FEEL THE HEAT

Signal conditioning for high-temperature gas turbine engine tests

BY DOUGLAS R. FIRTH

LEFT: Precision Filters 28000 signal conditioning system for rotating machinery

Designers of measurement systems for gas turbine engine testing have to deal with a complex set of challenging environmental conditions. Hundreds of sensors and lead wires collect data on pressure, strain, vibration and temperature, while interacting with the extremes of these conditions. The test environment is further complicated by hot gases, magnetic fields and noise pick-up. A systems approach that combines world-class signal conditioning with fast, rigorous self-testing separates critical data from the noise and ensures the data is valid.

Precision Filters' 28000 system offers a suite of signal conditioning and amplifier cards to meet these testing challenges. Testing is expensive and time-consuming – signal conditioning systems must provide the highest level of confidence in the validity of their test data, while reducing setup and troubleshooting time.

MEASURING STATIC AND DYNAMIC STRAIN

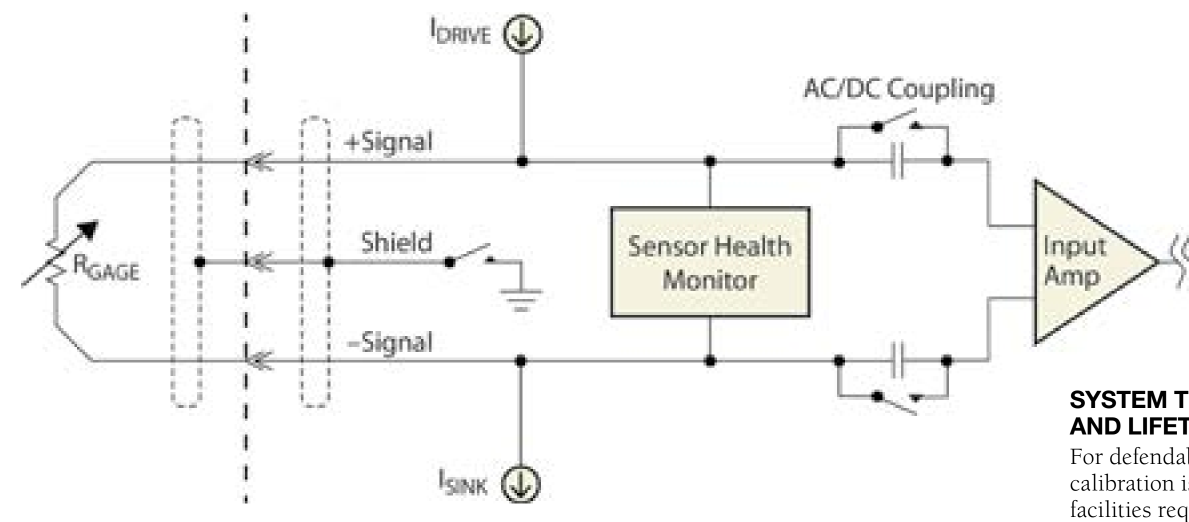
Strain gauges are commonly used in R&D testing on gas turbine engines. These gauges measure strain on both the rotor and the stator, often at extreme temperatures and in noisy environments. The Precision 28144 quad-channel conditioner provides a universal transducer conditioning solution for high-temperature static and dynamic strain gauges.

Strain gauges subjected to very high temperatures while measuring dynamic strain require high-temperature alloys for leads. The temperature change after engine startup results in sensor lead resistance changes of tens or even hundreds of ohms. On the engine's rotating side, leads pass through a slipring, where there is a high potential for noise coupling. In a high-temperature environment, a gauge's substrate can break down, causing leakage.

Furthermore, the environment may contain high electrostatic and magnetic fields that couple into the cables.

Precision Filters has developed balanced constant current technology to enable the wide dynamic range measurement of strain in harsh environments using only a two-wire connection to the gauge. The circuit is insensitive to temperature-induced changes in lead resistance. As a result of the circuit being balanced, the differential input amplifier rejects noise pick-up in the leads. Also, the circuit continues to measure strain if a gauge terminal shorts to the test article.

Balanced constant current technology is available on the Precision 28144 and the 28458 high-density dynamic strain conditioner. (For more information on PFI's balanced constant current technology, see *Balanced constant current excitation for dynamic strain measurements*, available for download at www.pfinc.com.)



ABOVE: Balanced constant current connection for dynamic strain measurement

A basic strain gauge cannot distinguish between strain imposed by the 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 called apparent strain.

At moderate temperatures (below 250°C), temperature-compensated strain gauges can minimize apparent strain. Typically, a three-wire Wheatstone bridge configuration connects the gauge to the bridge completion inside the signal conditioner. This three-wire connection, however, can suffer from variable lead-wire resistance, causing measurement uncertainty due to gauge desensitization and possible DC output from the bridge. In a noisy environment, electrical imbalance and poor electrostatic noise rejection make it impossible to get simultaneous static and dynamic readings from the same gauge.

At temperatures above 250°C, a second gauge is arranged in a half-bridge configuration with the measurement gauge. The compensating gauge should be placed in the same thermal environment as the measurement gauge while avoiding strain caused by the mechanical process. Because both gauges exhibit the same response to apparent strain, the apparent strain readings cancel in the half-bridge configuration. A three-wire connection may be used to condition the half bridge; however, this configuration is susceptible to gauge factor desensitization and DC errors caused by resistance changes in the extension wires.

With both voltage and balanced constant current excitation, Precision's 28144 has the flexibility to address virtually any high temperature static or dynamic strain measurement problem.

ACCELEROMETER CONDITIONING

As a gas turbine gets hotter, measuring vibration gets harder. High-temperature accelerometers can perform at temperatures in excess of 750°C. At such temperatures, accelerometers often have extremely low insulation resistance across the piezoelectric sensing element. Using a general-purpose charge amplifier could result in low-frequency gain peaking as high as 20-30dB – causing excessive low-frequency noise, gain errors, or even total saturation of the charge amplifier.
Precision's vibration amplifiers are compatible with the highest-temperature accelerometers on the market and exhibit minimal peaking – even with accelerometer shunt resistance as low as 10kΩ.

VERIFYING CABLE AND SENSOR HEALTH

The best signal conditioner is of little value if the measurement system fails during a test. Discovering a faulty gauge or a defective cable after the test is too late. Lost data can never be recovered, and often it is impossible or too costly to repeat a test. A simple, failsafe protocol for verifying the health of all gauges, lead wires, and cabling is essential to any successful measurement system.

The Precision Filters 28000 signal conditioning system has built-in hardware and software that allow the measurement team to quickly and easily run a series of automated sensor, circuit, and cable run checks. Precision Filters feature signal conditioning cards that facilitate real-time monitoring of sensor and cable health, measure and report cable roll-off, and detect insulation leakage.

SYSTEM TESTING, CALIBRATION, AND LIFETIME COSTS

For defendable test data, yearly calibration is a must. Most research facilities require additional validation and documentation of performance specifications. Continual setup and teardown take a toll on sensitive circuitry and demand a rigorous approach to system verification. Yet verification protocols are seldom followed if inconvenience and cost outweigh the perceived benefits. The Precision 28000 self-test subsystem conducts comprehensive yearly calibrations and on-site pretest go/no-go diagnostics at the push of a button – without removing the system from the equipment rack.

The lifetime cost of a test measurement system is the total cost of ownership. This includes the purchase price of the components; installation; time required for setup, teardown and reconfiguration; acceptance testing; maintenance; and calibration. Operation and maintenance costs, notably staff time, generally exceed acquisition costs, particularly with poor-quality equipment. Often overlooked is the cost of bad data, or no data – a high price to pay for failing to conduct adequate pretest verifications. The cost of a failed test, even one gas turbine engine trial, can be immense.

The Precision Filters 28000 system significantly reduces lifetime costs and provides automated self-diagnostic and calibration capabilities that can reduce or eliminate component or system failures.

A systems approach to designing a signal conditioning system helps to ensure accurate measurements in the challenging environment of gas turbine engine testing. The Precision Filters 28000 system's innovative signal conditioning techniques, combined with automated go/no-go testing and simple annual calibration, give you confidence in your data – while reducing lifecycle and ownership costs.

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