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Practical considerations in using IEPE accelerometers with modern data acquisition systems

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For many years, sensor manufacturers have offered high quality signal conditioning amplifiers to go along with their sensors. In particular, accelerometer makers offer amplifiers for both their piezoelectric charge (PE) and piezoelectric voltage IEPE (Integrated Electronics Piezoelectric) accelerometers. These amplifiers are highly flexible, allowing the user to configure almost any combination of input accelerometer sensitivity and output scale factor, for use with a downstream data acquisition system.

For the most part, accelerometer manufacturers have been satisfied with offering signal conditioning amplifiers, and have stayed out of the data acquisition system market space. However, with the rapid increase in popularity of IEPE accelerometers, and the seemingly simple ease of constructing an IEPE signal conditioner, several data acquisition system vendors have begun to offer IEPE accelerometer signal conditioning integrated into their systems. While use of these signal conditioner/data acquisition systems can be a great convenience and cost reducer for the IEPE accelerometer user, there are several factors for the user to consider, ensuring their measurements are of the quality level they require. These factors will be discussed individually.

Power requirements – Current

Unlike piezoelectric charge (PE) type accelerometers, IEPE accelerometers require power to operate. The signal conditioner/data acquisition system must be able to supply the appropriate power required by the accelerometer. The user should always refer to the accelerometer's datasheet for power requirements, as different IEPE accelerometers will have different requirements. (Note that there is no industry consensus standard on IEPE, such as an ISA or ANSI specification.) Without appropriate power, that meets the manufacturer's specifications, the user cannot be assured the accelerometer is operating properly, thus running the risk of poor quality or invalid measurement data.

The IEPE power scheme is unique in that it uses constant current, rather than constant voltage, to power the accelerometer's internal electronics. Refer to Figure 1 for a general schematic of the IEPE power scheme. One of the first considerations, then, that an IEPE accelerometer user must make is whether their data acquisition system can supply sufficient constant current. IEPE accelerometers are frequently specified to operate over a wide range of constant current, with the minimum often being 2 mA. Whatever the required minimum, the user should ensure that their data acquisition system can supply this minimum amount of current. This should be specified in the data acquisition system's specifications, or it can be measured. To measure it, refer to Figure 2. Using a 1 kΩ resistor connected from the IEPE power source to ground, measure the current that flows through the resistor using a current meter. This is the constant current that the system can supply. The 1 kΩ resistor simulates the presence of an accelerometer, and effectively "tells" the data acquisition system to turn on the constant current source.

For applications requiring long cables, or the measurement of high amplitude, high frequency vibrations, more current than the accelerometer's minimum specified constant current may be required from the data acquisition system. This issue will be discussed in a later section.

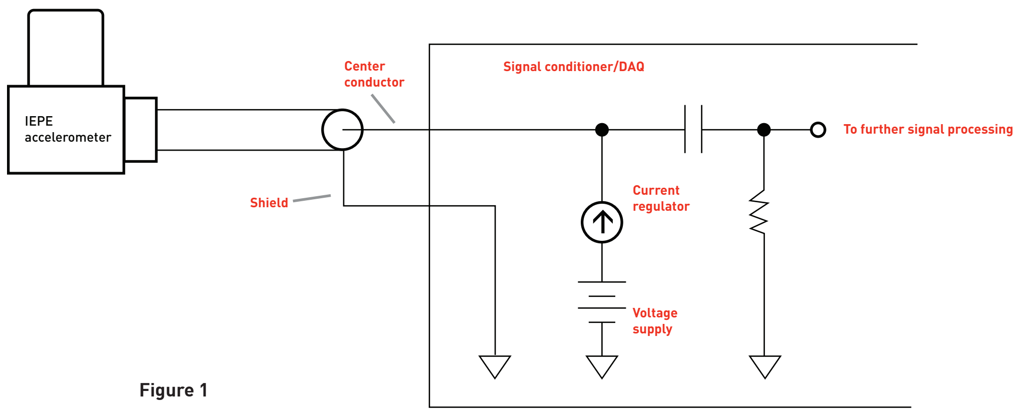

Figure 1

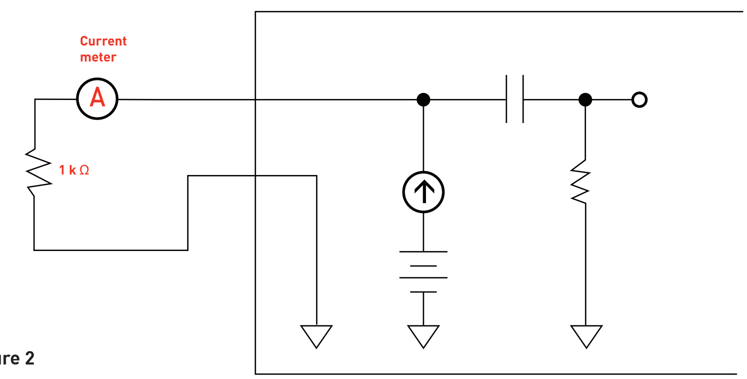

Figure 2

Power requirements – Compliance voltage

While the IEPE power scheme utilizes constant current, the accelerometer still requires a voltage in order to output its voltage signal in a distortion free manner. This voltage, known as the compliance voltage, is the maximum voltage available from the constant current source. If the signal conditioner/data acquisition system does not supply a high enough compliance voltage, the accelerometer may not reach its specified fullscale range expected by the user, resulting in a distorted output signal and erroneous data. The IEPE accelerometer user must consider, then, whether their signal conditioner/data acquisition system can meet the compliance voltage requirement of the accelerometer. As with current, IEPE accelerometers are often specified to operate over a range of voltage, with the minimum frequently being 18 Vdc, but can be as high as 24 Vdc.

The user must ensure their data acquisition system can meet at least this minimum voltage. As with the constant current, this compliance voltage should be specified in the data acquisition system's specifications. But its approximate value can also be measured in the following simplified way. Refer to Figure 3. Connect a 50 kΩ resistor from the IEPE power source to ground. The voltage measured across the resistor is the approximate compliance voltage.

Note that in some special circumstances, it may be permissible to operate an IEPE accelerometer slightly below the required minimum constant current and compliance voltage; under no circumstance should the accelerometer be operated above the specified maximums. Doing so risks permanently damaging the accelerometer.

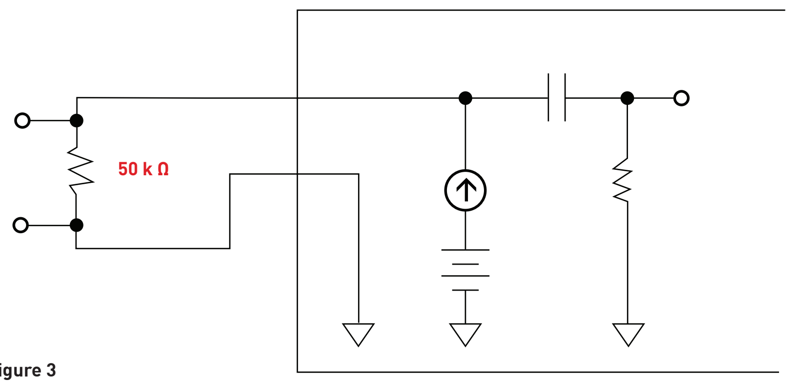

Figure 3

Noise considerations

Many IEPE accelerometers have excellent noise specifications, but if the signal conditioner/data acquisition system cannot take advantage of this capability, this high performance can be degraded. The user must consider the noise performance of the data acquisition system to ensure it does not degrade the quality of the measurements being taken by the accelerometer.

Some lower cost signal conditioner/data acquisition systems may especially have a problem in this area. Inherent in the way the IEPE powering scheme works (see Figure 1), any noise originating from the voltage supply for the constant current regulator will directly couple into the accelerometer's output signal. Frequently, the voltage supply used on these lower cost systems is derived from simple switching DC-to-DC converters, which typically are noisy. There is not much the user can do to manage this, other than to avoid these lower cost, lower quality data acquisition systems in general. This does, however, highlight one of the significant drawbacks to the signal conditioner/data acquisition system integration approach.

Frequency response – High frequency

Depending on the application, the user must consider the frequency limits, both high and low, of the instrumentation they are using. The frequency responses of IEPE accelerometers are usually well specified, but, as with noise performance, the user must ensure the signal conditioner/data acquisition system does not degrade this performance to unacceptable or unexpected levels.

The high frequency response of the system is dependent on the maximum acceleration signal amplitude to be measured, the capacitance of the cable between the accelerometer and signal conditioner/data acquisition system (and, therefore, the length of this cable) and the constant current available from the data acquisition system to drive this cable. This dependency can be expressed mathematically as:

$$f\,\text{max} = \frac{I}{2\pi aSLC} \quad \text{(units in Hz)}$$

where I = **constant current available to drive the cable (units in A)**

a = **amplitude of acceleration signal expected (or desired) to be measured (units in gpk)**

S = **sensitivity of accelerometer (units in mV/g)**

L = **total cable length (any length unit)**

C = **cable capacitance per unit length (units in F/unit length, note that length unit must match cable length unit)**

(Note that 1 mA should be subtracted from the total constant current from the signal conditioner/DAQ. This 1 mA is used by the accelerometer's electronics itself, while the remaining current is available to drive the cable.)

From this equation, it is clear that available current from the data acquisition system is directly proportional to the high frequency cutoff (-3 dB). Insufficient current from the data acquisition system, even if enough to meet minimum requirements of the accelerometer, will reduce the measurement system's bandwidth. The user must consider how much current is available from the signal conditioner/data acquisition system to ensure the system frequency bandwidth is adequate for the measurement being taken. This warrants particular attention if the system utilizes long cables, or the measurement involves high amplitudes and/or high frequencies.

Frequency response – Low frequency

IEPE accelerometers, when properly powered, output a DC bias voltage, as well as the dynamic AC signal proportional to acceleration. This is inherent in the IEPE powering scheme. This DC bias must be filtered out within the signal conditioner/data acquisition system in order for the dynamic signal to be further processed. This is typically done with an RC network, thus setting the low frequency response of the system. The user must consider, then, what the low frequency cutoff is for their signal conditioner/data acquisition system and whether it is adequate for their application. The accelerometer may be specified down to a very low frequency, but if the data acquisition system isn't specified to the same (or better) level, it will degrade that performance.

Conclusion

In summary, there are several factors for a user to consider when using an IEPE accelerometer, particularly when used with newly available integrated signal conditioner/data acquisition systems. These factors are:

1. Ensure the signal conditioner/DAQ system supplies adequate constant current to properly power the accelerometer.

2. Ensure the signal conditioner/DAQ system meets the proper compliance voltage requirement of the accelerometer.

3. Consider the noise performance of the signal conditioner/DAQ system. Many lower cost systems can significantly degrade the noise performance of the accelerometer.

4. Consider the high frequency response of the measurement system. In particular, ensure the signal conditioner/DAQ system can supply adequate current when using long cables, or measuring high amplitude and/or high frequency accelerations.

5. Consider the low frequency response of the signal conditioner/DAQ system.

Correctly managing these factors will help the user avoid erroneous data from their IEPE accelerometer and ensure the quality of the measurement data is at the level they expect and require. This is particularly true in developing flight hardware and critical applications where crew and passenger safety is of utmost concern.