NETWORK-BASED WAVEFORM MONITOR FOR THE J-PARC ACCELERATOR COMPLEX

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Abstract

In an accelerator control, the remote observation of waveforms is very important. We have been interested in a commercial product, WE7000 of Yokogawa, as a low-cost network-based oscilloscope. As a part of development studies of an EPICS-based control system for the J-PARC accelerator complex, we have developed three EPICS drivers for the WE7000 modules: a 100 MS/s oscilloscope (WE7111), a 100 kS/s digitizer (WE7271), and a 10MHz function generator (WE7121). This report describes the functions and performances of the EPICS drivers of the WE modules, and experimental applications of them during beam-commissioning studies at the KEK 60-MeV proton linac.

INTRODUCTION

J-PARC (Japan Proton Accelerator Research Complex) is a high-intensity proton accelerator facility, which consists of a 400-MeV linear accelerator, a 3-GeV RCS (Rapid Cycle Synchrotron), and a 50-GeV MR (Main Ring). This is a joint project between JAERI (Japan Atomic Energy Research Institute located in Tokai, Ibaraki) and KEK (in Tsukuba, Ibaraki), and the construction site is Tokai [1,2].

In the J-PARC accelerator, remote observation of beam-monitor waveforms and RF waveforms is indispensable. We have been interested in a commercial product, "WE7000", provided by Yokogawa [3]. WE7000 is a module-type measurement station (Fig.1). Among a variety of measurement modules, oscilloscopes and digitizers are provided at low cost. Three communication types with a host (usually a PC) are possible: an optic-fiber cable, an Ethernet, and a serial line.

We have studied how to use WE7000 modules as low-cost network-based waveform-monitors with our EPICS-based control system. The use of Ethernet communication is preferable from the viewpoint of the future use of optic-fiber cables against electric noise. In addition, we have developed other network-based EPICS drivers, such as PLC and EMB-LAN (a dedicated interface developed for DTL-Q power-supplies) [4,5,6].

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Figure 1: WE7000 station

EPICS DRIVER DEVELOPMENT

About EPICS

EPICS (Experimental Physics and Industrial Control System) is a software toolkit that is used to develop a distributed real-time control system for large accelerators. The development of EPICS started in ANL and in LANL in the 1990'es. It is now widely used in many accelerator institutes in the world [7]. We decided to use the EPICS toolkit for developing the control system of J-PARC [8,9].

WE7000 driver development for EPICS

Software applications and API (application interfaces) of WE7000 are commercially available by Yokogawa, but only for the Windows PC environment. We developed EPICS drivers (EPICS device supports) for three modules during fiscal year 2001: (a) 100 MS/s oscilloscope (WE7111), (b) 100 kS/s digitizer (WE7271), and (c) 10MHz function generator (WE7121). Table 1 lists the functions currently supported for the oscilloscope module (WE7111).

After fiscal year 2002, we updated the drivers occasionally. For example, we added support of the sequence synchronization (a WE7111 module informs the end of data-acquisition to a host) in April 2003.

Sample application and driver performance

As a first example, we developed a general-purpose waveform monitor with WE7111 oscilloscope modules. As shown in Fig.2, the left panel is used to control the WE7000 station parameters (for example, a time-axis selection, trigger parameters, etc.). The right panel gives controls for an individual WE7111 module with a waveform display. The GUI (graphic user interface) was

Table 1: Supported functions of WE7111

Function	Record-type	Possible values	
Waveform data-size RECLEN RECLEN_R	mbbi mbbo	0 1 2 3 4	1k 5k 10k 30k 100k
Time-axis selection TIMDIV TIMDIV_R	mbbi mbbo	0 1 2 | 15 16 17	50s 20s 10s | 500ns 200ns 100ns
Signal level selection VDIV VDIR_R	mbbi mbbo	0 1 2 | 7 8 9	5V 2V 1V | 20mV 10mV 5mV
Coupling CPLNG CPLNG_R	mbbi mbbo	0 1 2	AC DC GND

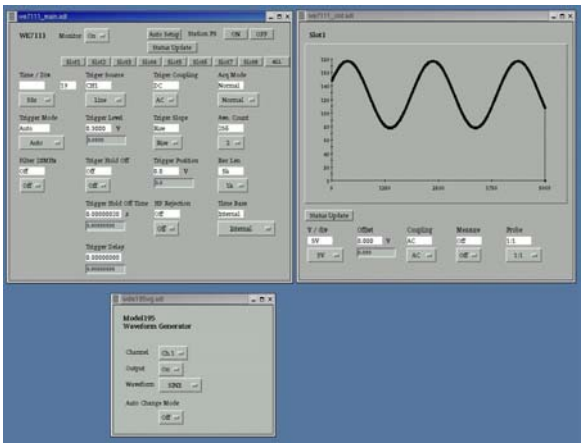

Figure 2: General-purpose waveform monitor

developed using dm2k, which is one of the standard tools of EPICS.

The layout of the control computers is shown in Fig.3. The monitoring application (dm2k) runs at a console (a Linux PC), and EPICS run-time databases are configured on the IOC where EPICS drivers are loaded with a VxWorks real-time environment. The VME-bus board computer with a PowerPC750 chip is used for the IOC.

A performance measurement of the WE7111 oscilloscope driver was carried out using this dm2k application. The dummy signals, each corresponding to a 5kB-size waveform, are transferred from a WE7000 station to the console. We measured the time stamps of network packets at the console by using a network packet analyzer. The observed time differences between data requests and replies correspond to the data-acquisition times of a waveform. In addition, we measured the times for multiple oscilloscope modules. The results are summarized in Table 2.

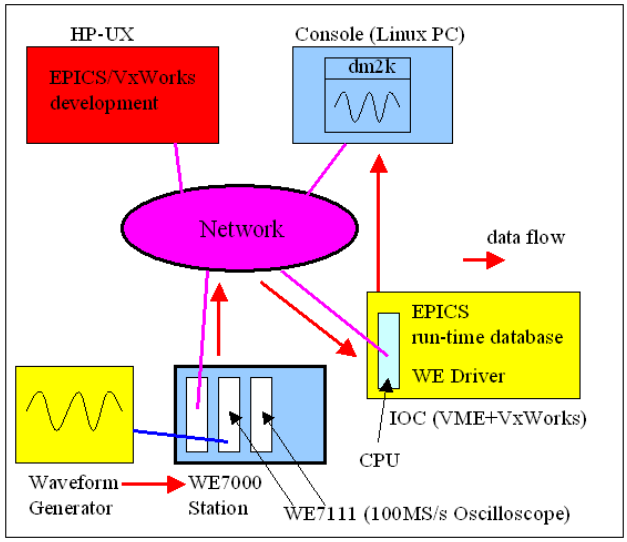

Figure 3: Relationship of console, IOC and WE7000

Table 2: Data-acquisition times of 5-kB waveforms

Number of WE7111 in a station	1st (ms)	2nd (ms)	3rd (ms)	Average Acquisition (ms)	Average throughput (ms/5kB)
1	33	33	32	33	33
2	66	76	70	71	35
3	88	78	89	85	28
4	102	115	100	106	26
5	141	120	141	134	26
6	144	168	145	152	25
7	169	194	164	175	25
8	191	186	191	189	23

The data-acquisition time of a one 5kB-size waveform is about 33 ms. The transfer throughput becomes slightly better as the number of waveforms increases: 23 ms per 5 kB when eight waveforms are transferred at once.

APPLICATIONS AT THE KEK PROTON LINAC

KEK 60-MeV proton linac

Although the construction site of J-PARC is Tokai, the initial 60-MeV of the proton linac has been constructed at the Tsukuba site. Early studies with proton beams started in 2002 [10]. We are developing a prototype control system for this KEK 60-MeV linac based on EPICS [11].

JK template

In order to enable easy development for a prototype control system, we have arranged a "JK template" over the original EPICS distribution. The JK template is a collection of tools and device drivers, which is sufficient enough for our development purpose. For example, basic EPICS tools (medm, dm2k, vdct, and so on) are included. It also contains the EPICS device supports of PLC, EMB-LAN, LAN-GPIB, and some VME modules, which we have possibilities to use in the J-PARC controls. The device supports of WE7000 modules were also added to the template.

CT beam-monitor waveform observation

Before 2002, studies of beam-current monitors (CT) were made with a Windows PC and a WE7000 station with multiple oscilloscope modules. An application was developed using Visual Basic to watch three CT waveforms at the same time. During the previous beam commissioning in February, 2003, we developed a new dm2k application to emulate the original one. Three CT waveforms, each 5-kB size, were shown online, as in Fig.4.

The observed data-acquisition rate with dummy signals is 10 Hz. When using an average functionality of the WE7111 oscilloscope module, the rate is 6 Hz. These rates are roughly consistent with previous measurements (see 2.3).

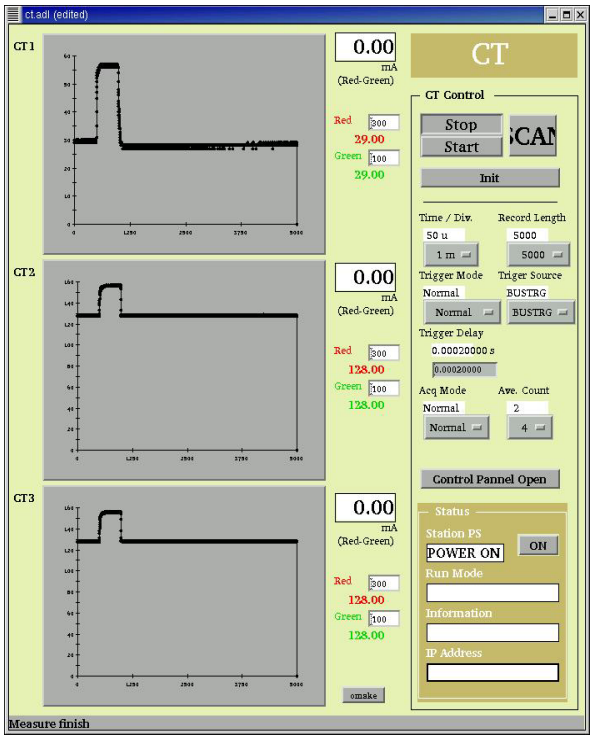

Figure 4: dm2k application for the CT beam-monitors

With the EPICS-based application, we have advantages over the previous environment: (a) studies can be made at any place where a console is available, (b) simultaneous monitoring at multiple consoles becomes possible, and (c) the development of secondary applications using the EPICS records (beam currents, waveforms) becomes possible.

For next beam commissioning

We are now in a shutdown period (March to September, 2003) to extend the proton linac to have DTL components. We will start the next beam commissioning soon with newly installed DTL sections.

We have already developed applications for other beam-monitors, FCT (phase monitor) and BPM (beam-position monitor), with the same oscilloscope module (WE7111). Studies with three different beam monitors will be carried out in the next commissioning with the present EPICS drivers for WE7000.

CONCLUSION

We have developed EPICS device supports for a network-based measurement station (Yokogawa WE7000). The data-acquisition times with 100 MS/s oscilloscope modules (WE7111) were found to be 23-35 ms per 5-kB waveform. Applications of beam-monitors have been developed with the oscilloscope modules for the KEK 60-MeV proton linac.

After development experience, the device support of WE7111 has reached at a practical level. We have made fewer studies using two other modules (WE7121 and WE7271). Thus further, studies with them are needed.

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