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Research Paper

Gated integrator PXI-DAQ system for Thomson scattering diagnostics

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ABSTRACT

Gated Integrator (GI) PXI based data acquisition (DAQ) system has been designed and developed for the ease of acquiring fast Thomson Scattered signals (~50 ns pulse width). The DAQ system consists of in-house designed and developed GI modules and PXI-1405 chassis with several PXI-DAQ modules. The performance of the developed system has been validated during the SST-1 campaigns. The dynamic range of the GI module depends on the integrating capacitor (C_i) and the modules have been calibrated using 12 pF and 27 pF integrating capacitors. The developed GI module based data acquisition system consists of sixty four channels for simultaneous sampling using eight PXI based digitization modules having eight channels per module. The error estimation and functional tests of this unit are carried out using standard source and also with the fast detectors used for Thomson scattering diagnostics. User friendly Graphical User Interface (GUI) has been developed using LabVIEW on Windows platform to control and acquire the Thomson scattering signal. A robust, easy to operate and maintain with low power consumption, having higher dynamic range with very good sensitivity and cost effective DAQ system is developed and tested for the SST-1 Thomson scattering diagnostics.

1. Introduction

The SST-1 Thomson Scattering Diagnostic (TSD) [1–5] is used to profile the spatial temporal electron density and temperature of the plasma generated in the Tokomak. The TSD system is designed using multiple Nd:YAG lasers with 10nsec pulse width and repetition rate ranging from 30 Hz to 1 KHz. The Thomson Scattered photons are dispersed using five channel interference filter polychromator [6] and detected using IR enhanced silicon avalanche photodiode (APD). The total number of scattered photons for a given wavelength band is detected using APD and an amplifier is designed to enhance the signal intensity and improve the signal to noise ratio [7]. The APD output is expected to have large dynamic range with a load of 50 ohm considering the density range of plasma (from core to edge) combined with the option of operating the laser system in different operating modes (energy range of 9.6 J to 1.6 J). The main objective of this GI DAQ design is to have accurate and cost effective detection and acquisition of high speed signals at desired and flexible repetition rates. In general the TSD signal is digitized using high speed digitizer [8] which is very expensive and an alternative solution has to be considered when the requirement of large number of channels is to be met at a reasonable cost. The typical pulse width of the TSD scattered signal is around 20–50 nsec and the amplitude around 10 mV to 300 mV. Initially, CAMAC based Charge-to-Digital Converter (QDC) [9–11], Charge-to-Time Converter (CTC) and Time-to-Digital Converter (TDC) [12] have been tried for the data acquisition of TSD. CAMAC system has got limitation of data transfer rate of around 3 MB/s [13] and the conversion time of the module is also very large which limits the temporal resolution of the measurement. The requirement of digitisation and acquisition of large number of channels in the case of filter polychromator based multipoint Thomson scattering system requires many CAMAC modules resulting in higher cost. The option of PCI extensions for instrumentation (PXI) systems with high sampling digitizers to acquire the signals has got the advantage of better temporal resolution in comparison to that of CAMAC. However, digitizing the signals of each detector unit with GHz range sampling of large number of channels requires many PXI DAQ cards apart from dealing with huge volume of data. The high cost of implementation and the complexity of data handling for very large number of detector channels is the main disadvantage of this option.

The integrated intensity of TS signal (number of photons received on each detector) is more important than the waveform for the estimation of plasma parameters and hence sampling of this high frequency raw analog signal is not very essential. Instead, the information of area can be arrived by integrating the analog output of detector (APD) for a certain duration (GATE) and digitize the integrated waveform. This technique of measurement is

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called Gated Integrator measurement, which has got the advantage of significant cost reduction as it involves low sampling (250 KS) and minimum data handling (2 Bytes) [14,15] based DAQ for TSD system. The output signal from the detector is integrated for the duration of scattered signal using this Gated Integrator (GI) based DAQ system.

A single channel GI consisting of simultaneous sampling ADC (ADS8364) and ARM processor (LPC2148) has been already designed and validated for SST-1 Thomson scattering system [16]. However, this design has the limitation of having a single channel and difficulty in using with multiple channels as required for Thomson scattering diagnostics (it has to use serial/USB communication for the entire channels simultaneously). This increases the data transfer duration significantly, as the duration is related to the number of GI channels which restricts the overall sampling rate of the DAQ system. To overcome this limitation and to improve the required sampling rate (kHz), PXI based DAQ system is adopted and integrated with the GI modules (each module has eight GI channels).

This paper describes the design, development and validation of the GI module integrated with PXI based DAQ system for simultaneous sampling of 64 channels of the Thomson scattering diagnostics. Besides the Thomson Scattering experiment, it can also be used for other applications e.g. scintillator detectors where fast pulse charge output from APD/PMT is to be measured with user defined gate widths. The developed DAQ system is optimised for its linearity and resolution using a standard pulsed charge generator module. The developed GI based PXI-DAQ system is integrated with the SST-1 Thomson scattering diagnostics and the results show that the GI DAQ system is quite effective as a DAQ system for fast signals (10 ns) with KHz repetition.

2. The structure of tsd system

Fig. 1 shows the block diagram and hardware architecture of the GI PXI-DAQ system, which primarily consists of two components namely GI and PXI – DAQ system with both integrated together for the TSD data acquisition. Nd:YAG laser is operated at a predefined repetition rate (30 Hz–1 KHz) based on the experimental requirement. To operate the lasers in synchronisation with the SST-1 central control system with a precise timing, a laser control electronics module is designed and developed using microcontroller. This laser control electronics generates two TTL pulses that can drive flash lamp and Q switch of the laser system as required by the experimental situation. The pre-loop voltage trigger (−250 msec) from main control room is used as a trigger pulse for the laser control electronics. The GUI provides the user to define the operation mode and the timings. A status signal generated by this module can be used to interface this with the other sub-systems for the monitoring and control purpose. Photodiodes placed behind the beam steering mirrors are used for reference signal generation which in turn are used for generating GATE signal with appropriate pulse width and delay. The photodiode signal triggers the SRS (Stanford Research Systems) pulse generator which generates the GATE signal with required duration. The entire system can also work in free run mode of the laser system (when there is no demand of measurement for the defined time) where the data acquisition duration is set based on the pre-trigger and the photodiode signal. In this case the timing of each laser pulse with respect to the loop voltage is measured and stored for the reference.

The PXI platform is used as the main control part of the DAQ system. It is responsible for control, data acquisition, processing and storage. The PXI is a PC-based platform for measurement and automation. The integrated output is digitized using PXI based simultaneous sampling module through buffer. The digitized data from different ADC module are handle by the PXI based embedded controller.

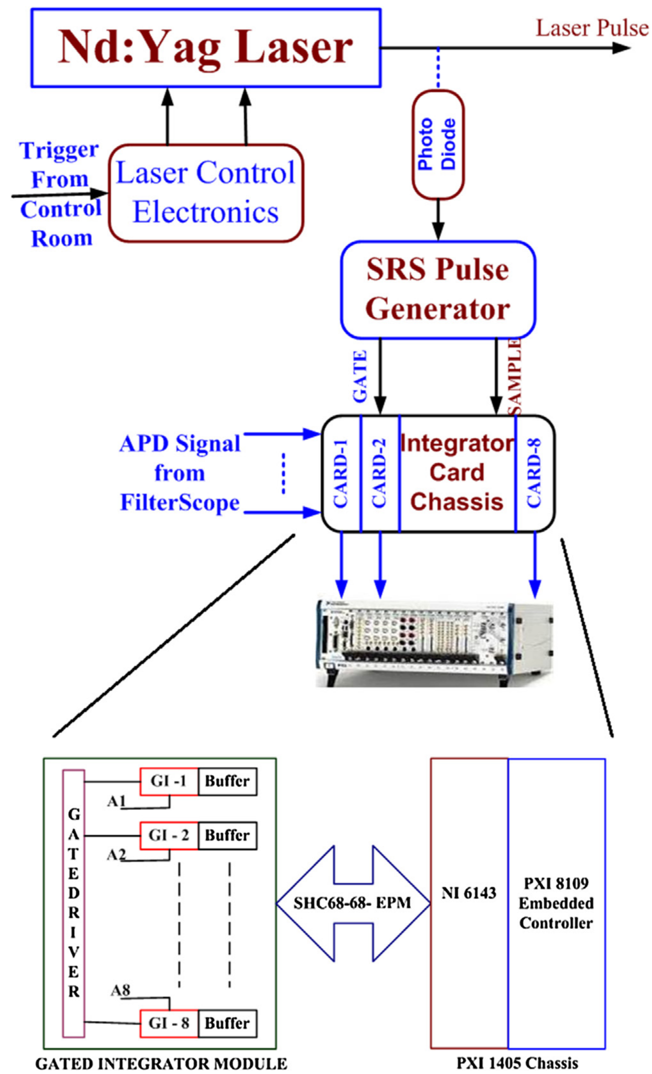

Fig. 1. TSD data acquisition system (component layout and hardware architecture).

2.1. Gated integrator (GI)

GI is an important module in the newly developed PXI-DAQ system which is used to integrate each output waveform of the detector connected to the respective inputs of GI for a specified interval of time (Gate) and gives the output waveform which is the integrated wave form of the input. The GI module consists of an analog multiplexer and an integrator [16]. Each gated integrator requires GATE signal to select the time and duration to be integrated. This minimizes the contribution of background and electronic noise. Each channel of GI is composed of two units like one analog switch and another integrator. Individual GATE signals for each of the eight GI's present in the integrator card are generated from gate driver (On Semiconductor, MC10H645 Clock Driver). The integrator circuit can process the incoming pulse of ± 2.5 V (maximum) and pulse width as short as 8 ns. It can respond to 2 ns rise and fall time. The peak output voltage of the integrator is equal to the time integral of the input voltage. The output voltage amplitude of the integrator depends on the value of the integrating capacitor (C_i). The gain of the integrator is inversely proportional to the C_i. The optimum value of C_i (12 pF and 27 pF) is decided from the