Investigation of new technologies and concepts for reliable computation and fast communication

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Outline

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Introduction

• Electronic Systems are based in the co-existence between analogue and digital components
  • Central core (the “brain”) is usually a μProcessor, or an FPGA.
  • Computational, control and communication tasks
• The faster our “brain” works, the more (and better) things we can do!

• However!!! Radiation Effects to Electronics have always been a limitation factor when it comes to performance:
  • Future upgrades mean
    • More data, higher speeds
    • More radiation -> showstopper?
Problematic

- So far there are two main types of systems:
  - Systems that operate in high speed
  - Systems that conduct complex operations

- What if we want both speed and complexity?
- What about reliability?
- Different applications require different features
  - A long investigation on FPGAs and μProcessors
  - Provide users with as many options as possible for them to choose
FPGA Solutions ProASIC3E

- Traditionally at CERN two FPGAs have been used:
  - ProASIC3E FPGAs for less critical applications
  - Anti-FUSE FPGAs for critical applications.
- Several new FPGAs and technologies are being considered by equipment groups and not only and are tested
- EN-SMM-RME leads the qualification of new FPGA and μProcessors
- Component level + System Level

ProASIC3E Flash Based FPGA tests:
- EN-SMM-RME + BE-BI for the GEFE System.
  - Team of R. Ferraro, I. Deg’Innocenti, M. Barros Marin and G. Tsiligiannis
  - System Level testing @ CHARM
- E. Gousiou tests for NanoFIP converter @ PSI
- Results @ EDMS 1863774, 1183301
FPGA Solutions SmartFusion2

- **SmartFusion2** Flash Based SoC FPGA: Fabric + ARM Cortex-M3
- Full qualification campaign @ PSI with 200MeV protons
  - flip flops, PLL, BRAM, DSP, dose level limitation, re-programmability, applications etc.
  - Results @ EDMS 1607767
- CHARM tests by TE-CRG @ EDMS 1892584
- Further tests with μProcessor + FPGA fabric for fast transmission of data using RAW Ethernet
  - Bare Metal + RTOS - G. Gnemmi driving the tests now
  - Combined tests at PSI, CHARM (protons) and CHARM (Heavy Ions)
  - Results under processing and towards a full reliability analysis
  - RADECS + EDMS on the way!
FPGA Solutions Artix7

- The **Artix7** FPGA has been targeted: System Level testing
  - Configuration memory (CRAM) testing at CHARM, Am-Be, ESRF and ILL facility
  - System Level testing with µBlaze + LwIP @ CHARM
- A novel methodology has been introduced:
  - Reliability analysis of a System based on CHARM SEU data
  - Failure prediction of the System

Reliability function of the application for locations G 0 and R 1, with and without the use of the soft error mitigation IP (scrubber).

Probability of the number of system failures for position RR53 calculated with the annual fluence for the LHC under run 2 at $2 \times 10^8$ HEH and for the HL-LHC at $2.7 \times 10^9$ HEH.

Am-Be Facility @ CERN

PSI Radiation campaign
**FPGA Solutions NanoXplore**

- **NanoXplore** supported by ESA and CNES to create a “made in Europe” RadHard FPGA
- NG-MEDIUM: 65nm Rad-Hard SRAM Based FPGA
- Full qualification @ PSI with 200MeV protons
  - FlipFlop, DSP, PLL, RAM, TID limits, CRAM etc
- Promising results
  - >3kGy + Good SEE response
- Technical Training to be scheduled the 30th of January to the 1st of February
- Results @ October RADWG meeting (indico)
- Results to be published to the next RADECS + EDMS
MCU Solutions

- New approach for certain tasks that don’t necessarily need an FPGA (we don’t want to shoot a fly with a bazooka!)
- **STMicroelectronics** and **Atmel** offer large variety of COTS
- M0, M4 and M7 ARM Cores
- Multi-level testing:
  - Internal RAM, ADC, FPU, peripherals, Ethernet, Wireless
- **STM32F4, STM32F7, SAM4E, SAMV71, SAMD21** tests @ PSI with 200MeV protons
- G. Piscopo, A. Damigos Papotis, G. Gnemi
- Results show that some MCUs have outstanding resilience to TID (up to 500Gy)
  - Reports @ EDMS **2059030 + 2059033**
  - Further results: NSREC + RADECS +EDMS
Future Work

- Several options exist that can be well adapted to a wide range of applications
- Radiation can be limiting but thanks to the vast expansion of FPGAs and MCUs since the last decade, a wide range of COTS exists that can cover our needs
- Further developments and testing at the FPGA and MCU level
  - Focus at the System level performance of certain applications
  - Understand better and invest in Reliability Methods for the prediction of the performance of Systems operating in radiation environments
- More components to be tested -> always seeking for the best balance between performance and reliability
  - More fine grained tests
Thank you for your attention!

Questions?!