

What is the Leakage Current of My Probe Station?

When customers ask this question, they are requesting information about the lowest current measurement possible using a probe station. Measurement of small currents requires skill and understanding of the many processes that can affect the measurement. In this document, small currents mean less than 100 fA (less than 10^{-13} A).

A current measurement requires several components that the experimenter selects and assembles into a measurement system. These include the instruments and components directly used in the measurement, voltage source, cable connectors, adapters, device to be tested, and current meter. Other components include the environment of the device under test, the environment of the instrumentation, the measurement protocol, and the topology of the connection. All of these components contribute to the quality of the current measurement. The only consistent method to state the performance of any component in the measurement system is in the context of the entire measurement system. This note will demonstrate that it is possible, with a well-designed measurement system, to measure changes in current of less than 2 fA on samples mounted in a Lake Shore probe station.

Lake Shore Cryotronics Desert Cryogenics Division probe stations with coaxial and guarded sample holders are designed not to be the limiting factor in a DC current measurement for current changes greater than 2 fA. Coaxial and guarded sample holders are not available on electromagnet probe stations when the 360° rotation stage is installed.

Measurement of 100 GΩ Resistor

Measurement on a Grounded Sample Holder

A 100 GΩ (10^{11}) resistor was measured. The resistor was mounted on two pieces of gold-plated sapphire. The sapphire pieces were mounted on the grounded sample holder (SH-1.25-G). Two probe arms were used for the measurement. One arm is connected to the drive of the source meter. The return of the source meter is connected to the probe station ground. The return arm would normally just be tied to the probe station body, but in this case the arm was returned through an electrometer. This allowed the measurement of the current returning from the probe station through the arm. The source meter reports the total current from the source meter. The wiring is shown in figure 1a.

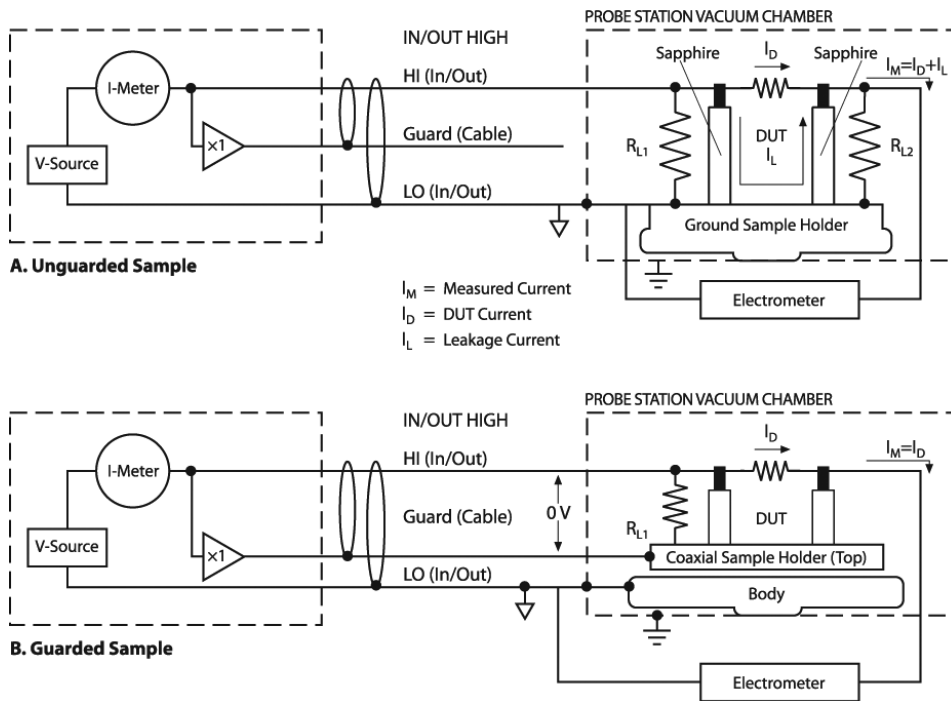


Figure 1 High impedance measurements

Figure 2 shows the IV plot for the 100 GΩ resistor. Both the current reported by the source meter and the current reported by the electrometer are in the plot. Both are straight lines (good ohmic contact) but there is a difference in the current from the source meter and the electrometer. The difference is typically 30 to 40 fA.

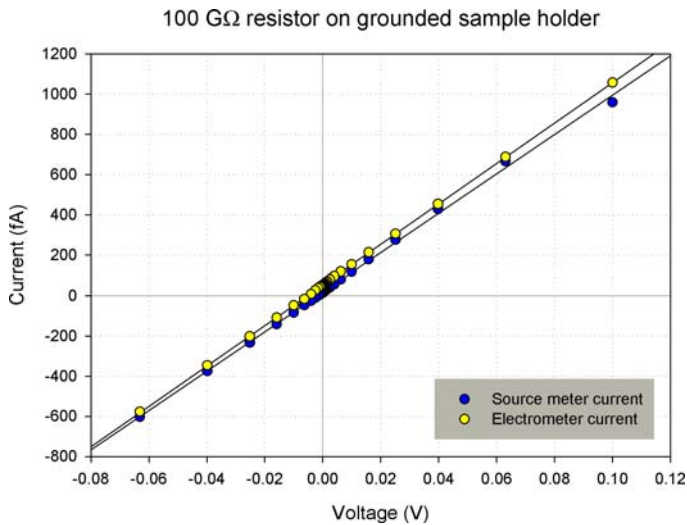


Figure 2 100 GΩ resistor IV plot on grounded sample holder

Driven Coaxial Sample Holder

The grounded sample holder was replaced with a coaxial sample holder (SH-1.25-C). A junction box was built to drive the top of the sample holder with the guard from the source meter (figure 1B). This effectively extends the guard to the top of the sample holder. The measurement was repeated and shown in figure 3. The two lines now lay on top of each other.

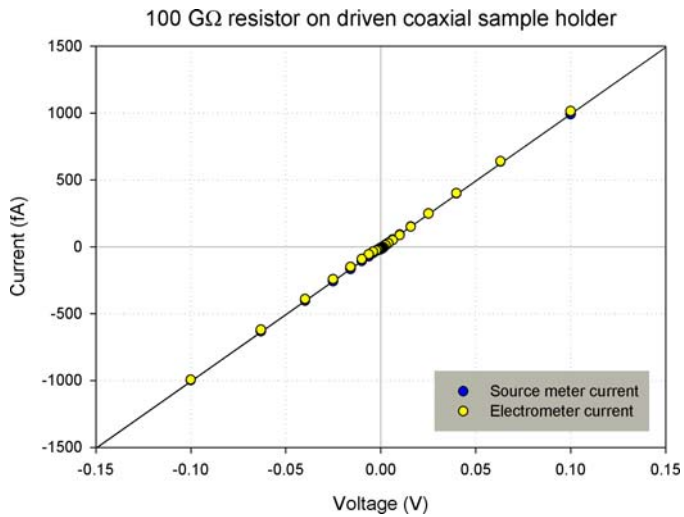


Figure 3 100 GΩ resistor IV plot on driven coaxial sample holder

Measurements of Kapton® Tape

To demonstrate the abilities of a Lake Shore Cryotronics TTP4 probe station, the resistance of a piece of Kapton® tape was measured. The measurement method was to use a source meter to apply a voltage and measure the current. An IV curve is obtained by varying the voltage. The resistance of the tape is determined from the slope of the IV curve. Figure 4 is a plot of typical measurement results. The resistance corresponding to the best-fit straight line is $8 \times 10^{15} \Omega$. The RMS deviation from the best-fit straight line for the tape is 0.9 fA. The offset current, in this case about 20 fA, depends on the room temperature and relative humidity. Despite this offset, changes in current of 1 fA can be detected.

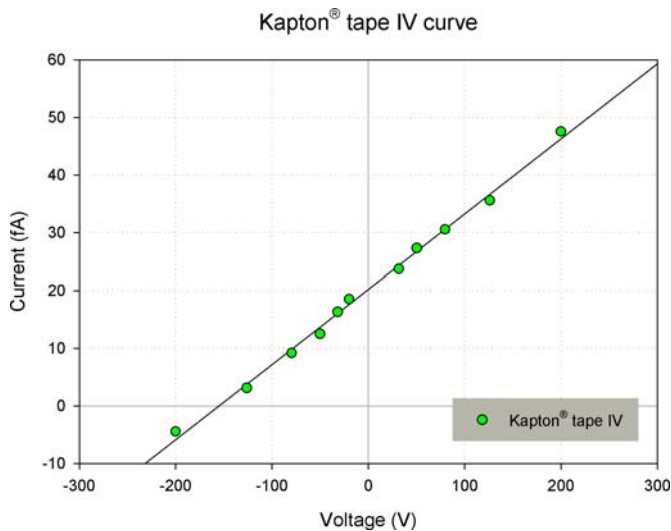


Figure 4

Five Points to Remember when Doing Low Current Measurements

1. Keep the sample to be measured at constant temperature using the probe station temperature controller. If possible, keep variations in the room temperature constant (temperature variation less than 0.5 °C).
2. For currents less than 1 pA, always use a driven guarded coaxial sample holder.
3. For currents less than 10 nA or resistances more than 10 MΩ, always uses driven guarded triax cables
4. Keep cables as short as possible
5. Laboratory humidity range is 5% to 60%.

A Note on Accuracy

The typical accuracy of source meter current measurements is 1% reading +10 fA. The absolute current value (like the offset current in Figure 4) is never known to better than 10 fA. However, a change in the current (as in the slope in Figure 4) is determined by the repeatability or noise in the measurement and is typically better than 1 fA.