Miswiring piezoresistive accelerometers and pressure transducers

Technical Paper 341

By Bruce Lent

Because of the fine gage wiring used and the multitude of wires (4 – 6), connection errors can be a problem with piezoresistive accelerometers and pressure transducers. Connecting wires to the wrong pins or solder bridges between connector pins are the most common wiring errors.

While pressure transducers and accelerometers measure different physical events, they both utilize Wheatstone bridge circuits. This paper is centered on the Endevco 8500 series of pressure transducers and the 7200 series of piezoresistive accelerometers.

The basic circuit

The basic circuit utilized is a Wheatstone bridge. The pressure transducers use a full bridge configuration. The accelerometers use a half bridge with two bridge completion resistors making them appear as a full bridge to the external electronics.

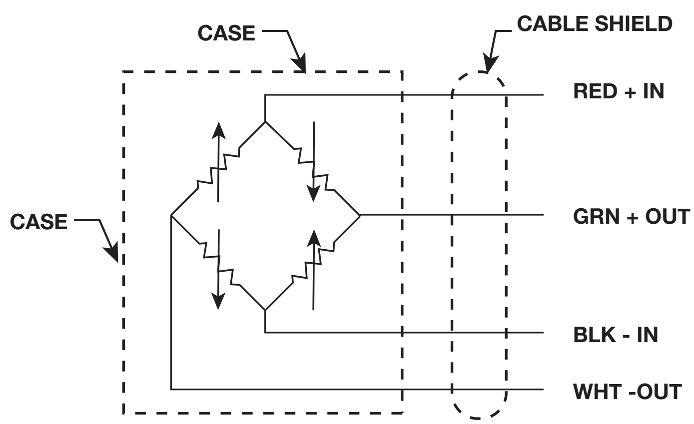

Figure 1: Full bridge pressure transducer with four active bridge arms

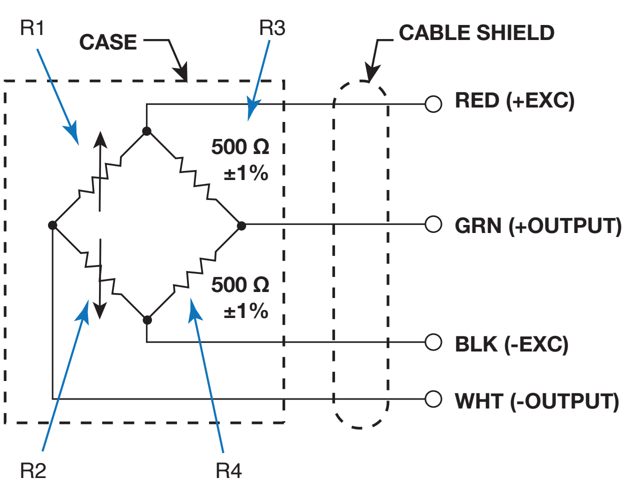

Figure 2: Half bridge configuration used on piezoresistive accelerometers. Note two active arms and two bridge completion resistors.

Endevco products follow the industry standard for wire colors, however one should confirm the color codes when using non-Endevco products. (Red is + excitation, black for - excitation, green for + signal output and white for – signal output).

Wiring error examples:

This section will discuss making the wrong connections and the result.

Application of the excitation voltage between a single-arm of the bridge resulting in a configuration shown in figure 3.

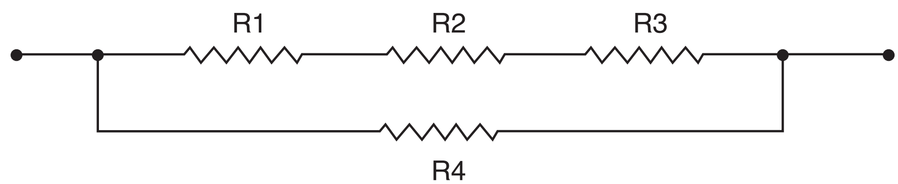

Figure 3: Equivalent circuit when excitation voltage is improperly connected between the white and black leads or red and green leads.

All resistors (including the active arms) are assumed to be 500 Ω each. Therefore:

$$Rs = R1 + R2 + R3 = 1500\ \Omega$$

$$Rt = \frac{Rs\ \ R4}{Rs + R4}$$

$$Rt = \frac{1500 \times 500}{1500 + 1500} = 380\ \Omega$$

If the power were applied (10 VDC) to the correct leads, red and black, resistance (Rt) would be approximately 500 Ω resulting in a current of approximately 20 mA. If the power is applied between the black and white leads, the resistance is approximately 380 Ω (per the above equation) resulting in a higher current of 26 mA. Furthermore, most of the current (20 mA) is flowing thru R4 (see figure 3). This is problematic since four resistors, when wired correctly, share the current flow and, when wired incorrectly, only one resistor carries most of the current.

Other factors that can contribute to the damage caused by miswiring include the time duration of the voltage applied, ambient temperature, mounting, etc. When power is applied, the resistors will heat-up and, if the piezoresistor over-heats, the PN junction can be destroyed. If the accelerometer is not mounted, it is more susceptible to thermal damage than if it were mounted on an aluminum plate. It can also be seen that if power is applied for a few seconds or a few hours, the results may differ. In the above example, there is little doubt that there is potential for damage.

Prior to placing the transducer into service, the wiring error needs to be corrected and one or all of the below "trouble shooting" procedures below should be followed.

Trouble shooting

If a bridge sensor is damaged in some way either by miswiring to an excitation source or by overstressing it (subjected to too large of an acceleration level or pressure level), there are a number of simple troubleshooting steps to take to determine the condition of the sensor.

The first step is to locate the applicable calibration certificate for the unit in question. The certificate provides vital information needed for trouble shooting. The necessary parameters include:

Zero Measurand Output (ZMO)

Input resistance

Output resistance

Sensitivity

Once the calibration certificate is located, there are simple measurements the user can make to determine the condition of the transducer.

1. Measure input and output resistance

Input resistance is the resistance measured across the excitation legs from +EXC to –EXC (red and black wires). Output resistance is the resistance across the output legs from +Output to –Output (green and white wires). Input and output resistances are specified to be within certain tolerances. For example, the input resistance for the model 7264B should be within 300 to 900 Ω. If your sensor measures outside these specifications, there is reason to suspect your sensor has been damaged. Further, the original calibration certificate that came with the sensor contains the actual input and output resistances. Field measurements will not exactly match these original numbers. If later measurements deviate significantly, there is also reason to suspect damage to the sensor.

2. Measure ZMO

ZMO was measured and recorded on the original calibration certificate that came with the sensor. This measurement is made carefully and precisely at the factory since it is the output from the sensor at zero acceleration. Although these conditions cannot be duplicated in the field, it is worthwhile to measure the output of your sensor while subjecting it to as close to zero acceleration as possible for troubleshooting purposes. In the case of an accelerometer, this can be approximated by turning the sensor on to its side (sensitive axis parallel to level ground). The accelerometer is then oriented 90° to gravity and subjected to approximately zero acceleration. The voltage measured should be relatively close to the ZMO voltage value recorded on the calibration certificate. If the value has significantly deviated, again there is reason to suspect the sensor has been damaged.

3. Turn-over test

Piezoresistive accelerometers are DC responding, thus they can measure the acceleration due to gravity. This characteristic can be utilized for a quick check of the accelerometer's sensitivity for troubleshooting purposes. Orient the sensor flat to level ground (sensitive axis is parallel to level ground). Assuming the sensor has a nominal sensitivity of 0.20 mV/g (for a 2000 g full scale unit) in this orientation, the sensor's output should read 0.20 mV plus or minus the ZMO (which could be 10's of mV). Now rotate the sensor 180° (turn the sensor over), making sure the sensitive axis is parallel to level ground. The sensor's output should now be reading -0.20 mV plus the ZMO. The value is negative because of the polarity feature of the sensor. Polarity simply means the output of the sensor is positive when exposed to a positive going acceleration and negative when exposed to a negative going acceleration. Subtracting the two values read yields 0.40 mV (ZMO subtracts out). This is the value expected for the 2 g change to which the accelerometer was exposed (positive 1 g to negative 1 g) or doing the math this way: 2 g x 0.20 mV/g = 0.40 mV. If your sensor deviates significantly from this value, it is very likely the sensor has been damaged.

The turn-over test is very effective when testing high sensitivity accelerometers. Low sensitivity accelerometers, as described in the above paragraph, may give ambiguous readings due to noise pick-up.

Open or short?

For purposes of discussion, assume that a connector has been attached to one end of the transducer cable and the power has been applied between the green and black wires (figure 2). There are now three malfunctions that can exist: open resistor, shorted resistor and normal. The most likely condition will be an open resistor caused by excessive current. The truth table below will assist with making a decision as to the suspected condition.

A shorted resistor can also be the result of excessive current flow through one leg of the bridge. The user should inspect the connector looking for a solder bridge, which is a common occurrence. Once the short has been corrected, make the measurements suggested in the trouble shooting section above.

Table 1: Truth table showing the approximate values for an open, shorted arm and a normal functioning bridge. These readings are from a simulated bridge circuit and actual results may vary, however the magnitude of the change is what is important.

Parameter	Normal bridge	Open arm	Shorted arm
Input resistance	500 Ω	1k Ω	512 Ω
Output resistance	1k Ω	1k Ω	343 Ω
Supply current	20 mA	5mA	20mA
ZMO	43 mV	5 Volts	0 Volts

Considerations for pressure transducers

In the case of pressure transducers, the above tests are applicable with the exception of the turnover test, which is not applicable. Below are descriptions of test procedures for gage and absolute pressure transducers.

1. A gage type of pressure transducer ZMO measurement is made the same way as an accelerometer. For example, if the transducer is placed on a laboratory bench, the same pressure level is applied to both the measurement and reference ports (see figure 4). Thus, the output voltage is equal to the ZMO.

Figure 4: A typical 8510B pressure transducer showing the measurement and reference ports

2. An absolute pressure transducer's reference is a vacuum so the output voltage will equal the ambient pressure plus or minus the ZMO. For example:

Given:	Ambient pressure:	14 psi
	Sensitivity:	1.5 mV/psi
	ZMO:	20 mV
Output due to pressure:		14psi X 1.5mV = 21mv
Total output voltage:		ZMO + pressure output
		20mV + 21 mV = 41mv

As can be seen, it is necessary to subtract the pressure output (in mV) from the total output voltage (in mV) leaving a ZMO of 20 mV.

An ounce of prevention

There are actions a user can take to ensure the wiring is correct before placing the sensor into service.

1) Measure the input and output resistance as described above. A common VOM will do the job.

2) If it is necessary to power-up the transducer, use a power supply with an adjustable current limit for testing. The current limit feature is common on most modern bench power supplies. Use the voltage setting equal to the calibration voltage (see the calibration certificate).

3) Inspect wiring. Use a magnifying lamp to inspect the connector wiring. Look for solder bridges, broken wires, and possible cold solder joints. Note the small gauge wires can be easily broken during assembly.

Conclusion

Powering a piezoresistive transducer that has been miswired may or may not cause permanent damage. By performing the tests described in this paper, one can determine the actual condition of the transducer. It is always recommended that wiring be checked as described herein.

www.endevco.com | Tel: +1 (866) ENDEVCO [+1 (866) 363-3826] | 10869 NC-903, Halifax, NC 27839 USA