Celera MOTION
A Novanta Company

# Selecting Position Sensors for Harsh Vibration Environments

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# INTRODUCTION

Machines that are subject to harsh or prolonged vibration present challenges for many components - none more so than position and speed sensors.  This article suggests 10 simple rules for design engineers selecting position and speed sensors that must cope with shock or vibration.

There are many examples of harsh shock and vibration environments: off-road vehicles, airborne avionics and mining equipment. There are also some less obvious examples - such as pumps, motor drives and refrigeration plant – where the vibration is less extreme but persists over many years. Of course, characteristics will vary from application to application but generally all environments with vibration or shock can present significant problems for position sensors.

*Figure 1. Airborne equipment is often subject to harsh and prolonged vibration*

The Following 10 Simple Rules Should Help Design Engineers Select Position Or Speed Sensors That Won't Fail Once Installed In The Field.

## 1. Use Non-Contact Sensors

Potentiometers are by far the most common form of position sensor but are generally not suitable for environments with either extreme or prolonged vibration. This is because a potentiometer's sliding contacts wear and so they have a finite lifetime. If we consider a potentiometer with say a life-time of 1 million cycles, this is likely to be fine for a benign application which cycles perhaps 100 times per day because this equates to 10,000 days (or 27 years). However, place the same potentiometer in an application which is vibrating at 20Hz as shown in Figure 1 (like an engine or pump, for example), and the same potentiometer is likely to fail in less than a day. This is because the potentiometer's contacts will see each vibration as a cycle on a microscopic scale. If the potentiometer is normally positioned at a particular point, the wear effect is accelerated, and the potentiometer is likely to fail even more quickly.

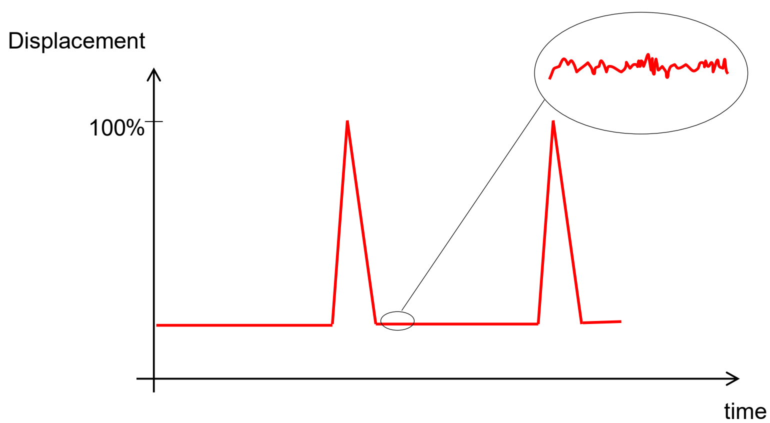


***Figure 2**. Vibration causes potentiometers to wear out quickly*

## 2. Damp The Sensor Output

By definition, the position or speed being measured is likely to be changing at the vibrating frequency (or some function of the frequency). A sensor with undamped electronics will output the measured position and so its output will appear to bounce along at the vibration frequency. However, if the sensor's output is electrically damped, the output becomes the average of the measured position. In some sensors the length of time over which the output is averaged can be varied – from a fraction of a second or many seconds- to suit the application.

### 3. Measure Directly Rather Than Indirectly

If position or speed is to be measured in a vibrating system, it is likely that different components within the system will be vibrating at various frequencies and amplitudes. Accordingly, it is more important in vibrating environments to measure the position of the actual elements whose position or speed is to be measured directly. This is opposed to measuring position indirectly – say at the end of a gear-train or multi-link mechanism. Without direct measurement, measurement accuracy will be degraded.

### 4. Avoid Delicate Glass Scales in Transmissive Optical Encoders

Transmissive optical encoders use a glass scale with opaque and transparent lines which modulate light as the scale turns. In benign environments, free of contaminants, optical sensors deliver high levels of performance. However, glass scales are susceptible to fracture in applications with heavy shock or vibration. Interferential encoders are more resilient to shock and vibration as the scale can be mounted on a hub which fully supports the scale.

### 5. Use Caution with Magnetic Sensors

Magnetic encoders, both Hall and magnetoresistive, are rugged, compact and can be very cost-effective. The magnetic track is, however, relatively brittle and can be susceptible to shock.

### 6. Minimize Sensor Weight

An often over-looked phenomenon is that damage imparted to sensors is usually not directly due to the vibration itself but rather as a result of the momentum of the sensor's own components. Minimizing weight, minimizes momentum and hence minimizes the potential for damage. Lightweight sensors are generally less susceptible in harsh vibration environments.

### 7. Use Heavy-Duty Connectors - Or Preferably No Connectors

The single largest cause of electrical failure in hash vibration environments is cables and connectors. Harsh vibration environments are no place for the relatively flimsy connectors normally used on consumer electronics. Instead, connectors should be heavy duty – such as military standard 38999 (shell types) – or at least include jack screws to bind the connector's male and female elements. If possible, connectors should be eradicated and electrical interconnections made by direct wiring or flying leads.

## 8. Potting and Encapsulation

An excellent way to mitigate problems due to vibration is to pot sensors and cables in to position. There is a wide variety of 2 part epoxies used for electronic encapsulation and these are an excellent way of securing position sensors in to the host equipment. This has added advantages of providing a barrier against contaminants and improving heat dissipation at elevated temperatures.

## 9. Stress Relieve Connecting Wires

Wires and cables tend to be forgotten in stress and vibration analyses, but a moving cable is a sure way to generate problems from conductors or electrical joints cracking due to fatigue. Potting is an excellent way to eradicate such problems but alternatives include cable wraps, potting or tightly fitting conduit.

## 10. Lock Any Fasteners

This may seem an obvious step but nevertheless it is one that is often forgotten. Fasteners that secure position sensors should be bonded in to position with thread lock or, preferably, an anti-rotation fastener such as a tab washer to prevent hex-headed screws from turning and becoming loose.