

# HIOKI

## BATTERY IMPEDANCE METER BT4560

NEW



Laboratory  
&  
Production line



## A new platform for EIS measurement and equivalent circuit analysis

*Introducing a measurement solution for R&D and  
manufacturing of high-capacity batteries for EVs and ESSs*



US UL standard compliant

# BATTERY IMPEDANCE METER BT4560

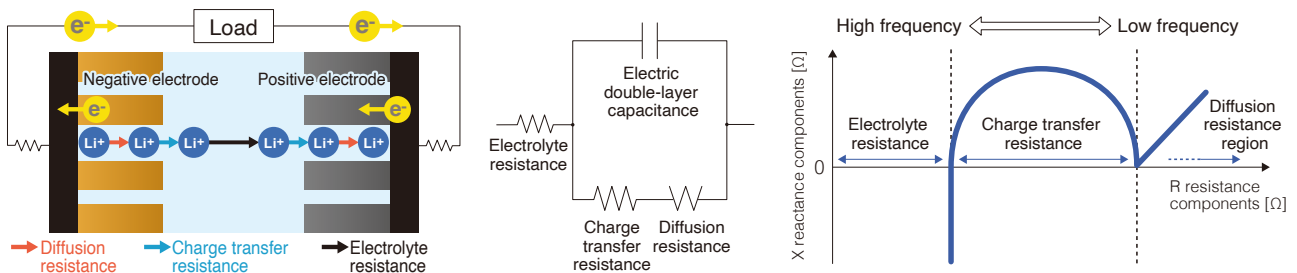


## A reliable EIS measuring instrument for applications ranging from R&D to manufacturing

The Battery Impedance Meter BT4560 can make EIS measurements quickly and easily in applications ranging from R&D to manufacturing. It delivers high-precision measurement capability for quality control of high-capacity batteries, and it can be expanded into an evaluation system for efficiently measuring multiple batteries. In addition, a new LAN interface simplifies the process of building a testing system, offering additional convenience.



### What is battery EIS measurement?



Electrochemical impedance spectroscopy (EIS) is a type of testing that measures a battery's impedance across a broad frequency range using small AC signals. The technique, which yields detailed insights into characteristics such as a battery's internal resistance and electrode reactions, aids in the understanding of battery behavior and performance, making it useful in R&D and quality control applications.

# Why choose Hioki for EIS measurement?

## Bench-top EIS measurement



Battery Impedance Meter BT4560

- A compact EIS instrument that doesn't require an electronic load device
- Simultaneous measurement of impedance, voltage, and temperature
- Convenient evaluation application software for R&D use
- Compatibility with third-party equivalent circuit analysis software

### BT4560 basic performance

|                           |   |
|---------------------------|---|
| Impedance                 | Maximum resolution: 0.1 $\mu\Omega$       |
| Voltage range             | $\pm 5$ V, resolution of 10 $\mu\text{V}$ |
| Measurement current       | Max. 1.5 A rms                            |
| EIS measurement frequency | 10 mHz to 1050 Hz                         |

## Advanced multi-channel solutions

Option



Switch Mainframe SW1002

- Reduce measurement error with multiplexer circuitry designed with impedance measurement in mind
- Channel switching time: 11 ms
- Ideal for shortening test-times and building reliable testing systems

### SW1001 basic performance

|                             |  |
|-----------------------------|--|
| Number of multiplexer slots | 3                                      |
| Channels                    | Up to 18 (4-terminal-pair measurement) |

### SW1002 basic performance

|                             |  |
|-----------------------------|--|
| Number of multiplexer slots | 12                                     |
| Channels                    | Up to 72 (4-terminal-pair measurement) |

## Measurement setup

### Flexible capability to accommodate a variety of EIS measurement situations

Hioki supplies not only measurement hardware and software, but also clamp fixtures\* to accommodate various battery shapes so that you can build an environment that lets you start evaluating and analyzing batteries right away.

\*Fixtures are special ordered options. Please contact Hioki for assistance.

#### Single-channel



BT4560 + fixture (1 channel)

#### Multi-channel

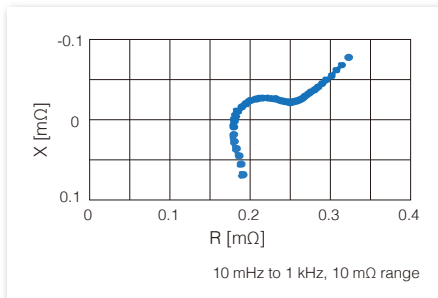


BT4560 + SW1001 + fixture (6 channels)

# High-precision, high-stability measurement performance

## Ideal for use with the high-capacity batteries used in EVs and ESSs

### 0.1 $\mu\Omega$ resolution impedance measurement

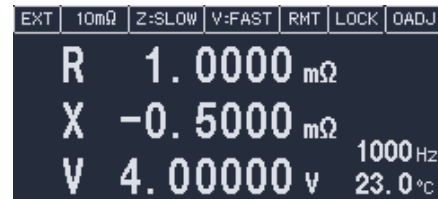


The BT4560 can accurately measure high-capacity batteries with internal impedance of less than 1 m $\Omega$ . It provides reproducible data that boosts the reliability of analysis and evaluation.

### High-precision DC voltage measurement

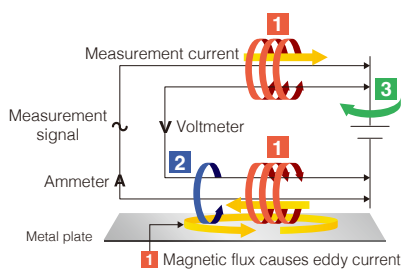
Accuracy:  $\pm 0.0035\%$  rdg.  $\pm 5$  dgt.

Measure a 4 V Li-ion cell with an accuracy of  $\pm 190$   $\mu\text{V}$ .



This level of precision places the BT4560 on par with a 6 1/2 digit high-precision voltmeter, realizing simultaneous high-precision measurements of battery voltage and impedance.

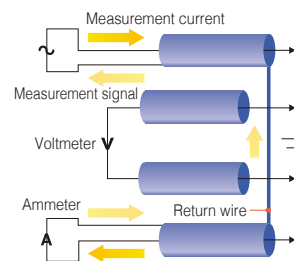
### Improve the stability of high-frequency measurement with 4-terminal-pair measurement



Induction fields lead to measurement error

**Influences of induction fields on 4-terminal measurement**

- 1 Magnetic flux is caused by measurement current
- 2 Magnetic flux is caused by eddy current
- 3 Magnetic flux comes from external sources



**BT4560**

**Reducing effects of induction fields with 4-terminal-pair measurement**

Current flows in the opposite direction of the measurement current to limit magnetic flux, reducing the effects of the induction field.

4-terminal-pair measurement is a method for using a return wire to cancel magnetic flux caused by the measurement current. Nearby metal objects can cause eddy currents, with measurement variation increasing as the distance to the wire decreases. The 4-terminal-pair method cancels the effects of such eddy currents. This significantly reduces variability in measured values when wires move during measurement. As a result, compared to ordinary 4-terminal measurement, 4-terminal-pair measurement excels at high frequencies measurement (generally about 200 Hz or higher).

### 4-terminal-pair measurement probes

#### Choose from 2 types depending on the battery's shape

##### Clip-Type Probe L2002

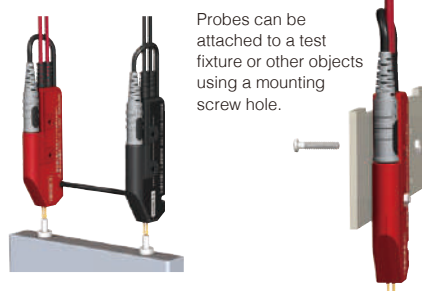
For measuring laminated batteries



Probes can be adjusted by sliding the stopper to ensure uniform contact position.

##### Pin-Type Probe L2003

For measuring various types of batteries, for example when the instrument is embedded in production line equipment



Probes can be attached to a test fixture or other objects using a mounting screw hole.



Customers considering embedding the BT4560 in an automated system

Special-order measurement probe cables can be extended to a length of up to 4 m depending on the operating environment. If you need advice concerning system development, for example about topics like fabricating your own probes or wiring, Hioki's global support network can propose solutions quickly and efficiently.

# Data acquisition software that's convenient in R&D work

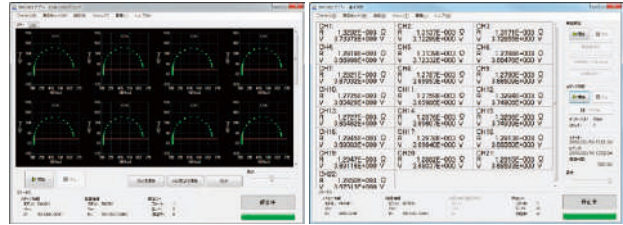
## Computer application software

### Easily acquire EIS measurement data



You can easily acquire EIS measurement data using the computer application software that comes with the instrument as a standard accessory. The software can also make measurements at a fixed interval, for example to evaluate the correlation between temperature variations and internal impedance.

### Measure multiple batteries



Hioki provides software for controlling the SW1001/SW1002 Switch Mainframe to perform EIS measurement of multiple batteries. This software, a standard accessory to both of the switch mainframes, can perform EIS measurement across up to 72 channels, display Nyquist plots in real time. It supports data logging for EIS and single frequency measurement.

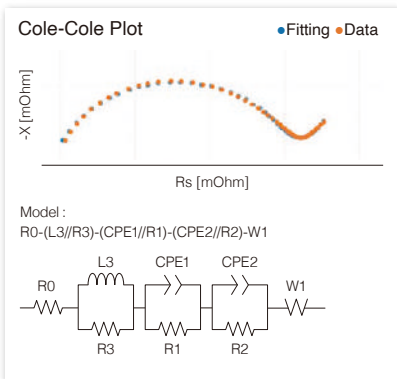
## Circuit Fitting: a simple analysis web app

Find the application here:  
<https://www.circuitfitting.net>



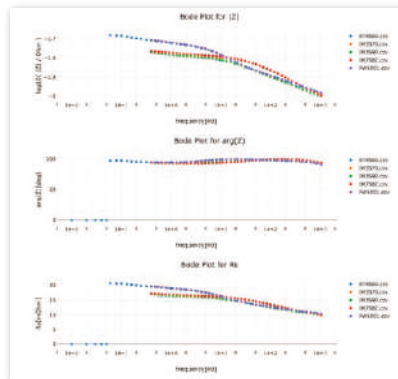
This free web application can perform equivalent circuit analysis and create two- and three-dimensional comparative graphs of Nyquist plots (Cole-Cole plots).

### Automatically display equivalent circuit analysis results



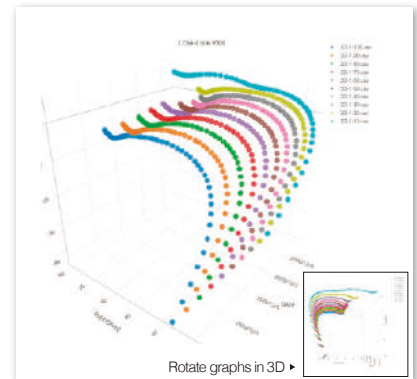
Analyze battery impedance using predefined models. Automatically display analysis results simply by uploading a measurement file.

### Creation of bode plots to ascertain phase characteristics



Create Bode plots and Nyquist plots simultaneously. Bode plots allow you to ascertain phase characteristics.

### Analyze characteristics using 3D graphs



Create Nyquist and Bode plots using the time or date as a third axis. Rotate 3D graphs in any direction to review them and export bitmap images.

## Interoperability with third-party software

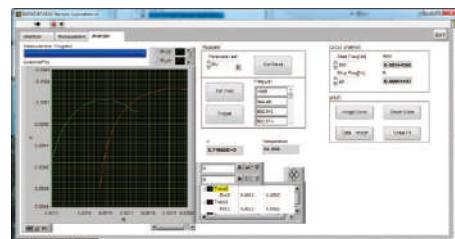
### Data compatibility with ZView® equivalent circuit analysis software



Import data acquired with the BT4560's standard application software into ZView®, a third-party equivalent circuit analysis software package to conduct detailed analysis.

\*ZView® is a trademark of Scribner Associates Inc.

### LabVIEW driver for BT4560



Hioki provides a LabVIEW driver to be used when developing evaluation systems integrated with instruments such as thermostatic chambers and charge/discharge testers. The LabVIEW driver is bundled with a sample application software with functionality for overlaying 5 graphs and conducting simple equivalent circuit analysis.

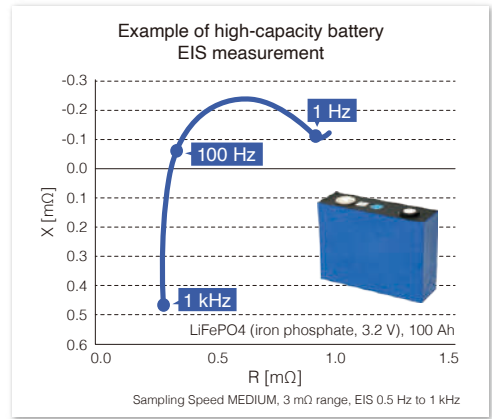
# Quality control and inline testing

Perform low-frequency impedance testing to accommodate the characteristics of high-capacity batteries.

## Low-frequency impedance measurement objectives and advantages

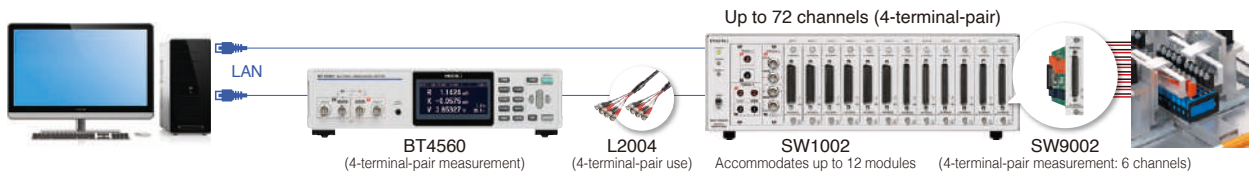
- Perform cell screening using zero-cross points\*\*
- Accumulate data for degradation diagnostics
- Analyze the causes of cell and module defects
- Improve the reproducibility of testing (using measurement at low frequencies can reduce the effects of eddy currents)

\*1: The frequency point at which X = 0 Ω in a Nyquist plot. In high-capacity batteries, this point tends to shift towards frequencies that are lower than 1 kHz.



## Example automatic testing system using a multiplexer

You can use the BT4560 to build an automatic testing system that can efficiently measure multiple batteries. You can flexibly expand the number of channels to match your desired test-system size by using the 6-channel Multiplexer Module SW9002 (designed for impedance measurement) and the Switch Mainframe SW1001 or SW1002 (which houses multiplexer modules).



## Scanning measurement times (reference values)

| Number of channels | Measurement frequency | Measurement speed mode | Total time (all channels)   | Conditions  |
|--------------------|-----------------------|------------------------|-----------------------------|---|
| 6                  | 1 kHz                 | FAST                   | 0.75 s, approx. 123 ms/ch   | SW1001 + SW9002<br>RX measurement function<br>Sample delay: 0 ms (0 waves)<br>LAN communication |
| 6                  | 1 kHz                 | MEDIUM                 | 0.95 s, approx. 158 ms/ch   |   |
| 6                  | 100 Hz                | FAST                   | 0.84 s, approx. 140 ms/ch   |   |
| 6                  | 100 Hz                | MEDIUM                 | 1.25 s, approx. 208 ms/ch   |   |
| 6                  | 1 Hz                  | FAST                   | 7.50 s, approx. 1250 ms/ch  |   |
| 6                  | 1 Hz                  | MEDIUM                 | 13.54 s, approx. 2257 ms/ch |   |

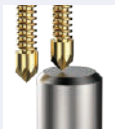
## Functionality and interfaces

### Functionality suited to automatic testing

The BT4560 provides LAN, RS-232C, and USB communication interfaces along with a range of judgment/data output features needed for automatic testing.

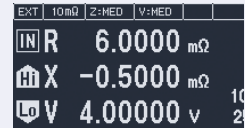
#### Contact check function

By monitoring probes' contact resistance before and after measurement, the instrument can verify that probes have made proper contact with the circuit under measurement.



#### Comparator function

- Simultaneous judgment of impedance and voltage
- Overall judgment result output
- Two-tone buzzer for checking judgments

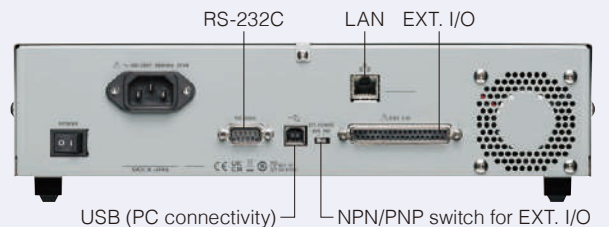
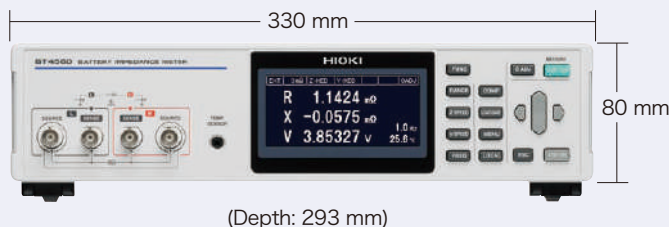
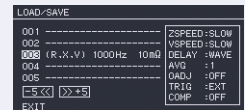


#### NPN/PNP switching

The BT4560's EXT. I/O circuit can be switched between current sink output (NPN) and current source output (PNP).

#### Panel save/load function

Save up to 126 sets of measurement conditions and load them from the EXT. I/O interface.



## BT4560 Specifications

### Accuracy specifications

#### Impedance measurement accuracy ( $\alpha$ is as shown in the table below.)

##### ■ 3 m $\Omega$ range (0.01 Hz to 100 Hz), 10 m $\Omega$ range, 100 m $\Omega$ range

R accuracy =  $\pm (0.004 |R| + 0.0017 |X|)$  [m $\Omega$ ]  $\pm \alpha$

X accuracy =  $\pm (0.004 |X| + 0.0017 |R|)$  [m $\Omega$ ]  $\pm \alpha$

(The units of R and X are [m $\Omega$ ].  $\alpha$  is as shown in the table below.)

Z accuracy =  $\pm 0.4\%$  rdg.  $\pm \alpha (|\sin\theta| + |\cos\theta|)$

$\theta$  accuracy =  $\pm 0.1^\circ \pm 57.3 \frac{\alpha}{Z}$  ( $|\sin\theta| + |\cos\theta|$ )

##### ■ 3 m $\Omega$ range (110 Hz to 1050 Hz)

R accuracy =  $\pm (0.004 |R| + 0.0052 |X|)$  [m $\Omega$ ]  $\pm \alpha$

X accuracy =  $\pm (0.004 |X| + 0.0052 |R|)$  [m $\Omega$ ]  $\pm \alpha$

(The units of R and X are [m $\Omega$ ].  $\alpha$  is as shown in the table below.)

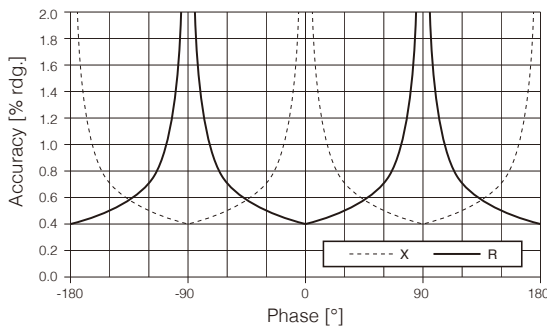
Z accuracy =  $\pm 0.4\%$  rdg.  $\pm \alpha (|\sin\theta| + |\cos\theta|)$

$\theta$  accuracy =  $\pm 0.3^\circ \pm 57.3 \frac{\alpha}{Z}$  ( $|\sin\theta| + |\cos\theta|$ )

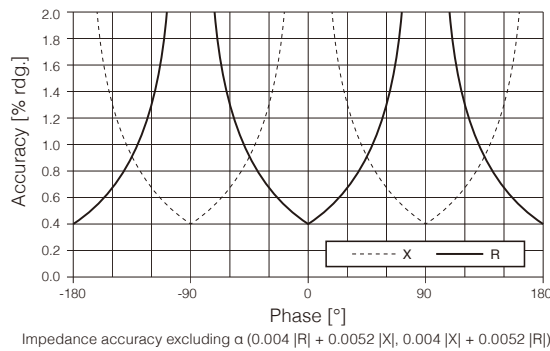
|                         | Sampling speed  | 3 m $\Omega$ range | 10 m $\Omega$ range | 100 m $\Omega$ range |
|-------------------------|---|--------------------|---------------------|----------------------|
| $\alpha$                | FAST  | 25 dgt.            | 60 dgt.             | 60 dgt.              |
|                         | MED   | 15 dgt.            | 30 dgt.             | 30 dgt.              |
|                         | SLOW  | 8 dgt.             | 15 dgt.             | 15 dgt.              |
| Temperature coefficient | R: $\pm$ R accuracy $\times$ 0.1 / $^\circ$ C; X: $\pm$ X accuracy $\times$ 0.1 / $^\circ$ C; Z: $\pm$ Z accuracy $\times$ 0.1 / $^\circ$ C; $\theta$ : $\pm$ $\theta$ accuracy $\times$ 0.1 / $^\circ$ C (applied in the ranges of 0 $^\circ$ C to 18 $^\circ$ C and 28 $^\circ$ C to 40 $^\circ$ C) |                    |                     |                      |

#### Accuracy graph

##### ■ 3 m $\Omega$ range (0.01 Hz to 100 Hz), 10 m $\Omega$ range, 100 m $\Omega$ range



##### ■ 3 m $\Omega$ range (110 Hz to 1050 Hz)



#### Voltage measurement accuracy (when self-calibration is performed)

|                         |   |                                  |
|-------------------------|---|----------------------------------|
| Voltage                 | Display range   | -5.10000 V to 5.10000 V          |
|                         | Resolution  | 10 $\mu$ V                       |
| Voltage accuracy        | FAST/MED/SLOW   | $\pm 0.0035\%$ rdg. $\pm 5$ dgt. |
| Temperature coefficient | $\pm 0.0005\%$ rdg. $\pm 1$ dgt. / $^\circ$ C (applied in the ranges of 0 $^\circ$ C to 18 $^\circ$ C and 28 $^\circ$ C to 40 $^\circ$ C) |                                  |

#### Temperature measurement accuracy (BT4560 + Z2005 temperature sensor)

|                         |  |
|-------------------------|--|
| Accuracy                | $\pm 0.5^\circ$ C (measurement temperature: 10.0 $^\circ$ C to 40.0 $^\circ$ C)<br>$\pm 1.0^\circ$ C (measurement temperature: -10.0 $^\circ$ C to 9.9 $^\circ$ C, 40.1 $^\circ$ C to 60.0 $^\circ$ C) |
| Temperature coefficient | Temperature coefficient: $\pm 0.01^\circ$ C / $^\circ$ C (applied in the ranges of 0 $^\circ$ C to 18 $^\circ$ C and 28 $^\circ$ C to 40 $^\circ$ C)   |

### General Specifications (accuracy guaranteed for 1 year)

|                |                                 |
|----------------|---------------------------------|
| Measured items | Impedance, voltage, temperature |
|----------------|---------------------------------|

#### Impedance measurement

|                              |  |                       |  |
|------------------------------|--|-----------------------|--|
| Measurement parameters       | R resistance, X reactance, Z impedance, $\theta$ phase angle |                       |  |
| Measurement frequency        | 0.01 Hz to 1050 Hz   |                       |  |
| Frequency setting resolution | 0.01 Hz to 0.99 Hz   | in 0.01 Hz increments |  |
|                              | 1.0 Hz to 9.9 Hz   | in 0.1 Hz increments  |  |
|                              | 10 Hz to 99 Hz   | in 1 Hz increments    |  |
|                              | 100 Hz to 1050 Hz  | in 10 Hz increments   |  |
| Measurement ranges           | 3.0000 m $\Omega$ , 10.0000 m $\Omega$ , 100.000 m $\Omega$  |                       |  |
| Allowable input voltage      | Up to 5 V  |                       |  |

#### Measurement/DC-load currents

(DC load: offset current applied to measured object during impedance measurement)

|                     | 3 m $\Omega$ range   | 10 m $\Omega$ range   | 100 m $\Omega$ range |
|---------------------|----------------------|-----------------------|----------------------|
| Measurement current | 1.5 A rms $\pm 10\%$ | 500 mA rms $\pm 10\%$ | 50 mA rms $\pm 10\%$ |
| DC load current     | 1 mA or less         | 0.35 mA or less       | 0.035 mA or less     |

#### Number of measurement current waves

|                   | FAST | MED | SLOW |
|-------------------|------|-----|------|
| 0.01 Hz to 66 Hz  | 1    | 2   | 8    |
| 67 Hz to 250 Hz   | 2    | 8   | 32   |
| 260 Hz to 1050 Hz | 8    | 32  | 128  |

#### Voltage measurement

|                   |   |
|-------------------|---|
| Measurement range | 5.00000 V (single range)  |
| Resolution        | 10 $\mu$ V  |
| Measurement time  | FAST:0.1 s, MED:0.4 s, SLOW:1.0 s<br>(When self-calibration is performed, 0.21 s is added to the measurement time.) |

#### Temperature measurement

|                  |                                     |
|------------------|-------------------------------------|
| Display range    | -10.0 $^\circ$ C to 60.0 $^\circ$ C |
| Resolution       | 0.1 $^\circ$ C                      |
| Measurement time | 2.3 s                               |

|  |   |
|--|---|
| Measurement functions                    | (R, X, V, T), (Z, $\theta$ , V, T), (R, X, T), (Z, $\theta$ , T), (V, T)  |
| Functions                                | Comparator, self-calibration, sample delay, average, voltage limit, potential gradient compensation for impedance measurement, charge/discharge prevention during AC signal application, key lock, system test, panel saving and loading (up to 126 condition sets) |
| Measurement error detection functions    | Contact check, measurement current error, voltage drift on measured object, overvoltage input, voltage limit  |
| Interfaces                               | LAN (TCP/IP, 10BASE-T/100BASE-TX)<br>RS-232C (transmission speed: 9,600 bps/19,200 bps/38,400 bps)<br>USB (pseudo COM port)   |
| EXT. I/O                                 | TRIG, LOAD, Hi, IN, Lo, and others (NPN/PNP can be switched)  |
| Operating temperature and humidity range | 0 $^\circ$ C to 40 $^\circ$ C (32 $^\circ$ F to 104 $^\circ$ F), 80% RH or less (no condensation)   |
| Storage temperature and humidity range   | -10 $^\circ$ C to 50 $^\circ$ C (14 $^\circ$ F to 122 $^\circ$ F), 80% RH or less (no condensation)   |
| Operating environment                    | Indoor, pollution degree 2, altitude up to 2,000 m  |
| Power supplies                           | Rated supply voltage: 100 to 240 V AC<br>Rated supply frequency: 50/60 Hz   |
| Rated power                              | 80 VA   |
| Dielectric strength                      | 1.62 kV AC, 1 min., cutoff current 10 mA (between all power supply terminals and protective ground)   |
| Applicable standards                     | Safety: EN61010<br>EMC EN61326 Class A  |
| Dimensions and weight                    | Approx. 330W $\times$ 80H $\times$ 293D mm (12.99W $\times$ 3.15H $\times$ 11.54D in.), approx. 3.8 kg (134.0 oz.)  |
| Included accessories                     | Power cord $\times$ 1, instruction manual $\times$ 1, zero-adjustment board $\times$ 1, USB cable (A-B type) $\times$ 1, CD-R (comes with communication instruction manual, PC application software, USB driver) $\times$ 1   |

## Multiplexer specifications

### Switch Mainframe SW1001/SW1002

|                         |  |
|-------------------------|--|
| Number of slots         | 3 slots (SW1001),<br>12 slots (SW1002)                           |
| Supported BT4560 module | Multiplexer Module SW9002<br>(4-terminal-pair, 2-wire)           |
| Max. input voltage      | 60 V DC, 30 V AC rms, 42.4 V peak                                |
| Interfaces              | LAB, USB, RS-232C (host),<br>RS-232C (command transfer function) |
| EXT. I/O                | SCAN input, SCAN_RESET input,<br>CLOSE output (scan control)     |

### Multiplexer Module SW9002

|                           |   |
|---------------------------|---|
| Wiring method             | 4-terminal-pair (6-wire) or 2-wire  |
| Number of channels        | 6 channels (4-terminal-pair, 2-wire)  |
| Contact method            | Mechanical relays   |
| Channel switching time    | 11 ms (not including measurement time)  |
| Maximum allowable voltage | 60 V DC, 30 V AC rms, 42.4 V peak   |
| Maximum allowable current | Source: Between HIGH and LOW<br>2 A DC, 2 A AC rms<br>Sense: Between HIGH and LOW<br>1 A DC, 1 A AC rms |
| Connectors used           | D-sub 37-pin pin header   |

### Effect on accuracy of using the instrument with the SW9002<sup>\*1</sup>

| Range        | Effect                              |                                      | Conditions, remarks  |
|--------------|-------------------------------------|--------------------------------------|--|
|              | Frequency range<br>0.1 Hz to 100 Hz | Frequency range<br>110 Hz to 1050 Hz |  |
| 3 mΩ R       | ±0.05% f.s.                         | ±0.1% f.s.                           | –  |
| 3 mΩ X       | ±0.1% f.s.                          | ±1.0% f.s.                           | –  |
| 10 mΩ R      | ±0.015% f.s.                        | ±0.03% f.s.                          | –  |
| 10 mΩ X      | ±0.03% f.s.                         | ±0.3% f.s.                           | –  |
| 100 mΩ R     | ±0.01% f.s.                         | ±0.01% f.s.                          | –  |
| 100 mΩ X     | ±0.015% f.s.                        | ±0.03% f.s.                          | –  |
| All V ranges | ±5 μV                               |                                      | After operating environment temperature has stabilized within 1 min. after contacts closed |

\*1: Effect before zero adjustment.



SW1001



SW1002



SW9002



Connection Cable L2004  
BNC, 0.91 m (2.99 ft.)

## Product



### Model: BATTERY IMPEDANCE METER

Model no. (order code): BT4560-50

Measurement probes are not included with this product. Please separately select and purchase the measurement probe options appropriate for your application.

### Example special specifications

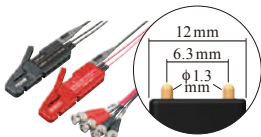
Support for a measurable battery voltage of 20 V<sup>\*1</sup>  
(Please contact Hioki for more detailed specifications.)

| Measurement frequency | Measurable battery voltage | Impedance measurement range | Measurement current             |
|-----------------------|----------------------------|-----------------------------|---------------------------------|
| 0.01 Hz to 1050 Hz    | 20 V                       | 30 mΩ, 300 mΩ, 3 Ω          | 150 mA rms, 50 mA rms, 5 mA rms |

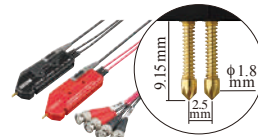
\*1: No LAN interface

## Options

### Probes and sensors



CLIP TYPE PROBE L2002  
Cable length: 1.5 m (4.92 ft.)



PIN TYPE PROBE L2003  
Cable length: 1.5 m (4.92 ft.)



TIP PIN 9772-90  
For replacing the tip of Pin Type Probe L2003 (one piece)



TEMPERATURE SENSOR Z2005  
Cable length: 1 m (3.28 ft.)



4-TERMINAL PROBE L2000  
Ideal for clipping to screw terminal, cable length of 1 m (3.28 ft.), cannot be used with 3 mΩ range when connected to BT4560, no combined accuracy defined

### PC connectivity



LAN CABLE 9642  
Straight, cross conversion connector included, cable length: 5 m (16.40 ft.)



RS-232C CABLE 9637  
For a PC, 9-pin to 9-pin connectors, cross cable, cable length: 1.8 m (5.91 ft.)

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# HIOKI

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