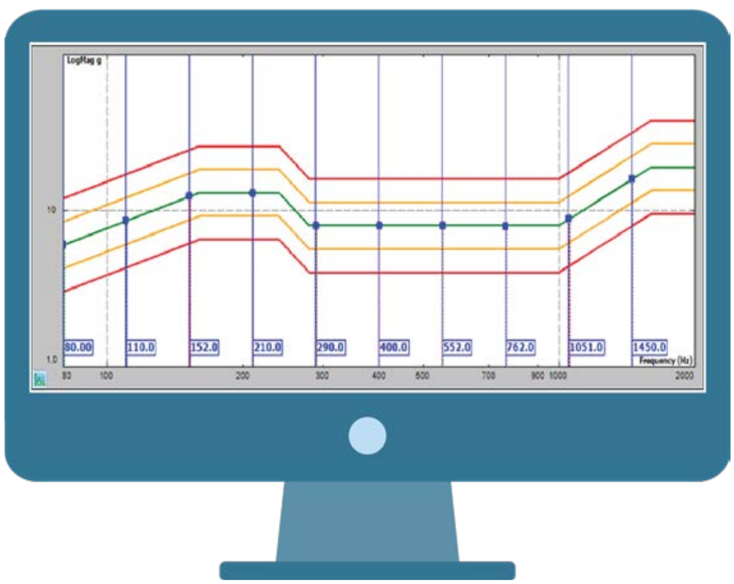
Automotive Multi-Sine Test

Application Note 042



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Multi-Sine is a new type of Sine test which facilitates multiple sine tones sweeping simultaneously at once. In automotive testing, engine mounted components such as fuel lines, turbos, headers, sensors, heatshield… are all subjected to high vibration levels during their operational life cycle. High cycle fatigue testing of engine mounted components is often done with a standard Swept Sine test. By performing a Swept Sine test, all resonances within the frequency ranges are excited and measured. Since the greatest fatigue damage happens at the excitation frequency and is also potentially high near these resonances, it is important to measure the vibration level at these frequencies. The standard Swept Sine only sweeps one frequency at a time with a single tracking filter. To test for fatigue, multiple sweeps need to be carried out for the entire frequency range at multiple times during a multiple sweeping rate. Using the standard swept sine test, we can estimate the test time as follows with the example criteria: (Figure 1.1)

This is performed with one single tone at a time: sweeping up/down through the frequency range at the specific sweeping rate.

For a test range between 80 Hz and 2 kHz, 2E6 stress cycle, and 10 Hz resonance width, the test time would be **178.8 hours**. The amount of time can be reduced as much as 75% by performing a Multi-Sine test instead. Approved and adopted by many German automobile companies, this method has the advantages of sweeping multiple tones with multiple tracking filters at the same time. If we divide the above test into 10 intervals, with 10 tones sweeping at the same time, this particular test can be completed in **17.88 hours**.

There are two types of multi-sine tests: (a) Multi-Sine Type 1, and (b) Multi-Sine Type 2.

$$\frac{Test\ time}{h} = \frac{No.of\ load\ cycles}{3600} \cdot \frac{\ln\left(\frac{f_{max}}{Hz}\right) - \ln\left(\frac{f_0}{Hz}\right)}{\frac{\Delta f}{Hz}}$$

- number of target load cycles
- resonance frequency width Δf
- frequency interval [f_0, f_{max}]

Figure 1.1

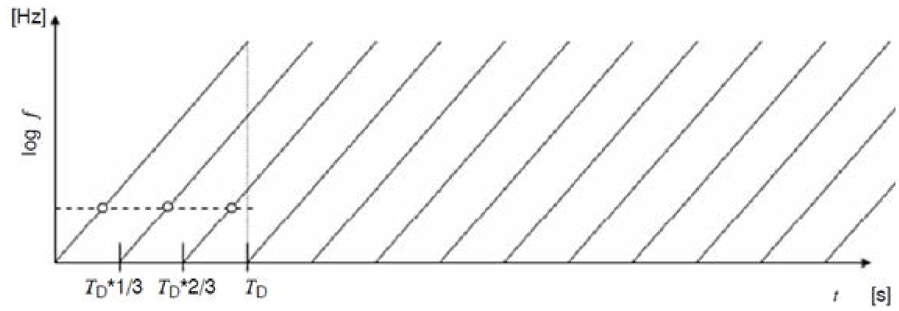

Figure 1.2

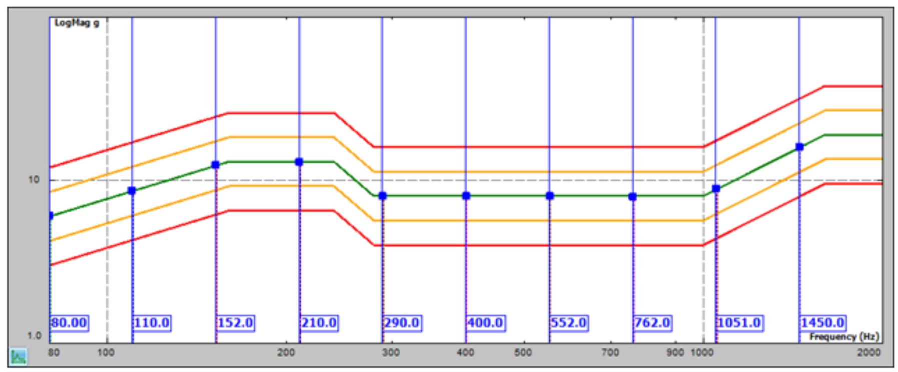

Figure 1.3

For Multi-Sine type 1, there is only *one* sweep direction and each tone is excited by a delay. The tones are, one by one, excited and swept up. As it reaches the defined interval duration (defined by every 1 Oct/min), a new tone will be excited and swept up. This process is repeated until the total test duration and all frequency range are achieved. (Figure 1.2)

Crystal Instruments provides **Multi-Sine Type 2** for the Spider Series Vibration Controller System.

In Multi-Sine type 2, all tones are excited at the same time throughout the frequency range, and sweep in both directions. (Figure 1.3)

From the example mentioned previously, we can break up the frequency range into 10 intervals. All intervals will have the same duration per sweep. The first tone from 80 Hz to 110 Hz will require the same amount of time to run per sweep as 110 Hz to 152 Hz, and so on. The interval factor is calculated based on the **Interval Factor.** (Figure 1.4)

From this, the interval of our tones is defined as following: (Table 1)

All 10 tones will be excited, ramped up, and will sweep all at once in both directions (up and then down). This is the fundamental idea of Multi-Sine Type 2. This method realized the possibility to cut down testing time by a significant factor. Crystal Instruments currently provides Multi-Sine Type 2 for automobile testing to satisfy the standard requirements.

References

Maier, R. (2009). Environment Tests: Vibration Test, testing of engine attachment parts. BMW Group Standard, 18.

$Interval\ Factor = (\frac{F_{max}}{F_{min}})^{\frac{1}{No.of\ Spectra}}$	• F_{max} = 2000 Hz, F_{min} = 80 Hz, 10 intervals Interval Factor = 1.3797

Figure 1.4

Frequency (Hz)		Multiply the Interval Factor		Next Frequency Mark (Hz)
80		80 x 1.3797	→	110
110	↓	110.38 x 1.3797		152
152		152.29 x 1.3797		210
210		210.11 x 1.3797		290
290		289.89 x 1.3797		400
400		399.96 x 1.3797		552
552		551.82 x 1.3797		762
762		761.35 x 1.3797		1051
1051		1050.43 x 1.3797		1450
1450		1449.28 x 1.3797		2000

Table 1

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