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REMOTE WAVEFORM ACCESS SUPPORTS WITH EPICS FOR TPS AND TLS CONTROL SYSTEMS

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Abstract

To eliminate long distance cabling for improving signal quality, the remote waveform access supports have been developed and applied on the TPS (Taiwan Photon Source) and TLS (Taiwan Light Source) control systems. Waveforms include pulse magnets power supplies waveforms, AC waveforms of main power supplies, LLRF waveforms, beam signals, etc., and these are necessary to be monitored during routine beam operation. One is that use the EPICS-embedded data acquisition systems which are formed by the Zynq System-on-Chip architecture to capture the waveform signals; the other is that a dedicated EPICS IOC is used to communicate with the present Ethernet-based oscilloscopes to acquire each waveform data. According to specific purposes use, the different graphical applications have been developed and integrated into the existing operation interfaces. These are convenient to observe waveform status and to analyze the acquired data on the control consoles. The efforts are described at this paper.

INTRODUCTION

TPS is a new and highly bright synchrotron light source constructed at National Synchrotron Radiation Research Center (NSRRC) in Taiwan. It consists of a 150-MeV electron linear accelerator, a booster synchrotron, a 3-GeV storage ring and experimental beam lines. Civil construction began in February 2010 and was completed in the first half of 2013. Installation and integration of the accelerator system began later in 2013. The control system environment was ready in middle of 2014 to support the testing and commissioning of the final subsystem integration without the beam. Commissioning with the beam was successful in December 2014.

TLS is a third generation of synchrotron light source built at the National Synchrotron Radiation Research Center (NSRRC) site in Taiwan, and it has been operated since 1993. The TLS consists of a 50 MeV electron Linac, a 1.5 GeV booster synchrotron, and a storage ring with 360 mA top-up injection. The TLS Control system is a proprietary design [1]. It consists of console level workstations and VME based intelligent local controller (ILC) to interface with subsystems. Hardware and software on console level workstation change several times due to evolution of fast evolution of computer technology. Due to the well design of the original control software structure, port to new Linux platform without difficult.

EPICS (Experimental Physics and Industrial Control System) 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 the particle accelerators and large scientific experiments [2].

EPICS were chosen as control system framework for the Taiwan Photon Source (TPS) of 3 GeV synchrotron light source [3]. The TPS control system with EPICS mechanism had been integrated and commissioned. On the other hand, in order to adopt update technology and re-use expertise of manpower, the upgrade and maintenance for TLS control system adopts the EPICS as its framework was decided. Moreover, some new installed subsystems runs EPICS control environment also. Mixed existed TLS control system and EPICS environment were proofed without problem

One of EPICS database records is the waveform record which stored data array acquired from the device. There are many waveforms such as signals which should be observed in synchrotron light sources including waveform variation of booster current, beam current measured by the fast current transformer, and filling pattern, RF pulse, pulse magnet current, etc. Acquiring waveform data should be based upon EPICS waveform supports. Through PV (Process Variable) channel access the client console can observe the waveform by using various toolkits (EDM, CS-Studio, MATLAB, Python, etc.). In addition, one of the benefits on EPICS waveform supports is that LXI-compliant [4] oscilloscopes with Ethernet interfaces can be adopted to be controlled remotely and users can observe the related waveform data on the control consoles easily.

Another solutions of waveforms access for some parts of subsystems are using the standalone EPICS embedded data acquisition system and the PCI-Express form factor digitizer. The standalone EPICS embedded data acquisition system is convenient to access data by EPICS PVs via Ethernet interface. The PCI-Express form factor digitizer is plugged into Linux-PC with PCI-Express slot, and the related functional libraries of device driver are necessary for building as an EPICS IOC. The efforts of implementing remote waveforms access supports with EPICS for the TPS and TLS control systems are summarized in the following paragraphs.

SYSTEM ARCHITECTURE OF WAVEFORM SUPPORTS WITH EPICS

Remote waveforms access supports with EPICS mechanism have been developed and applied on both TPS and TLS control systems. The system architecture of waveform supports is illustrated as Fig. 1. During the commissioning phase of TPS control system, the oscilloscopes have been widely adopted to monitor

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variations of subsystems, and also used for adjusting parameters on-site. In order to observe the waveforms data on control consoles for beam operation, the EPICS supports of accessing waveforms are necessary to be implemented.

Standalone fan-less PC-based platform that has a Linux operating system was set up as the dedicated soft-IOC to connect with oscilloscopes via an Ethernet interface. An IOC uses the VXI-11 [5] or TCP/IP protocol to communicate with LXI or Ethernet based oscilloscopes. Control consoles can observe the waveform data by use of specific GUI toolkits through EPICS PV channel access.

At the routine operation phase, a part of subsystems' waveforms variations have to been observed and archived by long time and need not to use oscilloscopes of high sample rate for data acquisition. The commercial standalone data acquisition system with embedded EPICS IOC is suitable to use on this purpose. The operation interfaces based on difference purposes have been implemented and are executed to access their waveform data via EPICS channel access on the control clients.

The digitizer with high sample rate and high bandwidth is under test. The digitizer which is PCI-Express (PCIe) form factor is installed into a Linux-PC with PCIe slot as an EPICS IOC. The IOC can directly access waveform memory of digitizer by use of provided software development kit (SDK). The EPICS support with SDK of digitizer needs to be developed for PVs channel access.

Some waveforms date have been calculated and translated to specific data formats to be easily monitored and archived into database server. Consoles apply toolkits to show trends of observed signals and to retrieve the archived data for long term analysis.

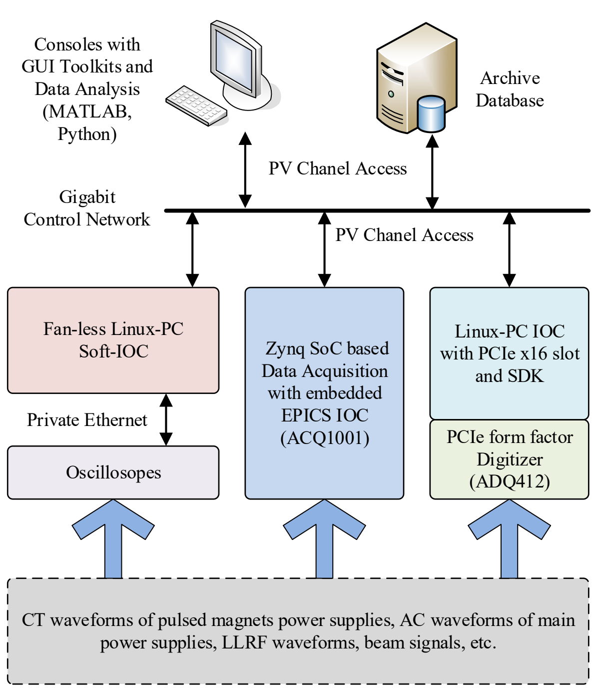

Figure 1: System architecture of waveform support with EPICS for TPS and TLS control systems.

WAVEFORM SUPPORT OF ETHERNET-BASED OSCILLOSCOPES

Remotely access subsystems waveforms from oscilloscopes are set up for eliminating the requirement of long-distance cabling to improve the signal quality. To implement the EPICS supports of LXI/Ethernet-based oscilloscopes, the device supports were built to communicate oscilloscopes with the device driver. The related record supports were created with a link to the device supports. The software block diagram of establishing EPICS support for oscilloscopes is shown as Fig. 2.

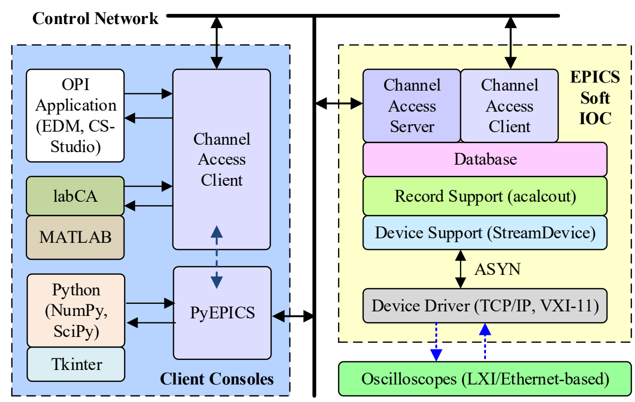

Figure 2: Software block diagram of building EPICS support for acquiring waveforms from LXI/Ethernet-based oscilloscopes.

A user can easily analyse the acquired waveform data using specific toolkits (Python, C/C++, MATLAB, etc.) with the EPICS channel access library. For example, a higher resolution (12-bit) oscilloscope has been used to observe a beam signal from one of BPM (Beam Position Monitor) for fill pattern measurement. To monitor every bunch current, the waveform PV data acquired from oscilloscope are processed online by the MATLAB toolkit and formed to one dedicated waveform PV. The GUI has been created to show the calculated fill pattern as Fig. 3.

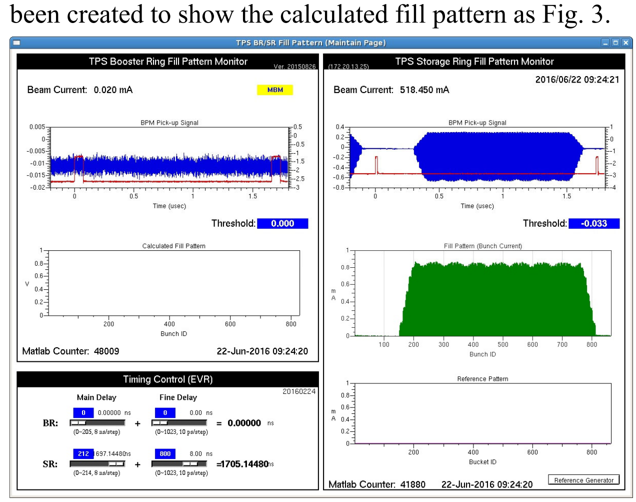

Figure 3: GUI created for monitoring fill pattern of TPS storage ring.

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ZYNQ SOC BASED DATA ACQUISITION WITH EMBEDDED EPICS IOC

A part of subsystems' waveforms need to been continuously observed variations without higher sample rate acquisition during route operation. The ACQ1001 data acquisition [6] is suitable on this purpose and also with low power consumption. The ACQ1001 is a smaller size appliance with external 12V DC power, and supports both provided FMC and ELF modules. It is carried the Zynq System-on-Chip architecture with featuring low power and integral FPGA device. The ACQ1001 supports external clock and trig options, and can be synchronized between units using HDMI cable bus. The outward of ACQ1001 is shown as Fig. 4. Its software environment equips the Linux operation system, and an EPICS IOC is embedded as standard.

Figure 4: Outward of ACQ1001 with FMC module.

The ACQ1001 with ACQ430FMC module supports eight simultaneous channels with 24-bit 128 kSPS. Three ACQ100 data acquisitions have applied on the TLS control system of booster ring. These are used to monitor waveforms of booster main power supplies, beam current, extraction pulsed power supplies CTs for long term. The GUI for monitoring essential waveforms has been created as shown in Fig. 5, and waveforms observation integrates with new ACQ1001 system and EPICS support of existed oscilloscopes. The EPICS applications have been gradually supported and operated on the consoles environment of TLS control system.

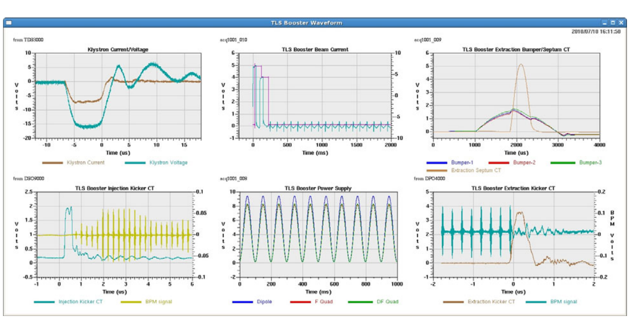

Figure 5: EPICS GUI of monitoring essential waveforms which integrated with new ACQ1001 and existed oscilloscopes for TLS booster ring.

PCI-EXPRESS FORM FACTOR DIGITIZER

The ADQ412 digitizer [7] is equipped up to 4 GSPS sampling rate per channel, up to 2 GHz analog bandwidth and 12-bit vertical resolution. It also supports four input channels, and external clock reference and external trigger input. The ADQ412 digitizer is available in the PCI-Express form factors as shown in Fig. 6, and PCIe for integration in a PC platform. The PC with installing ADQ412 is as an EPICS IOC to be developed the waveform access support with provided SDK. The software framework of EPICS support is under construction and test, and can be verified with actual signals on-site in the future.

Figure 6: Outward of ADQ412 with PCIe form factor.

SUMMARY

To eliminate long distance cabling for improving signal quality, remote waveform access supports are necessary to be implemented. A dedicated EPICS IOC is used to acquire waveform data from Ethernet-based oscilloscopes. In addition, the EPICS IOC embedded data acquisition system which formed by the Zynq System-on-Chip architecture has been also used to monitor waveform during route operation. The EPICS support of PCIe digitizer with high sample rate and high bandwidth under construction and test. The GUI of waveform supports for specific purposes have been created and applied on the TPS and TLS control systems, and enhanced continually.

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