UNIQUE INLINE DC AMPLIFIER WITH REMOTE AUTO-ZERO

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Abstract: Transducer applications increasingly demand a greater dynamic range in order to achieve more accurate measurements. Any offset error from the transducer diminishes the amount of gain that can be applied by a pre-amp before clipping occurs at the input to the user's DAQ when DC coupling. In order to address this need, Measurement Specialties has developed the Model 140 Inline Amplifier series that provides ultra high measurement resolution and user-actuated auto-zero in a miniaturized metal package with five user selectable gain settings.

Figure 1: Model 140 Inline DC Amplifier

Introduction: A bridge-type transducer typically outputs a low level signal that requires amplification prior to the user's data acquisition system. The effectiveness of this gain stage is often limited by the use of a pre-amp that cannot be located physically close to the transducer. This allows noise to couple along the signal lines prior to amplification which can result in a boost in noise level along with the signal. Another shortcoming is that any offset error from the transducer diminishes the amount of gain that can be applied by the pre-amp before clipping occurs at the input to the DAQ when DC coupling. This paper discusses how the 140, shown in Figure 1, has been designed to address these issues in a miniaturized cost-effective product. Table 1 contains the performance specifications of the 140.

Table 1: Model 140 Inline Amplifier Specifications

Dynamic

Input Type	Differential
Input Range (each input referenced to ground)	0.5 Volts to (Vexc – 0.6 Volts)
User Selectable Gain Settings	X10, X25, X50, X100, X200
Bandwidth (-3dB)	DC to 100kHz
Noise	0.03 μV/√Hz RTI + 2μV/√Hz RTO
Zero Output After Auto-Zero Actuation	±1.5mV with respect to 2.5VDC ref out
Input Range Limit for Auto-Zero Function	±10 Volts/gain

Electrical

Excitation Voltage	5 to 30 Vdc
Reverse Polarity Protection	-20 Volts on excitation line
Quiescent Current	15 mA
Reference Out	2.50 ±0.05 Vdc referenced to ground
Output Voltage Limit	±2 Volts referenced to 2.5Vdc ref out
Gain Accuracy	0.5%
Output Impedance	<50 Ω
Insulation Resistance	>100 MΩ @ 50Vdc
Supply Out (>5.2 Vdc Excitation Required)	5.0 Vdc +0.0 Vdc, -0.1 Vdc (<100mA)

Environmental

Operating and Storage Temperature	-20°C to +70°C
Environmental Protection	IP50
Mechanical Shock	50g-pk any direction

Physical

Case Material	Anodized Aluminum
Electrical Connectors, two places transducer and instrumentation ends	Binder receptacle P/N 09-0098-00-05 (mates with Binder plug P/N 99-0413-10-05)
Weight	34 grams

Installation: The output of the 140 can be connected single-ended, with a full scale swing up to ±2 volts and a bias of 2.5 Vdc. Or, it may be hooked up differentially using the 2.5 Vdc reference voltage provided as the negative input to the user's DAQ.

There are two options for powering the user's transducer. A 5 Vdc regulated supply is available from the designated socket on the instrumentation end of the 140. For other supply requirements, a matching set of sockets act as a pass through of the user's excitation source of 5 to 30 Vdc as seen in the wiring diagram of Figure 2. This voltage also powers the 140 signal conditioning circuit. The 5 Vdc regulated supply has a typical line and load regulation of 2mV when drawing up to 100 mA.

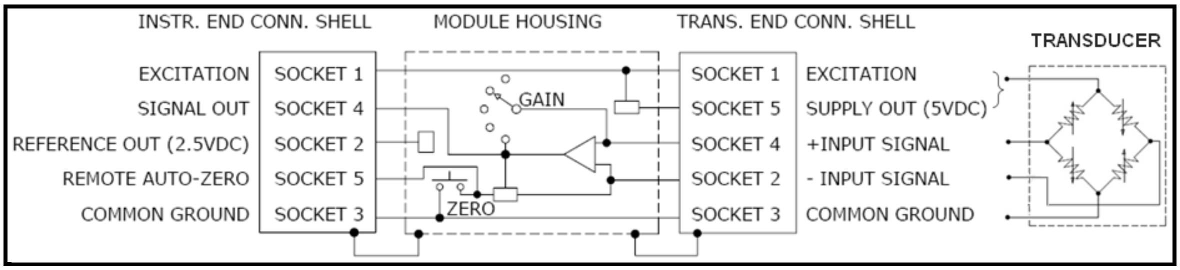

Figure 2: 140 Wiring Diagram

Auto-Zero: The 140 incorporates a unique auto-zero function that is triggered by momentarily grounding an electrical connection for a period of two seconds minimum. Auto-zero may be actuated by two methods. One is manually pushing a recessed button built into the body of the 140. The other involves remotely grounding a designated connector pin on the 140 through a wire in its detachable mating cable. The input range limit for successfully performing auto-zero is ±10 volts/gain. For example, a gain setting of X25 restricts the zero offset from the transducer to ±400mV. Multiple actuations may be needed to achieve the ±1.5mV limit. Note that the auto-zero correction factor is permanently retained until its next actuation (i.e., auto-zero cannot be disabled). If the gain setting on the amplifier is changed at any time, or the transducer is replaced, the auto-zero procedure needs to be repeated.

Auto-zero possesses a number of advantages. For one, this provides a zero reference output within ±1.5mV of true zero. It also corrects for zero errors due to mounting misalignment. Lastly, any long term drift errors can be corrected in real time so that the user can zero out the device just prior to taking a measurement.

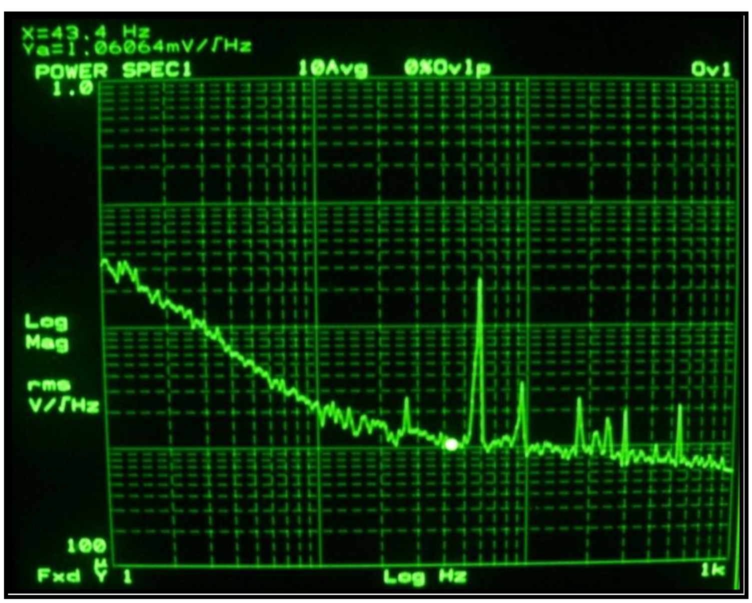

Figure 3: PSD of 3022-010 PR Accelerometer Plugged into a 140

Residual Noise: Figure 3 displays a screen shot of the PSD output from a 140 with a Measurement Specialties Model 3022-010 piezoresistive accelerometer plugged into it. The 3022 is an unamplified silicon MEMS accelerometer in a Wheatstone bridge configuration rated ±10g full scale. It was powered by the regulated 5 Vdc supply from the 140. The 140 gain was set to a gain of X50 in order to produce 200 mV/g sensitivity. The amplifier in the noise measurement system has a X1000 gain so the reading at the cursor is actually 1.06 μV/√Hz. Broadband noise from 0.1 to 1000 Hz measured 47μVrms which translates into a measurement resolution of 0.24 mg. This represents a dynamic range of 90dB for this case.

Excitation Voltage: The rated excitation voltage range is from 5 Vdc to 30 Vdc. However, when using the 5 Vdc regulated supply out, the excitation voltage may need to be derated for a given load current draw. The derating curve is shown in Figure 4. As an example, a 100 ohm bridge transducer draws 50 mA from the 5 Vdc supply. Therefore, the excitation applied to the 140 cannot exceed 10.5 Vdc. Note that the excitation pass through feature does not have this restriction.

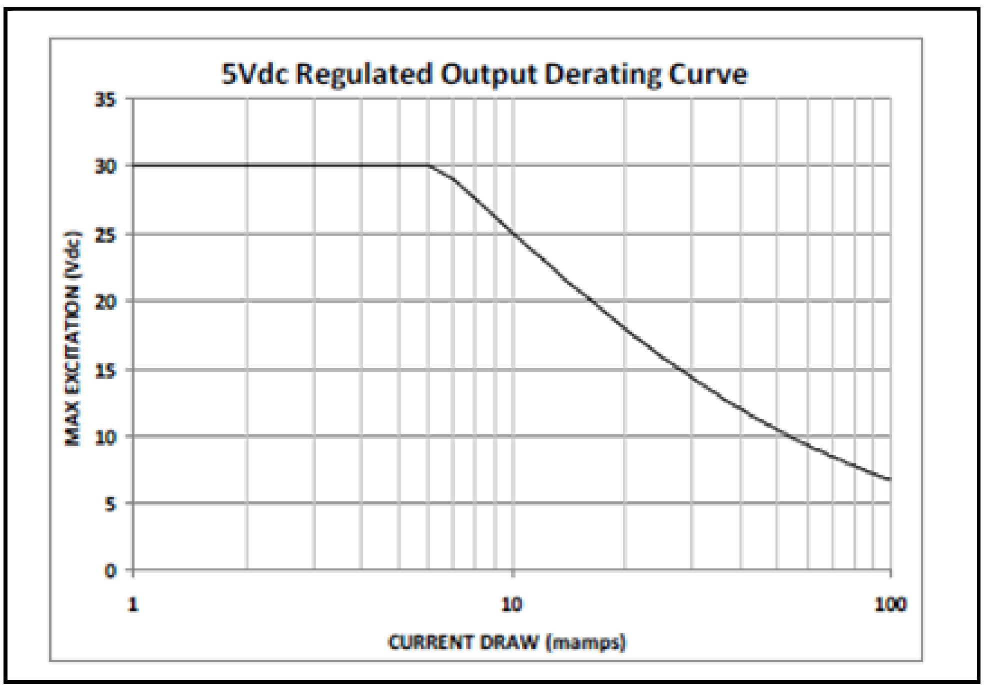

Figure 4: Output Load Current Derating Curve

Construction: The 140 is of a rugged design that features an anodized aluminum body with integral threaded circular connectors on either end. The connectors are standard offerings from Binder. Figure 5 shows the envelope dimensions.

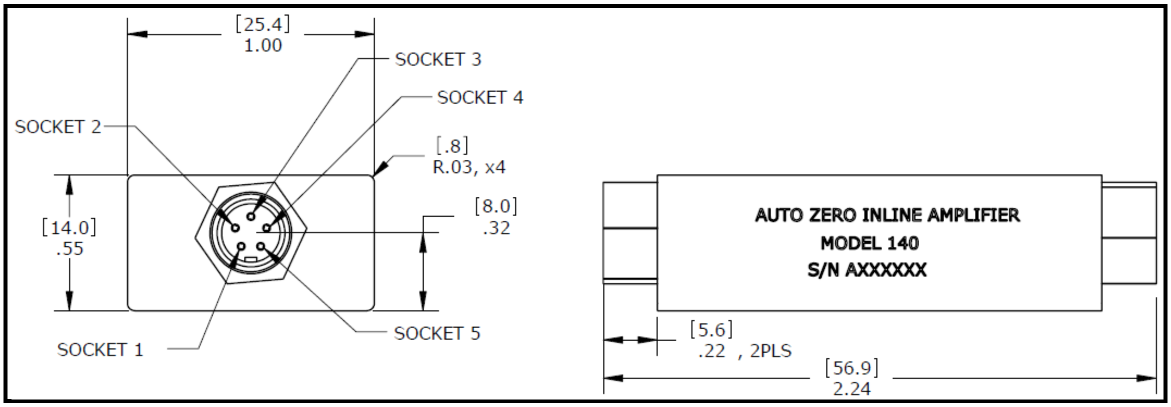

Figure 5: Physical Dimensions

Figure 6 shows a screw driver slot in a five position rotary switch for gain adjustment. The switch is recessed into the body of the 140. A recessed push button actuates the auto-zero function. Note that these mechanical switches are what determine the shock limit of 50g for the 140.

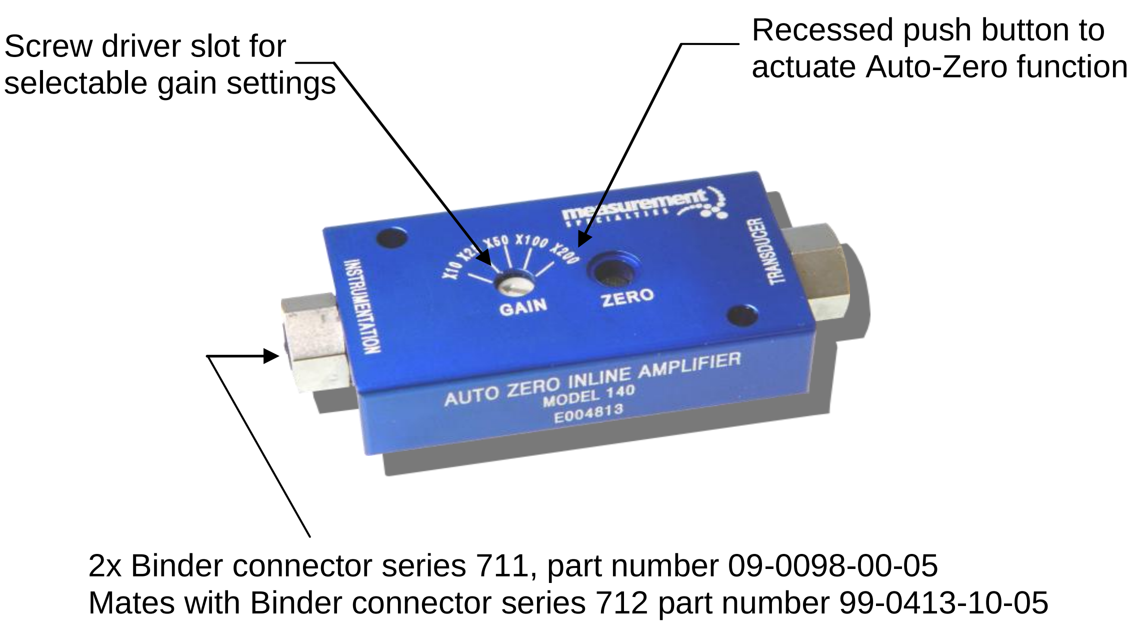

Figure 6: Mechanical Features

The mating cable is Cable Assembly Model 379 as shown in Figure 7. It is fully shielded and the cable shield ties to the aluminum housing of the 140 when connected. The 140 housing is anodized to prevent ground loops. The mating cable uses PFA insulated leads and a TPE jacket with #30 AWG conductors.

Figure 7: Model 379 Cable Assembly

Mounting: The 140 in-line amplifier can be screw mounted, adhesively mounted (such as silicone RTV), or attached with double-sided tape. Two mounting holes are available for screw attachment as shown in Figure 8.

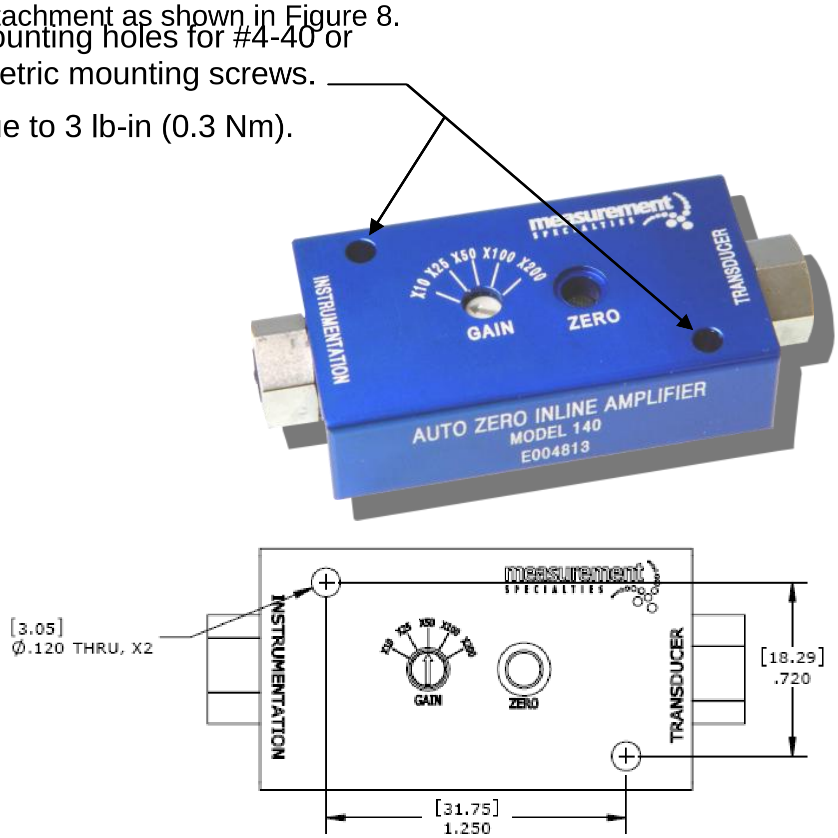

Figure 8: Screw Mounting Holes

Circuit: The signal path of the 140 is fully analog. Its on-board electronics include a low noise instrumentation amplifier with an adjustable gain stage. There is also a low dropout 5 Vdc regulator and a 2.5 Vdc voltage reference. Auto-zero is accomplished by an on-board microprocessor. It captures the zero offset correction factor when the auto-zero is actuated and applies it to the bias adjust on the instrumentation amp. The correction factor is stored in nonvolatile memory. The circuit construction is SMT with a conformal coating for environmental protection.

Factory Calibration: The Calibration Certificate of the 140 reports the measured supply output (5 Vdc nominal), reference output (2.5 Vdc nominal), and actual gains to four significant digits at each gain setting.

Applications: The 140 is ideal for use with differential output transducers intended for pressure and level indication, static acceleration testing, instrumentation labs, load monitoring, and strain measurement. The following sections detail actual application experiences that demonstrate the broad scope of installations that can take advantage of the capabilities of the 140.

Pressure Sensor: A customer is using the 140 with a Model XPCM10 miniature pressure sensor produced by Measurement Specialties. The pressure sensor has a stainless steel diaphragm and measures both static and dynamic pressure. It features metallic strain gages in a 350Ω four-active Wheatstone bridge configuration. This arrangement was selected by the customer in order to monitor the pressure going into a nozzle on a newly designed conformal coating machine. The low noise that this system allows, along with the auto-zero, were the primary reasons for the selection. The pressure sensor is depicted in Figure 9.

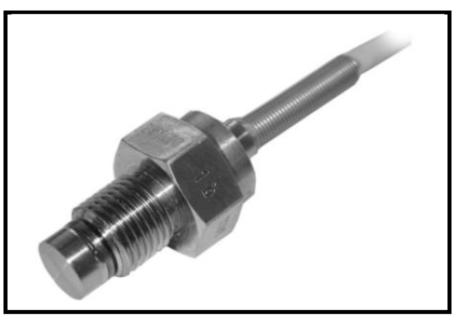

Figure 9: XPCM10 Pressure Sensor with M10 Thread

Load Cell: A university research project required the 140 to be connected to a Model FN3280 load cell produced by Measurement Specialties. The arrangement was intended to measure fog deposition on a leaf wetness sensor (LWS) and on a small tree branch. These test articles are hung by a thread from the load cell in a Plexiglas fog chamber. The apparatus measured the weight of water deposited on the test articles. The load cell is rated to a full scale range of 2 Newtons (182 gm-f) which is sensitive to low measurement forces while the 140 provides high measurement resolution. The setup is shown in Figure 10.

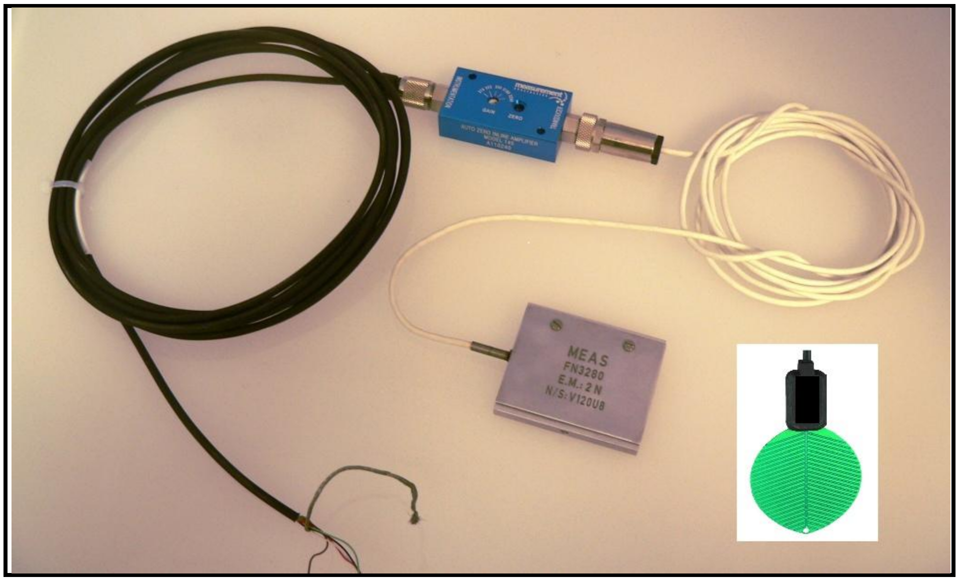

Figure 10: Low Range Load Cell Connected to 141

String Pot: The Model 141 Inline DC Amplifier is a version of the 140 that was developed for use with transducers that require relatively small signal amplification, down to unity, but still need to utilize the auto-zero feature. It has selectable gain ranges of X1, X2, X5, X10, and X20. It is suitable for use with Measurement Specialties’ line of amplified accelerometers, such as the Models 4610 and 4000A.

One application for a tractor manufacturer required string pot Model PTX101 from Celesco, which is a division of Measurement Specialties. It has a zero to fifty inch stroke and is shown in Figure 11.

The string pot is a half bridge so the 141 needed to accommodate a single-ended output by connecting its negative signal input to common ground. The string pot was powered by the 5 Vdc regulated output of the 141. The string was drawn out to ten inches and then the auto-zero triggered. The full scale range for the measurement was then made from nine inches to eleven inches. Measurement resolution of the system was calculated to be 10 µinches-rms over a bandwidth of 0.1 to 10 Hz. This provided a dynamic range of 92dB for the two inch stroke.

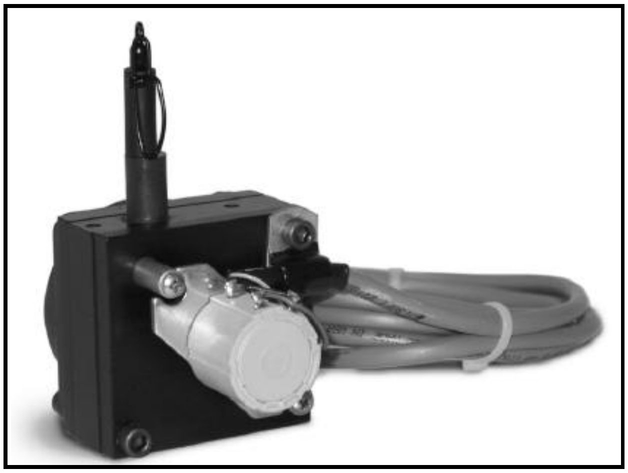

Figure 11: Celesco String Pot

Strain gage: The Model 142 is another variation of the 140 that was developed to connect with uniaxial quarter-bridge strain gages. It features precision completion resistors mounted on-board. The user can order versions of the 142 with the following completion resistor values installed by the factory: 120Ω, 350Ω, 500Ω, 700Ω, and 1000Ω. Gain settings of X50, X100, X200, X500, and X1000 are selectable by the user. Four wires are connected to the user's strain gage in order to minimize lead wire resistance errors as seen in Figure 12.

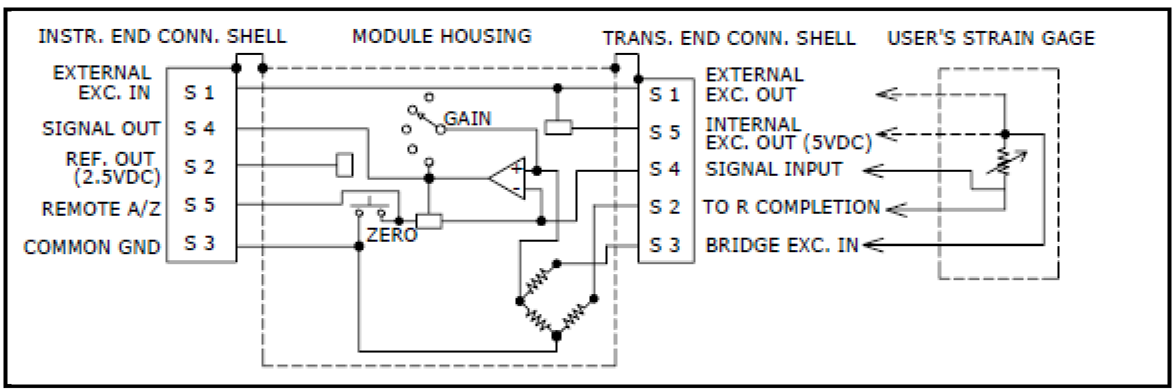

Figure 12: 142 Quarter-Bridge Strain Gage Wiring Diagram

An aircraft manufacturer needed to conduct ground tests involving strain measurements on parts contained in the aft strut fairing region of an engine operating at full power. Prior to the use of the 142, a technician had to go into the field and tweak trim pots in order to adjust residual offsets as close to zero as possible. The 142 eliminated this chore

Figure 13 shows a strain gage attached to a cantilevered stainless steel bar. The setup measures the strain due to weights applied at the end of the beam.

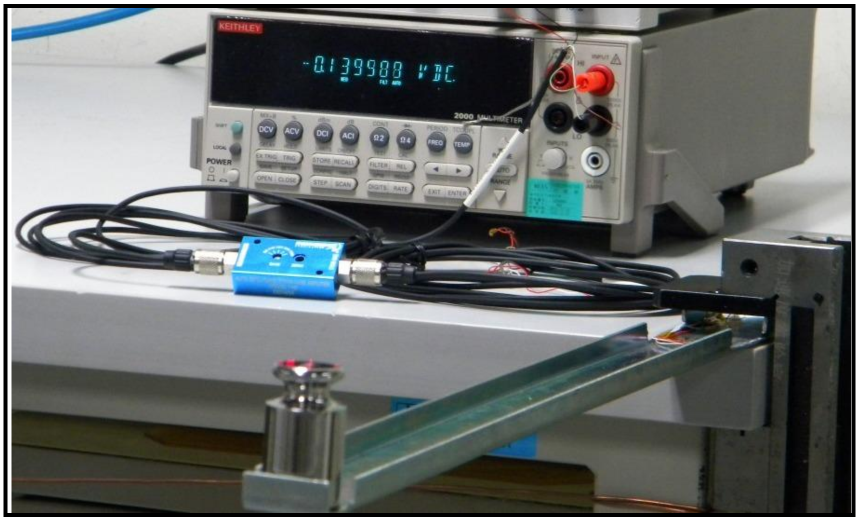

Figure 13: Strain Gage Measurement on Cantilevered Bar

Expanded Offering: The patent pending technology of the 140 has been adapted into a new ultra low noise accelerometer Model 4807A with built in auto-zero as shown in Figure 14.

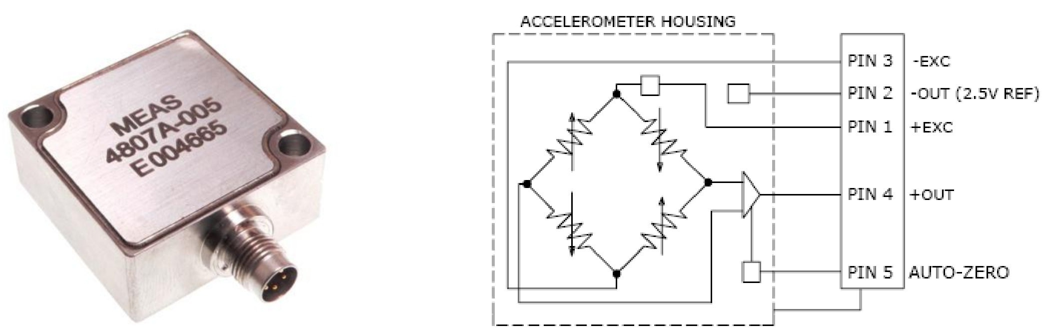

Figure 14: Model 4807A and Wiring Diagram

The 4807A incorporates the same basic circuit approach as the 140 but with the addition of a piezoresistive sensor element. The silicon MEMS sensor is gas-damped with integral mechanical stops for shock protection up to 5000g. Its passband is from DC up to 1500 Hz. It operates from an 8 to 18 VDC supply and provides an amplified output.

The 4807A utilizes its on-board MCU to correct for thermal zero and sensitivity shifts. Each device is individually characterized for temperature performance and then normalized at the factory for ±2 volt full scale output. The 4807A features a total error band of less than 2% operating over the temperature range of -40°C to +125°C. Figure 15 shows the thermal errors of the ±5g full scale version.

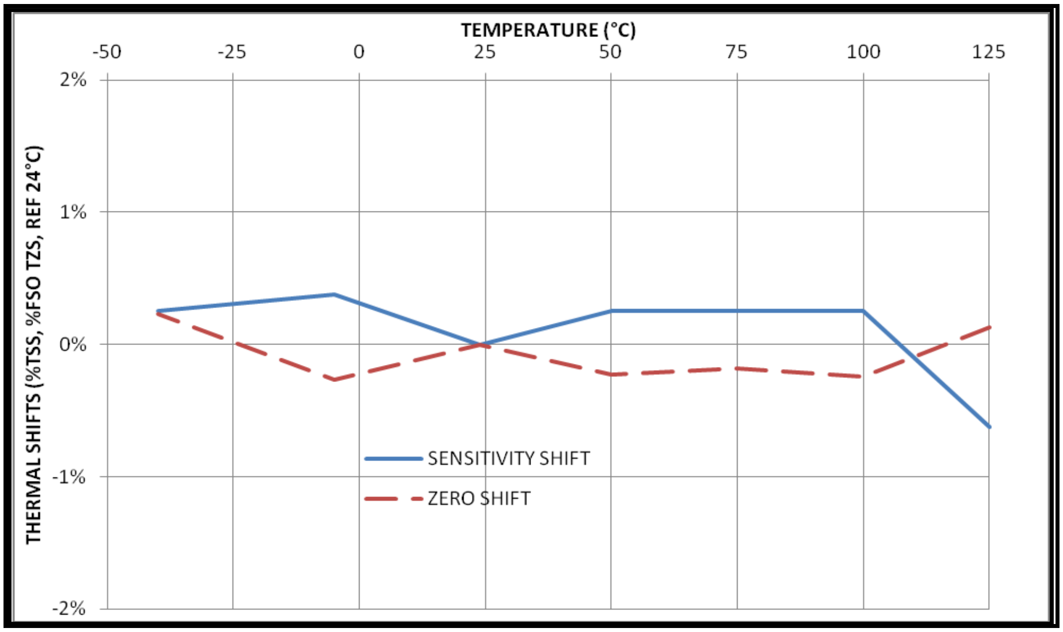

Figure 15: 4807A-005 Temperature Response

It features the same ultra low noise characteristic as the 140 that provides micro-g resolution with a dynamic range of 96dB. This represents an order of magnitude improvement over competitive offerings. It also features the auto-zero function which is accomplished by momentarily grounding a designated pin on the integral connector. Figure 16 shows a typical frequency response plot.

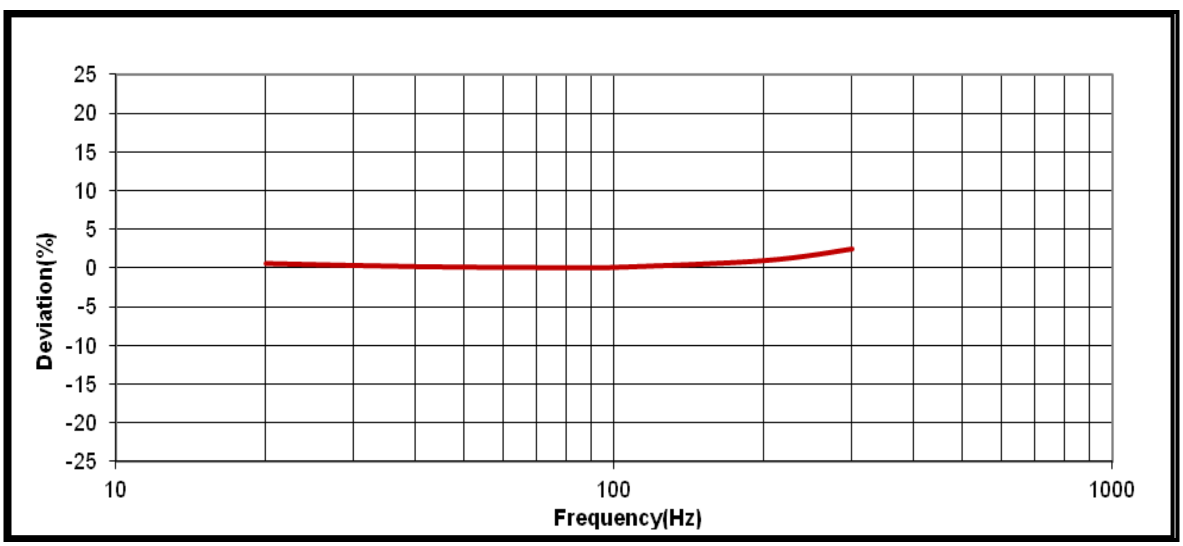

Figure 16: 4807A-005 Frequency Response

The 4807A is offered in full scale ranges from ±2g to ±200g. The 4807A is designed for rugged environments with a hermetically sealed stainless steel case and connector. Its footprint is 0.92 inch square with a height of 0.4 inches. It can be screw or adhesively mounted.

Conclusion: Measurement Specialties is proud to offer an innovative ultra low noise DC inline amplifier series that succeeds in significantly improving measurement accuracy for bridge-type transducers. It features a unique auto-zero function (patent pending) that can be actuated just before the taking of data, either on-board or remotely.

Bibliography: Tom Connolly has been involved in transducer design since 1982. He has held the position of Senior Design Engineer at the Vibration Design Center of Measurement Specialties, Inc. (MEAS) in Aliso Viejo, California since January 2007 where he is responsible for the development and qualification of accelerometers using piezoresistive and piezoelectric technologies. Over a span of twenty years prior to MEAS, he was further involved in vibration sensor design while working for PCB Piezotronics and Endevco (Meggitt) where he advanced to Engineering Manager of Silicon Products. His transducer development experience also includes the application of variable capacitance MEMS, variable reluctance, inductive proximity, Hall effect, and magnetoresistive technologies for speed and position sensing in military/aerospace, industrial, and automotive applications. He received his Bachelors of Electrical Engineering degree from Cleveland State University, Ohio, in 1978. He earned his Masters of Business Administration from California State University, Fullerton, in 1993.