at ambient temperature.

Reference

Conductive Properties of Metals and Alloys

Material	Content [%]	Density ($x10^3$) [kg/m^3]	Conductivity	Temp. Coeff. (20°C) [ppm]
Annealed copper wire	Cu>99.9	8.89	1.00 to 1.02	3810 to 3970
Hard-drawn copper wire	Cu>99.9	8.89	0.96 to 0.98	3770 to 3850
Cadmium copper wire	Cd 0.7 to 1.2	8.94	0.85 to 0.88	3340 to 3460
Silver copper	Ag 0.03 to 0.1	8.89	0.96 to 0.98	3930
Chrome copper	Cr 0.4 to 0.8	8.89	0.40 to 0.50 0.80 to 0.85	20 30
Carlson alloy wire	Ni 2.5 to 4.0 Si 0.5 to 1.0		0.25 to 0.45	980 to 1770
Annealed aluminum wire	Al>99.5	2.7	0.63 to 0.64	42
Hard-drawn aluminum wire	Al>99.5	2.7	0.60 to 0.62	40
Aldrey wire	Si 0.4 to 0.6 Mg 0.4 to 0.5 Al remaining portion		0.50 to 0.55	36

Copper Wire Conductivity

Diameter [mm]	Annealed copper wire	Tinned annealed copper wire	Hard-drawn copper wire
0.01 to less than 0.26	0.98	0.93	–
0.26 to less than 0.50	0.993	0.94	0.96
0.50 to less than 2.00	1.00	0.96	0.96
2.00 to less than 8.00	1.00	0.97	0.97

The temperature coefficient changes according to temperature and conductivity, so if the temperature coefficient at 20°C is α_{20} and the temperature coefficient for conductivity C at t°C is α_{ct}, α_{ct} is determined as follows near ambient temperature.

$$\alpha_{ct} = \frac{1}{\frac{1}{\alpha_{20} \times C} + (t - 20)}$$

For example, the temperature coefficient of international standard annealed copper is 3930 ppm @20°C. For tinned annealed copper wire (with diameter from 0.10 to less than 0.26 mm), the temperature coefficient α_{20} at 20°C is calculated as follows:

$$\alpha_{20} = \frac{1}{\frac{1}{0.00393 \times 0.93} + (20 - 20)} \approx 3650 \text{ ppm}$$

Appendix 3 Temperature Conversion Function (Δt)

Utilizing the temperature-dependent nature of resistance, the temperature conversion function converts resistance measurements for display as temperatures. This method of temperature conversion is described here.
According to IEC standard 60034, the resistance law may be applied to determine temperature increase as follows:

$$\Delta t = \frac{R_2}{R_1}(k + t_1) - (k + t_a)$$

Δt	Temperature increase [°C]
t_1	Winding temp. [°C, cool state] when measuring initial resistance R_1
t_a	Ambient temp. [°C] at final measurement
R_1	Winding resistance [Ω] at temp. t_1 (cool state)
R_2	Winding resistance [Ω] at final measurement
k	Reciprocal [°C] of temp. coefficient of conductor material at 0°C

Example With initial resistance R_1 of 200 mΩ at initial temperature t_1 of 20°C, and final resistance R_2 of 210 mΩ at current ambient temperature t_a of 25°C, the temperature increase value is calculated as follows:

$$\Delta t = \frac{R_2}{R_1}(k + t_1) - (k + t_a)$$
$$= \frac{210 \times 10^{-3}}{200 \times 10^{-3}}(235 + 20) - (235 + 25)$$
$$= 7.75°\text{C}$$

Therefore, the current temperature t_R of the resistive body can be calculated as follows:

$$t_R = t_a + \Delta t = 25 + 7.75 = 32.75°\text{C}$$

For a test object that is not copper or aluminum with a temperature coefficient of α_{t0}, the constant k can be calculated using the formula shown for the temperature correction function and the above formula, as follows:

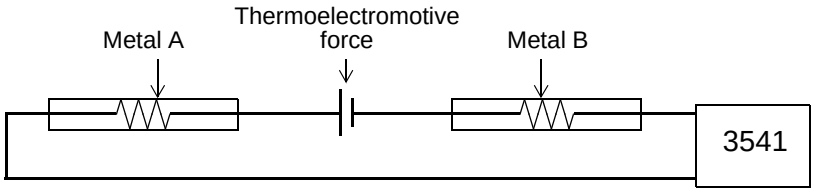
$$k = \frac{1}{\alpha_{t0}} - t_0$$

For example, the temperature coefficient of copper at 20°C is 3930 ppm, so the constant k in this case is as follows, which shows almost the same value as the constant for copper 235 defined by the IEC standard.

$$k = \frac{1}{3930 \times 10^{-6}} - 20 = 234.5$$

Appendix 4 Effect of Thermoelectromotive Force

Thermoelectromotive force is the potential difference that occurs at the junction of two dissimilar metals, which if sufficiently large, can cause erroneous measurements. Because this instrument functions by measuring potential difference while applying a constant direct current through the test object, the effect of thermoelectromotive force can affect measurements. The amplitude of thermoelectromotive force depends on the temperature of the measurement environment, with the force generally being greater at higher temperature.
Thermoelectromotive force typically occurs at any junction of dissimilar metals, including between the test probe tips and the test object.
The following diagram illustrates thermoelectromotive force.



Measurement discrepancy caused by thermoelectromotive force:

Example If the amplitude of electromotive force is 10 µV and the resistance to be measured is 2 Ω, the measurement current of the LP 2Ω range is 10 mA, and
the actual measured value displayed on the instrument is as follows:
(2 Ω x 10 mA + 10 µV) ÷ 10 mA = 2.00100 Ω

The effect of this thermoelectromotive force can be suppressed by enabling this instrument's Offset Voltage Compensation (OVC) function.
In the 2Ω or higher range and the 200mΩ range (100 mA measurement current), a measurement R_{ON} is first taken with measurement current on, then the current is switched off and another measurement R_{OFF} is taken, with the true measurement value calculated by $R_{ON} - R_{OFF}$ for display.
In the 20mΩ and 200mΩ ranges (1A measurement current), the following value is displayed as the true resistance obtained from the value R_P(>0) measured with measurement current flowing in the positive direction and the value R_N(<0) measured with measurement current flowing in the negative direction.

$$\frac{R_p - R_N}{2}$$ (R_N is a negative value)

With inductive test objects such as a power transformers or solenoid coils, the following stabilization time is required to achieve a steady-state level after current is applied.
When using the Offset Voltage Compensation (OVC) function, presume 10 times the calculation voltage when setting the delay.

$$t = -\frac{L}{R}\ln\left(1 - \frac{IR}{V_0}\right)$$

L	Inductance of test object
R	Resistance of test object + test leads + contacts
I	Measurement current (refer to 9.2 Accuracy (Page 172))
V_O	Open-terminal voltage (refer to 9.2 Accuracy (Page 172))

Appendix 5 JEC 2137-Compliant Resistance Measurement of Inductive Machines

Standard JEC 2137 specifies the determination of resistance values according to the following formula:

$$R_{t_R} = R_{t_T} \times \frac{t_R + k}{t_T + k} \quad \text{..... Formula 1}$$

R_{tR}	Winding resistance at reference temperature t_R
R_{tT}	Measured value of winding resistance at t_T
t_0	Reference temperature [°C]
t_T	Temperature of winding during measurement [°C]
k	Constant (235 for copper wire)

Transforming Formula 1 provides the following:

$$\frac{R_{t_R}}{R_{t_T}} = \frac{t_R + k}{t_T + k} = \frac{1}{1 + \frac{1}{t_R + k}(t_T - t_R)} \quad \text{..... Formula 2}$$

On the other hand, Formula 3 shows the temperature correction process with the 3541.
So the temperature coefficient to be set is determined as shown in Formula 4.

$$R_{t_R} = \frac{R_{t_T}}{1 + \alpha_{t_R} \times (t_T - t_R)} \quad \text{..... Formula 3}$$

$$\alpha_{t_R} = \frac{1}{t_R + k} \quad \text{..... Formula 4}$$

For example, if the reference temperature is 20°C, set the temperature coefficient for the instrument as follows.

$$\alpha_{t_R} = \frac{1}{t_R + k} = \frac{1}{20 + 235} = 3922 \text{ [ppm/deg]}$$

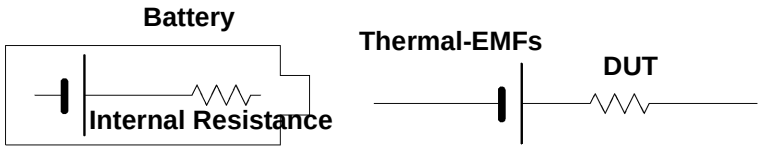
Appendix 6 DC and AC Models

Both AC and DC resistance meter models are available. Use the type appropriate for the intended purpose.

- DC Models 3540 mΩ HiTESTER, 3541 RESISTANCE HiTESTER
- AC Model 3560 AC mΩ HiTESTER, 3561 BATTERY HiTESTER

The DC models are commonly used for general-purpose ohmmeters, and for measuring the resistance of windings and contacts.

AC models are used to measure the internal resistance of batteries and other for cases where measurements cannot be made with DC, such as for measuring with extremely low power.By using alternating current for measurement, AC models are able to measure the resistance of an object without being affected by battery-EMF or Thermal-EMFs.



DUTs which have EMF

On the other hand, with AC measurements, iron losses may have to be included in the series equivalent resistance of windings, so consideration should be given to the difference in values measured with DC.

Reference

We offer Model 3560 AC Milliohm HiTESTER for measuring resistance with AC, which complies with all of the measurement conditions regulated by the IEC (International Electrotechnical Commission), and Models 3550, 3551 3555 and 3561 Battery HiTESTERs for measuring battery internal resistance.

Measurement conditions regulated by the IEC are as follows:

- •Frequency: 1kHz ±200Hz
- •Accuracy: ±10%
- •Current (RMS): 1A or less
- •Voltage (crest): 20mV or less

Comparison of DC and AC Resistance Meters

<table>
<tr><th></th><th colspan="2">DC Resistance Meters</th><th>AC Resistance Meter</th></tr>
<tr><td>Model</td><td>3541</td><td>3540</td><td>3560</td></tr>
<tr><td>Measurement Principle</td><td colspan="2">DC current measurement</td><td>AC current measurement</td></tr>
<tr><td>Advantages</td><td colspan="2">• Capable of relatively stable, high-precision measurement
• Able to measure resistance of windings</td><td>• Very low-current (low power) measurements
• Measures even with DC bias, internal (operating) resistance measurement. Unaffected by Thermal-EMFs.</td></tr>
<tr><td rowspan="2">Disadvantages</td><td colspan="2">• Because measurements cannot be performed with DC bias, they are susceptible to Thermal-EMFs.
Relatively high measurement power is required to overcome effects of Thermal-EMFs.
• Oxidized film on contacts can be damaged and it degrades measurement accuracy.
• MR elements can be damaged.
• Chip inductor characteristics can be altered.</td><td rowspan="2">• In some cases, resistance measurement of windings and inductors may not be possible.
• Less accurate than DC method.</td></tr>
<tr><td>However, if the error is within the realm of Thermal-EMFs, it can be countered by OVC. Also, MR elements and chip inductors can be measured with the low-power measurement function</td><td></td></tr>
<tr><td rowspan="2">Usage</td><td colspan="2">• General-purpose resistance measurement
• Measurement of winding resistance, for power circuits
• Measurement of switch contact resistance
• Measurement of conductor resistance</td><td rowspan="2">• Measurement of internal resistance of batteries and semiconductors(operating resistance*)
• Measurement of contact resistance of switches for very small current, such as electronic components*
• Conductor resistance measurement of bi-metallic junctions</td></tr>
<tr><td>• Measurement of contact resistance of switches for very small current, such as electronic components
• Measurement of fragile components such as MR elements and chip inductors</td><td></td></tr>
<tr><td>Measurement current and resolution</td><td>0.1 μΩ, 1A
1 μΩ, 1A/ 100mA
10 μΩ, 100mA / 10mA
100 μΩ, 10mA / 1mA</td><td>10 μΩ , 100mA
100 μΩ , 10mA</td><td>1 μΩ , 7.4mA
10 μΩ , 1mA
100 μΩ , 0.1mA</td></tr>
</table>

*Not all AC power relays are measurable.

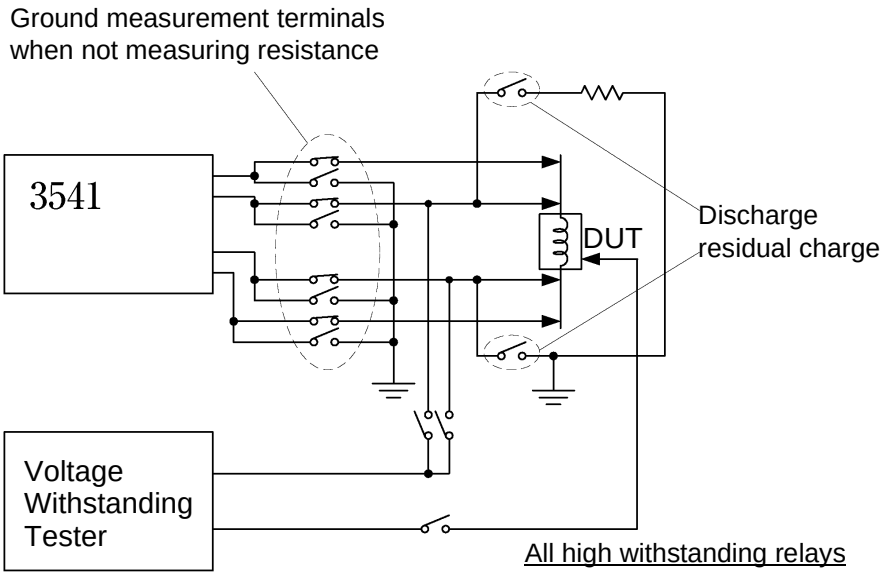
Appendix 7 Combination with Voltage Withstanding Tester

The 3541 may be used together with a voltage withstanding tester as part of a testing system for wirewound components. When used in this way, current stored in the winding can flow into the 3541 when abruptly connected, and aside from blowing the fuse, could damage the 3541. In addition, the input protection fuse in the 3541 is a special type with ultra-low Thermal-EMFs, which is not intended to be customer replaceable.
Therefore, bear in mind the following when constructing a testing line that uses the withstanding tester in combination:

(1)The voltage withstanding specification of switching relays should include a safe margin over the withstanding testing voltage (such as 5/10kVDC between contacts).

(2)All 3541 measurement terminals should be grounded during voltage withstanding testing.

(3)Measure resistance first, and voltage withstanding last. If voltage withstanding testing must be performed before resistance measurement, ground both sides of the DUT to discharge any residual charge after voltage withstanding testing. Then, after the discharging, measure resistance.



Combination with Voltage Withstanding Tester

Appendix 8 Unstable Measurement Values

If the measurement value is unstable, verify the following.

(1)Effect of Noise from Power Supply Lines

Noise from power supply lines arises from commercial power, and not only from power lines or outlets, but also as radiated emissions from fluorescent lights and home appliances. The frequency of the noise from power supply lines depends on the commercial supplied power frequency, and is typically 50 or 60Hz.

To minimize the affects of this noise from power supply lines, measurements are generally timed to occur at an integer multiple of the supplied power period.

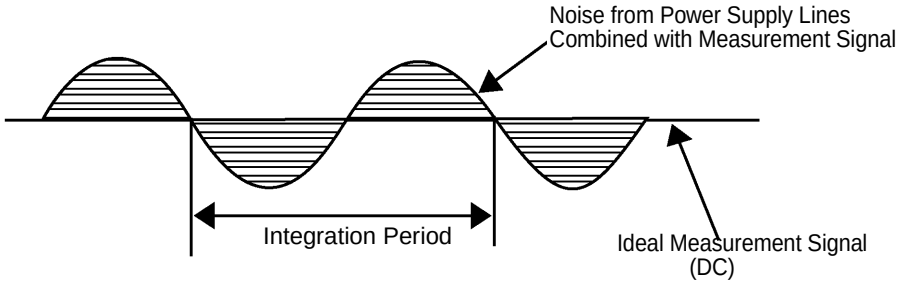


Figure 1. Effect of Noise from Power Supply Lines

Model 3541 offers four sampling rates: FAST, MEDIUM, SLOW1 and SLOW2. With the FAST setting, measurements are not synchronized with the supplied power period.

When the FAST setting is used with high-resistance or low-power measurement functions, measured values may be unstable.

In such cases, use the MEDIUM, SLOW1 or SLOW2 settings, or apply appropriate noise countermeasures.

For high-resistance measurements, noise ingress can be adequately suppressed by shielding at the potential of Source-L (Fig. 2). For low-power measurement function, in addition to shielding at Source-L potential, twisting the main test leads together may be effective (Fig. 3).

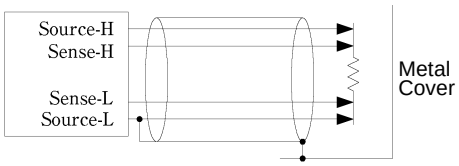


Figure. 2
For High-Resistance Measurements

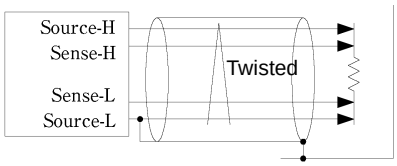


Figure. 3
For Low-Power Resistance Measurements

If using the factory-default 60Hz supplied power frequency setting in a region using 50Hz supplied power, measurement values are unstable even with MEDIUM, SLOW1 and SLOW2 sampling rates. Verify the supplied power frequency setting of Model 3541 before use.

(2)Using Low-Power Measurement Functions

The current used for low-power measurement function is as little as one-tenth that used for normal resistance measurements, so susceptibility to electrical noise ingress and Thermal-EMFs is ten times greater.

Measurement should be conducted as far as possible from devices emitting electric or magnetic fields such as power cords, fluorescent lights, solenoid valves and PC displays. If electrical noise ingress is a problem, prepare the measurement leads as shown in Figs. 2 and 3.

If Thermal-EMFs is a problem, use the 3541's OVC function.
If OVC cannot be used for reasons such as tact time limitations, use a low-Thermal-EMFs material such as copper for wiring, and protect against airflow on connecting parts (test object or connectors).

(3)Multi-Point Contacts with Clip Leads

The ideal conditions for four-terminal measurements are shown in Fig. 4: current flows from the far probe and voltage is detected with uniform current distribution.To facilitate measurement, the tips of the Model 9287-10 Clip Type Lead are jagged. When a clip is opened as shown in Fig. 5, measurement current flows from multiple points, and voltage is detected at multiple points. In such cases, the measurement value varies according to the total contact area. Additionally, as shown in Fig. 6, when measuring the resistance of a 100mm length of wire, the length between the nearest edges of the clips is 100mm, but the length between the farthest edges of the clips is 110mm, so the actual measurement length (and value) has an uncertainty of 10mm (10%).
If measured values are unstable for this reason, use Model 9453 Four Terminal Lead or Model 9455 Pin Type Lead to measure with point contacts.

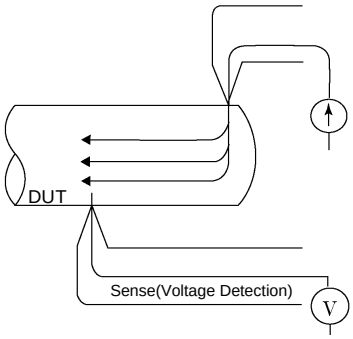


Figure. 4
Ideal Four-Terminal Method

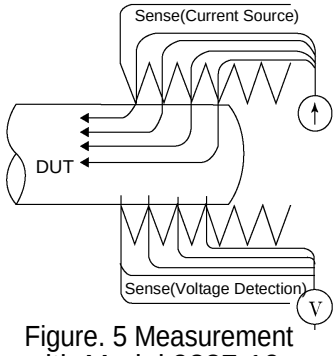


Figure. 5 Measurement with Model 9287-10

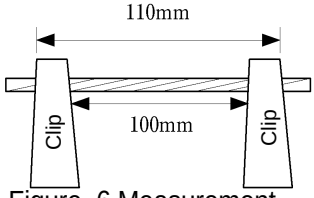


Figure. 6 Measurement with Model 9287-10

(4)Wider/Thicker DUTs

If the DUT has a certain width or thickness like boards or blocks, it will be difficult to measure accurately using Pin Type Leads or Clip Type Leads. By using such measurement probes, there may be considerable fluctuation of the measured value due to contact pressure or contact angle. For example, when measuring a W300 x L370 x t0.4 mm metal board, the measured values are fairly different, even if measuring the same points, as shown below:

- •0.2mm pitch Pin type lead: 1.1mΩ
- •0.5mm pitch Pin type lead: 0.92 to 0.97mΩ
- •9287-10 Clip Type Lead: 0.85 to 0.95mΩ

This does not depend on the contact resistance between probes and the DUT, but on the current distribution on the DUT. Fig. 7 is an example of plotting equivalent electric potential lines of a metal board. Similar to the relation between atmospheric pressure distribution and wind on a weather forecast diagram, current density is higher in locations where the equivalent electric potential lines are narrowly spaced, and lower in locations where they are widely spaced.
On the other hand, when the interval of equivalent electric potential lines is wide, there is less current density. Through this example, it is shown that the electric potential slope is larger around current applying points. This phenomenon is caused by high current density while current expands on the metal board. Due to this phenomenon, measured values should be fairly different, even if the connected position difference is quite slight, in case connecting voltage detection terminals (of measurement probes) near current applying points.

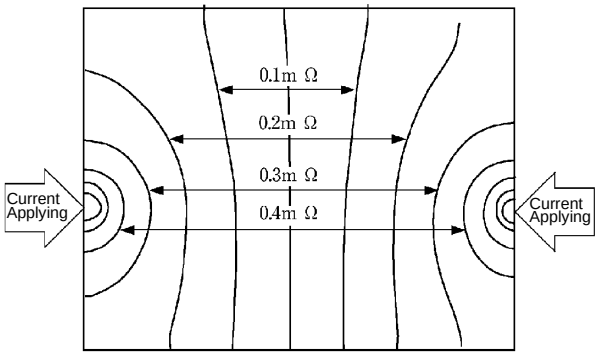


Figure. 7 Current Distribution on a Metal Board (W300 x L370 x t0.4mm) (Applying 1A current on points on edges and plotting equivalent electric potential lines at each 50microV level)

To avoid the effects of this phenomenon, Model 9453 Four Terminal Lead is the recommended probe to be used for detecting the voltage inside of current applying points.
Generally, if the distance between the voltage detection points (Sense-H, Sense-L terminals) and their corresponding current application points (Source-H, Source-L terminals) is greater than the width (W) or thickness (t) of the DUT, current distribution may be considered uniform. As shown in Fig. 8, sense leads should be W or t mm or more inside from the Source leads.

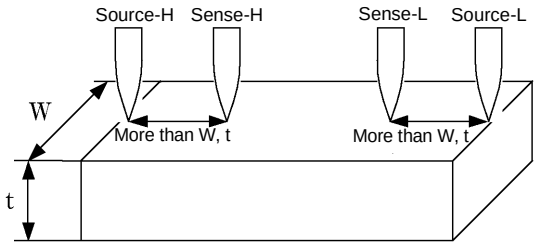


Figure. 8 Plobe Positions on Wider/Thicker DUT

(5)Unstable Temperature of the DUT

Copper wire has a temperature coefficient of about 0.4%/°C. Just holding a copper wire in the hand raises its temperature, causing its resistance to be increased as well. When the hand is removed from the wire, temperature and resistance decrease.

Varnished windings are more susceptible to temperature increase, so the resistance tends to be relatively high.

If the temperatures of a DUT and probe are different, the Thermal-EMFs generated can cause a measurement error.

To avoid such errors, allow the temperature of the DUT to stabilize at ambient temperature. If the tact time is limited, HIOKI Model 3444/3445 Temperature HiTESTER (Infrared type) can be used to measure the surface temperature of DUTs, so that the measured resistance value can be converted to its equivalent resistance at a reference temperature.

(6)DUT Becomes Warm

In order for the 3541 to support the following standards:

- JIS C5441 Testing Method of Switches for Electrical Devices
- JIS C5402 Testing Method of Connectors for Electrical Devices
- JIS C8306 Testing Method of Wiring Tools,

measurement current for the 20mΩ and 200mΩ ranges is set to 1A. Because of that, 200mW of power (200mΩ x 1A x 1A) has to be dissipated by a DUT that measures 200mΩ, which is enough to warm up a DUT which has small heat capacity, resulting in its resistance changing.Users who measure small heat capacity DUTs and are not concerned with JIS standards may select the 2Ω or LP-Ω range.

(7) Unstable Ambient Temperature

When using the Temperature Compensation function, measurement values may be scattered if the ambient temperature is unstable.

When the temperature coefficient is set to 4000ppm/°C and the temperature changes by 0.1°C, measured values change by 400ppm (0.04%).

(8) Ingress of External Noise

Measurement should be conducted as far as possible from devices emitting electric or magnetic fields such as power cords, fluorescent lights, solenoid valves and PC displays.

If external noise ingress is a problem, prepare the measurement leads as shown in Fig. 9.

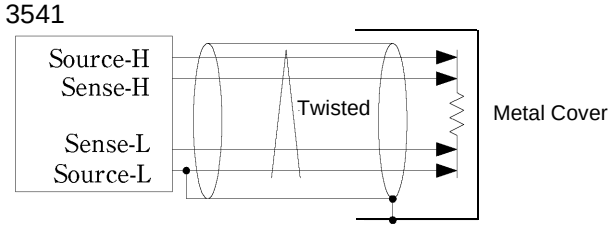


Figure9. Wiring to Minimize Noise Ingress

(9)Measuring Transformers and Motors

If noise enters an unconnected terminal of a transformer or if motor rotor moves, measurements may be unstable due to induced voltage on the measured winding.

Pay attention to the treatment of unconnected terminals on transformers or to motor vibration.

(10) Measuring Large Transformers or Motors

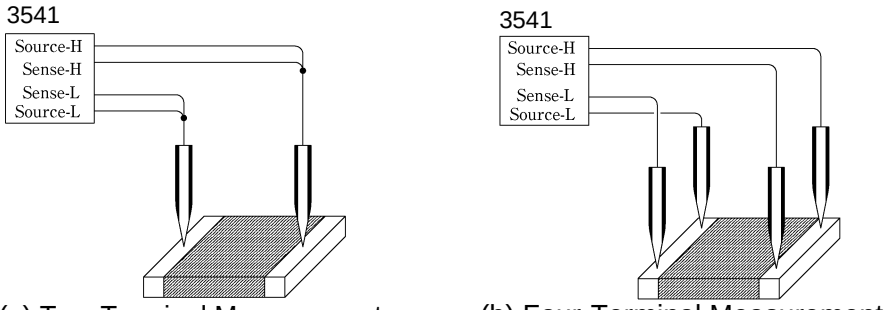
When measuring high-inductance (high-Q) DUTs such as large transformers or motors, measured values may be unstable.

The 3541 depends on constant current flow through the DUT, but producing constant current becomes impossible as inductance approaches infinity. To obtain stability in a constant-current source with a large inductance, response time is sacrificed. If you find that resistance values are scattered when measuring large transformers or motors, please consider the above or contact your local HIOKI distributor for further assistance.

(11) Non-Four-Terminal Measurements

The four-terminal method requires that four probes be connected to the DUT. By measuring as shown in Fig.10(a), the measured resistance includes that of the contacts between the probes and DUT. Typical contact resistance is several milliohm with gold plating, and several tens of milliohm with nickel plating. With measurement values of several kΩ this would not seem to be a problem, but if a probe tip is oxidized or dirty, contact resistance on the order of a kΩ is not unusual.

To maximize the opportunity for proper measurements, emulate the four-terminal method as close as possible to the contact points of the DUT. (Fig.10(b))



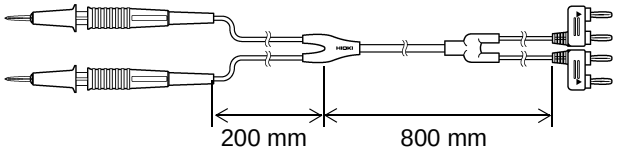
(a) Two-Terminal Measurement (b) Four-Terminal Measurement

Figure 10. Four-Terminal Measurement and Two-Terminal Measurement

Appendix 9 Test Lead Options

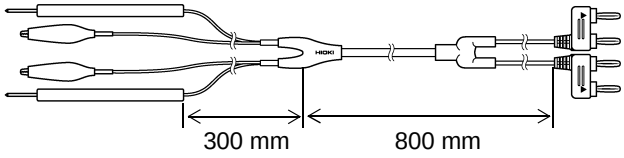
9452 CLIP TYPE LEAD

The probes have pincer-type tips.
Allows reliable four-terminal measurements even on test objects with small contacts such as relay terminals and connectors.
Bifurcation-to-probe length: approx. 200 mm
Plug-to-bifurcation length: approx. 800 mm



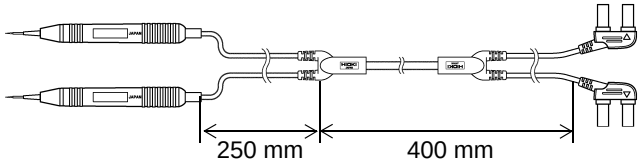
9453 FOUR TERMINAL LEAD

The SOURCE leads of this four-terminal lead set have covered alligator clips, and the SENSE leads have standard test probes. Use for measuring printed circuit board pattern resistance, and where SOURCE and SENSE leads need to be connected separately.
Bifurcation-to-probe length: approx. 300 mm
Plug-to-bifurcation length: approx. 800 mm



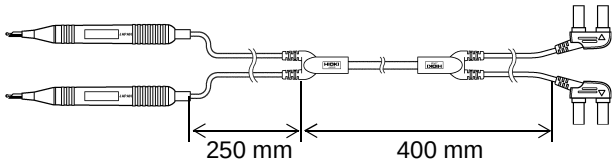
9455 PIN TYPE LEAD

The probe tips have a four-terminal structure designed for checking for floating IC leads on printed circuit boards. Correct measurements are obtained even with very small test objects.
Bifurcation-to-probe length: approx. 250 mm
Plug-to-bifurcation length: approx. 400 mm



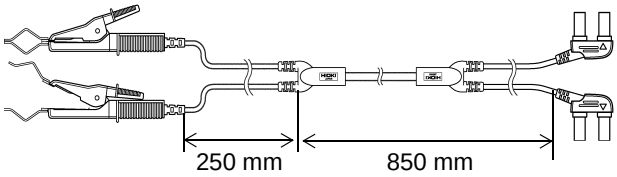
9461 PIN TYPE LEAD

These probes are designed to be pressed on flat contact surfaces unsuitable for clipping, or for test objects with small contact areas such as relay terminals and connectors.
Bifurcation-to-probe length: approx. 250 mm
Plug-to-bifurcation length: approx. 400 mm



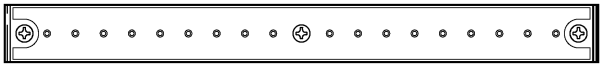
9467 LARGE CLIP TYPE LEAD

These leads are designed to attach to test object with large diameter contacts. Four-terminal measurements can be made just by clipping.
Bifurcation-to-probe length: approx. 250 mm
Plug-to-bifurcation length: approx. 850 mm
Maximum clip diameter: approx. 29 mm



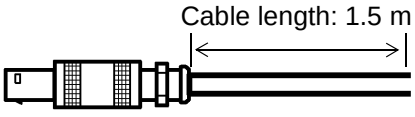
9454 ZERO ADJUSTMENT BOARD

The Zero-Adjust board is used to provide zero-adjustment when using the 9461 PIN TYPE LEAD and 9465 PIN TYPE LEAD. This board has a 2-layer structure consisting of a printed board and steel plate, so the pin-type leads can be shorted together only by pressing the pin tips into the specified contact holes. This board is not used for the 9465 PIN TYPE LEAD.
Dimensions: 214W x 24H x 8D mm



9300 CONNECTION CABLE

This is a low-noise cable for use with INPUT B.
This minimizes noise pick-up during high-resistance or low-power measurements



Appendix 10Rack Mounting

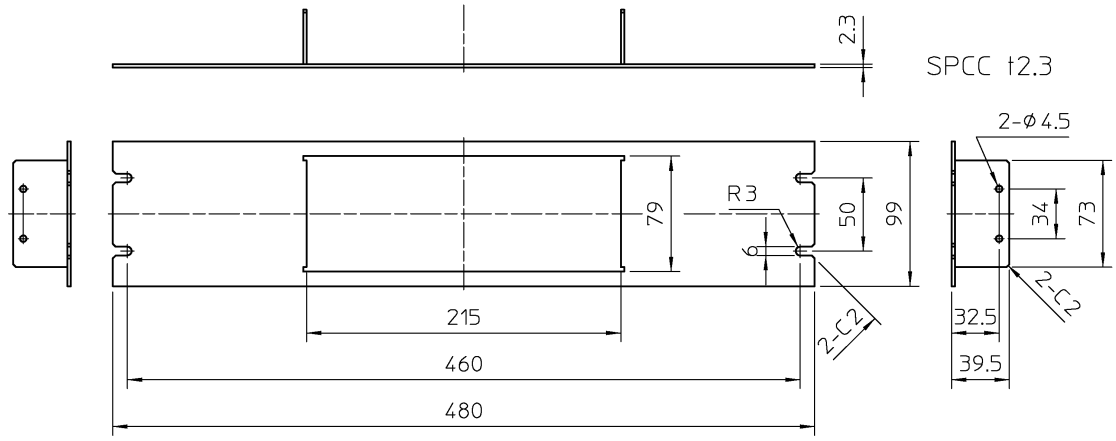
By removing the screws on the sides, this instrument can be installed in a rack mounting plate.

WARNING

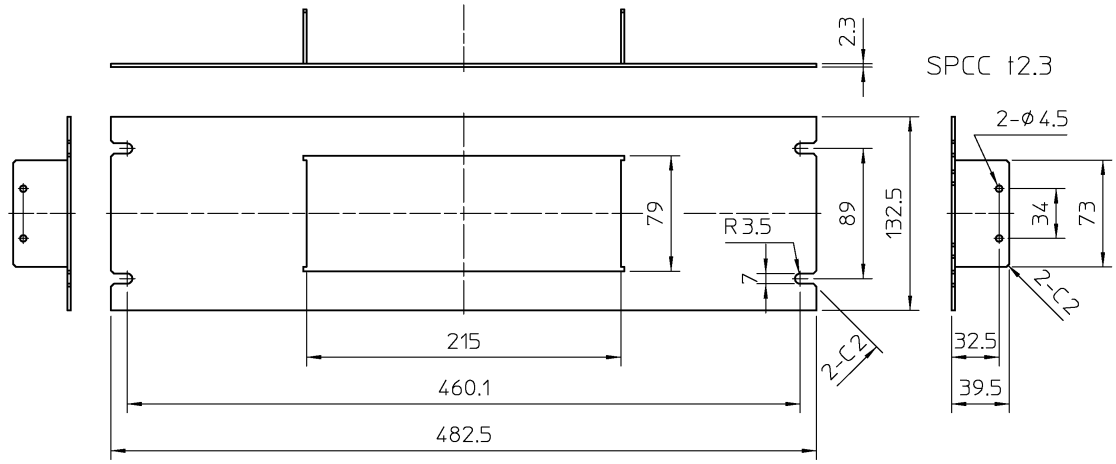
Observe the following precautions regarding the mounting screws to avoid instrument damage and electric shock accidents.

- **When installing the Rack Mounting Plate, the screws must not intrude more than 3.5 mm into either side of the instrument.**
- **When removing the Rack Mounting Plate to return the instrument to stand-alone use, replace the same screws that were installed originally. (Feet: M3 x 6 mm, Sides: M4 x 6 mm)**

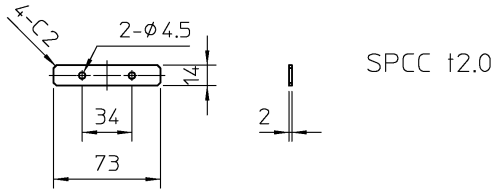
Rack Mounting Plate Template Diagram and Installation Procedure



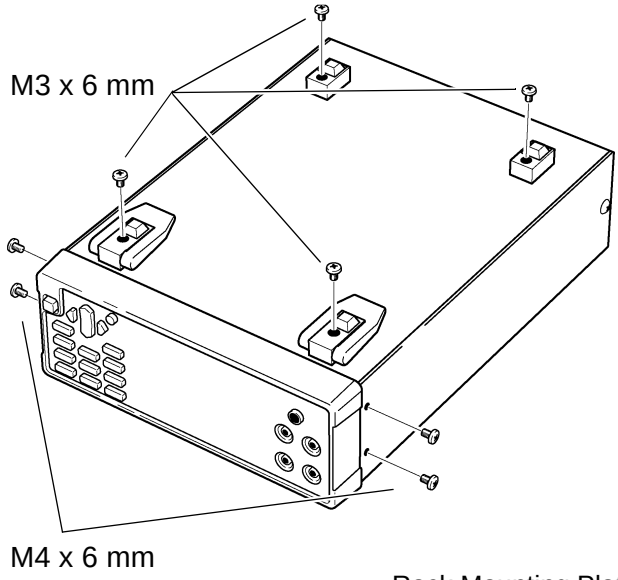
Rack Mounting Plate (JIS)



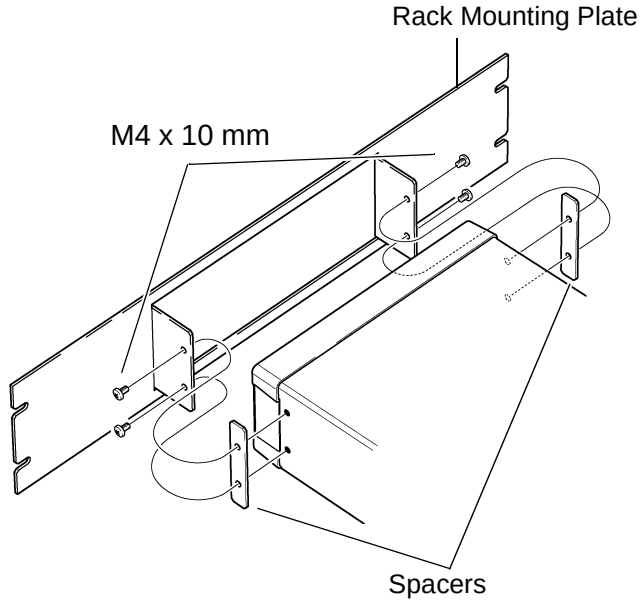
Rack Mounting Plate (EIA)



Spacer (Two Required)



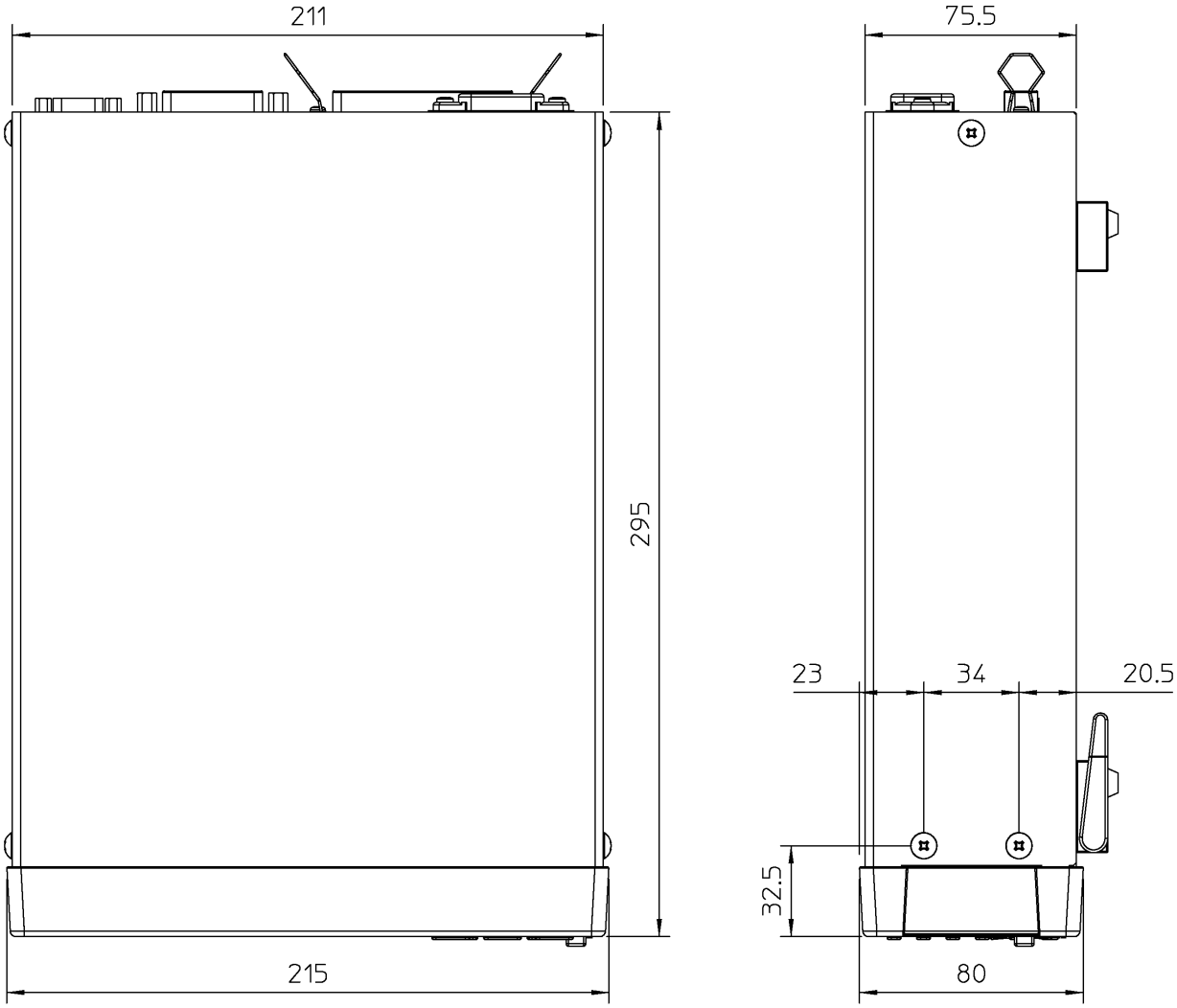
1. Remove the feed from the bottom of the instrument, and the screws from the sides (four near the front).

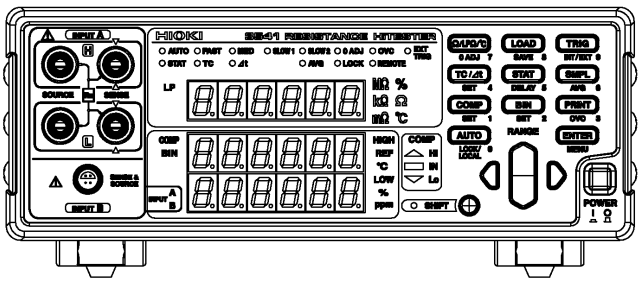


2. Installing the spacers on both sides of the instrument, affix the Rack Mounting Plate with the M4 x 10 mm screws.

When installing into the rack, reinforce the installation with a commercially available support stand.

Appendix 11Dimensional Diagram





Appendix 12 Calibration

(1) Calibration equipment

Please use the following for calibration equipment.

Resistance measurement equipment

FLUKE 5700 A (10 or greater)
Alpha Electronics MSR-19 mΩ
Alpha Electronics MSR-190 mΩ
Alpha Electronics CSR-1.9 Ω

Temperature (Pt) measurement equipment

YOKOGAWA 2793-01

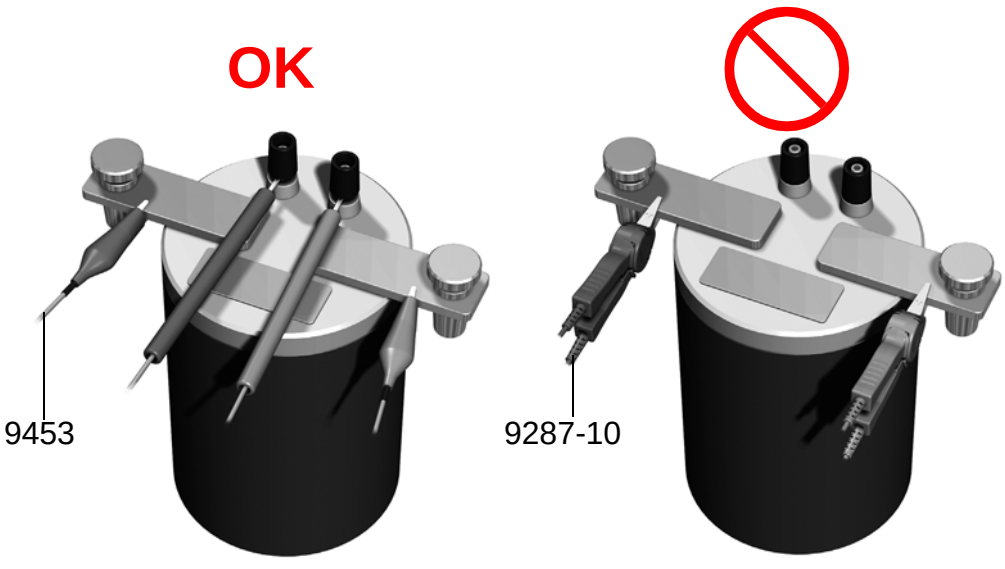
Analog input testing equipment

FLUKE 5700A, or ADVANTEST R4142

If the FLUKE 5700A cannot be used, please use the following equipment.
However, calibration will not be possible in the 10 M range and 100 M range.

Alpha Electronics CSR-19 Ω
Alpha Electronics CSR-190 Ω
Alpha Electronics CSR-1.9 Ω
Alpha Electronics CSR-19 kΩ
Alpha Electronics CSR-19 kΩ
Alpha Electronics CSR-104
Alpha Electronics CSR-105

(2) When using the YOKOGAWA 2792 to calibration, use the separately sold 9453 FOUR-TERMINAL LEAD from Hioki. Note that connection cannot be made with the 9287-10 CLIP TYPE LEAD.



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HIOKI

DECLARATION OF CONFORMITY

Manufacturer's Name:	HIOKI E.E. CORPORATION
Manufacturer's Address:	81 Koizumi, Ueda, Nagano 386-1192, Japan
Product Name:	RESISTANCE HiTESTER
Model Number:	3541
Accessories:	9287-10 CLIP TYPE LEAD 9451 TEMPERATURE PROBE
Options:	9300 CONNECTION CABLE 9452 CLIP TYPE LEAD 9453 FOUR TERMINAL LEAD 9455 PIN TYPE LEAD 9461 PIN TYPE LEAD 9465 PIN TYPE LEAD 9467 LARGE CLIP TYPE LEAD

The above mentioned products conform to the following product specifications:

Safety:	EN61010-1:2001
EMC:	EN61326:1997+A1:1998+A2:2001+A3:2003 Class B equipment Minimum immunity test requirement EN61000-3-2:2000 EN61000-3-3:1995+A1:2001

Supplementary Information:

The products herewith comply with the requirements of the Low Voltage Directive 73/23/EEC and the EMC Directive 89/336/EEC.

HIOKI E.E. CORPORATION

15 September 2006

T. Yoshiike

Tatsuyoshi Yoshiike

President

3541A999-03

HIOKI 3541 RESISTANCE HiTESTER
Instruction Manual

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