COTS Journal

Vibration Test Techniques Shake the Status Quo

By: Jeff Child

With traditional Mil-Spec qualifications growing out-of-date, newer, more comprehensive methods of testing vibration are gaining awareness and acceptance.

None of the U.S. Armed Forces' current or future crop of advanced communications, weapons control and signal intelligence systems—just to name a few—would be possible without COTS. The COTS movement provides system developers the freedom and the mandate to use state of the art commercial electronics and computer subsystems.

Because the COTS mandate shifts the focus on requirements instead of meeting rigorous specifications, system developers are also free to embrace new environmental test methods. Unfortunately, that side of the COTS shift has had less success. That lack of success is partly because of a reliance on Mil-Specs, most of which tend to be ten or more years out of date. Military contracts, for example, still make reference to MIL-STD-810F, the specification for environmental testing. But that spec doesn't make any mention of advanced environment screen methods like highly accelerated life testing (HALT) and highly accelerated stress screening (HASS).

HALT and HASS

Compared to pure Mil-Spec subsystems of the past, commercial off-the-shelf boards, boxes and racks are developed for relatively short-term applications. That means such COTS gear often needs to be modified to withstand pre-production thermal ramping and random vibration stimulation, collectively called HALT, and must be able to withstand post-production highly accelerated stress screening (HASS). While HASS and HALT are far from new, their strict adherence is far from universal among military system designers.

Wayne Tustin, president of Equipment Reliability Institute, says there's a huge gap between the traditional "qualification" tests that military programs do, and the test screening done by reliability test labs. "Qualification tests are done with a different mindset, because there the test engineers do everything they possibly can to pass the tests," says Tustin, "In contrast, in test screening you do everything you can to make it fail. Unfortunately when people are trying to pass a qual test there are often things that go wrong that have been observed in a lab, but they weren't called failures. If they have a documented failure they may not get that contract, so they don't call it a failure."

As Tustin says, the general core goal of HASS and HALT is to stress a product to make it fail. The most effective tools to accomplish that are rapid thermal change—which forces materials to expand and contract, often at different rates—and multi-axis, broad spectrum, random vibration. The combination of those two tools is also important.

Combining the random vibration with thermal stressing can result in new failure modes.

Thermal and Vibration Tests Combined

A system can behave differently to vibration tests depending on whether the temperature is hot, cold or changing. A handful of test chamber vendors combine thermal stressing and vibration stress in the same unit. QualMark's line of Typhoon Chambers (Figure 1), for instance, incorporates liquid nitrogen cooling into a high ramp rate thermal system, with an integral six degree of freedom repetitive shock vibration system.

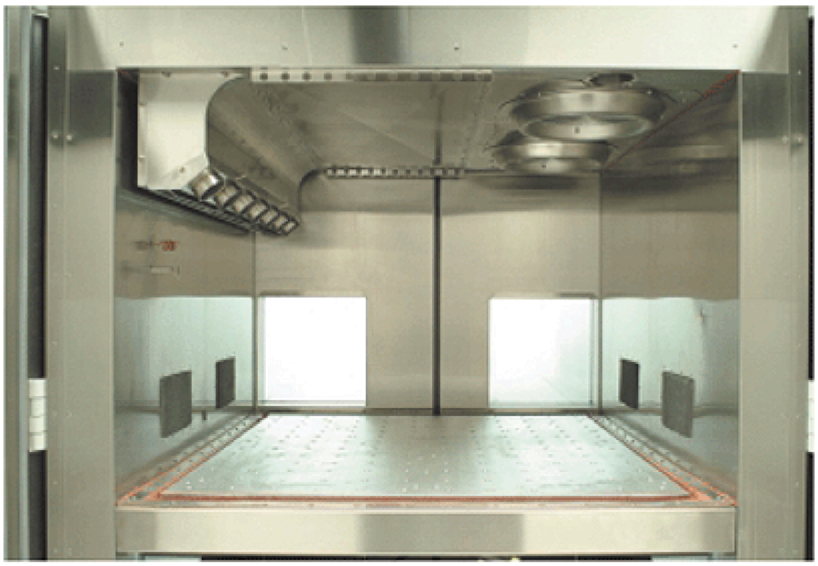

Figure 1

Combining the random vibration with thermal stressing can result in new failure modes—ones that aren't detectable when vibration and thermal stressing are done separately. Serving such needs, QualMark's Typhoon Chambers combine a high ramp rate thermal system with an integral six degree of freedom repetitive shock vibration system.

One area within HASS and HALT that's starting to gain awareness is random vibration. Random vibration test calls for multi-axis excitation rather than traditional single-axis-at-a-time shaking. The traditional method was to use a mechanical shaker to shake a system in x direction, and then along its y direction, and then its z axis. Such tests are far from realistic because in the real world vibrations in different directions exist simultaneously.

Multiple-axis shaking can be done using electrodynamic shakers—which are, in principle, like overgrown loudspeakers. Test labs that can do all six axes of shaking using electrodynamics are rare. For its part, the Army Research Lab (Adelphi, MD) reportedly shifted to multiple-axis shaking when the test engineers found certain Army equipment failing in field use. In the test lab the equipment was surviving traditional single-axis-at-a-time vibration tests. The lab moved to a multiple-axis-at-a-time shaking scheme implemented with three shakers, three power amplifiers and three channels of control. That enabled the test engineers to successfully identify more failures and the designs were improved.

More realism can be achieved with additional shakers to provide roll, pitch and yaw torsional vibration motions. Total laboratory motion thus provides six degrees of freedom, which better simulates in-flight vibrations. These are not new ideas. We might mention here that 6-axis input motions routinely mimic road inputs to automotive vehicles. The auto industry employs six or more relatively long-stroke electrohydraulic shakers, rather than the electrodynamic shaker. The multi-axis inputs of seismic events are modeled in some labs by multiple electrodynamic shakers, and in other labs by multiple electrohydraulic shakers.

Less Expensive Option

The downside of electrodynamic shaking systems is their cost. Because they're so expensive, labs with such equipment are rare. Fortunately, there's a less expensive way to get more than one axis of vibration testing. Using a number of pneumatic repetitive shock devices can drive a softly sprung platform. Hardware is attached to such a platform for multi-axis testing or screening. Because the repetitive shock units are not phased, the platform and test hardware receive not only x, y and z motions, but also roll, pitch and yaw motions.

Mainly because of lower cost compared to electrodynamic shaker systems, many suppliers to the military, and in some cases the military services themselves, are investing in repetitive shock chambers. Repetitive shock testing isn't without its drawbacks however. Such systems can't perform traditional "sine sweep" investigations. Sine sweeps are needed to identify each and every resonance in a system. That kind of resonance investigation often leads to an understanding of why equipment failed and to a structural remedy.

PCB Vibration Issues

Printed circuit boards (PCBs), for their part, respond quite differently to multi-axis shaking. Circuit cards can be very flexible or can be stiffened in multiple ways, and components can significantly affect the stiffness. Under random vibration, stresses from multiple mode shapes combine. All these complexities affect component life. An apt illustration of how random vibration affects PCBs is the motion of a trampoline. If you shake a trampoline's supporting frame, the trampoline would flex along many axes at once.

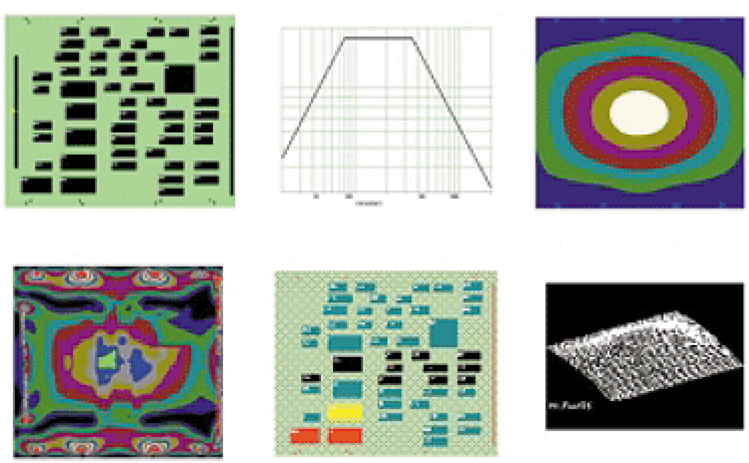

Figure 2

Shown here are a model image, vibration requirement, modal displacement and curvature contours, component life fraction use and modal animation plots viewable using the CirVibe tool. CirVibe uses a patented method that greatly eases the analysis while maintaining accurate results for understanding circuit card life. Models can be built interactively or built with the benefit of extraction of data from various electronics CAD programs.

Aiming specifically at those PCB vibration issues, CirVibe makes a tool for establishing, evaluating and optimizing environmental vibration stress screens for assurance of quality of components, PCBs and electronic assemblies. The tool, also called CirVibe, (Figure 2) performs detailed Finite Element Analysis (FEA) and does automated FEA model generation, modal analysis and detailed component stress calculations, and fatigue evaluations are performed from simple geometric descriptions of the hardware. Through a partnership with Mentor Graphics, the CirVibe tool has a uni-directional interface that lets geometric data required by CirVibe to be read directly from a Mentor Graphics Board Station. Board shape, component details and positions are transferred into CirVibe for use in detailed analysis.

CirVibe
Plymouth, MN.

(763) 559-5166.
[www.cirvibe.com].

Equipment Reliability Institute
Santa Barbara, CA.
(805) 564-1260
[www.equipment-reliability.com].
Mentor Graphics
Wilsonville, OR.
(503) 685-7000.
[www.mentor.com].

QualMark
Denver, CO.
(303) 254-8800.
[www.qualmark.com].