SHAKEN, NOT STIRRED! *

VIBRATION TESTING EXPLAINED

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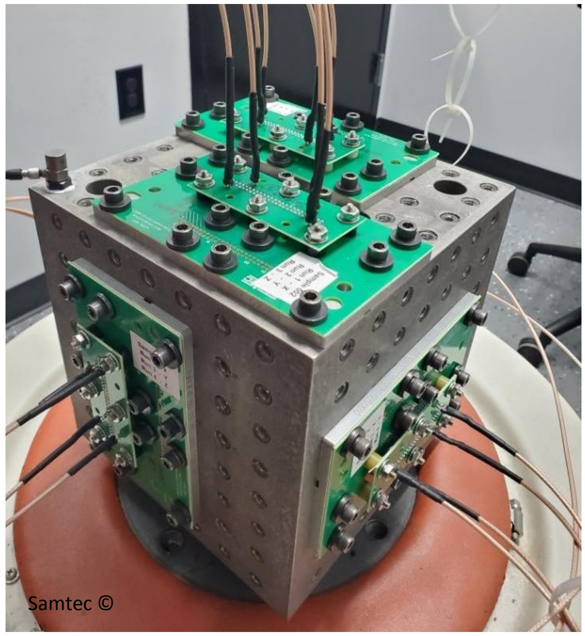
* RIP Sean Connery



Shaking is what we want to be doing … *stirring* up a bunch of questions is not!
This document will discuss the rationale, techniques and procedures used to perform Vibration testing at Samtec.

SUMMARY

Vibration testing is routinely performed to assess the mechanical and electrical performance and stability of a product when subjected to the types of vibration that may be encountered during normal use. The type of vibration and the control parameters are dictated by the intended product market. Proper test fixtures and mounting techniques are key to successful test exposure. *Mechanical Shock* is an associated test that will be discussed separately.

TOPICS:

General discussion – What is vibration …
Vibration test types
Vibration system operation
Test sample preparation
Sine vibration theory
Random vibration theory

WHAT IS VIBRATION

That annoying buzzing sound when the freezer is running, or that rattling sound coming from the washer or dryer. If you can hear it, it is vibrating … but not all vibrations can be heard.

Simply put, vibration is an oscillating mechanical motion … up and down, back and forth, side to side. These are the typical orthogonal directions (also called mutually perpendicular axes) of concern and are defined as X, Y and Z.

Of course, in actual use all of these axes of vibration are occurring at the same time to varying degrees.

WHAT ARE THE COMMON SOURCES OF VIBRATION

Vehicular transportation is a very easy one to relate to, but so many sources are much more difficult to pinpoint. Contained within many products are multiple sources of vibration such as speakers, motorized assemblies, solenoids, cooling fans, transformers, or even something as seemingly benign as fingers tapping on a keyboard. So, vibration stress can be imposed on an assembled product "environmentally" and also from components inside the unit. This is also true for the internal components of a system.

WHAT ARE THE COMMON VIBRATION FAILURES

If a product/component is damaged or defective prior to vibration, the vibration test can exacerbate the problem thus identifying the pre-existing issue.

Damage caused by vibration can range from gross physical damage such as cracks and wear to subtle, microscopic damage internal to the components.

These issues can result in catastrophic mechanical failures or something more difficult to track down, such as:

- High speed electrical signal disruptions
- Loss or attenuation of optical signals
- Cracked solder joints
- Broken welds
- Broken wire bonds
- Wear-through of the plating on contacts (see my paper on Fretting Corrosion for details)
- Loosened crimp joints
- Wire fatigue
- Many, many more …

WHAT IS A VIBRATION TEST?

Vibration tests shake things up to specified frequency, amplitude and duration requirements in accordance with industry/military/aerospace, etc. standards or research protocols.

Random vibration example:

7.56 grms (amplitude or level), 50 to 500 Hz (frequency band), 2 hours/axis duration, three axes total (X, Y and Z).

Sample preparation and *mounting are critical*:

The test samples are typically mounted to a rigid structure attached to the armature, also called the exciter or shaker.

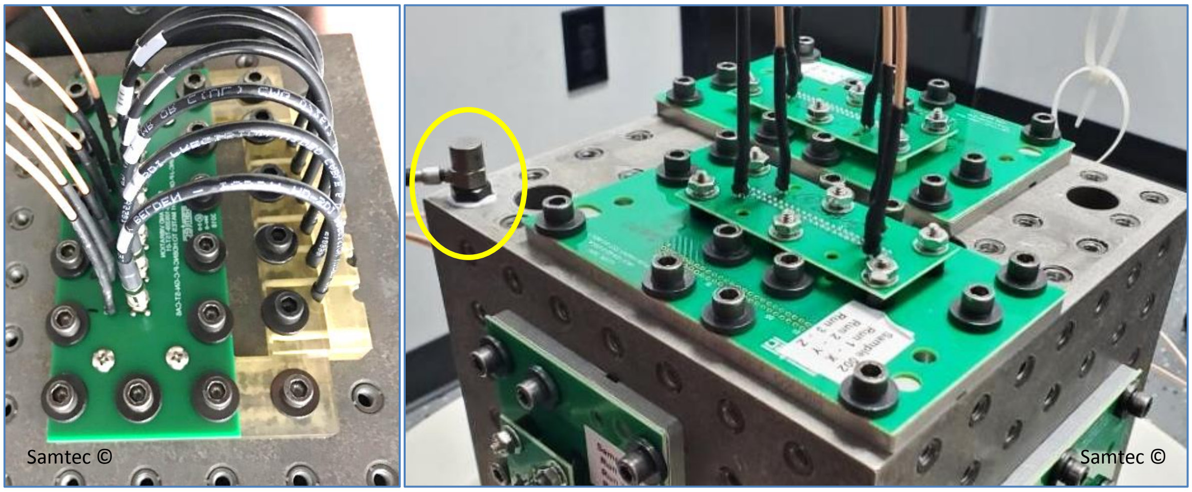
When testing components such as connectors, the typical goal for board mounted products is to mount the specimens in fixtures that *will not allow the connector halves to move relative to one another*.

Why such robust mounting fixtures:

Since Samtec or any other component manufacturer cannot control the application into which their products will be placed, all we can do is to be sure that the component itself can withstand those stress levels without outside influence such as a resonating fixture or poorly supported sample.

Robust Mounting

Notice how many mounting points are secured in the following images. This mitigates external resonant bands that might have developed within the test fixtures. Accelerometer (in yellow oval) monitoring and controlling the vibration level.



Images 1 and 2 illustrating optimal mounting practices

Cable products will typically have 8” of unsupported cable to simulate the expected space between a cable connector system and the first cable clamp.

Of course, there are many scenarios for the many products and markets out in the world and each must be dealt with as required so fixture designs can vary greatly and must be documented as performed.

Test system:

A closed loop feedback system is used to supply the required “shake” to the test specimen. This system will be discussed in more detail within this paper.

WHY PERFORM VIBRATION TESTING

1. To subject the test item to the general type of vibratory exposure for the expected market.
2. Qualification for a product to be accepted for a specific industry standard such as VITA, IPC, ANSI, etc.
3. Research and development of new products
4. Failure analysis and detection of product defects

WHAT TYPES OF VIBRATION TESTS CAN BE RUN IN THE LABORATORY AT SAMTEC (in order, most to least requested)

1. Random Vibration - defined “noise” spectrum controlling a full random application of vibration within a specified envelope spectrum within an average overall level
2. Swept Sine - simple sine wave excitation sweeping through the defined frequency band at the specified G (peak) level or at a controlled displacement.
3. Custom Military/Aerospace/Medical/Proprietary product specifications, etc.
4. Resonance search
5. Sine-on-random

PASS/FAIL CRITERIA (examples)

Physical/mechanical damage

No evidence of cracks or physical damage in the connector body
No contact wear that would expose the non-noble metals
No cracked or displaced contacts

Electrical degradation

No changes in the Low-Level Contact Resistance (LLCR) greater than the specified limit
The Insulation Resistance shall not be less than the specified value
Dielectric breakdown or leakage shall not occur when the specified voltage is applied
Electrical disruption during vibration in the form of Low nano-second electrical events or electrical discontinuity shall not exceed the required voltage/time characteristic.

Optical signal degradation

Increased attenuation shall not exceed the limits so specified
No fiber termination damage shall be observed
Optical fiber shall be properly retained/attached

SOME TYPICAL INDUSTRY STANDARDS ORGANIZATIONS:

- ECA – Electronic Components, Assemblies, Equipment & Supplies Association (formerly EIA)
- Military specifications (-STD, -DTL, -PRF, etc.)
- Telcordia
- American National Standards Institute (ANSI)
- International Electrotechnical Commission (IEC)
- JEDEC – JEDEC Solid State Technology Association, former Joint Electron Device Engineering Council
- TIA – Telecommunications Industry Association

VIBRATION TEST SYSTEM OPERATION

Typical closed loop vibration system monitors the vibration level close to the sample and adjusts the system accordingly to maintain the proper test conditions.

- CONTROLLER: Sends the proper signal to the amplifier via closed feedback loop
- AMPLIFIER (amp): Boosts signal to proper power level to drive the shaker
- SHAKER (exciter): Provides the mechanical motion to the cube
- CUBE: Mounting platform for samples under test
- ACCELEROMETER: Provides feedback to the controller which the controller uses to adjust its output to keep the test within the specified tolerances and completes the feedback loop.

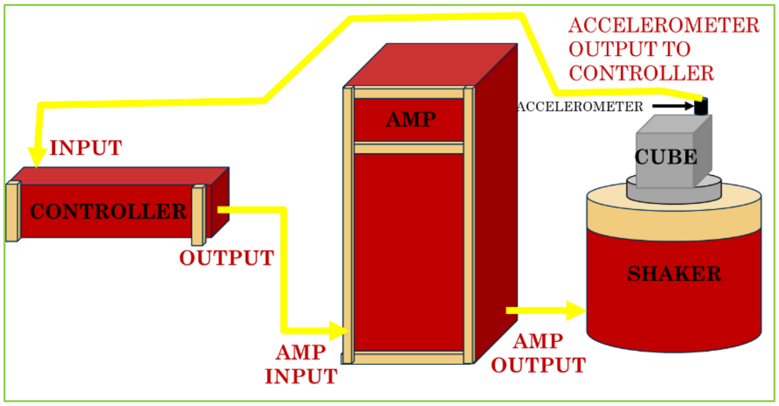


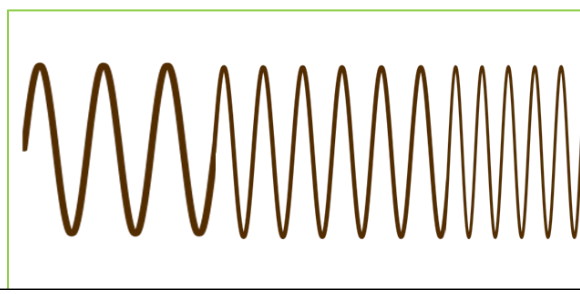
Figure 1
Closed loop vibration system

SINE VS. RANDOM VIBRATION

The following figures show the basic differences between the motion that ocurrs during typical Sine and Random vibration tests (X aixs is Time and the Y axis is the Amplitude):

The modulated sine wave below represents the concept of a pure sinusoidal motion of varying/swept frequency typically from 10 to 2000 Hz and the most common level run at Samtec is 15 G PEAK.

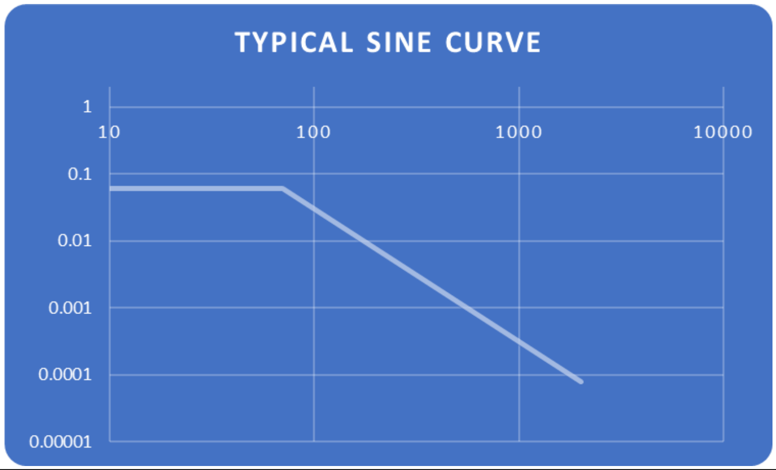
Now to be clear about the G level, this value (15G PEAK) is the level during the Constant Acceleration (CA) portion of the test (70 to 2000 Hz). There is also a Constant Displacement portion of the test run at 0.06" Double Amplitude Displacement (DA) controlled displacement that covers the frequency band from 10 to 70 Hz. This is done because otherwise the DA to produce a 15 G wave at 10 Hz would be ~3 inches and outside what would be considered normal vibration conditions. At 70 Hz (called the crossover frequency) the displacement of 0.06" = 15 G PEAK. ($G=0.0512 * f^2 * DA$). This is the frequency where the displacement equals the peak G level.



Lower frequencies -------sweeping to------Higher Frequencies
(X aixs is Time and the Y axis is the Amplitude (G's))

Figure 2
Swept sine wave (Time Domain)

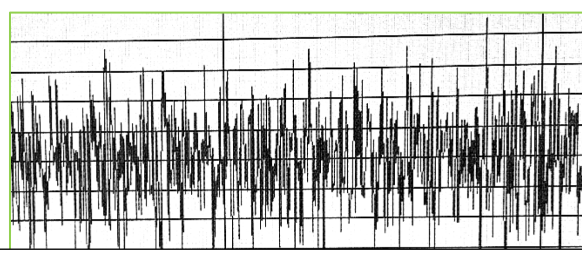
The following Frequency Domain curve represents the displacement characteristic of a typical sine vibration test. You can see how the displacement stays constant to the crossover point and then the displacement decreases to maintain the specified, Peak G level. The flat portion of the curve from 10 to 70 Hz is the Constant Displacement (CD) band held to 0.06" DA; the remaining downward sloping band of the curve from 70 to 2000 Hz is the Constant Acceleration (CA) part held at 15 G's and thus the decreasing displacement.



X aixs is Frequency
Y axis is the Displacement in inches

Figure 3
Swept sine curve

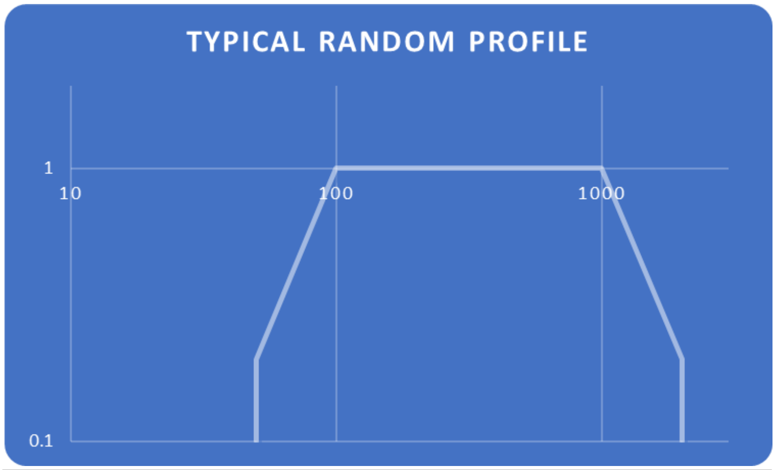
The random vibration, time domain waveform below shows varying amplitudes and frequencies typically from 50 to 2000 Hz and the most common level run at Samtec is 7.56 grms.
The grms value is based on the average (Root Mean Squared) of all the random waves with the maximum peaks being limited to 3 times the average value. So, with a specified level of 7.56 grms, there will be some peaks that go as high as 22.7 G's peak.



Frequencies occurring at random times and amplitudes
(X aixs is Time and the Y axis is the Amplitude)

Figure 4
Random vibration Time Domain waveform

The random vibration frequency, domain spectrum below shows varying amplitudes expressed in Power Spectral Density (PSD) with the crazy unit called g^2/Hz on the Y axis and frequency on the X axis typically from 50 to 2000 Hz and the most common level run at Samtec is 7.56 grms.
Don't be stirred up by the PSD - g^2/Hz stuff! Simply put the shape of the spectrum indicates how much of the vibration power (stress) is occurring with respect to the frequency bands – in this case Hz represents the *frequency band* and *not a discreet frequency*.
Once this shape is programmed into the controller, then the overall grms level can be adjusted while maintaining the proper vibration power/frequency distribution.



(X aixs is Frequency and the Y axis is the PSD in g^2/Hz)

Figure 5
Random vibration Frequency Domain waveform

MONITORING/MEASUREMENTS BEFORE, DURING AND AFTER VIBRATION

The two most common monitoring tests are Low Level Contact Resistance (LLCR) and Low Nano-second Event Detection (sometimes referred to as *discontinuity monitoring*).

1. *LLCR* is used to assess the resistance stability by comparing the contact resistance measured before and after the vibration exposure.
2. *Event Detection* monitors the dynamic electrical stability to a pre-specified requirement, such as “X”Ω for a duration of “Y”nS.
3. *Visual/mechanical examination*

SO WHAT HAVE WE LEARNED

1. Proper test fixtures and robust mounting techniques are the key to performing successful vibration testing.
2. Successful product testing leads to successful product performance in the field.
3. Perform testing that is taylored for the intended application or specified in the standard that you are trying to meet.

AND WHAT IS LFET TO BE LEARNED

Chosing the proper connector for a proposed application and what to expect for vibration performance from different interconnect system designs.
This will be the topic of my next paper.