Exploring Embedded Systems’ Dedicated Cores for Real-Time Applications

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Introduction

Sirius, the new 3 GeV Brazilian Light Source
- Technological challenges
- Controlling and monitoring a large variety of equipment
- Embedded solution for general and critical controls:
  Beaglebone Black and its Programmable Real-Time Units (PRUs)

Beaglebone Black
- In use since 2016 (UVX facility) – Debian distribution
- Inexpensive open hardware
- Chosen as distributed cores for Sirius Controls System
- Dual Programmable Real-Time Units as SoC subsystems
- High level tools can be installed on it

PRU: an embedded real-time core
- 32-bit RISC core running at 200 MHz
- 8 KB instruction memory
- Interface with userspace environment
- Access to Beaglebone hardware
- More than 8 KB for data storage

High-Performance Serial Interface

Purpose: fast serial communication interface to critical device (PRUserial485).
Aspects:
- External UART, configurable up to 15 Mbps
- Single package large data transfers
- Python or C interface to PRUs
- Synchronous and conventional mode
- RS-485 standard

Data transfers (userspace ↔ PRUs)
- Memory mapping:
  - Shared RAM (faster) and external DDR for different modes
- Sync operation
  - Serial messages after a timing pulse
- Modes:
  - general broadcast message
  - single curve via setpoints
  - multiple curves via setpoints
- Recovery time: 3.1µs

Multi-Purpose Counting System

Main purpose: Diagnostics with Bergoz Beam Loss Monitor (Diff BLM) and in-house developed gamma detectors.

Board configuration:
- PoE powered
- 2 Bergoz driver and input channels
- 6 digital single-ended channels

Maximum counting rates

<table>
<thead>
<tr>
<th>Active Channels</th>
<th>Assembly [MHz]</th>
<th>C [MHz]</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>14.3</td>
<td>4.0</td>
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<tr>
<td>2</td>
<td>12.5</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>11.1</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>10.0</td>
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</tbody>
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Status: Installation in progress in Sirius Storage Ring

Water Leak Monitor

Purpose: detect minimal water leaks in tunnel area with capacitive sensors and a coaxial line in Sirius girders.

Distance calculation: signal and reflected signal travel time. One-way max error: 0.61 m
Status: final developments

Conclusion

Having both embedded Linux and a dedicated core in the same SoC reduces costs and system overall complexity, allowing developers to design time-critical applications with the advantage of sharing data with largely used tools, such as EPICS and Redis. Demonstrated applications using this architecture are vital to ensure Sirius operation, once low jitter, low latency and determinism are important for real-time applications.

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