ACCELERATED RELIABILITY TEST TECHNIQUES USED TO FIND DEFECTS WITHIN PRINTED CIRCUIT BOARDS

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BIOGRAPHY

Mike is an experienced leader in reliability improvement through analysis and testing. He has also led numerous quality system development programs and compliance programs, including Safety and EMC. He has 18 years of reliability, quality, and compliance experience, the majority in start-up companies. Mike is also an expert in accelerated reliability techniques, including HALT and HASS. He set up and ran an accelerated reliability test lab for 5 years, testing over 300 products for 100 companies in 40 different industries. Mike is co-founder and managing partner at Ops A La Carte, a Professional Business Operations Company that offers a broad array of expert services in support of new product development and production initiatives. Through Ops A La Carte, Mike has had extensive experience as a consultant to high-tech companies, and has consulted for over 50 companies including 3COM, Ciena, Intuitive Surgical, AeroGen, and Brooks-PRI Automation. He has consulted in a variety of different industries including telecommunications, networking, medical, semiconductor, semiconductor equipment, consumer electronics, and defense electronics. Mike has authored and published 7 papers on reliability techniques and has presented these around the world including China, Germany, and Canada. He has also developed and currently teaches 5 courses on reliability techniques. Mike has a BS degree from the University of Colorado at Boulder, and is both a Certified Reliability Engineer and a course instructor through the American Society for Quality (ASQ), IEEE, Effective Training Associates, and Hobbs Engineering.

ABSTRACT

Accelerated reliability testing is one of the fastest growing segments of the testing industry because it enables the user to ruggedize products, to accelerate product introduction, and to introduce mature products into the market. The two principle stresses used during accelerated reliability testing are rapid temperature transitions and OmniAxial (6 degree-of-freedom) random vibration. In addition to these, other stresses that are often used are power cycling and voltage and frequency margining.

This paper illustrates how accelerated reliability testing was able to successfully find one of the most difficult failure modes to uncover, defects within printed circuit boards (PCB's).

INTRODUCTION

The customer was experiencing a high fallout rate in manufacturing test and in the field due to PCB related problems. The testing was performed at the completed assembly level using production samples.

All products were tested on a QualMark OVS-2.5HP combined OmniAxial^{TM} Vibration and UltraRate^{TM} Thermal System. The input vibration consisted of broadband energy from 2 to 10 kHz measured in Grms on the product.

KEY WORDS/DEFINITIONS

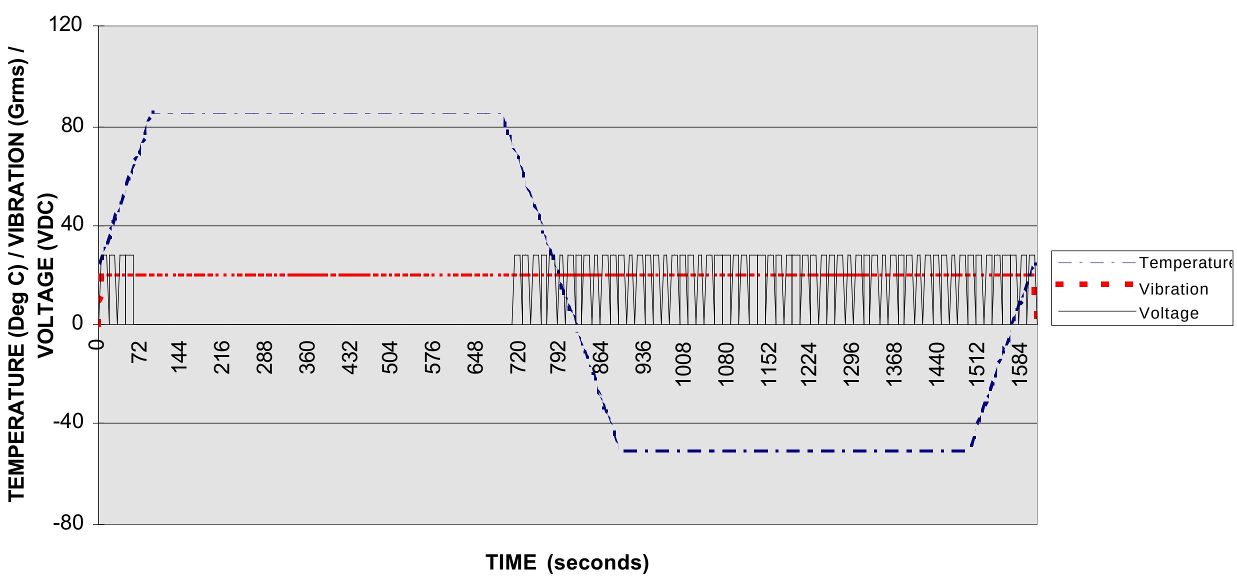
PCB	Abbreviation for Printed Circuit Board. Also known as Printed Wiring Board or Fabrication. This is the bare board before it is stuffed with components.
Hot Air Leveling	The process of completely immersing a PCB into solder followed by an air knife removing the solder so a level surface remains on the PCB.

PROFILE

The stresses used for the accelerated reliability test were a combination of rapid temperature transitions, OmniAxial (6 degree-of-freedom) random vibration, and power cycling. The functional test consisted of running the boot-up on-board diagnostics.

The process for determining the optimal profile for any product is to take the product through a characterization process to determine upper and lower limits, as well as to expand margins as much as possible. The characterization process was bypassed per the customer's request. Two contributing reasons for this was 1) because the product was quite mature and the customer had a large amount of field data in the product, and 2) the customer was only looking for one particular process-related failure mode. Instead, the profile chosen was based on the author's past experience with similar products as well as the customer's knowledge of this product (field conditions as well as current production screening levels. The profile consisted of cycling the temperature from -50°C to +85°C at 40°C per minute as measured on the product, dwelling at each extreme for 10 minutes, combined with 20 Grms of random vibration run continuously throughout the profile. The power cycling profile was 12 seconds on, 3 seconds off for the entire profile except for temperatures above +70°C in which the power was left off. Each board was subjected to 8 full cycles. The following figure, "Figure 1 - Accelerated Reliability Test Profile," shows the cycling that was performed. Only one of the eight cycles is shown.

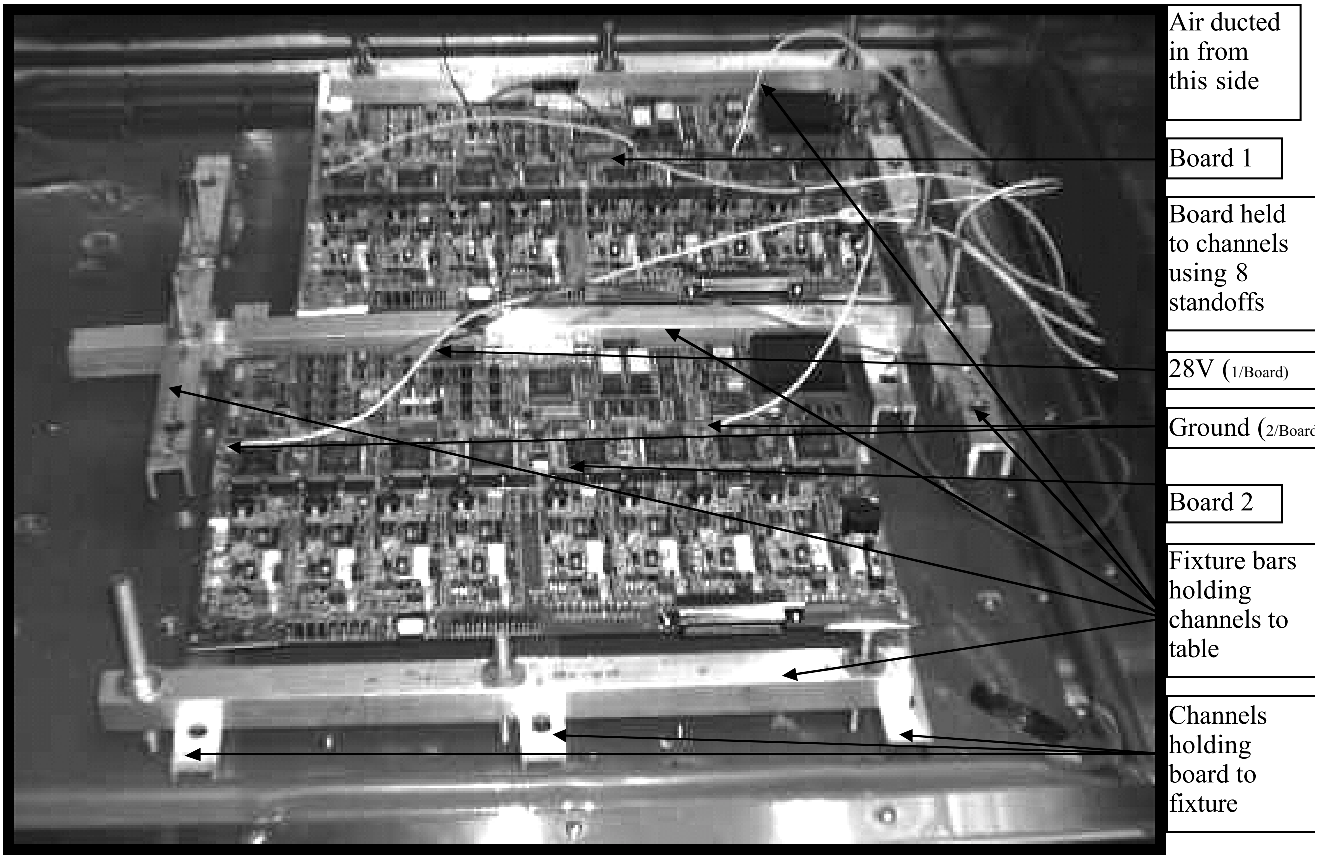
Figure 1 - Accelerated Reliability Test Profile



For test samples, twenty boards from Vendor B, the vendor that manufactured the boards experiencing high production fallout, and five boards from Vendor A, a vendor that manufactured the same boards, but experiencing very low production fallout, were used. For the twenty board sample, each board chosen had various numbers of opens (between 0 and 9), found at a few different steps in the manufacturing process. All opens were repaired with jumpers prior to the start of the test. The reason for choosing boards with opens was because if opens were already found, then more may still exist. For the five board sample, none of the boards had opens. Several different versions of one particular board design were tested, but the size and number of layers remained consistent - 20 inches by 14 inches, 8 layers.

The boards underwent a more thorough functional test at the customer's board stuffing house prior to the accelerated reliability test, after 4 complete cycles of the test, and then again after 8 complete cycles. Two boards were screened at a time and each board was on a separate fixture. Each fixture consisted of mounting the board to three separate one inch aluminum channels using _" standoffs through the existing eight mounting holes in the board. To hold the fixture to the table, two 1 inch aluminum channels crossed over the top of each end of the three channels and each were bolted to the table in three places. The following figure, “Figure 2 - Thermal/Vibration Fixture for the Accelerated Reliability Test,” shows how the boards were fixtured within the test chamber.

Figure 2 - Thermal/Vibration Fixture for the Accelerated Reliability Test



The purpose of the test was to assess the probability of assemblies built with Vendor B’s PCB’s failing in the field due to PCB related causes. The major problems seen during manufacturing were open traces due to interplane post separation, plating pulling away from holes, and hole wall failures. The majority of these defects had been observed in production by the customer’s board stuffing house. Out of a population of over 8000 boards, the fallout rate was 1.6% through the production process. The customer determined that the area in the production process that caught the most failures was the test step after re-hot air leveling, possibly because of the intense heat associated with this process.

The customer searched the field database prior to the start of the accelerated reliability test, and it showed no increase in the previous 8 months due to PCB related failures. However, the customer’s field database does not capture the failure cause for returned assemblies until after troubleshooting and repair, and there were a significant number of returned boards that had not yet been analyzed. Therefore, the customer did not have conclusive data if Vendor B’s PCB’s were failing or would be failing at a higher rate than Vendor A’s PCB’s in the field.

The customer also searched the production Environmental Stress Screening database prior to the start of the accelerated reliability test, and it showed no increase in the previous 8 months due to PCB related failures. However, the customer’s production Environmental Stress Screen is fairly benign, consisting of maintaining the boards at 70°C for 12 $\pm$ 2 hours, and power cycling - on for 13 minutes, off for 2 minutes (power is applied to the boards during the test and the output voltages are monitored, but no functional test is run). Therefore, the customer’s Environmental Stress Screen database also did not give conclusive data if Vendor B’s PCB’s would fail at a higher rate than Vendor A’s PCB’s in the field.

TEST RESULTS

The results for the accelerated reliability test are shown in the following figure, "Figure 3 - Number of Opens Before and After the Accelerated Reliability Test."

Figure 3 - Number of Opens Before and After the Accelerated Reliability Test

Board Number	*Vendor*	*Before Test*	*After 4 cycles*	*After 8 cycles*
1	A	0	0	0
2	A	0	0	0
3	A	0	0	0
4	A	0	0	0
5	A	0	0	0
1	B	0	0	0
2	B	0	0	0
3	B	0	1	N/A (Note 1)
4	B	1	0	0
5	B	1	0	1
6	B	1	0	0
7	B	1	0	0
8	B	1	0	2
9	B	1	0	2
10	B	1	0	1
11	B	1	7	N/A (Note 1)
12	B	2	0	0
13	B	2	0	0
14	B	2	0	0
15	B	2	0	0
16	B	2	0	1
17	B	5	1	N/A (Note 1)
18	B	8	6	N/A (Note 1)
19	B	9	4	N/A (Note 1)
20	B	9	7	N/A (Note 1)

Note 1 The board could not be repaired and was not returned for the second four cycles of accelerated reliability testing.

CONCLUSIONS

Several conclusions can be drawn from the data:

1. Since 11 of 20 (or 55%) boards from Vendor B (suspect PCB's) developed opens or had more opens after the test than before, the accelerated reliability test was definitely able to precipitate latent defects. And since none of the five boards from Vendor A (known good PCB's) developed opens, this proves that the accelerated reliability test did not overstress any of the boards.
2. The accelerated reliability test found failures that the customer's production ESS could not find.
3. Several of the boards did not develop opens until after the second four cycles of accelerated reliability testing. This is a good indication that the profile levels were not high enough. It is possible that the temperature limits could have been expanded, but without running a characterization process prior to the accelerated reliability test, it would not have been wise to do this. For future stress testing on PCB's, the two options then are to 1) run a characterization process prior to running the accelerated reliability test in order to maximize the limits, or 2) to run the accelerated reliability test with expanded temperature limits at the PCB level to eliminate the possibility of component damage.

SUMMARY

No problem plagues a manufacturing organization more than intermittent failures, and few types of intermittent failures are more difficult to find than PCB failures. This study has proved that accelerated reliability testing used in production can find PCB failures before they get into the field without having to overstress hardware to find the failures.

This study also shows that developing an optimal screen for production hardware requires that the product go through a characterization process as well as a screen development process.

REFERENCES

1. Silverman, Mike, "Summary of HALT and HASS Results at an Accelerated Reliability Test Center," 1996.