

# 3550 Series Battery HiTESTERs

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*User's Guide*



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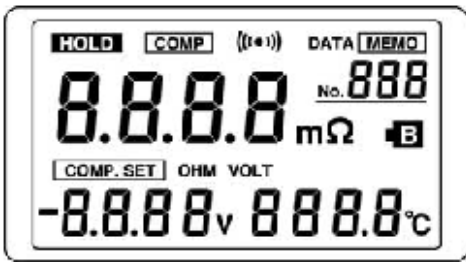
## Questions & Answers

### CONTENTS

<b>1</b>	Display Q 1 - 3	.....	1
<b>2</b>	Printer Output/Memory Q1 - 8	.....	2
<b>3</b>	Comparator Q1 - 7	.....	3
<b>4</b>	Input Protection Q1 - 3	.....	4
<b>5</b>	Leads Q1 - 15	.....	5
<b>6</b>	Resistance Measurement Q1 - 14	.....	8
<b>7</b>	Voltage Measurement Q1	.....	11
<b>8</b>	Temperature Measurement Q1 - 2	.....	12
<b>9</b>	Batteries Q1 - 13	.....	12
<b>10</b>	Miscellaneous Q1 - 19	.....	15
<b>11</b>	References	.....	18

1 Display.....

Q1. Why does the 3550 series comparator display a warning when it finds the resistance of a battery to be between the upper and lower limits, i.e., (lower limit resistance value) < resistance < (upper limit resistance value)?



3550 Display

Q2. If a negative voltage is displayed, the comparator makes an incorrect evaluation if the polarity of the test leads is reversed when connected to the battery. (To be more precise, rather than incorrectly evaluating the voltage, it judges the voltage low.) Is it possible to ignore the negative polarity for the evaluation?

Q3. After inserting batteries in the 3551 (or connecting the AC adapter), power does not come on immediately. Is this a defect?

A1. When a battery is new, it has a low internal resistance, but as the battery deteriorates the internal resistance becomes larger. This is due to corrosion on the plates, loss of electrolytic solution, etc. Therefore, when the comparator is found to be in the "IN" condition during battery maintenance work, a warning is generated. However, when the battery is shipped from the factory, it passes inspection as long as it falls between the upper and lower limits for both resistance and voltage. At HIOKI, we use these units in combination with the 3225 and the 3236.

A2. Although it is not possible with the 3550 series, we will consider implementing such a capability in a future BATTERY HiTESTER/AC mΩHiTESTER.

A3. When batteries are first inserted or when batteries were fully depleted and are replaced (or when the AC adapter is connected), the unit will not come on for about 15 seconds. This is because the internal backup capacitor is being charged. It is not a defect. Information about this point is included in the manual.

2 Printer Output/Memory.....

Q1. How can I load data stored in memory into a personal computer?

Refer to the reference material at the end of guide.



A1. Refer to the reference material at the end of this sales guide. The material describes how to use the 3550 and 3551's printer output to load data from memory into a personal computer. The method that is described uses a commercially available RS-232C converter to load the data into a personal computer running under Windows 95. Hyper Terminal, provided with Windows 95, is the software that is used. Note: Units ( $\Omega$ , V, C, etc.) are also output.

Q2. Is conversion of output to Centronics - RS-232C possible?

A2. At present, the 3550 can store 260, 3551 can store 250 items of data in memory. Because the memory in the unit is already being used to the fullest extent possible, it is not possible to increase the amount of data that can be stored in memory.

Q3. Is it possible to increase the amount of data that can be stored in memory?

A3. When batteries are first inserted or when batteries were fully depleted and are replaced (or when the AC adapter is connected), the unit will not come on for about 15 seconds. This is because the internal backup capacitor is being charged. It is not a defect. Information about this point is included in the manual.

Q4. I have imported the data to a PC and want to process them with Microsoft Excel, but the unit symbols prevent proper calculation or graph display. What should I do?

A4. Unit symbols such as " $\Omega$ ", "V", or "C" can be deleted using the global replace function of Excel.

Q5. Can measurement data be selectively deleted or added?

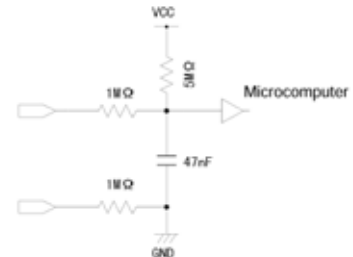
A5. With the 3550 and 3551, it is only possible to delete the latest data or all data. The 3551 has a new function which allows over writing data selectively.

Q6. Can I print out measurement data selectively?

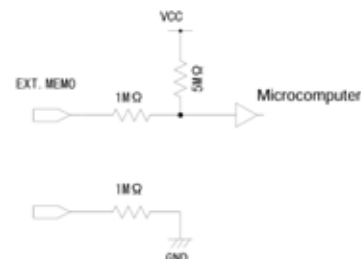
A.6 This is not possible. The 3550 and 3551 send all data to the 9203 in one operation, and the 9203 prints all of these data.

Q7. I want to externally control EXT.HOLD and EXT.MEMO. Where is the circuit common point? Is it possible to perform control with 0/5 V (CMOS level)?

A7. Refer to the circuit configuration of EXT.HOLD and EXT.MEMO shown below. The internal circuit operates at 5 V. Control at the CMOS level is therefore possible.



Circuit configuration of EXT.HOLD and EXT.MEMO in 3551



Circuit configuration of EXT.MEMO in 3550

Q8. Does the printout differ, depending on the software version of the 9203?

A8. The software version and compatible models are listed below.  
 Ver.1.00:3227  
 Ver.1.01:3550, 3227  
 Ver.1.10:3550, 3551, 3227  
 When version 1.10 is used and the 3550 is connected, "NG" is displayed as "- -". When the 3551 is connected, printout is as explained in the manual. When version 1.01 is used and the 3551 is connected, the 3 mΩ range cannot be printed. For details, please contact the HIOKI Head Office.

### 3 Comparator.....

Q1. Is it possible for HIOKI to research the battery data and write the comparator values to memory?

A1. Although HIOKI is engaged in battery charging and discharging tests, the data generated by these tests is intended only for reference purposes. Users must provide the data on individual batteries.

Q2. Is it possible to increase the number of comparator?

A2. Yes. It is possible to increase the number of comparator numbers up to 30(3550 and 3555 but 3551 is not possible). Such cases are handled as special orders.

Q3. Is it possible to input upper and lower limit values for a voltage comparator?

A3. This is not possible with the 3550 series. Inspections conducted by the battery manufacturer when the batteries are shipped from the factor are performed with upper and lower limit values. However, if the voltage is higher than normal during maintenance work, a

Q4. Is it possible to use the comparator for voltage only?	A4.	failure in one of the other batteries that is connected in series in a UPS could be causing a relative increase in the battery voltage, or the charger could be malfunctioning. Increases in a battery's voltage that are discovered during maintenance appear never to be the result of a problem with the battery itself.
Q5. Can the battery type number be displayed instead of the comparator number?	A5.	This is not possible, because it would require not only a software upgrade but also a new LCD.
Q6. I want to measure a 48 V battery assembly. Since voltage evaluation is not needed, can evaluation be based on impedance only?	A.6	The maximum input voltage is 50 V DC for the 3550 and 3555 and 60 V DC for the 3551. Therefore the impedance of a 48 V battery assembly can be measured if voltage evaluation is not required. Use the comparator setting screen and set the voltage comparator value to - 3000dgt (3551: - 3100dgt).
Q7. Is it possible to obtain separate comparator outputs for resistance and voltage?	A7.	Because resistance and voltage comparator output is obtained by software, it is not possible to obtain separate comparator outputs for resistance and voltage.

**4** Input Protection.....

Q1. Is input overvoltage protection implemented, and how?	A1.	Basically, in the case of both the 3550, 3555 and the 3551, it is not possible to input voltage in excess of 50V DC (3551:60V DC), nor is it possible to input AC voltage or current. If such voltage or current is input, the unit will be damaged. Although a design change that adds a fuse will be implemented in new lots in the near future in order to minimize the number of failures resulting from such mis-operation, the fuse will not be user replaceable. Note that any unit failures caused by overvoltage input will only be repaired for a fee.
Q2. Can maximum allowable input voltage be increased?	A2.	This is a frequently expressed request for the 3550 and 3551. However, for reasons of

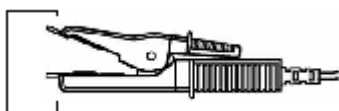
Q3. What type of damage will occur for various types of mis-operation?

safety and because extensive parts modifications would be required, it is not possible to increase the rated maximum input voltage of the 3550 series models. The 3551 has passed overload tests up to 400 V DC. When a voltage of about 330 V or more is applied, an intermittent warning tone will be heard. However, when high voltage is applied, sparks are produced when the input coupling capacitor is charged, which can be dangerous. The rated maximum input voltage therefore is 60 V DC.

A3. If AC voltage is input, depending on the amount of voltage, the surge absorber will be damaged, and the fuse will be damaged (once the design change for adding the fuse is implemented). In some cases, the A/D converter will also be damaged. If overvoltage is input, the capacitor and surge absorber will be damaged. If a battery is inserted with reversed polarity, the battery will leak and the power supply circuitry will be damaged.

**5** Leads.....

Q1. Will the spring pressure of the 9460 be increased?



A1. Compared to when the product was initially released, the diameter of the spring has been increased, resulting in greater strength.

Q2. Will the tip of the 9461 pin be made rounder? And will the spring pressure of the pin tip be reduced?



A2. The pin tip has been made rounder, and the spring pressure has been reduced. As a result, the tip will be less likely to damage battery terminals.

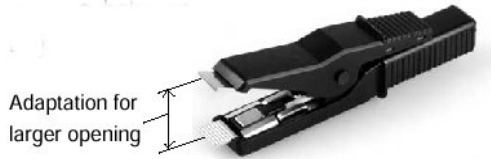
Q3. Will the tip of the 9461 pin be made thinner?



9461 PIN-TYPE LEADS

A3. The 9174-02 semi-standard product can be used with the 3550 and 3555. However, because the probes are not red and black, the user must mark them by wrapping them with red or black tape, as appropriate. In addition, the 9461 can be modified for special orders. However, because pin tip 1172 is a four-terminal probe that was developed for in-circuit testing, it offers extremely high accuracy, but is susceptible to damage when used manually.

Q4. Is it possible to special order the 9460 CLIP- TYPE LEADS WITH TEMPERATURE SENSOR with a wider opening between the jaws?



Q5. Is it possible to extend the leads?

Q6. Describe the pin arrangements, including shielding, so that we can produce our own leads.

Q7. Can the 9287 CLIP- TYPE LEADS be used With the 3550 series?



9287 CLIP-TYPE LEADS

Q8. Can the 9461PIN- TYPE LEADS be used with the 3550 and 3551?



9461 PIN-TYPE LEADS

A4. We provided 9467 LARGE CLIP TYPE LEADS. But it cannot measure temperature.



A5. We have confirmed that it is possible to extend the leads up to 5m. However, only the thick, bundled portion between the points where the leads branch out at each end can be extended. Note also that extending the leads results in increased susceptibility to external noise, so in some environments the measured values may fluctuate.

A6. The pin arrangements are indicated on the 3550 and the 3555 themselves. In addition, the shielding wires in the 9460 and 9461 are connected to SENSE- LO.

A7. Yes, with some restrictions. Because the 9287 leads are test leads for low- resistance meters, they are not designed to be used to test objects to which voltage is being input. Therefore, they cannot be used in the maintenance of batteries used in a UPS, for example. When checking a battery by itself (less than absolute maximum input voltage), the 9287 leads can be used without any problems.

A8. Yes, with some restrictions. Because the 9461 leads are test leads for the 3555, they are designed to be used at less than 50V DC. Therefore, they cannot be used in the maintenance of batteries used in a UPS, for example. When checking a battery by itself (less than absolute maximum input voltage), the 9461 leads can be used without any problems.



Q9. Can the 9465 PIN- TYPE LEADS be extended?

9465 PIN-TYPE LEADS



A9. When the 3551 is used, no extension is possible because measurement values would become unstable. With the 3550 and 3555, extension for up to five meters is possible. Only the heavy-gauge part between junctions can be extended.

Q10. Can the 9173 FOUR- TERMINAL LEADS be modified to use banana plugs?

A10. This is possible only when used with the 3555. Precision assurance with the 3550 and 3551 is not given. The 9173 is available as a special-order option with banana plugs.

Q11. The pin tip of the 9465 PIN- TYPE LEADS has become damaged. Is it possible to replace the pin tip only?

A11. The measurement leads cannot be repaired. A new lead must be purchased. 3550 series BATTERY HiTESTER

Q12. What are the usage limitations of the 9287 CLIP- TYPE LEADS and 9467 LARGE CLIP TYPE LEADS?

A12. The 9287 can only be used with the 3555. Because the 9287 has no barrier at the clip section, measuring a UPS battery involves a risk of electric shock and is therefore not allowed with the 3550 and 3551. The 9467 can be used with all models, but with the 3551, measurement results will differ by about 15dgt. in the 3 m Ω range, due to measurement lead length.

Q13. Can the lead of the 9466 REMOTE CONTROL SWITCH incorporated in the 9465 PIN- TYPE LEADS?

A13. This is not possible. Internally, the EXT.MEMO/EXT.HOLD and measurement terminal wiring circuits are insulated, but if the 9466 lead is run together with the 9465 lead, the 2.3 kV rms rating will no longer apply and a risk of electric shock exists.

Q14. Can the zero adjustment board also be used with the 9461 PIN- TYPE LEADS? Can zero adjustment be performed by using a thick metal plate in place of the zero adjustment board?

A14. The zero adjustment board can also be used with the 9461. A thick metal plate cannot be used in place of the zero adjustment board, because the resistance of that plate would be measured.

Q15. Can the 9465 PIN- TYPE LEADS be used with the 3550?

A15. Yes, but not for temperature measurements. Zero adjustment must be performed with the zero adjustment board.

**6 Resistance Measurement.....**

Q1. Can the impedance of a battery not be measured with a DC type ohmmeter?

A1. A DC type ohmmeter applies a constant DC current and measures the voltage reduction caused by the load to determine the resistance. In the case of a battery, its electromotive force prevents correct measurement of impedance using such a setup. In order to eliminate the influence of the battery's electromotive force, an AC type ohmmeter must be used.

Q2. Why is testing conducted with a 1kHz AC current?

A2. There is no standard or rule that requires battery testing to be conducted with a 1kHz current. The reason why testing is conducted at 1kHz is due to the current flow of existing AC- type resistance meters. AC- type resistance meters were developed for measuring contact resistance. Contact resistance meters conform to IEC512- 2, JIS C 5402, and JIS C 5441, and one item in these standards calls for testing to be conducted at 1kHz. Accordingly, the majority of AC resistance meters are designed for 1kHz testing. Because commercially available resistance meters are frequently used for measuring the internal resistance of a battery, a considerable amount of data on measurements taken at 1kHz has been accumulated. Therefore, in order to maintain compatibility with this previously accumulated data, we decided to design the 3550 series to take measurements at the 1kHz frequency. While we realize the internal resistance of a battery is frequency- dependent, there are indications that this characteristic is relatively flat between 100Hz and 1kHz.



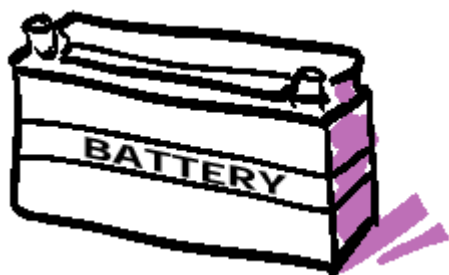
Q3. Can the range used by the 3550 series be changed?

A3. It is not possible at present to change the testing range.

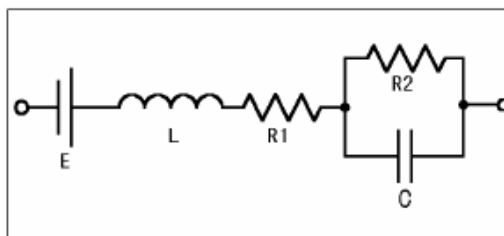
Q4. Can the testing current be changed?

A4. If the testing current is changed, the voltmeter gain must also be changed at the same time. Changing the gain is an extremely delicate proposition, since it is accompanied by changes in the temperature characteristics, noise characteristics, etc. Therefore, it is not possible to change the testing current. We will study this issue when we develop future AC m ΩHiTESTERs.

Q5. Describe the equivalent circuit for a battery.

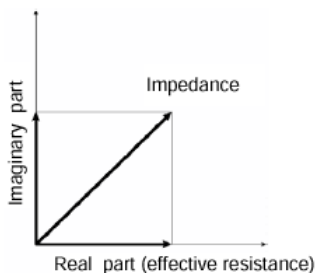


A5. The equivalent circuit for a battery is shown below. In the diagram, "E" represents the electromotive force, "L" represents the inductance of the plates and conductors, "R1" represents the resistance of the electrode plates and the electrolytic solution, "R2" represents the resistance of the movement of the electric charge between the electrode plates and the electrolytic solution, and "C" represents the electric double layer capacitance. This shows that internally, a battery exhibits not just resistance, but also impedance that includes capacitance and inductance. Synchronous wave detection is a method of measuring just the real impedance. The 3550 series uses synchronous wave detection to measure real impedance.



Equivalent circuit for a battery

Q6. Is the resistance displayed by the 3550 series impedance, or is it pure resistance?



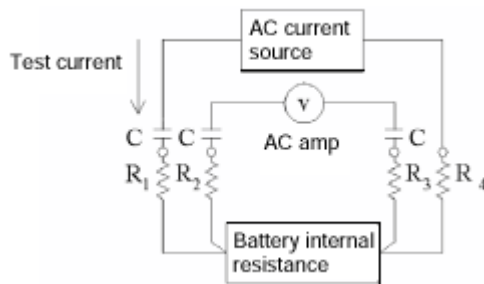
Relationship between the real and false components of the impedance

A.6 A battery's internal resistance is the vector sum of a resistance component and a reactance component. Because the 3550 series uses the synchronous wave detection method, the reactance is eliminated by analog means and only the (real) resistance component is displayed. Therefore, the measured value is not impedance, nor is it pure resistance; it is the real component of the impedance (the effective resistance).

Q7. What is "synchronous wave detection?"

A7. This method detects the test signal by using a reference signal that is in phase with the test current. This method is much like a type of filter circuit. This method demonstrates excellent frequency selectivity characteristics for the frequency of the reference signal. Another characteristic of this method is that it cancels out the reactance component (the false portion of the impedance), eliminating that component from the test results.

Q8. Why do the 3550 series use the AC four-terminal method?



R1 to R4: Lead resistance and contact resistance  
C: Coupling Capacitor

A8. There are basically two general methods for checking battery deterioration: the charging/discharging test method, and measuring the internal resistance. Each method has its own strengths and weaknesses. The charging/discharging test method is capable of accurately measuring the discharge capacity of the battery. On the other hand, this method requires a considerable amount of time. Measuring the internal resistance, however, evaluates the deterioration of the battery on the basis of the correlation between the measured internal resistance and the discharge capacity of the battery. While the accuracy of the measured results suffers somewhat, the test can be conducted very quickly and the test equipment can be fairly small. In resistance measurement, the four-terminal method is used to measure items, such as batteries, that have very low resistance. The AC four-terminal method is illustrated below. The input impedance of the voltmeter is large, so practically no test current flows to the voltmeter. As a result, it is possible to measure the resistance of the subject only, with the lead resistance and the contact resistance excluded.

Q9. Why does the zero adjustment board have to be removed at least 10 cm from the unit when performing zero adjustment?

A9. The electromagnetic field generated in the loop formed by the zero adjustment board and the measurement leads would otherwise affect operation of the unit. Care must also be taken not to have any other metal objects in the vicinity of the zero adjustment board, because magnetic influences can falsify the measurement.

Q10. After performing zero adjustment with the 9460 CLIP- TYPE LEADS WITH TEMPERATURE SENSOR, is it possible to change leads and take a measurement with the 9465 PIN- TYPE LEADS?

A10. Measurement precision is assured only with the same lead that was used for zero adjustment. However, in the 300 mΩ, 3 Ω, and 30 Ω ranges, the measurement lead influence can be largely disregarded.

Q11. Performing renewed zero adjustment every time is a bother. Is it possible to retain adjustment data while the unit is turned off?

A11. Zero adjustment data are written to volatile memory and are therefore lost when power is turned off. Zero adjustment must be performed every time when the unit was turned off.

Q12. Why is the display value different from the calibration value when performing calibration? \*See also Q 6 and A 6.

A12. [Resistance measurement]  
Is the AC 1 kHz resistance value being used for calibration? The AC calibration value and DC calibration value do not necessarily match. The DC calibration value is a true resistance value, whereas the AC 1 kHz calibration value is an rms value. These will normally be different. The 3550, 3555, 3551, and 3225 measure the AC 1 kHz resistance value.  
[Voltage measurement]  
Is the SOURCE- Hi terminal connected to the

Q13. When measuring a battery connected to and operating UPS, do ripple voltage components caused by the charging process affect the measurement?

Refer to the reference material at the end of guide.

Q14. Why does the 9465 pin type lead use curled cables?

generator? When all four terminals are connected, the constant current generated by the 3550 series unit may cause malfunction, preventing correct voltage from being output. Information about this point is included in the manual.

A13. The 3550 and 3551 use noise-canceling technology to reduce the influence of ripple voltage components on the measurement. However, if ripple voltage components are very large, the indication may fluctuate and will not be correct. The allowable ripple voltage rating is listed at the end of the documentation for the 3550 and 3551.

A14. Resistance measurements can be affected by electromagnetic induction from nearby metallic objects. This problem becomes more pronounced when small resistance values are to be measured and when the loop area of the divided section of the measurement leads is large. The 9465 uses curled cables to keep the loop area of the divided section as small as possible.

**7** Voltage Measurement.....

Q1. Why is voltage measurement necessary?

A1. Voltage measurement is performed simultaneously with the measurement of specific gravity during maintenance for lead storage batteries and alkaline storage batteries. If the voltage is extremely low, the battery may be damaged (it may have in internal short circuit). In addition, if the voltage is high, it is possible that a charger or another battery connected in series with the battery in question could suffer damage. The 3550 and 3551 detects battery deterioration through the battery's internal resistance, and checks whether the battery is damaged according to its voltage and temperature (only 3550). The internal resistance of a battery differs during charging and recharging. The 3555 check for excessive discharging according to the battery voltage .The 3550 and 3551 also checks whether the battery is damaged in the same manner.

**8** Temperature Measurement.....

Q1. Why is temperature measured?

A1. Temperature measurement is important for two reasons. One is because the internal resistance changes according to the temperature. This allows workers to use the temperature of the electrolytic solution to determine the extent of battery deterioration. Another reason is to discover damaged batteries. A battery with an internal short circuit will reveal itself by heating up when it is charged. Although the 3550 and 3551 is not able to measure the temperature of the electrolytic solution, it is able to measure the temperature of the terminal, which is close to the temperature of the electrolytic solution. However, in a 12V lead storage battery, 6 individual batteries are connected in series; we have heard that even if one of those batteries is damaged internally, the terminal temperature does not rise very much.

Q2. Why is the temperature measurement sensor inside the probe?



End of a 9640 Clip-type Lead with Temperature Sensor

A2. This was done in order to avoid adding to the work that the worker must do. Because the temperature sensor is built into the test probe, the terminal temperature can be measured simply by clipping the probe onto the terminal. In addition, measuring the terminal temperature rather than the ambient temperature provides a clearer picture of the degree of battery deterioration.

**9** Batteries.....

Q1. Does the internal resistance of a battery change after charging or after discharging?

A1. Yes. When measuring the internal resistance of a battery with the 3555, the most accurate measurements can be taken when the battery is fully charged. Because maintenance is performed on a UPS with the 3550 and 3551 when the battery is in a normally charged state, this issue is not a concern.

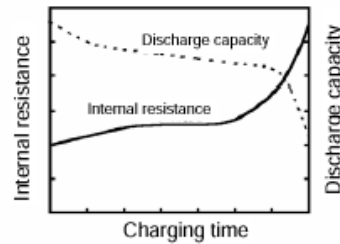
Q2. Does the internal resistance of a battery change according to its temperature?

Refer to the reference material at the end of guide.

A2. The internal resistance does change according to the temperature. Sample measurements taken by HIOKI for reference purposes are included at the end of this sales guide in the paper on "Applying Low Resistance Measurement Techniques to the Evaluation of the Performance of Backup Batteries."

Q3. What is the relationship between the charging interval and the internal resistance, and between the number of cycles and the internal resistance?

A3. When a battery is charged for a long time, or as the charging/discharging cycle is repeated, the discharge capacity of the battery decreases due to corrosion on the plates and loss of electrolytic solution. An example discharge curve is illustrated below. The curve differs according to the battery type. It is also said that temperature has an effect on how fast a battery deteriorates.



Correlation between charging time and internal resistance

Q4. Does the AC signal used for measurement cause battery deterioration?

A4. Normal small- size batteries and larger batteries will not be affected, because the measurement current is very small (50 mA) and the 1 kHz AC signal does not cause a chemical reaction in the battery.

Q5. What is the importance of the specific gravity?

A5. For wet- type lead storage batteries and alkaline storage batteries, the temperature of the electrolytic solution and the specific gravity are measured and used to evaluate the deterioration of the battery. Specific gravity is measured with a densitometer, but because the value changes according to the temperature of the solution, this value is customarily converted to the value at a temperature of 20°C and then compared to the value specified by the manufacturer of the battery. If the specific gravity is low, it indicates that the battery is depleted and that its discharge capacity is low. The internal resistance of the battery tends to be high in this case. Conversely, if the specific gravity is high, it indicates that the battery is overcharged.

Q6. What types of batteries can be tested by the 3550 series?

A.6 Basically, the 3550 series can be used to test any type of battery. However, batteries with a resistance of several hundred mΩ, such as button- type batteries, will be out of range. The 3550 series also cannot be used to test batteries with a total voltage of 50V(3551:60V DC) or more, such as batteries used in industrial machinery. Although lithium ion batteries can also be tested, those that are part of a package are connected in series to a PTC device as a safety mechanism. This device has an internal resistance of over 100mΩ in addition, there is also an FET for current control that is inserted in the path of the current; this FET has an ON resistance of over 30m Ω. These values are large enough in comparison



- with the internal resistance of the battery that they cannot be ignored. The difference in resistance between a good lithium ion battery and a deteriorated lithium ion battery is also sometimes quite small compared to other batteries. Some nickel- metal hydride batteries also include a PTC device.
- Q7. What protection measures are used for rechargeable nickel- metal hydride batteries and rechargeable lithium- ion batteries?
- A7. Nickel- metal hydride batteries have a low hazard rating and are normally only fitted with a safety valve to prevent explosion. Lithium- ion batteries use organic electrolyte and have a high energy density. Under extreme conditions, such batteries may explode or ignite. Therefore the following protection measures are used: (1) Shutdown separator (Separator holes close when temperature rises above a certain level.) (2) PTC elements (Resistance rises when temperature rises.) (3) Safety valve (Reduces internal pressure in battery.) (4) Protection circuit (FET or similar is used for temperature, current, or voltage control.)
- Q8. What is sulfation occurring at the electrodes of lead batteries?
- A8. Lead sulfate ( $PbSO_4$ , and insulating substance) is deposited on the electrodes, which reduces their effective area and increases the impedance of the battery.
- Q9. What is the dry- up phenomenon?
- A9. The reduction of electrolyte is called the dry-up phenomenon. It occurs mainly when a battery is overcharged.
- Q10. What is dendrite?
- A10. Dendrite is a leaf- shaped crystalline metal growth that can occur on the electrodes of a battery. When it advances, the electrodes may become short- circuited.
- Q11. What is the memory effect?
- A11. When a battery is repeatedly discharged partially and then charged again, the so- called memory effect can develop which causes a reduction in apparent capacity of the battery. This occurs mainly with alkaline type batteries (Ni-Cd, Ni-MH), not with lead type and lithium-ion type batteries. The memory effect can be countered by several cycles of deep discharge and full charge.
- Q12. What are rechargeable alkaline batteries?
- A12. The term rechargeable alkaline batteries normally refer to nickel-cadmium (Ni- Cd) batteries.
- Q13. The resistance value of a rechargeable lead battery differs with every measurement. What is the cause for this?
- A13. The following causes are possible:  
 (1) The probe is applied to different points on the battery terminals.  
 (2) The battery charge condition differs.  
 (3) The battery terminals are not in proper contact, so that measurement is not carried out for all 4 terminals.  
 (4) The measurement lead is broken.



- (5) The battery temperature is different.
- (6) There is a large ripple voltage across the battery terminals.

**10** Miscellaneous.....

- |     |  |     |   |
|-----|--|-----|---|
| Q1. | Up to what capacity is testing possible?   | A1. | It depends on how many valid digits the user requires. Batteries have a smaller internal resistance the larger their capacity is. As a guide, in the case of a lead storage battery with a capacity of about 400Ah, the resistance is approximately 0.5mΩ. When measured with the 3550 or 3551, the result would be about 50 counts or 500 counts. Alkaline storage batteries have an even smaller resistance.  |
| Q2. | What is the relationship between the deteriorated state and the internal resistance?       | A2. | According to a JAPAN STORAGE BATTERY ASSOCIATION Technical Reference (SBA3508-1984), once the capacity drops below 80%, it decreases at an accelerating pace; therefore, the point at which the capacity drops below 80% is regarded as a guide for determining when a battery has reached the end of its operational life. At this point, the internal resistance of the battery is about 1.5 to 2 times greater than when it was a new battery. Accordingly, even if you do not know what the internal resistance of the battery should be when the battery is in good condition, it is possible to measure the internal resistance at regular intervals and use the extent of the trend towards increased resistance to estimate the deterioration of the battery.   |
| Q3. | Can a battery other than an alkaline battery be used for the power supply?                 | A3. | Manganese dry cells can also be used. Although Ni-Cd dry cells can also probably be used, the system shuts down soon after the battery indicator first appears, so from the standpoint of saving data, we cannot recommend the use of Ni-Cd batteries.  |
| Q4. | Aside from AC resistance measurement, what are methods available for diagnosing batteries? | A4. | There are basically two methods for evaluating the deterioration of a battery. One is to directly measure the discharge capacity of the battery by conducting charging/discharging testing. The other is to measure the internal resistance and use that information to estimate the deterioration of the battery. There are furthermore two methods for conducting charging/discharging testing: discharging a fully charged battery until it is completely discharged, and discharging a fully charged battery for a few minutes and then using that information to estimate when the battery will be fully discharged. There are also two methods for measuring resistance. One is the AC measurement method, and the other entails causing a momentary short circuit between the battery terminals and then calculating the resistance based on the drop in voltage. All of |

Q5. Where are the 3550 series used?	A5. The 3550 and 3551 are primarily used for UPS maintenance. The 3555 seem to be used in service departments that service small electronic devices.
Q6. When calibrating, are there any points that require special consideration?	A.6 A standard resistor is used for calibration. Because the calibration values are slightly different for DC and AC, the calibration value for AC 1kHz are used when calibrating the 3550 series. Please note that calibration should be done only at an authorized HIOKI distributor or at HIOKI.
Q7. Is testing in accordance with IEC512- 2, JIS C 5402,and JIS C 5441 possible?	A7. The requirements of these standards are as follows: 1.Frequency: 1kHz $\pm$ 200Hz 2.Ampere execution: 1A or less 3.Voltage peak: 20mV or less 4.Accuracy: within $\pm$ 10% The 3550 series fail to satisfy No.3. Therefore, testing in accordance with these standards for contact resistance testing is not possible.
Q8. Can these units measure the contact resistance of a relay?	A8. Although they can measure contact resistance, they cannot do so in accordance with the test standards mentioned above.
Q9. Can you provide a block diagram for the 3550 series testing systems and digital systems?	A9. These block diagrams are provided at the end of this guide. Note that the 3555 is not capable of temperature measurement. <div style="background-color: black; color: white; padding: 2px; text-align: center;">Refer to the reference material at the end of guide.</div>
Q10. I would like to retrieve the comparator output. Is it possible to modify the units in order to do so?	A10. No. At present, we would recommend that you use the 3225 and the 3236 in combination. The 3225 model revision was planned with this capability in mind.
Q11. Is it possible to collect data from the batteries that pass testing and use those data as the comparison values?	A11 It should be possible for the user to set these values. Through battery maintenance it is necessary to collect data on a regular basis, and it should be possible to estimate the degree of deterioration in a battery on the basis of the rise in the curve of its internal resistance data.
Q12. What do "CE" and "CAT - I" mean?	A12. The CE mark displayed on the unit indicates that the product complies with the CE mark requirements for safety, which are necessary for marketing a product in the EU. The "CAT- I" indication shows the installation category (voltage proof category) of the product. UPS battery installations correspond to category I. The following four installation categories are defined. Installation category I: Signal levels, special equipment or part of equipment,

	communication equipment, electronic technology, etc. Installation category II: Local levels, tools, portable equipment, etc. Installation category III: Distribution levels, fixed installations Installation category IV Primary power levels, power lines, cable systems, etc. The 9287 and 9467 do not comply with CE marking requirements.
Q13. To which point of the battery terminals should the pin type leads be applied?	A13. The resistance of battery terminals is higher than commonly assumed and may differ depending on the contact point. Be sure to apply the pin tips always to the same position.
Q14. Which points should be considered when measuring the impedance of a battery pack?	A14. Many battery packs have protective circuitry that is located between the battery and the external terminals. Some representative types of protection circuits are: (1)PTC element (Resistance rises when temperature rises.); (2)Diode; (3)Battery control IC. If only a PTC element is installed, the measured value will be the combined resistance of the PTC element and battery impedance. If diodes or a battery control IC are installed, correct impedance measurement is not possible.
Q15. How can the 3550 and 3551 measure the impedance of a battery that is being charged? Why can the 3555 not measure the impedance of a battery that is being charged?	A15. The 3550 and 3551 incorporate bandpass filters which remove the influence of signals (such as UPS ripple voltage) other than the measurement frequency. The 3555 does not have such bandpass filter circuitry and can therefore not reliably measure a battery in a noisy environment such as in a UPS. The 9461 pin type lead supplied with the 3555 also has no barrier and is not allowed for measurements in hazardous equipment such as a UPS.
Q16. Can IEC R6 rechargeable ni-cad batteries be used in place of IEC R6 alkaline batteries?	A16. Rechargeable Ni-Cd batteries can be used, but the unit does not have a facility for recharging such batteries. A separate charger is required.
Q17. How long can the unit operate on six IEC R6 manganese batteries?	A17. 3550:about 2.5 hours 3551:about 1.5 hours
Q18. Is there a carrying case for the AC adapter?	A18. The carrying case for the logic probe of the 8800 series has just the right size and can be used for the AC adapter.
Q19. Can the LCD be equipped for backlighting?	A19. The LCD used in the 3551 is a reflective type that cannot be adapted to backlighting.

## References

<b>1</b>	Transferring Data Stored in the Memory of the 3550 or 3551 BATTERY HiTESTER to a Personal Computer .....	19
	Windows NT4.0, Windows 95/EXCEL (Microsoft)	
<b>2</b>	Technical Report: To Evaluate the Performance of Secondary Batteries Using Low Resistance Measurement Techniques .....	21
	Proceedings of 7th Shinshu meeting of SICE, p.p.1-4 (June 1996)	
<b>3</b>	Allowable ripple voltage graph .....	28
<b>4</b>	Block diagram for the 3550 .....	29

## Transferring Data

### Transferring Data Stored in the Memory of the 3550 and 3551 BATTERY HiTESTER to a Personal Computer

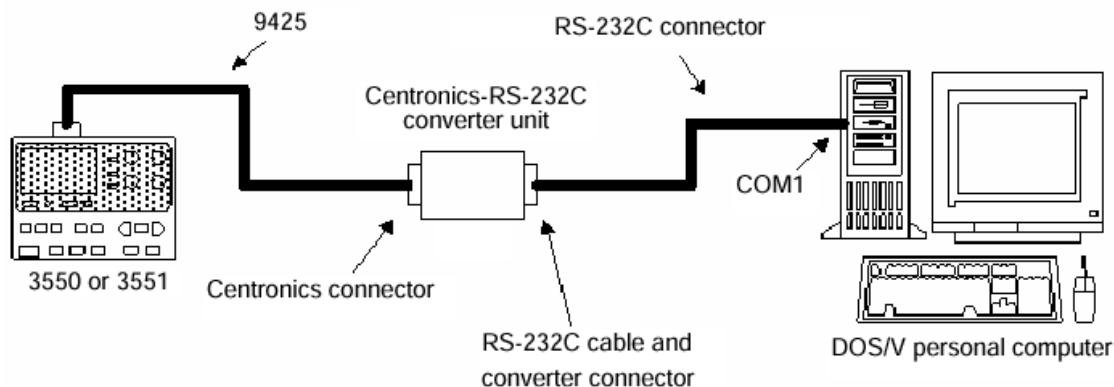
Although the data stored in the memory of the 3550 and 3551 BATTERY HiTESTER can normally be output to a printer via a Centronics interface, it is also possible to output the data to a personal computer by using a Centronics-RS-232C converter unit. The method for doing so is described below.

#### 1. Equipment required

- 3550 or 3551 BATTERY HiTESTER
- Personal computer (A DOS/V personal computer with Windows 95 installed is assumed.)
- Centronics-RS-232C converter unit
- 9425 connecting cable, or a PC98 printer cable (for connecting the 3550 or 3551 to the converter unit)
- RS-232C cable (25-pin D-sub, crossed type)
- RS-232C converter connector (25-pin/9-pin D-sub, straight type)

#### 2. Equipment connections

Connect the equipment as shown in Fig. 1.



**Fig. 1 Equipment Connections**

#### 3. Equipment settings

##### (1) Centronics-RS-232C converter unit settings

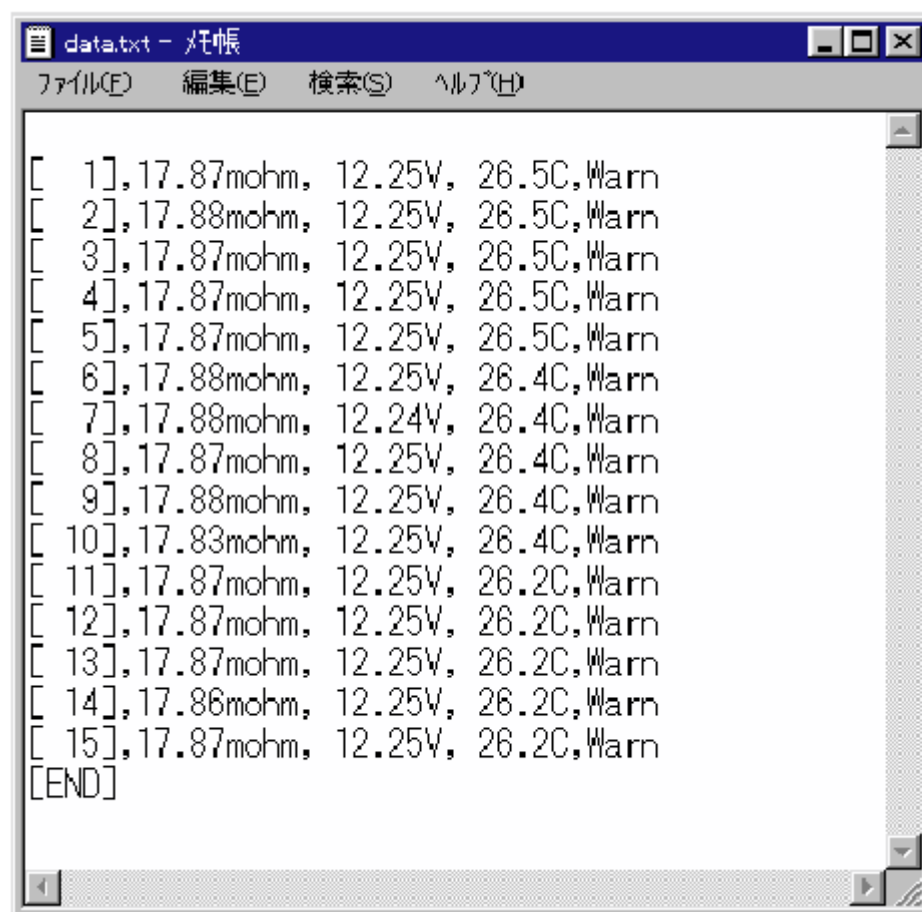
- Communications speed: 9600bps
- Flow control: Hardware
- Data length: 8 bits
- Parity: none
- Stop bits: 2
- (For details on the functions set, refer to the converter unit manual.)

##### (2) Personal computer settings Preparation

Use the communications software "HyperTerminal" that is included with Windows 95 to receive the

data stored in the 3550 or 3551's memory. HyperTerminal can be found under "Accessories" in the Program menu accessed through the Start button.

(If "HyperTerminal" is not found, open "Add/Remove Applications" in the Control Panel, and then select the "Windows Files" tab. Select "Communications" for "File Type", click the "Details" button and then select "HyperTerminal" in order to install the software.)



**Fig. 2 Sample Display of a Retrieved File**

(Japanese version shown)

**Technical Report****To Evaluate the Performance of Secondary Batteries Using Low Resistance Measurement Techniques**

Hiroshi Kutsukake - Kenji Kobayashi - Mitsuyoshi Tanaka

**HIOKI E.E.CORPORATION*****Abstract***

As portable communications terminals for individuals (typified by devices such as cellular telephones and notebook computers), uninterruptible power supplies (UPSs), and other types of equipment that use secondary batteries become widespread, there is a growing need to be able to easily evaluate the performance of secondary batteries. In this paper, we propose using the internal resistance of a secondary battery as a guide for the evaluation of secondary battery performance. The internal resistance of a secondary battery is measured with low resistance measurement techniques. Development of such a tester has already completed.

**1. Introduction**

The advances made in the miniaturization of electronic devices and in constructing the communications infrastructure have led to the rapid spread of compact, high-performance cordless equipment, such as portable telephones and notebook computers. In addition, uninterruptible power supplies (UPSs) are being installed in facilities where equipment cannot be allowed to stop operating due to a power failure. Secondary batteries that allow repeated use through recharging are used in such cordless equipment and UPSs, and demand for such batteries is increasing as the market for such equipment expands. As a secondary battery undergoes repeated charge/discharge cycles, the capacity of the battery begins to decrease due to the effects of deterioration of the chemical matter inside the battery. Consequently, the continuous discharge time of the battery is reduced, which can hinder the operation of the equipment in which it is being used. This phenomenon is specifically seen as deterioration in the performance of the secondary battery.

Generally, in order to accurately evaluate the deterioration of a secondary battery, it is necessary to perform a charge/discharge test and measure the capacity of the battery. While this method can accurately determine the state of the secondary battery, the test takes a good deal of time to perform. Therefore, there is a need for a test method that can be used to evaluate the performance of a secondary battery easily and quickly. Research now indicates that there is a correlation between a decrease in a secondary battery's capacity and an increase in its internal resistance.<sup>1</sup> Therefore, we have developed a secondary battery internal resistance tester that utilizes low resistance measurement techniques, and we measured internal resistances of secondary batteries with varying the state of those.

## 2. Overview of Secondary Batteries

A secondary battery is one that can be used repeatedly after recharging, and differs from primary batteries, such as manganese dry cells, that cannot be re-used once they are discharged. Another distinction of secondary batteries from primary batteries is that secondary batteries are capable of discharging large current; as a result, they are used for equipment that requires large current. Typical secondary batteries are lead-acid batteries and nickel cadmium (Ni-Cd) batteries. However, in order to address environmental concerns and the need for batteries that can power smaller devices for longer periods of time, new nickel metal hydride (Ni-MH) and lithium ion (Li-ion) batteries were developed and put into use; these batteries are smaller, provide a large capacity, and pose little danger of polluting the environment. Table 1 shows characteristics of the secondary batteries described above. This table lists characteristics for each type of battery, including voltage per cell, the energy density by mass (Wh/kg) and the energy density by volume (Wh/l). In this table it is found that lithium ion batteries offer a high energy density and excellent performance. In practice, the type of secondary battery that is used in a particular application depends on the requirements of the equipment in which it will be used.

**Table 1. Characteristics of Typical Secondary Batteries.<sup>2</sup>**

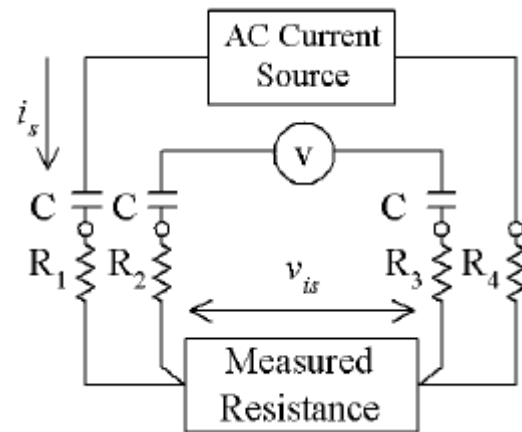
Battery type	Voltage	Energy density		Features (V/cell)
		Wh/kg	Wh/l	
Lead-Acid	2.0	30 - 40	70 - 100	Low cost, high reliability
Nickel cadmium (Ni-Cd)	1.2	45 - 70	100 - 150	Capable of rapid charging/discharging, withstands excessive charging and discharging well
Nickel metal hydride (Ni-MH)	1.2	50 - 65	150 - 200	Superior characteristics compared to nicad batteries without polluting the environment
Lithium ion (Li-ion)	3.6	60 - 90	150 - 220	High energy density, high voltage



### 3. Measuring the Internal Resistance of Secondary Batteries

#### 3.1 Principles of Measurement

While the internal resistance of secondary batteries varies according to the battery type and its capacity, the figure generally ranges from several  $m\Omega$  to several hundred  $\Omega$ . Generally, in order to accurately measure a low resistance, the four-terminal method is used, in which a constant current is applied to the resistor that is being measured, and the resistance is calculated from the voltage drop that is detected. For secondary batteries, internal resistance is measured by applying a constant alternating current, in order to avoid any effects from the DC voltage generated by the secondary battery. This method is called the "AC four-terminal method," and is distinguished from the DC four-terminal method in which direct current is applied. Fig.1 illustrates the principles of the AC four-terminal method. A constant alternating current " $i_s$ " is supplied to the resistor that is being measured, and the voltage drop " $v_{is}$ " generated across the resistor is detected. In this case, " $i_s$ " is always constant, regardless of the resistance being measured, the wiring resistance, and the contact resistance between the wires and the resistor being measured. In addition, because the input impedance of the voltmeter is sufficiently large, practically no current flows to the voltmeter so it is possible to detect only the voltage drop due to the resistor being measured. Therefore, it is possible, with this method, to measure the resistance without any effect from wiring resistance or contact resistance.



$R_1$  to  $R_4$ : Lead and contact resistance  
 C: Coupling Capacitor

Fig. 1: Measuring Resistance with the AC Four-terminal Method

#### 3.2 Equipment Configuration

Fig. 2 illustrates the configuration of the internal resistance measuring equipment. The AC four-terminal method shown in Fig. 1 is being applied to a secondary battery. When a 1kHz constant alternating current " $i_s$ " is applied to the secondary battery, the voltage drop " $v_{is}$ " due to the internal resistance of the battery is detected. In order to obtain the voltage drop that is due only to the battery's internal resistance, a synchronous detector circuit is used. This

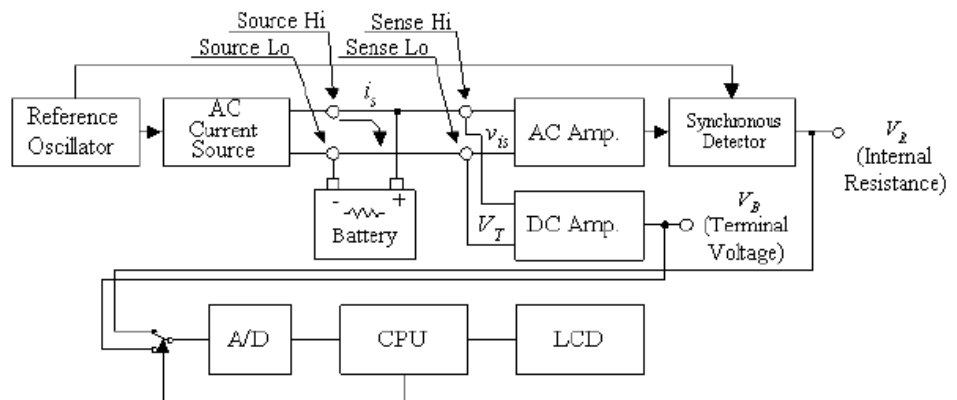


Fig. 2: Configuration of Internal Resistance Measuring Equipment

circuit operates to filter out the effects of reactance within the secondary battery and in the test system without any effects from external noise. In addition, the DC terminal voltage "VT" of the secondary battery is also measured. Then the CPU switches between the internal resistance output "VR" and the terminal voltage output "VB" as the input to the A/D converter so that both the internal resistance of the battery and the terminal voltage can be displayed simultaneously.

The synchronous detection method used with this measuring equipment is the detection method to determine the signal level of the in-phase components of a given signal and a reference signal.

Fig. 3 shows a simple example of the circuit configuration of a synchronous detection circuit. This circuit consists of a multiplier, which multiplies together the two signals, and an LPF that removes just the DC component of the output from the multiplier.

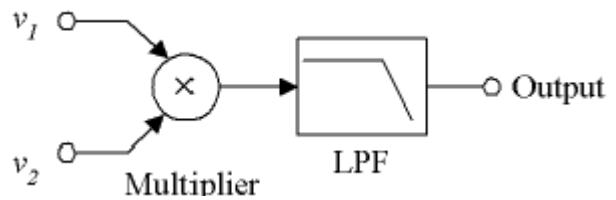


Fig. 3: Synchronous detection circuit

Assuming "v1" as the voltage of the reference signal for the constant alternating current generated by the measuring equipment, and "v2" as the voltage of the signal in which synchronous detection is to be performed, these values can be expressed by the following equations:

$$v1 = A \sin \omega t \dots \dots \dots (1)$$

$$v2 = B \sin(\omega t + \theta) \dots \dots \dots (2)$$

where A and B are the amplitudes of "v1" and "v2", respectively, and  $\theta$  in equation (2) is the phase difference from "v1" due to reactance. If synchronous detection as shown in Fig. 3 is performed using "v1" and "v2", the result can be expressed by the following equation:

$$v1 \times v2 = AB \sin \omega t \sin(\omega t + \theta)$$

$$= 1/2 AB \cos \theta - 1/2 AB \cos(2\omega t + \theta) \dots \dots \dots (3)$$

The output of the multiplier circuit is given by equation (3). In this equation, the first element is the DC voltage component, and the second element is the AC voltage component. By inputting these output voltages into the LPF, it is possible to obtain just the DC voltage component. Assuming the secondary battery impedance  $Z$  is  $Z = R + jX$  (where  $R$  is the internal resistance and  $X$  is the reactance), and considering that  $R = |Z| \cos \theta$ , we find that the DC voltage component is the real part of  $Z$ , that is, the voltage drop caused by the internal voltage  $R$ . Therefore, by using the synchronous detection method, it is possible to measure internal resistance without any effect from the reactance component.

## 4. Experimental Results of Internal Resistance Measurement

### 4.1 Change Characteristics of the Internal Resistance in Secondary Batteries While Discharging

As a battery continually discharges itself in order to supply power to an external load, its capacity decreases and its terminal voltage drops. In order to find out how the internal resistance changes under these conditions, we used a prototype internal resistance tester to take measurements. After charging a variety of brand new battery packs (Ni-cd, Ni-MH, and lithium ion) intended for use in portable telephones fully, we measured their internal resistance and terminal voltage as they were discharged at a constant current for one hour in an ambient temperature of 23°C. We set the constant alternating current " $i_s$ " generated by the equipment at 5mA (rms). Figs. 4, 5, and 6 show the measured results for each of the batteries. While observing that the internal resistance increased as discharging continued in the case of both the Ni-cd and lithium ion batteries, we saw that the opposite was true in the case of the Ni-MH battery. When we tested other batteries of different capacities, we observed the same phenomenon, making it likely that this characteristic is dependent on the type of the battery.

Making a judgment based only on these results, it would seem that if a battery is required to output a large current when it has little capacity remaining, the internal voltage drop in a Ni-cd or lithium ion battery increases and the actual output voltage drops, while in the case of a Ni-MH battery it is able to output a large current without dropping in the output voltage. The terminal voltage gradually decreased for all of the batteries.

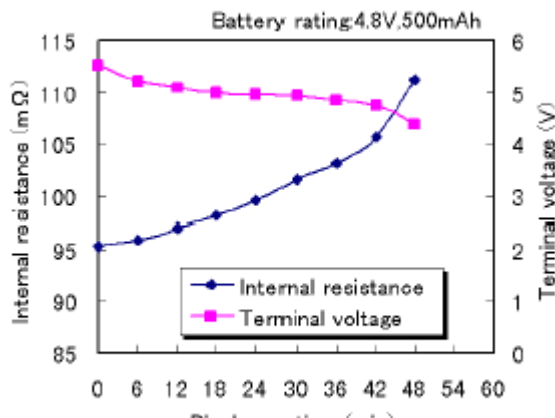


Fig. 4: Change characteristics of the internal resistance in a Ni-cd battery while recharging

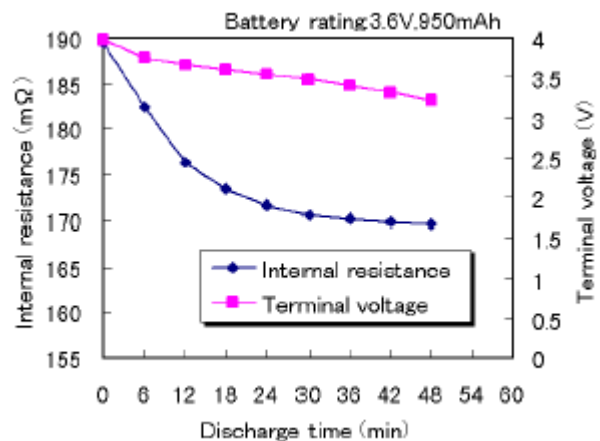
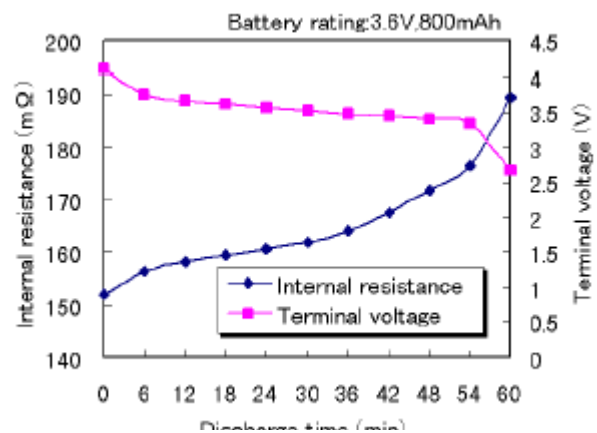


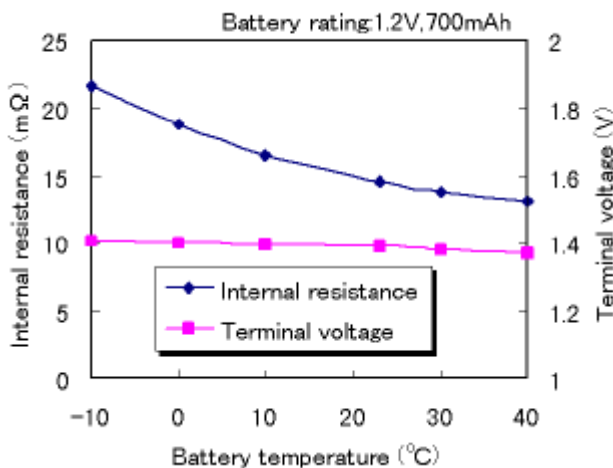
Fig. 5: Change characteristics of the internal resistance in a Ni-MH battery while recharging (Discharge current: 950mA)

#### 4.2 Temperature Characteristics of the Internal Resistance in Secondary Batteries

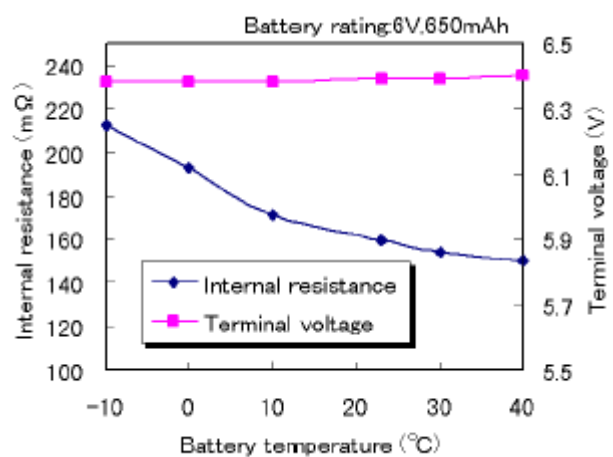
A battery's performance depends on the temperature of the environment in which it is used. It is reported that at low temperatures the amount of output current decreases, and at high temperatures the operational life of the battery is reduced.<sup>3</sup> Then, after charging a variety of batteries (Ni-cd, Ni-MH, and lithium ion) fully, we measured their internal resistance and terminal voltage while changing the ambient temperature from  $-10^{\circ}\text{C}$  to  $+40^{\circ}\text{C}$ . Figs. 7, 8, and 9 show the measured results for each of the batteries. While the change in terminal voltage was small for all of the batteries, we observed that as the temperature increased, the internal resistance of the Ni-cd and Ni-MH batteries decreased. On the other hand, the change in the internal resistance of the lithium ion battery was small.



**Fig. 6: Change characteristics of the internal resistance in a Lithium Ion battery while recharging**  
(Discharge current: 800mA)



**Fig. 7: Temperature characteristics of the internal resistance in a Ni-cd battery.**



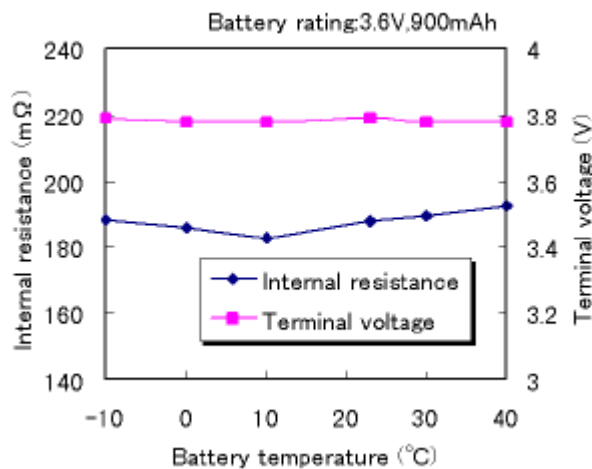
**Fig. 8: Temperature characteristics of the internal resistance in a Ni-MH battery.**

This means that although the performance of Ni-cd and Ni-MH batteries suffers at low temperatures since the amount of current that they can output is limited, a lithium ion battery can output a stable amount of current even at low temperatures.

## 5. Conclusion

We developed an internal resistance tester in order to measure internal resistance as a means to quickly and easily evaluate the deterioration of secondary batteries. In this tester, low resistance measuring techniques based on the AC four-terminal method and the synchronous detection method were used. In our experiment using this tester to measure the internal resistance of a variety of types of secondary batteries, it was found that there are different characteristics for each type of battery. These differences may arise from

differences in the materials of which the batteries are made. We did confirm that it was possible to use this



**Fig. 9: Temperature characteristics of the internal resistance in a Lithium Ion battery.**

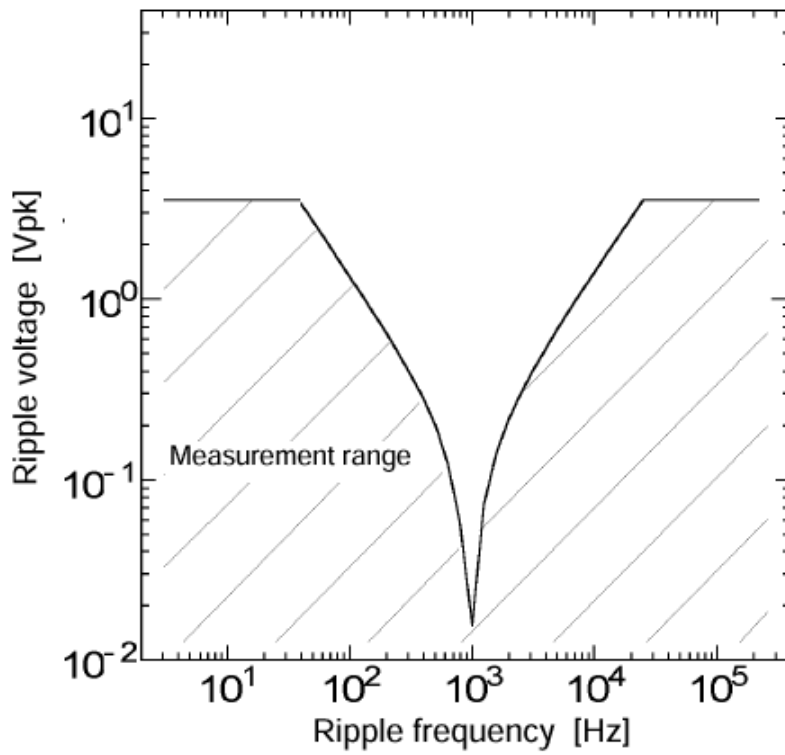
tester to measure battery characteristics. Even if making a precise evaluation of the deterioration of a secondary battery on the basis of the results of a charge/discharge test, it should be possible to provide information that can be used as a guide for determining the state of a battery by simultaneously measuring the internal resistance and terminal voltage. We now need to conduct long-term charge/discharge cycle testing on secondary batteries in order to confirm in detail the relationship between the change in internal resistance and decrease in battery capacity due to battery deterioration, and also to confirm whether internal resistance is related to other

parameters of secondary battery performance.

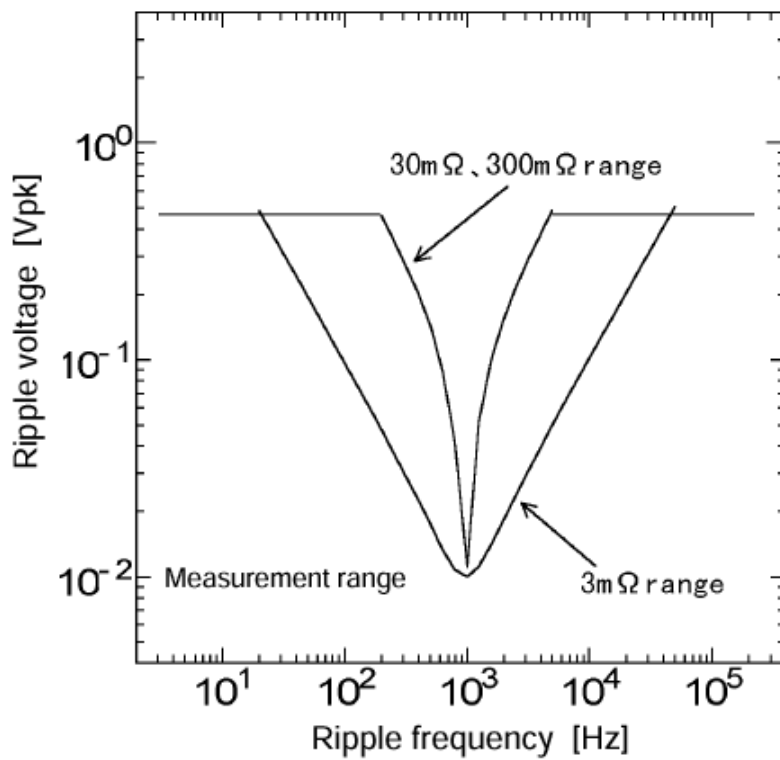
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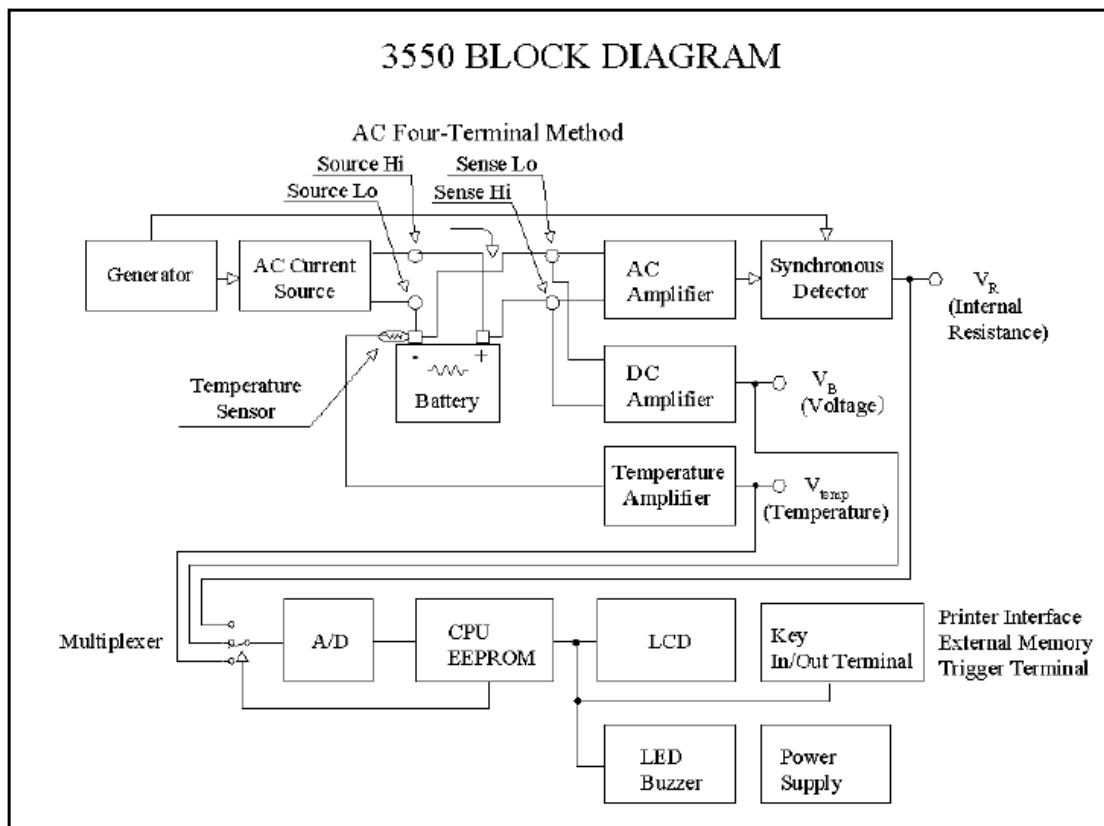
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**3550 and 3551 Allowable Ripple Voltage**



3550





**HIOKI 3550 Series Battery HiTESTERS**

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