Measuring Dynamic Strain on Gas Turbine Blades

Introduction

In gas turbine engine development, the dynamic strain characteristics on the rotating fan, compressor and turbine blades are crucial information. With a careful survey of strain ratios for a specific blade shape, the strategic placement of a strain gage can infer strain in other locations and detect multiple vibratory modes. Dynamic strain measurements are crucial in substantiating theoretical models and characterizing operational safety margins such as stress limits, deflection limits, casing clearances and high cycle fatigue.

The Problem

Accurate strain measurements in the hot sections of gas turbine engines are extremely difficult. Traditional foil backed strain gages cannot handle the high temperatures and corrosive atmosphere of the hottest sections of the gas turbine. Usually special high temperature wire wound strain gages are welded, cemented or flame sprayed onto the part under test. At high temperature and repeated vibrations, strain gages may provide only hours of service life. The insulation can break down resulting in a resistive leakage path to ground. Fatigued or delaminated gages can short to the test article, ending service life. Lead wires with suitable temperature capability, strength and corrosion protection usually have high resistance, and worse yet, resistance which changes dramatically with temperature. Due to the engine vibrations, some extension wire types have been found to output their own electrical noise signals that can further corrupt the gage reading.

Slip rings are used to make connections to the rotating sections of the engine. With ever increasing demand for more and more data channels, slip ring contacts are a premium, driving measurement hookup schemes to the most-simple 2-wire connection. Slip rings themselves can have a modulated contact resistance and other contact noise sources. Often the logistics of routing extension wire on rotating parts prevents the use of an electrostatic shield.

All these factors combine to make strain measurements on gas turbine engines an extremely difficult task. While it may be tempting to utilize simple 2-wire Wheatstone bridge, this approach suffers from many problems and is not suited to this type of measurement.

2-Wire Wheatstone Bridge Problems:

- Lead wire resistance decreases gage sensitivity, and must be measured and compensated for using channel gain. In-situ resistance measurements on multiple channels are time consuming, error prone, and costly. Additional measurement uncertainty exists if lead wire resistance changes during a test.
- A 50% loss of gage signal inherent in the quarter bridge circuit requires 6dB additional channel gain. Additional gain amplifies input noise along with the gage signal, decreasing overall signal-to-noise ratio.
- The quarter bridge connection to a remote gage is inherently unbalanced and highly susceptible to electrostatic noise pick-up with no protection afforded by CMRR of the signal conditioner.
- Insulation breakdown on either side of the gage shunts excitation current and ends service life.

The Solution

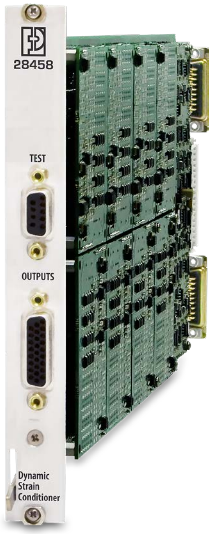
Precision Filters, Inc. (PFI) has been working closely with the leading manufacturers of gas turbine engines for more than 20 years. We are proud to say that we have been a part of the evolution of state of the art technology for dynamic strain measurements on gas turbine engines. PFI proprietary balanced constant current is a far superior technique for making dynamic strain measurements in the harsh conditions of gas turbine engines.

Advantages of PFI Balanced Constant Current Technology:

- **Lead wire resistance has no effect on excitation delivered to the gage, with NO decrease in gage sensitivity at any temperature.**
- **With constant current, 100% of the gage signal is measured by the signal conditioner, 6dB less channel gain is required compared to the Wheatstone bridge.**
- **Connection to signal conditioner is totally balanced allowing CMRR to reject noise pickup. Approximately 30 dB improvement in signal-to-noise ratio compared to Wheatstone bridge measurement.**
- **Balanced constant current sources proper excitation to gage with insulation breakdown on either gage terminal. *No loss of data!***

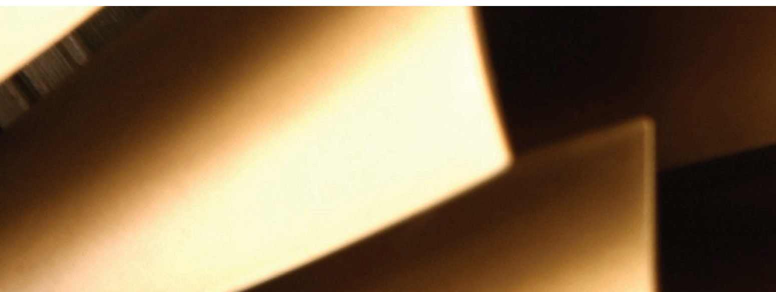
28458 Octal-Channel Conditioner *with Balanced Constant Current Excitation*

- 8 channels/card, 128 channels/system
- Balanced programmable constant current source with 20 V compliance
- Up to 100 kHz "filtered' or 190 kHz "wide-band" bandwidth
- Programmable gain to x1024
- 2-wire plus shield AC coupled input interface
- Sensor open and short detection
- On-the-fly report of measured transducer excitation, resistance and leakage to ground



28144 Quad-Channel Wideband Transducer Conditioner *with Voltage and Current Excitation*

- 4 channels/card, 64 channels/system
- Balanced programmable constant current or constant voltage excitation
- Programmable 4 or 8 pole filters with programmable cutoffs to 204.6 kHz
- Programmable gain to x8192
- Programmable bridge completion with 2 to 10-wire interface to the bridge
- On-the-fly report of measured transducer excitation, resistance, open/short and leakage to ground

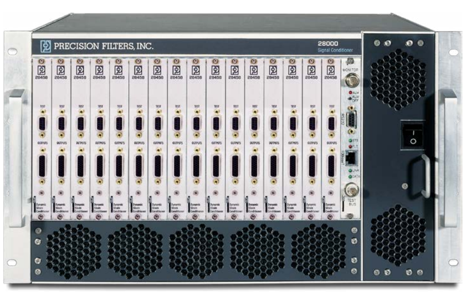


Users of PFI Balanced Constant Current Technology

- GE
- Pratt & Whitney
- Honda
- US Air Force Research Lab
- Honeywell
- Siemens
- National Research Council
- Boeing
- NASA
- Rolls-Royce

Dynamic 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 dynamic strain measurement task.



128-Channel Dynamic Strain Conditioning System

- Up to 128 channels with 8-channel 28458 Octal Dynamic Strain plug-in cards
- Up to 64 channels with 4-channel 28144 Dual Mode Bridge/Strain Conditioning plug-in cards
- Self-contained chassis system; cards, controller, power supply and cooling requires only 6U (10.5 inches) of cabinet space

64-Channel Dynamic Strain Conditioning System

- Up to 64 channels with 8-channel 28458 Octal Dynamic Strain plug-in cards
- Up to 32 channels with 4-channel 28144 Dual Mode Bridge/Strain Conditioning plug-in cards
- Self-contained chassis system; cards, controller, power supply and cooling requires only 3U (5.25 inches) of cabinet space

32-Channel Dynamic Strain Conditioning System

- Up to 32 channels with 8-channel 28458 Octal Dynamic Strain plug-in cards
- Up to 16 channels with 4-channel 28144 Dual Mode Bridge/Strain Conditioning plug-in cards
- Self-contained chassis system; cards, controller, power supply and cooling requires only 2U (3.5 inches) of cabinet space

For more information, please contact Doug Firth, Precision Filters, Inc. at 607-697-9102, or doug@pfinc.com.

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ISO 9001 CERTIFIED QUALITY

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