Measuring High Temperature Static Strain

Introduction

Static strain measurements at high temperature are among the most difficult for the test engineer. The basic strain gage cannot distinguish between strain imposed by the intended mechanical process and expansion of the test material due to its temperature coefficient of expansion. This reporting of strain due to thermal expansion is often described as “apparent strain” or “thermal strain”. At moderate temperatures (below 250 °C), temperature compensated strain gages are available which minimize reported strain due to thermal expansion. While three-wire Wheatstone bridge instrumentation is commonly used for these measurements, three sources of measurement uncertainty must be understood and properly managed.

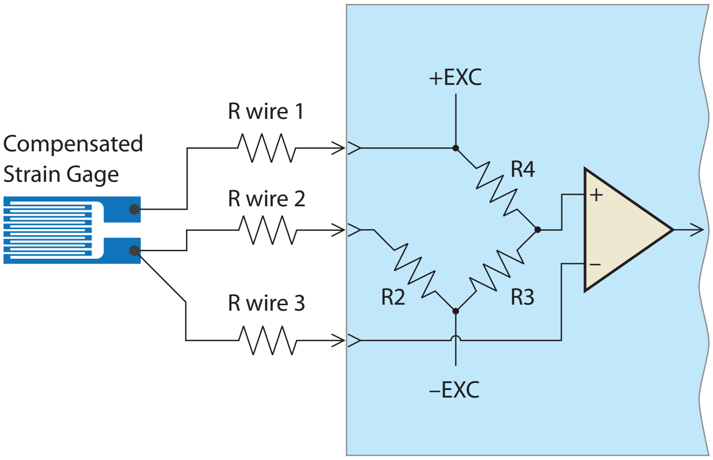

Figure 1: 3-Wire Wheatstone Bridge Connection to a Compensated Strain Gage

Three Sources of Uncertainty for Wheatstone Bridge Measurements

1) Any resistance in the current carrying lead wires (R wire 1 and R wire 2 in Figure 1) causes a decrease in gage sensitivity. While channel gain can be used to compensate for nominal desensitization, extension wire resistance variations with temperature during the test cause multiplicative measurement uncertainty.
2) The 3-wire Wheatstone bridge connection relies on exact temperature coefficient of resistance (TCR) match of the current carrying lead wires (R wire 1 and R wire 2) to maintain bridge balance. Even the slightest thermally induced variability in these wires during a test can create significant DC shift at the output of the bridge. This “zero-shift” error is indistinguishable from mechanical strain of the test article and creates an additive measurement uncertainty.
3) The 3-wire Wheatstone bridge connection is physically and electrically unbalanced and has no rejection of electrostatic noise. To remove the noise pickup for static measurements, the 3-wire connection must be aggressively filtered and therefore cannot be used for simultaneous measurement of static and dynamic signals in a noisy environment.

Best Techniques for Measuring High Temperature Static Strain

4-Wire Kelvin Connection (Best Solution <250°C)

For strain measurement up to approximately 250°C, specially developed temperature compensated strain gages are available for measurement of certain materials. The 4-wire Kelvin connection with Precision Filters proprietary Balanced Constant Current™ (BCC™) excitation is the optimal measurement technique for a temperature compensated strain gage. The use of constant current excitation rather than constant voltage delivers the exact excitation to the active gage regardless of lead wire resistance. Since high impedance sense lines measure only the gage signal, the 4-wire connection totally eliminates gage desensitization and zero shift errors without concern for match characteristics of the 4 lead wires.

With a balanced connection to the gage, the common mode rejection of the amplifier provides a high degree of noise immunity allowing for measurement of both static and dynamic data from a single strain gage.

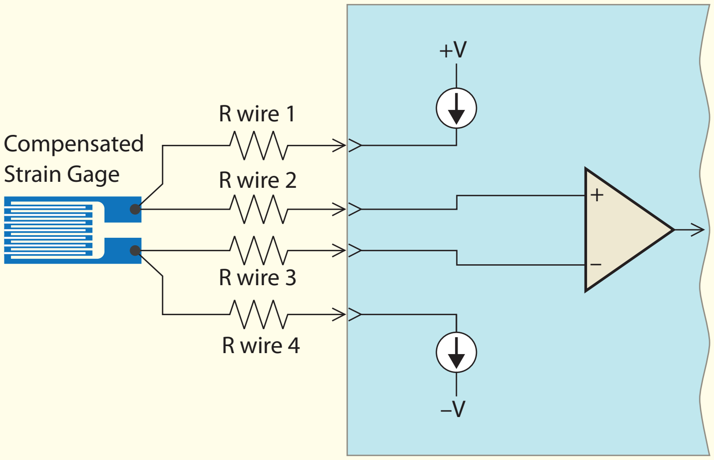

Figure 2: 4 Wire Kelvin BCC Connection to a Compensated Strain Gage

5-Wire Push-Push BCC Connection (Best Solution >250°C)

At higher temperatures above approximately 250°C, temperature compensated strain gages are not available. Apparent strain compensation is achieved via a second compensating gage that is carefully placed so it sees the same thermal environment as the active gage while avoiding strain caused by the mechanical process.

PFI's proprietary Push-Push Balanced Constant Current™ (Push-Push BCC™) is employed to condition the active and compensating gages. Since the compensating gage is exposed to the exact same thermally induced apparent strain as the active gage, the apparent strain portion of the readings are common to the signal conditioner input and are eliminated by the CMR of the differential amplifier. The use of constant current excitation assures exact measurement sensitivity with desensitization due to lead resistance.

Nickel alloy lead wires are used for the strain gage hookup due to their strength and corrosion resistance at these higher temperatures. These alloys have very high resistance that may not be perfectly matched on the two leads that carry the excitation current leading to zero shift. The 5-wire Push-Push BCC connection eliminates zero shift verses lead resistance drift or mismatch by using dedicated leads to deliver the excitation.

It should be noted that the 5-wire half bridge Wheatstone bridge circuit, typically used for this application, is susceptible to noise pickup and must be heavily low-pass filtered in the signal conditioner, preventing its use for dynamic strain measurements. The balanced topology of the Push-Push BCC circuit overcomes this limitation as it is immune to SNR degradation in high noise environments. Both static and dynamic components of the strain are accurately measured using Push-Push BCC.

The Push-Push BCC connection may simplified to 3-wires if the lead wires have matched resistance versus temperature so that a stable zero is maintained. If a ground local to the strain gage is available, then the connection reduces to only 2-wires.

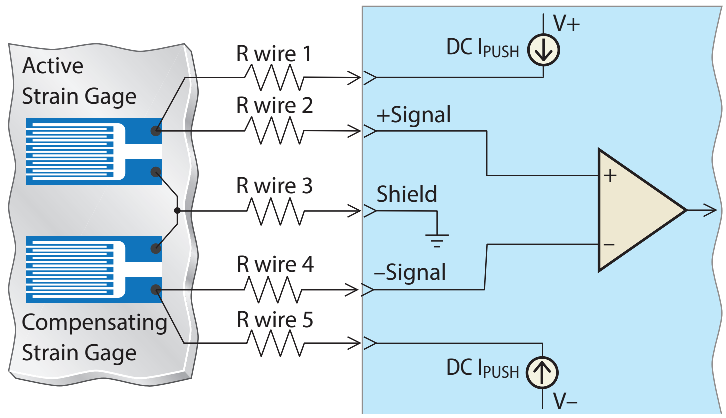

Figure 3: 5-Wire Push-Push BCC Connection

28144 Quad Strain/Bridge Conditioner *with* Voltage & Current Excitation

Whether your test regimen requires 3-wire bridge conditioning, 4-wire Kelvin conditioning, or 5-wire Push-Push BCC conditioning the 28144 Dual Mode Strain/Bridge conditioner meets all requirements with current or voltage excitation, bridge completion, auto balance, and programmable gain and filtering per channel.

- Balanced Constant Current (BCC), Push-Push-BCC Constant voltage excitation
- Programmable gain to x8192
- Programmable 4 or 8-pole filters with cutoffs to 204.6 kHz
- On-the-fly report of measured transducer excitation, resistance, open/short and leakage to ground
- Programmable bridge completion for 120, 350 or 1 kΩ bridges
- 2 to 10-wire interface to the gage

Static Strain Conditioning Turn-Key Systems Scalable to Your Needs

With three fully self-contained chassis systems to choose from, the Precision 28000 Signal Conditioning System is scalable to meet any size static strain measurement task.

64-Channel Static Strain Conditioner

- 28016 chassis with sixteen 28144 Quad-Channel Strain/Bridge Conditioner plug-in cards
- Requires only 6U (10.5 in.) of cabinet space

32-Channel Static Strain Conditioner

- 28008 chassis with eight 28144 Quad-Channel Strain/Bridge Conditioner plug-in cards
- Requires only 3U (5.25 in.) of cabinet space

16-Channel Static Strain Conditioner

- 28004 chassis with four 28144 Quad-Channel Strain/Bridge Conditioner plug-in cards
- Requires only 2U (3.5 in.) of cabinet space

For more information, please contact Alan Szary, Precision Filters, Inc. at 607-277-3550, ext: 7237 or ars@pfinc.com.

PRECISION FILTERS, INC.
ISO 9001 CERTIFIED QUALITY

Precision Filters, Inc.
240 Cherry Street
Ithaca, New York 14850

Telephone: **607-277-3550**
E-mail: **pfinfo@pfinc.com**
Web Site: **www.pfinc.com**

P8471 TN-2 Rev. A