Piezo-Metrics Featured Article

Generic Null Balance
and Temperature Compensation

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Introduction

If semiconductor strain gages are directly installed into a constant voltage Wheatstone bridge, it is likely that the null balance, i.e. the bridge output at no load, would be non-zero. Also, the bridge output would be very sensitive to any temperature changes the strain gages may experience. To bring the bridge to a near zero output condition at no load and to have the bridge self-compensate for changes in temperature, the bridge can be nulled and compensated using a set of series and shunt resistors in the bridge circuit.

Temperature Compensation Scheme

Figure 1 shows the possible null-balance and temperature compensation resistors which could be added to the basic Wheatstone bridge circuit. The resistors consist of series resistor, RS, and parallel resistor, RP, before the bridge, the RZ1 and RZ4 shunt resistors acting on gages G1 and G4, respectively, and RB2 and RB3 series resistors acting on the left and right branches, respectively, in the bridge. Only one shunt resistor, RZ1 or RZ4, is needed and only one series resistor, RB2 or RB3, is needed.

To wire up the bridge, the RED is connected to the positive source, the BLK and YEL are connected to the negative source, the GRN is connected to the positive signal line and the WHT is connected to the negative signal line.

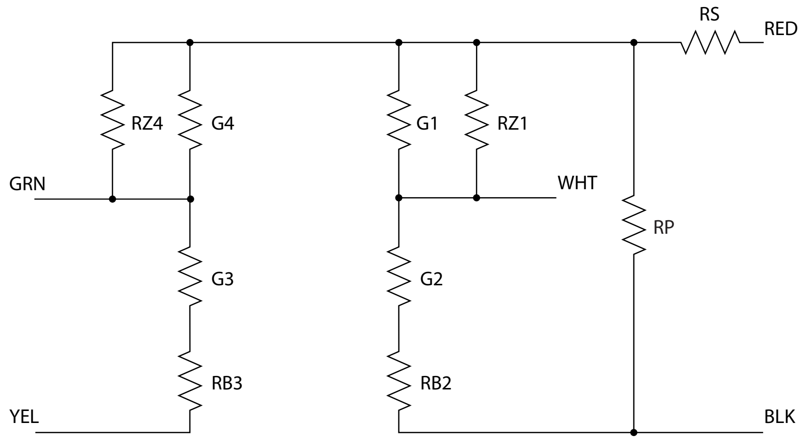

Figure 1: Compensation resistors to achieve null output at zero load and compensation for temperature changes in a constant voltage bridge. Yellow and Black leads are connected together in the final bridge configuration.

It has been found that the temperature coefficient of resistance of Piezo-Metrics gages are quite well matched. This matching means that the gages change resistance with temperature at the same rate. So, in general, no shunt resistor, RZ1 or RZ4, is needed.

Also, it has been found that a RS and RP equal to 1000 or 3000 ohms allows a good degree of temperature compensation to be obtained for strain gage resistances less than 1000 ohms. The null condition can be achieved by selecting the proper series resistor RB2 or RB3.

It should be noted that these values of RS, RP, RZ1, RZ4 and RB2 or RB3 will not scale the bridge output to a desired value. Calibration of the bridge output is found by measuring the bridge output at full-scale load. The calibration factor is in terms of unit load per volt.

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The value of RB2 and RB3 can be calculated using the following equations,

assuming RB2 = 0,
$$RB3 = \frac{RG2 \cdot RG4 - RG1 \cdot RG3}{RG1} \tag{1}$$

assuming RB3 = 0,
$$RB2 = \frac{-RG2 \cdot RG4 - RG1 \cdot RG3}{RG4} \tag{2}$$

where RBn and RGn are resistance values of the series resistor and gage resistance, respectively. The proper series resistor, RB2 or RB3, will be indicated by a positive value for either equation 2 or 3.

The output of the bridge at full load is determined by

$$\frac{e_0}{E_{exc}} = \frac{1}{4}\left(\frac{\Delta R_1}{R} - \frac{\Delta R_2}{R} + \frac{\Delta R_3}{R} - \frac{\Delta R_4}{R}\right) \tag{3}$$

where

e_0 is the bridge output,

E_{exc} is the bridge excitation voltage,

R is the nominal strain gage resistance,

ΔRn is change in resistance of strain gage n.

The power dissipated, *P*, by each strain gage in a standard full-bridge configuration with a nominal resistance of *R* is calculated by

$$P = \frac{1}{4}\frac{E_{exc}^2}{R} \tag{4}$$

The power dissipated by the strain gage should be kept to 5 mW or lower to prevent self-heating.

The relationship between the change in gage resistance and the structural strain is

$$\frac{\Delta R}{R} = GF \cdot \varepsilon \tag{5}$$

where

GF is the gage factor,

ε is the structural strain.

Therefore, the full scale bridge output, e0, is determined by the amplitude of structural strain at full load, the strain gage's gage factor, the positioning of the four strain gages in regions of tension and compression, and the bridge excitation voltage.

The instrumentation used to measure e0 must have sufficient resolution and noise suppression to obtain high signal-to-noise results.

Worked Example

RG1 (ohms)	RG2 (ohms)	RG3 (ohms)	RG4 (ohms)
478.0	487.7	480.2	490.3

Inserting the resistance values of G1 to G4 into equations 1 and 2, RB3 is equal to 20 ohms and RB2 is equal to -19.5 ohms. Therefore, a 20 ohm resistor is needed in the RB3 position.

The final Wheatstone bridge configuration is:

RS = 3000 ohms

RP = 3000 ohms

RZ1 = infinite

RZ3 = infinite

RB2 = 0 ohms

RB3 = 20 ohms

Typically, a 5 VDC excitation voltage is used. For the above bridge configuration where the average gage resistance is 484 ohms and accounting for the RS only as an approximation of the circuit, the excitation voltage across the bridge is 695 mV. The power dissipated by the strain gage is therefore 0.25 mW which will minimize changes in gage resistance due to self-heating.

Contact Us

Piezo-Metrics has worked with innovative companies on optimal selection, placement, and processing of semiconductor strain gages for high frequency, high pressure, and high-temperature applications. If you'd like to discuss your application or design, please contact us for a free, confidential consultation either by email using our **Contact Us Form** or phone **(805-522-4676).**

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As a Principal Scientist at Piezo-Metrics Inc., Franklin applies his knowledge and expertise to the development of innovative, high accuracy and reliable sensors that have wide application to defense, aerospace, medical and industrial sectors. Currently, he's advancing the state-of-the-art in solid propellant sensors as Principal Investigator for the Air Force Research Laboratory, Motor Aging and Surveillance Technology Program.

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