IET LABS, INC

Application Note

IR Testing Lithium Batteries for Medical Devices
Using the 1865+ Megohmmeter

1865+ Product Information http://www.ietlabs.com/1865-megohmmeter.html

For the medical industry, batteries with high energy densities are most commonly used, in particular the lithium battery (lithium anode). Their properties provide extremely long life and reduced size, characteristics particularly important for implanted medical devices.

Because of the need for high reliability, Insulation Resistance (IR) Testing is an extremely important test to perform not just in R&D phase, but also in the production process. This application note details:

1. Why IR test batteries?
2. What is being tested?
3. Connection of battery to the 1865 IR Tester
4. Important factors for making accurate, repeatable measurements

CAUTION
Do NOT perform an IR test on a battery that has been filled with electrolyte.
Doing so could cause the battery to explode, causing serious bodily injury.

Why IR Test Batteries?

If an electrical "short" exists between the anode and cathode or between either to the case, once the battery is filled with electrolyte, the battery would become very unstable and possibly explode. The effect of a high density lithium battery exploding could be very hazardous!

IR testing is a **safety** test which checks to make sure there is at least a minimum resistance level between these connections to ensure an electrical "short" does not exist.

IR testing also can be used as a tracking tool in the production phase to evaluate **material quality**. By tracking IR levels of each battery, changes in insulation material properties and production processes can be detected and tracked.

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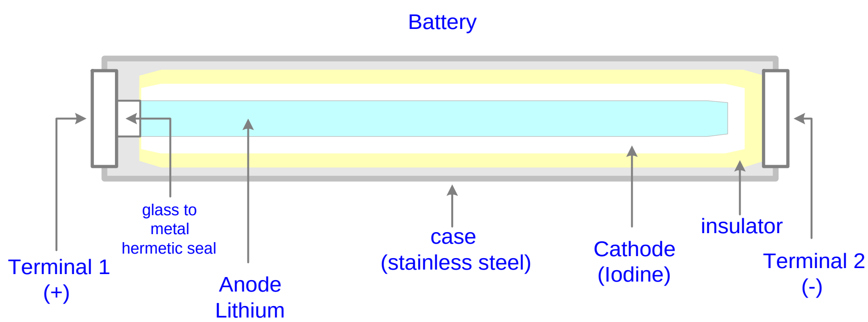
What is Being Tested?

There are three basic insulation resistance tests that can be run: terminal 1 to terminal 2, terminal 1 to case, and terminal 2 to case. These three tests are typically run on batteries with two insulated terminals and an outer conductive case as illustrated in Figure 1.



IR Test 1: Terminal 1 to Terminal 2
IR Test 2: Terminal 1 to case
IR Test 3: Terminal 2 to case

Figure 1: Battery Configuration

For this configuration of battery, terminal 1 (or 2) to case tests the insulation material (typically a glass-to-metal hermetic seal) for a minimum insulation resistance. This material is used to provide electrical isolation between the lead and the outer case. The IR test applies a specified DC voltage that is higher than the operating voltage of the battery. This voltage stresses the insulation material to detect any flaws, defects, or weakness in the isolation properties of the insulation material.

A common test condition might be on the order of 1000Vdc with 100GΩ minimum insulation resistance or greater.

The other test that may be run on this style of battery is the terminal 1 to terminal 2 test. This test is used to check for an electrical "short" between the positive and negative polarity connections internally. A typical test condition may be on the order of 200Vdc with 1MΩ minimum insulation resistance or greater.

For batteries used in implantable medical devices, there is usually only one IR test to run, the terminal to case measurement. This is because there is an insulated lead protruding from the battery providing a polarity connection, and the other polarity connection is the case itself.

The minimum required insulation resistance and test voltages typically depend on the installation environment and the output voltage of the battery. It is best to refer to the manufacturer's specification for a particular battery type. Many times batteries are designed for custom applications.

Connection of battery to the 1865 IR Tester

Figure 2 illustrates a battery connected to the 1865 Megohmmeter/IR Tester using the 1865-51 lead set. The 3-wire grounded connection measures the IR from terminal to case of the battery.

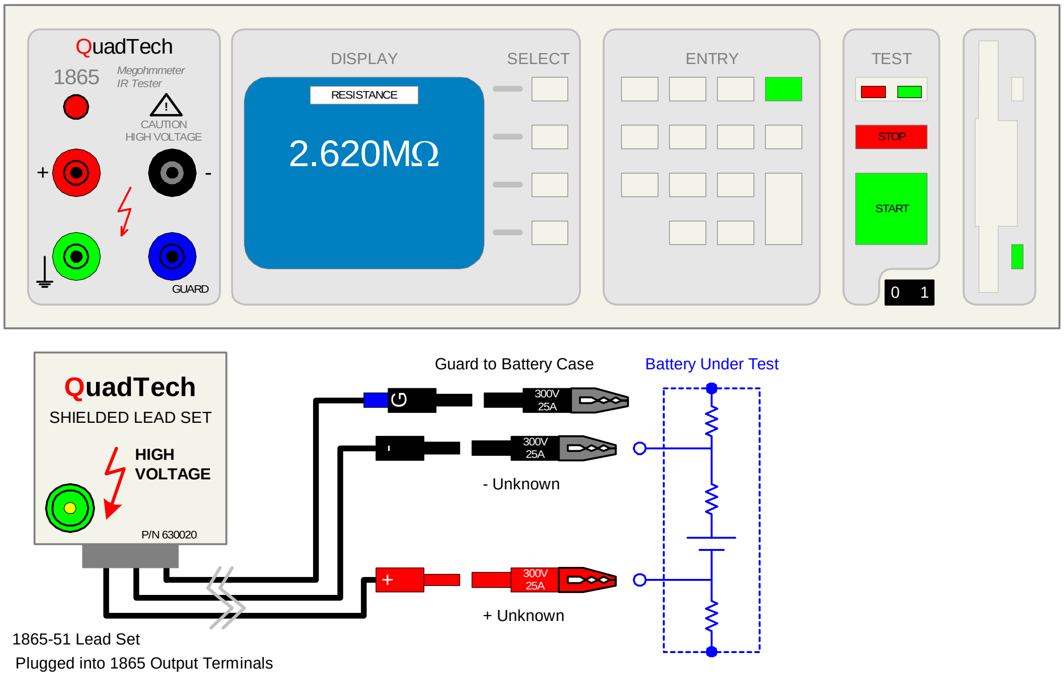
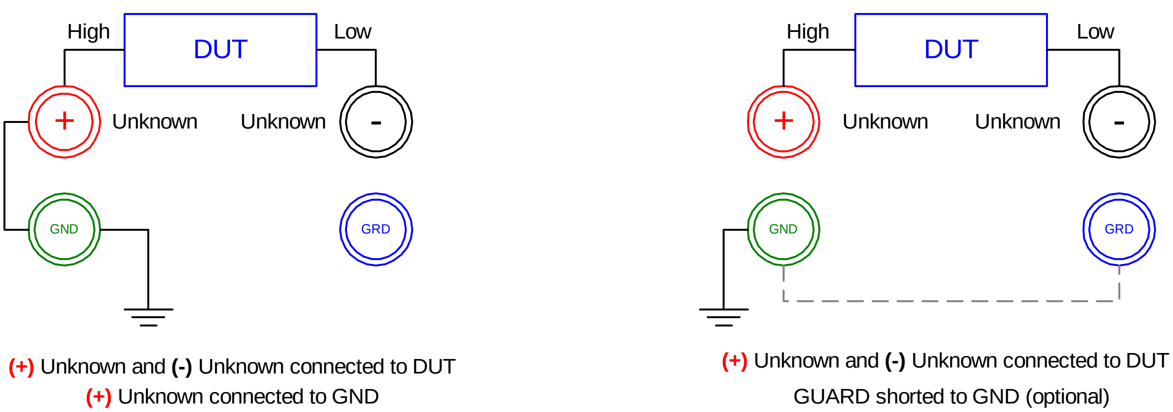


Figure 2: Battery Connected to 1865 Megohmmeter

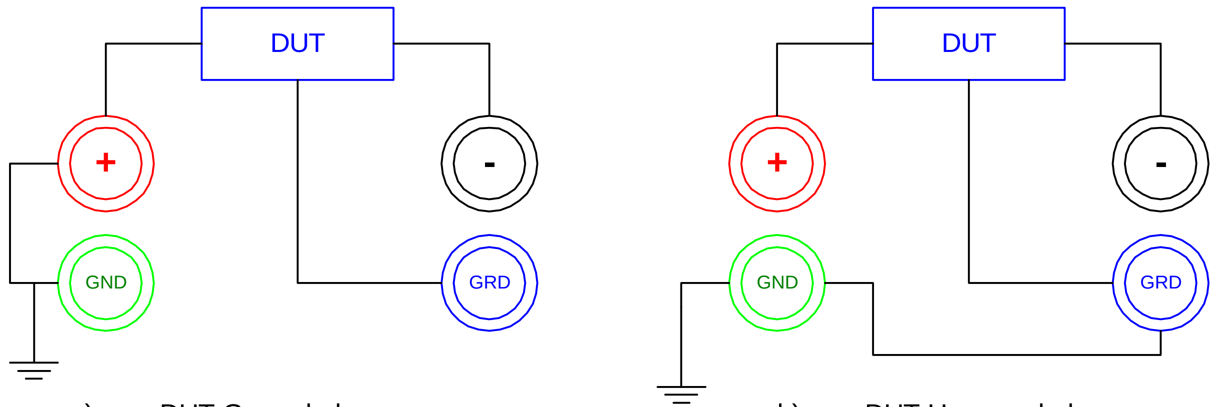
The 1865 using an optional shielded lead set, IET Labs part number 1865-51, can provide connections as seen in Figures 3, and 4:



a) 2-Wire Grounded **b) 2-Wire UnGrounded**

Figure 3: Two-Wire Connections

3-Wire Connection



a) DUT Grounded

b) DUT Ungrounded

+ Unknown and **-** Unknown are connected to DUT

GUARD to DUT Guard Point

+ Unknown shorted to GND

OR

GUARD shorted to GND

Figure 4: Three-Wire Guarded Connections

For making measurements from terminal to case, the 2-wire grounded connection method used in Figure 3a would be most suitable.

For making measurements from terminal to terminal, there will be some leakage current flowing from the terminals to the case. This current needs to be subtracted out of the measurement made by the 1865. To do this, a 3-wire connection would be the method to use. This method shown in Figure 4, takes any leakage current from the terminal to case and drains it through the "Guard" wire. Internally, the 1865 can then subtract out this leakage current from the total leakage current. Representing this mathematically:

$$(1)\quad I_{MEASUREMENT} = I_{TERMINAL\text{-}TERMINAL} - I_{TERMINAL\text{-}CASE}$$

Where:

$$(2)\quad I_{TERMINAL\text{-}TERMINAL} = I_{\text{"+"} - \text{"-"}}$$

$$(3)\quad I_{TERMINAL\text{-}CASE} = I_{\text{"+"} - \text{"GUARD"}}$$

Measurement Accuracy and Repeatability Factors

The 1865 IR Tester applies a voltage, measures the leakage current, and then determines the resistance according to Ohm's Law. When making very high resistance measurements, it becomes more and more difficult to make accurate leakage current measurements. Let's say, for example, one applies 1000Vdc to a 200GΩ load (a possible terminal to case measurement). This means the current flowing through the load will be 5nA, which is very small. This current is small enough such that even the smallest amount of electrical noise coupled into the battery, test leads, or the IR Tester can drastically effect the measurement being made. By moving a hand near the battery or the leads can couple a small amount of current that could drastically effect the current measurement.

What can be done? There are a few things:

Shielded Test Leads

Using shielded test leads is of utmost importance. This aids in reducing coupled AC noise.

Test Fixturing

If accurate and repeatable measurements are going to be made at very high resistance levels, a shielded test fixture will help tremendously.

This helps in two ways:

1. The shielded test fixture connected to the shield of the cables will further increase the immunity of electrically coupled ambient noise. The battery is inserted into the fixture; the fixture is then closed, shielding the battery. However, make sure the battery is not touching the shield and is isolated from it at least into the teraohm (TΩ) range.
2. The test fixture, including the wires, is fixed and unable to move. The connections to the battery attach to the same point each and every time. This makes it possible to perform an offset measurement that will be valid for each and every battery tested. If the cable position, test fixture, or connections vary from battery to battery, the leakage current lost in the cables and fixturing changes, as well as the contact resistance of the connections will vary.

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Battery Impedance and Gain Calculation

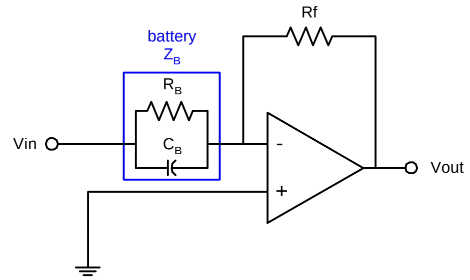

Figure 5: Battery Impedance (Z_B)

A quieting resistor can also aid in increased measurement accuracy. In Figure 5, current flows through the load of the battery (Z_B) and through the range resistor (R_F), giving a gain equivalent to:

$$(4)\ \text{Gain} = V_{OUT}/V_{IN} = R_F / Z_B$$

Where Z_B for Applied DC Voltage is:

$$(5)\ Z_B = R_B = \text{Insulation Resistance of Battery}$$

And Z_B for AC Noise is:

$$(6)\ Z_B = X_B = 1/2\pi f C_B$$

And C_B is the capacitance between the two points being measured on the battery. Combining formula 6 and 4, we see the Gain measurement is effected by an AC noise with frequency "f" and capacitance "C":

$$(7)\ \text{Gain}_{AC} = R_F / (1/2\pi f C)$$

For DC, the analysis of Gain is quite straightforward. Assuming we apply 1000Vdc to a 200GΩ load, this yields 5nA. This would result in R_F being a 200MΩ feedback resistor. Using formula 6, the DC Gain would be:

$$\text{Gain}_{DC} = 200M/200G = 0.001$$

This means the 1865 detector circuitry will be:

$$V_{OUT} = 1000VDC \times 0.001 = 1.000VDC$$

Now, to see the effect of AC noise, let's inject an AC noise signal of about 1Hz. If "C" is in the Micro-Farad ($\mu F = 10^{-6}$) range, then the Reactive Impedance (X_B) would be calculated:

$$X_B = 1/2\pi\,(1)(1\times10^{-6}) = 159.2k\Omega$$

Quieting Resistor

Calculating the AC Gain: $Gain_{AC} = 200M/159.2k = 1256$

If we assume a 1mV noise signal, the resulting voltage into the detector would be:

$$V_{OUT} = 1mV \times 1256 = 1.256V$$

This would be an error of 25.6% due to coupled AC noise. We can minimize the AC noise effect by using a Quieting Resistor in series with the battery as illustrated in Figure 6.

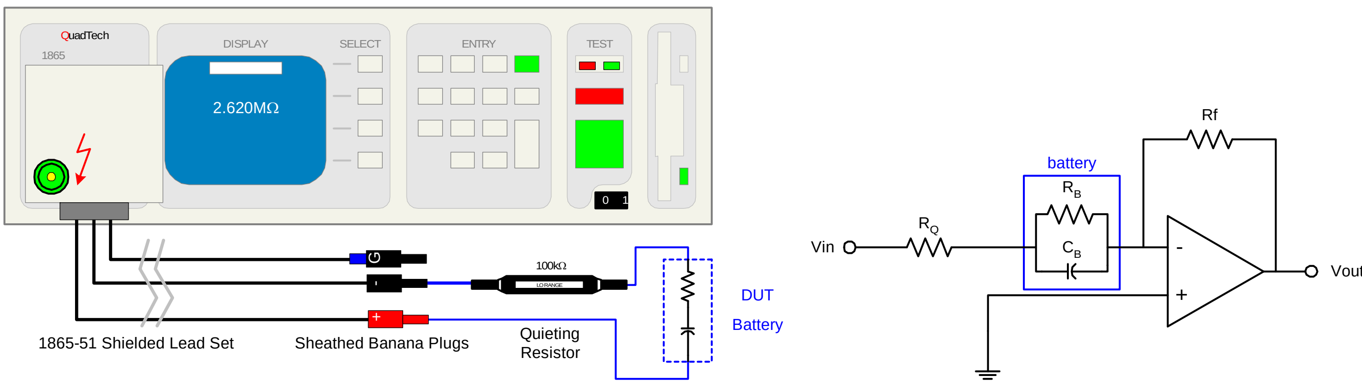

Figure 6: Quieting Resistor

By inserting a quieting resistor R_Q in series with the DUT, the AC Gain would then be:

$$Gain_{AC} = R_F / (R_Q + X_B)$$

Choosing R_Q of 1MΩ: $Gain_{AC} = 200M/(1M + 159.2k) = 172$

Assuming a 1mV noise signal, the voltage into the detector would be:

$$V_{OUT} = 1mV \times 172 = 0.172V$$

This minimizes the AC noise out of the measurement.

DC Effect

But you're probably wondering how that 1MΩ (R_Q) is going to affect the DC Gain. Inserting 1MΩ (R_Q) in series with 200GΩ (R_B) has an insignificant effect. In other words, this would add 1MΩ to 200GΩ, changing the measured result to 200.001GΩ. This would change the resulting DC gain by only 0.0005%.

For complete product specifications on the 1865 Megohmmeter or any of IET Labs's products, visit us at http://www.ietlabs.com/1865-megohmmeter.html Call us at 516-334-5959 or email your questions to info@ietlabs.com. The information presented in this application note is subject to change and is intended for general information only.