8-bit Microcontroller ATMega128/AT90CAN128

Engineering, Test & Qualification Center B

Dr. A. Schüttauf TEB32

04.11.10

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Outline

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- Comparison 80C32/52 ATMega128 AU16
- ATMega/CAN128 radiation results SEL/SEU
- New developments e8051, JOP
- Summary

Introduction

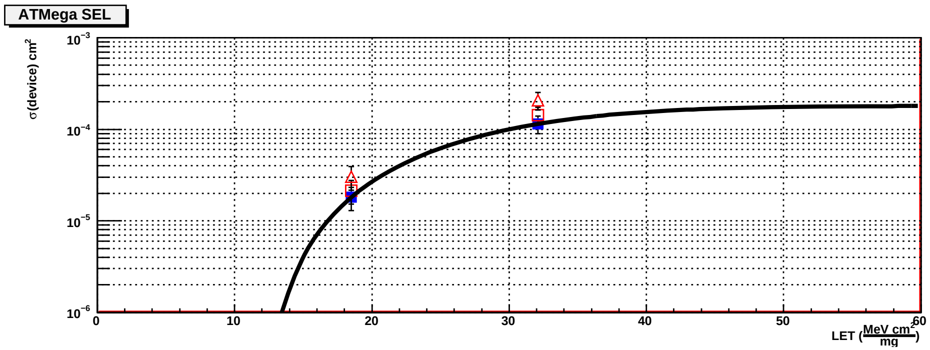
The usage of commercial off the shelf components (COTS) in space environment has become unavoidable since many semiconductor manufacturers have discontinued offering dedicated space or military grade components. Especially the availability of "state of the art" microcontrollers for space applications at a reasonable price is limited. The typically used 80C32/52 controller does often not match the nowadays needed performance and interface capabilities for modern payloads.

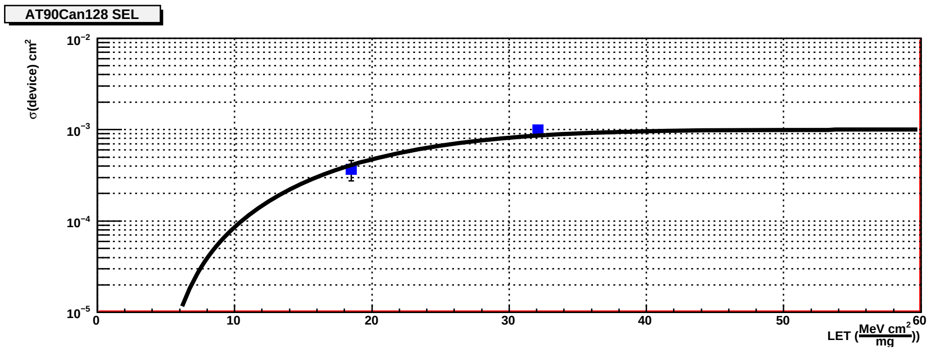
Comparison between 80C32/52 and ATMega128-AU16

- 80C32/80C52
  - Power control modes
  - 256 bytes of RAM
  - 8 Kbytes of ROM (80C52)
  - 32 programmable I/O lines
  - Three 16 bit timer/counters
  - 64 K program memory space
  - 64 K data memory space
  - Fully static design
  - 0.8µm CMOS process
  - Boolean processor
  - 6 interrupt sources
  - Programmable serial port
  - Temperature range : commercial, industrial, automotive, military

- ATMega/CAN AVR
  - 128kBytes in-system programmable flash memory,
  - 4kBytes EEPROM and
  - 4kBytes internal SRAM.
  - Advanced RISC architecture up to 16 MIPS
    - 133 instructions single clock cycle
    - 32x 8 registers
  - Built-in master/slave TWI serial interface (I²C bus interface),
  - 8-channel, 10-bit AD converter with programmable gain set
  - 53 digital I/O lines.
  - SPI Interface for In-System Programming
  - CAN-bus interface (only AT90CAN128)
  - 8- and 16-Bit-Timer
  - UART
  - Watchdog
  - External SRAM

ATMega128 &AT90CAN128
Latch up results

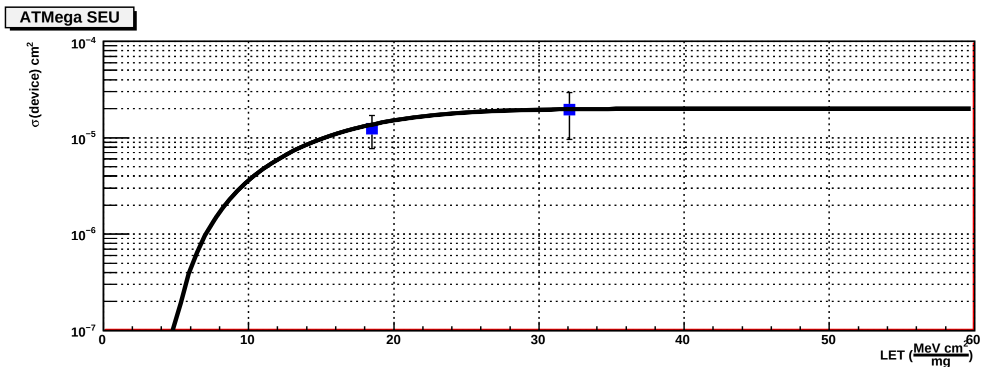


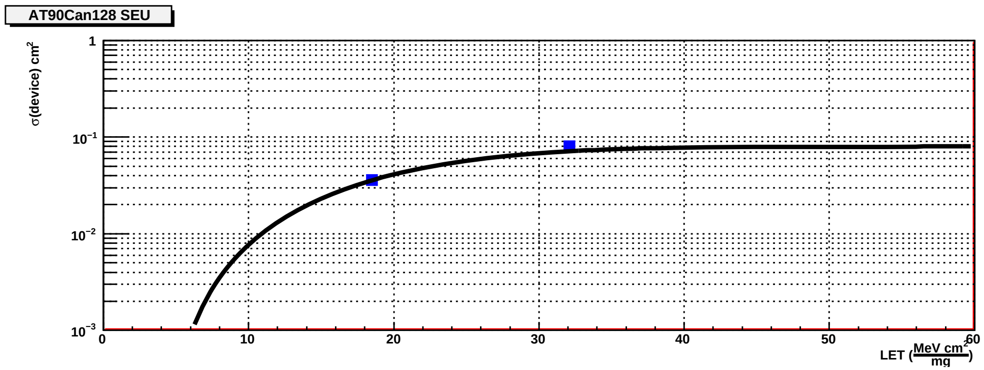


The measurement for the Latch-up test together with a Weibull fit though the data for the ATmega128 (upper plot) and AT90CAN (lower plot) are shown. To perform the Weibull fit we assumed a vanishing Latch-up cross section at 30 % (ATmega128) and 10 % (AT90CAN128) of the Krypton LET (32.2 MeVcm^{-2} mg^{-1}).

The saturation cross section resulting from the Weibull fit shows, that the Latch-up probability differ by one order of magnitude (ATmega128 1.18 10^{-4} cm2, AT90CAN128 1.0 10^{-3} cm^2).

ATMega128 &AT90CAN128
SEU results



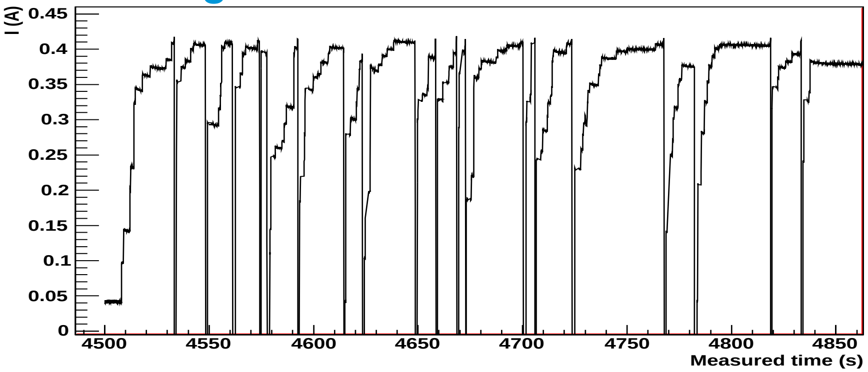


The SEU cross sections are presented in Figure 2 for the ATmega128 (upper) and AT90CAN 128 (lower) were the error-bars include the statistic and systematic errors. For the Weibull fit we assumed a vanishing cross section at 10% of the Krypton LET (32.1 MeVcm^{-2} mg^{-1}).

A comparison between the two microcontrollers shows, that the AT90CAN128 has a 3 orders of magnitude higher SEU saturation cross section (8.0 10^{-2} cm^2) than the ATmega128 (1.11 10^{-5} cm^2).

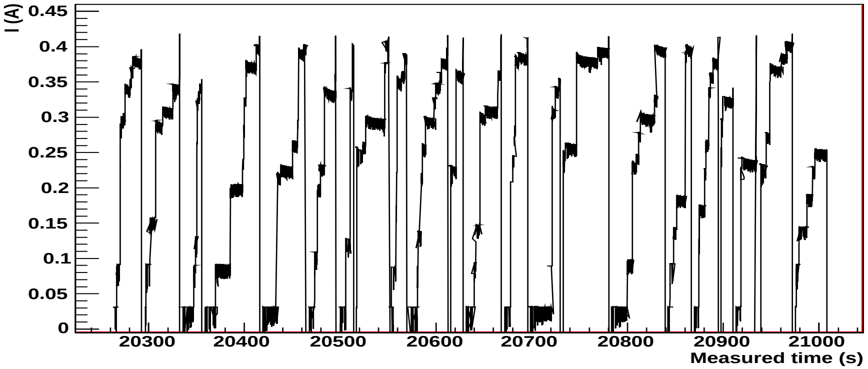
ATMega128 &AT90CAN128
Current dependence during irradiation

ATMega128



The overall trend for the current consumption during irradiation for the ATmega128 has a "plateau like" behaviour before the Latch-up condition is fulfilled the AT90CAN128 tends to have "step like" behaviour which sets in at lower currents.

AT90CAN128



This significant difference between the microcontrollers was not expected from their electrical and technological properties.
Comparing the thermal and electrical properties of the ATmega128 (-40-125 º C, 200-400 mA) and the AT90CAN128 we can point towards the difference, that the AT90CAN128 has the smaller temperature range -40-85 º C and a lower DC current limit 200 mA.

ATMega128 &AT90CAN128
Radiation test results

A radiation test was performed using Iron and Krypton ions at a LET of 18.5 and 32.1 $MeVcm^{-2}mg^{-1}$.

ATmega128 microcontroller:

- Latch-up rate (SEL) of once in 481 years
- SEU rate of once in 690 years

AT90CAN128 microcontroller:

- Latch-up rate of once in 24 years.
- SEU rate of once in 3 month.

Both SEEs rates are calculated for 100 mils aluminum shielding at an inclination of 51° and 400 km under quiet solar conditions

LEO 100 mil

ISS LEO 100 mils				
Function	**Nominal**	**Maximum Flare Peak**	**Max.Fl. Orbit average**	**Unit**
Latch-up ATmega	5,69 10-6	1,07 10-1	1,76 10-2	Day^{-1}
Latch-up AT90CAN	1,14 10-4	1,92 10-4	2,73 10-3	Day^{-1}
SEU ATmega	3,97 10-6	6,44 10-2	8,22 10-3	Day^{-1}
SEU AT90CAN	1,0 10-2	168	23,8	Day^{-1}

GEO 100 mil (for information only)

GEO 100 mils				
Function	**CRÈME M1**	**CRÈME M2**	**CRÈME M3**	**Unit**
Latch-up ATmega	1,12 10-4	1,07 10-4	1,77 10-4	Day^{-1}
Latch-up AT90CAN	1.61 10-3	1,57 10-3	2,60 10-3	Day^{-1}
SEU ATmega	4,84 10-5	4,62 10-5	7,65 10-5	Day^{-1}
SEU AT90CAN	1,78 10-2	1,37 10-1	2,26 10-1	Day^{-1}

New developments
Embedded cores

The e8051 core

- 100% instruction set compatible with standard 8051 and 8052 microcontrollers.
- Fully synchronous single-clock architecture (for one cycle instructions, MIPS rate = clock rate).
- Very high clock rates.
- 256 registers and 64k program and 64k data space - easily expandable.
- Full standard peripheral set including 3 timers and 2 serial ports.
- Users can add their own ports and peripherals.
- Four-clock and one-clock timer-counting-modes as well as standard twelve-clock mode.
- Two standard data pointers (DPTR and DPTR1).
- Full set of 24 separately vectored interrupt sources.
- Low gate count/cell count - as low as 700 CLBs in Xilinx Spartan FPGAs.
- Synchronous design suitable for high-coverage scan test.
- Low power consumption.
- Low cost (see prices).
- Full-speed evaluation net list available for developing small test programs on any platform.

JAVA Optimized Processor

- JOP is a fully pipelined architecture with single cycle execution of microcode instructions and a novel approach to mapping Java byte code to these instructions.

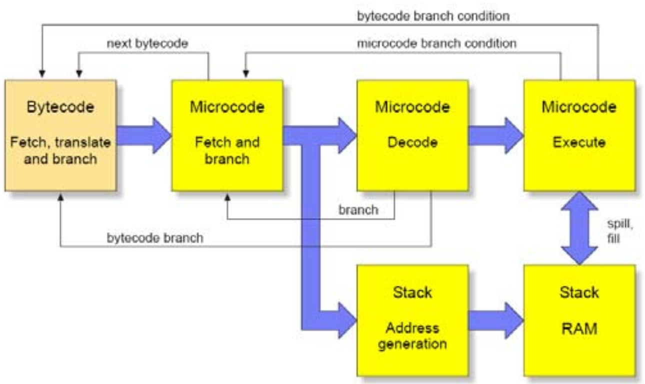


Figure 5.5: Datapath of JOP

byte codes – the instructions of the JVM – and translates these byte codes into addresses in microcode. Byte code branches are also decoded and executed in this stage.

Summary

- Modern payloads have a demand on various interfaces and monitoring capabilities
  - The ATMega AVR series offer these functionality at low power and price.
  - Backdrop a radiation test is unavoidable !
- Heavy Ion result for ATMega128
  - The ATMega128-AU16 has an acceptable behavior for a ISS LEO environment.
    - SEL once in 481 years
    - SEU once in 690 years
  - The AT90CAN128-AU16 is not acceptable for space application.
- New developments show interesting features
  - E8051 embedded controller allows early tests and IF evaluation of FM solutions before the HW is build.
  - JOP gives a new opportunity to implement an JVM in HW on low cost and space.

Back-up
Radiation physics basics I

- LET=Linear Energy Transfer
  ➔ Deposited energy

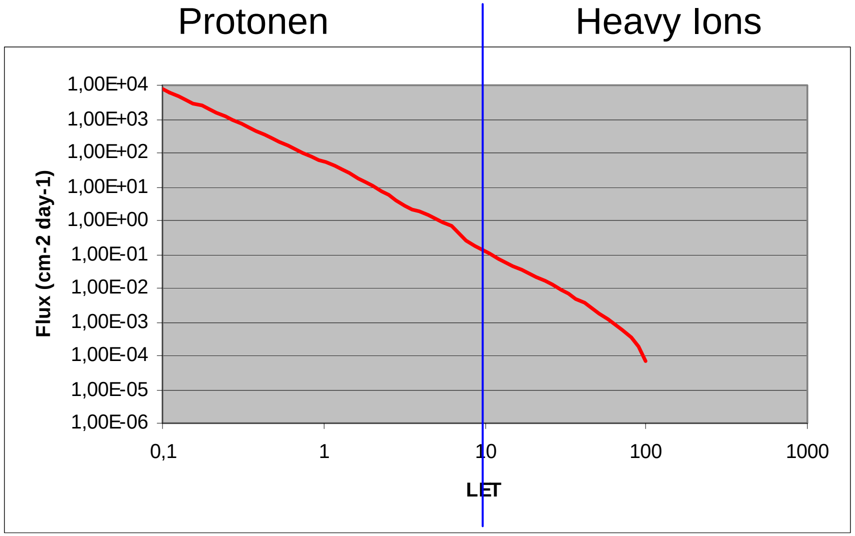
- Particles passing though matter deposit energy

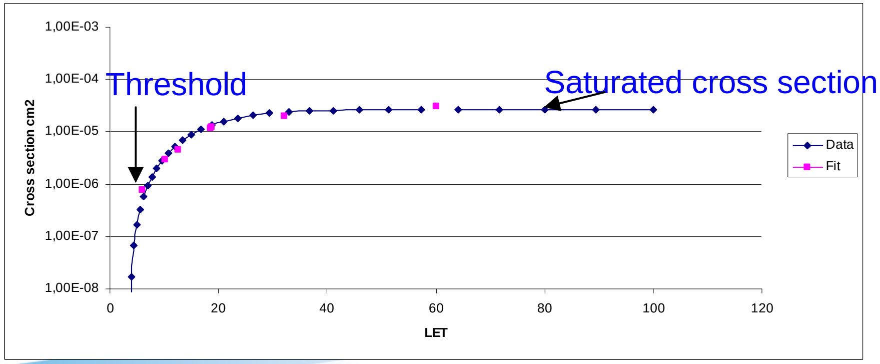
  $$dE/dx \sim Z^2/\beta^2$$

- Flux $n/cm^2 \cdot day$; n=protons, HI

- Fluence = Σ Flux ➔ $1/cm^2$

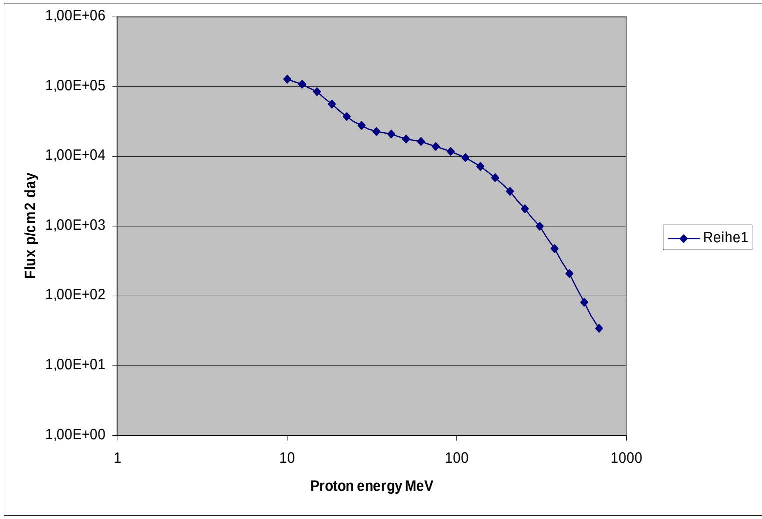
- Cross section = Probability of an event (SEE) ➔ SEE/Fluence in cm^2



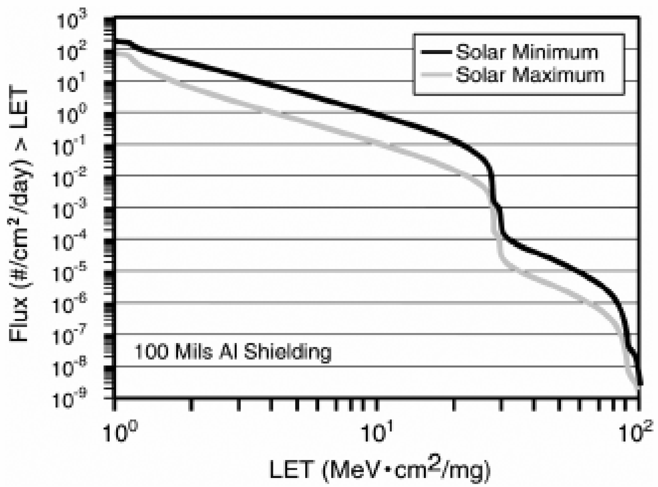


Back-up
Radiation physics basics II

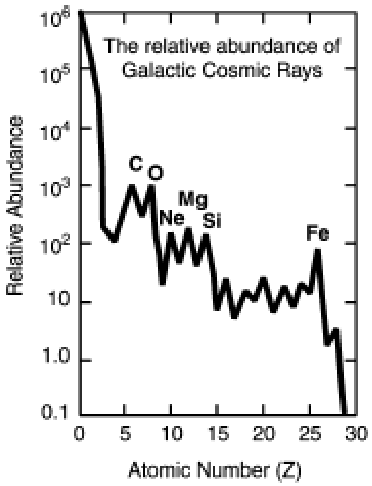
- ISS (LEO) proton average spectrum ends 500-600 MeV
- Protons @ 200 MeV cover LET till ~ 10 MeV



ISS Poton Spectrum



ISS LET Spectrum



Relative abundance of Glactic Cosmic Rays