Identifying Low Current Probing Problems

Abstract

This application note will address the identification of common equipment and setup problems in a low current probing applications through characteristic distortions and problem “signatures” in the data obtained. This application note follows and expands upon the setup information for low current probing as outlined in Micromanipulator Application Note A1009492 “Basics of Low Current Probing”.

Introduction

Analytical probing at very low (femtoamp) current levels can be done reliably and is straightforward. It need not be a mysterious and anxiety-producing endeavor if you use the proper equipment and setup discipline. To date, however, the available information on how to properly evaluate the equipment, setup the probing application and recognize the effects of both on the measurement data is sparse. While common problems to avoid are relatively easy to tabulate, troubleshooting a low current setup for those problems is often a “blind” endeavor unguided by information which can point out a direction in which to start troubleshooting.

There are, however, typical “signatures” of common setup and equipment problems which show up in the measured data. Some of these become readily apparent, some are subtle and can even be overlooked and remain unnoticed as they produce inaccurate and perhaps more importantly, inconsistent results.

The most common problems encountered include Random Noise Introduction (typically as a result of poor shielding), Induced Periodic Noise (typically the result of vibrations or acoustic noise), Noise Coupled through the measurement equipment, Poor Probe Contact and “Leaky” Probes (Inadequate Probe and Chuck Isolation Characteristics).

What follows are the typical distortions or other effects on the data that are produced by these common problems.

Random Noise Introduction

This category includes such problems as EM noise transmitted through shielding, charge coupled noise resulting from activity around the test setup and triboelectric effects induced through probe cables. The data tends to show large distortions but these are not periodic in nature.

Offset or “drifting” of the current data is not typically a problem, but the “cleanliness” of the data is poor. Attempts to remove this noise through averaging and filtering may actually produce an erroneous data offset and certainly long measurement times, so it is best to remove these problems at their source by correcting shielding problems.

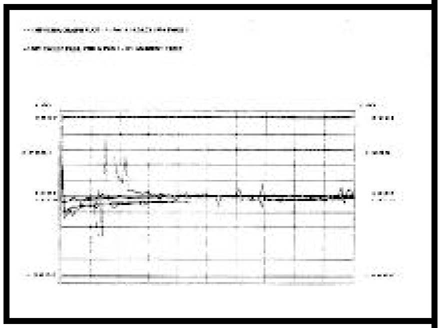

Fig 1. Sampling sweep with random noise.

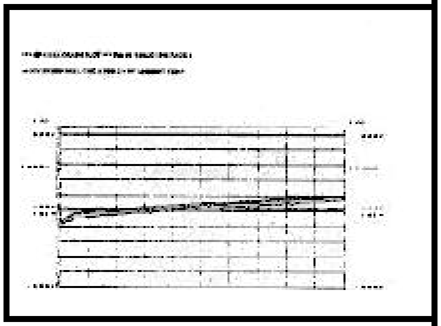

Fig 1A. Sampling sweep, good shielding

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Figure 1 shows a sampling sweep (voltage held steady over time) for a probe in a poorly shielded setup. Notice the noise signature being random in nature and distorting the data. This distortion shows again when actual data is taken as shown in the gate oxide (GOX) sweep of *Figure 2*. Finally, random noise can be introduced through triboelectric effects. Mostly this occurs when the probe cable is moved during the test. The movement may be small and not necessarily human induced. For example, the blow-off valve of small compressors used to float vibration isolation tables can cause movement in a random, but sharply intense manner. *Figure 3* shows the result of just such a disturbance at two places in the measurement with the resulting triboelectric noise generated. Note the “ringing” nature of the noise signature with a sharp peak that then subsides.

By properly shielding the probing setup and by proper cable selection, proper cable mounting and strain relief to avoid triboelectric effects, this kind of noise can be eliminated. Data can then be taken with short integration times, revealing more detail but remaining free of the distortion due to poor shielding. *Figure 1A* shows the sampling sweep with correct shielding. *Figure 2A* shows the good GOX data. *Figure 3* shows the triboelectric noise.

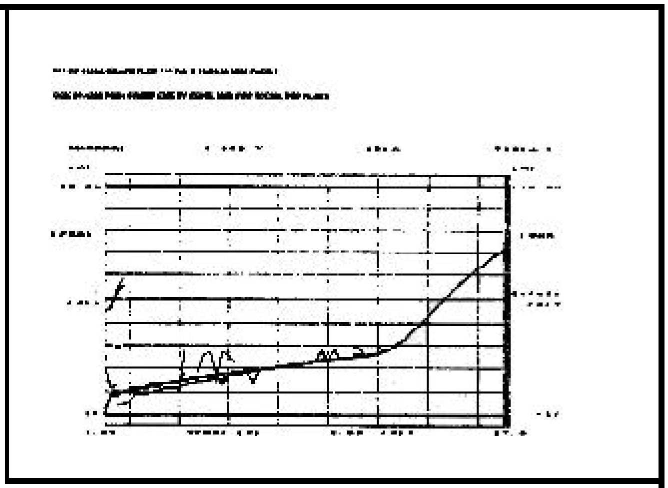

Fig 2. GOX sweep with random noise.

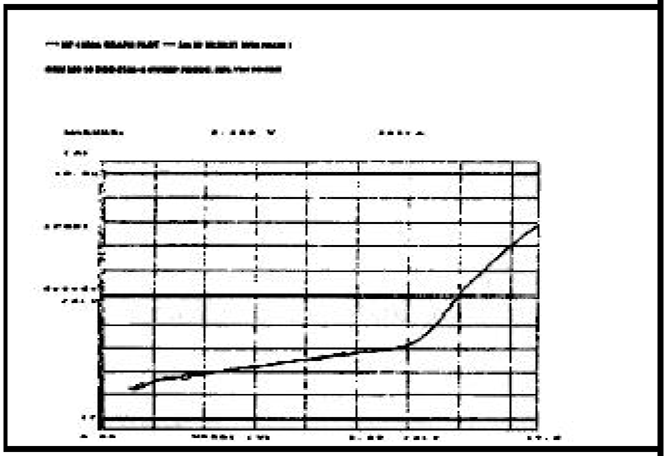

Fig 2A. GOX, with good shielding.

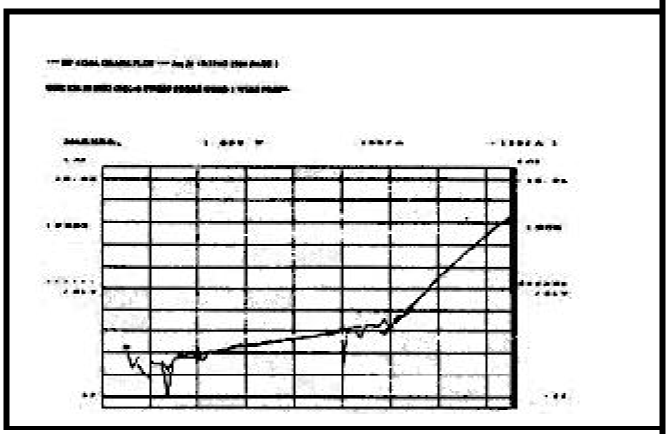

Fig 3. Triboelectric noise.

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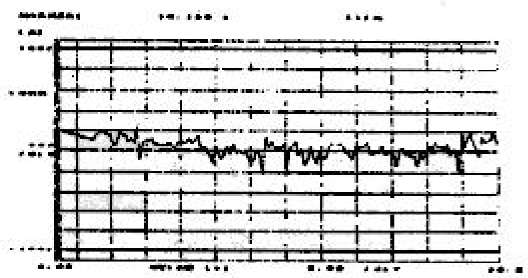

Fig 4. Periodic noise.

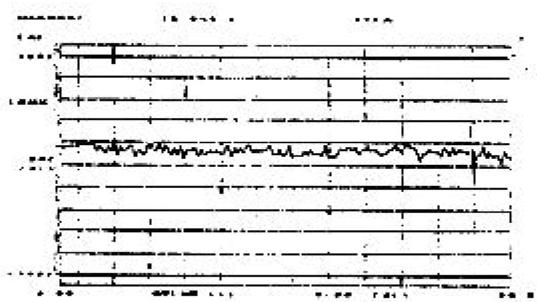

Fig 4A. Periodic noise source removed.

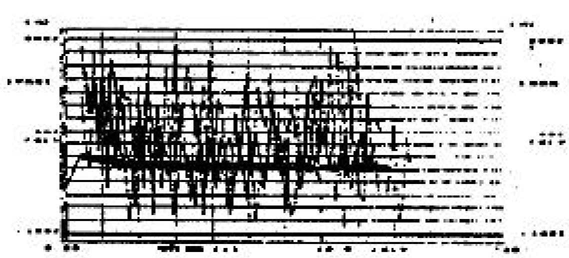

Fig 5. Coupled noise.

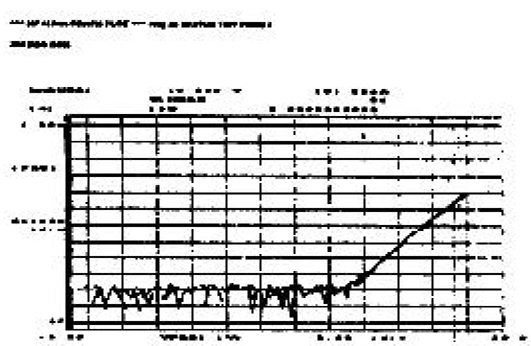

Fig 5A. Coupled noise in measurement.

Periodic Noise Introduction

Some sources can cause periodic noise in the test data. These sources produce data that is repeated throughout the test and may appear in multiple periodic forms.

Figure 4 shows a sampling sweep where such noise is present, with *Figure 4A* showing the “normal” sampling sweep characteristics of the setup when the problem is removed.

Note that the noise presents itself in two ways. First, the peak to peak magnitude of the noise of the system increases throughout the sweep. Secondly, notice that the data is offset in what appears to be a sine wave with a larger period across the sweep.

These signatures are characteristic of noise sources with continuing, repetitive natures, producing, for example, physical or acoustical noise. The short period noise could be caused, for example, by an illuminator power supply fan resting on the prober vibration isolation table while the larger period noise is caused by improper tuning (air pressure or balancing) of the vibration table producing low frequency vibration effects.

Noise Coupled through Measurement Equipment

Poor tester and prober grounding or a poorly isolated or guarded probe or chuck will allow electrical noise from power supplies or external circuits to enter the probing environment and be coupled to the measurement.

Figure 5 shows the Coupled Noise present in a poor setup. Note that the chuck is very noisy compared to the probe. The noise from the chuck shows up in the measurement even when data is taken through the probe, although it is attenuated *(Figure 5A)*.

This noise will show up in a chuck which is “actively” held at room temperature. Some chucks produce their worst noise in this temperature range because heating and cooling are both occurring and effectively “battling” each other to control the chuck temperature. Liquid cooled chucks do not exhibit this problem.

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Also, the source of this kind of noise can be simply that the chuck is left off in the belief that no noise will be generated. Instead, this actually deactivates the internal filtering and grounding designed into the chuck controller and allows the controller and cables to act as a large antenna, coupling noise to the probing site.

Grounding problems are harder to spot. Often this shows up as random noise but accompanied by drifting offsets in current. *Figure 6* shows a measurement taken with proper grounding.

Figure 6A shows the same measurement with poor grounding producing a large offset and excessive noise in the low current data.

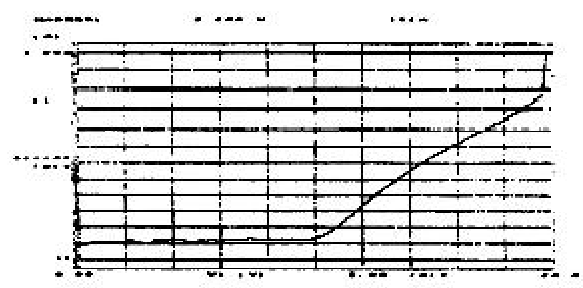

Fig 6. Proper grounding.

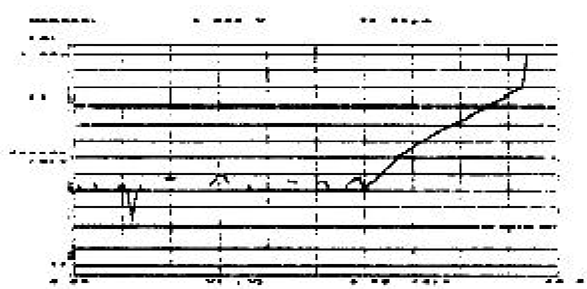

Fig 6A. Effects of poor grounding.

Probe Contact

Many times noisy data from a probing setup can be traced to bad probe contact. In extreme cases, the fact that the probe is not making good contact is obvious. However, poor contact as opposed to no contact can also distort data and is not so obvious.

Poor probe contact tends to show itself as distortions at lower current levels and may disappear entirely at higher levels. The following data show some examples.

If poor probe contact is suspected, a small increase in probe overdrive can usually change the data indicating contact is the culprit. This is the easiest solution that can be done while taking data.

Additional remedies for poor probe contact are: using a fresh probe, using a stiffer probe, using a probe with lower resistance tip properties (for example a beryllium tip) and changing the attack angle of the probe to the DUT (a high attack angle generally makes good contact but can make viewing difficult under high magnification, so a compromise must be reached).

Figure 7 shows very poor contact, enough to get data but as you can see by the graph, contact varies over the measurement sweep. The probe contact introduces some noise, but more importantly distorts the shape of the data curve.

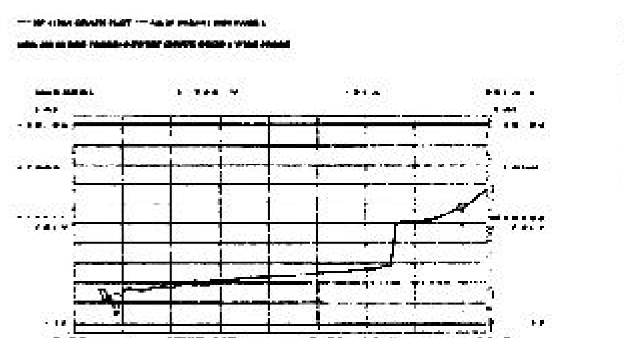

Fig 7. Poor probe contact.

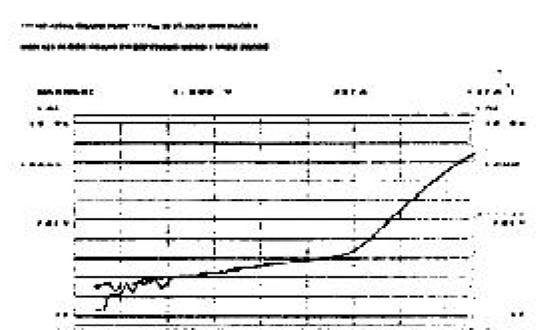

Fig 7A. Incomplete probe contact.

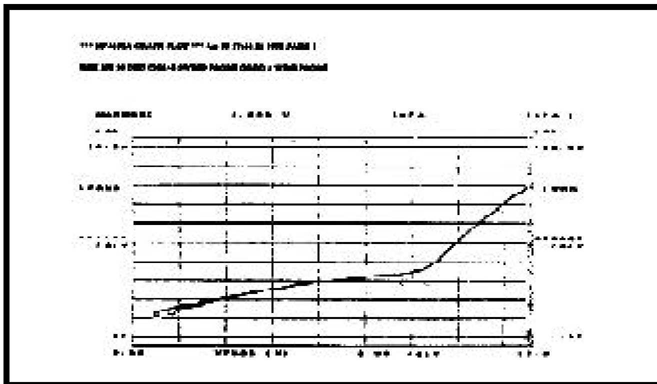

Fig 7B. Good probe contact.

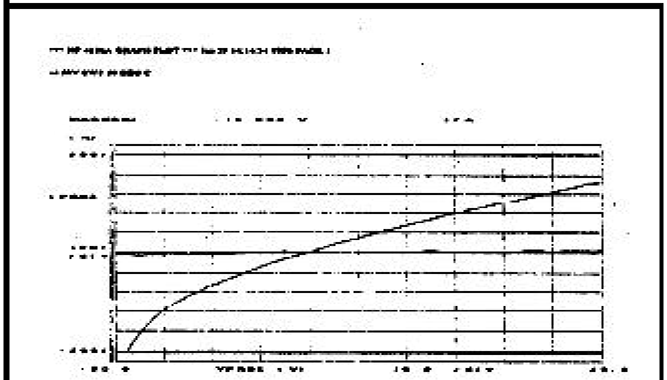

Fig 8. "Good" and "Leaky" probes voltage sweep.

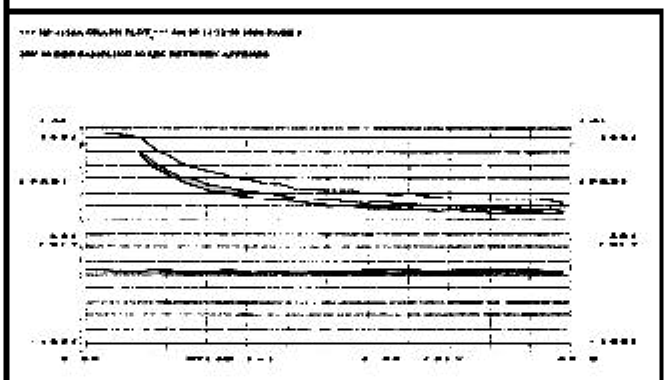

Fig 8A. "Good" and "Leaky" probes sampling sweep.

Figure 7A shows probe contact that is not good enough but just slightly so. The distortion and noise show up in the 20-100 fA range but then goes away as current levels increase.

Figure 7B shows data with good probe contact. Notice the smoothness of the data and the clearly uniform shape of the curve.

"Leaky" Probes

Much is made about probe "leakage." Some companies even specify "leakage current" of probes as if it was a fundamental property. Technically, the characteristic of concern is really isolation (impedance) between the center conductor and ground (that is, the leakage path). The leakage current of a probe will be determined by its isolation characteristics and the driving voltage. Even in a guarded configuration, a leakage path to ground will see current flow proportional to the magnitude of the voltage applied to the DUT. Leaky probes distort data by offsetting it. Sometimes it is hard to tell that this is happening. Leakage paths in most high performance probes are capacitive in nature and so they charge, changing their characteristics over time.

Leaky probes can also couple current to good probes in close proximity. One bad probe can make all others look leaky as well.

Leaky probes are most easily spotted with a voltage sweep. Figure 8 shows a voltage sweep of two probes, one "good" with high isolation to ground and one with lower isolation. Note that even the "good" probe shows some change in current. Even with an isolation of 5,000 Teraohms, 50 volts will produce 10 fA of current (note that these are single wire probes, not Kelvin probes).

For the "leaky" probe, notice the shape of the curve. It indicates a capacitive nature by its shape and by the fact that it does not pass through zero at zero volts (it is charging).

This charging effect produces another problem. With repetitive sweeps, the probe leakage current changes (diminishing with repetitive sweeps depending on the time between sweeps).

Figure 8A shows a sampling sweep where the probes are hit with 20 volts and then held there for 60 seconds. The sweep is repeated 3 times. The leaky probe shows a decreasing offset with capacitive characteristics and the good probe shows a repetitive, flat data set.

This effect cannot be compensated for by the test equipment (short of using a Kelvin set up) as:

- The current varies significantly with voltage.
- The offset varies with repeated charging and so is unpredictable.

Figure 8B shows the actual test results with the leaky probe showing a shift in the data for repetitive sweeps.

Figure 8C shows the same test using the good probe with the two sweeps matching closely.

Kelvin Probes can be used to minimize or even negate the leakage effects shown here. However, the use of Kelvin probes has its own drawbacks including:

- SMU instruments are expensive.
- Kelvin Probes are expensive.
- The best SMU available has a resolution of one femtoamp whereas single input electrometers are available with tenth-femtoamp resolution.

Summary

The information presented above shows the effects of common low current analytical probing setup and equipment problems. These problems are difficult to find and correct. Each, however, carries its own typical signature that appears in the data taken with the probing setup as can be seen from the examples presented.

With recognition of these signatures, the source of the problem can be deduced and identified and steps can be quickly taken to remedy the problem resulting in consistent and reliable low current probing measurements.

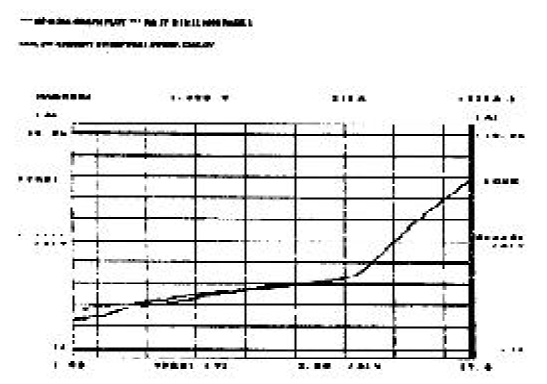

Fig 8B. "Leaky" probe causing data offset.

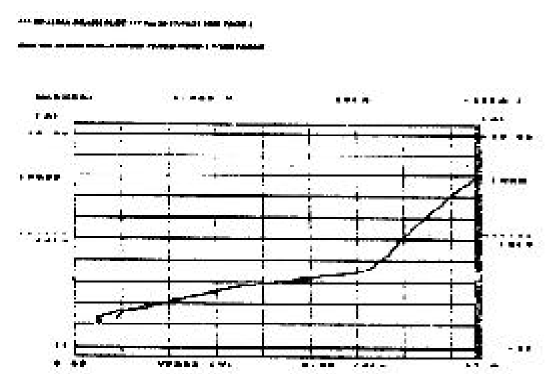

Fig 8C. Good probe, no data offset.

Equipment Listing

The following equipment was used to produce the information in this application note:

Micromanipulator Products:

- Model 8860 semi-automatic probe station
- Model 79-8000 probe holders with various series 7 probe tips
- Model H1000 thermal chuck
- Model 8800-DRYSHIELD integrated dry and shielded environment
- Model 8800-LTE Light Tight Enclosure
- Model 8800-DRY-V1 air dryer

Hewlett Packard:

- Model 4156 Parametric Test System