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An FPGA-based Quench Detector and Data Acquisition System for Superconducting Insertion Devices

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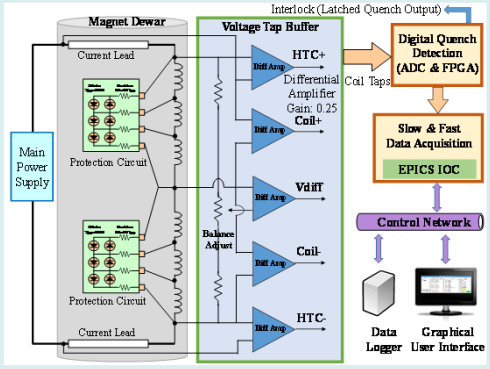
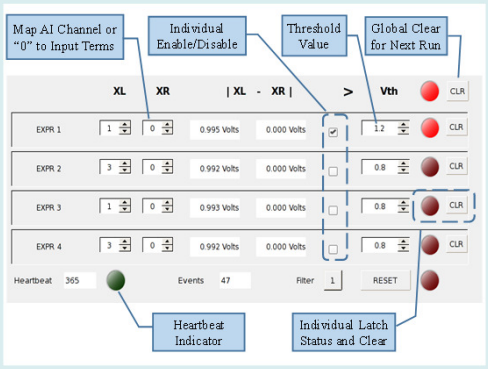
Abstract

A novel quench detector and acquisition system for superconducting insertion devices has been developed. This module consists of two functional components: quench detection and output latch signals for interlock purposes, which is based on a field-programmable gate array, and a data acquisition system based on a set of simultaneous sampling ADC modules. The data acquisition system has two concurrent modes of operation: A fast capture mode that is triggered by a user specified coil quench voltage with a sampling rate of up to 500 kHz, and a continuous data mode that can monitor data at 10 Hz in real time using the same acquisition system. The system was designed in a modular structure using commercially available hardware. This approach makes the new system easy to scale for superconducting insertion devices with coil and lead voltage tap configurations. A detailed description of the system along with test results is presented in this paper.

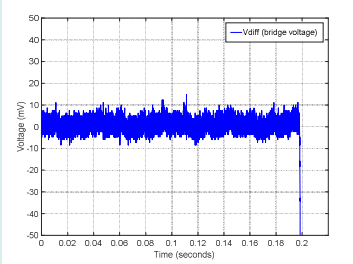
Description of the System

- System layout
  - The whole system consisted of differential amplifiers, data acquisition ADC cards, FPGA and ARM Cortex™-A9 processors, running a Linux operation system.
  - Important subsystems of quench detection system include the voltage tap interface, low pass filters, differential amplifiers with voltage scaling, 16 channels of simultaneous ADC module (500 kSPS/channel, 18 bits resolution), the FPGA-based quench detection interface, and the data acquisition and experimental physics and industrial control system (EPICS) Input/Output Controller (IOC).
- Quench detection algorithm
  - Four independent quench detection formulas with individual enable or disable.
  - Eight channel selects, select any from 16 channels of ADC module or zero.
  - Four individual latch status with individual clear.
  - One global latch status with global clear.
  - Two TTL level of quench latch outputs.
  - Heartbeat.
- Data acquisition and logger
  - Fast capture mode (sixteen simultaneous 18-bit, 500 kHz, ±10 V analog inputs) that is triggered by a quench latch evet
  - Continuous data mode that can in real-time monitor data at 10 Hz rate using the same acquisition system.

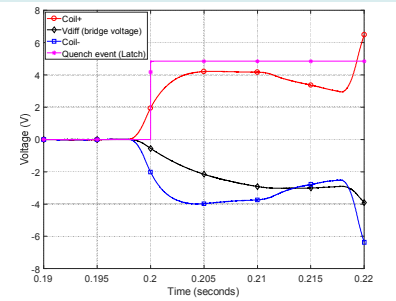




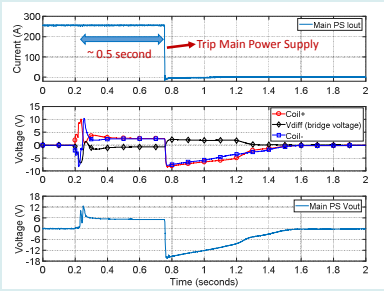
Commissioning Results



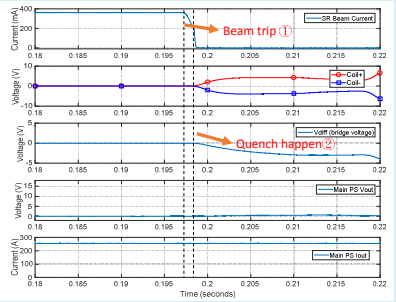
- An example plot of noise level of ADC module.
- The peak noise spikes of bridge voltage are about 20 mV at a current of 255 Amps.
- This is small compared to the threshold setting of 2 V.



- Real time detection of a in-achromatic superconducting wiggler (IASW) quench.
- The quench latch event is active if any of the coil voltages and bridge voltages exceed the threshold setting of 2 V.
- The functionality of this quench detection system is thus verified.



- The post-mortem data is essential to obtaining information about the cause of the main power supply trip at a quench event of a IASW.
- Clearly, the power supply current does not decrease before a quench event is activated..



- A quench event of an IASW sometimes is caused by a beam trip in the storage ring.
- The post-mortem data is used to effortlessly identify the possible causes for the quench event of the IASW.
- A beam trip in the storage ring follows an occurrence of an IASW quench during normal TLS operation.

Conclusion

An FPGA-based quench detection system including slow and fast data logging of signals is developed to facilitate testing of superconducting IDs. The system is implemented using mostly commercially available components to reduce development time of hardware. Furthermore, quench detection systems based-on SoC technology is more flexible and the control software is based on the EPICS framework. Prototypes of the quench detector were tested and installed during the past six months. The system has been successfully used to detect quenches of superconducting IDs and for fast and continuous data logging at the TLS. Experiences accumulated during the past years is helpful for the design of the quench detection system. This new system is easily scalable for superconducting insertion devices with coil and lead voltage tap configurations. Diagnostics of various quench events are also included to identify possible causes.

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