Manage Electrode Reaction Resistance, Electrolyte Resistance, and Welding Resistance

The Ultimate Instrument for Measuring Large-Capacity Li-ion Batteries for EVs
Improve the quality of battery cell inspections

- Set your own measurement frequency between 100 mHz and 1.05 kHz
- Use low frequencies to measure electrode reaction resistance
- Use high frequencies to measure electrolyte resistance and welding resistance
- Create Cole-Cole plots (with bundled application program)
- Use equivalent circuit analytic software to analyze internal battery defects

Use the BT4560 for impedance measurement... To isolate defective factors in battery cells

DC-IR measurement using a charging/discharging tester

DC-IR measurement passes electric currents into R1 and R2, which makes it difficult to measure electrolyte resistance and reaction resistance separately. (See the equivalent circuit diagram shown above)
Exceptional Accuracy
Unsurpassed Stability

Measure very low impedances of 1mΩ or less
Some high-capacity Li-ion batteries have an internal impedance less than 1 mΩ. The BT4560 can measure very low impedances of 1mΩ or less, stably and with high reproducibility.

Measure DC voltage with high accuracy
Accuracy: ±0.0035% rdg. ±5 dgt.
The BT4560 achieves an accuracy comparable to a 6.5-digit DMM. It can be used to measure both OCV and impedance in batteries.

Four-terminal pair measurement resolves system construction problems
The four-terminal pair method reduces various effects of induced magnetic fields, such as cabling influence, eddy-current influence due to surrounding metals, and interference when multiple devices are used simultaneously. When compared to the conventional four-terminal method, the BT4560 controls magnetic fluxes generated by the measurement current. This significantly reduces the impact on the measured value when cabling for measurements is changed, improving stability when the measurement instrument is embedded within the production line.

Dedicated probes for four-terminal pair measurement reduce the magnetic flux generated
Dedicated probes with the four-terminal pair structure provide stable measurement less affected by environmental noise or cabling.

CLIP TYPE PROBE L2002
For measuring laminated sheet batteries
Adjust the point of contact by sliding a stopper.

PIN TYPE PROBE L2003
For line-embedded applications and various other types of batteries
Threaded holes are provided to secure the probe on an inspection fixture.

* Contact your local Hioki distributor for details of the probe tip shapes
Battery cell selection extends the battery pack service life

Battery pack deterioration factors
Heat reduces or deterioriates the battery capacity. Large-capacity batteries for EVs that charge/discharge with large currents generate significant amounts of heat.

Selection is necessary for extending battery pack service life
Combining cells with the same battery capacity and internal resistance equalizes heat generated, extending the service life.

If the resistance of the battery pack is different, some of the batteries will heat up excessively, thereby lowering the capacity and accelerating deterioration.

The protective circuit works based on the cell with the lowest capacity, reducing the discharging capacity of the entire battery pack as a result.

Checking the battery deterioration level

Compare measured data for new and deteriorated batteries
Here, Cole-Cole plot data is compared for new Li-ion battery cells (upper-left plot) and deteriorated Li-ion battery cells of the same kind (lower-left plot).

R1: Electrolyte resistance and welding resistance
R2: Reaction resistance (Reaction resistance of positive/negative electrodes)

Comparing the new Li-ion battery with the deteriorated one confirms significant changes in the reaction resistance value. Although much depends on the deterioration factors, in addition to heat effects, the deterioration of the electrode reactive portion appears on a graph as reaction resistance for particular applications, such as repeated charging/discharging at low temperature and repeated deep charging/discharging (SOC: Between 0 and 100%).
**Isolate battery deterioration factors**

Cole-Cole plot data obtained by using the BT4560 and commercially-available equivalent circuit analysis software, such as "ZView™", can be used to analyze deterioration factors.

The impedance characteristics of a Cole-Cole plot are generally expressed as a pseudo equivalent circuit.

A pseudo equivalent circuit is expressed by:
- **Resistance in the electrolyte and tab welding portions** (R₁)
- **Positive/negative electrode reactions within the battery** (R₂//C₂, R₃//C₃)
- **Lead and other inductance** (L)

... to give just a few examples.

Once a pseudo equivalent circuit is constructed, equivalent circuit analysis software (ZView®) can provide the circuit constant of each element by means of curve fitting. Quantifying the changes in each element’s constant when a battery is new and when it deteriorates allows analysis of which portions within the battery have changed. This serves to isolate battery deterioration factors.

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**Create Cole-Cole plots using bundled software**

A free PC application that comes with the BT4560 can conduct measurement and draw Cole-Cole plots. Additionally, "ZView™" from Scribner Associates Inc. also provides detailed analysis based on equivalent circuit analysis.

1. **Bundled PC application**
   Creates Cole-Cole plots. Measurement results can also be output in Excel and CSV files.

2. **Application bundled with LabView driver**
   Compares multiple overlaid graphs. Equipped with a simple equivalent circuit analysis function, this application also gives insight into electrolyte resistance and reaction resistance.

3. **AC impedance analysis software "ZView™"**
   "ZView™" creates certain equivalent circuits based on CSV files output from the above application while quantifying each element, to analyze deteriorated portions in a battery.
Characteristics and features of BT4560

**All-in-one compact unit**
The BT4560 requires no loading devices and provides measurements simply as a stand-alone unit, without having to establish a complicated measurement system.

**Self-calibration**
Correct any offset voltage and gain drift that may be present in the circuit to improve the accuracy of voltage measurement.

**Sample delay**
Specify a delay between AC voltage being applied and sampling being started so that measurement can start after the response stabilizes.

**Prevent charging or discharging when AC voltage is applied**
To prevent the battery that is being measured from charging or discharging, the battery impedance meter terminates the applied measurement signal when zero is crossed.

**Simultaneous measurement of impedance and voltage**
Reduce tact time by testing both impedance and high accuracy DC voltage at the same time.

**Slope correction function**
If measurement signals drift due to the battery characteristics or the input impedance of measurement instrument, the BT4560 applies correction to the linear drift.

**Temperature measurement**
Reaction resistance measured at low frequency is sensitive to temperature. An optional temperature sensor measures the temperature around the battery and associates the results with data, thereby improving the reliability of the measurements.

*Functions available during impedance measurement

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**Functions to accommodate automated machines**

**Contact check**
Monitor the contact resistance of the probe before and after measurement so that the measurement will only start when the measuring electrode on the probe is in contact with the object to be measured.

**Comparator**
- Simultaneously measure impedance and voltage
- Output overall determination results
- Use the two-tone buzzer to indicate determination results

**NPN/PNP switch**
Switch the input/output circuits for EXT. I/O according to the type of output: current sink output (NPN) or current source output (PNP).

**Panel saving and loading**
Store up to 126 sets of measurement conditions in internal memory so that they can be called through EXT. I/O for future measurements.
Accuracy specifications

Impedance measurement accuracy

- 3 mΩ range (0.1 Hz to 100 Hz), 10 mΩ range, 100 mΩ range
  - R accuracy = ±(0.004 |R| + 0.0017 |X|) [mΩ] ± α
  - X accuracy = ±(0.004 |X| + 0.0017 |R|) [mΩ] ± α
  - Z accuracy = ±0.4% rdg. ± α (|sinθ| + |cosθ|)
  - θ accuracy = ±0.3° ± 57.3° (|sinθ| + |cosθ|)
  - (α is as shown in the table below.)

<table>
<thead>
<tr>
<th>α</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAST</td>
<td>25 dgt.</td>
</tr>
<tr>
<td>MED</td>
<td>15 dgt.</td>
</tr>
<tr>
<td>SLOW</td>
<td>8 dgt.</td>
</tr>
</tbody>
</table>

Temperature measurement accuracy

- ±0.5°C (measurement temperature: -10.0°C to 9.9°C, 40.1°C to 60.0°C)
- ±0.01°C/°C (applied in the ranges of 0 °C to 18 °C and 28°C to 40°C)

Voltage measurement accuracy

- ±0.0035% rdg. ±5 dgt.

<table>
<thead>
<tr>
<th>Voltage</th>
<th>Display range</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>10 μV</td>
<td>±0.0035% rdg. ±5 dgt.</td>
</tr>
</tbody>
</table>

Temperature measurement accuracy

- BT4560 + Z2005 temperature sensor
- ±0.005% rdg. ±1 dgt./°C (applied in the ranges of 0°C to 18°C and 28°C to 40°C)

BT4560 specifications

- Accuracy guaranteed for 1 year, Post-adjustment accuracy guaranteed for 1 year

**Measurement signals**
- Impedance, voltage, temperature

**Impedance measurement**
- Measurement parameters: R resistance, X reactance, Z impedance, θ phase angle
- Measurement frequency: 0.1 Hz to 1050 Hz
- Measurement range: 3 mΩ, 10 mΩ, 100 mΩ
- Measurement current/DC load: 0.1 mA or less, 0.35 mA or less

**Voltage measurement**
- Measurement range: 5.00000 V
- Resolution: 10 μV
- Measurement time: 2.3 s
- Display range: 10.0°C to 60.0°C

**Temperature measurement**
- Display range: 0.1°C to 18.0°C
- Resolution: 0.1°C
- Measurement time: 2.3 s
- Measurement error: 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)
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Model : BATTERY IMPEDANCE METER BT4560

Model No. (Order Code) (Note)

BT4560

Note: This product is not supplied with measurement probes. Please select and purchase the measurement probe options appropriate for your application separately.

Options

<table>
<thead>
<tr>
<th>Probe Type</th>
<th>Cable Length</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLIP TYPE PROBE L2002</td>
<td>1.5 m (4.92 ft)</td>
<td></td>
</tr>
<tr>
<td>PIN TYPE PROBE L2003</td>
<td>1.5 m (4.92 ft)</td>
<td></td>
</tr>
<tr>
<td>TEMPERATURE SENSOR Z2005</td>
<td>1 m (3.28 ft)</td>
<td></td>
</tr>
<tr>
<td>RS-232C CABLE 9637</td>
<td>1.8 m (5.91 ft)</td>
<td>For the PC, 9 pins - 9 pins,  cross,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cable length 1.8 m (5.91 ft)</td>
</tr>
</tbody>
</table>

Custom specification line-up

<table>
<thead>
<tr>
<th>Measurement Voltage</th>
<th>Standard/M Custom specifications</th>
<th>Measurement Range</th>
<th>Measurement Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 V (±5.10000 V)</td>
<td>3 mΩ/10 mΩ/100 mΩ</td>
<td>1.5 A/500 mA/50 mA</td>
<td></td>
</tr>
<tr>
<td>10 V (±9.99999 V)</td>
<td>30 mΩ/300 mΩ/3 Ω</td>
<td>500 mA/50 mA/5 mA</td>
<td></td>
</tr>
<tr>
<td>20 V (-1.00000 V to 20.40000 V)</td>
<td>30 mΩ/300 mΩ/3 Ω</td>
<td>150 mA/50 mA/5 mA</td>
<td></td>
</tr>
</tbody>
</table>

Custom-made options

<table>
<thead>
<tr>
<th>Custom-made options</th>
<th>Custom-made SET options</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-TERMINAL PROBE L2000</td>
<td>BNC-Banana Plug</td>
</tr>
<tr>
<td>Cable length 1 m (3.28 ft)</td>
<td>Transducer</td>
</tr>
</tbody>
</table>

Measure electrochemical parts and materials

For property evaluation of electrodes and electrolyte

Model : CHEMICAL IMPEDANCE ANALYZER IM3590

Model No. (Order Code)

IM3590

Measurement range : 100 mΩ to 100 MΩ
Measurement frequency : 1 mHz to 200 kHz

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