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Steps to Selecting the Right Accelerometer

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Steps to selecting the right accelerometer

At first look, an accelerometer manufacturer's catalog or web site can be intimidating to both the novice and often the more experienced user. Accelerometers are offered in a variety of technologies, shapes, sizes, ranges, etc.

This article will provide a trail that the user can follow that will lead to the optimum accelerometer for the application.

Technology selection

The first step in the selection process is to determine the type of measurement to be made. The measurement type will be the first step in the technology selection. There are three widely used technologies used for acceleration measurements.

Piezoelectric (PE) accelerometers are the most widely used accelerometers for test and measurement applications. These devices offer a very wide measurement frequency range (a few Hz to 30 kHz) and are available in a wide range of sensitivities, weights, sizes and shapes. These accelerometers should be considered for both shock and vibration measurements. PE accelerometers are available with a charge or voltage (IEPE) output, discussed later in this article.

Piezoresistive (PR) accelerometers generally have low sensitivity making them desirable for shock measurements. They are also used extensively in transportation crash tests. Because of the low sensitivity, they are being used less for vibration measurements. PR accelerometers generally have a wide bandwidth and the frequency response goes down to zero Hz (often called "DC responding") or steady state, so they can measure long duration transients.

Variable capacitance (VC) is among the newer accelerometer technologies. Like PR accelerometers, they are DC responding. VC accelerometers have high sensitivities, a narrow bandwidth and outstanding temperature stability. These devices are highly desirable for measuring low frequency vibration, motion and steady state acceleration.

Type of measurement

In this section, the basic measurement types will be described and then, later in this article, more detail will be provided. For the purposes of this article, acceleration measurements will be divided into the following categories:

Vibration: An object is said to vibrate when it executes an oscillatory motion about a position of equilibrium. Vibration is found in the transportation and aerospace environments or as simulated by a shaker system.

Shock: A sudden transient excitation of a structure that generally excites the structure's resonances.

Motion: For the purpose of this article, motion is a slow moving event such as the movement of a robotic arm or an automotive suspension measurement.

Seismic: This is more of a motion or a low frequency vibration. This measurement usually requires a specialized low noise–high resolution accelerometer.

Once the measurement type is determined, the reader can go directly to the measurement section (in this article) of interest, or review the different measurement types.

General considerations

Prior to going into the technologies and applications, here are a few general considerations.

The frequency response is an important parameter when considering any accelerometer. This parameter is usually specified within ±5% of the reference frequency (usually 100 Hz). Many devices will have the specifications extended to ±1 dB and in some cases ±3 dB. Most data sheets will have a typical frequency response curve to assist the user. The frequency range will usually be determined by the test specifications or as determined by the user.

Another consideration is the number of axes to be measured. Accelerometers are available in single and triaxial (see Figure 1) versions. Another approach to making a three axis measurement is to mount three accelerometers on a triaxial mounting block. Both methods allow for the measurement of three orthogonal axes simultaneously.

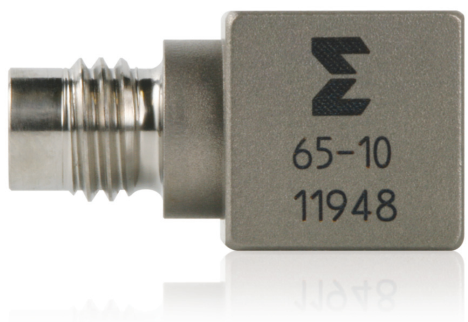

Figure 1 **A miniature triaxial accelerometer that incorporates three accelerometers in a single package for the measurement of three orthogonal axes simultaneously.**

Vibration

Piezoelectric accelerometers are the first choice for most vibration measurements since they have a wide frequency response, good sensitivity and resolution and are easy to install. There are two subdivisions of piezoelectric accelerometers which include the basic charge-mode accelerometer and the voltage mode Internal Electronic Piezoelectric (IEPE) types.

IEPE piezoelectric

In recent years, the IEPE type has become the most commonly used accelerometer type. IEPE sensors are often sold under different trade marked names, but all virtually comply with a pseudo industry standard and are interchangeable between brand names.

Basically, an IEPE accelerometer is a device with the charge amplifier built-into the accelerometer. They require no external charge amplifiers and use ordinary low cost cable. The accelerometer does require a constant current power source and many data acquisition systems have built-in power sources. If the user knows the vibration range and the operating temperature is in the range of -55°C (-67°F) to 125°C (257°F) then an IEPE device should be considered. Note that high temperature versions are available in some models that have a maximum operating temperature of 175°C (350°F).

Charge mode piezoelectric

Charge mode piezoelectric accelerometer advantages include high temperature operation and an extremely wide amplitude range. A typical charge mode accelerometer will have an operating temperature range of -55°C to 288°C (-67° to 550°F). Special purpose accelerometers are available for extreme environments as low as -269°C (-452°F) to as high as 760°C (1400°F). Special radiation hardened charge mode accelerometers are available for use in a nuclear environment.

Unlike the IEPE accelerometer, the charge type accelerometer requires the use of special low noise cable. The low noise cable is expensive compared to the standard commercial coaxial cable. A charge amplifier, or an in-line charge converter is also required.

Variable capacitance

In instances where vibration measurements at very low frequencies are required, a variable capacitance (VC) accelerometer is a choice to consider. VC accelerometers have a frequency response from 0 Hz to 1 kHz, depending on the sensitivity required. When making very low frequency measurements, a VC accelerometer with a frequency range from 0 Hz to 15 Hz will provide a high sensitivity of 1 Volt/g. VC accelerometers are useful on electro hydraulic shakers, flutter measurements and many transportation applications.

Figure 2 **Variable capacitance accelerometer shown with a popular mounting configuration. Models are available with a 10-32 stud mount.**

Motion

Two technologies are available for shock measurements and a variety of accelerometers are available depending on the levels and final data required. It is important to know the expected shock level, since this will determine the type of accelerometer to be used. Here is a rough guide to assist the reader in choosing the proper accelerometer.

- Low level ‹ 500 g
- Crash ‹ 2000 g
- Far field 500 g to 1000 g sensor located 2 meters from the point of impact
- Near field › 5000 g with the sensor located ‹ 1 meter from the point of impact

For low-level shock measurements, a general purpose accelerometer will generally do the job. The accelerometer will need a linear range of at least 500 g and a shock survivability rating of 500 g. An IEPE type is usually preferred since they are less susceptible to producing erroneous results from cable motion. The user should use an amplifier with a low-pass filter to attenuate the accelerometer resonance.

Automotive crash testing is a rather specialized area of shock testing. Piezoresistive accelerometers are usually used (see Figure 3).

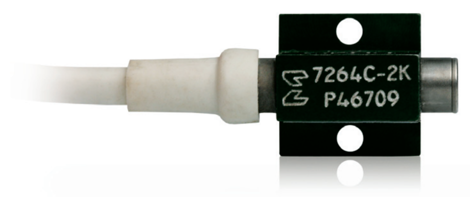

Figure 3 **Automotive crash test accelerometer shown in an industry standard package.**

For far field shock measurements, a special shear mode accelerometer with a built-in electronic filter is often adequate. These are usually lightweight IEPE types with solder connections. The electronic filter electronically attenuates the resonance frequency of the accelerometer to prevent overloading of the data acquisition equipment.

Near field measurements are usually very high levels often in excess of 20 000 g. Here the choice of accelerometers is dependent upon the type of test being conducted. Specialized accelerometers of either piezoelectric (charge mode and IEPE) or piezoresistive may be appropriate. Typically, an IEPE with characteristics similar to the far-field accelerometer is appropriate, but with the addition of an internal mechanical filter. The mechanical filter will ensure the survivability of the accelerometer and will generally eliminate "zeroshift".

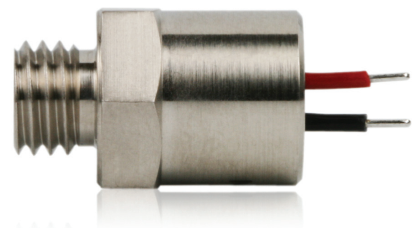

Figure 4 **Example of a near field shock accelerometer with built-in mechanical filter and rugged ¼-28 mounting stud**

A detailed discussion of zeroshift is beyond the scope of this article. In general terms, the zeroshift phenomenon appears with the time history not returning to the zero acceleration level following the shock event. This shifting results in distortion of data when performing integration. If a piezoresistive accelerometer is selected, zeroshift is rare.

As is the case with vibration, the frequency response is an important parameter for shock. In general, a shock accelerometer should have a wide frequency response range (10 kHz is typical), depending on what is being tested.

Motion, constant acceleration and low frequency vibration

This category is where variable capacitance (VC) accelerometers should be considered. This technology allows for the measurement of low level, low frequency vibration with a high output level. They also provide a high degree of stability over a broad temperature range.

When a VC accelerometer is placed in a position where the sensitive axis is parallel to the earth's gravity, an output equal to 1 g will be produced. This phenomenon is often referred to as "DC responding". Because of this characteristic, VC accelerometers are very useful for measuring centrifugal force or for the measurement of acceleration and deceleration of devices such as elevators.

In the realm of vibration testing, VC accelerometers are used in applications where low frequency events are to be studied and preservation of phase data is important.

VC accelerometers have found their niche in the area of aircraft flutter testing. They are also valuable tools for measuring vehicular ride quality.

The low frequency characteristics make VC accelerometers ideal for ride quality measurements in automobiles, trucks and railroad equipment. These are low frequency devices and a wideband frequency response is not a characteristic of VC devices.

Environment

Once the technology has been selected and the test type determined, there are a number of other factors to be considered. As a starting point, the environment is to be considered.

The environmental characteristics include temperature, maximum acceleration levels and humidity.

Below is a table, showing typical values to assist with temperature selection:

Technology	Temperature range	Comments
Piezoelectric - general	-55 °C to 260°C	The range is extended in some cases
Piezoelectric-high temperature	-55 °C to 650°C	Special high temperature accelerometers
Cryogenic piezoelectric	-184°C to 177°C	
IEPE general types	-55 °C to 125°C	
IEPE high temperature	-55 °C to 175°C	
Piezoresistive	-55 °C to 66°C	

The specified g range is often confusing to the new accelerometer user since this parameter appears twice in the specifications. The actual usable range, of the accelerometer is found in the dynamic specifications. For example, an IEPE accelerometer might have a "Range" of 500 g, and, under the environmental characteristics the device has a shock limit of 1000 g and a shock limit of 2000 g. In the above example, 500 g is the maximum range of linear operation of the accelerometer. The parameters specified in the environmental section are indicative of the maximum survivable shock and/or sine acceleration levels.

In the case of charge mode piezoelectric devices, a range is not specified under the dynamic characteristics since it is largely determined by the charge amplifier. The user should refer to the amplitude linearity specifications, in the dynamic characteristics section of the data sheet. As above, the maximum range specified in the environmental characteristics section is a maximum survivability figure.

The humidity specification is usually given as "Hermetic", "Epoxy seal", or "Environmental seal". Most of these seals will withstand high levels of moisture. If the accelerometer is being used in the space environment, underwater or very long exposures to excessive humidity, an hermetic seal is recommended. It should be noted that continuous temperature cycling can make an epoxy seal fail.

If accelerometers are designed to operate within a nuclear radiation environment, the data sheets will so indicate.

Magnetic susceptibility is seldom specified since it is usually not a problem with newer accelerometers. Non-magnetic materials are used in modern accelerometers thus reducing this problem.

If the accelerometer is going to be mounted on a highly flexible surface, the base strain specification becomes important. A flexile surface tends to bend inducing strain on the accelerometers base. The resulting strain can appear as vibration in the accelerometer's output.

Accelerometer weight

When an accelerometer is attached to the test article, the measured acceleration will be altered. These effects can be reduced to an insignificant amount by being mindful of the accelerometer's weight. As a rule-of-thumb, the weight of the accelerometer should be no greater than 10% of the weight of the test article.

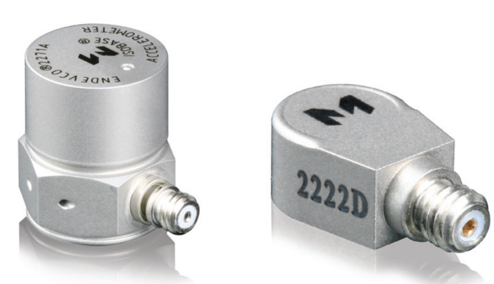

Figure 5 Shown on the left is a popular side connector accelerometer that weighs 7.8 grams and is used on heavy test articles. The unit on the right is a miniature accelerometer that weighs 0.5 grams that can be mounted on lightweight structures and PC boards.

Mounting

There are a number of ways to mount an accelerometer to the unit under test (UUT). Methods include everything from permanent mounting to temporary methods. This article will discuss the most common mounting methods.

By far the best mounting method is the use of a threaded stud, or screw. Stud/screw mounting provides the best transmissibility at high frequencies since the accelerometer is virtually fused to the mounting surface. High frequency response can be enhanced by the application of light oil between the accelerometer and UUT. If this method of mounting is desired, accelerometers should be purchased that are designed for stud and/or screw mounting.

Adhesive mounting is often required, especially on small surfaces and PC boards. A cyanoacrylate is the preferred mounting adhesive since it can be easily removed if the proper removal techniques are used. The user has a couple of accelerometer choices for adhesive mounting. Many accelerometers are available that are specifically designed for adhesive mounting and this fact will be noted on the data sheet. A stud-mount accelerometer may be mounted using an adhesive, but a cementing stud should be used to prevent the adhesive from damaging to the accelerometer's threads.

Ground isolation

Accelerometers are available with ground isolation or with the ground connected to the accelerometers case. Accelerometers with ground isolation usually have an isolated mounting base and, where applicable, an isolated mounting screw, or in some cases the entire accelerometer case is ground isolated.

Ground isolation becomes important when the test articles surface is conductive and at ground potential. A difference in ground voltage levels between the electronic instrumentation and the accelerometer may cause a ground loop resulting in erroneous data.

Sensitivity and resolution

An accelerometer is a transduction device that converts mechanical energy into an electrical signal (the output). The output is expressed in terms of millivolts per g, or in the case of a charge mode accelerometer the output is expressed in terms of pC per g. Accelerometers are offered in a wide range of sensitivities and the optimum sensitivity is dependent on the level of the signal to be measured e.g., in the case of a high g shock test, low sensitivity is desirable.

In the case of low level signals, it is desirable to use an accelerometer of high sensitivity in order to provide an output signal well above the amplifier's noise level. For example, suppose the expected vibration level is 0.1 g and the accelerometer has a sensitivity of 10 mV/g, then the voltage level of the signal would 1 mV, thus a higher sensitivity accelerometer may be desirable.

In the instance where either a low level signal and/or a wide dynamic range is required, then the accelerometer's resolution and sensitivity become important.

Resolution is related to the accelerometers minimum discernable signal. This parameter is based on the noise floor of the accelerometer (and in the case of an IEPE type, the internal electronics) expressed in terms of g rms.

Other considerations

The above information will help the potential user to make a preliminary decision as to which accelerometers can potentially perform the measurement task. There are other parameters that are equally important that should be discussed with potential suppliers. These important items may include:

- Signal conditioning and powering
- Transverse sensitivity
- Temperature response
- Cable types

It is recommended that once the questions in this article have been answered, further discussion with the manufacturer is recommended.

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