Developing MESA: An Accelerated Reliability Test

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SUMMARY & CONCLUSIONS

This paper describes the on-going research on an accelerated reliability test strategy called MESA (Multiple Environment Stress Analysis) intended to find in a fast and efficient manner (potential) reliability problems during the design phase of high volume consumer products. This test has shown promising results on its capability to provoke failures, especially on failures formerly registered as NFF (no-fault-found). The strategy applies combinations of stressors in a statistically efficient test scheme. To validate results, MESA must be able to reproduce failures with similar stressor configurations and test scheme. First pilot tests have been completed. The results show that it is possible to induce realistic, previously unknown, field failures in an efficient manner during the design stage. Considering that this test was the first pilot on the development of MESA, many opportunities are still left to be further explored

1. INTRODUCTION

In new product development the requirement of fast delivery of reliable products into the market must be met. Therefore, it is necessary for the designer to know the product weaknesses earlier in the design process. In the field of high-volume consumer electronics, where many consumer products are used in the field under a wide range of, often quite unpredictable conditions, it is not uncommon that products returned without a clear failure description (Ref. 1). Testing of the product in that case often leads to the conclusion that the product meets the specifications. This type of returns is called NFF (No-Fault-Found), NTF (No Trouble Found), NAD (No Apparent Defect), RTOK (re-test OK), or etc. It has been shown that the fraction of NFF is usually between 25% and 50 % (Ref. 4) and sometimes even up to 80 % (Ref. 5). Replacing defective components may be a short-term solution but when failures happen too frequently and no clear design or manufacturing flaw can be found, it is very difficult to determine the exact failure causes (root cause). For high-volume consumer products these failures are especially relevant in the early phases of product life (generally within the warrantee period). Using the stressor-susceptibility model it is possible to explain especially these early failures in terms of (combinations of-) extreme products and/or extreme users (Ref. 2). In order to prevent these failures from occurring, it is necessary to develop a test method, which can not only accelerate the test but can identify the product weaknesses as well, especially those related to NFF returns. Then the question arises as to what kind of test is suitable to meet these requirements, and how to develop this test method. These questions lead to the use of the MESA (Multiple Environment Stress Analysis) in the test strategy.

MESA is an analysis test designed to provoke failures by applying multiple stressors on the product. This test differs from the existing tests in the PDP (Product Development Process), which are designed for verification and or validation, using one stressor and applied based on the product specifications. In practice, there are many identified stressors that may influence the occurrence of failures. These stressors may or may not have a contribution, independently or in interaction, to the occurrence of failures. During a MESA test the number of stressors can be quite large especially when dynamic stressors are involved. With the help of Design of Experiment (DOE) techniques it is, however, possible to explore the resulting large state spaces quite efficiently.

2. MESA IN THE PDP (PRODUCT DEVELOPMENT PROCESS)

Most tests that are carried out in the PDP are designed for verification and or validation purposes. The verification is to assure “the product has been built right” from one development phase to the next. On the contrary, validation is to assure “the right product has been built”, Ref. 9 defines more detailed explanations on these terms. These tests take place almost in the entire PDP phase as shown in figure-1. Unlike verification and or validation

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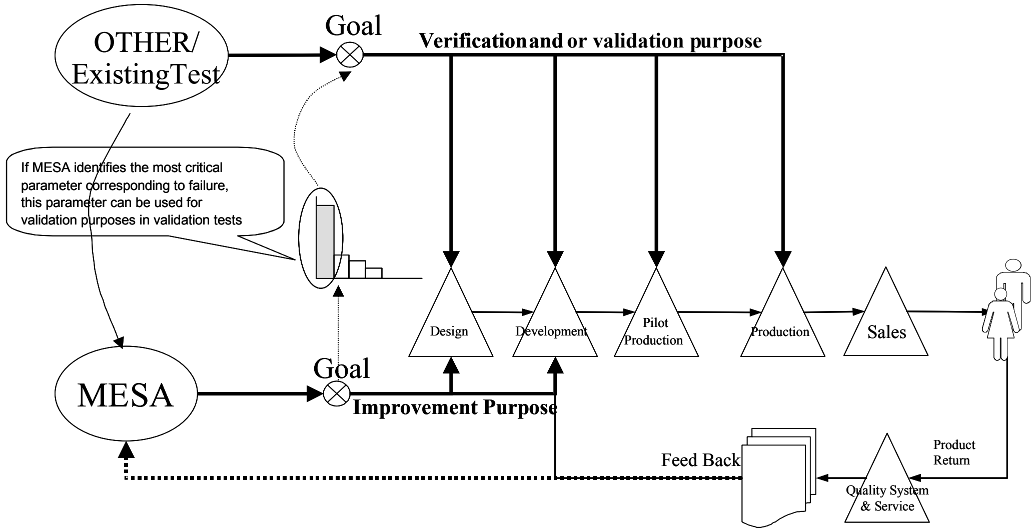

Figure-1: MESA in PDP

tests, MESA is intended to be used early in the development process i.e. either in design or development phase. The goal is to improve the product by identifying the weaknesses or flaws as early as possible in the design process as well as to determine the critical stressors that contribute to the product failure. These identified stressors can also be used to update or improve the existing verification and or validation tests. In the future when MESA has been successfully applied and has proven to be able to significantly improve the products by eliminating their weaknesses, it is possible that MESA can even replace part of these tests.

3. CONCEPT OF MESA

The basic concept of MESA is to stress the object, under multiple worst-case environment and usage conditions to bring to the surface the weaknesses or flaws of the design. The level of stress applied on the product makes this test different from other available tests e.g. HALT (Highly Accelerated Life Test) or HASS (Highly Accelerated Stress Screen)(Ref. 4). These tests are intended to prove that the product life is up to specifications using acceleration principles (for example by raising the temperature). Of course there are strong points and weaknesses for every test but our goal is to do research on the applicability of the MESA-test on high volume consumer products. However, best practices of HALT and HASS and other similar methods may also be used.

4. CASE STUDY

The case study was conducted jointly with a large multinational corporation that produces high volume consumer products. Recently the company has invested in a test chamber, which can generate and simulate vibration and temperature. In the past the company had not yet developed any other method of (accelerated) testing in addition to their existing tests. As a consequence, there is still no standard test procedure or guideline available for this test. Therefore, the results of this case study, on one of the assemblies or modules, can also be used to develop a standard test method and procedure for MESA.

4.1 Product Identification

It is quite difficult to determine what kind of product or assembly is to be used in the experiment. Usually on the first test there is no similar past experience that can guide the test. Therefore we choose the assembly/module where not only we can measure the response easily but also some other requirements could be met. To guide the selection of product to be tested, we considered whether the module could suffer an unsuccessful result, usually to be called NFF (no-fault-found), when testing with existing tests. The field call rate should also be high enough in order to make a comparison with the actual field failures. Finally, the product where this module fits should be one that needed improvement. Based on these requirements an (audio) power 4-amplifier module was chosen for the pilot experiment.

4.2 Stressor Determination

After having determined the product to be tested, a power 4-amplifier module, it was important to brainstorm the possible failure causes using a Ishikawa diagram. This exercise resulted in the identification of possible stressors to be applied on the module during the test.

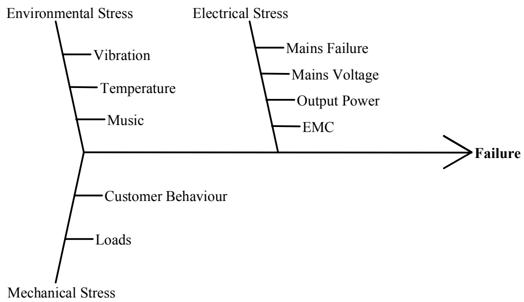

Figure-2: Ishikawa diagram of stressor determination

Following this identification of stressors, a test plan was developed for the experiment. For this plan also the requirement for automating of the test was taken into account.

4.3 Test plan

The necessity to develop the test plan is to ensure that the test will be smoothly performed and capture as much information as possible during the test. It should be considered that the test is not only time consuming but should result in a reasonable cost as well. We were not able to breakdown the cost required to perform the test in more detail. However, one should understand that the operational cost of the chamber as well as other involved costs should be taken into consideration when including this test on the routine test scheme.

Some other considerations such as what stressor cycle and settings should be used, how the response will be measured, how to identify failure, how to steer/control the test automatically, how to capture data, and when the test must stop should be considered during the test plan development.

The team then developed a test plan based on the above considerations and decided to have a trial run on the chamber. At last the team decided to run a 40 test (sample) of the power 4-amplifier modules. Having this number one may question whether this number is sufficient to capture the failures or flaws on the product. It is quite difficult to define the exact appropriate number of samples, especially on a first trial, but it is reasonable to consider to prepare as many samples as possible in order to be sure that the test will, at least, be able to generate failures. Still, at this stage we don't know yet when or after how many cycles the failure will occur.

Parameter	Name of Parameter	Number of settings	Duration one variable (sec)	Total duration for one loop (sec)
A	Temperature	3	200	600
B	Mains failure	4	2	8
C	Vibration	2	200	400
D	Load	8	10	80
E	Mains voltage	3	30	90
F	Output power	3	10	30
G	Music	4	60	240
H	EMC	2	5	10

Table-1: Stressors setup

Table-1 describes the stressor list and the number of settings per parameter (for example for music heavy metal, classic, rave, noise). The cycle times on every parameter are different. Although we don't know yet how many cycles are required until the product fails, we expect that the failure will appear as soon as possible. Other consideration was on the number of stressors that should be applied during the test. Looking at these stressors and their settings, we can easily estimate that the test will take a long time in order to complete all the possible combinations. This implies that another method, design of experiments, is required to speed up the process. This is a topic requiring further research. For the first pilot project, on the power 4-amplifier module, the focus was not on the screening of the stressors yet but only on provoking and then replicating the failure.

4.4 Development of test bench

In order to be able to perform the test automatically, the chamber had to be modified by adding data logging facilities and external control of the stressors. Because the chamber was only suited for using temperature and vibration as stressors, provisions had to be made for the other stressors. The preparation of this modification took quite a long time especially on combining the existing controls and additional controls into one control system. Since relevant timescales can vary between milliseconds (electrical events) and minutes (thermal events) then the problems turned out to define an efficient setup scheme especially for handling a huge database of measurement results.

5. RESULTS AND ANALYSIS

After finishing all preparation the test then started with the stressor scheme as on table-1. The power 4-amplifier module break down at a certain time as indicated by the output voltage of the left amplifier channel, denote as VCC_left on figure-3 (Test 29), goes to zero and remains there. This finding lead to the first result of the test a failure can be generated by applying those stressors. This finding also lead to the question whether this failure can be eliminated or not. This question represents the validation strategy i.e. the ability to replicate the failure by repeating the same stressors. When the failure is reproducible, we can argue that those stressors contribute to the failure and therefore further analysis, for example root cause analysis, should be done.

Further tests on other power 4-modules using the same test setup resulted in a similar failure. Figure-4 (Test 40) shows that this failure repeated again almost at the same time, providing validation.

The next question to be answered was what stressors at what settings provoke the failure? To answer this question a method to screen these stressors is required in order to be able to indicate which is the significant one. For the described case however, this first pilot test did not go that far as our intention was only to replicate the failure. Meanwhile, the root cause analysis of the failures on the power 4-amplifier gave an indication of the most possible stressors that influenced the failure (Figure-5). The failures take place mostly on the amplifier.

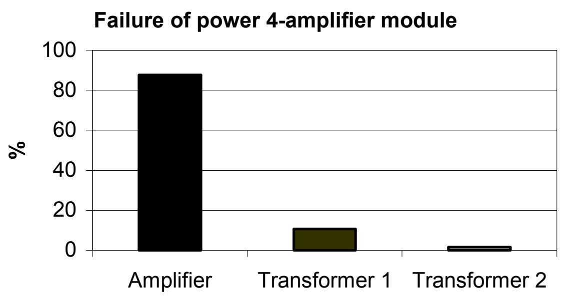

Figure-5: Pareto of failure power 4-amplifier module

Having this Pareto chart of failures will make the development easier to further analyze the root cause of the power 4-amplifier module. Therefore fast identifying failure on power 4-module early in the development process, will reduce the risk of delivering unreliable products to the market.

6. DISCUSSION

The on-going research has shown that MESA is capable of provoking failures by applying as many identified stressors as possible. Disregarding how much time and what cost is required to do the test, MESA is also capable of replicating this type of failure when the same stressors setting are repeated again at the same scheme. It means that the first milestone on the MESA development has been passed. Further steps such as defining the efficient design of experiment and expanding the test to products where the failure cannot be provoked easily need to be further developed.

It is also important to consider the situation when the identified stressor produces no failure on the product although from the field failures are known. On a situation like this one should consider that the used stressors can be considered as traditional stressors. Therefore a non-traditional stressor, like an extreme user, should be taken into account.

There is also a situation when the failure occurs but the response cannot be measured automatically. This is mostly when the failure can only be observed visually. In a situation like this there are two possible alternatives: rely on visual inspection or define some measurable indication to detect the response. Whatever the choice is, it should be noted that the failure must be replicable otherwise the test is invalid.

Expanding the MESA testing and integrate it with the existing available tests in the PDP is also one of the issues which should be considered next. Especially when we expect to bring this test as early as possible. The issue such as cost of test, and test effectiveness should be considered because on some products we may easily replicate the failure. The issue of effectiveness like how long the response should be measured, how intense we apply the stressor, and how to determine the testing level itself require also further research. These identified issues will be used to guide the development of the test strategy in continuing research.

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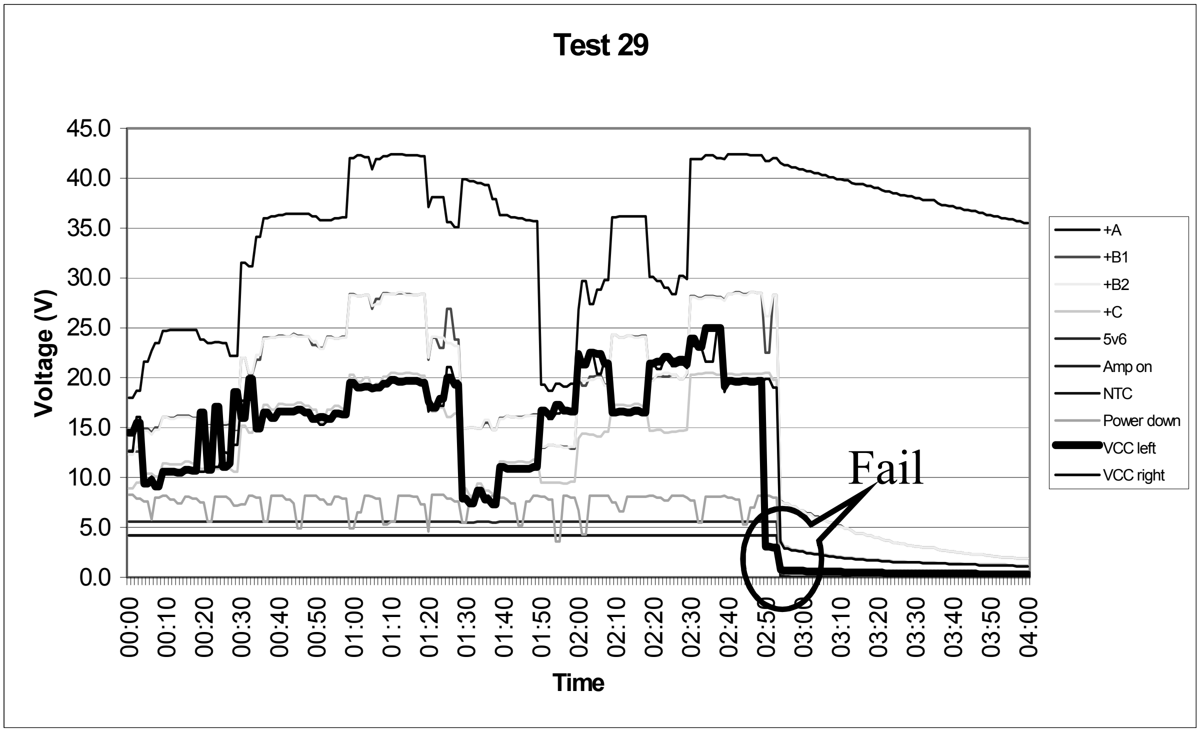

Figure-3: First Failure Indication

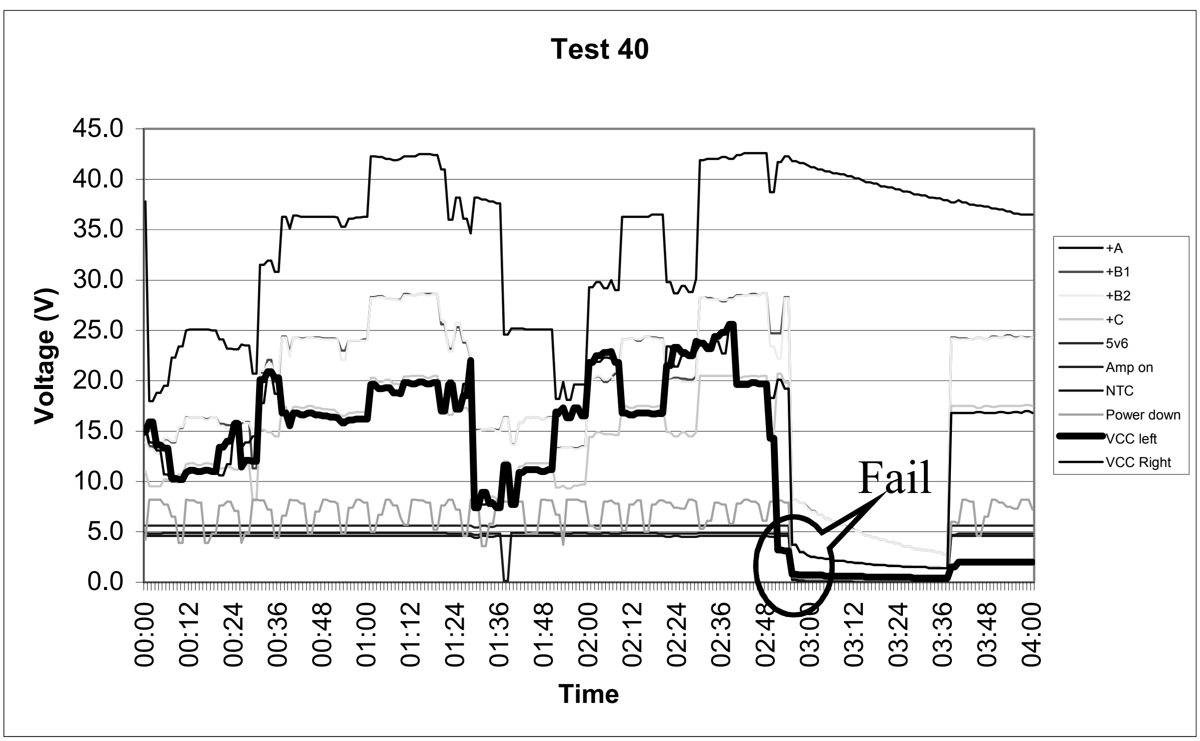

Figure-4: The same failure after repeating the test on another module