Appendix C

Typical Tests and Equipment

Traditionally, a HALT screen tries to induce multiple stresses at once on a UUT, substantially exceeding the design margin until the device breaks. The lessons learned are then applied to a modified design and then the test repeated—sometimes intentionally increasing the margins yet again (Figure 2). It's important to know when to stop to avoid exceeding the worst-case conditions ever to be seen by the production product. The challenge is correlating a test to a real-world "worst case".

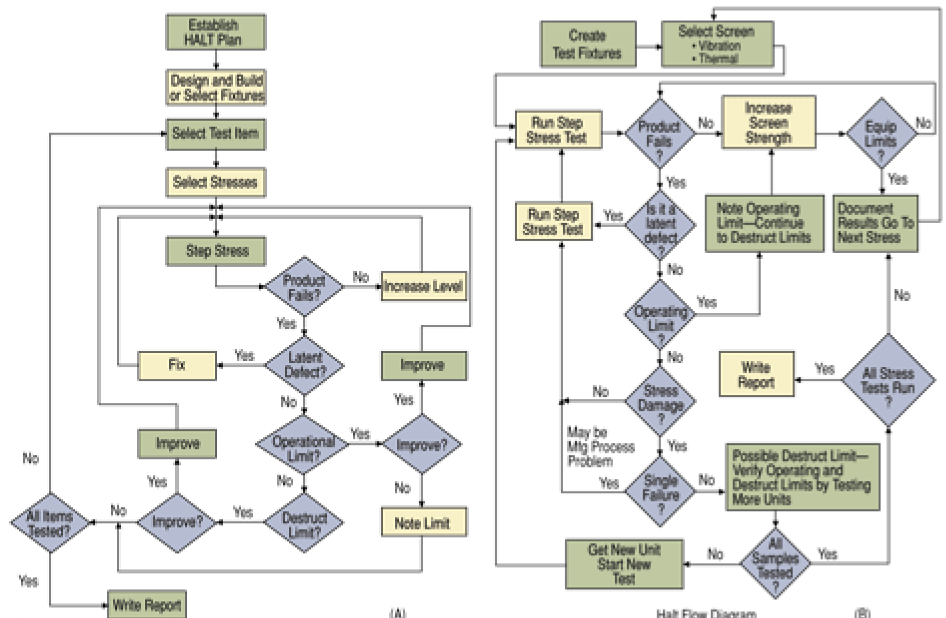

Figure 2

Two examples of HALT test plans. The left (A) is used by Curtiss-Wright, whereas the right (B) is a generic flow provided by The Equipment Reliability Institute and C. Felkins (www.equipment-reliability.com). Note that both flows iterate increasing stress until failure—a fundamental characteristic of highly accelerated life testing.

As Figure 2 shows, there's a bit of a recipe to HALT. According to Thermotron Industries, a leading manufacturer of accelerated stress testing equipment, the procedure is something like this: make the UUT fail or destruct; follow with thermal cycling; then apply vibration. This grueling torture eventually breaks the product but also establishes boundaries for HASS. As the design is modified to remedy what HALT revealed, HASS may use less extreme temperatures and possibly a slower ramp cycle, plus less extreme vibration. In this way, HALT and HASS go hand-in-hand.

It's important during HALT and HASS that an electronic UUT has full coverage; that is, it should be operating as expected during the actual in-service application. It would be poor engineering practice to miss out on an intermittent failure (such as an IC bond wire open) on one cycle that corrects itself on the next. In COTS electronic systems such as single board computers, this can be avoided by running an operating system and typical application code that exercises as much of the board and I/O as possible during the test.

Moreover, it's critical to have sensors and monitoring equipment that can withstand the rigors of HALT or HASS. Thermotron has partnered with National Instruments to facilitate "parallel testing" during extreme situations such as in a temperature chamber under random 6-axis vibration (Figure 3). Current practice with leading-edge COTS products is to increase Willoughby's temperature ramps by 10x to as much as 50°C/minute using nitrogen chambers for cold temperature excursions. Such dwells during HALT testing (when done to extremes) or HASS (within expected boundaries) may uncover latent defects not revealed during a slower cool/anneal cycle.

Appendix C

Figure 3

Combined temperature/vibration chambers are essential as they apply multiple stresses during HALT and HASS, such as this system from Thermotron. Additionally, coupling the system with test equipment from National Instruments allows actual performance monitoring of in-operation UUTs.

We stated above that while temperature and vibration are common stresses, they are by no means the only ones. Often a humidity or pressure test is added to the mix—either separately or in combination with other stresses such as voltage, temperature or vibration. Equipment to conduct concurrent tests is available from companies like Thermotron, but the complexity of a stand-alone piece of gear tends to make it out of reach of many COTS vendors and even military contractors. The automotive market has long recognized the benefit of combining multiple tests for HALT and HASS and has published its recommendations in the Automotive Electronic Council document AEC Q100 (www.aecouncil.com). Additionally, JEDEC spec JESD22-A110-B provides additional guidelines for humidity HAST on microcircuits.

Some words about random vibration are in order. Low-cost single-axis electro-dynamic shaker tables are the norm in the electronics industry. Attaching the UUT to the table with sensors to monitor operation provides vibration stresses in only one direction. To facilitate 3-axis testing, the unit is then mounted orthogonally and the test repeated until x, y and z are covered. Industry experts such as Wayne Tustin of the Equipment Reliability Institute argue that while this is good, it’s not good enough.

Tustin cites an example of a U.S. Army military system that exhibited failures in the field that were not predicted by their previous single-axis testing. However, a 3-axis test did correlate failures to what was seen in the field.

A shaker system that can vibrate all three axes at once more closely approximates a real-world situation. And, since the table tends to add a rotational vibration around each axis, this set-up equates to 6-axis testing, which is more likely to induce failure (Figure 4). Multi-axis testing is done routinely by the automotive industry as well as by seismic (earthquake) simulator systems—but the electronics industry is still slow to catch up with 3-axis repetitive shock (RS) testing. Tustin has other suggestions, such as the careful placement of accelerometers to measure the actual vibration intended and imposed on the UUT, fixture design, and ways of mitigating resonation during HALT or HASS testing. These can be found in his new book “Random Vibration & Shock Testing” (Figure 5), which he has shared with COTS Journal.

Appendix C

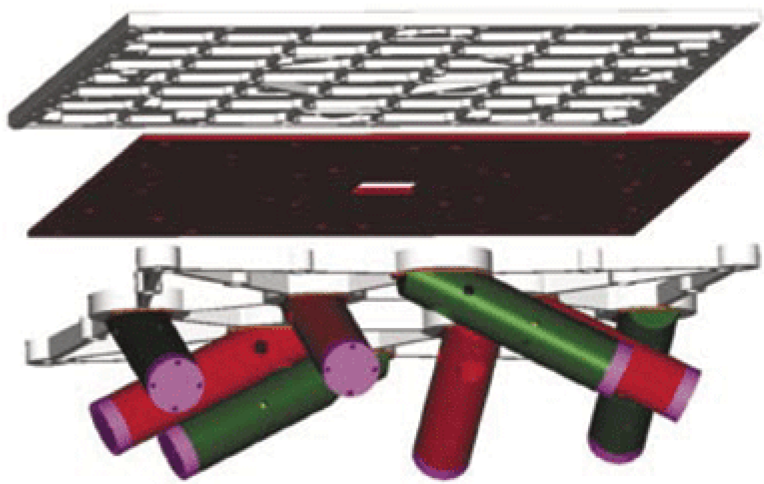

Figure 4

A multi-axis repetitive shock (RS) shaker is the best set-up because it induces random vibration in up to six axes simultaneously (x, y, z and a rotation about each). (Courtesy: Equipment Reliability Institute and QualMark.)

Problems with HALT and HASS

There are several problems with HALT. First, it's expensive. Besides the cost of the test itself, a successful HALT screen suite uses lots of company resources and personnel from many departments. That's because while the product is still under design, variables including the design itself and manufacturing procedures, are still in flux. To create, implement and iterate a HALT screen will involve engineering, quality and reliability, human factors, manufacturing, purchasing, and many other disciplines. HALT is a big commitment.

In addition, HALT ruins products. Even with low-cost COTS electronics, ruining boards or systems costing from thousands to tens of thousands of dollars is a big investment. And the repetitive nature of test to breakage, redesign and test again doesn't lend itself to being repeated too many times. The iterative nature of HALT also makes product planning a challenge: it simply isn't possible to anticipate how much time will be required. Minor failures may facilitate only small design changes; major failures could render an entire product as junk—completely missing a market or program window and affecting revenue.

But the biggest problem with HALT is that—if done correctly—it encourages over-design. Testing a product to failure may sound like a robust way to make darned sure nothing ever goes wrong in the field, but the reality is the product often ends up over-designed and tested beyond the target specs. According to component expert Gerald Servais, Delphi Delco Electronics Systems Technical Fellow (retired) and an advisor to NASA's Aerospace Technology Working Group (ATWG), a 1000-hour automotive electronics temperature cycle test imposed by HALT equated to more than 90 years of typical automotive usage. Servais told COTS Journal that many HALT screens have little correlation with an actual application, and if a product passed the tests it's likely it would never experience field problems related to that test anyway.

Unrealistic tests lead to unrealistic failures, which causes engineering to fix "problems" revealed by the test but which may not really exist in the end application. Program delays and increased product costs soon follow. The negative question might be: if the UUT passed HALT, so what? Is this a condition that the product might actually see in the field? By its very nature, HALT intends to create conditions different from—and much more stringent than—what the product will see in the field. This begs the question if HALT is really a worthwhile reliability test.

Appendix C

Since HALT is used to establish the boundaries for ESS production testing via HASS, it's very possible that these test limits may still be above operational limits. In fact, HASS tends to reduce a product's life, thereby inadvertently adding in "ticking time bomb" failure mechanisms that may cause a system to fail in the future. For example, excessive temperature during HASS (but below that used for HALT) can induce stress cracks in circuit boards or even fundamentally change the physical properties of semiconductors. Electro migration, initiated by high temperature testing, may shorten an IC's life and cause a premature COTS system failure in the field.

But again, there may be ways around this downside. Curtiss-Wright Controls is cognizant of this problem and implements a Safety of Screen (SOS) procedure to determine if HASS has left sufficient life in a product for field use. The product is put through qualification testing, followed by a predetermined safe number of HASS screens (typically 20), and then finally the unit is exposed to a second qualification test. If the unit passes, the HASS profile is considered "safe". But it goes to show that neither HALT nor HASS can be applied blindly.

COTS Journal
By Chris A. Ciufo