A Service-Oriented Platform for Embedded Monitoring Systems in Belle II Experiment

F. Di Capua[1,2(✉)], A. Aloisio[1,2], F. Ameli[3], A. Anastasio[2], P. Branchini[4], R. Giordano[1,2], V. Izzo[2], and G. Tortone[2]

[1] University of Naples "Federico II", Via Cinthia, 80126 Naples, Italy
[2] INFN, Sezione di Napoli, Via Cinthia, 80126 Naples, Italy
dicapua@na.infn.it
[3] INFN, Sezione di Roma, Piazz.le A. Moro, 00100 Rome, Italy
[4] INFN, Sezione di Roma Tre, Via della Vasca Navale, 00100 Rome, Italy

Abstract. uSOP is a general purpose single board computer designed for deep embedded applications in control and monitoring of detectors, sensors, and complex laboratory equipment. In this paper, we present its deployment in the monitoring system framework of the ECL endcap calorimeter of the Belle2 experiment, presently under construction at the KEK Laboratory (Tsukuba, Japan). We discuss the main aspects of the hardware and software architectures tailored on the needs of a detector designed around CsI scintillators.

Keywords: Embedded control system · Microprocessor · Detector monitoring

1 Introduction

uSOP is a Service Oriented Platform, designed for embedded applications, including the monitor of complex experiments. The system is based on the high performance ARM processor core Sitara AM335x [1] family of Cortex-A8 SoC produced by Texas Instruments.

The uSOP design is a derivative of BeagleBone [2], designed by the BeagleBoard.org Foundation [3], which promotes open source development of ARM-based single board computers for embedded applications.

uSOP board [4] adopts a Sitara AM3358 microprocessor with up to 512 Mbyte RAM and 4 Gbyte Flash. Host and device USB ports are foreseen for an easy connection of peripherals and host units. The most used serial busses, like SPI, I2C and JTAG, are galvanically isolated. A 10/100 Ethernet port is also available for networking. An independent network module Lantronix Xport Pro [5].

This last element allows the user flashing the operating system and uploading the bootloader. As operating system, we have chosen the Debian Linux distribution, version 7, with a kernel release 3.x (Fig. 1).

Z.-A. Liu (Ed.): TIPP 2017, SPPHY 212, pp. 54–57, 2018.
https://doi.org/10.1007/978-981-13-1313-4_12

Fig. 1. The uSOP board in a 3-slot minicrate

2 uSOP Operations in Belle II Experiment

The Belle II [6] experiments has been designed to investigate the CP-violating asymmetries in rare B mesons, the elements of CKM matrix and to perform dedicated searches of new physics in the dark sector.

Belle II will operate at the SuperKEKB [7] electron-positron asymmetric collider (KEK, Tsukuba, Japan). The new collider will give an instantaneous luminosity (of the order of 10^{35} cm^{-2} s^{-1}) a factor of 40 higher than the former KEKB.

The applications of uSOP system in Belle II environment will be described in the following.

2.1 Belle II Electromagnetic Calorimeter Monitoring

The Belle II Electromagnetic Calorimeter (ECL), inherited by Belle [8], consists in a barrel 3 m long with an inner radius of 1.25 m and two annular endcaps, named forward and backward.

The ECL barrel 8736 CsI(Tl) scintillating crystals, which main characteristics are high light yield and short radiation length. The two endcaps are made of 2112 CsI(Tl) crystals, distributed in 32 sectors.

CsI(Tl) crystal light yield variations as function of temperature has been found to be 0.3%/°C at 20 °C [9], in addition CsI crystals are hygroscopic and will not tolerate exposure at high humidity levels [10]. In order to measure the environmental parameters, each sector is equipped with three Semitec AT-2 thermistors [11] and an active Vaisala HMP60 humidity probe [12].

uSOP system has been used to acquire and process data from environmental monitors. For this application, a specific temperature and humidity controller based on the LTC2983, a SoC with 24-bit ADCs [13], has been developed.

The measurement sequence has been implemented on the controller in order to find the best excitation current for the thermistors, then the optimal ADC dynamic range and, eventually, to subtract the parasitic thermocouple effects. Two controllers have been connected to uSOP through SPI, each of them monitoring two calorimeter sectors.

During Belle shutdown, in 2010, the two endcap wheels have been dismounted and placed at rest for electronic upgrade. In order to monitor CsI crystals during the long shutdown, their environmental parameters have been acquired by an uSOP system. Reading four over 32 sectors of two endcaps. During this period, the system has been fully tested and debugged. For about two years, it operated continuous, running unattended acquisition tasks and exporting data samples and plots on the web.

At beginning of 2017, the backward ECL endcap has been installed in the Belle II detector. In the slow-control framework, temperature and relative humidity of the two endcaps (forward and backward) are monitored by a uSOP-based system: 96 thermistors and 32 humidity probes, placed in the forward and backward sectors, are sampled.

A uSOP board can control up to four calorimeter sectors. Therefore, in order to monitor a full ECL sector, four uSOP boards are housed in a 19-in. 6U Eurocard crate (Fig. 2).

Fig. 2. uSOP in the rack of the Electronic Hut in Tsukuba experimental hall at KEK.

The monitored parameters are transferred by uSOP via Ethernet, according to the EPICS protocol, and they are archived and plotted by CS Studio.

2.2 uSOP Application in Beast II

The successful operations of Belle II experiment, given the increased designed luminosity of the SuperKEKB collider, depends critically on the amount of background processes. Aiming at a better knowledge of principal background contributions, a dedicated experiment, called BEAST II [14], has been carried out. In the Phase 1 of BEAST II, a suite of beam background detector systems were installed around the

interaction point. A measurement of the dose rate in real-time was performed by PIN diodes, positioned in several experimental locations; for the measurement of the neutron fluxes, a detection system based on TPCs was deployed; the high-level dose rate close to the interaction point was measured by diamond sensor. He3 tubes were used for detection of thermal neutrons. In addition, some calorimeter modules made by BGO crystals and Plastic Scintillators were also deployed.

BEAST contained also a calorimeter six calorimeter modules based on three scintillating crystals: Thallium-doped Caesium Iodide (CsI(Tl)), pure Caesium Iodide (CsI) and Cerium-doped Lutetium Yttrium Orthosilicate (LYSO). In order to monitor temperature and humidity of such modules, a uSOP system was used to acquire and publish the data.

3 Conclusions

uSOP is a Service Oriented Platform actually in use in Belle II experiment for monitoring of the environmental temperature and humidity of CsI crystal scintillators. uSOP can be fully managed remotely including critical operations like bootloader and operating system uploads. The platform has shown to be a resilient and reliable solution for high-energy physics experiment.

References

1. Sitara™ AM335x Processors, Texas Instruments. http://www.ti.com/lsds/ti/processors/sitara/arm_cortexa8/am335x/overview.page
2. BeagleBoard Black. https://beagleboard.org/black
3. About BeagleBoard.org and the BeagleBoard.org Foundation. http://beagleboard.org/about
4. Aloisio, A., et al.: uSOP: a microprocessor-based service oriented platform for control and monitoring. IEEE TNS **99**, 1 (2017)
5. XPort Pro Embedded Device Server User Guide, Lantronix. https://www.lantronix.com/wp-content/uploads/pdf/900-560e_XPort_Pro_UG_release.pdf
6. Abe, T., et al.: Belle II Technical Design Report. arXiv:1011.0352 [physics.ins-det]. https://arxiv.org/abs/1011.0352
7. Ohnishi, Y., et al.: Accelerator design at SuperKEKB. PTEP **2013**, 03A011 (2013)
8. Abashian, A., et al.: The Belle detector. NIM A **479**, 117–232 (2002)
9. Zhu, R.-Y.: Precision crystal calorimetry in high energy physics. Nucl. Phys. B (Proc. Suppl.) **78**, 203 (1999)
10. Chen, R.-F., et al.: Property measurements of the CsI(Tl) crystal prepared at IMP. Chin. Phys. C **32**, 2 (2008)
11. Semitec Corp., High Precision Thermistor, AT Thermistor
12. Vaisala, Users's Guide Vaisala Humidity and Temperature Probes HMP60 and HMP110 Series
13. LTC2983 - Multi-Sensor High Accuracy Digital Temperature Measurement System. http://www.linear.com/product/LTC2983
14. BEAST II Technical Design Report DRAFT For use in US Belle II Project TDR. https://indico.phys.hawaii.edu/getFile.py/access?contribId=1&resId=0&materialId=slides&confId=469