

HALT/HASS Testing Drives Product Reliability

Abstract

The critical nature of electronic systems, both in the military/aerospace arena and in many high reliability commercial applications, demands that fielded products are as reliable as possible. Functional test can be performed at the end of the manufacturing process; however, this approach may not uncover issues that may result in latent failures or are related to manufacturing processes. Highly accelerated life testing and stress screening (HALT/HASS) can quickly uncover problems associated with design and production capabilities resulting in more reliable products, reduced life cycle support costs, and shorter time to market. Understanding this test environment, as well as the application challenges associated with test equipment selection and implementation, will ensure critical performance data is available as needed.

Introduction

HALT and HASS rely on techniques that shorten the time required to identify potential causes of failure and is performed by applying much higher stresses than exist in actual product use, which forces failures to occur in significantly less time than under normal conditions.

HALT is performed during product development cycle with the aim of shortening time-to-market. Identifying and correcting potential design issue early in the cycle can significantly reduce overall development costs and schedule delays. HASS focuses on uncovering issues that may occur during the manufacturing process such as machine, process or workmanship can result in expensive rework and scrap expense.

Since hundreds of products may be aged and monitored simultaneously, the challenge for test engineers is the large number of test channels needed, environmental conditions such as electrical noise that can be present in a production environment, as well as the cost and reusability of test systems. Designing an effective test system requires a clear understanding of the environment, the implementation and measurement challenges

and the performance characteristics of the test equipment; these considerations will be discussed in the following sections.

HALT / HASS Fundamentals

In HALT, temperature and vibration stress conditions are used during product development to find weak spots, both in the design and in the product's planned fabrication processes. Test stimuli may include humidity, thermal cycling, burn-in, over-voltage, voltage cycling, and anything else that could logically expose defects. This phase of testing requires only a few units and a short testing period to identify the fundamental limits of the technology being used. Generally, every weak point should be identified and re-designed to meet the product specifications.

In production, HASS uses the highest possible stresses; frequently well beyond the qualification level. Also proof-of-screen techniques must be used to protect good product (identify defects without damaging good product). Keep in mind that HASS usually is not as effective unless HALT is done earlier in the process, because fundamental design limitations will tend to restrict HASS stress levels.

Typically, a population of products will exhibit reliability characterized by a bathtub-shaped curve (see Figure 1) with three distinct failure-rate regions.

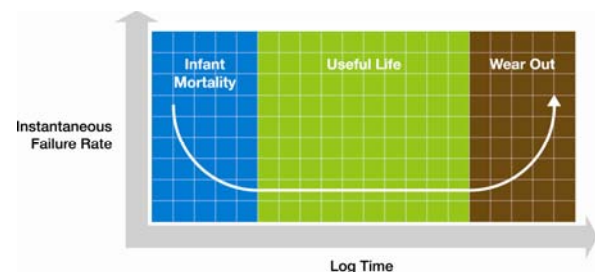


Figure 1 - Reliability Curve

The first region of the curve is infant mortality, which has a decreasing failure rate and is associated with built-in (i.e., not designed-in) defects. These are the types of defects that can often be identified by HALT testing. The amount of time required for a given HASS test is determined by the infant mortality region of

the reliability curve. Generally speaking the higher the stress, the sooner the failures, the narrower the infant mortality region, and the shorter the HASS test period.

As mentioned, test profiles can include temperature and vibration as well as other stimuli designed to reveal a wide range of problems. Some common profiling examples and test objectives are identified below:

Temperature:

- Determine the minimum and maximum product operating temperature limits
- Apply extreme temperatures to accelerate the aging process of the device under test (DUT)

Humidity:

- Determine the effects of high/low humidity on the DUT (corrosion, electrostatic discharge, ESD damage)
- Identify latent shorts on printed circuit boards (PCBs) that are related to humidity

Vibration:

- Determine the maximum product operating vibration levels
- Find mechanical defects early in the cycle

The test parameters during any of these HALT/HASS profiles can vary, but are usually limited to the signals that indicate whether or not the product is functioning properly.

Test Equipment Considerations

HALT / HASS are conducted in environmental chambers where high or low temperature, vibration, and other stress conditions can be applied to the DUTs. In many cases, additional stresses not associated with the chamber can also be applied, such as full power (burn-in) and over-voltage conditions.

There are a number of considerations associated with the selection of test hardware including channel count, signal input levels, measurement speed and bandwidth, along with cabling and connectorization. Multiple DUTs are often connected through a multiplexer to maximize testing efficiencies. With appropriate characteristics, a multiplexer can increase throughput, reduce test

equipment costs, maximize test equipment utilization, and improve consistency and reliability.

When a DC stimulus must be applied to the DUTs and their response measured, synchronization and triggering are issues associated with speed and accuracy. For example, parasitic capacitance in cables and connectors makes it necessary to allow for signal settling time before measurements are made, otherwise inaccuracies can occur; this is often seen when long cable lengths are used to connect devices in a test chamber. Typical mechanical relay settling times are rate at <5mS, however additional time will be needed to compensate for the cabling effects.

Test System Implementation

HASS burn-in testing is common for switching power supplies and it is not unusual to test hundreds of these products simultaneously within a chamber. The challenge is the high levels of electrical noise produced by such a large number of switching supplies. Power supplies for computers typically have four to six voltage outputs that are usually measured while the temperature in the environmental chamber is cycled between upper and lower limits, and the power supply output is repeatedly cycled on and off.

A digital multimeter (DMM) is connected in parallel with the load resistance to measure the power-supply voltage. The load resistance is chosen to simulate that found in the final application, or may be chosen to force the power supply to its maximum output capacity for testing purposes. Power supply output cycling, which increases the level of stress, is a preliminary test before burn-in; this helps weed out power supplies with major problems. To capture this failure data, the output voltage can be measured each time the supply is turned on.

A precision switch/measure and I/O technology, such as VTI's EX1200, is ideal for both the voltage and temperature measurements required in this example. The EX1200-304, a 48-channel multiplexer card, has two connections (HI and LO) for each power supply. Additionally, the same terminal configuration can be used for thermocouple measurements because of built-in automatic cold-junction compensation (CJC). Once the

field terminations are complete the instrument is configured using the Ethernet-based LXI communications interface; this platform provides a scalable solution that can expand with application requirements.



Figure 2 (VTI's EX1200)

Measurement Challenges

Environmental noise is a prime error source during HALT/HASS testing, and placing hundreds of switching power supplies in an environmental chamber creates very challenging measurement conditions. Switching power supplies radiate high-frequency noise, and if the ground connection is noisy, conventional data-acquisition systems will be unable to make satisfactory measurements. Noise not only degrades the overall quality of data, but can also result in good product being identified as unacceptable; this will result in lower throughput and result in higher costs.

A commonly used approach to reduce the effects of noise spikes involves varying the integration time of the instrument. Integration time is typically determined by the number of Power Line Cycles (PLC) used, based on 60Hz. For example:

$$\begin{aligned} 0.1\text{PLC} &= 1.667\text{mS} \\ 1\text{ PLC} &= 16.67\text{mS} = 1/60\text{Hz} \\ 10\text{ PLC} &= 166.7\text{mS} \end{aligned}$$

A longer integration time provides the best common-mode and normal-mode noise rejection. This technique will result in a measurement that is less susceptible to noise but it can significantly increase the measurement time; for example scanning 288 channels at 10PLC would take 48 seconds to complete ($288 \times 166.7\text{e-3} = 48$).

Relay wear is another consideration because mechanical relays have a finite life; typical mechanical relays are rated at 1×10^7 operations, closure time $< 5\text{mS}$, with a path resistance of less than $500\text{m}\Omega$. Relay contacts will eventually degrade, and can affect the quality of the measurement due to

increased contact resistance and thermal EMF; features such as built-in counters can monitor contact closures to identify units needing maintenance. Another alternative involves using solid state relays. Switching times are fast, less than $500\mu\text{S}$, but path resistance can be as high as 10Ω ; this may not be suitable for all applications.

Summary

HALT/HASS implementation does involve an initial investment and planning, but this will ultimately result in products that are more reliable and less costly to produce. While implementation costs can be minimized by selecting test equipment that is easily connected, reconfigured and scalable. And ultimately customer benefits such as improved uptime and performance cannot be underestimated.