Check cable capacitance

Dan Romanchik - June 01, 2004

When using accelerometers with long cables, you must be careful that the cables do not attenuate the signals at high frequencies. Engineers at PCB Piezotronics point out that such attenuation may occur when insufficient current is available to drive cable capacitance (Ref. 1). The capacitive loading of the cable may distort or filter higher-frequency signals depending on the supply current and the output impedance of the sensor.

Generally, this signal distortion is not a problem when measuring signals below 10,000 Hz. But when you are measuring high-frequency vibration, shock, or transient signals with cables longer than 100 ft (30 m), the possibility of signal distortion exists.

The maximum frequency that a given cable length can transmit is a function of both the cable capacitance and the ratio of the peak signal voltage to the current available from the signal conditioner:

where

\[ f_{\text{max}} = \frac{10 \times C}{V} \times I_c \]

\( f_{\text{max}} \) = maximum frequency (Hz)
C = cable capacitance (picofarads)
V = maximum peak output from the sensor (volts)
Ic = constant current from the signal conditioner (mA)
10 = scaling factor to equate units.

Note that in this equation, 1 mA is subtracted from the total current supplied to sensor (Ic). This compensates for powering the internal electronics. Some specialty sensor electronics may consume more or less current; contact the manufacturer to determine the correct supply current.

When driving long cables, as the equation shows, a greater constant current will be required to drive the signal as the length of cable, the peak voltage output, or the maximum frequency of interest increases.

Consider this example: A 100-ft (30-m) cable with a capacitance of 30 pF/ft (98 pF/m) will have a total capacitance of 3000 pF. If the sensor has a maximum output voltage of 5 V and the constant current signal conditioner is set at 2 mA, the maximum frequency at which the cable is usable is approximately 10.2 kHz.

Note that higher current levels will deplete battery-powered signal conditioners at a faster rate. Also, any current not used by the cable goes directly to power the internal electronics and will
create heat. This may cause the sensor to exceed its maximum temperature specification. For this reason, do not supply excessive current over short cable runs or when testing at elevated temperatures.

**Testing long cables**

To more accurately determine the effect of long cables, you can measure their frequency response. As shown in the **figure**, you connect the output from a standard signal generator to a unity-gain, low-output impedance (≤5 Ω) instrumentation amplifier to simulate the sensor.

In place of the signal generator and instrumentation amplifier, you may also use commercially available sensor simulators, which package a small signal generator and amplifier in one unit.

To check the frequency response of the system, set the signal generator amplitude to the maximum output voltage of the sensor you are trying to simulate. Next, set the frequency to the highest frequency you will need to measure.

Then, measure the voltage output at the far end of the cable. If the ratio of input voltage to output voltage is 1:1, or close to 1:1, then the cable will be adequate for your test. When making the measurement, be certain to factor in any gain in the signal conditioner or scope.

If the output voltage is significantly less than 1:1, then the cable is not adequate for the test. You will need to either use a lower capacitance cable or increase the constant current supplied by the signal conditioner.

Also note that it may be necessary to physically install the cable in your test setup during cable testing. This may be necessary as the geometry of the cable route can affect the cable capacitance and thereby affect the frequency response of the cable.

**Reference**