Applications of an EPICS Embedded and Credit-card Sized Waveform Acquisition

Y. S. Cheng#, D. Lee, C. Y. Liao, C. Y. Wu, K. H. Hu, K. T. Hsu
National Synchrotron Radiation Research Center, Hsinchu 30076, Taiwan

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Abstract

To eliminate long distance cabling for improving signal quality, the remote waveform access supports have been developed for the TPS (Taiwan Photon Source) and TLS (Taiwan Light Source) control systems for routine operation. The previous mechanism was that a dedicated EPICS IOC has been used to communicate with the present Ethernet-based oscilloscopes to acquire each waveform data. To obtain higher reliability operation and low power consumption, the FPGA and SoC (System-on-Chip) based waveform acquisition which embedded an EPICS IOC has been adopted to capture the waveform signals and process to the EPICS PVs (Process Variables). According to specific purposes use, the different graphical applications have been designed and integrated into the existing operation interfaces. These are convenient to observe waveform status and to analyze the caught data on the control consoles. The efforts are described at this paper.

Credit-card Sized Waveform Acquisition

- Waveform acquisition module is a FPGA-based (Field Programmable Gate Array) hardware architecture, named "Red Pitaya", which is an open-source hardware formed into a credit-card sized layout.
- Acquisition module has 7.5 Watt power consumption, and is much lower than power consumption of traditional oscilloscope.
- Acquisition module internally supports Linux operation system which installed into micro-SD card for setting up related software packages, compiled FPGA codes and application programs.
- Waveform acquisition module can be equivalently employed to replace several traditional oscilloscopes for being long-term waveform observation.

Table 1: Specification of Acquisition Hardware

Component	Specification
Processor	Dual Core ARM Cortex A9
FPGA	Xilinx Zynq 7010 SoC
RAM	512 MB
RF Input	Channel: 2 Sample Rate 125 MS/s ADC Resolution: 14 bit Full Scale: +-1 V, +-20 V
Bandwidth	50 Mhz
Memory Depth	16 K Samples
Ethernet	1 GigE
Storage	Micro-SD up to 32 GB
Power Connector	Micro-USB, 5 V
Power Consumption	7.5 Watt

System Architecture

- Two or three parts of acquisition modules have been combined into one box for the remote waveform access support. Front panel of box is for signal inputs and external trigger, and back panel is for control network connections.
- Custom-made attenuators with frequency compensation have been also designed and implemented to meet various signal type, such as 50 Ohm, 1 MOhm, high input voltage, etc.
- New waveform acquisition module is as a standalone EPICS IOC which connects to the control network. The captured waveform data are calculated in the EPICS IOC, and the PVs of processed waveform data are published.
- Waveform PVs are launched to the existing graphical user interfaces according to various functionality.

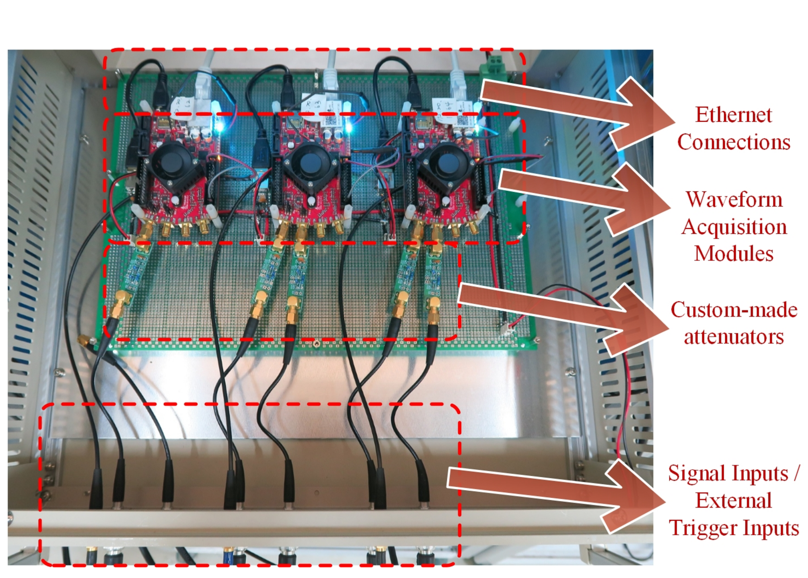

Figure 1: Photo of an assembled box with three waveform acquisition modules.

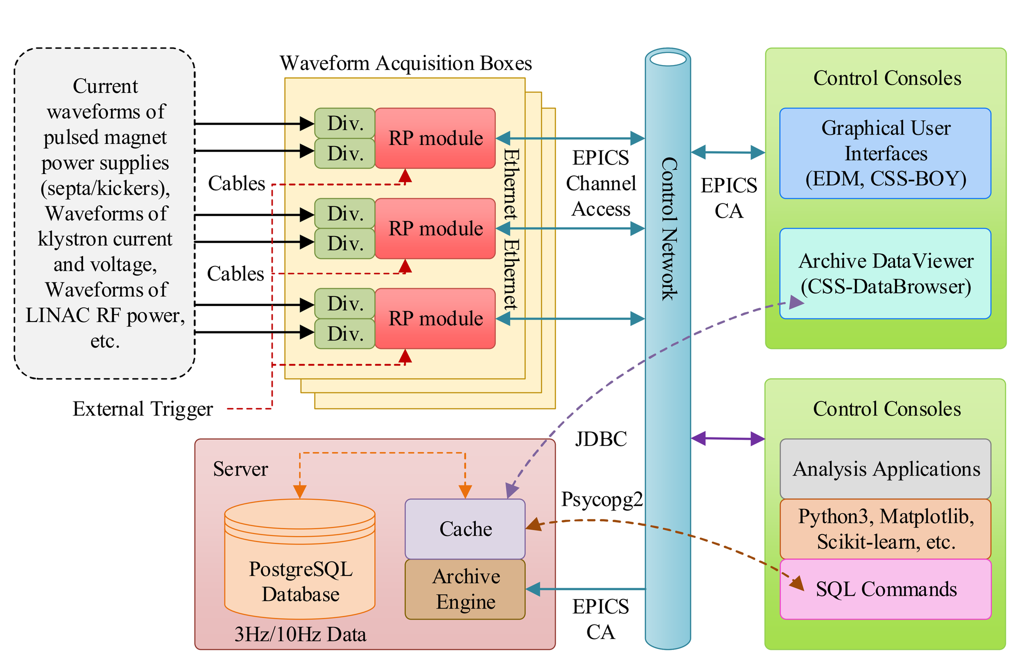

Figure 2: System architecture with credit-card sized waveform acquisition systems.

System Architecture (cont.)

- Each waveform data is also extracted several characteristic parameters, such as peak amplitude and peak time location, in the EPICS IOC to observe its long-term variation and stability on injection of 3 Hz or 10 Hz.
- Extracted parameters have been archived into the relational database for long-term analysis usage. Client users can use the specific toolkits to retrieve the data from database.
- Waveform acquisition module operates Linux operation system, and compiled FPGA image file has been loaded to communicate with the device support via API library.
- Related record supports were created with a link to the device supports, and especially the waveform records are made basis array data processing.
- Complex array calculation is done by the Python program in the IOC.

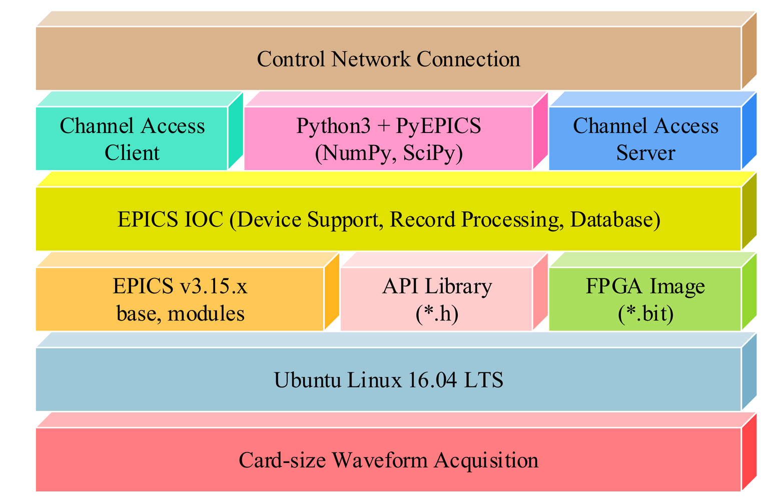

Figure 3: Software block diagram of EPICS embedded and credit-card sized waveform acquisition systems.

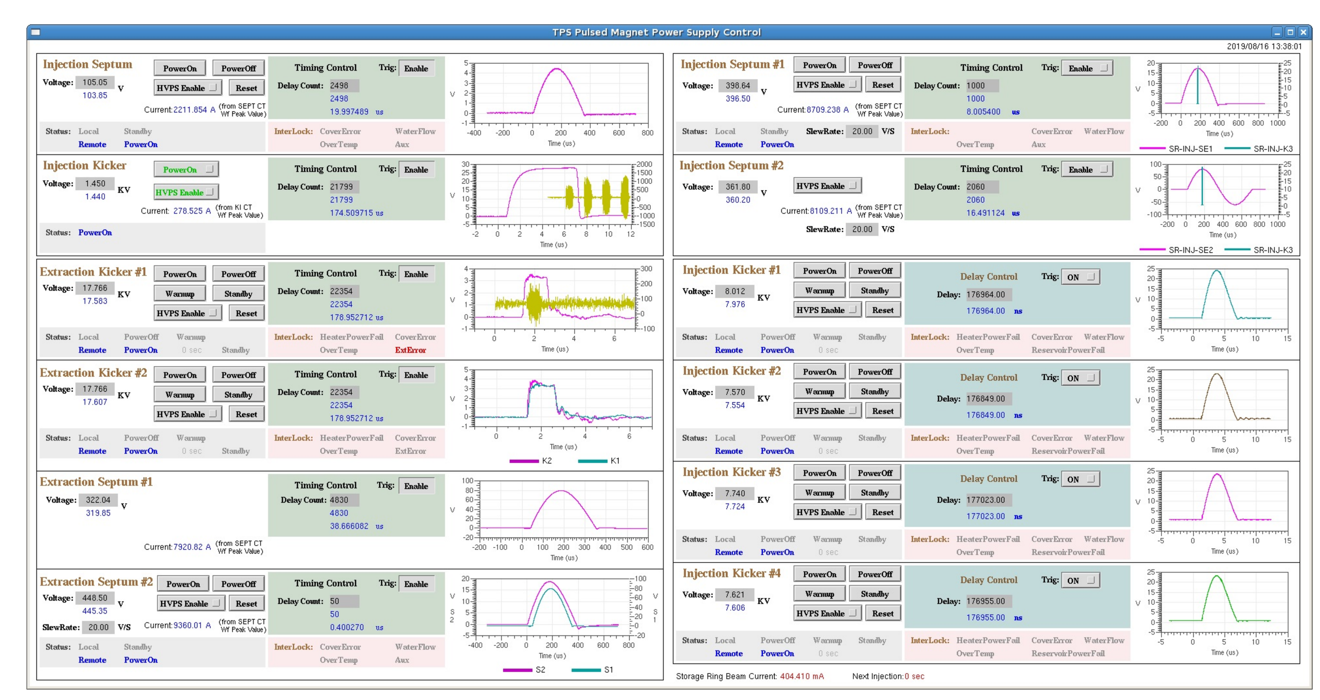

Figure 4: Several credit-card sized waveform acquisitions employed and integrated into the sub-systems of TPS: GUI of TPS pulsed magnets power supplies.

Automated Analysis with Machine Learning Algorithm

- Amount of archived parameters are huge from routine operation with 3 Hz /10 Hz injection, and can be the chance of judging which time is abnormal status manually.
- To simplify the mission, an automated analysis method to judge abnormal status will be more essential.
- "Decision Tree" algorithm can be used for automatically judging abnormal status of captured current waveforms via processed sample data.
- Archived data is retrieved and divided into two parts; one is for training, the other is for evaluating the model.
- Decision tree model is generated based on critical parameters with training data, then the model is verified via testing data repeatedly.
- After completing the evaluated model, new captured data can be approximately predicted the result of the normal or abnormal status.
- Accuracy with advanced model will be raised through more and more new acquired data.

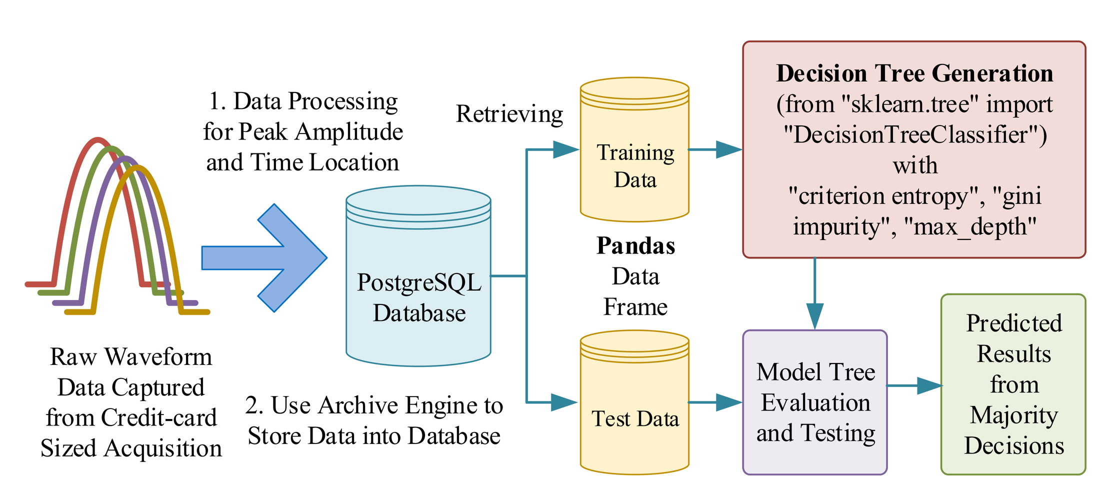

Figure 5: Functional block diagram of building a decision tree mechanism for training amount of archived data to judge abnormal status automatically.

Summary

- A new EPICS embedded and credit-card sized waveform acquisition system has been implemented and applied on the TPS and TLS control systems.
- This is successful to replace broken Ethernet-based oscilloscopes which interfaced with a dedicated EPICS IOC.
- Analysis applications are designed and enhanced continually, and hope to provide automated analysis service in the future.
- New waveform acquisition system will accomplish better diagnostic toolkit and highly reliable routine operation.

#E-mail: cheng.ys@nsrrc.org.tw