DEVELOPMENT OF EMBEDDED EPICS ON F3RP61-2L

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Abstract

Accelerator control systems based on Experimental Physics and Industrial Control Systems (EPICS) [1] adopt many Programmable Logic Controllers (PLCs) these days. They are supervised by Input/Output Controllers (IOCs) being controlled and monitored through Ethernet connections. In this type of control systems, having controllers (PLCs) under yet another controller (IOC) doubles the workload for the implementation of the front-end software. In order to solve the problem by replacing ladder programs with EPICS sequencer programs, we developed an embedded EPICS system on F3RP61-2L [2], a new CPU module running Linux which can function with a base module and I/O modules of FA-M3 PLC. We found that the IOC program can run without any modifications on the CPU module. This paper describes the new type of IOC for the control systems for accelerators in operation and under construction.

INTRODUCTION

Control systems of modern accelerators, such as RIBF at RIKEN, KEKB and J-PARC at KEK adopt many PLCs. They are connected with IOCs through Ethernet connections like other devices such as oscilloscopes. The adoption of PLCs, as a result, introduced two layers of front-end controllers (PLCs and IOCs). Since autonomy and independence are required for the front-end controllers, the most of control logics need to be implemented on the PLC, leaving the IOC just a protocol converter between EPICS Channel Access (CA) and the company's proprietary communication protocols. This solution is not cost-effective, since the development and maintenance of ladder programs cost us more than those of EPICS application programs do. In addition, the cost of learning both ladder programs and EPICS became a serious burden for programmers. It is more cost-effective to run EPICS on the PLC CPUs to make PLCs themselves IOCs with replacing ladder programs with EPICS sequencers.

F3RP61-2L AS IOC

Recently, PLC CPUs with real-time Operating System (OS), in which application can be developed in C/C++ language, are available on the market. They can be possible candidates for "the IOC on the PLC-bus". Among those, we chose F3RP61-2L, a new CPU module of FA-M3 PLC running Linux. Table 1 lists main specifications of the CPU module, and Figure 1 shows a PLC system with the CPU module for J-PARC controls.

Table 1: Main Specifications of F3RP61-2L

Item		F3RP61-2L
CPU		MPC8347E (PowerPC), 533MHz
OS		Linux 2.6.24.3-based
Memory	FLASH ROM	64MB
	DDR2 SDRAM	128MB
	SRAM	512KB
	User SRAM	4MB
I/F	Ethernet	100BASE-TX (2ch)
	RS-232C	9.6kbps ~ 115.2kbps
	IEEE1394	IEEE1394a
	CF	TYPEII
	JTAG	Special 10pin connector
	PCI	For utility modules
RAS Support		Watch dog timer etc.

Simplification of Device/Driver Modules

The kernel level driver to access I/O modules of FA-M3 PLC, the Board Support Package (BSP), is supplied by the PLC company with the CPU module. EPICS device/driver modules can be implemented on the driver by just wrapping the APIs (system calls) of the driver. An EPICS device support module supports an I/O through a specific input/output relay or a register of a module. Features of the I/O module are expressed not in the device support but in a set of EPICS records. Therefore, there is no need to add device support modules when we introduce a new I/O module of FA-M3 PLC. These features make maintenance works very simple.

Efficient Development of Applications

Using Linux, there is no need to reboot the system upon a modification of the application, since it suffices only to kill a process and execute it again after the modifications. This feature makes application development cycle shorter compared with other operating systems.

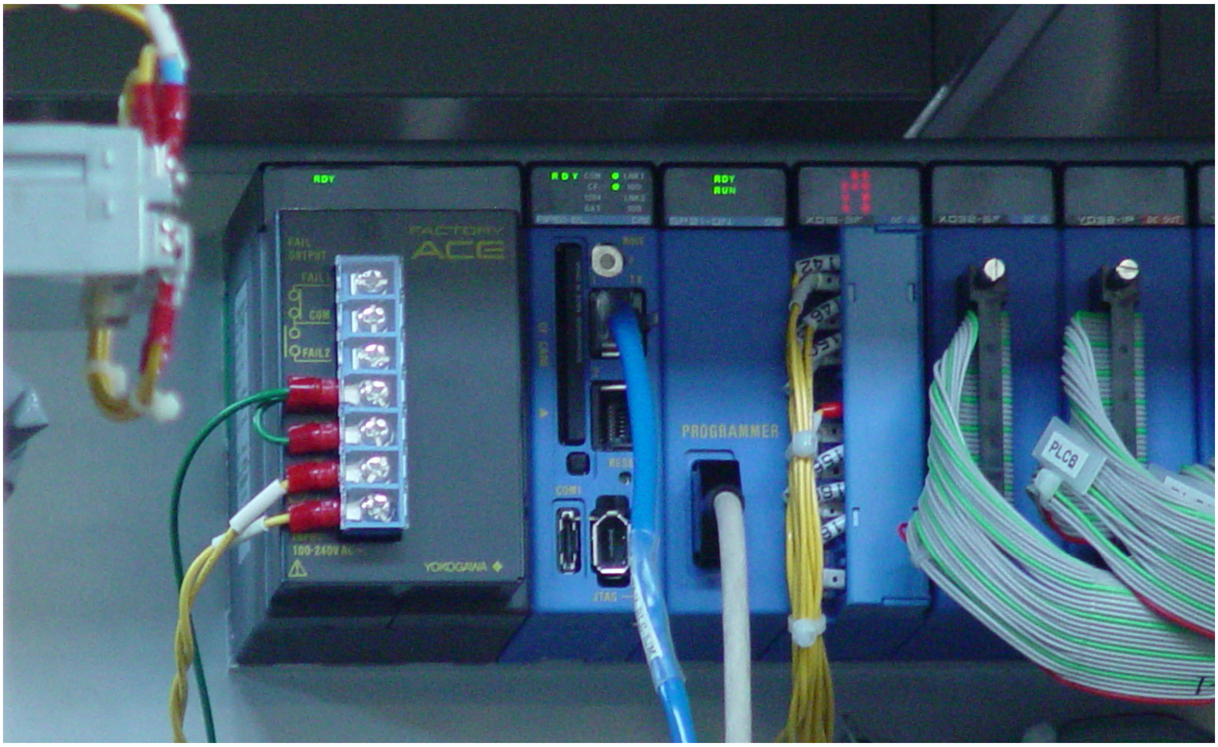

Figure 1: F3RP61-2L (the second left most module) serving as an EPICS IOC to control a septum magnet power supply for J-PARC Main Ring slow extraction

Another point which enhances application development is to use EPICS sequencer instead of ladder programs. Beside very simple logic such as moving values read from input contacts onto output contacts with taking AND/OR, EPICS sequencer programs are easier to read and write, compared to ladder programs. This feature boosts the development of applications significantly if the developer uses a powerful text-based editor such as Emacs.

Fully Open Source System

The BSP to access PLC I/O modules includes target dependent part of the Linux kernel and I/O drivers. The source code of them is available under General Public Licence (GPL). Together with EPICS, which is distributed under EPICS Open Licence, a fully open system can be realized on the product. The users can investigate the source code from the top to the bottom through all the layers of the software running on the CPU if necessary. It also allows us to use some patches for hard real-time extension of the Linux kernel.

Combination with Sequence CPU

A F3RP61-2L can be used together with a conventional Sequence CPU running ladder program side by side. This feature is important from the two reasons.

Firstly, real-time response of Linux is limited. Even though the pre-emption option of Linux kernel 2.6 is enabled in the default kernel configuration, it can not ensure definite worst case latency. Therefore, we sometimes need to rely on ladder programs running on a Sequence CPU if a miss of deadline causes a fatal result. This may be the case when the PLC serves for a machine protection system.

Secondly, EPICS IOCs are supposed to be logged in by developers at any time. They might stop an IOC by mistake. If an application concerns critical safety interlocks, especially for human protection, it is more appropriate to implement them by ladder programs on a Sequence CPU so that they are free from human errors at run-time.

BUILDING IOC SOFTWARE

Development Environment

The PLC company provides Embedded Linux Development Kit (ELDK) for F3RP61-2L, which assumes Red-Hat-based Linux distributions. It provides cross compilation feature for the PowerPC-based target such as F3RP61-2L. The BSP, also provided by the company, includes a build tool chain for the PowerPC-based target. We have used PCs with CentOS 4.6 and Scientific Linux 4.3 to develop our embedded EPICS systems.

Building IOC Core Program

In order to build the IOC core program of EPICS Base for F3RP61-2L, we added a few configuration files and modified some existing configuration files. We followed the standard procedures of EPICS Base implementation to add a new target. We found that the IOC core program can be built and run on F3RP61-2L without any modifications in the source code.

Implementation of Device/Driver Support

As mentioned above, there is nothing special to implement EPICS device/driver support modules. We have implemented a driver support module and device support modules to support analog input/output, binary input/output, long input/output, string input/output and multi-bit binary input records.

Building and Testing EPICS Sequencer

Since the main goal of our embedded EPICS on F3RP61-2L is to replace ladder programs by EPICS sequencer programs, it is important to confirm that EPICS sequencer programs run stably on F3RP61-2L. We tested basic function of EPICS sequencer by running a test program. It accesses digital input and digital output modules, connecting the channels each other to make a loopback circuit, to change On/Off status at 10 Hz. We found that the test sequencer program run stably at least a period of a hundred hours.

APPLICATIONS

Encouraged by successful results, some pieces of embedded EPICS system with a F3RP61-2L and I/O modules (hereafter PLC-IOC) have been introduced in accelerators at RIKEN and KEK.

RIBF at RIKEN

A PLC-IOC has adopted to control inserting and extracting some Faraday cups in the injector linac of RIBF. The Faraday cups had been controlled by a dedicated motor controller connected to the motor drivers, and by an operation panel (hardware) using metal cables. By replacing an operation panel with a PLC-IOC, operators can access to the controller over the network. It also allows operators to log the controller data automatically by computers.

KEKB at KEK

Two PLC-IOCs have been adopted and being under test for: 1) motion control of a mask in a vacuum chamber to cut synchrotron radiation, and 2) power supply control for pulse quadrupole magnets. EPICS sequencers were developed and implemented for both. A problem was found in the behaviour of the sequencer program for the case 1), however, it was solved by disabling the compiler optimization. While the case 2) is still under implementation, and will be completed soon..

J-PARC at KEK

The slow extraction devices of J-PARC Main Ring mainly relies on PLC-IOCs. They are used to control: 1) power supplies for electrostatic septa and magnetic septa , and 2) motion control of some of the septa and beam profile monitors. Up to now, we have evaluated a PLC-IOC for a power supply of one of those septa, and found that there is no problem (Figure 1). While the test with the motion control has not yet done. There may be no risk in the case 2), since almost same application for motion control has been established at KEKB.

FUTURE PLAN

The only limitation of the F3RP61-2L as an IOC is that real-time response stays at a soft real-time level of Linux. We plan to extend the kernel to support hard real-time by applying a real-time patch such as Real-Time Application Interface (RTAI) [3] in the future.

CONCLUSIONS

A new type of embedded EPICS was realized on F3RP61-2L, a PLC-module-type CPU running Linux. The F3RP61-2L enabled us to implement EPICS device/driver software in a PLC system. It also allows us to develop application programs more efficiently than before.

Some embedded EPICS system with F3RP61-2L have been introduced in accelerators at RIKEN and KEK. We have experienced that new technology has boosted up our application development very much. Stability in the long-term operation is proven in the foreseeable future.

REFERENCES

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