TECH NOTE

Triboelectric Effects in High Precision Temperature Measurements

PURPOSE

This tech note discusses triboelectric effects in high precision temperature measurements using the ILX LDT-5900 Series Temperature Controllers. We will demonstrate that triboelectric currents can be great enough to throw the measurement accuracy out of specification.

BACKGROUND

Triboelectric currents are generated when two dissimilar materials, usually a conductor and an insulator, rub against each other and transfer electrical charges. These currents are nearly always present, but the effect is seldom great enough to cause concern. When the signals are very small however, triboelectric effects can influence measurement accuracy and stability.

The LDT-5900 uses a thermistor to sense the load temperature at 10 µA or 100 µA depending on the load temperature range. An analog-to-digital (A/D) converter measures the voltage drop across the thermistor, and converts that voltage to a resistance value.

To achieve measurement accuracy, the input voltage to the thermistor A/D must be stable within 0.2 mV. A thermistor operating at a room temperature of 25^{o}C has a resistance of about 10kΩ. Using Ohm's Law, we can determine the thermistor excitation current stability must be better than 20 nA.

$I = V / R = 0.2\ mV / 10k\Omega = 20\ nA$

If the excitation current instability is greater than 20 nA, the voltage measured across the resistor will vary enough to impact measurement accuracy.

MEASUREMENT SETUP

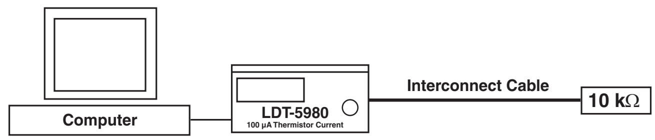

FIGURE 1 – Experiment Setup

Figure 1 shows the setup used to measure triboelectric current effects with the LDT-5900 Series and a standard ILX CC-595H interconnect cable. Three experiments were conducted with this simple setup:

1. Resistor connected to the end of the cable, and the cable recently unrolled.
2. Resistor connected directly to the instrument back panel.
3. Resistor connected to the cable and secured to the lab bench for 48 hours before the starting the experiment.

RESULTS

Figure 2 shows the data from the first experiment. The 6' interconnect cable was connected to the LDT-5980, and a low temp 10kΩ resistor connected to the thermistor sense pins. The cable was laid out on the bench as the experiement was started, and the resistance measurement recorded overnight.

The apparent resistance measurement instability is 3W. The resistance at 10 kΩ, and the thermistor drive current supplied by the LDT-5900 Series are both stable. Therefore, the variation measured by the A/D must be caused by the triboelectric current generated in the cable.

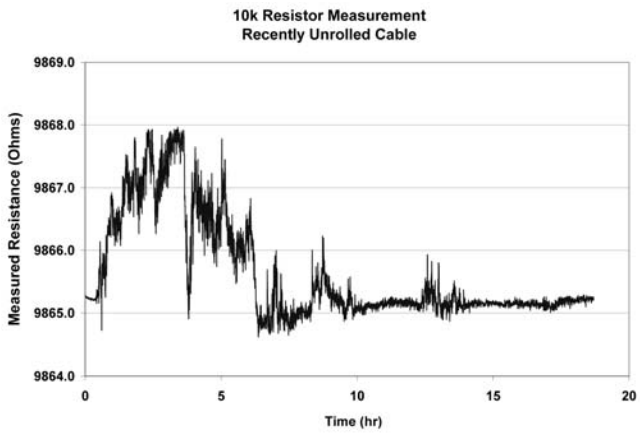

FIGURE 2 – Triboelectric Current Effect

The triboelectric current can be calcuated using a simple two-step procedure. First, calculate the voltage variation that is measured by the A/D converter:

Voltage Variation = I_{therm} * $R_{variation}$ = 100 µA * 3Ω = 300 µV

Next, divide the voltage instability by the thermistor nominal resistance, which is known to be stable at approximately 10 kΩ:

Triboelectric Current = $V_{variation}$ / $R_{nominal}$ = 300 µV / 10 kΩ = 30 nA

After 14 hours, the cable is fully relaxed and the triboelectric current subsides. Using the same method as above, we can calculate that the apparent current instability is approximately 2.5 nA.

Figure 3 shows the results of experiment #2, with the low temp resistor attached directly to the instrument back panel instead of the cable. In this case, the equivalent current instability is approximately 0.9 nA. This illustrates an ideal case where triboelectric effects are no present because there is no cable.

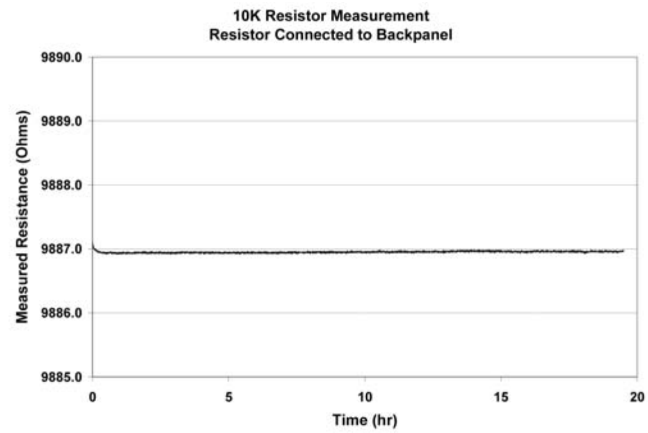

FIGURE 3 – Resistor only Measurement Stability

Finally, Figure 4 shows the results of experiment 3, which the resistor attached to the end of the cable and the cable secured to the lab bench. The setup was left undisturbed for two days before the experiment began so the cable was fully relaxed and most of the trioelectric currents eliminated. The current instability is 1 nA over the full 16 hour test.

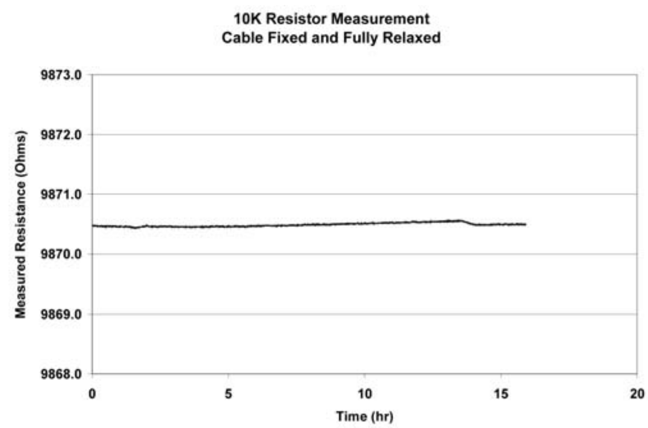

FIGURE 4 – Instability with Cable Secured

Table 1 Experiment Results

	Triboelectric Current Instability	Apparent Resistance Instability	Equivalent Temperature Instability at 25°C	Equivalent Temperature Instability at 70°C
Experiment 1 Cable Unstable	30 nA	3 Ω	0.0075°C	0.06°C
Experiment 1 Cable Relaxed	2.5 nA	0.25 Ω	0.00063°C	0.005°C
Experiment 2 No Cable	0.9 nA	0.09 Ω	0.00023°C	0.0018°C
Experiment 3 Cable Fixed	1 nA	0.1 Ω	0.00025°C	0.002°C

Table 1 presents the results of these three experiments, and includes the equivalent temperature instability that would be displayed by the LDT-5980 at two operating temperatures.

CONCLUSION

The measurement accuracy specification for the LDT-5980 is ±0.05°C in the 100 μA setting. If the cable is still settling, triboelectric currents can cause the measurement uncertainty to increase to the point that the instrument is apparently out of specification (Experiment 1). Securing the cable and allowing 48 hours for it to relax will substantially reduce triboelectric current effects (Experiment 3) and increase measurement accuracy and stability.