MEASUREMENT TIPS
Volume 1, Number 1

Making Good Thermocouple Measurements in Noisy Environments

Temperature measurements are an important part of product characterization, whether you are developing or verifying a design or you are qualifying products during production test. Often, you need to make your temperature measurements in environments with high levels of electrical noise. Devices under test, such as small gas-powered engines, compressors, fans, motors, etc. actually generate their own electrical noise. Rotating machinery, high-voltage-discharge devices such as spark plugs, distributors and arcing on relay contacts all contribute to the noisy environment. In addition, high AC line voltages may be present and in close proximity to the devices you are testing. Making good measurements in a hostile, noisy environment can be a challenge, especially when the voltages you are measuring are small, as is the case if you are using thermocouples.

TESTING IN A NOISY ENVIRONMENT

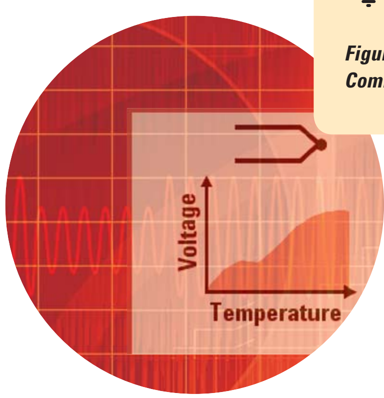
Snapshot: Small Engine Test

A manufacturer of small gas-powered engines was setting up a test cell to monitor the performance of its engines under a variety of conditions. Engineers were monitoring many parameters, including fuel flow, rpm, torque, combustion pressure, head and exhaust temperature, etc. Initially, their temperature measurements were erratic. Upon examination, they uncovered three culprits. First, the thermocouples were mechanically mounted to the engine, which caused a ground loop. Second, no shielding was used on the various wiring runs, so electrostatic noise was coupled into the thermocouples. Third, in an effort to make everything "look neat," all the wiring was bundled together and secured with tie wraps. Isolating the thermocouples from ground, using twisted shielded pair, and separating the thermocouples from the power line runs cured the problem.

Thermocouple measurements

Thermocouples are commonly used to measure temperature; they are rugged, inexpensive, and cover a wide temperature range. However, they also produce voltages in the millivolt range, with microvolt changes per degree C temperature change. Modern data loggers such as those manufactured by Agilent hide the complexity of measuring thermocouples. Typically, you connect a thermocouple to the data logger, set the type of thermocouple you are using, and the instrument will return the results in degrees C.

A thermocouple consists of two dissimilar metals joined at one end, preferably by welding. As this junction is heated, a non-linear voltage corresponding to the temperature is generated across the leads of the thermocouple. This voltage is very low, just over 50 µV at 0 °C for a J-type thermocouple. Further, thermocouples don't change much with temperature: J-type thermocouples change on the order of 5 µV per degree C. A good measuring device is required to measure these small voltages and resolve the small changes in voltage. A little bit of noise can have a large impact on the measurement.



Noise sources

There are many sources of noise that can affect thermocouple measurements. The three most common sources of noise are:

1. Ground loops, which generate **common mode noise**
2. Electromagnetic fields, which generate **normal mode noise**
3. Rotating equipment, which generate **electrostatic noise**

1. Common mode noise creates an unwanted voltage that is present on both leads of the thermocouple. Typically, common mode noise is caused by a ground loop that is created when a system has a potential difference between two grounds. Because the tip of a thermocouple is a bare wire junction, it is at risk to create a ground loop. If the tip is grounded where it is measuring temperature, and that ground is at a different potential from the ground at the measuring end of the thermocouple, a ground loop is formed and current will flow.

MEASUREMENT TIP

The best way to avoid a ground loop is to avoid grounding the tip of the thermocouple, using isolated thermocouples when necessary. Common mode errors are also reduced by using a DMM with high impedance to ground, such as those used in the Agilent 34970A and 34980A data acquisition systems.

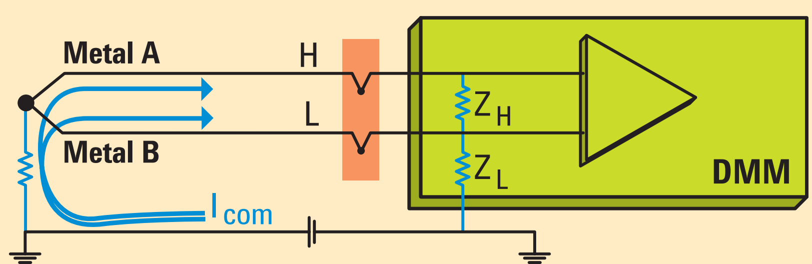


Figure 1:
Common mode noise is generated by ground loops.

2. Normal mode noise creates a current that flows in the same direction as the measurement current. This type of noise is typically caused by large AC current sources, such as AC power lines, that create a magnetic field. In turn, the magnetic field creates a current in the measurement path. High-current devices include motors, lights, and power mains. Normal mode noise is typically at line frequency of 50/60 Hz. The normal mode error current is proportional to the strength of the field, the size of the loop, and the orientation of the loop to the field.

MEASUREMENT TIPS

- Reduce the field strength interfering with the measurement. It is better to run more wire and avoid the field than run the thermocouple wire through the field.
- Minimize the size of the measurement loop. Use twisted-pair cabling, which leaves little room between the cables. It's like making a smaller receiving antenna.
- Run the measurement wires perpendicular to high-current wires, changing the orientation to the field. Never run thermocouples in parallel with power lines or other noisy signals.
- Filtering can be used to reduce normal mode currents. A relatively simple filter can reduce the normal mode noise on a DC signal by several orders of magnitude.
- Normal mode noise is typically the same frequency as the line frequency, which is also described as a power line cycle or PLC. An integrating A/D will return the average voltage during the integration period. If you integrate over the same period as the line frequency or PLC, the average value of the normal mode noise will be zero.
- Another advantage of the integrating A/D is that you can trade speed for reading rate. For 60 Hz line frequency, 60 readings per second can be achieved using 1 PLC; only 6 readings per second can be achieved using 10 PLCs. The slower reading will have better resolution and better noise rejection.

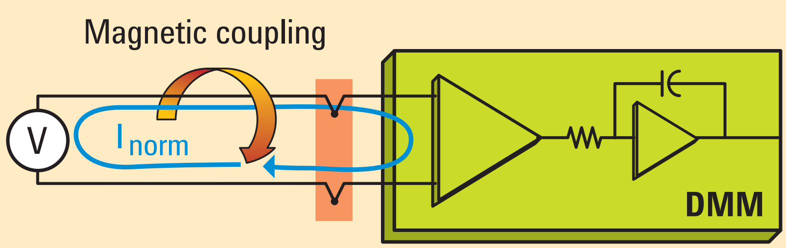


Figure 2:
Magnetic flux or RF energy are common sources of normal mode noise.

Learn more about the Agilent 34970A data acquisition/switch unit at
www.agilent.com/find/34970A

Learn more about the Agilent 34980A multifunction switch measure unit at
www.agilent.com/find/34980A

3. Electrostatic noise is coupled into the measurement path via stray capacitance. Electrostatic noise is caused by rotating equipment; it's generates an AC current that is capacitance-coupled into the measurement path. Stray capacitance can couple electrostatic noise through the tip of a thermocouple.

MEASUREMENT TIP

To combat electrostatic noise, use shielded wiring. Also, using a DMM with high impedance to ground will help. When using a shield to prevent electrostatic noise coupling, only ground one end of the shield to avoid creating a ground loop.

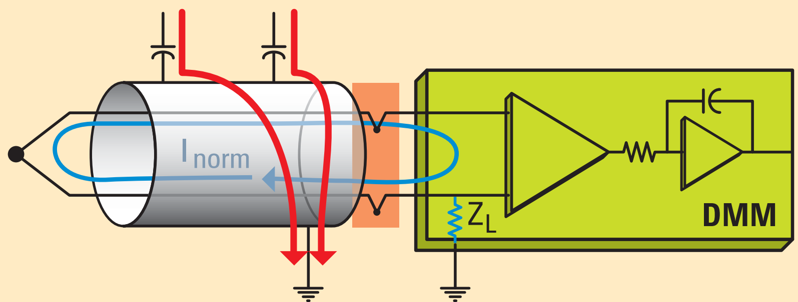


Figure 3:
Stray capacitance can couple electrostatic noise through a thermocouple.

Summary

We have discussed three sources of noise that can affect thermocouple measurements and have described several ways to eliminate or minimize the noise:

- **Common mode noise** – typically generated by ground loops. Avoid ground loops to minimize the effect of common mode noise.
- **Normal mode noise** – created by running the measurement loop through a magnetic field. Use twisted shielded pair to minimize the exposure to the magnetic field, avoid the fields altogether, use a filter, and select the integration period of the A/D to minimize the impact of normal mode noise
- **Electrostatic noise** – coupled into the measurement via stray capacitance. Use shielded twisted pair and ground one end of the shield to minimize the capacitive coupling to the thermocouple

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