Evaluation of the TSC695F
0,5µm Rad hard V7 Sparc processor
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Abstract
An evaluation of the TSC695F, a space devoted 32-Bit RISC processor manufactured by ATMEL, has been performed. Further to the development phase, this evaluation has consisted in electrical characterisation, physical analysis, endurance and radiation tests in order to assess the specific failure modes and the intrinsic reliability of this product in the space environment.

The different tests will show, among others:
- preservation of functionality and AC/DC parameters within specification limits until 300krads and better (low dose rate irradiation),
- Low single event sensitivity regarding the space flux of ionised particles
- Latch-up immunity up to 100MeV/mg/cm².
- No reliability defect found.

These results demonstrate the ability of the TSC695F to be used in space applications.

Introduction
In order to satisfy commercial space programs needs, Atmel has carried out an evaluation of the TSC695F sparc single chip processor, under a CNES contract and with his support, to check that this product meets the space requirements.

This evaluation plan which includes radiation, destructive and endurance tests, has been designed in order to assess the manufacturing quality and the reliability of the product. These tests also intend to evaluate the margins related to performances and reliability with regards to space missions.

Product description
The TSC695F (ERC32 Single-Chip) is a highly integrated, high-performance 32-bit RISC embedded processor implementing the SPARC architecture V7 specification. It has been developed with the support of the ESA (European Space Agency), and is offering a full development environment for embedded space applications.

The processor is manufactured using the Atmel 0.5 um radiation tolerant (300 Krads (Si)) CMOS enhanced process (RTP). It can operate at a low voltage for optimized power consumption. It has been especially designed for space, as it has on-chip concurrent transient and permanent error detection.

The TSC695F includes on chip an Integer Unit (IU), a Floating Point Unit (FPU), a Memory Controller and a DMA Arbiter. For Real Time applications, the TSC695F offers a high security Watch Dog, two Timer’s, an Interrupt Controller, Parallel and Serial interfaces. Fault tolerance is supported using parity on internal/external buses and an EDAC on the external data bus. The design is highly testable with the support of an On-Chip Debugger (OCD) and boundary scan through JTAG interface.

The hardening of the technology was reported at the former ESCCON.

The work to be done is twofold:
- Parts manufacturing completed by 2nd Quarter of 2001.
- Evaluation program, for the destructive tests, electrical and endurance tests and radiation tests.

Parts Manufacturing
This step consists in the finalisation of the product specification in accordance with the ESA/SCC system (adaptation of the existing data sheet), and in the manufacturing and the electrical screening of the quantity of parts required for the evaluation.

This product manufactured and tested in Nantes facility was assembled in Grenoble, the Atmel space dedicated assembly facility.

Components Evaluation
Electrical Characterisation
After analysis of the process control monitor (PCM) measurement, the lot is situated with regards to the process specifications. The product is characterized with an extended voltage range (4V to 6V) and every specified parameter is measured over the full space temperature range. The following characteristics are addressed:
- Leakage Tests III/IIH/IOZL/IOZH
- IO driving capability VOL/VOH
- Power Consumption and dissipation
- Dynamic Tests
In addition, destructive tests (ESD and Latch-up) are performed to class the product in the right category.

**Physical Analysis**
This activity is undertaken by CNES. The Front-End process and the Back-End operations (die-attach, bonding, encapsulation, ...) are analyzed on ten parts.
This activity will consist in:
- Internal vapor content analysis on 3 parts,
- X-Rays inspection,
- Internal visual inspection,
- Bond pull and Stud pull tests (according to MIL-STD-883E M2011 & M2027 respectively),
- Glassivation integrity test (according to MIL-STD-883E M2021),
- SEM inspection including microsections to analyze the front-end process.

The technological analysis carried out by CNES revealed that the assembly process in Atmel Grenoble is well under control regarding the space criteria.

**Endurance Test**
20 parts are dedicated to life test as follows:
- 10 parts are submitted to a Life test at 140°C for 2000h with intermediate readouts after 168h (measured at -55,25,125°C), 500h(25°C), 1000h(25°C) and 2000h(-55,25,125°C), tested and recorded according to the applicable specification. These tests are intended to verify the life endurance by applying accelerated conditions to the normal use of the circuit. **No part failed after this test.**
- 10 other parts are stressed during a 175°C 3000h life test, far beyond the maximum authorized temperature: the purpose of this test is to demonstrate any potential failure mechanisms or drift and to extrapolate the corresponding end-of-life time. **No part failed after this test.**

**Radiation Tests**
Thanks to its RTP enhanced process, the extreme Total Ionizing Dose resistance of the TSC695F has been demonstrated during the development phase with no parameter drift after a 300krads(Si) deposited dose; therefore, no additional test were required. Nevertheless a new irradiation has been conducted with 10 spare parts from the lot and the previous results were confirmed. A slight increase of the ICCSB after 200 or 300krads is observed while the impact on the operating current is negligible.

Although the TSC695F design was using SEU hardened flip flop that have been tested without error at 100MeV.cm²/mg while implemented in the MG2RTP test vehicle, the tolerance to single event upset was to be confirmed and some tests were conducted at IPN Orsay. Actually no upset has been confirmed in static mode @ 30MeV.cm²/mg while evidence of some transient effects (The error rate is frequency dependant) were demonstrated that induce few trap errors. These traps are not fatal as they can initiate a recovery routine.

**Conclusions**
The evaluation of the TSC695F for space application has been successfully conducted. The electrical characteristics and reliability figures are clear evidences of the suitability of the product to fulfill space application requirements. The total dose hardness brings designer solution far beyond most severe needs while heavy ion tests will provide system managers reliable event rate probability.