

Ask the Applications Engineer—27

By Bill Englemann

SIGNAL CORRUPTION IN INDUSTRIAL MEASUREMENT

Q. *What problems am I most likely to run into when instrumenting an industrial system?*

A. The five kinds of problems most frequently reported by customers of our *I/O Subsystems (IOS) Division* are:

1. GROUND LOOPS

Ground loops are the bane of instrumentation engineers and technicians. They cause many lost hours troubleshooting obscure and hard-to-diagnose measurement problems. Do these symptoms sound familiar?

- Readings slowly drift even though you know the sensor is not changing.
- Readings shift when another piece of equipment is turned on.
- Measurements differ when a calibration device is connected at the end of an instrument cable instead of directly at the input.
- A 60-Hz sine wave is superimposed upon your dc measurement input.
- There are unexplained measurement equipment failures.

Any of these problems can be caused by ground loops— inadvertent flows of current through “ground,” “common” and “reference” paths connected to points at nominally the same potential. And all of these problems can be eliminated by *isolation*, the key signal-conditioning attribute we offer in all our signal conditioning series.

Sometimes separate grounding of two pieces of equipment introduces a potential difference and causes current to flow through signal lines. Why would this happen if they were both grounded? Because the earth and metal structures are actually relatively poor conductors of electricity when compared with the copper wires that carry power and signals. This inherent resistance to current flow varies with the weather and time of year and causes current to flow through any wires that are connecting the two devices. Many factory and plant buildings experience potentials of several tens or hundreds of volts. Appropriate signal conditioning eliminates the possibility of ground loops by electrically *isolating* the equipment. Signal conditioning will also protect equipment, rejecting potentially damaging voltage levels before entering the sensitive measurement system.

Isolation provides a completely floating input and output port, where there is no electrical path from field input to output and to power. Hence, there is no path for current to flow, and no possibility of ground loops.

Q. *How is this possible? How can we provide a path for the signal from input to output, without any path for current to flow?*

A. It's done by magnetic isolation. A representation of the signal is passed through a transformer, which creates a magnetic—not a galvanic—connection. We have perfected the use of transformers for accurate, reliable low-level signal isolation. This approach employs a modulator and demodulator to transmit the signal across the transformer barrier, and can achieve isolation levels of 2500 volts ac.

One of the most frequently encountered application problems involves measuring a low-level sensor such as a thermocouple in the presence of as much as hundreds of volts of ground potential. This potential is known as *common-mode voltage*. The ability of a high-quality signal conditioner to reject errors caused by common-mode voltage, while still accurately amplifying low-level signals is known as *common mode rejection (CMR)*. Our *5B*, *6B* and *7B* Series signal conditioning subsystems provide sufficient common-mode rejection to reduce the impact of these errors by a factor of 100 million to 1!

2. MISWIRING AND OVERVOLTAGE

You know what happens when a cable from a sensitive data acquisition board is routed into another cabinet, or another part of the building—the input and output wiring terminals are grouped among hundreds of other terminals carrying diverse signals and levels: dc signals, ac signals, milli-voltage, thermocouples, dc power, ac power, proximity switches, relay circuits, etc. It's not difficult to imagine even a well trained technician or electrician connecting a wire to the wrong terminal. Wiring diagrams are often updated in real time with a red pen, as system needs change. Equipment gets replaced with “equivalents.” Sometimes power supplies fail and excess voltages are applied inadvertently. What can you do to protect your measurement system?

The answer lies in using rugged signal conditioning on every analog signal lead. This inexpensive insurance policy provides protection against miswiring and overvoltage on each input and output signal line. For example, the use of a *5B Series* signal conditioner will provide 240 -V ac of protection, even on input lines used to measure sensitive thermocouple signals, with levels in the millivolt range. You can literally connect a 240-V ac line across the same input lines used to measure the thermocouple, without any damage. The use of signal conditioning to interface with field I/O will protect all measurement and data acquisition equipment on the system side.

3. LOSS OF RESOLUTION

Resolution is the smallest change in the measurement that the analog-digital converter (ADC) system can detect and respond to. For example, if a temperature reading steps from 100.00° to 100.29° to 100.58°, as the actual temperature gradually increases through this range, the resolution (least-significant-bit value) is 0.29°. This would occur if you had a signal conditioner measuring a thermocouple with a range of 0° to +1200° and a 12-bit ADC. There are two ways to improve this (make the resolution smaller) and detect smaller changes - use a higher resolution ADC or use a smaller measurement range.

For example, a 15-bit plus sign ADC of the type used in our *6B Series* would offer resolution of 0.037° on the 0 to 1200° range example, 8 times smaller! On the other hand, if you knew that most of the time the temperature would be in the vicinity of 100°, you could order from Analog Devices a thermocouple signal conditioner with a custom range, calibrated for the exact thermocouple type and temperature measurement range. For example, a custom-ranged signal conditioner with a span of +50° to +150° would offer resolution of 0.024° with a 12-bit ADC, a big improvement over the 0 to 1200° range.

4. MULTIPLE SIGNALS DON'T ALL HAVE THE SAME PROPERTIES

This can pose quite a challenge to traditional industrial measurement approaches where 4, 8 or even 16 channels are dedicated to interfacing to the same signal type. For example, let's say you need to measure two J thermocouples, one 0 to +10 V signal, four 4-20 mA signals and two platinum RTDs (resistance temperature detector). You can either buy individual transmitters for each channel and then wire them all into a common 4-20 mA input board, or use a signal conditioning solution from Analog Devices that is configured channel-by-channel, but is also integrated into a simple backplane subsystem.

These subsystems incorporate all connections for input, output and field wiring, as well as simple connections for a dc power supply. They offer a choice of output options: 0 to +5 V, 0 to +10 V, 4-20 mA and RS-232/485, and more! Input and output modules are mix-and-match compatible on a per-channel basis and hot-swappable for the ultimate flexibility.

5. ELECTRICAL INTERFERENCE

Today's industrial factories and plants contain all kinds of interference sources: engines and motors, fluorescent lights, two-way radios, generators, etc. Each of these can radiate electro-magnetic noise that can be picked up by wiring, circuit boards and measurement modules. Even with the best shielding and grounding practices, this interference can show up as noise on the signal measurement. How can this be eliminated? By providing high noise rejection in the signal conditioning subsystem.

Lower-frequency noise can be eliminated by choosing signal-conditioning subsystems with excellent common mode and normal mode rejection. Common mode noise present on both the plus and minus inputs can be seen when measuring either the plus or minus input with respect to a common point like ground. Normal-mode noise is measured in the difference between the plus and minus inputs. A typical common mode rejection specification on our signal conditioning subsystems is 160 dB. This log scale measurement means that the effect of

any common mode voltage noise is reduced relative to signal by a factor of 10^8 , or 100 million to 1!

Very high frequency noise in the radio frequency bands can cause dc offsets due to rectification. It requires other approaches, including careful circuit layout and the use of RFI filters such as ferrite beads. The performance measures are indicated by our compliance with the EN certifications for electromagnetic susceptibility popularized by the CE mark requirements of the European community. A typical application where this is important would be where a two-way radio is used within a few feet of the input wiring and signal conditioning subsystem. It is necessary to reject measurement errors whenever the radios are transmitting. Good panel layout practice and the use of signal conditioning will ensure the best accuracy in these noisy environments.

CONCLUSION

Q. What are some good installation and wiring practices?

A. Here are a few suggestions. You may also want to take a look at "Design Tools" and the Analog Devices book, *Practical Analog Design Techniques*, available for sale in hard copy and free on the Web.

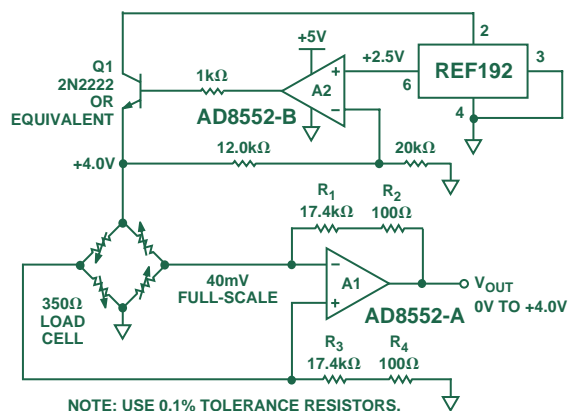
- Avoid installing sensitive measuring equipment, or wire carrying low level signals, near sources of electrical and magnetic noise, such as breakers, transformers, motors, SCR drives, welders, fluorescent lamp controllers, or relays.
- Use twisted pair wiring to reduce magnetic noise pickup. Look for 10 to 12 twists per foot.
- Use shielded cable with the shield connected to circuit common at the input end only.
- Never run signal-carrying wires in the same conduit that carries power lines, relay contact leads or other high-level voltages or currents.
- In extremely high interference environments, mount signal conditioning and measurement equipment inside grounded and closed metal cabinets. ▶

New-Product Brief

AMPLIFIERS

Zero-Drift, Single-Supply, Rail-to-Rail Input/Output Operational Amplifiers

The AD8551, AD8552, and AD8554 are single, dual, and quad high-accuracy op amps, featuring 1 μ V offset voltage, 5 nV/ $^{\circ}$ C drift, 130 dB PSRR, 140 dB CMRR, 145 dB Voltage Gain, and 10 pA bias current. They operate on a single 2.7- to 5-V supply and draw only 750 μ A per amplifier. With 20-bit accuracy, the AD855X is perfectly suited for the most demanding applications in medical, industrial and automotive instrumentation, battery management and a wide range of temperature, current, voltage, pressure and other sensor applications. They are packaged in 8 or 14 lead MSOP, TSSOP, and SOIC packages, and operate over the -40° C to $+125^{\circ}$ C temperature range. Price (1000s) for the singles/duals/quads is \$1.14/\$2.11/\$4.05.



A +5 V Precision Strain-Gage Amplifier