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Robustness and performance of electronics during immunity testing

Investigation of failure mechanisms and high-amplitude testing

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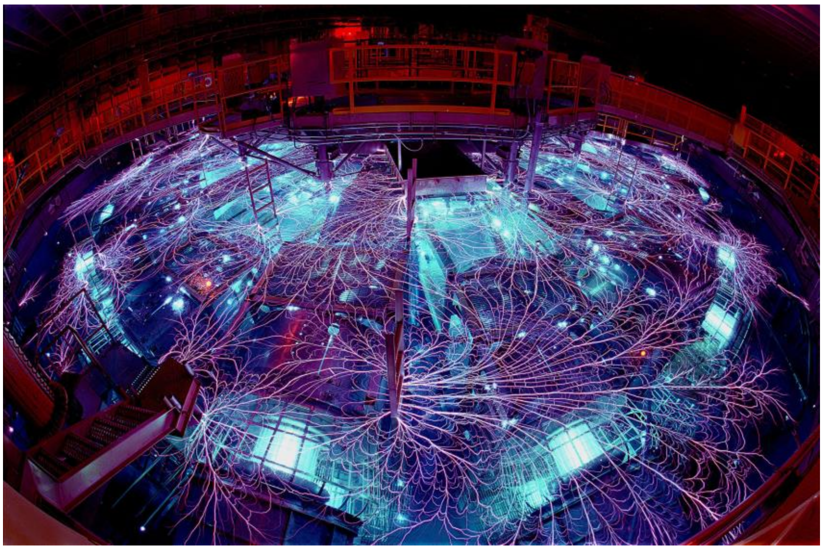

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SPM

Society for Reliability and Environmental Testing

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SPM initiates and finances unprejudiced investigations of common interest for its members – mainly in the field of reliability and testing of electronic components and materials.

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1. Abstract

The purpose of this project is to identify the more important parameters defining the immunity level and the robustness of electronic equipment.

This information is important, when an EMC test at increased stress level is planned, because the high-amplitude testing must be concentrated on parameters, which will uncover weaknesses of the construction.

HALT (in this case interpreted as High Amplitude Limit Testing) methodology is a highly suitable method for gaining information about the immunity level, and is utilised as part of this project.

2. Summary

The present project focuses on a key issue within the scope of SPM: the reliable operation of products and apparatus containing electronic circuits. The project has searched for EMC relevant failure mechanisms, which were not detected during standard EMC testing, not even using an increased test level. The project is based on the experience that from time to time the manufacturers experience equipment failures on the market, which are not known from the EMC qualification tests of the products.

The thesis of the present project is that it is possible to reveal more or other failure mechanisms than those identified during a standard EMC test, and thus provide an opportunity to eliminate these.

The overall conclusion of the project is that it is possible to stress potentially vulnerable part of the circuits by using the test signals and methods, which are described in more detail in this report. This is concluded from a series of experimental tests, where test signals and injection methods have been adapted and improved for practical testing.

An important issue is that the project has applied injection methods using more and other coupling paths into the circuits than usual for equipment testing. The applied test signals are characterised by very large amplitude and very short rise and fall times. At the same time, the injection method enables injection into potentially sensitive PCB tracks and circuits, and thus has the ability to trigger failure mechanisms that would not have been triggered through injection via cables.

Testing with radiated electromagnetic RF fields will also couple strongly too many PCB tracks at the same time. But even pulse modulated signals do not possess the large signal character, that is present using the pulse signals, and can thus not be expected to activate the same kind of failure mechanisms.

The project describes the failure mechanisms that apply at component level, and are typically the reason for malfunction. The report demonstrates the background of how the disturbance signals generate disturbances in the final construction. Disturbance signals, which are injected into the electronics, are demodulated by the non-linear behaviour of the semiconductors, and generate offset errors, unintended changes of state or ripple voltages. At high disturbance levels, saturation of semiconductors may occur, and the large-signal component models must be used for the analysis of the circuit behaviour.

The present project does not take into account, if the test signals and disturbances are comparable to signals found in a specific electrical environment, where the test object may be used. The aim is to provide a test method to reveal any potential failure mechanisms of the test object.

A goal of the project has been to use test methods that are quite simple to apply, but still have a strong impact on the test object. Focus is placed on using electromagnetic or capacitive coupling between the test jig and the test object, without the need for connecting numerous capacitors or injection networks. In order to use capacitive coupling, the risetime of the test pulses must be low, so the induced current at the rising edge is maximised. If the induced current or charge shall reach certain high amplitude, the step rising edge must have large amplitude. A generator has been constructed in the lack of suitable commercially available ones. The generator can provide 20 kV pulses at a risetime of less than 1 ns. The peak power during the short pulse is approx. 8 MW.

The test generator has been applied on a number of different test objects. In most cases the testing and signal injection has been done using the EMC workbench which has previously been described in the report SPM-174, "Advanced HALT". The EMC workbench can generate impulsive field strengths of up to 140 kV/m which represents a very large impact on the test object.

Testing has for instance been performed on a low-energy light bulb, which contains a discharge tube and a quite simple power converter, which provides the drive current for the tube. It was possible to disturb the electronics controlling the power converter, so that the current in the system became very high, and the electronics were burned. In practice a bang was heard during the testing, and a burned smell was observed. Visual inspection afterwards showed that a piece of the transistor encapsulation was blown off due to the local heating.

A number of electrical energy meters and district heat energy meters were tested. It was concluded that the test method was able to cause disturbances to the displays and to the measurement circuits. A failure observed by the manufacturer was reproduced using the test method, and was subsequently identified and handled by the manufacturer himself.

Testing was also performed on a couple of low-price energy monitors for hobby application by public energy-conserving users. The monitors consist of a measuring circuit, a power supply, operator panel and a display. At several occasions, the displays of the monitors were affected and were completely blanked. In some cases the fault did not disappear after disconnection from the mains. One monitor was disturbed, so there was a fixed offset on the readings for some time, even after power OFF/ON. The error disappeared after the test object was left without any power for a week. It was concluded that an input port related to range setting, gain setting or scaling had been disturbed, and affected the readings. The setting was permanent until a “cold start” with complete initialisation was completed, after some time without power. It was concluded that this also explained the displays recovering from being blank after some time.

Finally, the test method was also used for testing a PCB controlling the IGBTs of a large power converter. The purpose of the test was to initiate firing of a full IGBT bridge, and thus shorting the positive and the negative rail voltages together, if possible. This failure usually results in permanent damage of the IGBT components, and the converter ceases to operate. The testing succeeded in reproducing this response, which had not been observed during classical transient testing, and not even at increased testing levels.

As a supplement to the testing with fast pulse signals, an immunity test method utilising wideband white-noise like signals was investigated. The test signal was a digitally modulated RF signal having a bandwidth of approx. 85 MHz. The modulation can be explained as the generation of a large number of parallel signal channels spaced equally across the frequency range, and each randomly modulated. The opportunity to use such a signal, and thus saving a considerable amount of time on stepping/scanning, was compared with the amount of technical challenges and costs comprising the wideband testing method. It was concluded that the method is unpractical compared to classical testing, and that considerably higher amplifier power is required for generating a comparable test level. Using the method for radiated testing is considered irrelevant, as the varying power requirements vs. frequency will lead to unacceptably large test level differences, and also requires higher amplifier power levels.

Finally a brief test was performed, where the electrical immunity was tested at different test object temperatures. It was concluded that the test object was slightly more susceptible at low frequencies. This was concluded to be due to slightly faster semiconductor responses at minus 40ºC, and a correspondingly lower immunity.

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