Application Note

Testing Capacitors with the
1865 Megohmmeter / IR Tester

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The 1865 Megohmmeter/IR Tester is a state-of-the-art digital instrument capable of extremely good performance in the measurement of high resistances at test voltages to 1000 volts DC. A common use of such instruments is the testing and measurement of capacitor dielectric resistance. Such tests are useful to quality engineers in the production of capacitor products, at incoming inspection as a part of quality control and by design engineers to determine suitability for a particular application. A capacitor's dielectric material can be tested in two ways by the proper application of a megohmmeter type instrument.

First, the DC value of its impedance (resistance) can be determined. This is an important parameter in some types of capacitors such as ceramic or film where a high value of dielectric resistance is a primary reason in choosing them for an application. It may be that a design engineer has determined that his circuit will not work well below a certain value of dielectric resistance. In addition, the DC resistance of a capacitor tells something about its quality. Wide variations from unit to unit or consistently low values may indicate a quality problem.

Second, the measurement of the capacitor's dielectric resistance with high voltage is an excellent way of detecting flaws in the dielectric material which might not otherwise make themselves known until long after installation in the user's equipment. Ceramic dielectrics are subject to cracking (as are all ceramic materials), and often these cracks will not be noticed at normal voltages. However, with the application of 500 or 1000 volts, breakdown along the crack edges often occurs resulting in an abnormally low value for DC resistance.

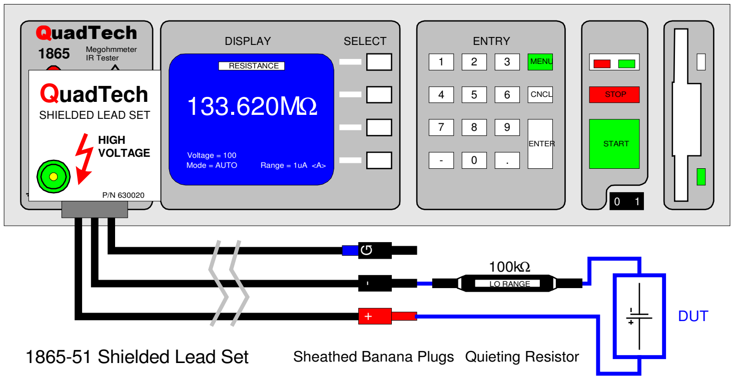

Figure 1: IET Labs 1865 Megohmmeter/IR Tester

Why are Capacitors hard to test?

If a capacitor with high dielectric resistance is attached to the measurement terminals of the 1865 unit, the user may notice some very strange behavior of the instrument. Resistance readings will fluctuate widely in continuous mode, and never settle down. If a pure resistor of similar value is substituted for the capacitor, the 1865 will settle down and measure the device perfectly.

This situation is not unique to the 1865, it has been noted on other commercially available megohmmeters, both analog and digital. What is interesting is that, although the variation of readings may be as great on an older design analog meter, it appears less. This is because the resolution on these older instruments is far less than on the 1865. An analog readout that covers one or two decades from zero to full scale will not seem to waver much for values changing by 2:1. On a digital readout, however, this can be annoying at the least and may make readings impossible. This strange behavior is caused by the way that megohmmeters measure resistance as illustrated in Figure 2.

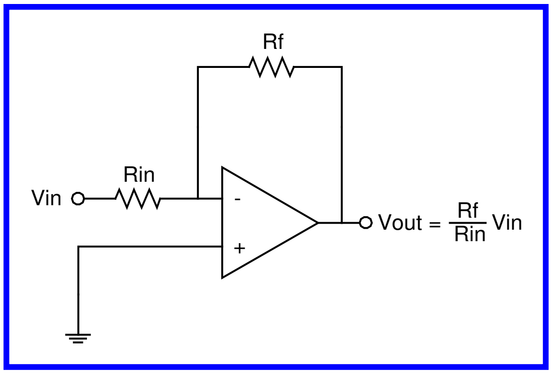

Figure 2: Typical Op-Amp Circuit

Figure 2 is a standard way of building an operational amplifier gain stage. This is used in the detector circuits of many types of instruments. The input resistor (Rin) is actually the unknown. The feedback resistor, Rf, is a range resistor selected by the 1865's software during auto ranging to match the level of current flowing into the detector. This range resistor is very stable and it's particular value is measured by the 1865 during calibration. The voltage out of the detector then depends upon the input voltage and the value of Rin (the unknown). The value of Vin is accounted for in the calibration process, so that Rin is the only variable. For the 1865 unit's most sensitive range (1nA full scale) the feedback resistor is 2GΩ ($2x10^9$ Ω). If the unknown were 2GΩ, and 1000 volts were applied to it, 0.5nA of current would flow, giving a half scale output of 1 volt. (Rf/Rin= 1:1). The detector would have a gain of 1.

Capacitor Equivalent Circuit

If the unknown is a capacitor, however, things get more complex as illustrated in Figure 3.

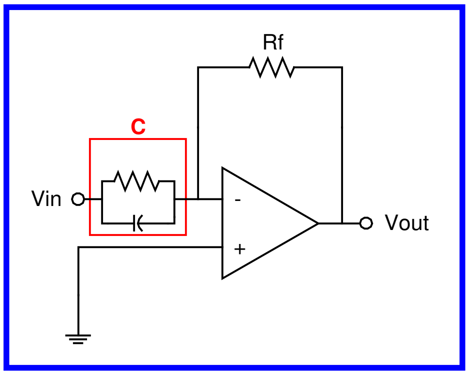

Figure 3: Capacitor Equivalent Circuit

A "real" capacitor consists of an ideal capacitor in parallel with its dielectric resistance. This ideal capacitor has infinite resistance at DC. As frequency goes up, however, its resistance decreases according to Equation 1. Note: f is frequency in hertz, and C is the capacitance in farads. Notice that we use the symbol X for the resistance of the pure capacitor, to distinguish from its dielectric resistance, R.

$$X = \frac{1}{6.28fC}$$

Equation 1: Decrease in DC resistance

A "typical" ceramic capacitor might be 2.2µf (2.2x10^{-6} farads) with a dielectric resistance of 2GΩ. This unit would be tested at 200V. The dielectric will pass 10nA. This would put the 1865 on the 100nA range with a feedback resistor of 20MΩ (20x10^{6} ohms). The gain of the detector would be [20MΩ/2GΩ] which equals .01. The detector would put out a voltage of [10nA x 20MΩ] which equals 200mV.

This all assumes DC. As soon as we consider AC, things change. At a frequency of 1Hz, the "ideal" capacitor in this unit will have an X of 1/(6.28x1x2.2x10^{-6})=7.2x10^{4}. The AC gain of the detector would be [20MΩ/7.2x10^{4}] = 270. The source of 1Hz voltage on the input could be any one of several things. The 1865 unit uses a switching power supply to develop the 200V DC. There could be noise on the 200V coming from the supply or room noise could be picked up by the meter leads. Even moving the leads (as on an automatic handler) can induce low frequency AC on them. The induced AC voltage will be small, perhaps 1mV. The detector would multiply this by 270 to give an output of 270mV. This is higher than the "true" reading of 200mV. The noise from this 1mV source can cause the result to vary by 135%!!

What to do about the AC Gain?

This situation could be improved by shielding the DUT and the test leads from the AC noise. Indeed, at high values of resistance (above 1GΩ) low noise shielded cables are highly recommended. The real solution to the problem of capacitor testing comes from remembering the cause - the high AC gain. If we can reduce the AC gain, we can eliminate the problem.

Recall that the AC gain is Rf/X. If we were to add a compensation resistor, Rc in series with the DUT, the AC gain would become:

$$\frac{Eac}{Vin} = \frac{Rf}{X + Rc} = 18.65$$

Equation 2: AC Gain

This is a lot better than 270! With the same 1mV of noise in, we get only 18.7mV out compared to the "true" signal of 200mV. The series resistor, Rc, has reduced the AC gain to 9.35% of the DC gain, a tolerable level.

DC Errors

At this point, one might worry that, although we've solved the instability problem, we've introduced an error term of 1MΩ. We have! But, so what? Remember, we're in the business of trying to measure 2GΩ versus an induced error of 1MΩ (=0.001GΩ). The error is .05%.

At lower values of DC resistance, a 1MΩ resistor may be significant, so the 1865 instrument has available two capacitor adapters: a "High range" for testing on the 1nA and 10nA ranges, and a "Low Range" for testing on the 100nA through 100uA ranges. Capacitors whose dielectrics fall below 100uA (100uA to 1mA) simply are too "leaky" to exhibit the problem in the first place.

Procedure

To determine the proper adapter to use, simply measure several units of the DUT and note the range selected in Auto Range by the 1865 instrument. For 100nA to 1mA, no adapter should be needed. Confirm this by looking for instability in the readings over a measure time of, say, ten seconds. Note that, during this time, the readings on an uncharged capacitor will change as the DUT charges up. But the reading should increase steadily, not fluctuate up and down. If the readings seem to fluctuate, add either adapter and try again. Pick the adapter that gives the best results.

Capacitor Adaptors

Table 1 is a quick look-up table to help select the proper adapter (quieting resistor) for the device under test (DUT). Note the current range is equivalent to your test voltage divided by the resistance limit. $I_{RANGE} = V_{TEST}/R_{LIMIT}$

Table 1: Choosing the Correct Adapter

Current Range	Quieting Resistor	(QR) Value
1nA	HI RANGE	1MΩ
10nA	HI RANGE	1MΩ
100nA	LO RANGE	100kΩ
1µA	LO RANGE	100kΩ
10µA	LO RANGE	100kΩ
100µA	Not Required	N/A
1mA	Not Required	N/A

In certain special cases, you may need to fashion your own adapter, say of 2Mohm or higher values. It is hard to predict when this will be required, as there are so many variables outside of the 1865 instrument itself (fixturing, cables, etc.). In general, though, either the Low range or High range adapters available from should suffice.

Lastly, the addition of series Rc will increase the charge time somewhat. This is unavoidable, but in most cases will be inconsequential.

For complete product specifications on the 1865 Megohmmeter/IR Tester or any of IET Labs' products, visit us at www.ietlabs.com. Do you have an application specific testing need? Call us at 1-800-899-8438 or email your questions to sales@ietlabs.com and we'll work with you on a custom solution.

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