Tips for better strain-gage measurements

Dan Romanchik - June 10, 2002

The strain gage is one of the most common sensors used in automotive tests. Automotive test engineers use strain gages in materials test, durability tests, aerodynamics tests, and powertrain tests to measure load, pressure, and flow as well as strain. Being able to make accurate strain-gage measurements, therefore, is one key to delivering good test results.

With that in mind, I canvassed several industry experts for advice on how to install, connect, and make measurements with strain gages. Here’s what they had to say:

1. **Select a sensor with more capacity than you need.** According to Javad Mokhbery, president and chief technical officer of Futek Advanced Sensor Technology, (Irvine, CA), many test engineers do not take into account the extraneous load, moment, and fatigue life factors when selecting strain gages. The result is that the sensor fails earlier than it should.

Mokhbery says, “Do not compromise the extraneous load moment and duty cycle requirements in order to use a sensor with a smaller package or higher resolution. This will only cause the sensor to fail early. If you choose a sensor with double or triple the capacity you need, you’ll extend the life of the sensor and your test system will be much more reliable.”

2. **Configure your data-acquisition board for bipolar and differential readings.** Figure 1 shows a typical strain gage with four elements connected in a Wheatstone bridge configuration. Because the output from the Wheatstone bridge is a bipolar signal, Tom Barkis, an application engineer for Keithley, advises that you configure the input to which you connect the strain gage to accept bipolar, differential signals.

Barkis notes that a Wheatstone bridge is really two parallel voltage divider circuits coupled to one voltage source, and the output signal is the difference between the voltage dividers. In Figure 1, if all four resistors are equal in value, and the voltage source is a unipolar 10-VDC supply, then VA and VB will both be 5 VDC, and the difference will be 0. Note, however, that if the reference point is 0 V, then the voltage at the input of the data-acquisition board will be 5 VDC referenced to ground. A gain of only 2 will generate a full-scale reading.

This is a problem because the output of the strain gage is so low—approximately ±10 mV full scale. To achieve optimum signal resolution, you need to amplify the output by much more than a factor of 2. A gain of 1000, for example will amplify the output to ±10 V, a typical full-scale range for many data-acquisition boards.

The solution is to use a bipolar excitation voltage of ±10 V. When using this type of supply, the difference voltage will be zero and the offset from ground will also be zero. The data-acquisition board can now amplify the signal with high gain and not drive the signal past the full-scale reading of the board.
3. Use bridge-completion resistors that are accurate and stable. While a strain gage with four elements gives the highest output, strain gages are also available with one or two variable elements. When using a one-element or two-element strain gage, make sure that the elements that are not strain gages (also called bridge completion resistors) have the same accuracy and stability as the strain-gage elements.

4. Monitor sensor output during installation. According to Mokhbery of Futek, one of the most common causes of strain-gage damage is mishandling during installation. He therefore recommends that you monitor the sensor output during installation by connecting it to the data-acquisition board or system.

"Let the sensor talk to you at all times," he says. "Doing so will help you avoid overloading the sensor, which could damage it, and will also minimize zero distortion after installation."

5. Knock out noise. Like all sensors, strain gages must minimize noise pickup to yield accurate results. The output of a strain gage is on the order of a few millivolts per volt of excitation, which means high-resolution measurement systems make measurements on the order of microvolts per count. It doesn’t take much noise to compromise these measurements.

Rachel D. Mullin, an application engineer for Futek, explains how you can protect your sensors from a noisy environment:

• **Choose low-resistance cables.** Lower resistance cables provide more protection against noise.

• **Use shielded cables.** A braided shield provides more protection than a spiral or drain-wire shield.

• **Ground cable shields.** Mullin advises users to ground shields on the instrument side. If you must ground the shield at the sensor, make sure the sensor is not grounded to avoid ground loops.

• **Enclose your system in a metal box.** If the system environment is very noisy, enclosing the system in a metal enclosure that provides magnetic shielding will reduce the effect of that noise.

6. Compensate for ambient temperature changes. According to Brian Betts, data acquisition product manager for National Instruments (Austin, TX), a varying ambient temperature is the most common cause of strain measurement error. Because ambient temperatures often change during a typical automotive test, you must compensate for that temperature change to ensure accurate measurements.

Ideally, the resistance of the strain gage should change only in response to applied strain, but as is the case with all conductive materials, the resistance of strain gages also changes with temperature. Temperature changes also make your measurements less accurate by affecting lead wire resistance.

Measuring the temperature and using a correction curve to correct the data can compensate for this sensitivity to temperature. Manufacturers often supply fourth-order polynomial coefficients to perform this compensation. You can find this information on the sensor’s data sheet. With these coefficients, you can make temperature corrections in software. You can fully automate this process by using a data-acquisition software package with custom scaling capability.

7. Use short leads or remote sensing to minimize voltage drop. Betts also notes that long leads can cause strain-gage measurement errors. The source of the errors is the voltage drop that occurs when the sense leads must also carry the excitation current. This voltage drop may be small, but because the full scale output of the strain gage is on the order of millivolts, it could be significant.
If your application requires you to use long leads, you’ll need a data-acquisition board or system that has remote sensing. Systems that have this feature use four wires to connect to the strain gage. Two wires connect the voltage supply to the strain gage and carry the excitation current, while the other two—called the sense wires—connect to the high-impedance data-acquisition input. The sense wires carry very little current, so the voltage drop—and the measurement error—is very low.

8. **Don’t overlook ground leakage.** According to Bob Magee, an application engineer for HBM, leakage to ground can cause measurement errors during dynamic tests. Such leakage can occur if you use the wrong protective coating or if the coating breaks down.

When the coating breaks down, moisture or residual flux gets trapped between the strain gage and the test specimen, which decreases the insulation resistance. If the test specimen is conductive, the flux or moisture will form a path to ground and cause measurement errors.

To check for leakage, always use a megohm meter that applies a test voltage of less than 50 V to avoid damaging the strain gage. The insulation resistance should be at least 5000 MV, and preferably 20,000 MV. If the insulation resistance is low, you need to remove the protective coating and carefully clean and dry the strain gage. Before you re-apply the coating, check the insulation resistance again.

9. **Watch out for self-heating.** Self-heating of the strain gage can be a source of error when you mount the gage such that insufficient thermal mass exists to keep the gage cool. One solution, Barkis suggests, is to apply the excitation, wait for the reading to stabilize, take the measurement, and then remove the excitation. This will keep self-heating to a minimum.

10. **Use a clean supply.** The bipolar supply needs to be clean, with as little ripple as possible. For this reason, Barkis says, you shouldn’t use the bipolar voltages from the PC bus, even though they are easily accessible. Some data-acquisition boards will have bipolar supplies designed specifically for exciting strain gages and other transducers. These supplies are certainly better than the PC’s supplies, but the cleanest supply to use for excitation voltage is a battery. Batteries are extremely quiet, although keeping them charged can be a problem. You certainly don’t want the battery to run down during a test run.

By following these tips for making strain-gage measurements, you can improve the accuracy of your measurements and thereby increase the effectiveness of your tests.

**For more information**


“Application of Strain Gage,” University of Colorado. [bechtel.colorado.edu/courseware/matlab/tension/application.html](http://bechtel.colorado.edu/courseware/matlab/tension/application.html).

“Strain Measurement,” Structural Dynamics Research Laboratory, University of Cincinnati. [www.sdrl.uc.edu/virtual/meas/strain/strain.html](http://www.sdrl.uc.edu/virtual/meas/strain/strain.html).