Long cables

Modern industrial piezoelectric sensors are, typically, voltage-mode devices. That is, they produce a voltage dependent on the vibration signal being measured. This vibration signal voltage is an Alternating Current (AC) voltage and, as such, is subject to all the limits of AC signals. High frequency AC signals are affected by the capacitance in AC circuits causing capacitive reactance. While many users may feel that vibration signals are not high frequency, compared to radio frequency signals, these signals are still affected by the capacitive reactance in circuits.

What does this mean to users of voltage-mode vibration sensors? When cables between the sensor power supply and the sensor are short (under 30 meters), circuit capacitance will usually have no noticeable effect upon the vibration data signals. But, long cables will likely introduce sufficient capacitance into the sensor circuit to allow the vibration signal to develop distortion and, hence, produce spurious signals. This additional capacitance creates a capacitive load on the output of the sensor's amplifier. The amplifier has the ability to sink fairly large amounts of current, but cannot provide an indefinite amount of current for driving capacitance.

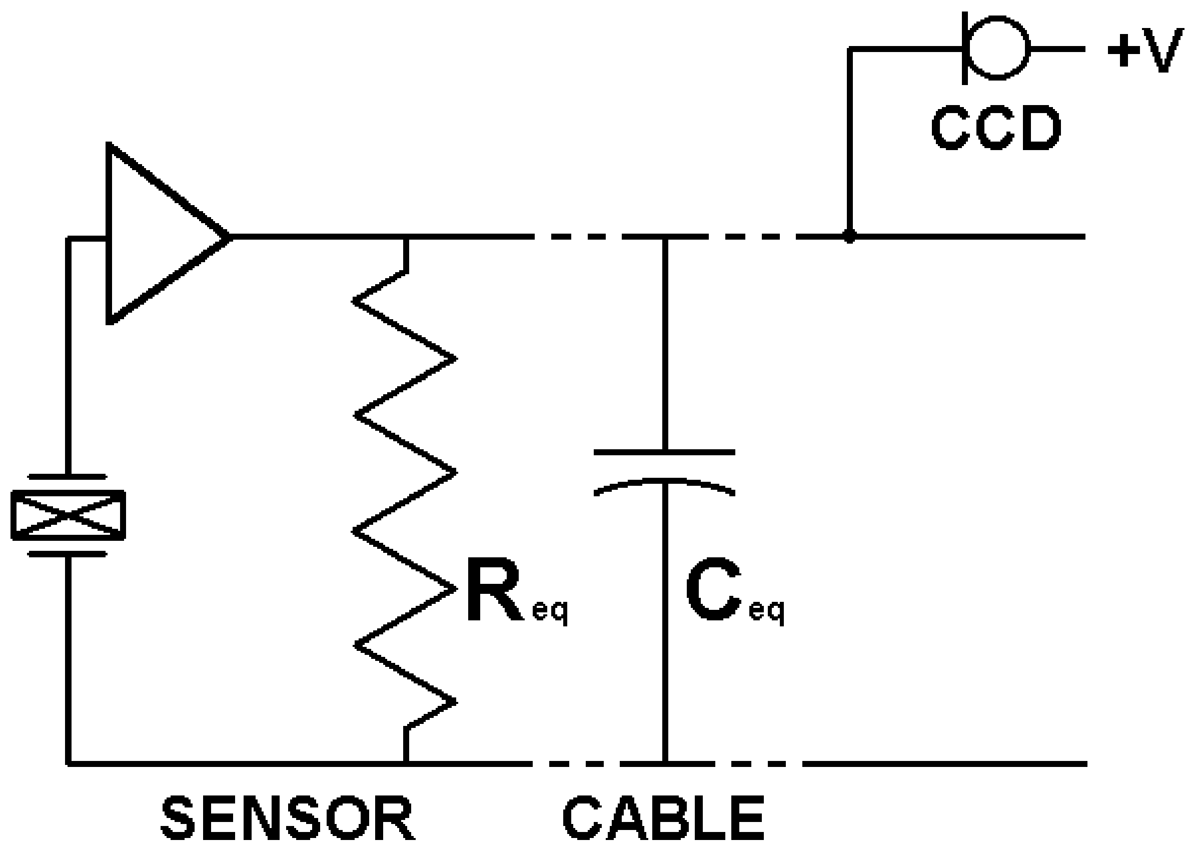


Figure 1 – sensor output equivalent circuit

In the circuit of Figure 1, the amplifier must provide all of the current to charge the capacitance of the cable when the signal voltage is positive. Each cycle of an AC signal being produced by the sensor's amplifier must have sufficient current available to adequately drive the cable capacitance. The amplifier itself, however, needs approximately 1 mA of current available for its own use. When the current needs of the on-board amplifier

Wilcoxon Sensing Technologies
8435 Progress Drive
Frederick, MD 21701
USA

Tel.: +1 (301) 330 8811
Fax: +1 (301) 330 8873
info@wilcoxon.com
www.wilcoxon.com

combined with the current required to drive the cable are insufficient, the amplifier output voltage will become "slew rate limited." In a practical sense, this means that the output signal, for an AC sinusoid, will not be able to accurately reflect the true signal.

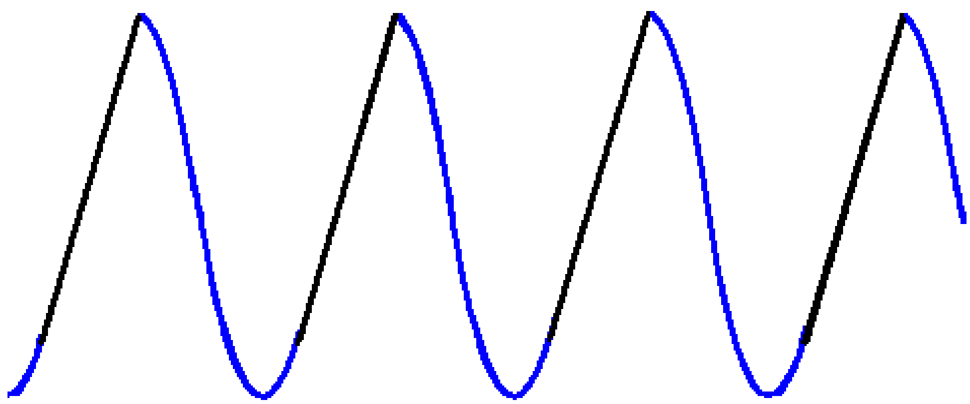


Figure 2 – Slew rate limited signal

Figure 2 is an illustration of a slew rate limited sinusoid. The positive-going part of the sine wave signal is being limited by the current available to drive the signal into the cable. It becomes a "straight" line because of the limited current available to drive the cable capacitance. During the negative-going portion of the sine wave, the amplifier must "sink" or "soak up" the current being discharged by the capacitor. The amplifier is far more capable at absorbing this discharge current, so the limiting factor in high frequency operation becomes the ability of the amplifier to provide the necessary current to charge up the cable capacitance.

When the current limitation point is reached, it is only the positive-going portion of the signal that is affected. The practical effect of this condition is that the signal actually becomes distorted and harmonics are generated. This could lead to vibration signals being misinterpreted as having strong harmonic components when they, in fact, do not have such harmonics present. In the extreme case, the signal waveform will actually start to resemble a triangle waveform. Triangle waveforms have strong harmonic components at all multiples of the fundamental frequency.

Computing the Maximum Frequency

The current through a capacitor is determined by the following differential equation:

$I = C \frac{dv(t)}{dt}$ where $v(t) = V \sin \omega t$, and $\omega = 2\pi f$ with f being the frequency of interest and V the peak voltage

Differentiating the v(t) function yields the following:

$$\frac{dv(t)}{dt} = V\omega \cos \omega t$$

Substituting this in the equation for capacitor current gives:

$I = C\,V\omega \cos \omega t$ or $I = C\,V\,(2\pi f) \cos (2\pi f)t$

However, since we are only looking at the current required to meet the peak voltage we must evaluate this equation at the point where the value is at its peak. The voltage is at its peak when $\cos \omega t = 1$. Now the equation for determining the limiting frequency looks like this:

$I = C\,V\,(2\pi f)$ where I is the current required for the capacitor

But the current required for the capacitor is only part of the total current. The equation for the total current in the circuit is expressed by the following:

$Iccd = I + 1mA$ where Iccd is the current supplied by the constant-current supply and 1mA is needed for powering the on-board electronics of the sensor.

Rearranging the equation yields:

$I = Iccd - 1mA$

Combining these equations results in the following:

$Iccd - 1mA = C\,V\,(2\pi f)$

By rearranging the terms to solve for the frequency, f, we get this equation:

$$f = \frac{Iccd - 1mA}{2\pi\,(C)\,(V)}$$

This is the equation that will yield the frequency limit. However, we will again rearrange these terms and add a scaling factor to allow the computation to be conducted in units typical for the application.

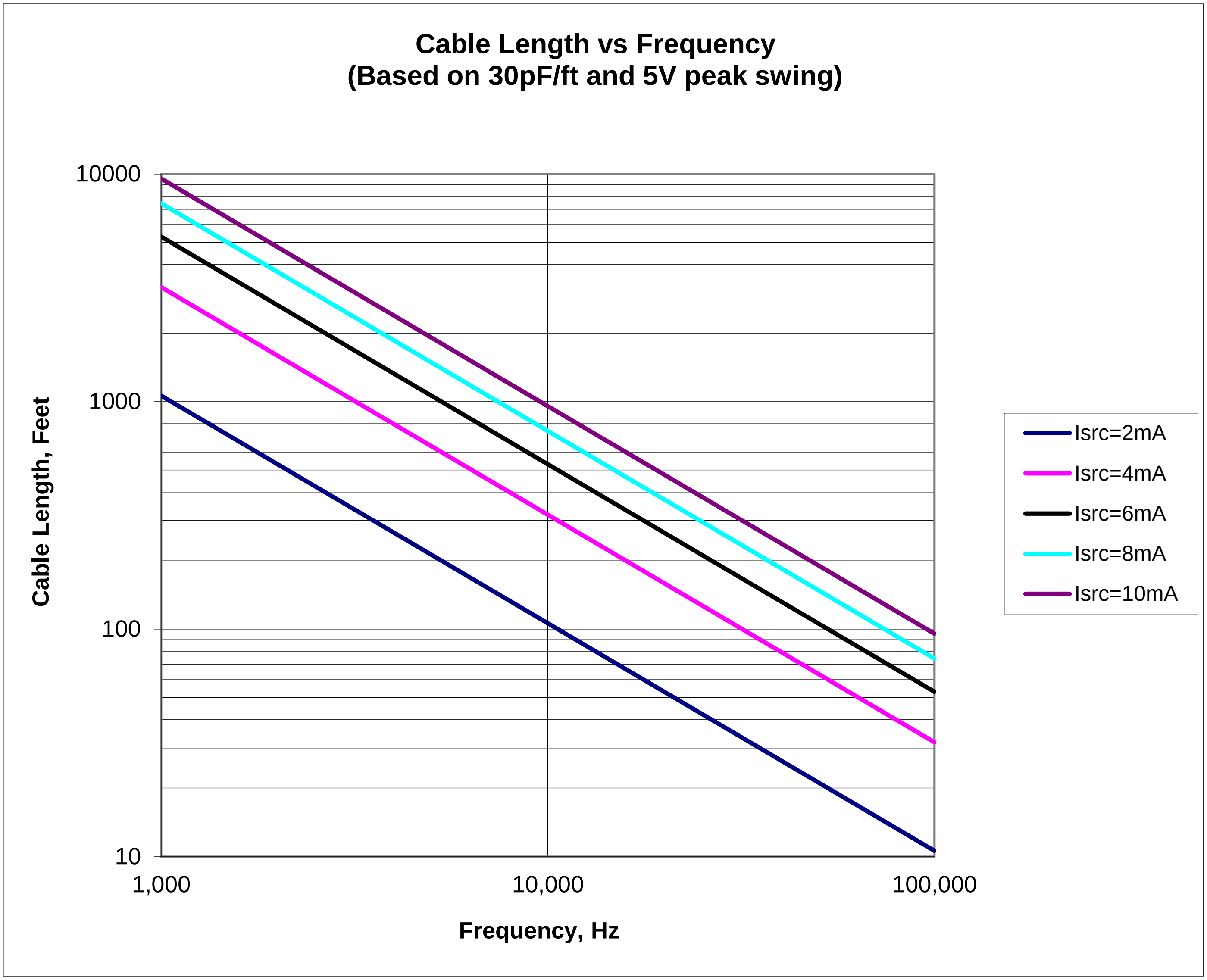
$$\mathbf{fmax} = \frac{\mathbf{10^9}}{\mathbf{2\,\pi\,C\,V / (Iccd\text{-}1mA)}}$$

where, fmax= maximum frequency (hertz)
C= cable capacitance (picofarads)
V= peak signal output from sensor (volts)
Iccd= constant current from signal conditioner (mA)
10^9 = scaling factor to equate units

NOTE: In this equation, 1 mA is subtracted from the total current supplied to sensor (Iccd). This is done to compensate for powering the internal electronics.

This equation illustrates that when cable capacitance increases, either the constant current value must increase or the maximum useable frequency must decrease to keep the equation in balance and avoid signal distortion. If the full amplitude range of the accelerometer will not be used, the highest useable frequency will also be increased. In any case, the equation above will allow vibration personnel to determine whether long cables will present a problem for vibration signals.

Figure 3 – Chart showing cable length limit vs. frequency for various current values for the CCD.



Wilcoxon Sensing Technologies
8435 Progress Drive
Frederick, MD 21701
USA

Tel.: +1 (301) 330 8811
Fax: +1 (301) 330 8873
info@wilcoxon.com
www.wilcoxon.com