Monitoring Complex Detectors: the uSOP approach in Belle II experiment

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Overview

• uSOP: a Service-Oriented Platform for embedded applications
• Hardware
• Software
• uSOP at work: monitoring complex detectors
  – Belle2, Beast2 @ KEK
• Conclusions
uSOP

- uP-based, Service-Oriented Platform for embedded applications
- Strongly oriented to SPI, I2C, JTAG, UART, with isolated power for peripherals and sensors
- Fully managed remotely
- 3U Eurocard native form factor, expandable
- Derived-from and compatible-with BeagleBone Black open-source project

- Running Linux OS (Debian) — porting armv7l
- Full support for compilers and applications
- Kernels: major releases available — 3.x and 4.x
uSOP – uP and utilities

- USB device
- 10/100 Ethernet
- USB host
- uSD
- 4 GB Flash eMMC

- 10/100 Ethernet (controls and management only. See next slide)

- 512 MB DDR3 RAM
- 5V, 500mA (typ)

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Remote Management

- Remote control over IP for:
  - uP Reset
  - Boot mode
  - Power on/off

- UART over IP:
  - Console
  - Bootloader

- More tasks can be implemented (watchdog, controls, ...)

- Based on the latest version of Lantronix Xport-Pro
- μP Freescale MCF5208, MMU-less architecture, 8MB RAM, 16MB Flash
- SoC running uCLinux with a full cross-compiled SDK
uSOP – Peripherals/Intf

- Timers
- PWM
- Event Capture
- PRU

16 x GPIO

- 2 x RS232 (*)
- JTAG (*)
- 2 x SPI (*)
- 2 x I2C (*)

- 4 x 12 bit AIN (**) + 2 on-board power monitoring

- • = fully isolated, 5V-12V supply
- ** = buffered

FPGA firmware download
QuickEval compatibility

SPI and I2C busses are accessible via connectors compatible with the QuickEval specifications from Linear Technology allowing the developer to benefit from a large variety of high-performance evaluation boards.
ΔΣ ADC – LTC2499 noise floor

- uSOP bench test with LTC2499:
  - ΔΣ ADC, 24 bit
  - I²C, powered by uSOP isolated supply
  - $V_{in} = 0V$, Input shorted to local ground
  - ~5 Hz sampling rate
  - 50 Hz filter
  - $V_{ref} = 5V$
  - Read-out by EPICS IOC
  - GUI by CSS/BOY

Source: linear.com
MONITORING COMPLEX DETECTORS
The Belle2 EndCap ECL* monitoring system

- Minimal, standalone monitoring system at the EndCap ECL test station
- 4 sectors over 32 monitored to control the conditioning system (T, Rh)
- Up-time ≈ 2 year
- Data available via both EPICS and cloud

*Belle2 EndCap Test Station at Fuji Exp. Hall, KEK

*ECL talk from C. Cecchi on Wed
The T-Rh Controller board (LTC2983)

- Dual channel architecture, custom designed for the endcap readout
- Each controller reads out two forward sectors (3x T, 1x Rh probes powered by uSOP) with galvanic isolation
We have programmed the on-chip uP to perform a 3-cycle measurement and processing:

- (a) Inject current in Rsense and probe ΔV across thermistor
- (b) Set the current to obtain ΔV ~1V (best ADC performance, low self-heating)
- (c) Invert ΔV polarity and take a second measurement, to cancel parasitic thermocouple effect by averaging
Signal Integrity

- 3 Hz read out speed achievable with good signal integrity up to 40m cable length
- Double exponential decays: full discharge in $O(1s)$
**uSOP @ BEAST**

- **BEAST2** (phase 1) is a detector that has taken data at SuperKEKB Interaction Point, to study beam background *(see P. Lewiss talk)*
- **uSOP** has been used to monitor T and Rh of the 18 BEAST2 crystals (LYSO, CsI, CsI(Tl)). Data available via EPICS and cloud display (Beebotte)
- **uSOP** used also to monitor upset in FPGA exposed to beam background *(see R. Giordano talk)*
ECL backward installation

- ECL backward installed in January 2017
- uSOP monitoring connected
The ECL EndCap monitoring system

- The final monitoring system has been installed at KEK during 2016
- Forward and Backward ECL:
  - 2112 CsI(Tl) crystals, 32 sectors
  - T and Rh monitor, 128 analog channels (96 thermistors + 32 Rh probes)
- Features:
  - 3-wire read-out to cancel the 40m cable stray resistance
  - Stray thermocouple effects cancellation
  - 4 uSOP boards, 8 T controllers with 24 bit ADCs for each endcap
  - 6U, 12HP form factor, shielded
  - Selective ground scheme to avoid loops
  - Read-out and controls via network
EPICS

Experimental Physics and Industrial Control System

- EPICS ([http://www.aps.anl.gov/epics/](http://www.aps.anl.gov/epics/)) is a set of Open Source software tools, libraries and applications developed collaboratively and used worldwide to create distributed soft real-time control systems for scientific instruments such as a particle accelerators, telescopes and other large scientific experiments.

- On uSOP:
  - Straightforward compilation on ARM
  - Variety of EPICS extensions available on board:
    - ALH (ALarm Handler)
    - PV gateway
    - Asyn
    - StreamDevice
    - Autosave
  - IOCs for:
    - Linear LTC2499 (I2C)
    - Linear LTC2983 (SPI)
    - Sitara ADC (parallel)
Displaying variables

Grafana metrics dashboards
fist derivative over one week
Conclusions

• uSOP has been intensively tested at KEK, starting from Apr. 2015
• Stable and reliable LINUX platform, with uptime ≈ 2 years
• Hardware controllers for all most common serial busses
• Fully (re)configurable and managed remotely (from brick to fully functional)
• Designed to work as a stand-alone unit, yet easy to deploy in complex control infrastructures
• EPICS compliant, IOCs developed for all the needed DAQ units
The End
BACKUP
# Cortex A Cores (32bit)

| ARMv7-A | Cortex-A5[22] | Application profile, ARM / Thumb / Thumb-2 / DSP / VFPv4-D16 FRU / Optional NEON / Jazelle RCT and DBX, 1-4 cores / optional MPCore, snoop control unit (SCU), generic Interrupt controller (GIC), AC, accelerator coherence port (ACP) | 4-64 KB / 4-64 KB L1, MMU + TrustZone | 1.57 DMIPS/MHz per core |
| Cortex-A7[24] | Application profile, ARM / Thumb / Thumb-2 / DSP / VFPv4-D16 FRU / NEON / Jazelle RCT and DBX / Hardware virtualization, in-order execution, superscalar, 1-4 SMP cores, MPCore, Large Physical Address Extensions (LPAE), snoop control unit (SCU), generic interrupt controller (GIC), AC, architecture and feature set are identical to A15, 8-10 stage pipeline, low-power design[25] | 8-64 KB / 8-64 KB L1, 0-1 MB L2, MMU + TrustZone | 1.9 DMIPS/MHz per core |
| Cortex-A8[27] | Application profile, ARM / Thumb / Thumb-2 / VFPv3 FRU / NEON / Jazelle RCT and DAC, 13-stage superscalar pipeline | 16-32 KB / 16-32 KB L1, 0-1 MB L2 opt ECC, MMU + TrustZone | Up to 2000 (2.0 DMIPS/MHz in speed from 000 MHz to greater than 1 GHz) |
| Cortex-A12[23] | Application profile, ARM / Thumb-2 / DSP / VFPv4 FRU / NEON / Hardware virtualization, out-of-order speculative issue superscalar, 1-4 SMP cores, MPCore, snoop control unit (SCU), generic interrupt controller (GIC), accelerator coherence port (ACP) | 16-64 KB / 16-64 KB L1, 0-8 MB L2 opt parity, MMU + TrustZone | 2.5 DMIPS/MHz per core, 10,000 DMIPS @ 2 GHz on Performance Optimized TSMC 40G (dual-core) |
| Cortex-A15[25] | Application profile, ARM / Thumb-2 / DSP / VFPv4 FRU / NEON / Integer divide / fused MAC / Jazelle RCT / hardware virtualization, out-of-order speculative issue superscalar, 1-4 SMP cores, MPCore, Large Physical Address Extensions (LPAE), snoop control unit (SCU), generic interrupt controller (GIC), AC, 15-24 stage pipeline[26] | 32 KB w/parity / 32 KB w/ECC L1, 0-4 MB L2, L2 has ECC, MMU + TrustZone | At least 3.5 DMIPS/MHz per core (up to 4.01 DMIPS/MHz depending on implementation)[20] |
| Cortex-A17 | Application profile, ARM / Thumb-2 / DSP / VFPv4 FRU / NEON / Integer divide / fused MAC / Jazelle RCT / hardware virtualization, out-of-order speculative issue superscalar, 1-4 SMP cores, MPCore, Large Physical Address Extensions (LPAE), snoop control unit (SCU), generic interrupt controller (GIC), AC | MMU + TrustZone | |
| ARMv8-A | Cortex-A32[31] | Application profile, AArch32, NEON advanced SIMD | 8-64 KB w/optional parity / 8-64 KB w/optional ECC L1 per core, 128 KB-1 MB L2 w/optional ECC shared |
BeagleBone Black

BeagleBone Black Development Board

Key Document
- BeagleBone Black Quick Start Guide (external link)
  - BeagleBone Black System Reference Manual (external link)
- View All Technical Documents (6)

Description
BeagleBone Black is a low-cost, open source, community-supported development platform for ARM® Cortex™-A8 processor developers and hobbyists. Boot Linux in under 10 seconds and get started on Sitara™ AM335x ARM Cortex-A8 processor development in less than 5 minutes with just a single USB cable.

BeagleBone Black ships with the Debian GNU/Linux™ in onboard FLASH to start evaluation and development. Many other Linux distributions and operating systems are also supported on BeagleBone Black including:
- Ubuntu
- Android
- Fedora

BeagleBone Black’s capabilities can be extended using plug-in boards called “capses” that can be plugged into BeagleBone Black’s two 40-pin dual-row expansion headers. Capses are available for VGA, LCD, motor control, prototyping, battery power and other functionality. More information.

Visit the BeagleBone Black Support Community

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AM5728

1 Device Overview

1.1 Features

- For Silicon Revision 1.1 Information, see SPR915
- ARM® Dual Cortex®-A15 Microprocessor Subsystem
- Up to 2 C66x™ Floating-Point VLW DSP
  - Fully Object-Code Compatible With C67x™ and C64x+™
  - Up to Thirty-two 16 × 16-Bit Fixed-Point Multiplies per Cycle
- Up to 2.5MB of On-Chip L3 RAM
- Two DDR3/DDR3L Memory Interface (EMIF) Modules
  - Supports up to DDR3-1066
  - Up to 2GB Supported per EMIF
- Dual ARM® Cortex®-M4 co-processors
- IVA-HD Subsystem
- Display Subsystem
  - Full-HD Video (1920 × 1080p, 60 fps)
  - Multiple Video Input and Video Output
  - 2D and 3D Graphics
  - Display Controller With DMA Engine and up to Three Pipelines
    - HDMI™ Encoder: HDMI 1.4a and DVI 1.0 Compliant
- 2x Dual-Core Programmable Real-Time Unit and Industrial Communication Subsystem (PRU-ICSS)
- 2D-Graphics Accelerator (BB2D) Subsystem
  - Vivante™ GC320 Core
- Video Processing Engine (VPE)
- Dual-Core PowerVR SGX544™ 3D GPU
- Cryptographic Accelerators
  - AES, SHA, RNG, DES and 3DES
- Three Video Input Port (VIP) Modules
- General-Purpose Memory Controller (GPMC)
- Enhanced Direct Memory Access (EDMA) Controller
- 2-Port Gigabit Ethernet (GMAC)
- Sixteen 32-Bit General-Purpose Timers
- 32-Bit MPU Watchdog Timer
- Five Inter-Integrated Circuit (I2C) Ports
- HDC™/1-Wire® Interface
- Ten Configurable UART/IRDA/CIR Modules
- Four Multichannel Serial Peripheral Interfaces (MCSIps)
- Quad SPI Interface (QSPI)
- SATA Gen2 Interface
- Multichannel Audio Serial Port (MCASP)
- SuperSpeed USB 3.0 Dual-Rolo Device
- High-Speed USB 2.0 Dual-Rolo Device
- PCIe Express® 2.0 Subsystems With Two 5-Gbps lanes
  - One 2-lane Gen2-Compliant Port
  - or Two 1-lane Gen2-Compliant Ports
- Dual Controller Area Network (DCAN) Modules
  - CAN 2.0B Protocol
- Up to 247 General-Purpose I/O (GPIO) Pins
- Power, Reset, and Clock Management
- On-Chip Debug With GDB Technology
- 28-nm CMOS Technology
- 23 mm × 23 mm, 0.8-mm Pitch, 760-Pin BGA (ABG)

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Beagleboard X15

BeagleBoard-X15

Sign up below for notifications of availability and approved distributors to place orders. Check the wiki for the latest production update. If you need a board right away and don’t care about FCC/ICE compliance, you can get an early version of X15 as the processor module of the AM5728 EVM.

What is BeagleBoard-X15?

BeagleBoard-X15 is the top performing, mainline Linux enabled, power-users’ dream board with a core tailored for every computing task and a highspeed interface for every connectivity need. Give your algorithms room to stretch!

Processor: TI AM5728 2×1.5-GHz ARM® Cortex-A15

- 2GB DDR3 RAM
- 4GB 8-bit MMC on-board flash storage
- 2D/3D graphics and video accelerators (GPMs)
- 2×700-MHz C66 digital signal processors (DSPs)
- 2×ARM Cortex-A4 microcontrollers (MCUs)
- 4×32-bit programmable real-time units (PRUs)

Software Compatibility

- Debian
- Android
- Ubuntu
- Clouds: DE on Node.js
- plus much more

Connectivity

- 2xGigabit Ethernet
- 3xSuperSpeed USB 3.0 host
- HighSpeed USB 2.0 client
- eSATA (500mA)
- full-size HDMI video output
- microSD card slot
- Stereo audio in and out
- 4×60-pin headers with PCIe, LCD, mSATA
- and much more...

Register your interest
3-WIRE READOUT

3-WIRE SENSOR w/DUAL MATCHED CURRENT EXCITATION. CONVERTS WITH A SINGLE DIFFERENTIAL MEASUREMENT. ADSELF-COMPENSAmates FOR MATCHED +/- LEAD RESISTANCES.