CAPTURING A FAILURE OF AN ASIC IN-SITU, USING INFRARED RADIOMETRY AND IMAGE PROCESSING SOFTWARE

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ABSTRACT

Failures in electronic devices can sometimes be tricky to locate—especially if they are buried inside radiation-shielded containers designed to work in outer space. Such was the case with a malfunctioning ASIC (Application Specific Integrated Circuit) that was drawing excessive power at a specific temperature during temperature cycle testing. To analyze the failure, infrared radiometry (thermography) was used in combination with image processing software to locate precisely where the power was being dissipated at the moment the failure took place. The IR imaging software was used to make the image of the target and background, appear as unity. As testing proceeded and the failure mode was reached, temperature changes revealed the precise location of the fault. The results gave the design engineers the information they needed to fix the problem. This paper describes the techniques and equipment used to accomplish this failure analysis.

Keywords: Radiometry, In-situ, Image Subtraction Software, ASIC Application Specific Integrated Circuit

INTRODUCTION

Spacecraft, or autonomous robots, are designed to operate in harsh environments where high-energy ionizing radiation, vibration and extreme temperature fluctuations can compromise the operations of scientific instrumentation and computer electronics. As a result, these sub-assemblies are pre-tested in laboratories with equipment designed to simulate space environments. The premise of this failure investigation began with an anomaly discovered during a temperature cycle test. The problem was narrowed to a computer that receives and transmits telemetry data, an application critical to the success of the mission. The peculiarity of this anomaly is that it only occurred when the oven cycled downward in temperature to 16 degrees Celsius. An intense study of this anomaly, by the design engineers of this circuit led to two recommended fixes, 1) write a software patch to try and remedy the anomaly or 2) locate the physical device responsible for the malfunction. With the launch date quickly approaching, there was just enough time to search, find and replace the bad device. By using infrared thermography coupled to real-time image subtraction software, the task was completed in two days, as opposed to the two weeks estimated by personnel familiar with rework procedures of this type.

THE INFRARED RADIOMETER SOFTWARE AND FIRMWARE

The camera used in this failure investigation was a PM390, short wavelength IR radiometer. IR Radiometers detect thermal radiation as well as provide calibrated temperature data useful for diagnostic applications and materials research.

Thermography/radiometry by itself is a powerful, Non Destructive Evaluation (NDE) tool used to recognize hot spots and obtain surface temperatures with accuracy better than 1/10th of a degree Celsius. The principle behind the image subtraction software is that it allows the observer to see small temperature changes as they occur in real time (in-situ). This is achieved by using a special data card in the computer, which takes the data output from the infrared camera and overlays a second data page on top of the live page. The result reveals continuous changes in temperature relative to the background.

SUMMARY OF THE INVESTIGATION

As shown in Figure 1, the IR camera was first used to establish a thermal radiation baseline from viewing the spacecraft hardware at a distance of approximately 6 feet. Measuring the background temperature, relative humidity, and noting reflective and absorptive targets in the field of view established calibrated temperature measurements.

The seven modules were of equal emissivity values ε=0.95. With the IR camera, video recorder and software ready to document operating conditions, power to the hardware was applied. As expected, increased temperature changes were observed with the IR camera coming mainly from the power supply module #7. This was at ambient temperature, 22 Degrees Celsius, not cold enough to produce the anticipated failure.

Next, we placed the IR camera inside the temperature chamber oven facing the hardware. Power to the hardware electronics was in normal operating mode. With the IR camera and computer software ready, the oven test cycle began. The module with the failed component was located, See Figure 4.

The next day the flight hardware was removed and the engineering model hardware was placed inside the chamber to verify if a similar failure mode would occur. The failure on the engineering model was verified.

The final test was to open the module with the failure and to point the IR camera at the PCB with the suspected failed device. We powered up the unit, with the IR camera and computer software ready, and the thermal radiation of the failed device was precisely located, See Figures 5-8.

CONCLUSION

Infrared thermography coupled with real-time imaging software is a very effective way to observe electronic devices with progressive temperature changes. The location of a failure with thermally radiative temperatures above 1 degree Celsius was observed with this technique. The expected use of resources initially planned for this failure analysis, if conducted by means other than IR, were cut drastically with the added benefit of minimizing changes to spacecraft assembly schedules.

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TEMPERATURE CYCLE OVEN TEST SET-UP

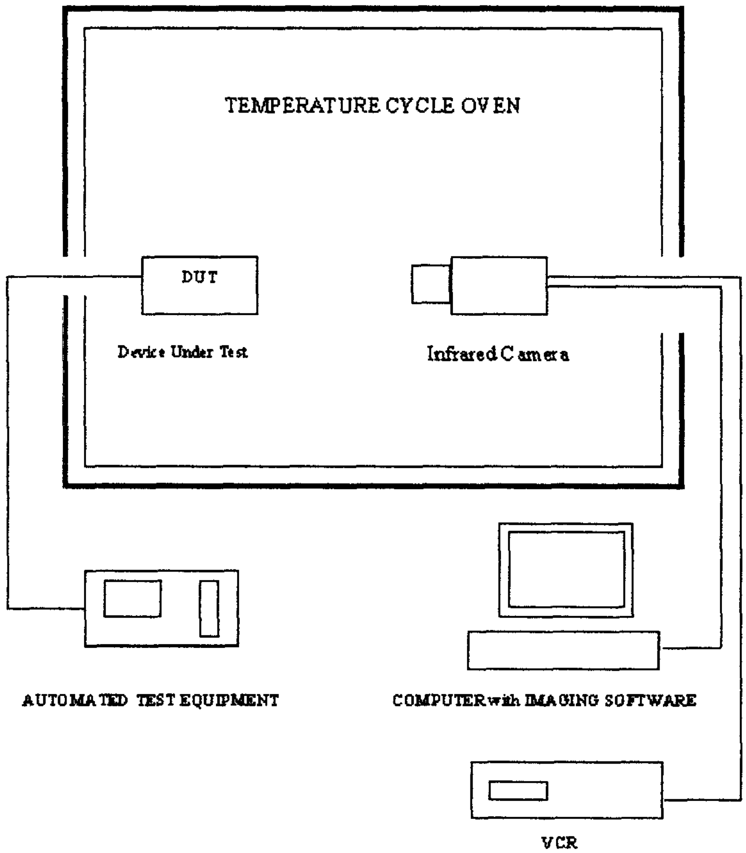


Diagram 1. The IR camera used in this analysis was the FLIR/Inframetrics PM390 connected to a computer with an Enhanced GRAM card and Thermogram® software by *Thermoteknix*, designed to work with Microsoft Windows 95. ThermoVac manufactured the oven; the VCR was a Panasonic AG1730. The Device Under Test (DUT) was the spacecraft hardware consisting of seven stacked modules. The Automated Test Equipment (ATE) was driven by software simulating spacecraft commands.

NORMAL OPERATING CONDITIONS OF THE SPACECRAFT HARDWARE AT ROOM TEMPERATURE

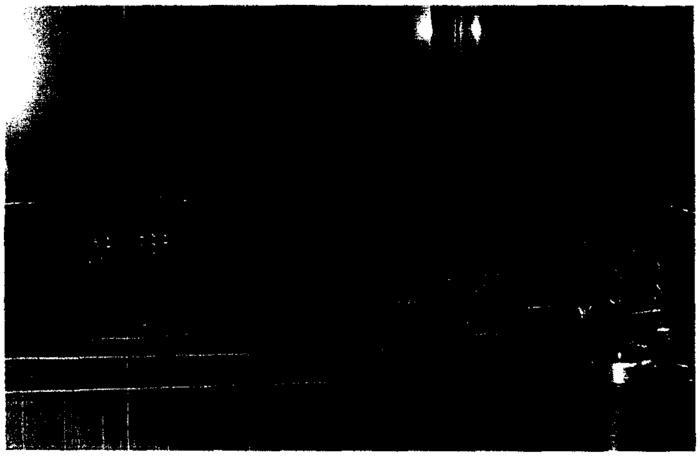


Figure 1. An optical image showing the S/C hardware in the thermal cycle chamber with the door open.

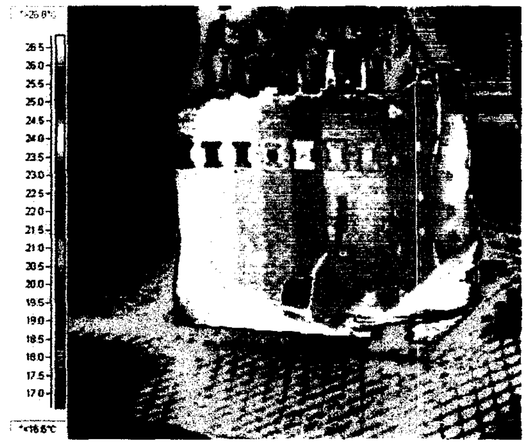


Figure 2. An infrared image showing the normal heat distribution from the power supply modules (the two right most modules) and several other modules, under normal operating conditions.

FAILED CONDITIONS OF THE SPACECRAFT HARDWARE WITH OVEN TEMPERATURE AT 16 DEGREES CELSIUS

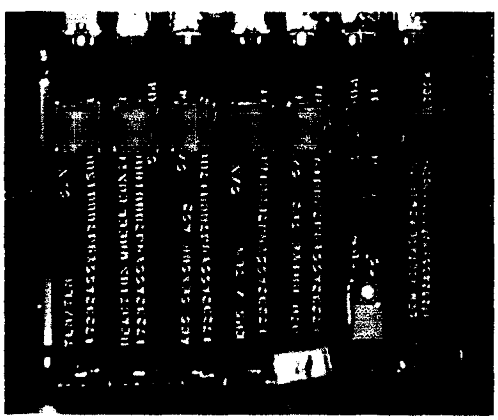


Figure 3. A close-up of the seven modules with computer electronics for spacecraft

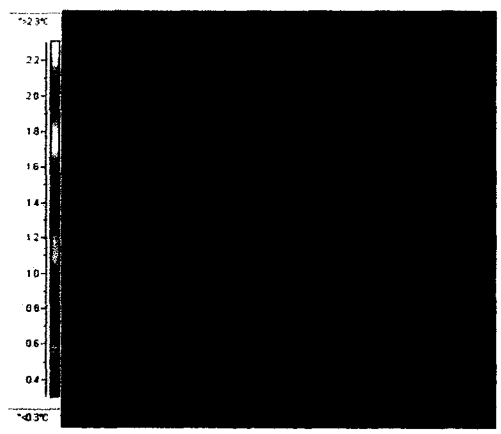


Figure 4. The infrared image shows the delta temperature coming from the module containing the bad device.

FAILED CONDITIONS OF THE SPACECRAFT HARDWARE AT 16 DEGREES CESIUS

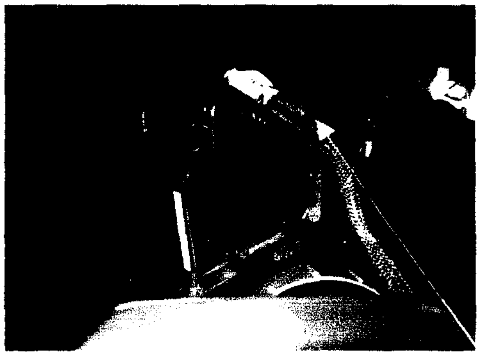
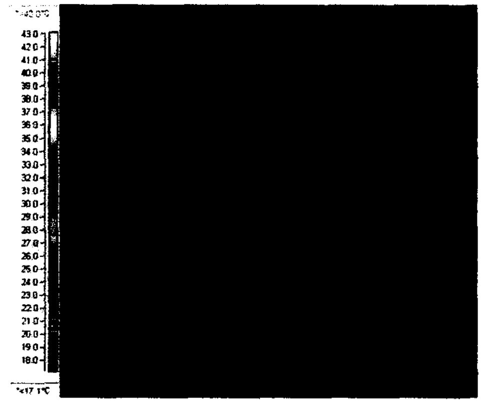


Figure 5. Optical image of the printed circuit board with the malfunctioning ASIC.



Heat from ASIC

Figure 6. An infrared image showing the origin of thermal radiation coming mainly from the edge of the ASIC device.

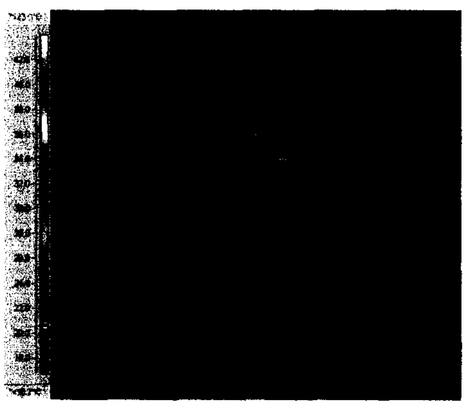


Figure 7. An infrared image showing progressive heat spreading on the PCB from the ASIC.

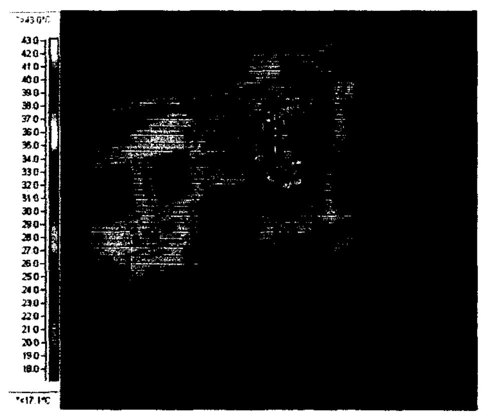


Figure 8. The temperature coming from the edges of the ASIC go well beyond 43 Degrees Celsius.