



High Reliability Challenge of Broadband Equipment

Optimizing Hardware Reliability with HALT and HASS

Abstract

As equipment bandwidth capabilities increase, there is a need for even higher reliability. Higher bandwidth equals more end customers being supported by a particular piece of equipment. We now have optical transmission equipment where one line card may simultaneously carry traffic for thousands of end customers, and this traffic includes lifeline voice. At the same time, services with disparate levels of quality and reliability are converging, and carriers need assurance that their converged network will maintain the higher level of reliability (rather than suffer degradation as the price of convergence). From the carriers' perspective, the reliability requirements for broadband equipment may conceptually equal those of "mil-spec". Consequently, conventional methods of hardware reliability development may prove to be inadequate.

Some telecommunications equipment manufacturers have adopted a reliability-development methodology that in many ways exceeds those methods employed by military subcontractors. This process, commonly referred to as Highly Accelerated Life Testing (HALT), results in optimized hardware reliability, well beyond verifying the product just "meets the spec". From HALT, a production stress screen is developed that employs the same techniques as HALT. Highly Accelerated Stress Screening (HASS) far exceeds conventional burn-in for screening out manufacturing flaws and component defects.

HALT and HASS are the centerpieces of Turin's hardware reliability assurance program. This paper demonstrates how HALT and HASS can meet the challenge of providing broadband equipment that meets the end customer need for zero downtime and uninterrupted traffic flow.

The Reliability Challenge

A challenge for many telecom equipment suppliers is to maintain hardware development processes that can continuously support ever-changing customer requirements, such as the need for greater hardware reliability. The demands on telecom equipment are constantly growing, and so is the impact of a hardware failure. With the amount of data passing through networks, and the revenue stream that the data represents, downtime simply cannot be tolerated. But can this challenge be met using conventional methods of hardware reliability development?

Since the early days of electronic reliability development, the main focus has been to qualify a design for production by subjecting the product to a simulated field environment, sometimes in an accelerated manner. But rarely did the applied stresses go beyond the specified operational limits, a contemporary example being NEBS testing. The main purpose of this type of reliability testing is to verify rather than actually develop reliability. This approach of simulating in order to verify does not always provide an adequate reliability safety margin.

HALT & HASS – A Paradigm Shift

But now the paradigm is shifting from simulation to stimulation, where the purpose is to stimulate all hardware weaknesses until they become detectable failures, then fixing the weakness and continuing with the stimulation until the next weakness is found. Highly Accelerated Life Testing (HALT) is such a stimulation process, and is used during product development to help design hardware with optimum robustness and reliability safety margin. Highly Accelerated Stress Screening (HASS) is derived from HALT and uses a similar approach to screen out hardware defects in production prior to shipment to customers. The philosophy of HALT and HASS is to force failures, not pass a test.

HALT & HASS are not new processes and have actually been around for perhaps two decades, yet they are still new to many industries and therefore relatively unknown to many companies. But momentum is growing, with more companies adopting this method as it has proven itself for both system and component suppliers.

Companies who have implemented HALT and HASS on existing products have experienced immediate and often dramatic decreases in field failure rates. It's these cases that have clearly shown the benefits of HALT and HASS over other methods. Companies such as Turin who implement HALT and HASS from the beginning of the product life cycle generally experience optimized field reliability (and minimum field failures) from the first shipment.

The HALT Process

By effectively causing hardware weaknesses to become detectable failures, HALT can very rapidly find product weaknesses that can be corrected, thereby improving the reliability. HALT is not just finding failures, but correcting the weaknesses that caused the failures. HALT begins by gradually increasing a stress or combination of stresses, until a failure occurs. Once failures are precipitated during HALT, the root cause of the failure is determined and corrective action is implemented in order to increase the robustness of the product. Then the application of stresses is continued in order to find the next weakness. Figure 1 graphically illustrates the HALT cycle. This cycle is continued until the fundamental technological limit is reached and further efforts at improving the product will have little or no benefit. This fundamental technological limit then represents the destruct limit of the product.

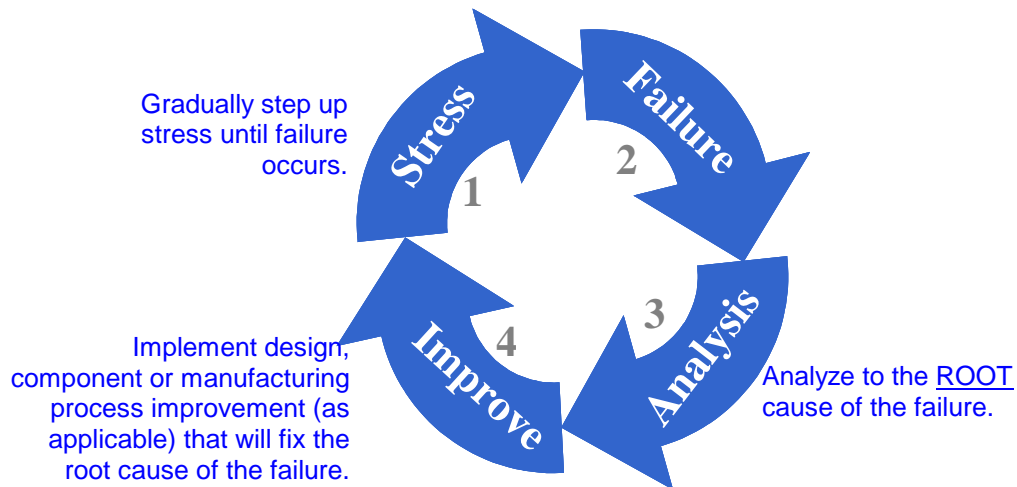


Figure 1: HALT Cycle

The stresses applied during HALT typically far exceed the field environment, and are intended to expose the design and manufacturing process weaknesses in a very short period of time. These stresses include such things as:

- Exposure to temperature extremes – possibly as low as -50°C to as high as +100°C
- Rapid rates of change of temperature – possibly as high as 60°C per minute
- Omni-axial (6-axis) random vibration – possibly up to 50 G's rms
- Power cycling
- Internal voltage margining
- Varying clock frequencies
- Exposure to high humidity

In all cases, the actual limit of the applied stress will be the fundamental technological limit (destructive limit). These stresses are applied one at a time and in combination. Experience shows that simultaneous combinations of stresses are the most effective at causing a weakness to become a detectable failure. The strategy in applying stresses is to use whatever it takes to force a weakness to become a detectable failure.

Benefits of HALT

HALT effectively increases the operating margin for the product, creating a wider gap between the specified limits and the actual operational limits. Figure 2 that follows shows this margin growth, which is what directly results in the improved reliability. Without the margin growth, actual failure distributions around the operational limits (as indicated by the bell curves) may drop within the operational specification limits, resulting in a failure. With the larger operating margins provided by HALT, manufacturing process variations and field environmental effects have minimal impact on product performance and reliability. The wider reliability margin also contributes to a reduction in the number of no trouble found (NTF) failures, which often represent the majority of field failures.

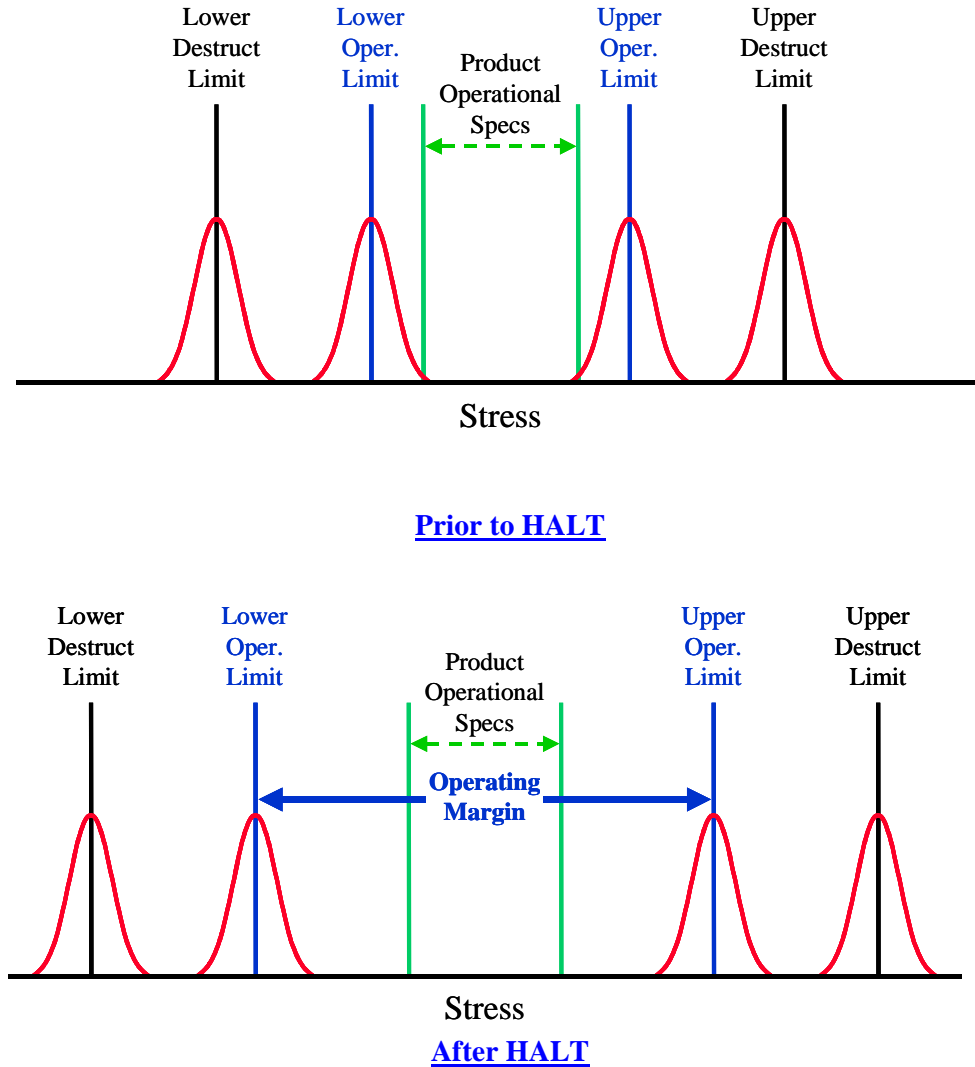


Figure 2: HALT Reliability Margin Growth

The HASS Process

HALT helps identify those stresses, or combinations of stresses, that most effectively force weaknesses to manifest as detectable failures. This knowledge, along with the known operational and destruct limits (also determined in HALT), provide all the information that is needed to design an effective production screen, which is then conducted on all assemblies prior to shipment to customers. The HASS process screens out not only infant mortality failures, but it precipitates latent device defects and identifies manufacturing process flaws. The key result of HASS is circuit cards with a very high degree of reliability at the time of shipment to the customer. In order to validate the HASS profile and verify the process does not consume excessive portions of the product's life, a "proof of HASS" is conducted where a sample of assemblies are run through HASS several times (e.g., 20 times), followed by a reliability life test. Proof of HASS can also help verify that there is little likelihood that defects will pass through HASS undetected. The HASS screening profile will include all or some of the same stresses that are used in HALT.

Figure 3 illustrates the HASS process flow, with the actual HASS part of the process being the precipitation and detection screens.

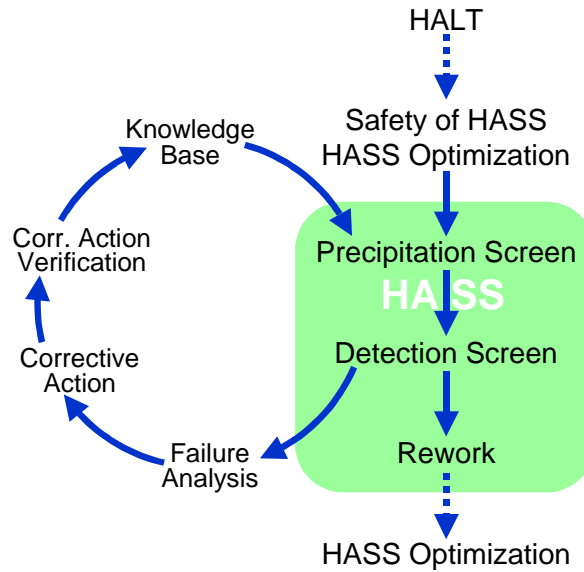


Figure 3: HASS Process Flow

The precipitation screen stresses the product beyond the operational limits in an effort to force weaknesses to become detectable failures. The stresses are then reduced during the detection screen, at which point dynamic functional testing is conducted in order to now detect the weaknesses that have been stressed into a failure state. Figure 4 graphically shows the relationship between the precipitation and detection screens.

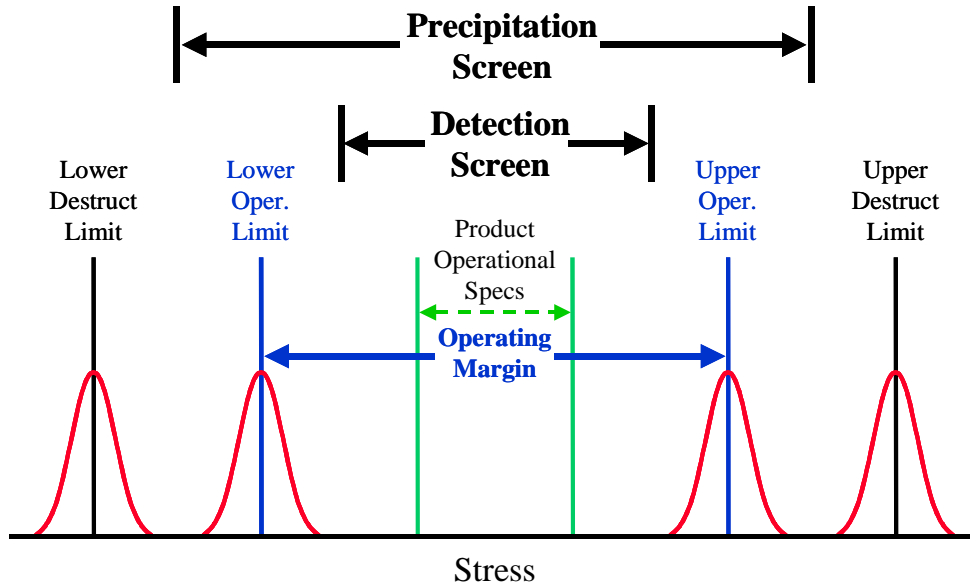


Figure 4: HASS Precipitation & Detection Screens

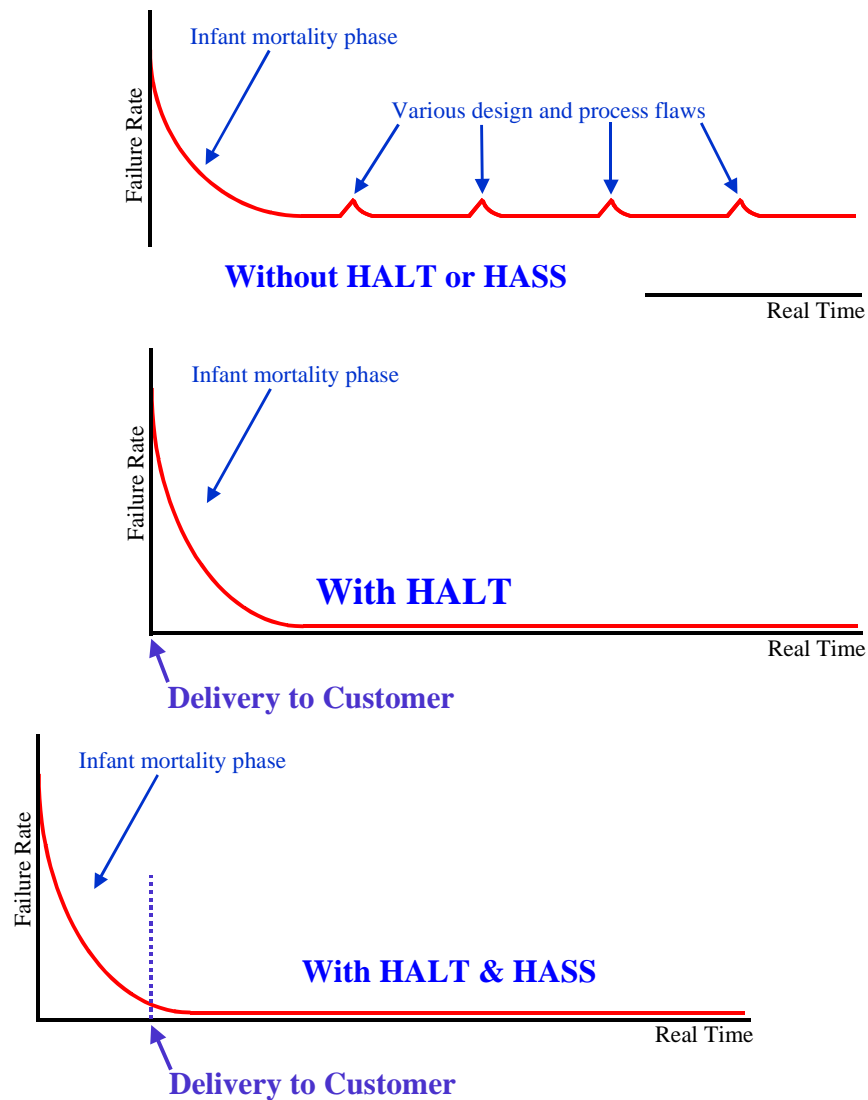
Benefits of HASS

HASS is much more effective than more conventional methods of reliability screening, such as burn-in. HASS is also a process that requires very little time, with typical HASS screens being around three hours; far less than the typical 48-hour burn-in. The rapid nature of HASS provides for equally rapid feedback of problems to the manufacturing process, contributing to quick corrective action. Thus, HASS is a key contributor of raw data to the manufacturing process control program.

HALT and HASS – Impact on Hardware Reliability

The most apparent benefit of HALT and HASS is minimized field failures. HALT also provides for minimal time-to-market of a product with optimized reliability, and at a minimal cost to achieve that reliability. Figure 5 shows the two-step effect that HALT and HASS have on the field reliability. With the addition of HALT, the steady-state failure rate can be greatly reduced. And with HASS made a part of the production process, the infant mortality failures can be screened out of the product, effectively resulting in the product being shipped to the customer at the point where the reliability is the greatest.

Figure 5 below: Effects of HALT & HASS on Field Reliability



Conclusion

As more companies adopt HALT and HASS, more data becomes available showing the overwhelming benefits over older methods. And in the telecom industry there are many notable equipment suppliers who have adopted HALT and HASS.

At Turin, HALT is done initially at the individual circuit board level, then conducted on un-populated chassis' and subassemblies (such as fan tray assemblies), and finally at the populated system level. HALT is conducted as soon as practical during the development process and may be repeated before product is released to production.

HALT testing is conducted at various stages throughout the "production" life of the product as well. Repeating HALT while in production not only ensures that the reliability margin does not drift with time, but it helps to re-validate the HASS process. The HASS profile can then change as the product changes, resulting in continuous screening process improvement and optimization of product reliability.

It is this kind of approach to implementing HALT and HASS that, when coupled with other common reliability assurance practices, has the best chance of meeting the end customers need for zero downtime and uninterrupted traffic flow.

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