White Paper | May 2012
Version 1.1

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Designing for Extreme Reliability

HALT and HASS Testing Helps Improve Product Reliability and Lower Total Cost

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Overview

Very high reliability is a preeminent requirement in many embedded market segments, such as military, aerospace and medical. Making designs more robust, long-established HALT and HASS processes can quickly identify functional and physical weaknesses in a product. This white paper discusses how Radisys applies HALT/HASS testing during product design and manufacturing in order to improve life cycle reliability (e.g., MTBF).

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Executive Summary

Very high reliability is a preeminent requirement in many embedded market segments, such as military, aerospace and medical. When human lives are at stake, it's impossible to quantify the value of safe and reliable systems.

One proven approach that improves product reliability is to design in additional margin. This is akin to demonstrating a product will operate at 10,000 revolutions per minute (RPM) when it will only be used in the field up to 5,000 RPMs. The resulting design is less susceptible to component variation in the manufacturing process or performance degradation due to typical wear and tear in the field, which otherwise could cause a failure. Margin translates into long term reliability.

Long-established HALT (Highly Accelerated Life Testing) and HASS (Highly Accelerated Stress Screening) processes are used to effectively assess and monitor design margin. The purpose of HALT testing is to identify a product's functional and physical limitations, which then can be improved until the fundamental limit of the underlying technologies is reached, thereby achieving the maximum attainable margin before a product is released to manufacturing. HASS screening, performed on 100 percent of manufactured products, verifies margins are maintained. This white paper discusses how Radisys applies HALT/HASS testing during product design and manufacturing in order to improve reliability (e.g., MTBF, availability and failure rate over time).

Rugged Applications

Systems, like unmanned ground vehicles (Figure 1) or man-wearable computers, must be ruggedized to stand up to extreme temperatures, thermal and dynamic shock, vibration and G-forces. Used on land, at sea or in the sky, these systems have to perform reliably in the field—under extreme temperatures and vibration conditions.

COM Express extended temperature designs are regularly used to satisfy these requirements because they can stand up to the rigors of the toughest environmental conditions. Running mission-critical applications, these systems are deployed in vehicles, aircraft and ships that require the maximum computing performance in thermally-challenged and space-constrained settings.

Figure 1. *Talon unmanned ground vehicles made by Foster-Miller are rugged, lightweight tracked vehicles widely used for explosive ordnance disposal, reconnaissance, communications, sensing, security, defense and rescue.*

HALT/HASS Overview

The roots of HALT and HASS processes can be traced back to 1969,[1] when Dr. Hobbs developed advanced practices for increasing equipment reliability and ruggedness. The premise is to subject products to extreme environmental conditions up until the point of failure in order to determine the weakest aspects of the design. Subsequently, primary, secondary and tertiary failures are removed by reengineering and redesigning the product until the fundamental limits of technology are reached (i.e., the physics of semiconductor devices). As a result, the product has an increased functional and physical design margin, which safeguards against failure.

HALT and HASS processes are intended to augment, not replace, other processes, such as design verification, and manufacturing and life testing, used to improve product quality and reliability. Many Mil/Aero customers require their suppliers, who are original equipment manufacturers (OEMs), to adopt HALT/HASS testing methodologies so they attain higher levels of product quality and reliability.

HALT Testing

HALT (Highly Accelerated Life Testing) is performed during the product design phase since the outcome often calls for design modifications. The product undergoes multiple stresses that far exceed its environment specifications, with the goal of overstressing the product and inducing failures in the product. Unlike other tests, HALT is not a Pass/Fail test, because the product is expected to fail as thermal and vibration test conditions increase in severity, well beyond use conditions.

The outcome is the determination of the product's functional and destruct limits, and if the identified failure modes are corrected, these limits can be pushed out. The main objective of HALT testing is to maximize the limits of a product design. When applied correctly, HALT can improve reliability, identify issues before the product ships, and reduce warranty costs, as indicated in Table 1.

Benefits Derived From the HALT Process

OEM Perspective	Component Manufacturer Perspective
Improves product reliability by increasing design margin	Identifies design and process limitations quickly
Identifies issues that can be addressed before the product ships	Allows engineers to evaluate and improve design margins
Reduces warranty cost because there are fewer field failures	Reduces product development and certification time when critical product flaws are discovered early
	Enables design problems to be eliminated before product manufacturing commences

Table 1. *Benefits Derived From HALT Testing*

Product testing is conducted in a HALT chamber, as shown in Figure 2, typically on a few units. Testing consists of stepped vibration and thermal stresses, which determines the actual limits of the design and board components. The vibration test covers six degrees of vibration movement: both directional and rotational movements along the X, Y and Z axes, as illustrated in Figure 3. The shock and vibration, measured in g's, is applied in increments, usually 5-10 Grms (i.e., root-mean-square of acceleration). The stress remains for a minimum dwell time of ten minutes; there must be enough time to run a full functional test on the product.

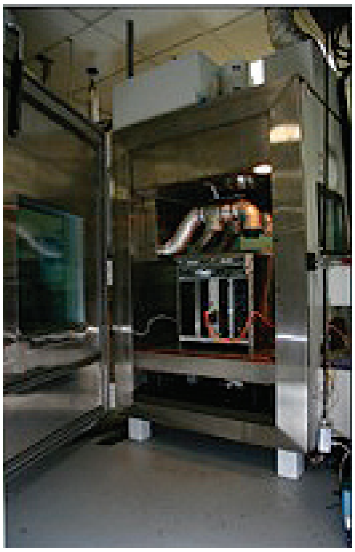

Figure 2. *A HALT Chamber Used to Test a Chassis with Boards*

HALT COVERS SIX DEGREES OF FREEDOM

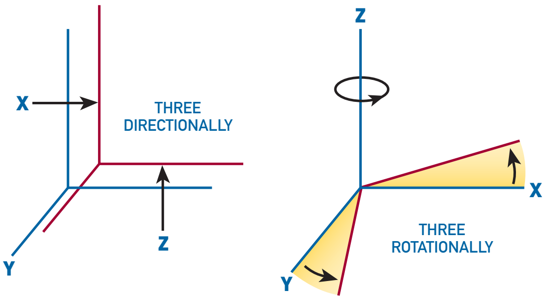

Figure 3. *Unlike Traditional Vibration Tests, HALT Covers Six Degrees of Vibration Movement*

During thermal testing, the temperature is stepped as quickly as possible in 10 degree Celsius increments. Starting at ambient, the temperature is lowered for the cold test and raised for the hot test, as shown in Figure 4. Similar to the vibration test, the dwell time at each step is a minimum of ten minutes, and the product must pass a full functional test. Finally, a profile of both thermal and vibration stresses is executed to assess robustness in a combined stress environment.

There is no standards specification for HALT tests; however, the common practice is to use multiple stresses:

- Maximum thermal limits: high and low temperatures
- Extreme thermal rates of change
- Maximum vibration
- Combinations of vibration and thermal stresses

Both thermal and vibration stress are fatigue tests that lead to mechanical and physical failures, examples of which are shown in Table 2. Thermal stresses are particularly effective at identifying electrical and semiconductor component marginality.

As failure modes are discovered, they are corrected by design or component improvement until further improvement is either impractical or constrained by the fundamental limit of the underlying technologies. By establishing that the design and components are capable of operating not only to the extended temperature specification but well beyond, HALT demonstrates the true operational limits of the product. The concept and execution of maximizing the design margin is critical to successfully producing reliable, extended temperature products.

When HALT testing is completed, the product's functional and destruct limits are determined, and the factors dictating design and manufacturing margin are identified. At this point, the product development team has incorporated the changes they deemed necessary, having repeated HALT testing on reengineered units to verify the efficacy of the modifications. Now there's enough data and design margin understanding to construct a HASS test used to screen products coming off the manufacturing line.

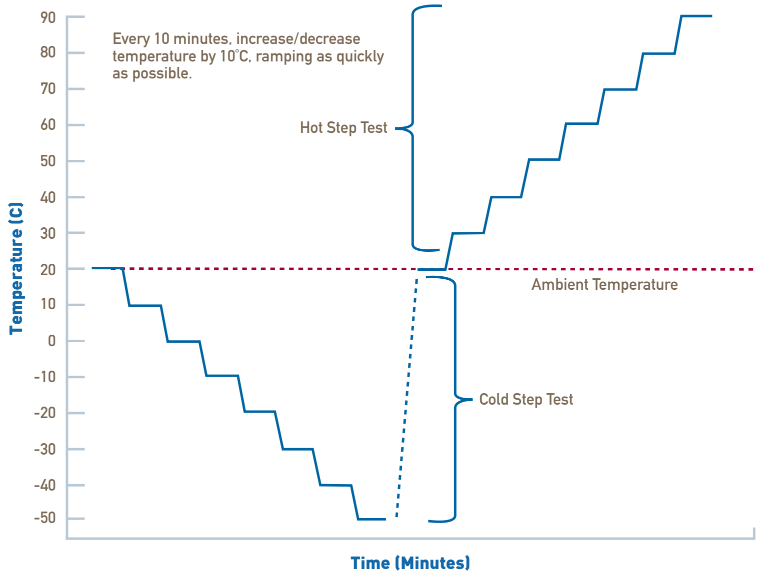

Figure 4. *Hot and Cold Step Stresses*

Vibration and Thermal Stress	Thermal Stress
Bad solder joints (e.g., metal composition)	Poor component placement (excessive loads, noise)
Surface mount issues (bonding strength)	IC quality problems\ (excessive leakage, electrostatic discharge—ESD)
Low mechanical tolerance (expansion coefficients)	Insufficient electrical tolerance (signal quality)
Raw board problems (e.g., delamination)	Timing issues (signal skew, setup/hold time)

Table 2. *The Types of Defects Identified Using HALT*

Next: HASS Screening

HASS (Highly Accelerated Stress Screening) ensures the performance of manufactured products exceeds the product specification by a certain level, called operating margin, as shown in Figure 5. The premise of the screen is that a product with greater operating margin will, on average, have higher long term reliability than a product with a lower margin.

The test conditions of the screen are established by backing off from the functional and destruct limits found through HALT testing to a level that will not take excessive life out of the product. This is verified with a "proof-of-screen" test, which also serves to confirm the screen is effectively identifying defective products. The proof-of-screen test repeats the proposed HASS profiles 20 times, while under continuous diagnostic observation. At the high and low test points, the product is powered off and allowed to settle before it is rebooted and retested. A full functional test is executed at the completion of the process to ensure no failures of any kind have occurred. The success requirement for the proof-of-screen test is that all units pass (no failures). An example is given in Table 3.

Typically, ten products are thoroughly characterized before and after the proof of screen test to look for any significant performance degradation, in which case the screen conditions are revisited. This exercise may be followed by a life testing on the sample to check whether any infant mortality failure mechanisms were induced by the screen.

In order for HASS to be truly effective, it must be performed on 100 percent of the products manufactured. In this way, an OEM can guarantee that each product not only meets the extended temperature requirement, but that it does so with additional operating margin, ensuring long-term performance and reliability.

By driving operating margin into the design, an OEM can become immune to material and process variation in manufacturing, attain high yields during all production phases and have sustained reliability and low warranty costs. So to recap, HALT drives the design to its fullest capability, and HASS ensures manufactured products have a certain level of operating margin.

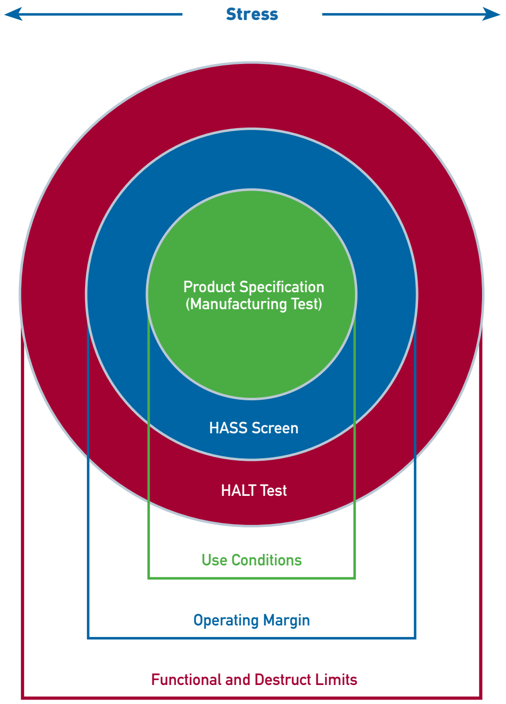

Figure 5. *Relative Stress: Manufacturing Test, HASS and HALT*

	HASS Screen	Proof-of-Screen Test
Thermal and Vibration	1) Starting at ambient temperature, the temperature is increased (20˚C per minute) to the high test point. During the dwell time, the product is powered down, rebooted and tested.	Repeat HASS screen 20 times.
	2) The temperature is ramped from the high to low test point while diagnostic tests are run. During dwell time, the product is powered down, rebooted and tested.	
	3) The temperature is ramped from the low test point to ambient temperature while functional. Comprehensive product testing is conducted.	

Table 3. *HASS Proof of Screen Test Example*

Measuring MTBF

One of the most widely used predictions of reliability is the mean time between failures (MTBF). The greater the MTBF, the higher the reliability is at a given point in time. The objective of the HALT and HASS processes previously discussed is to increase the inherent reliability of the product. This is achieved by identifying ways to increase the product's design margin (HALT) and ensuring the expected level of operating margin (HASS) in manufactured products. It is important to note that HALT and HASS processes do not yield MTBF data. This is because they are fatigue tests using conditions outside the normal operating range and specification of the product. MTBF is best demonstrated using life tests and actual field data.

Radisys uses two methods to arrive at MTBF calculations:

- *Sum of Failure Rates:* A product MTBF is derived by adding up the failure rate of every individual board component. Component failure rates, based on millions of operational hours in the field, are found in the MIL-HDBK-217 and Telcordia (Bellcore) SR-332 databases (require subscriptions).
- *Demonstrated Reliability:* Radisys tracks every unit it ships, and all field failures, in order to calculate a Radisys-specific MTBF based on cumulative data collected over twenty years.

Ruggedized COM Express Modules

Radisys extended and industrial temperature products are designed with higher capability components and are subjected to an extensive suite of environmental tests to demonstrate capability of operation in the -25˚C to +70˚C and -40˚C to +85˚C temperature ranges. One example is the Radisys CEQM57XT module, which combines Intel® Core™ i7 and i5 processors and the mobile Intel® QM57 Express chipset, and supports ruggedized vibration specifications. The module is designed for Mil/Aero, medical and industrial applications such as ruggedized computers/tablets, unmanned vehicles/robots and in-vehicle computers. With thorough design verification and 100 percent HASS screening, OEMs can depend on the sustained reliability of the Procelerant® COM Express in harsh, rugged environments.

Radisys designs ruggedness into the CEQM57XT by utilizing its proprietary implementation of the HALT testing during the design process to identify and correct product weaknesses prior to production. HASS is then used during production to continually monitor supplier quality and component robustness. Through rigorous HALT/HASS testing, Radisys ensures products are designed to satisfy extended temperature range limits required by its customers. This saves customers months of system development time previously dedicated to ensuring that a module can meet their extended temperature or vibration specifications. Radisys' proprietary design and test processes set the standard for COM Express ruggedness compared to simple screening processes employed in the industry.

Partner with HALT/HASS Specialists

"Military programs are very eager to use the HALT/HASS methodologies for both cost and schedule reasons," according to John E. Starr, consultant at CirVibe and Douglas D. Walker, Principle Test Engineer at ATK.[2] However, spending time and resources performing these tests, not to mention investing in the test equipment itself, is often a heavy burden. Alternatively, OEMS can select suppliers, like Radisys, who perform HALT/HASS testing upfront. By partnering with HALT/HASS testing specialists at Radisys, OEMs can reduce development time as well as deploy systems with extreme reliability—quickly and cost-effectively.

References

[1] http://www.haltandhass.com

[2] "A Look Under the Hood of HALT and HASS," COTS Journal, January 2008: http://upload.rtcgroup.com/cotsjournal/digital/pdf/cots0801.pdf, page 16.

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May 2012