Introduction to Vibration Measurement

The Vibration Problem

Vibration testing and measurement are very important in the development, testing, and monitoring of most engineered products. Whether you are involved in meeting Department of Defense vibration test standards (MIL-STD-810E , Method 514.4) or performing a simple shaker test the fundamentals are the same. Vibration measurements are commonly performed with accelerometers due to their high accuracy, wide bandwidth, small size, light weight, and ease of use. In the simplest terms, an accelerometer is a device that produces an electrical output proportional to the acceleration of its case. Techkor ARGUS, 9000B, and 9000E measurement systems in combination with M9B or M9E accelerometers overcome many of the common problems associated with vibration measurement.

Fundamental Relationships

Consider a simple mass spring system such as the suspension system in an automobile. If the mass (automobile) is given an initial displacement (bump), the system will oscillate. If there is no damping (shock absorbers) the system will oscillate as a sinusoidal wave (Figure 1).

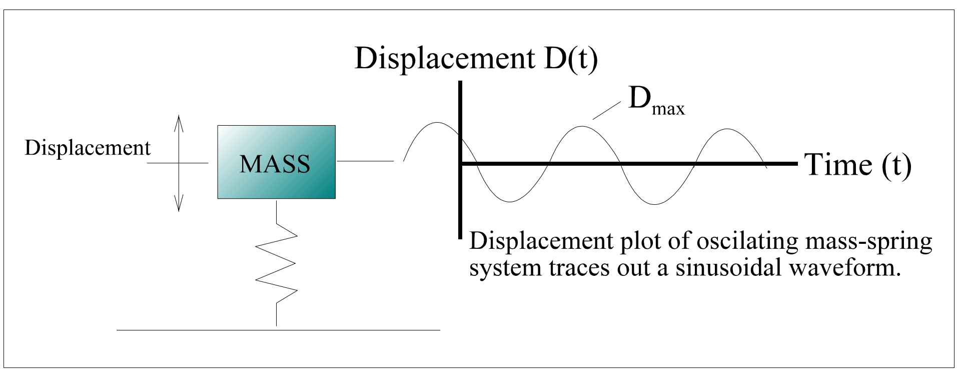

Figure 1, *Simple mass-spring vibration system with sinusoidal waveform output*.

The relationships between displacement, velocity, and acceleration for sinusoidal displacements are given by

$$D = D_0 \sin(2\pi \; f t)$$
$$V = 2\pi f \; D_0 \cos(2\pi f t)$$
$$A = -(2\pi f)^2 \; D_0 \sin(2\pi f t)$$

where D is the displacement, V is the velocity, A is the acceleration, D_0 is the peek displacement, f is the frequency in Hertz, and t is the time. Given the initial displacement (D_0) and the frequency (f) of oscillation, the displacement, velocity, and acceleration at any time can be computed. The relationships can be seen graphically in Figure 2. It should be noted that the velocity is 90° out of phase from the displacement and that the acceleration is 180° out of phase from the displacement. A phase shift of 90° represents a delay in the signal by 1/4 wave. The result is that the point of maximum positive or negative velocity is when the displacement is zero (at the middle). A phase shift of 180° represents a delay in the signal by 1/2 wave. The result is that the point of maximum positive acceleration is when the displacement is maximum negative.

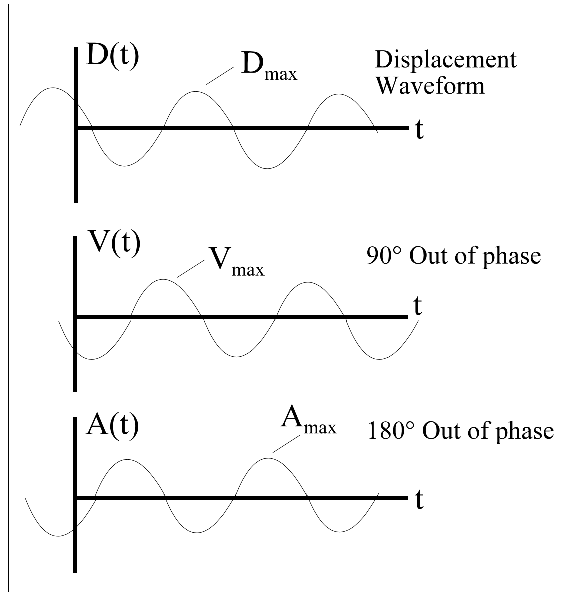

Figure 2, *Relationship between displacement, velocity, and acceleration signals*.

The acceleration in G's can be found from

$$G = \frac{A}{g}$$

where g is 9.80665 m/s^2.

Often it is desired to obtain only the maximum values of velocity and acceleration for a given sinusoidal input. Given the peak displacement, the maximum velocity and acceleration can be found from

$$V_{max} = 2\pi f \, D_0$$
$$A_{max} = (2\pi f)^2 \, D_0$$
$$G_{max} = \frac{(2\pi f)^2 \, D_0}{9.80665 \, {}^{m}/_{s^2}}$$

The equations relating displacement, velocity, and acceleration can be run backwards to determine velocity and displacement from acceleration. The relationship between displacement and velocity is

$$D = \int V dt + x_0$$

where x_0 is the initial displacement (if any). A single integration of the velocity signal will generate displacement. This can be easily implemented in software solutions. However, the user should take care to provide a velocity signal that is zeroed. Any offset component will be integrated continuously showing up as a false drift in the displacement signal. This is a function of the mathematics and has nothing to do with transducer drift.

The displacement can also be found from the acceleration signal. A single integration of the acceleration signal will yield velocity and a double integral will yield the displacement.

$$V = \int A dt + v_0$$
$$D = \int\int A dt dt + x_0$$

Again, the user is cautioned to provide an acceleration signal that is zeroed (i.e. 0 Volts for 0 acceleration). Any offset component will be double integrated showing up as a false drift in the displacement signal. This is a function of the mathematics and has nothing to do with transducer drift.

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