A new Fault Tolerant Local Monitoring Control Board with SEU mitigation and execution redundancy commercial micro-controller

José Antonio Lucio Martínez
Research group Prof. Udo Kebschull
Infrastructure and Computer Systems in Data Processing
Goethe Universität Frankfurt

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Outline

- Detector Control System Overview
- Radiation Problem: Single Event Effects
- Severity of errors
- MCU architectures available in the market
- Cortex-R at Beam Test
- FTLMC Prototype
- The EPICS SCADA
  - Channel Access
  - Database Records
- The RTEMS Operative System
  - Real time issue
  - Software Status
- Final Remark

Detector Control System Overview

- Monitor sensors and establish actuators values
- Ensures integration of digital / analog sensor data
- Provides connectivity with friendly end- user graphical interface
- Interconnects with FEE-DAQ
- Provides a finite state machine for detector status
- Prevents critical situations and issues alarms
- Provides database for archiving
- Input Output Controller (IOC) needed everywhere, also in radiation environments

Radiation Problem: Single Event Effects

- Some SEE's, like SEU's don't cause permanent damage in electrical equipment, TID seems to be bigger issue
- Cross section (SEU/SEE sensitive area) appears to be small
  - Even if the MCU is directly inside a particle beam (Details shown later on), SEU incidence is not constantly high
  - There are plenty of examples of ordinary equipment running control software in high energy physics facilities around the world without apparent anomalies in function

Severity of errors

- Multiple bits can be flipped depending on:
  - the transistor technology,
  - Linear Energy Transfer (LET)
- CPU unpredictable behavior and Corrupted data
- Logic is affected by Single Event Transients (SET)
- Memory is affected by Single Event Effects
- Unrecoverable data loss
- Erroneous values transmitted to critical actuators can have catastrophic consequences

MCU Architectures

- SEE's are problematic enough that can result in serious malfunction
- An additional problem is the anecdotal perception of low malfunction incidence
- Approach: ARM produces intellectual property processors that fit very specific needs
  - Find one that focuses in safety and redundancy: arm7v4 **Cortex R5F**
  - Find the vendor that bought the rights to produce such a chip for sales: **TI- TMS570**
  - Build a control board based on that chip: **FTLMC**

Cont. MCU Architectures

- Such a commercial device is not radiation hard specified
- But has ECC check when reading and writing to any memory inside MCU which allows us to implement a scrubbing daemon
- Runs same instruction in two different CPU’s and compares the result to prevent Single Event Transients

Beam test of the Cortex-R (TI-TMS570 Eval Board)

- Exposed MCU directly to beam during: 13 hours
- Beam: 2Gev Protons
- Total detected and corrected SEU's:
  - in Bank A: 718
  - In Bank B: 686
- No multiple bit errors, (no unrecoverable errors)
- Failure registers continuously monitored
- Database with error time-stamp
- No errors during beam off times detected

FTLMC Prototype, 53 x 89 mm

Galvanic isolated UART RS-485 &| Profibus

Galvanic isolated 2 x CANBUS

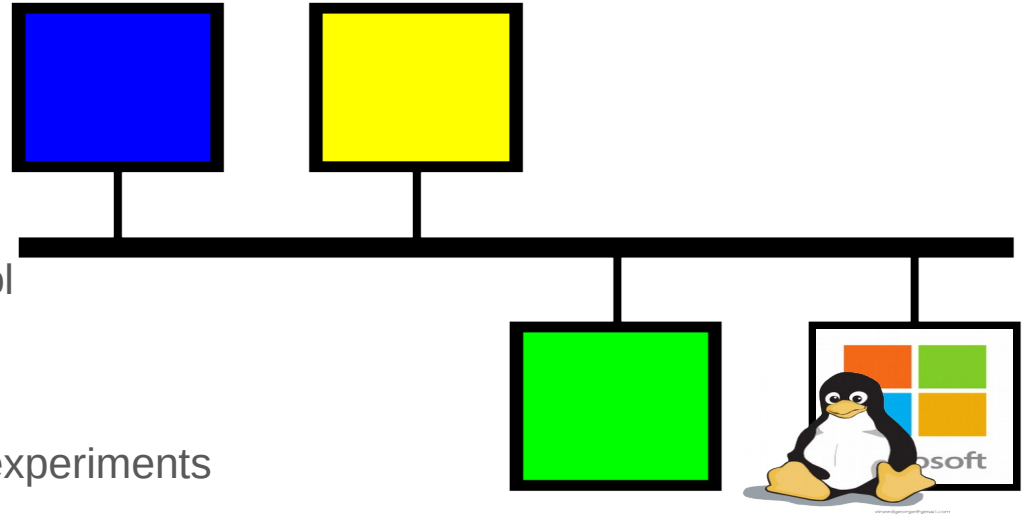
1Mb/s UART → RS-232

I^2C, SPI, 7 ADC Inputs, 85 GPIO’s

Ethernet capability

EPICS SCADA

- Up-Scalable
- Open Source
- Supports many platforms
- Support for ethernet protocol
  - Python
  - Java, etc
- Large trajectory in physics experiments
- Multiple motif graphical interface options
- Version compatibility with board is still in progress, RTEMS 5 Compatibility needed

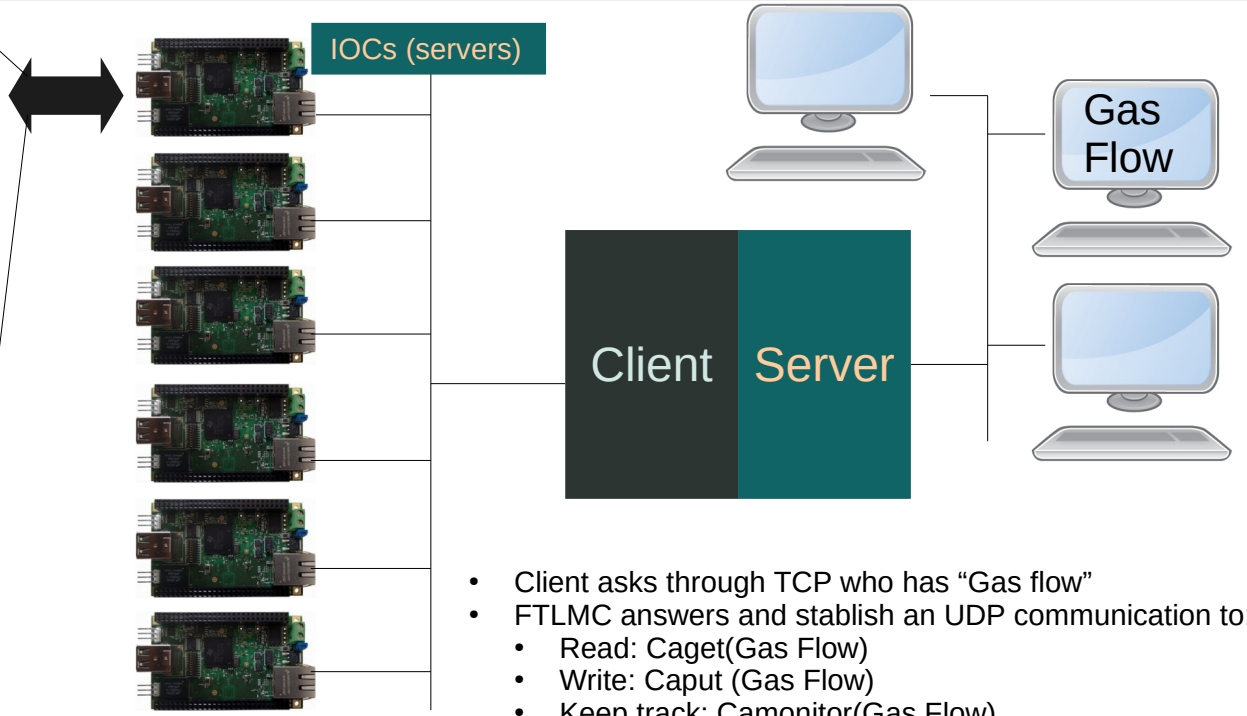


EPICS in DCS

- EPICS is considered for the CBM experiment:
  - (IOC) Input Output Controller → FTLMC
  - (CA) Channel Access TCP/UDP based protocol
  - (PV) Process Variables are any kind of value
  - Databases describe what variables are controlled by which IOC, how often are they probed and how are they interpreted

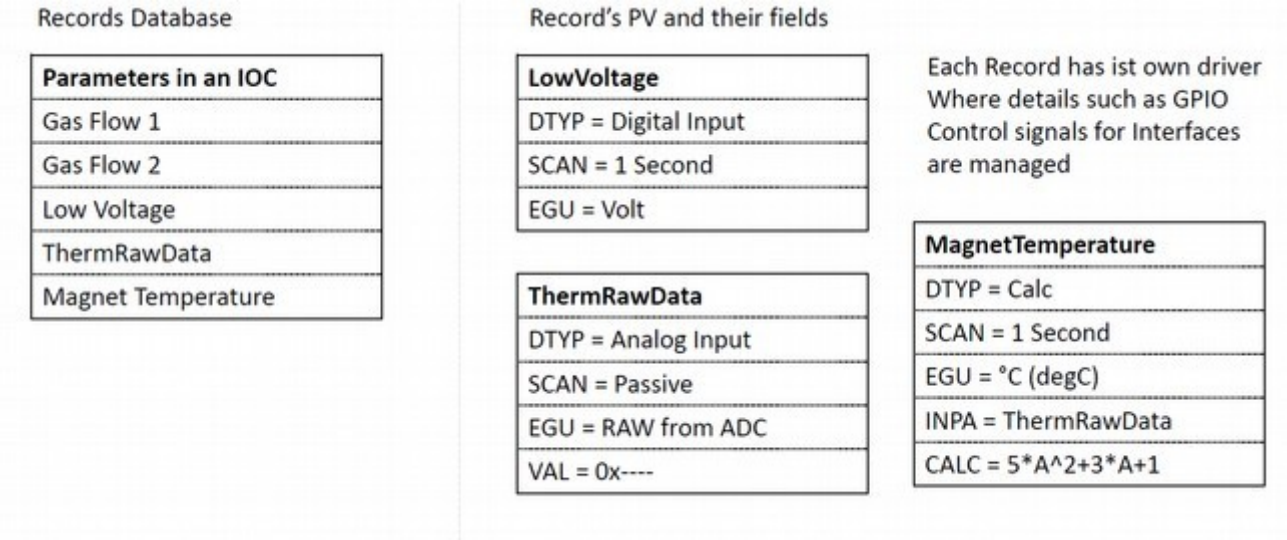
Channel Access

- FEB Temperature
- ASIC on/off
- ASIC Configuration
- Low voltage on/off
- LV control
- LV PS Temperature
- HV on/off
- HV control
- H_2O Sensor
- O_2 Sensor
- Gas component flow
- Gas supply line flow
- Detector level pressure



- Client asks through TCP who has “Gas flow”
- FTLMC answers and stablish an UDP communication to:
  - Read: Caget(Gas Flow)
  - Write: Caput (Gas Flow)
  - Keep track: Camonitor(Gas Flow)

EPICS Database Records



- Each IOC contains a database of all records and their PV's that are under their tasks

RTEMS OS

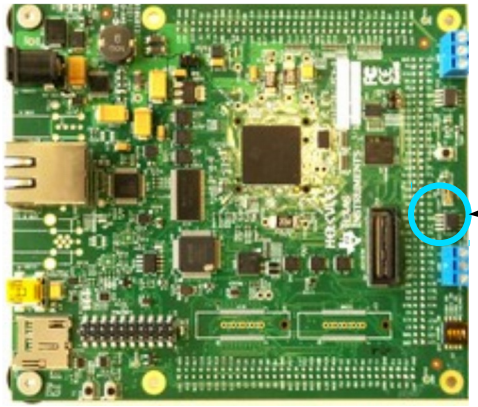
- Real Time capability
- Supports open standard application programming interfaces such as Posix
- Large community of developers and users
- Straight forward compiling toolchain
- Open source, own code and drivers can be integrated easily
- Memory scrubbing task daemon easily implemented as low priority task

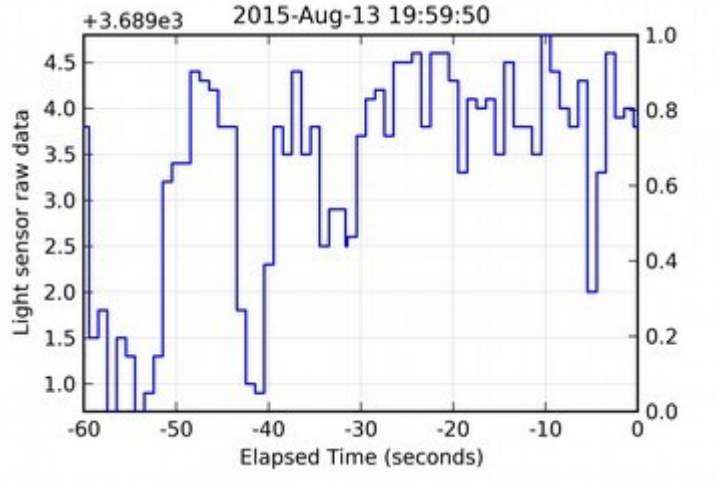
RTEMS: The Real Time issue in control

- The task scheduling method defines if an operative system is real time or not
- Non real time OS normally assign a priority based on which was scheduled first or which has the less executing time
- Real time OS schedule tasks based on the deadline: earliest deadline means higher priority
- Preemption is important for optimal performance
- It is important when maintaining or updating values with critical timing constrains

Software Status

- EPICS supports RTEMS <=4.10
- TMS570 Support was introduced in RTEMS until 4.11
- Own modifications in EPICS code allowed to make an RTEMS / EPICS /TMS570 demonstration in 2015 with a light sensor





Software Status

- Preliminary demonstration with EPICS 3.16.1 and RTEMS 4.11 is around the corner
- Final software version will be available when EPICS upgrades support for RTEMS 5

Summary

1. **Single Event Effects can cause severe malfunction**
   Micro processor industry is very diverse and has safety features implemented in some micro- processors

2. **Investing in a high radiation tolerant device is too costly**
   but the ECC/Redundancy approach can provide low cost additional fault tolerance aspects

3. **Board based on a commercial redundant architecture device**
   was built. Scrubbing works and RTEMS based EPICS is being ported