HALT AND HASS ON THE VOICEMEMO II^{TM}

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Biography

Michael A. Silverman, C.R.E., earned a BSEE from the University of Colorado in 1986. He has been employed by NBI Corporation in Boulder, Colorado and by GTE Government Systems in Mountain View, California as a Reliability Engineer. Currently, he is the Manager of Reliability Engineering at Centigram Communications Corporation in San Jose, California. He is currently responsible for all HALT (Highly Accelerated Life Testing) and HASS (Highly Accelerated Stress Screening) at Centigram. He is a member of ASQC.

Definitions

<u>HALT</u> <u>Highly Accelerated Life Testing</u>

In HALT, stresses such as OmniAxial (6 degree-of freedom) random vibration, rapid temperature transitions, voltage margining, frequency margining, and any other stresses that are appropriate are used to find the weak links in the design and fabrication processes of a product. HALT is performed during the design phase..

<u>HASS</u> <u>Highly Accelerated Stress Screening</u>

In HASS, the highest possible stresses are used in order to reduce the time of the screen. The screen must be proven using the HASS Development process prior to using it in manufacturing. HASS is performed on 100% of the units being shipped for the product being screened.

<u>Proof-of-Screen</u>

The process of showing that a screen does not damage good hardware and that the screen is effective in finding all of the defects present in a product.

Abstract

Much of the work in reliability at Centigram has been devoted to using analysis techniques such as reliability predictions, modeling, and failure modes and effects analysis. For tests, the only types used have been design maturity tests and on-going reliability tests.

HALT is a new tool that is revolutionizing Centigram's reliability activities. HALT is the process of applying a stimulus to a product until it fails and then redesigning it to be stronger than before. This is much different than the tools of the past. The tools of the past were slow and not very accurate because most of the analysis was theoretical, based on handbooks and standards, and most of the testing was slow and the results not timely. One of the favorite tools was MTBF calculations, but even though we could calculate the MTBF (mean time between

failure) for a product, we could not use the calculation to determine where we should concentrate our activities in order to strengthen the design.

HALT takes a different approach. Rather than try to calculate the reliability of a design, we start by trying to improve the design by stressing it until it breaks, analyzing and redesign the weak points, and then re-stressing until sufficient design margins are achieved.

The key advantages behind the HALT methods are the goals. Typical reliability tests attempt to simulate the operational environment or the written specifications. HALT, on the other hand, stimulates the product to find hidden defects. Because the stimulus is much higher than the normal environment, HALT is able to find defects beyond the infant mortality stage. The high stress levels act as a time compression. To achieve good time compression, the product must usually be taken over its specifications. There is no danger in doing this if the tests are performed properly. Proper proofs-of-screens will determine if latent defects are being introduced.

HALT Equipment

The equipment used to provide the vibration and thermal cycling is a QRS-410 Mobile Tri-axial Random Vibration and Temperature Cycling System. The frequency spectrum is a continuous 0-2000 Hz. The maximum temperature rate of change is 30 Deg C/minute.

Equipment Under Test

The VoiceMemo II^{TM} System is an Audio Information Processing^{SM} (AIP^{SM}) System capable of processing voice messages, FAX messages, and text. The system is comprised of 4 separate modules: A CPU Module, a Storage Module, a Fan Module, and a Power Supply Module. The heart of the system lies in the CPU Module, which has an AT backplane, with 16 slots. The backplane itself is screwed into the sheetmetal in 6 different places. Each slot can house many different board types, but for our testing, 15 of the slots contained 2-port linecards, and the remaining slot contained the 486 CPU board. Each card is held into the chassis by its card edge connector and by one screw from its bracket to the sheetmetal. On the opposite side of the backplane is the Module Control Board (MCB) which performs all of the I/O and modem functions. Like the backplane, it is held into place with 6 screws.

HALT Procedure

The HALT procedure is comprised of the following steps:

> PRODUCT CHARACTERIZATION FOR VIBRATION: A product characterization is performed to evaluate the transmission of vibration energy into the product by analyzing the resulting product responses. The section "Fixturing" contains how we characterized the product.
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> VIBRATION STEP STRESS: The goal of the vibration step stress is to determine the maximum product operating vibration level. This is achieved by increasing the vibration in steps (and running diagnostics at each step) until a failure occurs, then redesigning (ruggedizing) and then increasing the vibration more. This is done until the fundamental limit of the technology is reached.

VIBRATION PROOF-OF-SCREEN: A vibration proof-of-screen is performed to demonstrate that the selected screening level will not damage good hardware. If any failures do occur, the screen level is modified (if necessary), and the vibration proof-of-screen is re-performed. Note that the screen level is typically significantly lower than the maximum level determined in the step stress because during screening we don't want to damage good hardware. However, the level must be high enough in order to catch manufacturing defects. The optimal level is found by using an iterative process of screening and then tweaking the screen level, each step closing in on the ideal screen level for the product. Typically, this level is about 1/2 of the maximum level.

PRODUCT CHARACTERIZATION FOR TEMPERATURE: A product characterization is performed to evaluate the transmission of thermal energy into the product by analyzing the resulting product responses.

TEMPERATURE STEP STRESS: The goal of the temperature step stress is to determine the minimum and maximum product operating temperature limits. This is achieved by decreasing the temperature in steps (and running diagnostics at each step) until a failure occurs, then redesigning (ruggedizing) and then decreasing the temperature more. This is done until the fundamental limit of the technology is reached. Once this is found for the minimum temperature, the process is repeated to find this limit for the maximum temperature.

TEMPERATURE PROOF-OF-SCREEN: A temperature proof-of-screen is performed to demonstrate that the selected screening limits will not damage good hardware. The screen will consist of temperature cycling from the high limit to the low limit as fast as the equipment and product will allow for a set period of time. If any failures do occur, the screen limits are modified (if necessary), and the temperature proof-of-screen is re-performed. Note that the screen limits are typically significantly lower than the maximum limits determined in the step stress because during screening we don't want to damage good hardware. However, the limits must be high enough in order to catch manufacturing defects. The optimal limits are found by using an iterative process of screening and then tweaking the screen limits, each step closing in on the ideal screen limits for the product. Typically, these limits are about 20 Deg C away from the maximum limits.

SCREENING EXPERIMENT: A mini-screening experiment is performed with 20 or more samples of the product to assure that all the design defects have been caught and fixed and to tweak the screening levels to their optimal values.

Fixturing

The module was positioned on its face so that the backplane and MCB were parallel to the table, and the linecards and 486 CPU were perpendicular and at the top of the module. One bar was placed below the linecards perpendicular to each card's edge halfway between the card edge connector and the edge of the board. Two more bars were placed above the linecards perpendicular to each card's edge, one about one-third from each card edge, and the other about two-thirds. A fourth bar crossed the top two in the middle of each bar to strengthen the fixture at the center. Each bar was held into place by two threaded rods screwed into the table. A washer and nut were used to hold the bar to the rod and to hold the rod to the table. Each bar had 1/4 inch of padding on the contact surface to better hold each card in place without filtering any of the vibration.

As part of the Product Characterization for Vibration, we took accelerometer readings at different points on the module, including at least 6 separate points on the MCB, 486 CPU, and linecard, and then one common point on each of the linecards for a card-to-card comparison. What we found was that our ratio between input level and output response was 1:1 up to 5 GRMS and then began to drop off. Between 5 GRMS and 10 GRMS, the ratio was 3:2, and from 10 GRMS to 25 GRMS, the ratio was 3:1. These measurements are all averages calculated from many different readings across the module. The responses were best on the backplane and MCB, which are better secured to the module, and worst on the linecards and 486 CPU which are held in by one connector and one screw. The point-to-point measurements on each card indicated that the responses were best near the edge of each card, and got steadily worse towards the center of each card. Also, the measurements from card-to-card indicated that the responses were best on the outside linecards, closest to the sides of the chassis, and got steadily worse towards the center linecards. The center cards were getting about 40% less energy than the outside cards.

From these tests, we determined that we needed a better fixture. The problem that we were having was that we had significant energy loss in the threaded rods and in the bars. Also, the fixture did not lend itself to a quick setup time, which is something that is needed during production screening.

To increase the amount of energy into the product, we changed the fixture from rods to base plates, a significant increase in surface area. Each base plate was held onto the table with 5 hex nuts. To increase the consistency from point-to-point on each card, we changed to a three crossbar design, each above and perpendicular to the cards, at 1/4, 1/2, and 3/4 across the card. Finally, to increase the consistency from the side cards to the center cards, we increased the size and strength of each crossbar.

Delrin wear strips were added to improve the life of the fixture. Toggle clamps were used rather than washers and nuts to simplify the mounting of the product and to make the screens more consistent.

The energy transmissibility with the new fixture was significantly improved. The ratio between input level and output response was now 1:1 up to 15 GRMS and 3:2 from 15 GRMS to 25 GRMS. The point-to-point measurements were nearly uniform across each card and the card-to-card measurements were more consistent as well. The center cards were now getting only about 10% less energy than the outside cards.

Determining Screening Levels

In performing the vibration step stress, we increased the vibration until the assembly failed. This level was consistently between 25 and 30 GRMS. Typically, the failure was a broken component or a component that came out of its socket. After analyzing each of the components that failed in this way, we determined that redesign was not possible because we were approaching the fundamental limit of the technology.

Next, we backed off of our vibration design limit level by 50% in establishing a starting vibration screen level. Then we ran several proofs-of-screens, each time slightly changing the levels, to optimize the screening level.

Then we performed the same step stress for temperature in order to develop temperature screen limits. After both the vibration and temperature screen levels were established, we ran both together to assure that the increase in stress on the product from both stimuli simultaneously did not change the results. One defect we found as a result of this combination was that the type of glue used to glue the MOV to the transformer loses its adherence properties during the thermal profile, allowing the vibration to break the MOV from the board. We changed to a double-back adhesive.

The screen levels we ended up with were as follows:

Vibration: 15 GRMS
Thermal: -10 Deg C to +80 Deg C at 30 Deg C per minute
# of cycles: 3

Screening Experiment

In running our vibration/temperature cycling screening experiment, we also ran a controlled study between burn-in and vibration/temperature cycling to determine which is more capable of finding problems.

The results were that vibration was by far the most effective screening tool, and both burn-in and temperature cycling both were relatively ineffective for this product.

Burn-In

For the burn-in experiment, each card was in a system while running E-Test, a software program designed to simulate the recording, playback, and deletion of a message. The burn-in profile was 50 Deg C for 48 hours. After each set completed burn-in, E-Test was restarted and the logfile was checked. Any linecards that did not restart or that showed up in the logfile were recorded and sent to rework. The only two assemblies that were changed from one set to the next were the linecards and the MCB's. No design changes were made during the experiment.

Vibration/Temperature Cycling

For the vibration/temperature cycling experiment, each card was in a system with E-Test running. The vibration stimulus was 15 GRMS. The temperature cycle limits were -10 Deg C to +80 Deg C with 30 Deg C/minute temperature change and 3 minute dwells at the top and bottom. Each set was run for 5 cycles, or approximately 1 hour. After each set completed vibration/temperature cycling, E-Test was restarted and the logfile was checked.

Several design changes were made during the screening due to problems that arose. These problems were not previously discovered during the step stresses or proofs-of-screens. Because of these changes, the failure rate decreased during the experiment, causing it to appear lower than it actually would have been if no changes were made.

The design changes were as follows:

1. Beginning with the 8th system, the bus-bar nuts were tightened because the nuts would loosen during vibration, and in two cases, one came off completely, causing the system to shut down. The permanent fix was to change the nut to one containing a nylon insert.

2. Beginning with the 15th system, the MCB bracket was removed because the bracket was coming in contact with the LED's and causing the LED's to break off during vibration. The permanent fix was to enlarge the holes on the bracket, so that the bracket no longer touches the LED's.

3. Beginning with the 16th system, Crystal Y1 on the linecard was glued to the board with 5-minute epoxy, because the previous two systems had components break off. The permanent fix was to have epoxy applied between each side of Y1 and the board.

Conclusion

Vibration at 15 GRMS for 1 hour was a very effective screen on this module. Fourteen of the 21 failures that occurred during the experiment were due to vibration, and 3 others were due to a combination of vibration and temperature.

Temperature cycling from -10 Deg C to +80 Deg C for 1 hour was less effective of a screen than vibration on this module. Temperature cycling accounted for two defects, and partially contributed to three others.

Burn-In at 50 Deg C for 48 hours was not an effective screen on this module. Burn-in only accounted for one defect. The remaining seven defects were such that they would have failed within the first few hours of operation with or without the temperature stimulus. In fact, the six failures due to Capacitor C128 designed with the wrong value part are actually more due to the individual power supply being used rather than the length of time being tested. The part used is too low in value, but depending on the actual power supply being used, the part will be more or less likely to fail. Historically at Centigram, this method of burn-in has only been good at catching the types of defects due to incorrect or backwards parts that will fail in the first few hours of operation with or without burn-in. For the types of defects that take longer to fail, this stimulus catches many of the defects, but also let many through. The boards that get through then either fail in system test or in the field.

Burn-in Results

	Tested	Failed	Bench Failures	Failure Type	Failure Description	Qty	Responsible Stimulus
ECMOS Cards	1221	17	8	Design	C128 wrong value	6	None*
				Mfg	F6 wrong value-S/B 3A, is 1/4A	1	None*
				Comp	U18 failed	1	Burn-In
MCB	71	0	0				
Total	1292	17	8				

Failure Percent **0.6%**

Vibration/Temperature Cycling Results

	Tested	Failed	Bench Failures	Failure Type	Failure Description	Qty	Responsible Stimulus
ECMOS Cards	390	12	10	Design	Broken Y1	3	Vibration
				Component	Y1 failed	2	Vibration/Temp**
				Component	U61 failed	2	Temp Cycling
				Component	C87 burned up	1	None*
				Mfg	F6 wrong-s/b 3A, is 1/4A	1	None*
				Mfg	Dies due to bent pin @U64	1	Vibration
MCB	26	5	5	Mfg	Connector ear broke	2	Vibration
				Design	Critical alarm LED broke off	2	Vibration
				Unknown	Fails during vibration only	1	Vibration
486 CPU	26	1	1	Design	Time and date errors/Resets	1	Vibration/Temp**
Motherboard	26	2	2	Mfg	Pin on main connector broke	1	Vibration
				Mfg	Pushed pin on cable assy	1	Vibration
Chassis	26	3	3	Design	Bus bar washer fell off-lost gnd	2	Vibration
				Unknown	SCSI Terminator fell off	1	Vibration
Total	494	23	21				

Failure Percent **4.3%**

* None indicates that the failure would have occurred within the first few hours of operation, with or without a stimulus applied.

** Vibration/Temp indicates that we cannot determine which caused the problem, but we suspect that both contributed. We also cannot determine how much temperature cycling contributed versus burn-in.