

PULSED LASER TEST OF ATMEL CHIP

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Test conducted at:
Pulsed Laser SEE Facility
Naval Research Laboratory
Washington DC 20375

21st November 2003

1. Introduction

The Atmel ASIC chip used to generate the protocols for SpaceWire was tested with a pulsed laser at the Naval Research Laboratory's Pulsed SEE Facility. The pulsed laser has been shown to provide a good simulation of the SEEs injected into integrated circuits by heavy ions.

The experiment had two goals. One was to determine whether errors injected into the phase lock loop (PLL) caused different failure modes as compared with errors injected into the rest of the ASIC. The second was to compare the energy thresholds for errors in and outside the PLL.

2. Experimental Setup

Two computers were configured to communicate with each other via SpaceWire. Each computer contained a 4Links card on which was mounted an Atmel ASIC and other glue logic chips. Each card also contained the drivers and connectors for low voltage differential signaling (LVDS). The Atmel ASIC has three links. This permits communications with three other nodes via independent channels. However, for this test, communications were established only between the two computers, using all three channels. This required three SpaceWire cables, each about 1-meter long.

For focusing the light on the Atmel ASIC chip the motherboard was removed from one of the computers and mounted on an XYZ stage. The 4Links board was inserted in one of the connectors on the motherboard. A solid rod was used to provide more stability to the 4Links board by screwing one end of the rod into a base attached to the XYZ stage and the other end through the metal tab at the top of the 4Links board. Although this rod ensured that the board would not fall out of its slot, it could not stop movement of the 4Links board relative to the motherboard when the XYZ stage was moved. The power supply, floppy drive and fan were affixed to a rack that was placed on the optical table adjacent to the motherboard. The second computer was located on a mobile table adjacent to the optical table. Two monitors, two keyboards and two mice were also placed on the mobile table for controlling the system.

The metal cover over the DUT was removed. The part had the following label:

Dornier
TSS901EMA-E
SMCS332
0013Z24429H

The 100X microscope objective lens could not be used for this experiment because the SpaceWire board was not sufficiently stable to keep it in focus as the part was scanned in the X and Y directions. This made it virtually impossible to scan the chip for SEE sensitive areas. Instead, we used a 20X lens, which provided a focused laser beam of approximately 10 microns in diameter.

The pulsed laser generated 1 ps pulses of light having wavelength of 590 nm at rates that varied between 10 Hz and 1 KHz, depending on how rapidly the beam was scanned across the chip. The laser pulse rate has no effect on the nature of the upsets

obtained. There are three beam splitters in the beam line along which the light pulse travels from the laser to the microscope objective. One is for illuminating the chip with white light from an incandescent bulb and the second is for a CCD camera so that the location of the laser spot on the chip could be imaged on a monitor. This aided the scan because the location of the focused laser spot on the chip could easily be viewed on the monitor. A third beam splitter was used to extract a small fraction of the incident beam energy for measuring the energy of each pulse.

Figure 1 shows a diagram illustrating the layout of the ASIC provided by Atmel. The location of the phase lock loop is indicated by the blue color close to Pin 1.

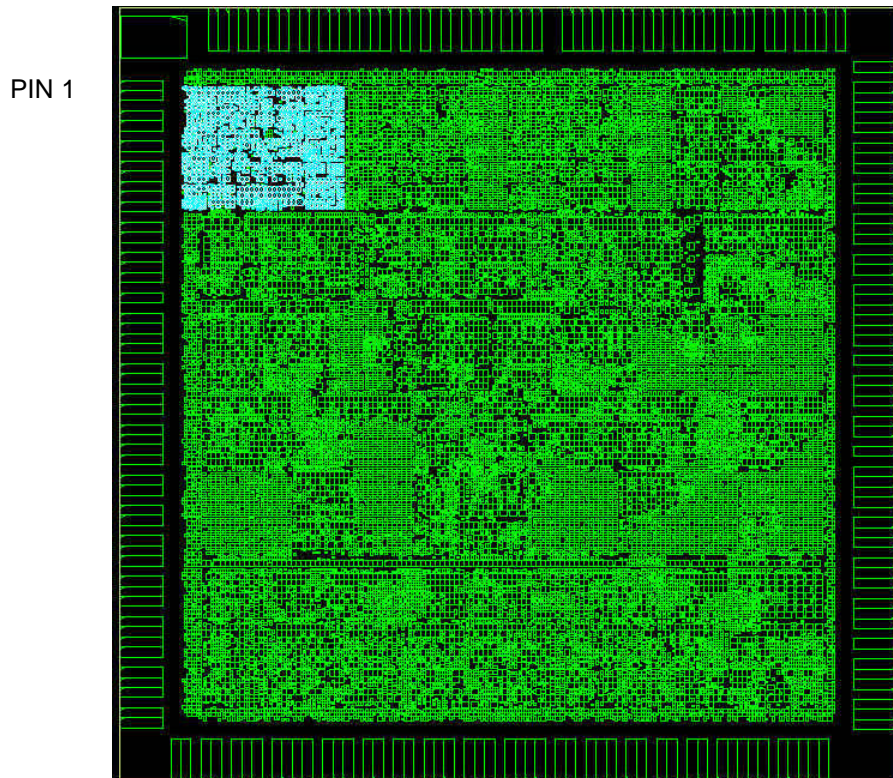


Figure 1. Layout of Atmel ASIC. The area in blue contains the phase lock loop.

The DUT was configured as the Master by ensuring that it sent out null tokens to the second computer (Slave) to initiate communications. Once communications were established, data packets were transmitted back and forth between the Master and the Slave at a rate of approximately 2 Mbps. Because SpaceWire is a full duplex system, data were transmitted and received simultaneously by both computers. The packets contained 1 K bits of data only. They lacked headers, which were not necessary because the network consisted of only two computers. The Master sent packets of all 0's to the Slave and received all 1's from the Slave. The information required for communications, such as buffer size and packet size, were hard coded onto the 4Links boards. Therefore, errors generated in the packets themselves could only result in miscompares of data and not errors affecting control.

3. Experimental Method

Communications were started between the Master and Slave computers. A photomicrograph of the chip shows that it is divided into thirteen equal columns by clearly visible metal lines. The pulsed laser light, focused to a spot with a diameter of about 10 microns, was scanned back and forth between two metal lines in a single column. All the rows in the column were scanned sequentially from “top” to “bottom.” By doing each column in succession, the entire chip was scanned.

Light passing over sensitive areas caused miscompares, link losses or crashes. After each link loss the total number of miscompares and the identity of the link that failed were read from the log file. No information about which link failed was available following a crash.

The threshold pulse energy for SEEs inside the PLL was compared with that outside the PLL by gradually decreasing the pulse energy and noting which areas were still sensitive to SEEs. Because of the size of the beam, it was impossible to compare the threshold energies with ion LETs.

4. Results and Discussion

Three major failure modes were observed when irradiating the part with pulsed laser light. They were:

- Miscompares identified by parity checks that do not cause a halt in communications. The identity of the link in which the miscompare occurred was written to a log file. At the end of a run, the total number of miscompares in each link was written to the log file.
- Link Errors, in which a link is disconnected resulting, in most cases, in a loss of communications that can be restored by software commands “Reset” and “Start”. The identity of the failed link is written to the log file that also contains the number of miscompares.
- System crashes in which communications stop. There is no information about what caused the crash and communications are restarted to launching the program.

All three types of errors occurred in the PLL and outside the PLL. Following is a more detailed summary of the types of system failures observed:

- Link losses occurred in both the Master and Slave computers even though the Master was the DUT for all tests.
- Miscompares occurred in both the Master and Slave computers, More areas in the Master produced errors.
- In most cases, a link loss caused a total disruption of communications. However, there was one case where link 3 was lost but link1 and link2 continued operating properly.
- In another case, when light was focused on a particular location in the chip, a stream of miscompares was generated that persisted even when the

light was removed. This could have been caused the injection of an error in a register that produced faulty data for the packet was not corrected until the program was reset.

- Only crashes were observed in the PLL when the laser energy was lowered to just above threshold. There were no miscompares. This suggests that the PLL is the most sensitive part of the circuit, and that it causes only crashes, as would be expected if one considers that disruptions to the clock can have major effects.
- Many more miscompares were logged for link3 than for link1 and link2. We do not know why.
- When scanning through one particular area, we noticed that all the miscompares were in the Slave computer whereas the link error that halted communications was in the Master.

The following observations are included in order to stress that some of the experimental conditions were less than ideal.

1. The link data rate was just over 2 Mbps, which is much slower than what will be used in SDO. SEEs tend to occur more frequently at higher data rates and it is not certain that we can scale the results for 2 Mbps up to 150 Mbps as the effects may be non-linear.
2. The packets did not contain any headers, so we could not evaluate the effects of control errors in the packets.
3. Link errors in each channel should be isolated so that should one go down the other two will continue to operate.