Troubleshooting accelerometer installations

Accelerometer based monitoring systems can be tested to verify proper installation and operation. Testing ensures data integrity and can identify most commonly occurring problems.

The troubleshooting techniques presented are very simple and can be performed using most monitoring systems and data collectors or simple test equipment. Many installation and sensor problems can be detected by measuring the bias voltage of the sensor. The bias voltage will indicate faulty cable routes and failed sensors. Many online systems are capable of trending the sensor bias voltage. Other problems can be detected by analyzing the time waveform and FFT spectrum.

Accelerometer operation and response

Most accelerometer faults can be diagnosed by measuring the bias voltage of the sensor amplifier. If the bias voltage is within correct limits the sensor is most likely operating properly. Most cabling faults can also be isolated by measuring the bias. After the bias is checked, the time waveform and FFT spectrum will verify fault diagnosis or proper operation.

AC coupling and the DC bias voltage

The sensor output is an AC signal proportional to the vibration applied. This AC signal is superimposed on a DC bias voltage, also referred to as Bias Output Voltage (BOV) or sometimes rest voltage. The DC component of the signal is generated by the 2 mA constant current diode in the power supply. This DC voltage needs to be blocked by a coupling capacitor in the measurement equipment, leaving the AC output signal. Most vibration data collectors, monitors, and sensor power units contain an internal blocking capacitor for AC coupling. If not included, a blocking capacitor must be field installed.

What is bias voltage?

The majority of accelerometers, PiezoVelocity Transducers (PVT®), and pressure sensors have a biased output. Biased outputs are characteristic of two-wire sensors used to measure dynamic AC signals. Vibration and pressure are examples of dynamic signals that vary with time. The external power supply provides a DC voltage to the accelerometer. This power supply voltage is normally 18 to 30 volts DC. The accelerometer amplifier circuit design establishes this voltage (or “biases” the voltage) to a preset level. This BOV is normally 12 VDC, although it may vary depending on the manufacturer and sensor design. The accelerometer’s specification sheet provides further information on the BOV. The BOV is determined by the amplifier design and is not adjustable.

The BOV remains the same regardless of the input power to the accelerometer, as long as the input power is within the specified range. For example, if the BOV is 12 VDC and the input power is specified as 18 to 30 V, then the BOV will be 12 VDC if the input power is 18 VDC. If the input power is increased to 30 VDC, the BOV will remain at 12 VDC. The BOV is set by the interaction of the amplifier circuit in the accelerometer and the constant current from the stand-alone power supply or the analyzer or data collector.

Figure 1 is a diagram representing the performance of the circuit. The line represented by "Instrument Power" and BOV is one conductor that has two functions. So even though the power supply is providing a higher input voltage, the BOV is the measured output voltage level on the cable connecting the accelerometer to the data collector or analyzer.

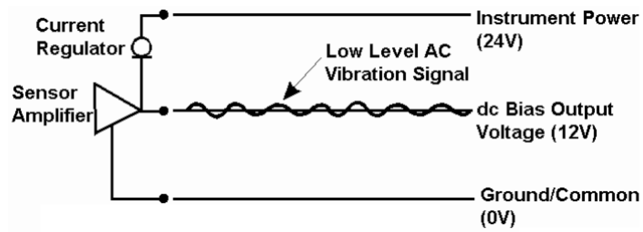

Figure 1: Sensor amplifier circuit

The BOV carries the dynamic vibration signal to the analyzer. The AC signal swings high and low from the BOV level and is limited by the power supply level and ground. For example, if the power supply level is 24 volts, the swing of the AC signal would be limited to no more than 24 volts and no less than ground (0 volts). These are theoretical limits. In reality, the limits to this swing occur at about 1.5 volts above ground and about 1.5 volts below the power supply level, as shown in figure 2.

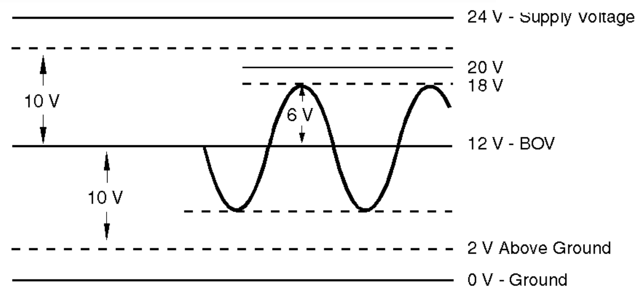

Figure 2: AC signal limits

Most portable data collectors and online systems supply 24 volts to the sensor. The sensor should have a nominal BOV of approximately one half of the power supply voltage, to maximize the amount of swing in the positive and negative directions. Most two-wire sensors produce an 8 to 14 volt bias. When the signal amplitude runs into the supply voltage or ground, clipping occurs. Clipping the vibration signal distorts the waveform. In other words, a clipped signal is no longer a true analog representation of the vibration the sensor is attempting to measure.

Measuring the BOV

The constant current diode (CCD) limits the current supplied to the sensor. It provides a constant current to the sensor regardless of the supply voltage because the use of unlimited power supply current will damage most internally amplified sensors. For this reason, most commercially available data collectors and vibration monitors have power supply circuits that include a CCD to regulate the power supplied to the sensor.

Most battery power supplies contain a 2 mA CCD to ensure long battery life. Line powered supplies (where power consumption is not a concern) should contain 6 to 10 mA CCDs. This offers the ability to drive long cables. For operation above 100° C, it is best to limit the current to less than 6 mA to reduce self heating. Most data collectors supply 2 mA of current to the sensor; most online systems supply 4 to 6 mA. If a power supply that is not current limited is used, a CCD should be placed in series with the voltage output of the supply. Ensure that proper diode polarity is observed. If a current limited power supply is probed with a voltmeter the supply voltage will be measured before the CCD. The bias voltage will be measured on the side of the CCD connected to the sensor. Figure 3 shows a schematic of a sensor power supply containing a fixed CCD between 2 and 10 mA.

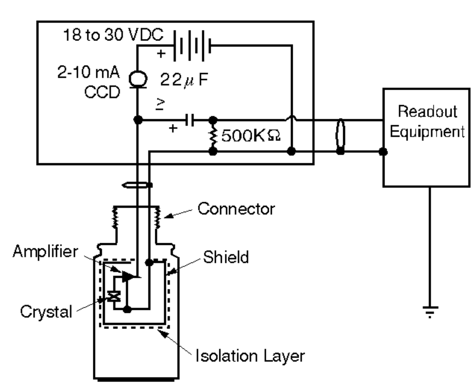

Figure 3: Schematic of a sensor power supply

The BOV should be measured periodically to check sensor operation. The best measurement device is a voltmeter, however, most portable data collectors can measure the BOV if the sensor is powered from a different source (other than the data collector). When using the data collector as a voltmeter the DC voltage input setting is used. Oscilloscopes can also measure the BOV by selecting the DC coupled input. The BOV can be trended with many online systems. Trending the BOV provides a record of sensor operation. If the sensor is disconnected or slowly develops a fault, the BOV data can show when the event occurred.

The BOV will also indicate the condition of the cabling and connectors. If the BOV level measurement is equal to the supply voltage, the sensor may be disconnected or reverse powered. A measurement of 0 volts indicates a short in the system. An unstable bias voltage can indicate poor connections, but can also be caused by a clipped signal or severe electromagnetic interference.

Time waveform and FFT spectrum fault analysis

The time waveform of a sensor can be measured with an oscilloscope, most data collectors, and online vibration monitoring systems. Reviewing the time waveform can immediately indicate a clipped signal, which usually looks truncated or flattened on one side and normal on the other. Severely clipped signals will cause the waveform to look jumpy. Poor connections can also cause a similar jumpy reading.

The FFT spectrum can give another quick indication of signal quality. The one-times (1X) operating speed vibration is usually present and a good indication of proper operation. The presence of a large ski slope can indicate distortion from sensor overload. However, a noisy accelerometer that has been integrated to velocity or displacement may also produce ski-slopes for various reasons.

Cable routing faults can also be detected by analyzing the FFT. Multiples of the line power frequency usually indicates improper shielding or grounding. If the time and frequency measurements read zero, the sensor is disconnected or is not operating.

Fault indications

Open bias fault: Supply voltage (18 - 30 V)

When the measured BOV equals the supply voltage, the sensor amplifier is disconnected or reverse powered. In most cases the problem is the connector or cabling. First check the cable termination at the junction box, data collector or monitoring system. If the cable is connected to a terminal block, make sure the wires are secure and in the proper terminal. Next check the cable connection to the sensor. Many times, the sensor was disconnected for maintenance and was never reconnected. If a faulty connector is detected, it can be disassembled or replaced, but avoid disassembling or removing the connector until all other fault sources have been checked. If each end appears good, check all other terminations, splices and connectors. Also ensure that the cable is not crushed or cut.

If the cable route and connections appear good, further test the cable continuity. Cable continuity can be tested by shorting the signal leads at one end of the cable to the shield wire and measuring the opposite end with an ohmmeter. Depending on the cable length, several ohms to no more than several hundred ohms should be measured from each wire to the shield. If the cable and all connections are in proper working order the fault is in the sensor. However, open faults inside the sensor are very rare.

Short bias fault: 0 volts

When the bias measures 0 volts, power failure or a system short is usually the problem. First ensure that power is turned on and connected. If the power supply is on, check for a short in the cabling. Like the open fault, it is very rare to have a short inside the sensor. The most common fault location is in junction box terminations. Check to make sure that a frayed shield is not shorting across the signal leads. Many times a crushed cable can produce a short. Use an ohmmeter to check electrical isolation between the leads. Disconnect the cable from all other devices and measure between all signal leads and shields. When measuring the resistance between the cable conductors, the ohmmeter should measure infinite or at least above 50 megaohms.

Damaged sensor: Low bias, high bias

Out of specification bias readings other than those listed above usually indicate sensor damage. Common sources of sensor damage are exposure to excessive temperature, shock impacts, mispowering, and electrostatic discharge. Excessive temperature is the most common cause of sensor failure. Sensors caught in a fire are usually destroyed and can show various bias readings depending on the failure mode within the sensor. Long term temperature failures are marked by a slowly rising or declining bias voltage. In many cases bias returns to normal as the temperature decreases. However, the damage to the amplifier is permanent and the sensor amplifier may continue to deteriorate. Figure 4 shows the bias trend of a sensor failing from long term temperature degradation in a paper machine dryer section.

Excessive shock, mispowering and electrostatic discharge can permanently damage the amplifier of unprotected sensors. Industrial sensors typically contain protection devices to prevent these types of failures.

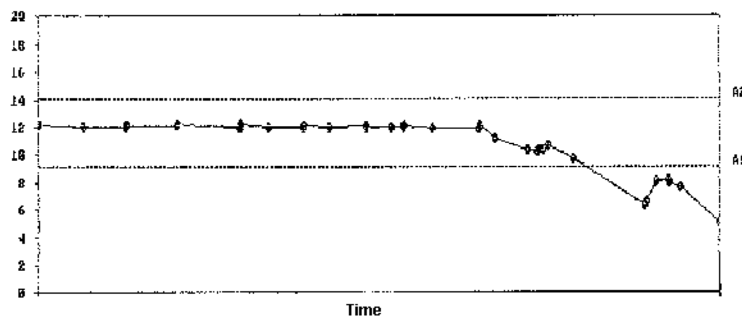

Figure 4: BOV trend of a sensor exposed to long-term excessive temperatures

Erratic bias and time waveform

The bias voltage should remain stable and unchanging for properly operating sensors. Shifting bias indicates a very low frequency signal that is not filtered out by a DC meter. In rare cases this indicates an actual low frequency signal, however in most cases this indicates a fault. Primary causes of erratic bias are thermal transients, poor connections, ground loops, and signal overload. Each of these faults will also be visible in the time waveform as erratic jumping or spiking of the signal. Thermal transients cause uneven thermal expansion of the sensor housing materials. This can be detected by the sensor as a low frequency signal. The problem is most evident when using low frequency sensors.

Poor or contaminated connections can also cause low frequency bias and contact noise. Look for corroded, dirty, or loose connections. Repair or replace the connection as necessary. Non-conducting silicone grease should always be applied to connectors to reduce contamination.

Ground loops are developed when the cable shield is grounded at two points of differing potential. Always ground the shield at one end only! An easy test for ground loops is to disconnect the shield at one end of the cable. If the problem disappears it was probably a ground loop fault. Figures 5a and 5b show a connection susceptible to ground loops and a correct installation where the shield is tied at one end only.

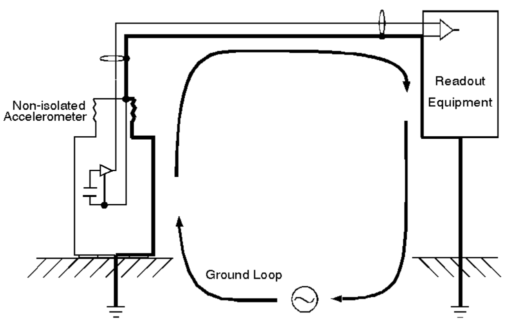

Figure 5a: A poorly grounded installation

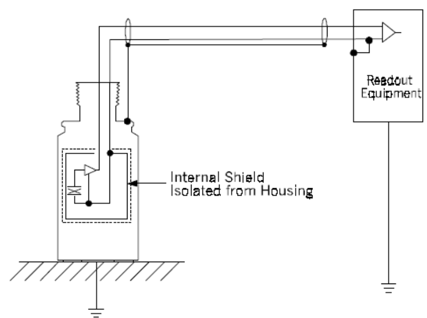

Figure 5b: A properly grounded installation

Sometimes spurious spikes from fast thermal shifts, lightning strikes, and shocks can overload the sensor and cause a momentary shift in the bias voltage. The shift in bias can trigger alarms and protection system shutdown devices. To prevent triggering alarms and shutdown, a longer delay can usually be programmed or hardwired into the monitoring system. The delay prevents the system from taking action until the sensor has settled.

High frequency, high amplitude vibration signals can also overload the sensor and in severe cases cause bias shift and erratic time waveform. However, overload problems are usually detected by observing truncated waveforms and large ski-slope spectrums.

Truncated time waveform: sensor overload

Truncated (flattened) time waveforms indicate that the signal is clipping. Clipping causes the amplifier to saturate and become overloaded. Some common mechanical causes of an overload in the sensor are severe pump cavitation, steam release, impacts from loose or reciprocating parts and even gearmesh. One way to reduce clipping is to use a higher power supply voltage and ensure that the bias voltage is centered between supply voltage and ground voltage. However the bias voltage and power supply are rarely adjustable. For example, if you are using an 18 volt power supply and a 12 volt bias, clipping will occur sooner than if you used a 24 volt power supply.

Long cables in excess of 200 feet can also reduce the amplitude swing at high frequencies and may be a problem in some applications. The easiest solution is to use a lower sensitivity sensor. A sensor with 10 mV/g sensitivity will have a hundred times larger amplitude range than a similar 1 V/g sensor.

Ski-slope spectrum

Sensor overload may also produce a ski-slope spectrum. If the amplifier saturates, intermodulation distortion occurs. This causes low frequency noise, also referred to as washover distortion. Figures 6a shows a normal spectrum. Figure 6b shows what can happen when the signal becomes overloaded due to excessive vibration.

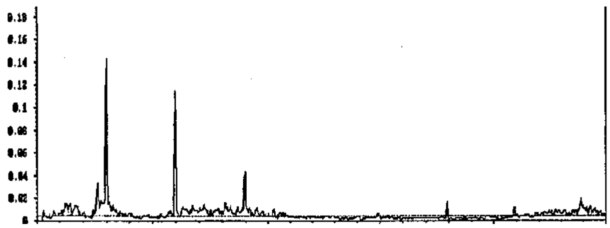

Figure 6a: Normal operation

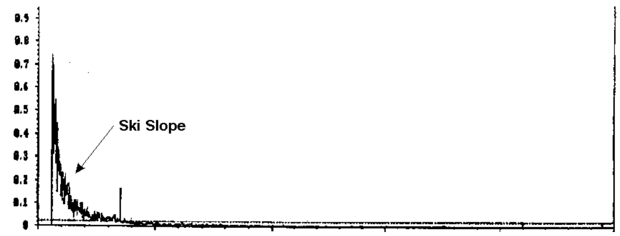

Figure 6b: Overloaded operation

Sometimes the ski-slope signals can be caused by the circuitry used to integrate acceleration signals to velocity or displacement. Figure 7 shows integration noise due to analog integration of an acceleration signal.

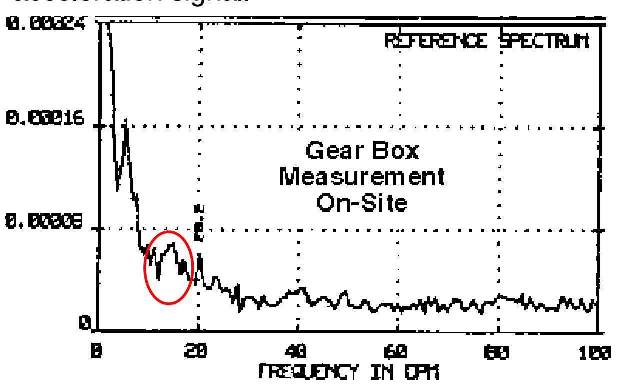

Figure 7: Ski-slope noise caused by analog integration

Mounting resonance spectrum

Mounting resonance can give false indication of high frequency machinery faults such as gear mesh and bearing problems. The problem is more likely to occur when using probe tips and magnets, and care must be exercised to prevent the measured mounting resonance peaks from being falsely identified as machine produced peaks. Mounting the sensor on thin plates such as machine guards, can also lower the mounting resonance. Figure 8 shows the resonance of several common mounting techniques. Mounting resonance plots are shown for: (a) probe tip; (b) magnet; (c) Wilcoxon's QuickLINK™; and (d) stud mounted configurations.

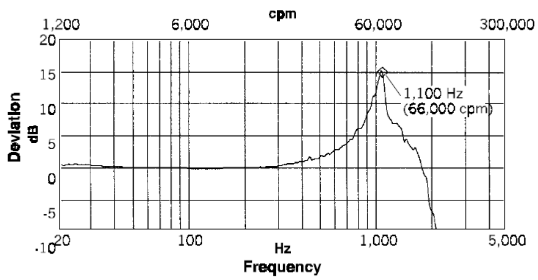

Figure 8a: Probe tip mounting resonance

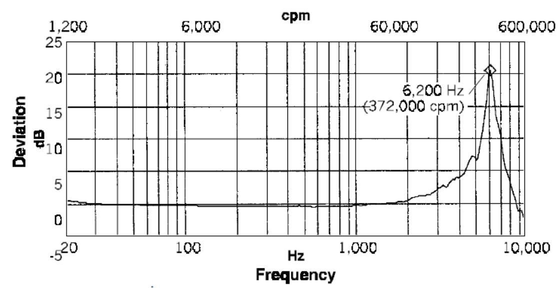

Figure 8b: Magnet mounting resonance

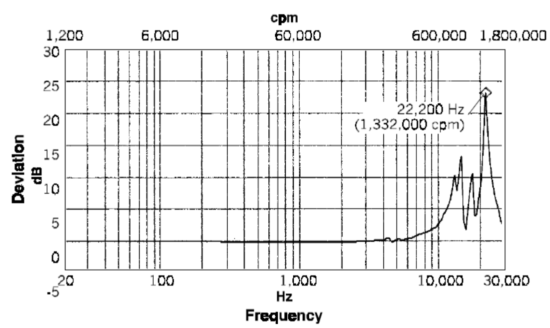

Figure 8c: QuickLINK™ mounting resonance

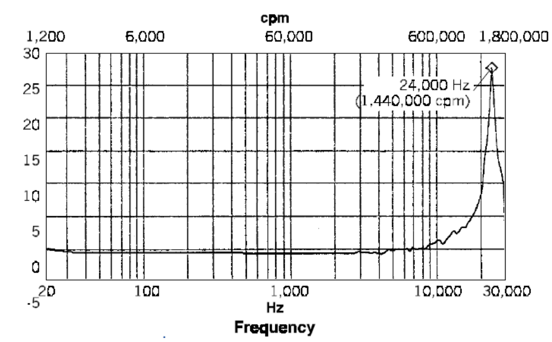

Figure 8d: Stud mounting resonance

Re-measuring with the sensor mounted at a different location will usually discriminate machine vibration from mounting resonance. However if a machine signal coincides with the resonance of the mounting configuration, a greatly increased signal can happen. This can lead to sensor overload which will be manifested with a spectrum dominated by a ski slope.

Line frequency harmonics in spectrum

Harmonics of AC line power frequency usually indicate interference from motors, power lines and other emissive equipment. First, ensure that the sensor shield is grounded (at one end only). If the shielding is good, check the cable routing. A good measurement practice is to run signal cables in cable trays separate from power line cable trays by at least 12 inches. If a signal cable tray must come near a power cable tray, they should cross at right angles to reduce the possibility of magnetically coupled signals. Using shielded, twisted pair cable will also help minimize any magnetically coupled noise into the signal cable. For example, if a power cable is 440 volts and the vibration signals from the sensor are at the millivolt level, any cross talk will severely corrupt the data.

Troubleshooting chart

Below is a troubleshooting chart for sensors with a 12 volt bias. For sensors with other bias voltages, the same concepts apply — only the stable bias range will be different.

BOV	Spectrum	Time waveform	Fault condition	Action
0 V	No signal	No signal	No power or cable/connector short	- Test/turn on power - Test cable isolation - Repair/replace cable
2.5 – 5.0 V	No signal	No signal	Damaged amplifier	- Replace sensor
10.0 – 14.0 V Stable	High low frequency ski slope	High amplitude high frequency noise	High frequency overload (steam release, air leak, cavitation, etc)	- Repair steam leak/dump - Use less sensitive sensor - Place rubber pad under sensor
10.0 – 14.0 V Stable	Very high low frequency ski slope No high frequency signal	Choppy	Damaged amplifier	- Replace sensor
10.0 – 14.0 V Stable	Good signal strong 50/60 Hz	50/60 Hz	Inadequate shielding	- Connect ground/cable
10.0 – 14.0 V Stable	High low frequency noise	High frequency spikes	ESD Arcing impacts	- Reroute cable - Use less sensitive sensor - Place rubber pad under sensor
10.0 – 14.0 V Stable	High low frequency noise	Jumpy/choppy	Intermittant connection	- Repair connection
18.0 – 30.0 V	No signal	No signal	Reversed powering	- Reverse leads
18.0 – 30.0 V	No signal 50/60 Hz	No signal	Open cable connections	- Repair connection