

SHOCK AND VIBRATION RESPONSE SPECTRA COURSE
Unit 3. Sine Sweep Frequency and Octave Calculations

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Introduction

A common specification for a base excitation test is a sine sweep test. An example is shown in Figure 1.

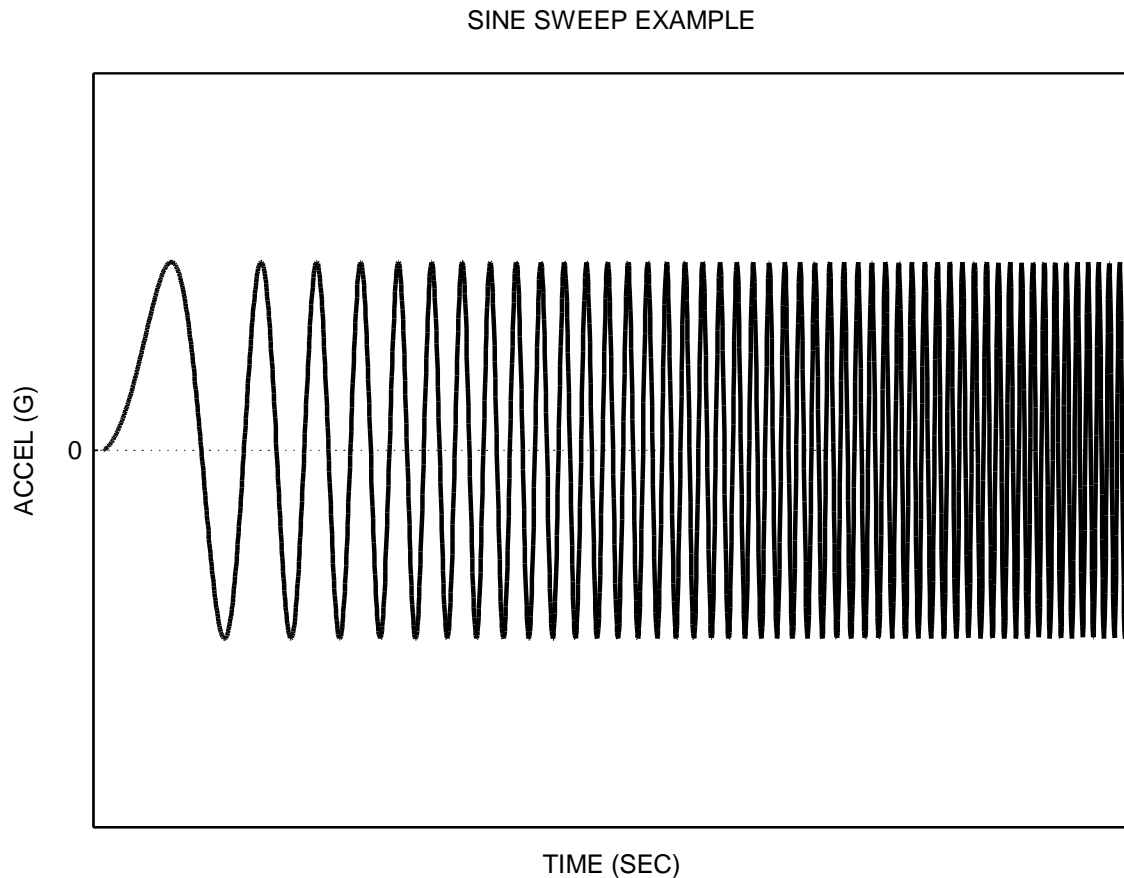


Figure 1.

The purpose of a sine sweep test might be to identify natural frequencies of the test item.

Another purpose might be to verify the design or workmanship of the item with respect to vibration.¹ For example, consider an avionics component subjected to a sine sweep test. The test is considered successful if the avionics component operates properly before,

¹ An argument can be made that random vibration is more effective for uncovering design or workmanship flaws. Nevertheless, some specifications require sine sweep vibration.

during, and after the vibration test. Note that the component is electrically powered and monitored during the vibration test.

The essence of a sine sweep test is that the base excitation input consists of a single frequency at any given time. The frequency itself, however, is varied with time.

The sine sweep test may begin at a low frequency and then sweep to a high frequency, or vice-versa. Some specifications require several cycles, where one cycle is defined as from low to high frequency and then from high back to low frequency.

The specification might require either a linear or a logarithmic sweep rate. The sweep will spend greater time at the lower frequency end if the sweep is logarithmic. The example in Figure 1 has a logarithmic sweep rate.

The amplitude in Figure 1 is constant. Nevertheless, the specification might require that the amplitude vary with frequency.

Specification Example

A vendor has a product that must withstand sinusoidal vibration with an amplitude of 12 G. The desired frequency domain is 10 Hz to 500 Hz. The shaker table has a displacement limit of 1.0 inch peak-to-peak, or 0.5 inch zero-to-peak.

Recall from Unit 2B that the displacement limit is a constraint at low frequencies. How should the test be specified?

The answer is to use a specification with two amplitude segments. The first segment is a ramp. The second segment is a plateau.

Furthermore, the first segment will be given in terms of displacement. The second segment will be given in terms of acceleration. The result is shown in Figure 2.

In this case, the ramp is 1 inch peak-to-peak. The plateau is 12 G. Note that the G value is understood by convention to be in terms of zero-to-peak. The compromise is that the acceleration amplitude at 10 Hz is 5 G. The compromise is needed for the sake of "testability."

SINE SWEEP SPECIFICATION EXAMPLE

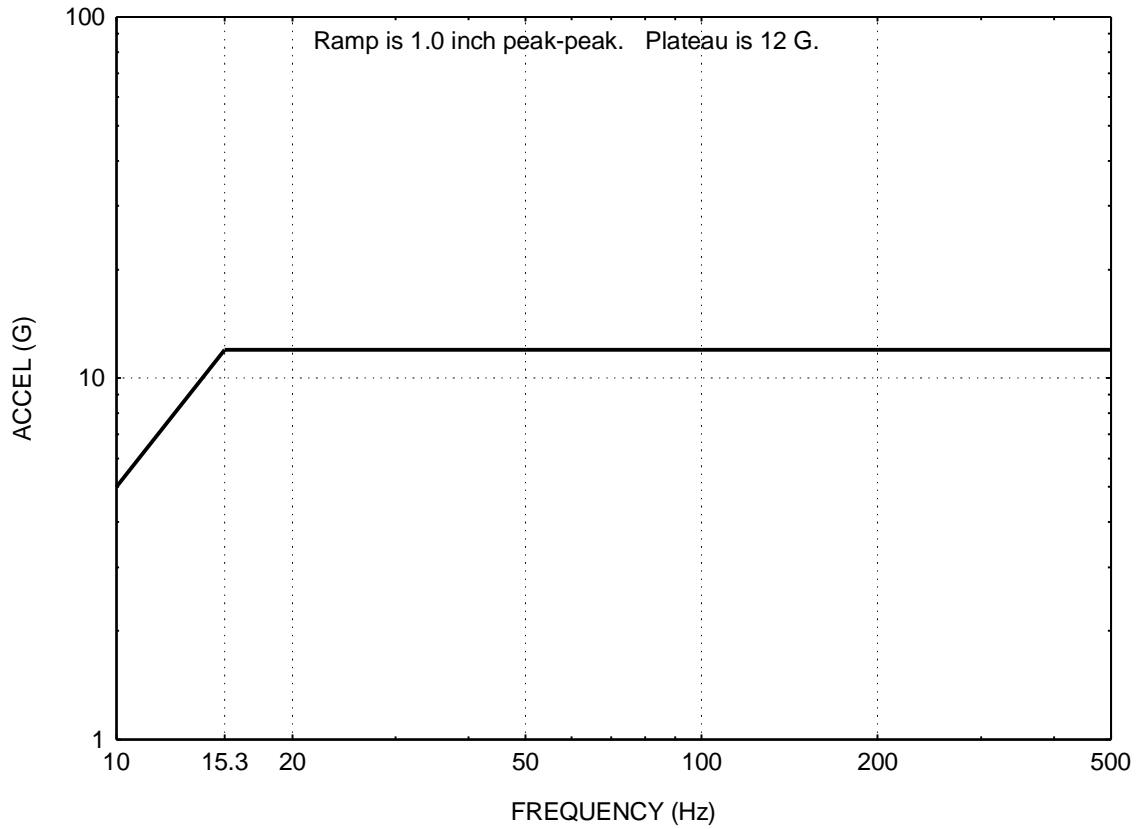


Figure 2.

The "crossover" frequency is 15.3 Hz. This is the frequency at which a 12 G acceleration has a corresponding displacement of 1.0 inch peak-to-peak.

The crossover frequency f_{cross} is calculated via equation (1).

$$f_{\text{cross}} = \frac{1}{2\pi} \sqrt{\frac{\ddot{x}_{\text{peak}}}{x_{\text{peak}}}} \quad (1)$$

where

\ddot{x}_{peak} is the peak acceleration (zero-to-peak)

x_{peak} is the peak displacement (zero-to-peak)

Furthermore, the acceleration should be converted from G to in/sec^2 or G to m/sec^2 , as appropriate.

Octaves

One octave is defined as a frequency band where the upper frequency limit is equal to twice the lower frequency limit. Thus a band from 10 Hz to 20 Hz is one octave. Likewise, the band from 20 Hz to 40 Hz is an octave.

The band center frequency f_c is taken as

$$f_c = \sqrt{f_l f_u} \quad (2)$$

where

f_l is the lower frequency

f_u is the upper frequency

The band center frequency calculation is not particularly important for sine sweep calculations. It will be important in later Units, however.

A greater concern to sine sweep testing is the total number of octaves. As an example consider the following frequency sequence in Hertz.

10 - 20 - 40 - 80 - 160 - 320 - 640 - 1280 - 2560

The sequence has a total of eight octaves.

Now consider a sine sweep test from 10 Hz to 2000 Hz. How many octaves are in this example? A rough estimate is 7.5. Nevertheless, the exact number is needed.

The number of octaves n can be calculated in terms of natural logarithms as

$$n = \frac{\ln \left[\frac{f_2}{f_1} \right]}{\ln [2]} \quad (3)$$

where

f_1 is the lower frequency of the specification

f_2 is the upper frequency of the specification

Thus, the frequency domain from 10 Hz to 2000 Hz has 7.64 octaves, per equation (3).

The number of octaves is then used to set the sweep rate, assuming a logarithmic rate. For example, the rate might be specified as 1 octave/minute. The excitation frequency at any time can then be calculated from this rate.

Or perhaps the total sweep time from 10 Hz to 2000 Hz is specified as 8 minutes. Thus, the sweep rate is 0.955 octaves/min.

Homework

1. A shaker table has a displacement limit of 1.5 inch peak-to-peak, or 0.75 inch zero-to-peak. An amplitude of 28 G is desired from 10 Hz to 2000 Hz. The specification will consist of a displacement ramp and an acceleration plateau. What should the crossover frequency be? What is the maximum acceleration at 10 Hz?
2. How many octaves are in the frequency domain from 10 Hz to 500 Hz?
3. Use program sine.exe to check your work in problems 1 and 2.
4. Program generate.exe can be used to synthesize a variety of signals. Generate and plot a few sample signals. Note: the sample rate should be at least ten times higher than the maximum frequency.
5. Optional. Read tutorial sweep.pdf.