DEVELOPMENT OF A PC/104-PLUS-BASED CPU MODULE WITH POWER OVER ETHERNET CAPABILITY

M. Ishii[#], T. Masuda, T. Ohata, R. Tanaka, JASRI/SPring-8, Hyogo, Japan

Abstract

We have been installing a VMEbus system in the equipment control system of SPring-8 as a main stream. On the other hand, we need a compact control system to handle a few I/O signals or a few motor axes. To construct a low-cost portable system that is easy to set up, we developed a PC/104-Plus-based CPU module with Power over Ethernet (PoE, IEEE 802.3af) capability. It is based on a Renesas Technology SH-4 CPU, which is used for embedded applications requiring both high performance and low power consumption. We ported a Linux 2.6 kernel to the CPU module and set it up to run on the diskless environment of NFSroot. By stacking a dedicated PoE power module onto the CPU module, it runs without an external power supply. The PoE capability provides the advantages of reduced use of power cable and remote power management via power sourcing equipment such as a switching hub. We can choose stackable PC/104 or PC/104-Plus peripheral I/O modules from a variety of commercial products such as analog inputs and outputs or digital inputs/outputs. Therefore, we can assemble a flexible, compact and low-cost embedded-measurement instrument. As a first application, we plan to apply the CPU module to a precise analog-signal measurement. We report the effect of the PoE power source on the precision of measurement.

INTRODUCTION

In SPring-8, the VMEbus system is the core system used to control the accelerators and beamlines. Many VMEbus computers have been set up around the large facility site. One of the advantages of the VMEbus system is that it can be used to construct a flexible control system by combining many VME modules. However, in some situations it is necessary to handle a few I/O signals or a few motor axes. In these cases, it is inappropriate to set up a VMEbus computer with a chassis in a 19-inch rack because of the large amount of space required for installation, low portability and high cost.

To construct a flexible, compact and low-cost embedded-measurement instrument, we used a PC/104-Plus form factor. The PC/104-Plus is a standard of embedded computer supporting an ISA bus (PC/104) and a PCI bus (PC/104-Plus). The form factor size is 90.17 mm x 95.89 mm. The PC/104-Plus has no backplane, which allows modules to be stacked together like building blocks. The PC/104-Plus can be used to stack up to four peripheral modules but not a CPU module. We can choose peripheral I/O modules from a variety of commercial products.

[#]ishii@spring8.or.jp

We have been adopting PoE technology in the SPring-8 control system to have greater freedom of deployment. The IEEE 802.3af standard PoE is a technology that can be used to supply electric power to a network-connected device via an Ethernet cable. Power sourcing equipment (PSE) can supply a power of up to 15W at 48Vdc to a powered device (PD) through a cable of length 100m. By using PoE technology, we can easily install a measurement instrument without the infrastructure necessary for an AC power line. Additionally, PoE technology enables efficient remote power management via PSE such as a switching hub.

We required an embedded-computing system that is more cost-effective than a VMEbus system. We developed a new CPU module that combines both the high flexibility and the compactness of PC/104-Plus and is convenient for the rapid installation using PoE technology.

DEVELOPMENT OF MODULES

We first tried to develop an all-in-one CPU module with a PoE circuit. However we could not mount the circuit, because the PC/104 connector and the PC/104-Plus connector occupied a large area of the CPU module. Therefore, we separated the PoE circuit from the CPU module. If higher performance of the PoE is necessary, we can adopt a CPU module (ND-PC104P-SH4) by stacking a dedicated PoE power module (ND-PC104-POE) as a PD. We developed the ND-PC104-SH4 and the ND-PC104P-POE in cooperation with Nichizou Electronic Control Corporation [1].

Table 1: Specifications of ND-PC104P-SH4

Processor	SH7751R (SH-4) 240MHz
Memory	Flash ROM 16MB SDRAM 64MB (Main Memory)
Interfaces	1 x 10/100Mbps Ethernet 2 x USB 2.0 1 x RS-232C 1 x H-UDI/JTAG
Power Supply	DC +5V, -5V, +12V, -12V
Size	112.57mm x 95.89mm

CPU Module (ND-PC104P-SH4)

A CPU with low power consumption is required to support PoE. We adopted a Renesas Technology [2] SH-4 CPU. The SH-4 architecture has been introduced in the SPring-8 control system as a multi controller unit for control of the pulse motor [3] and as a temperature measurement controller with PoE capability [4] in the

accelerator control equipment. The ND-PC104P-SH4 does not require a cooling function such as a heat sink or a fan. Table 1 shows the specifications of ND-PC104P-SH4. The SH7751R processor is a 32-bit RISC microprocessor featuring a built-in PCI bus controller compatible with PCs. A boot loader, SH Initial Program Loader, is installed in a Flash ROM. Figure 1 shows a top view of the ND-PC104P-SH4. The blue part of Figure 2 shows a block diagram of ND-PC104P-SH4, which has a power circuit to allow it to receive power from an external power supply (5Vdc).

PoE Power Module (ND-PC104P-POE)

ND-PC104P-POE is a dedicated PoE power module for ND-PC104P-SH4. The module has the following features.

- The voltage received from PSE via the RJ45 connector of the ND-PC104P-SH4 is fed to a PoE module circuit (Texas Instruments [5], PTB48540AAH) on an ND-PC104P-POE through the cable connection.
- The PoE module circuit generates a voltage of 5Vdc. The DC/DC converters produce voltages of -5V, 12V and -12V.
- Each power supply voltage (5V, -5V, 12V and -12V) is provided to stacked modules via a PC/104 connector and a PC/104-Plus connector.

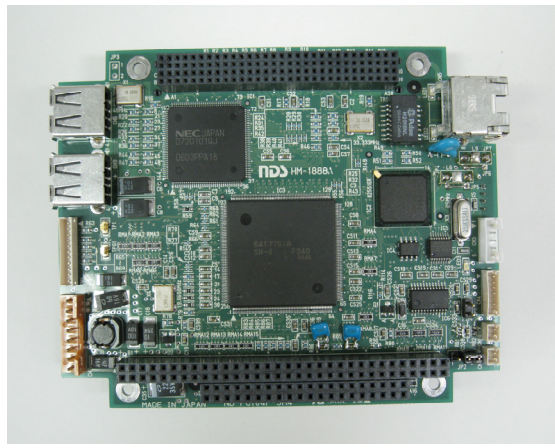

Figure 1: A photograph of an ND-PC104P-SH4. The upper connector is for PC/104-Plus. The lower connector is for PC/104.

If 5Vdc from an external power supply is provided, a switch circuit of the power source stops the output from the PoE module.

The yellow part of Figure 2 shows the power architecture of ND-PC104P-POE.

The power consumed during the system boot-up is 4.1W.

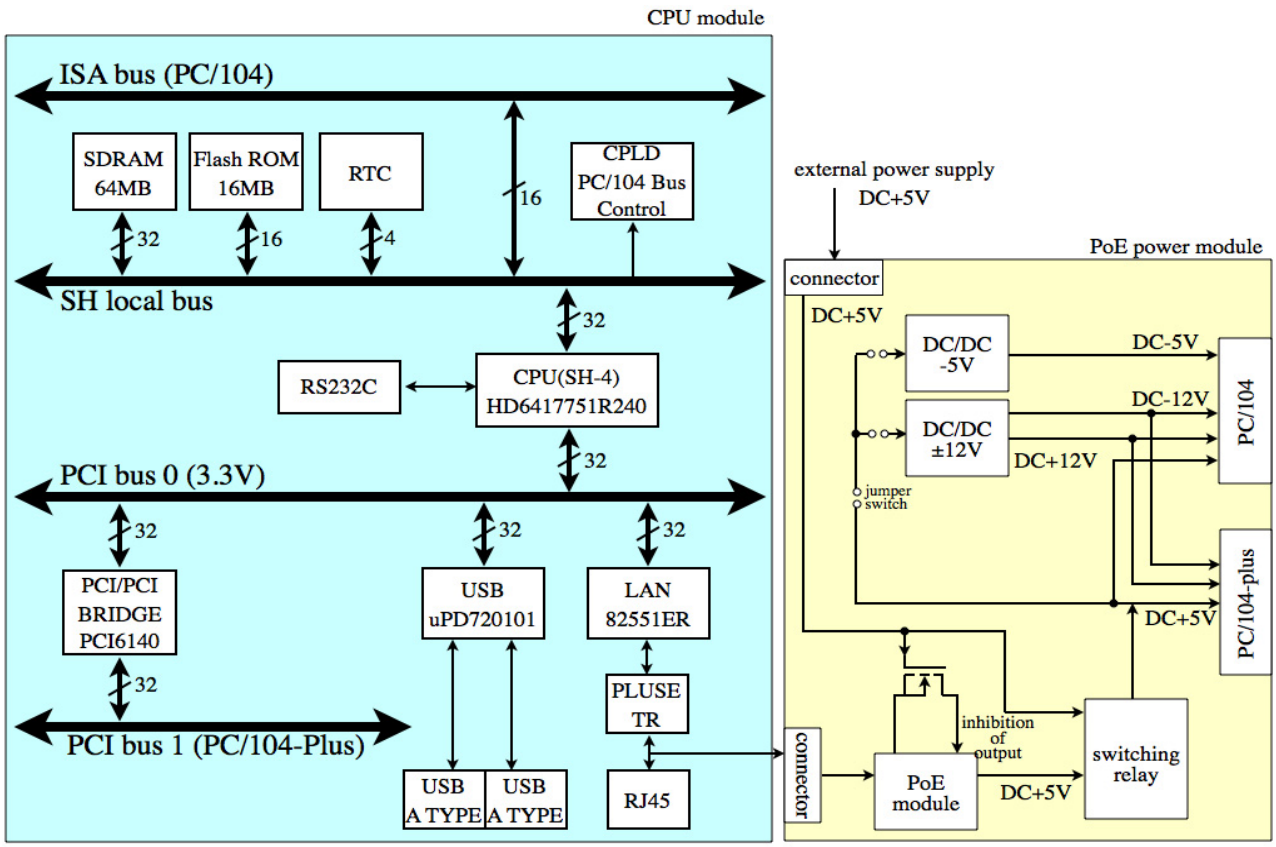

Figure 2: Block diagram of ND-PC104P-SH4 (blue part) and power architecture of ND-PC104P-POE (yellow part).

PORTING OF SH-LINUX

Generally we cannot modify an internal system of commercially available embedded instruments. We chose Linux as the embedded operating system for the ND-PC104P-SH4 for the following reasons:

- Linux supports a development environment for SH-4 architecture.
- We can use the free and wide variety of utility software developed for Linux.
- We can develop suitable applications for MADOCA, which is the SPring-8 control framework based on UNIX.
- We can tune the operating system or applications by ourselves.

To build a Linux kernel and applications for the ND-PC104P-SH4, we set up the cross development environment on Linux 2.6.24 and installed sh4-linux-gcc 3.4.4 as a compiler and glibc 2.3.5 as the standard C library for SH-4. First, we patched an SH-4 Linux package to the original Linux kernel source [6]. Next, we implemented parts dependent on the ND-PC104P-SH4 hardware such as interrupt handling and address translation handling of the memory management unit.

For the system execution environment, we constructed a diskless root file system with a network boot. An embedded instrument usually writes the operating system and applications to a storage device such as a built-in Flash ROM or a CompactFlash. By constructing an NFS root file system, we obtain the following advantages:

- We frequently recompile the kernel, drivers and applications during development and testing. It is not necessary to consider the write-cycle limitation of the storage device.
- After installation, we can modify the embedded system remotely.
- We can construct an application-rich system by mounting a large volume on a NFS server.
- There are no disks that may crash.

We successfully ported SH-Linux 2.6.16 to the ND-PC104P-SH4.

MEASUREMENT

As a practical application of ND-PC104P-SH4 we will construct a precise analog-signal measurement instrument such as a digital voltmeter. Therefore, we compared the accuracy of analog-to-digital conversion (ADC) powered through the ND-PC104P-POE with that of ADC directly input 5Vdc to the ND-PC104P-SH4. We measured two types of PC/104 ADC modules. One was a Micro/sys MPC624 [7] with a 24-bit ΔΣ ADC. The module generates the most accurate 29-bit data when the slowest sampling rate of 6.9Hz is selected. Since the input voltage range is set to +/-10.1V, 1 LSB is 3.7625×10^{-8}V. The other was a Micro Science ADM-616PC104 [8] with a 16-bit ADC and a sampling rate of 100kHz. Since the input voltage range is set to +/-10.0V, 1 LSB is 3.0517×10^{-4}V. Table 2 shows the results of measurement. For the MPC624 (low-rate sampling), we had good accuracy even if we used PoE. For the ADM-616PC104 (high-rate sampling), the accuracy decreased using PoE.

The ND-PC104P-POE mounts a DC/DC converter in a PoE module circuit to generate a voltage of 5Vdc. We consider that the switching noise from the DC/DC converter affects the ADC. If we require both high-accuracy analog-signal measurement and PoE capability, we need to carry out a filtering process such as averaging.

Table 2: Results of Measurement

		MPC624	ADM-616PC104
Direct 5Vdc power	**SD**	5.324×10^{-6}V	6.271×10^{-3}V
	Effective resolution	20 bits	10 bits
PoE	**SD**	5.862×10^{-6}V	9.832×10^{-3}V
	Effective resolution	20 bits	9 bits

SD is the standard deviation (σ). The effective resolution is 2σ.

SUMMARY

We developed a PC/104-Plus-based CPU module, ND-PC104P-SH4, which is flexible, compact and has PoE capability. We can construct an embedded-measurement instrument supporting PoE by combining ND-PC104P-SH4 and ND-PC104-POE. We successfully ported an SH-Linux 2.6 kernel to the ND-PC104P-SH4 and constructed a diskless root file system using a network boot. We compared the accuracy of ADC powered through the ND-PC104P-POE with that of ADC directly input 5Vdc to the ND-PC104P-SH4. The accuracy under the PoE condition was degraded compared with that under a direct power of 5Vdc. However, even if we use the PoE, it has high potential for use as a precise analog-signal measurement instrument by using a filtering process.

REFERENCES

[1] http://www.ndssf.co.jp/
[2] http://www.renesas.com/
[3] T.Masuda, et al., "Development of a Linux-based small-size controller using PoE technology", Proc. of ICALEPCS'05, Geneva, Switzerland, 2005
[4] T.Masuda, et al., "Development of an Intelligent Motor Control Unit with Ethernet Connectivity", Proc. of PCaPAC'05, Hayama, Japan, 2005
[5] http://www.ti.com/
[6] http://kernel.org/
[7] http://www.embeddedsys.com/
[8] http://www.microscience.co.jp/