

## Measuring low value resistance/impedance.

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### Introduction

A broad range of systems include components with very low resistance/impedance values such as current meters, force measurement devices, temperature sensors, battery/fuel cells, etc. Such impedance values can be in the range of 0.001 ohm to 0.1 ohm (maybe even smaller). In many cases, it is necessary to measure the impedance of those components to insure operation within specifications. AC/DC current meters may involve the use of sense resistors that usually have low resistance (milliohms) values to measure high currents. Verification of system accuracy is important. Strain gauge bridges, stimulated by an AC signal, are used extensively for force measurement. Although their unloaded resistance may be relatively high, the change in resistance under load may be in the order of milliohms/gram. As batteries age and discharge, their internal resistance increases. Monitoring the internal resistance can help engineers determine the remaining effectiveness of the system.

This application note describes techniques to measure a 0.005 ohm resistor with the Circuit Sleuth network/impedance analyzer. It also describes techniques for minimizing and controlling stray resistances in the milliohm region. The same general approach can be used to measure the impedance of any two-port device.

### Test setup considerations.

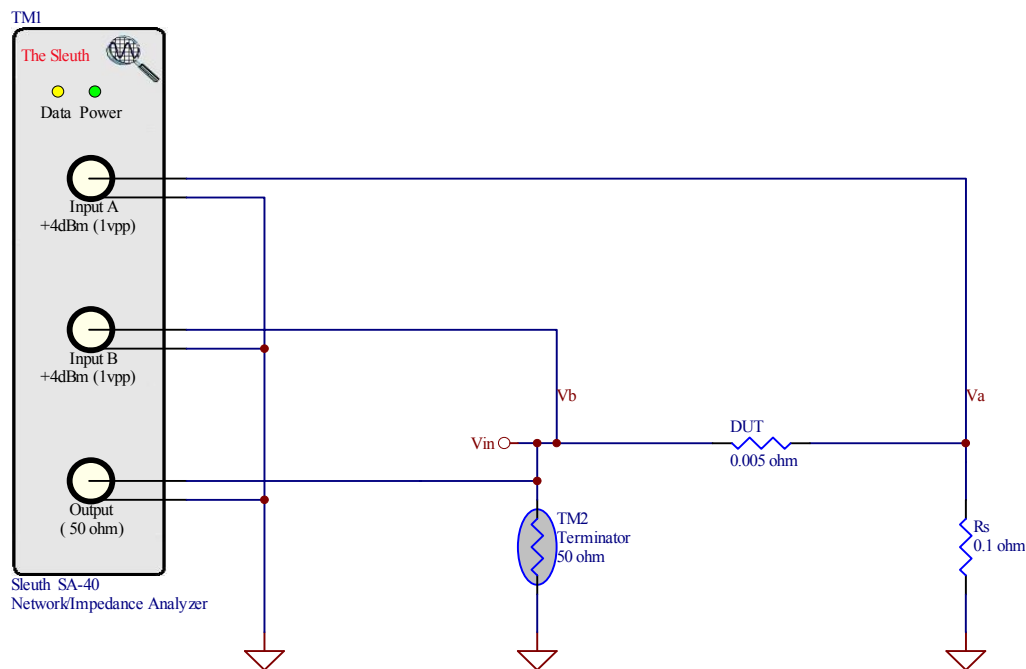
When measuring very low value resistances, keep in mind that connections and lead length must be managed to minimize stray/parasitic effects.

1. Manage lead lengths.
2. Make connections with good contact and solder if applicable. Keep in mind that, solder, if used as a path for conduction, will affect the measurement especially in the milliohm region.
3. The measurement point for very low values of resistance should be called out in the specification for the resistor. This is important because wire lead length will affect the resistance measurement.

4. Temperature effects, if applicable.
5. The measurements described here require a reference resistor. A precision resistor is preferred, or, it is possible to substitute a resistor that has a measured known value. A 50 –100 milliohm value for the reference resistor is acceptable.

### Remember the PHYSICS and know your test setup!

The test configuration for measuring a low value resistance is shown in figure 1. The device under test, DUT, is a 5 milliohm resistor and the reference resistor,  $R_s$  is a 100 milliohm reference resistor.

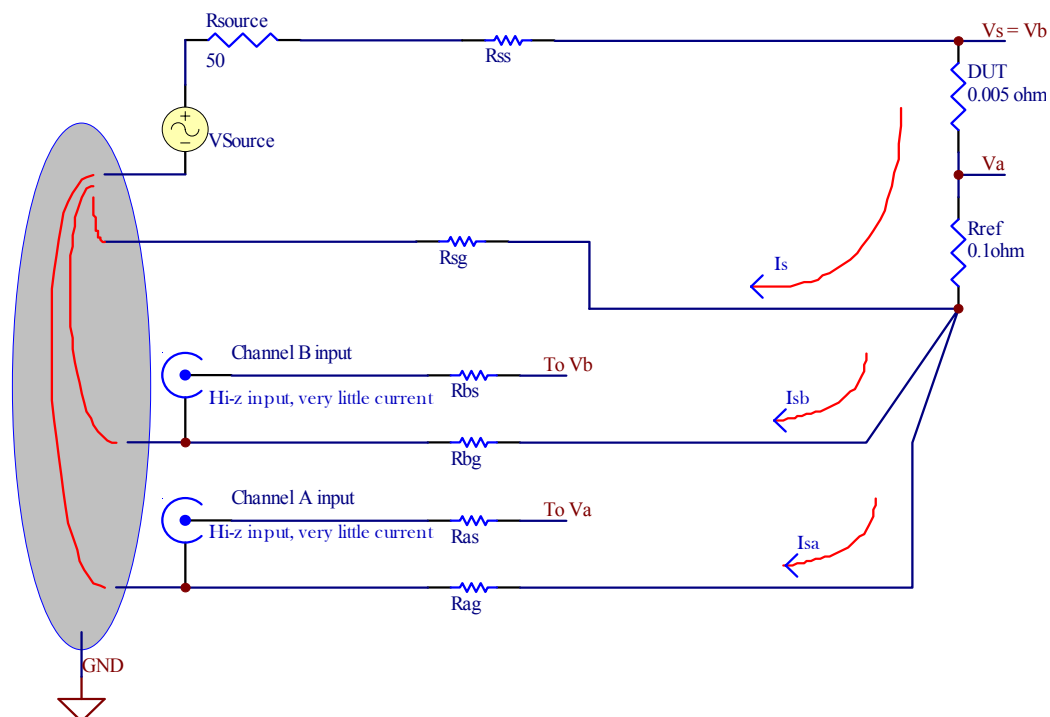


**Figure 1. Test setup to measure a 0.005 ohm resistor.**

Schematically, this looks innocent enough. But what does it *really* look like when you take into account the lead lengths for the stimulus signal and the probes?

Figure 2 shows a schematic of the test setup taking test lead resistance and current paths into consideration. The resistors,  $R_{ss}$ ,  $R_{sg}$ ,  $R_{bs}$ ,  $R_{bg}$ ,  $R_{as}$  and  $R_{ag}$  are the resistances of the wires used for the signal and return paths of their respective sources and inputs. The stimulus current,  $I_s$ , is supposedly contained in the  $V_{source}$  loop only, but a closer inspection reveals that if the test probes have a ground clip connected near the reference resistor,  $R_{ref}$ , some of the stimulus current will flow through  $R_{bg}$  and  $R_{ag}$  in addition to the current flowing through  $R_{sg}$ . It is undesirable to have current flowing in the ground lead of a test probe. A quick remedy in this case is to remove the ground clips at the reference resistor. At this point, the stimulus current is contained in the  $V_{source}$  loop.  $R_{sg}$  introduces another problem.

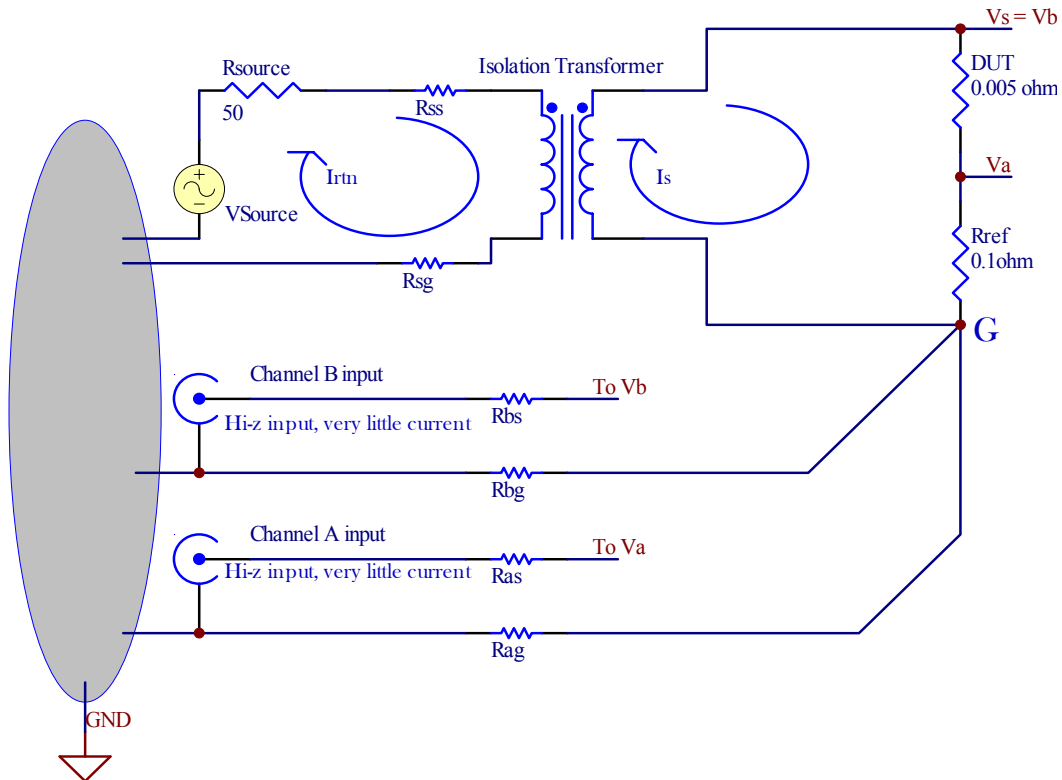
The value of the reference resistor is used to calculate the impedance of the device under test.  $R_{sg}$  introduces a parasitic resistance that must be added to the value of the reference resistor to get an accurate impedance measurement. There's a better way.



**Figure 2. Test setup considering test lead resistances.**

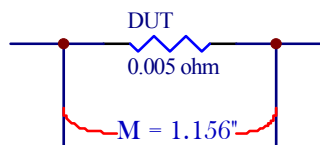
### Isolating the stimulus current.

Figure 3 shows the use of an isolation transformer for measuring low values of impedance. The isolation transformer insures that the stimulus current,  $I_s$ , flows only in the closed path of the secondary, no current flows in probe ground leads and point "G" is the reference point located close to the reference resistor.



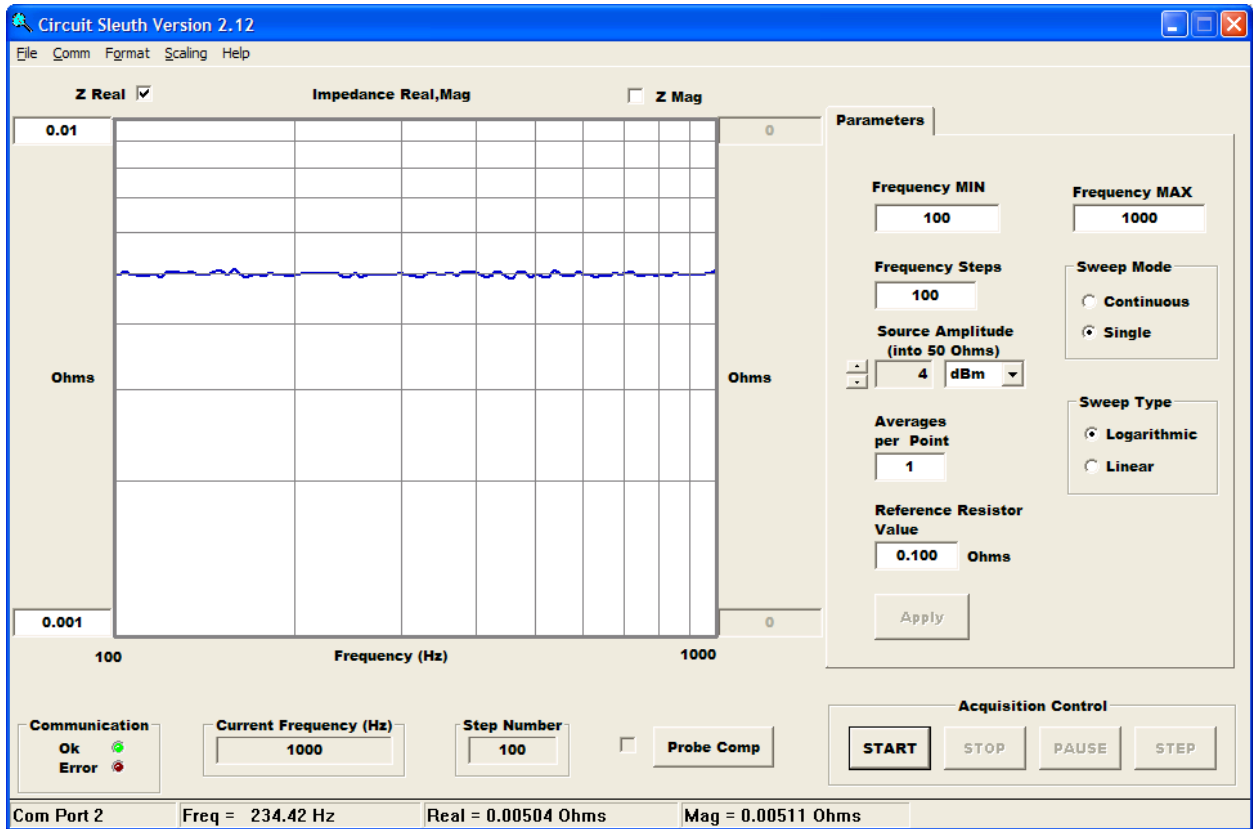
**Figure 3. Test setup using a transformer to stimulate the device under test providing isolation of the return currents.**

The manufacturers specification called for the measurement to be made by connecting the probes at specific points on the leads of the device. This is shown in figure 4. The lead length contributes to the resistance measurement.



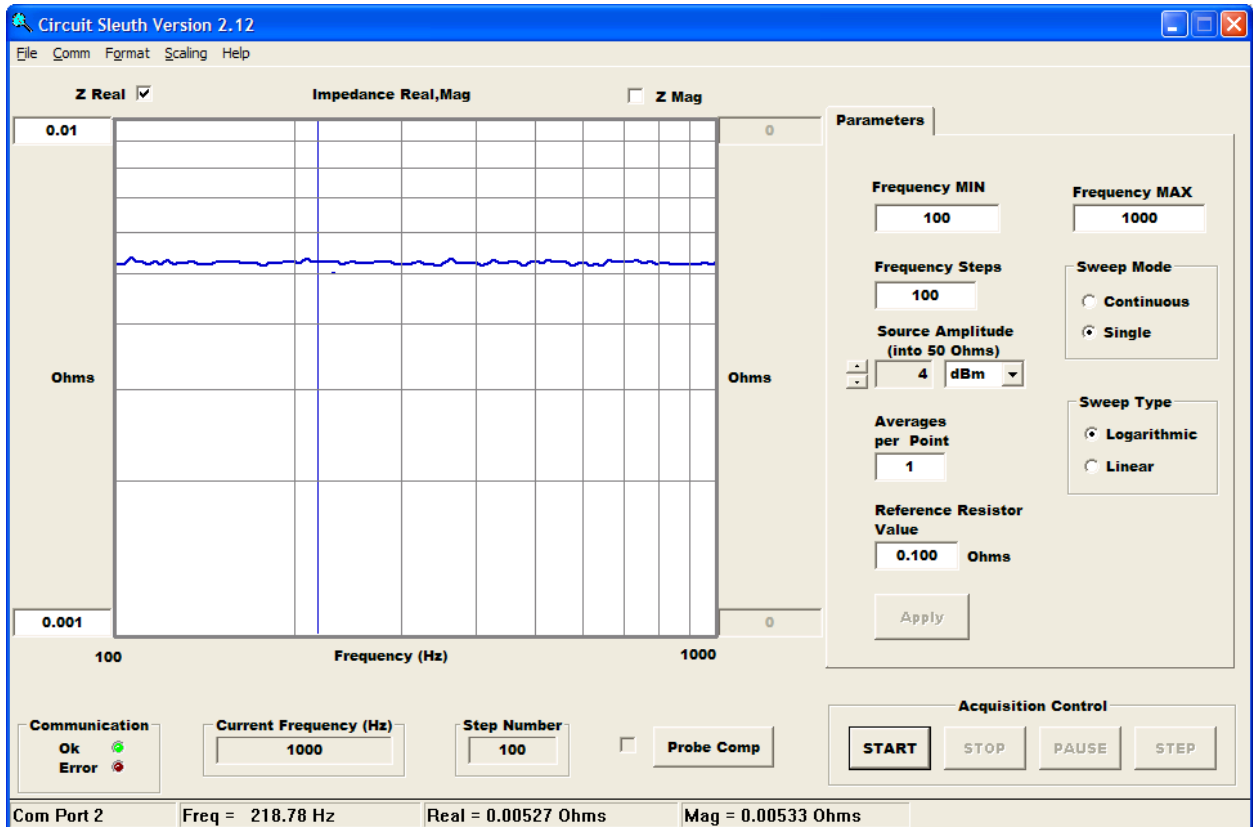
**Figure 4. Physical location of the test probes for accurate measurement.**

Figure 5 shows the Circuit Sleuth analyzer test results for a 0.005 ohm resistor using an isolation transformer to inject the stimulus signal.



**Figure 5. Circuit Sleuth measurement of a 0.005 ohm resistor using an isolation transformer for stimulus signal isolation. Probes are connected at position “M” as recommended by the manufacturer.**

Figure 6 shows the same measurement but with M increased by 0.250”. There is definitely a measurable difference!



**Figure 6. Circuit Sleuth measurement of a 0.005 ohm resistor using an isolation transformer for stimulus signal isolation. Probes are connected at position “M” + 0.250” to show measurable difference.**

## Summary

Many applications require measuring very low resistance values. Such values can fall into the 0.001 ohm to 0.1 ohm region. This application note described the measurement of a 0.005 ohm resistor. The measurement of such low value resistances required techniques that minimized or accounted for stray resistances due to wire lead length both for the stimulus signal path and the physical location of the test probes on the DUT. The first measurement was made with the test probes located at the positions specified by the manufacturer. The sensitivity of the measurement was demonstrated by placing the test probes at positions greater than that specified, making a second measurement and then, comparing the two. The same general approach can be used to measure the impedance of any two-port device.