EMBEDDED ENVIRONMENT WITH EPICS SUPPORT FOR CONTROL APPLICATIONS

Y. S. Cheng, Demi Lee, C. Y. Liao, C. H. Huang, K. T. Hsu
National Synchrotron Radiation Research Center, Hsinchu 30076, Taiwan

Abstract

System on a chip (SoC) is widely used in embedded environment. Current generation SoC commercial products with small footprint and low-cost have powerful in CPU performance and rich interface solution to support many control applications. To deal with some embedded control applications, the "Banana Pi" which is a card-size single-board computer and runs Linux-based operation system has been adopted as the EPICS IOC to implement several applications. The efforts for implementing are summarized in this paper.

INTRODUCTION

Using a circuit board to implement functions as a computer is called SBC (single-board computer) [1]. Its applications cover in telecommunications, industrial control, blade and high density servers, and lately laptops and mini-PCs, etc. Thanks to latest generation SoC technology, putting all major functionality into an integrated chip, educational used credit-card size SBC [2] likes the Raspberry Pi (RPi) and BeagleBone Black (BBB) are highly successful products. The Banana Pi (BPi) is the latest product of such category with powerful CPU, low power consumption SBC indeed, and the area of circuit board is only as credit card size.

The Banana Pi which design idea is similar to the RPi-style SBC, and it is a fork of the RPi project using different components while maintain compatibility as much as possible. Moreover the Banana Pi is added the functions of SATA interface, infrared transmission, microphone, USB-OTG ports, power button, reset button, etc. Then the BPi has 26-pin/40-pin GPIO which is compatible with the RPi. The A20/31 SoC as CPU/GPU, 1GB DDR3 memory and Gigabit Ethernet connection are applied on the Banana Pi. The hardware specification of Banana Pi is shown as Table 1 [3-4]. Linux-based OS can be worked well on the Banana Pi.

Table 1: Hardware specification of the Banana Pi

	Banana Pi M1/M1+/M2
CPU	A20 ARM Coretx-A7 1GHz Dual-Core A31S ARM Coretx-A7 1GHz Quad-Core
Memory	1GB DDR3 DRAM
Network	1Gbps Ethernet RJ45, Wi-Fi
Storage	SD card slot (up to 64GB), Extensible with SATA interface
I/O	GPIO, UART, I2C bus, SPI bus with two chip selects, CAN bus, ADC, PWM, +3.3V, +5V, GND
OS	Debian, Bananian, Lubuntu, Android ...

The EPICS (Experimental Physics and Industrial Control System) [5] is a set of open source software tools, libraries and applications developed collaboratively and used to create distributed soft real-time control systems for scientific instruments such as particle accelerators. Many facilities have good practical experiences for the EPICS and adopt it as accelerator control systems. Many resources and supports are available as well as numerous applications for accelerator have been developed.

The TPS (Taiwan Photon Source) control system of 3 GeV synchrotron light source is also based on the EPICS framework [6]. The EPICS toolkit provides standard tools for display creation, archiving, alarm handling, etc. The big success of EPICS is based on the definition of a standard IOC (Input Output Controller) structure together with an extensive library of driver software for a wide range of I/O cards. The EPICS framework which has various functionalities is employed to monitor and to control on embedded applications of accelerator system.

BANANA PI AS EPICS IOC

The stability and performance of Banana Pi is enough as the EPICS IOCs for specific control applications. The EPICS framework can be built on the Linux-based Banana Pi successfully [7]. At the TPS project, some control functions, such as frequency divider, direct digital synthesizer, radiation-sensing reader, alarm announcer, etc., are implemented by use of the Banana Pi platforms with EPICS support. The efforts for implementing are summarized as followings.

Software Architecture

To implement the Banana Pi as the EPICS IOC for specific control applications, the EPICS base and modules are necessary to be set up on the Banana Pi platform which operation system can be the Debian or Ubuntu Linux. The device driver of SPI (Serial Peripheral Interface) bus is built for communicating with DAC/ADC modules, and the device support interface is also developed as the glue between the EPICS records and device drivers. The EPICS records support with databases are created according to the specific functions. The application module, such as “autosave” function, is installed for logging setting parameters values and recovering last setting parameters values automatically when the IOC is start-up. Based on the EPICS PV (Process Variable) channel access, the archive server is set up to record various parameters variations for long time observation, and the PHP webpage can be developed to show the status information. At the client console side, the operation interfaces are created by used of the EDM, CS-Studio, etc. to control and monitor via EPICS PV channel

ISBN 978-3-95450-148-9

access, and the archived data can be retrieved with using a form of graphical representation of the CS-Studio based data browser. The schematic is shown as Fig. 1.

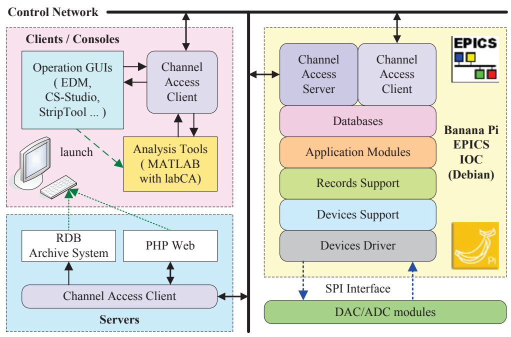

Figure 1: Software architecture of the Banana Pi with EPICS support.

Programmable Frequency Divider

Machine clock of the accelerator system generated discrete fast logic chip (ECL/PECL) or combined of fast logic and field programmable logic array (FPGA) usually. Typical jitter is in a few picoseconds order. The programmable clock generator has been implemented by using the AD9508 clock and delay generator to generate clock with 100 femtosecond jitter for some applications (laser clock, filling pattern measurement timing, etc.). The system schematic is shown as shown in Fig. 2. The chip divider and delay parameters can be controlled by use of the Banana Pi EPIC IOC via SPI interface. The implementation is shown as in Fig. 3.

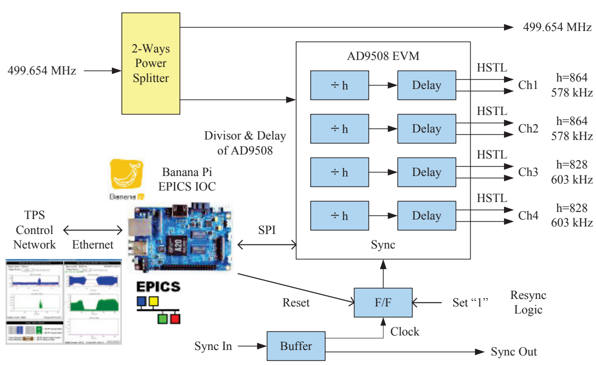

Figure 2: Block diagram of the programmable clock generator.

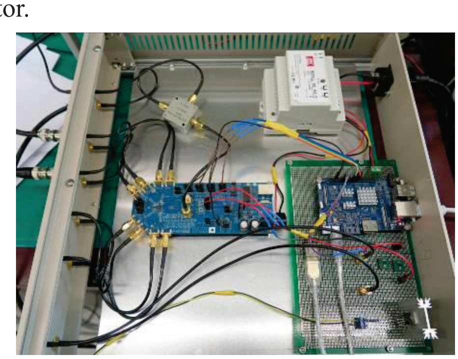

Figure 3: Photo of frequency divider unit for the TPS filling pattern measurement timing.

Direct Digital Synthesizer Control

To make possibility of different RF frequency without a similar multiplication factor (six) work for linear accelerator (Linac) and booster synchrotron to optimize machine performance without adjust too many parameters in Linac system, a RF signal generator direct digital synthesizer (DDS) which can synchronize at injection instance have been implemented. Functional block diagram of the prototype is shown in Fig. 4. The Banana Pi EPICS IOC is used to control the DDS to achieve goal. Synchronization is achieved to reset the phase of the DDS just before booster synchrotron injection to ensure constant phase relationship between RF system of Linac and booster synchrotron. Figure 5 shows the prototype DDS signal generator.

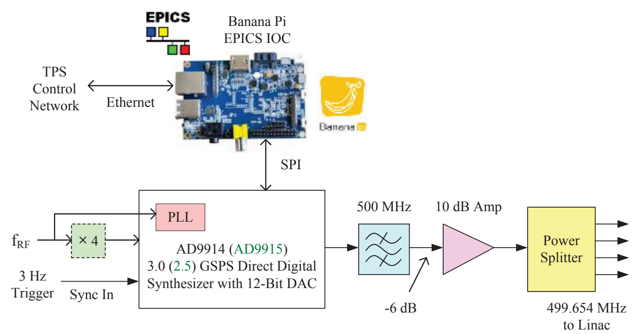

Figure 4: Block diagram of the direct digital synthesizer control.

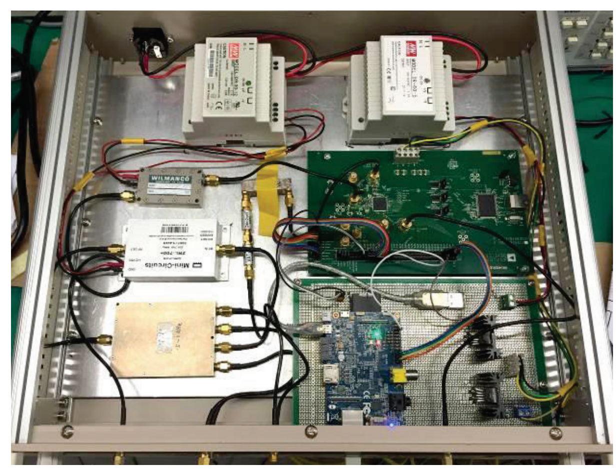

Figure 5: Photo of the prototype DDS signal generator.

RadFET Reader

To investigate the beam loss and its distribution during commissioning and operation phases of TPS and TLS, a sixteen-channel readout box was initially designed and implemented to read the threshold voltage of the RadFETs (radiation-sensing field-effect transistor) which were installed at accelerator tunnel [8]. The initial version design was that the reader plays a role of remote I/O for the EPICS IOC and the IOC collects voltage from readers distributed at the accelerator to deduce the integrated dose and dose rate.

ISBN 978-3-95450-148-9

The next version design is that the EPICS IOC will be embedded into the RadFET reader box. The Banana Pi will be also adopted as the EPICS IOC for collecting the threshold voltage of the sixteen-channel RadFETs. The data transmission time between the IOC and SPI bus with ADC modules will be improved.

The EPICS IOC performs data acquisition, calculation, and publishes the specific EPICS PVs of dosage. Dosage rate is calculated by the EPICS record processing. All of the threshold voltage values based on the EPICS PVs channel access can be recorded into the archive server for further off-line data processing. The MATLAB toolkit can be also used to analyze the RadFET threshold voltage archived data which retrieved from the RDB archive system directly. The control system also provides on-line display for virtualization usage. The system schematic of RadFET reader is shown as Fig. 6. The test prototype of RadFET reader with the Banana Pi EPICS IOC is shown as Fig. 7.

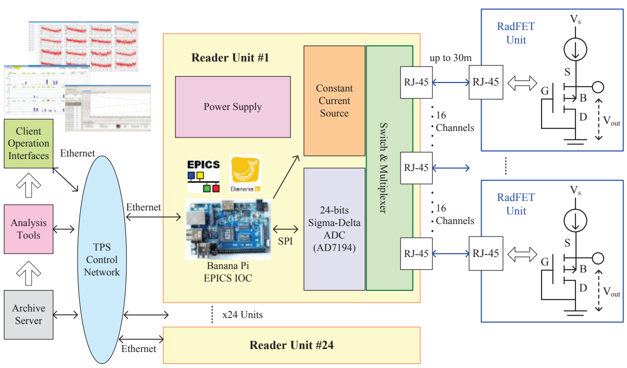

Figure 6: Block diagram of the RadFET readers system.

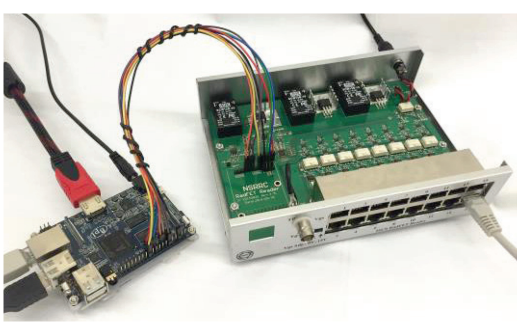

Figure 7: Photo of the prototype 16 channels RadFET reader with Banana Pi EPICS IOC.

Alarm Announcer

During the TPS commissioning and operation phases, the abnormal status may occur from one of sub-systems, and operators need to find out which sub-system problem happened from machine interlock interface. Due to many interlock signals need to be noticed, the sum signals of each interlock signals are necessary. According to the sum signals, the specific alarm message to be trigged and shown, and the Banana Pi is used as the EPICS IOC to receive the request and send alarm announcement sound to loud speaker for noticing. The system schematic is shown as Fig. 8.

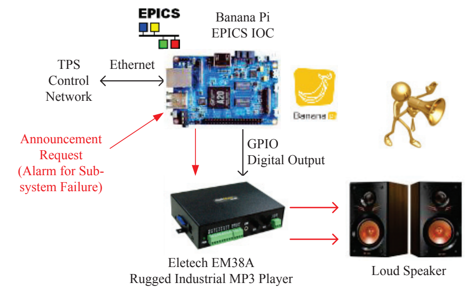

Figure 8: Block diagram of alarm announcer.

BEAGLEBONE BLACK APPLICATIONS

Vibration monitoring and voltage signal monitoring play an important role in the accelerators system for beam stability characterization. A commercial product DT7837 was adopted for this purpose. This device is a high accuracy dynamic signal acquisition module for vibration, and voltage signal measurements by the BeagleBone Black SBC [9]. Four 24-bit voltage input or IEPE sensor input data can be algorithmically processed in real time and the results presented to a host for analysis. Support of Linux-based OS and software development kit includes numerous components help the development. The EPICS is installed into the DT8837 for integration and data access. Synchronization interface is easy to integrate with accelerator timing system. Coherent data acquisition is under implementation.

CURRENT STATUS

Low cost credit-card size SBC is widely adopted for educational purpose and also suitable for small scale embedded applications. The BPi and BBB are chosen for several applications at the TPS control environment as auxiliary supports which are not suitable to use standard platform in existed control system due to economics, simplicity, speciality view points. More applications will be explored and implemented in near future.

REFERENCES

[1] Single-board computer website: https://en.wikipedia.org/wiki/Single-board_computer
[2] Educational single board computer website: http://edutechwiki.unige.ch/en/Educational_single_board_computer
[3] Banana Pi website: http://www.banana-pi.org
[4] Banana Pi website: https://en.wikipedia.org/wiki/Banana_Pi
[5] EPICS website: http://www.aps.anl.gov/epics/
[6] C. Y. Liao, et al., “Commissioning of the TPS Control System”, FRB3O01, these proceedings, ICALEPCS’15, Melbourne, Australia (2015).
[7] EPICS Pi website: http://prjemian.github.io/epicspi/
[8] D. Lee, et al., “Online RadFET Reader for Beam Loss Monitoring System”, MOPTY070, Proceedings of the IPAC’15, Richmond, USA (2015).
[9] DT7837 website: http://linuxgizmos.com/signal-analyzer-runs-linux-on-beaglebone-black-like-core/

ISBN 978-3-95450-148-9