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Design and Implementation of SoC Embedded Waveform Acquisition System for Surveillance and Diagnostics of Pulsed Magnets Power Supplies

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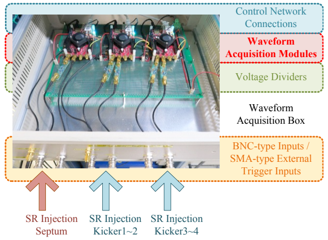
Abstract

Pulsed magnet power supply systems used for electron beam injection and extraction have been developed for the Taiwan Photon Source (TPS) and the Taiwan Light Source (TLS). Control systems for these supplies have been implemented with well-functioning operations interfaces. To accomplish higher reliability operation, advanced real-time diagnostic toolkits for pulsed magnet power supplies had to be developed. A SoC (System-on-Chip) embedded waveform acquisition system has been designed, implemented and applied to inspect pulsed magnet power supplies during routine operation. This waveform acquisition system not only operates at a 125 MS/s sample rate, 50 MHz bandwidth and 14 bits resolution, but supports also the EPICS software framework for complete system integration. The recorded beam current waveform and other specific characteristics can be extracted immediately to examine its status. In this paper, we discuss the design, implementation and real-time data analysis of the SoC embedded waveform acquisition system for the pulsed magnet power supplies.

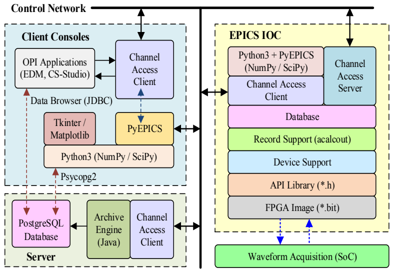
Hardware Architecture

- To replace the broken oscilloscopes and gain better performance, a SoC-embedded waveform acquisition system has been developed and implemented.
- This waveform acquisition system is a FPGA-based (Field Programmable Gate Array) hardware architecture, named "Red Pitaya", which is an open-source hardware formed into a card-size layout.
- This acquisition board consumes 7.5-Watt of power, which is much lower than that of a traditional oscilloscope
- To achieve higher reliability to acquire current waveforms, two or three parts of the acquisition boards have been integrated into one box.

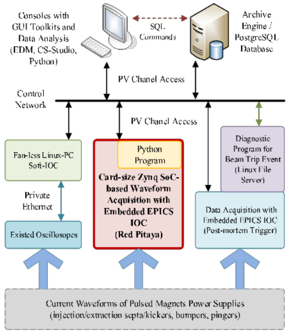


Integration into the Control System

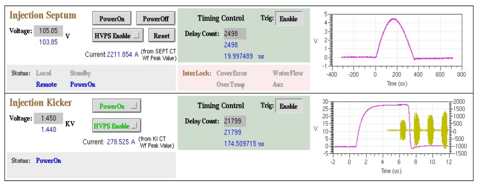
- SoC-embedded waveform acquisition modules have been applied online to capture the pulsed magnet power supply current waveforms and integrated into the existing control system.



- A compiled FPGA file has been loaded to communicate with the device support via an API library.
- Waveform records are the basic array data being processed by the "aCalcout" module. Complex array calculations are done by the Python program in the IOC
- Consoles utilize the specific graphical toolkits to observe waveform data through channel access mechanism.

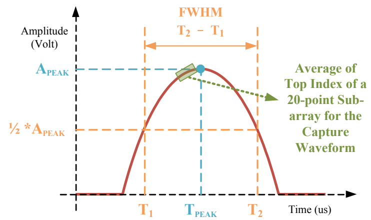


- Graphical control interfaces show critical information to observe the status clearly, and combined with power supply controls, status, interlock, timing control and beam current waveform.
- Waveforms can be adjusted in correlation with real beam signals for easy tuning.



Real Time Diagnostic and Analysis Tools

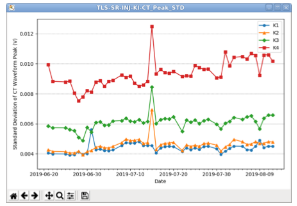
- Define characteristic parameters for captured waveforms to monitor long-term stability of pulsed magnet power supplies.
  - Peak amplitude "A_{PEAK}"
  - peak time location "T_{PEAK}"
  - Full Width at Half Maximum "FWHM"



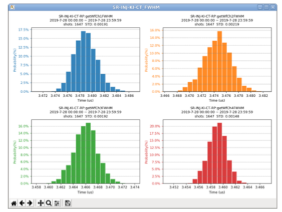
- Captured raw waveform data are processed first by use of a 5-point binomial formula to smooth the waveform array

$$y'(i) = \frac{y(i-2)}{16} + \frac{y(i-1)}{4} + \frac{3*y(i)}{8} + \frac{y(i+1)}{4} + \frac{y(i+2)}{16}$$

- Related characteristic parameters of current waveforms are derived and archived after smoothing waveform array during injection pulse at 3-Hz.
- Recorded characteristic parameters are stored in the database and can be retrieved for easily examination of stability by the specific toolkits.
- Diagnostic applications have been developed to generate statistics. These applications display trends of standard deviation and distributed histograms.



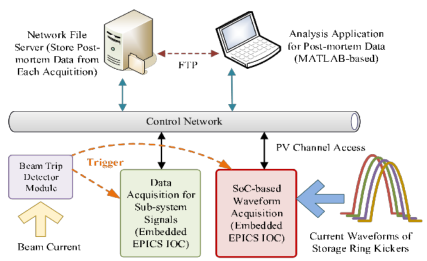
➢ Standard deviation trends of peak amplitudes of TLS storage ring kickers.



➢ FWHM histograms of current waveforms of TPS storage ring kickers.

Post-Mortem of Current Waveforms

- To figure out the root cause to trigger the electron beam trip, a post-mortem diagnostic system has been developed to serve as an important diagnostic toolkit to detect the reason(s) for beam loss.
- Analysis applications are available to analyze the post-mortem data via FTP protocols from the file server and the user can then contemplate the reason(s) for the beam trip.
- Stand alone SoC-embedded waveform acquisition system with external trigger input from a beam trip is useful to capture these abnormal waveforms. The latched waveforms data will be extracted into the post-mortem system for diagnostics.



Conclusion

- Injection and extraction of the electron beam can be affected by the pulsed magnet power supply system. It is also necessary to pay attention to the long-term control of pulsed magnet power supplies.
- A SoC-embedded waveform acquisition system has been designed and implemented and is now employed to monitor pulsed magnet power supply current waveforms for the TPS and TLS.
- New waveform acquisition systems provide the major benefit of lower power consumption and did not fail for more than half a year. Real-time and on-line diagnostic applications have been developed simultaneously and these will be useful to diagnose beam trip events.
- This SoC-embedded waveform acquisition system meets our expectation for highly reliable routine operation in the future.

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