INDUSTRIAL ACCELEROMETERS

FUNCTIONS & FEATURES

The Industrial Accelerometer is a common sensor that should be found in the toolbox of every vibration analyst. The accelerometer is a casing mounted sensor that measures the transmission of vibration from rotating equipment through the rolling element bearing, casing of the machine, and base of the accelerometer. As shown in Figure #1, the vibrations generated by the machine are measured by the accelerometer, and converted to a voltage proportional to g's (unit measure for acceleration, 1 g = 9.807 meters/second^2).

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the IEPE (Integrated Electronics Piezo Electric) design is used for industrial accelerometers. This is a two wire technology that incorporates a Piezo ceramic element and an integrated amplifier to convert the charge output of the ceramic element to a voltage and amplify it for use with vibration analyzers and data collectors. Since the sensing element and amplifier are contained inside of the accelerometer, a robust sensor comes in a very compact package for use with today's rotating equipment in diverse industrial environments. Most accelerometers are built in a shear mode design to eliminate the effects of base strain or thermal transients.

The shear mode design incorporates a center post, piezo ceramic, and reactive mass designed in a manner that allows the post to transmit machine vibration to the inside of the ceramic element and the mass to oppose the vibration on the outside of the ceramic element. This opposition of forces between the vibration and mass causes a shearing of the ceramic element that produces a charge output in pC/g (pico-Coulombs/g). The integrated amplifier then converts the charge to a voltage and amplifies it for use. Typical accelerometer outputs are 10 mV/g, 50 mV/g, 100 mV/g and 500 mV/g. General purpose vibration measurements normally rely on an accelerometer with an output of 100 mV/g. High amplitude vibrations (typically high in frequency) utilize 10 mV/g, and low amplitude vibrations (typically low in frequency) utilize 500 mV/g for better signal to noise ratio. An illustrated view of the accelerometer construction is shown in Figure #2.
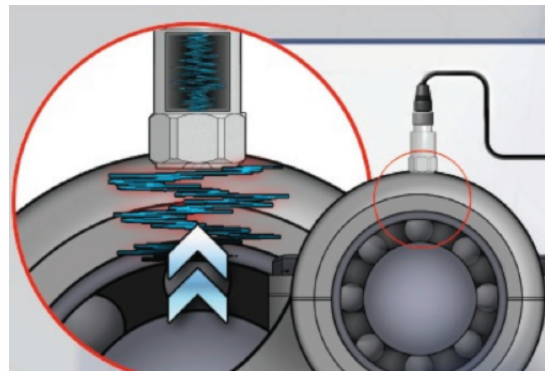

FIGURE 1: Vibration Transmitted to Accelerometer
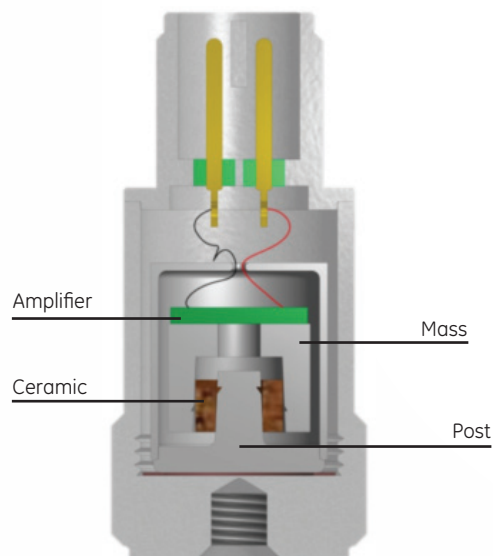

Amplifier

Mass

Ceramic

Post

FIGURE 2: Accelerometer Construction

THESE ROBUST IEPE TYPE INDUSTRIAL ACCELEROMETERS SHOULD PROVIDE YEARS OF RELIABLE SERVICE GIVEN PROPER INSTALLATION, USE, AND ENVIRONMENTAL CONSIDERATIONS.

Functions & Features

01 SENSITIVITY

The sensitivity of an accelerometer is the measured output voltage at a given frequency. Typical calibration frequencies are 80 Hz, 100 Hz and 159.2 Hz where 159.2 Hz would be considered the metric standard as it produces the equivalent vibration of 10 m/sec^2 rms. (acceleration), 10 mm/sec rms. (velocity), and 10 μm rms. (displacement). Using 80 Hz or 100 Hz, a vibration amplitude of 1 g rms. would be applied to the accelerometer, and the voltage output of the accelerometer would be measured. The sensitivity of the accelerometer is often referred to as the calibrated output of the accelerometer. Depending on the construction and application of the accelerometer, nominal sensitivities would be 10, 50, 100, and 500 mV/g, but actual sensitivities would be determined and bounded by the sensitivity tolerance of the accelerometer.

02 SENSITIVITY TOLERANCE

Every accelerometer will be calibrated to determine the sensitivity, and the actual measured output value must fall within the sensitivity tolerance. Typical tolerances are +/- 5%, +/- 10%, +/-15% and +/- 20% where 5% would be considered to be a premium tolerance, and 20% would be considered a marginal tolerance. Typical user values are 10% and 15% for general purpose vibration measurements. If you were to choose a 100 mV/g accelerometer with a +/- 10% sensitivity tolerance, the calibrated output of the sensor could range from 90 mV/g (-10%) to 110 mV/g (+10%). However, if you were to choose a 500 mV/g accelerometer with a +/- 10% sensitivity tolerance, the calibrated output of the sensor could range from 450 mV/g (-10%) to 550 mV/g (+10%). Since vibration analyzers or data collectors have a volts/unit input function, the calibrated accelerometer value can be entered in the set-up and used to normalize the measurement reducing sensor to sensor measurement error. Please keep in mind that the sensitivity tolerance only applies to the measured amplitude at the frequency that determines the sensitivity or calibration of the accelerometer. The amplitude

tolerance of all other frequencies will be determined based on the frequency response of the accelerometer.

03 FREQUENCY RESPONSE

Given the established sensitivity of the accelerometer, the allowable output at the calibration frequency will be identified as the sensitivity tolerance, but all other amplitudes will be bounded by the frequency response limits. These limits are typically established at +/- 5%, +/- 10% and +/- 3 dB above and below the measured sensitivity value, for those frequencies greater than or less than the calibration frequency. +/-3 dB will be the largest frequency range and is normally considered to be the usable range or working range of the accelerometer. Figure #3 illustrates the frequency response for a general purpose accelerometer with a nominal output of 100 mV/g and a measured sensitivity at 98.5 mV/g. This accelerometer falls within the +/- 5% sensitivity tolerance.

04 RESONANT FREQUENCY

As Figure #3 indicates, the resonant frequency for the accelerometer is 22,000 Hz with an amplitude of 24.613 dB. This would be the equivalent of the natural frequency of the accelerometer and at resonance produces a large gain in amplitude. Normally the vibration analyst will work below the resonance of the accelerometer using the data within the +/-3dB limits. Some data collector manufacturers will use the resonance of the accelerometer to amplify high frequency but small amplitude stress waves in proprietary algorithms commonly referred to as HFD (High Frequency Detection) programs. These programs can identify early deterioration of rolling element bearings and gears.

05 BIAS VOLTAGE

The DC operating voltage of the IEPE power circuit is often called the Bias voltage. Nominally this value is 12 VDC, but typically ranges from 10 – 14 VDC. Given that the IEPE circuit is a 2 wire design, both the sensor power and vibration signal must use these two wires to operate the accelerometer and measure the vibration. Essentially the vibration signal is an AC voltage riding on top of the DC Bias voltage. The IEPE circuit requires an 18 – 30 VDC,

2 – 10 mA constant current supply. In modern vibration analyzers, data collectors and on-line systems, the power supply and available current is dependent on the measurement device and accelerometer environment. Most data collectors will have a 2 mA supply as they are running on battery power. This is good for shorter cable runs and all temperature conditions. On-line systems may encounter longer cable runs that require the current to be increased to 4 – 10 mA, but this must also be balanced with the temperature of the environment. Excessive

current will generate more heat in the accelerometer, and if the environment is already quite hot, the accelerometer could exceed its maximum temperature limit. This makes it very easy for the vibration analyst to use an accelerometer in their daily measurements and route data collection. The power circuit also includes a de-coupling capacitor to block (remove) the DC Bias voltage and allow amplification of the AC vibration signal by the analyzer, data collector, or on-line system. Figure #4 will illustrate the IEPE power circuit.
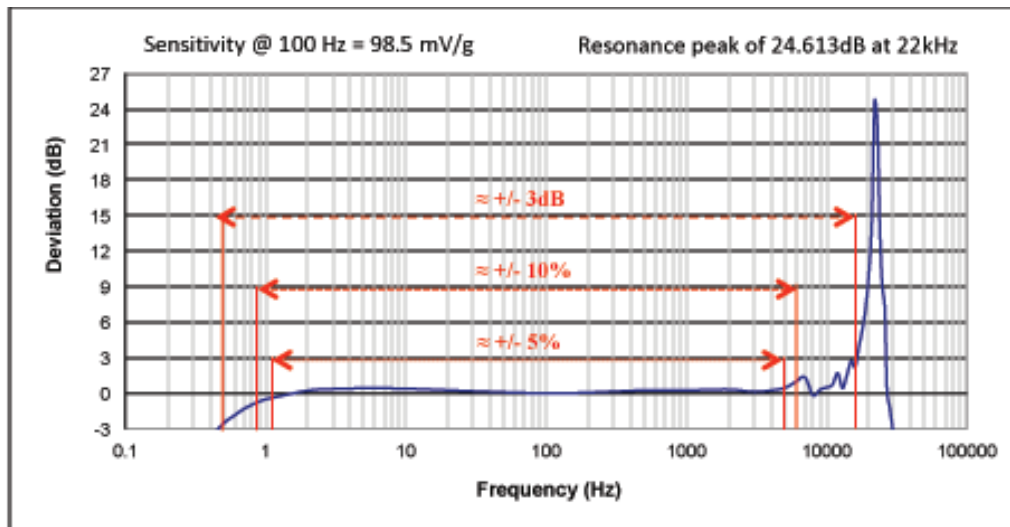

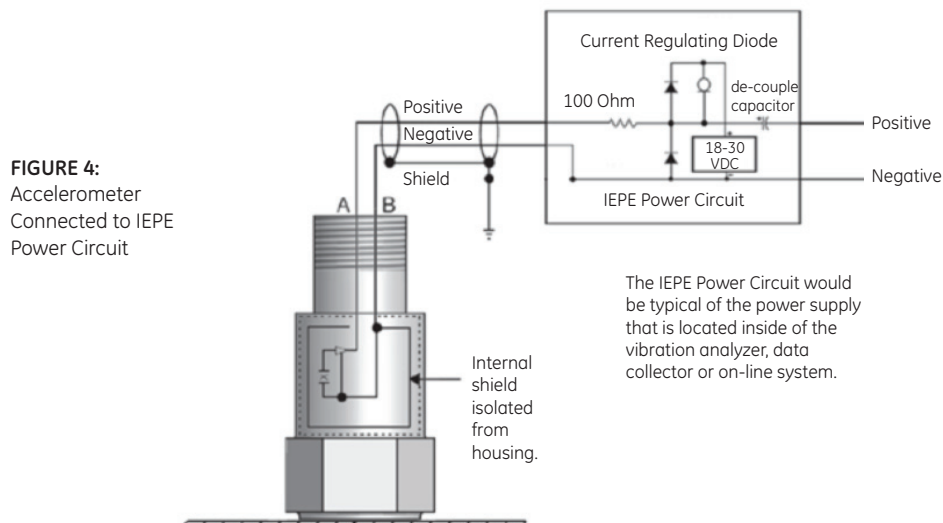**FIGURE 3:** Frequency Response with +/-5%, +/-10%, and +/-3dB Limits

FIGURE 4: Accelerometer Connected to IEPE Power Circuit

The IEPE Power Circuit would be typical of the power supply that is located inside of the vibration analyzer, data collector or on-line system.

06 DYNAMIC RANGE

The maximum and minimum amplitude that the accelerometer can measure is indicated by the dynamic range. Typically the dynamic range is limited to +/- 5 VAC_{Peak}, but some 100 mV/g accelerometers are available with a dynamic range extended to +/- 8 VAC_{Peak}.

If the nominal Bias voltage is 12 VDC, but can range from 10 – 14 VDC, The power supply must have greater potential than the Bias Voltage +/- the Voltage of the Vibration Signal. Three examples are given and illustrated in Figure #5:

(A) Given an 18 VDC power supply, 12 VDC Bias voltage, and maximum vibration amplitude (Dynamic Range) of +/- 5 VAC, the combined voltage output would vary between 7 to 17 volts. This is within the limits of the power supply.

(B) Given an 18 VDC power supply, 14 VDC Bias voltage, and maximum vibration amplitude (Dynamic Range) of +/- 5 VAC, the combined voltage output would vary between 9 to 19 volts. This exceeds the upper limit of the power supply by 1 volt and will cause clipping of the vibration signal. In this case a 20 VDC power supply would be required.

(C) Given a 24 VDC power supply, 12 VDC Bias voltage, and maximum vibration amplitude (Dynamic Range) of +/- 8 VAC, the combined voltage output would vary between 4 to 20 volts. This is within the upper limit of the power supply.

Figure #6 is a table of the typical sensitivities and dynamic ranges available to the analyst.

07 TURN ON TIME VS. SETTLING TIME

When power is supplied to an accelerometer there will be a turn on time for the amplifier circuit to power up and reach a stable Bias voltage before the vibration measurement can begin. The turn on time is identified as the time it takes to reach or normalize at +/-10% of the Bias voltage. Figure #7 is a measurement of turn on time after applying power to an accelerometer. Allowing the accelerometer to normalize around the Bias voltage will prevent ski slope in the FFT.

In portable hand held data collection, the accelerometer power will be applied when the data collector is turned on, and the accelerometer will remain powered on until the analyst powers down the data collector at the end of their collection process. If a portable accelerometer is being magnet mounted (or mounted by some other temporary means), it takes time for the amplifier circuit to normalize after the shock of mounting it. This is known as settling time. The time it takes for the amplifier circuit to stabilize and settle after temporarily mounting it is very dependent on the mounting process. If the accelerometer is mounted harshly on the machine by letting the magnet mount snap onto the mounting surface, the shock of the mounting will saturate the amplifier and an extended settling time will be required. If the magnet mount is gently rocked onto the mounting surface with little or no shock to the accelerometer, the settling time will be minimal. It is always preferred in portable data collection to mount the accelerometer as gently as possible to avoid any shock to the sensor or saturation of the amplifier. This allows the measurement process to start quicker, save time between measurements, and prevent ski slope in the FFT.

08 SPECTRAL NOISE

Each accelerometer has a noise floor and the amplitude of this noise is typically measured at 10, 100, and 1000 Hz in units of μV divided by the square root of the frequency, which is equivalent to the square root of the PSD (Power Spectral Density). Dividing the measured μV/√Hz value by the sensitivity of the accelerometer produces a μg/√Hz value. For example:

• Spectral noise measured at 10Hz = 1.4 μV/√Hz
• With sensitivity of 100mV/g, Spectral noise at 10Hz = 14 μg/√Hz
• Now we can calculate the amplitude of the noise floor at 10Hz as 14 μg/√10 = 4.43 μg

4.43 μg would be the amplitude of the noise floor at 10 Hz. To make a measurement above the noise floor, with acceptable noise tolerance, the SNR
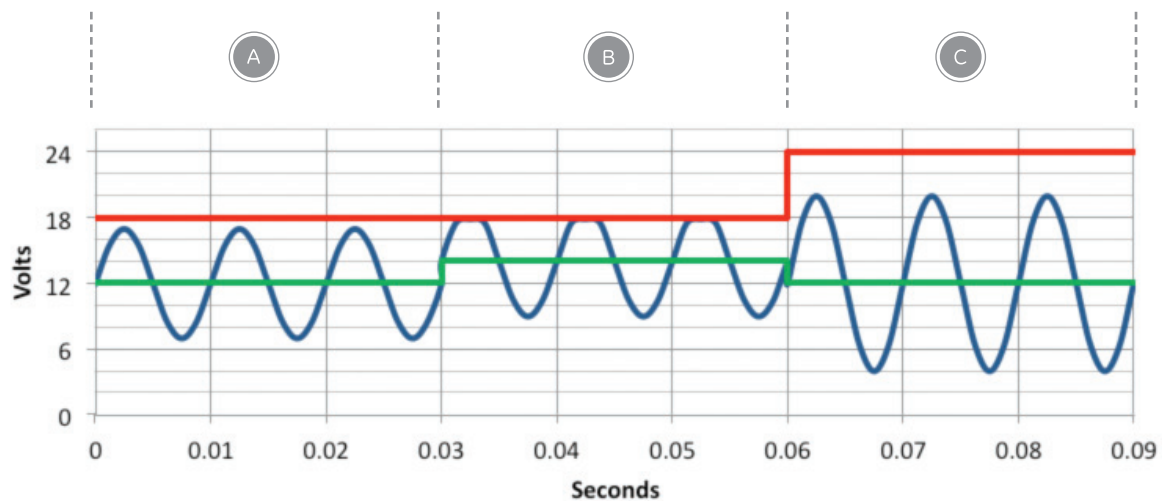
FIGURE 5: AC Vibration, DC Bias, DC Power

━━ AC VIB   ━━ DC BIAS   ━━ DC PWR

SENSITIVITY	X	DYNAMIC RANGE	=	VAC	POWER SUPPLY
10 mV/g	x	+/- 500 gPeak	=	+/- 5 VACPeak	≥ 20 VDC
50 mV/g	x	+/- 100 gPeak	=	+/- 5 VACPeak	≥ 20 VDC
100 mV/g	x	+/- 50 gPeak	=	+/- 5 VACPeak	≥ 20 VDC
100 mV/g	x	+/- 80 gPeak	=	+/- 8 VACPeak	≥ 24 VDC
500 mV/g	x	+/- 10 gPeak	=	+/- 5 VACPeak	≥ 20 VDC

FIGURE 6: Sensitivity & Dynamic Range Values

Measured Bias Voltage 11.76 VDC

-10% = 10.58 VDC

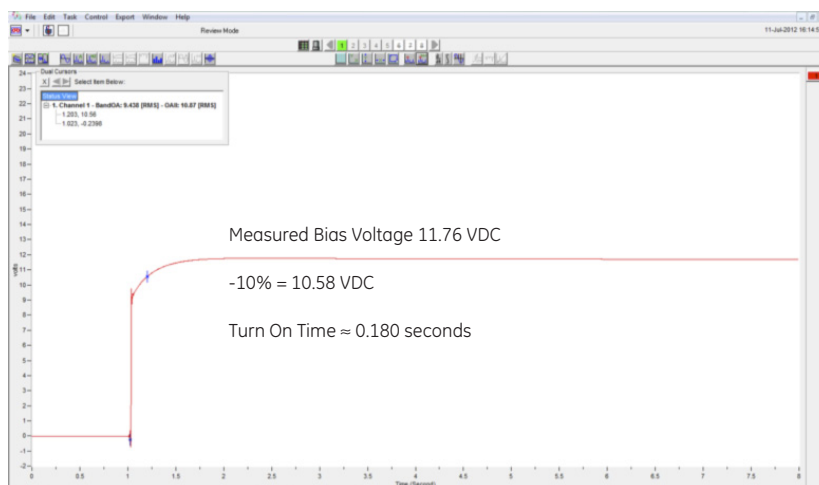Turn On Time ≈ 0.180 seconds

FIGURE 7: Turn On Time

(Signal to Noise Ratio) should be at least 10:1, or the vibration amplitude should be at least 44.3 μg in the above example. Low spectral noise will allow the vibration analyst to make a good measurement and keep the signals of interest well above the noise floor of the accelerometer.

SUMMARY

This article has focused on the functions and features of Industrial Accelerometers, and it has explained some of the designs and specifications that should be considered by the vibration analyst when choosing or using an industrial accelerometer.

SHEAR MODE DESIGN	04 RESONANT FREQUENCY
IEPE CIRCUIT/POWER	05 BIAS VOLTAGE
01 SENSITIVITY	06 DYNAMIC RANGE
02 SENSITIVITY TOLERANCE	07 TURN ON TIME VS. SETTLING TIME
03 FREQUENCY RESPONSE	08 SPECTRAL NOISE

The industrial accelerometer is the primary vibration sensor needed for rotating equipment utilizing rolling element bearings. The vibrations generated by the machine will be transmitted through the casing of the machine to the base of the accelerometer where the Piezo ceramic reacts with the mass in a shearing mode to produce a charge output. The charge is converted to a voltage and amplified internally in the accelerometer for measurement by the vibration analyzer, data collector, or on-line monitoring system.

These robust IEPE type Industrial Accelerometers should provide years of reliable service given proper installation, use, and environmental considerations. ■