

**Abstract**— Measurements are always associated with any experimental setup. But the requirements for the Plasma physics experiments and specifically Tokamaks are unique and different. Most of the plasma physics experiments operate in a pulse mode and capture the data during the plasma discharge and retrieve it later on for analysis and display. Next generation of Tokamaks are steady state where the discharge duration is of the order of 1000s of seconds. Such device demands a data acquisition system, which is capable of acquiring data without losing from plasma diagnostics so that no physics information is lost and no unnecessary data is acquired. The needs of loss less continuous acquisition have a significant effect on selection of acquisition hardware. The internal architecture of data acquisition board plays a very important role in meeting the goal of lossless acquisition for steady state. Specifically the data management due to large amount of data generated by experiment and online display of data during experiment becomes very crucial. Usually in case of large physics experiments the data acquisition system has been normally based on VME and CAMAC bus. But with an advent of newer technology many options are available for implementing loss less continuous data acquisition. The paper describes the Client/Server based PXI bus based loss less continuous data acquisition system making use of LabView, Lab windows/CVI. The collected data is directly streaming to hard disk and pushed on to network for users. In the paper performance of measure achieved on general purpose OS like windows operating system has been discuss along with future trends in technologies to meet the needs of present day plasma physics experiments.

**Keywords:** Data Acquisition; CAMAC; long pulse; steady state

**INTRODUCTION**

Next generation steady state Tokamak will operate like industrial plant – continuous control and monitoring is required for all subsystems, with periods of higher sampling rates during plasma pulses or abnormal situations. The plasma pulses can last for 1000s or more, and millions of measurements such as plasma diagnostics, radiation, vacuum, will be acquired both during and outside the plasma pulses generating data volume of few Tera bytes. This paper reviews the technical requirements of handling the needs of steady state Tokamaks. We explore the possibilities offered by existing technologies and compare the merits and demerits in achieving lossless needs of acquisition for plasma diagnostics for steady state machines.

In these days PC-based measurement systems has been widely used in the fusion science research fields. In this paper we introduce PXI based system and it’s some real applications. The users can use PXI, a extension of PCI for control and data acquisition purpose. The user friendly software offers great degree of freedom as if they are using oscilloscopes. When one develops one’s own application software, one can choose the adequate environment, language and software package.

As an operating system one can choose Windows. As a programming language one can choose LabVIEW and LabWindows/CVI. Various applications can be easily realized under these convenient software environments. For example the applications of lossless acquisition of Diagnostics signal can be easily implemented making use of library routine supporting dual buffer mode for continuous acquisition. Real time plasma discharge control and Machine monitoring system can also be very easily implemented on PXI platform.

[1] Next generation Tokamaks are steady state devices, designed for fundamental study of plasma physics. Such devices are deployed with various diagnostic systems. Being a steady state device, will require real time data handling, analysis and displaying capabilities. Specifically, management of the large amount of data generated by the experiment and online display of data during the experiment will be very crucial. To accommodate the variety of diagnostics needs, the system is being implemented using available PXI instrumentation. In order to be able to keep pace with technology, the host computer has been chosen to be outside the acquisition hardware, giving freedom to choose the best storage media available as technology grows. The fiber optic links between host and acquisition units have been selected to ensure noise immunity permit the digitizer to be close to the front-end electronics and automatically provide electrical isolation. This may save us from laying long & large numbers of cables from front-end electronics to data acquisition units. To reduce the amount of data without losing useful information, “Event Driven Sampling” has been incorporated for fast diagnostics. Data for a specific time interval will be acquired on events like gas puffing, NBI on, LHCD on, current ramp up and disruption.

**INTERNAL ARCHITECTURES**

**Technical Issues:**

The basic criteria of acquisition are that no physics information should be lost and at the same time no unnecessary
data should be acquired. This raises many technical issues and if they are not addressed properly it increases the network load, reduces the channel handling capacity, needs large storage devices, requires real-time OS for deterministic and low latency. Usually for large physics experiments the data acquisition system has been based on VME and CAMAC bus. Normally the digitizer based on these buses has on-board memory, which provides the storage for the shot duration. These buffers are read out at the end of the shot. Since the shot duration is short, the real-time viewing and transfer to host are not required during acquisition. But the scenario for continuous loss-less acquisition is different [2].

**Implementation Approach:**

In pursuit of the continuous data acquisition needs of various diagnostics, a PXI-based data acquisition system has been chosen for the slow diagnostics demanding a sampling rate up to 10 KHz. The PXI bus is a fast growing platform for instrumentation systems. Its architecture supports modular instruments, based on the PCI computer bus. PXI is a complete standard for instrumentation. The system supports a back plane activity at 132Mbytes/sec with various trigger lines, a local bus with ten lines and a clock for synchronization. The MXI-3 controller offers fiber optic connectivity between host and controller, supporting a data transfer rate of 1.2Gbits/sec. The system supports multiple chassis and a maximum distance of 200 meters. The PXI-based MXI-3 controller supports multiple I/O chassis and 256 PXI/CPCI devices. The typical system is shown in fig 1. Basically the controller is a PCI to PCI Bridge extending the host computers PCI bus with added lines suitable for instrumentation and acts as controller occupying slot one in the PXI chassis. The system complies with EMI/RFI standards. The PXI-compliant products are supplied with Win32 plug & play device driver.

**Fig 2: MXI-3 Connectivity**

The internal architecture supports the continuous acquisition mode. The data is transferred to host under DMA from the onboard FIFO, which permits simultaneous acquisition and read out.

PXI E Series boards are completely Plug and Play, multifunction analog, digital, and timing I/O boards for PXI. This family of boards features 1.25M/S aggregate sampling rate, 12-bit ADCs with 64 analog inputs, 12-bit DACs with voltage outputs, eight lines of TTL-compatible digital I/O, and two 24-bit counter/timers for timing I/O. It has three different input modes Nonreferenced single-ended (NRSE) input, Referenced single-ended (RSE) input, and Differential (DIFF) input. The single-ended input configurations provide up to 64 channels. The DIFF input configuration provides up to 32 channels. In addition to differential and nonreferenced single-ended Modes it offers referenced single-ended (RSE) mode for use with floating signal sources. Very flexible programmable function input (PFI) lines that can be used for software-controlled routing of interboard and intraboard digital and timing signals. Trigger Bus is available to share timing and control signals between devices and synchronize operations for control included for calibration and measurement accuracy. It provides the ability to set a trigger based on the level of an analog signal. Basically this makes event driven sampling possible.

Input modes are programmed on a per channel basis for multimode scanning. The software-programmable gain on these boards increases their overall flexibility by matching the input signal ranges to those that the ADC can accommodate. These boards have gains of 1, 2, 5, 10, 20, 50, and 100. The devices include the features like Temperature Drift Protection Circuitry to minimize the temp effect, Resolution-Improvement Technologies to minimize the noise, Onboard Self-Calibration. The on board built in ASIC offers better timing and optimize data transfer for multiple simultaneous operations using bus mastering with three scatter-gather DMA channels for maximum performance of concurrent I/O operations. They are ideal for applications ranging from continuous high-speed data logging to control applications to high voltage signal or sensor measurements.
**SOFTWARE ARCHITECTURE**

Keeping in view to avail the benefit of growing technology and to reduce the software development time by making use of off the self-available software development tools, an object-oriented architecture has been chosen on the popular platform. The application software for configuration loading, acquiring and retrieval will make use of tools like LabWindows/CVI, MS-SQL and COM/DCOM technology, which supports cross platform operation.

The pseudo code is given in Fig 2 for reference. The acquisition hardware is connected to an acquisition host server, which will be primarily doing the job of accessing the configuration from the database server, acquiring the data, streaming the data to hard disk for permanent storage whilst at the same time pushing the data on to network using Data Socket object. Basically in a Client-Server model it will act as an Acquisition server. Similarly using the Data Socket object, the client will receive the real time raw data for viewing and process the data to infer physics information. Since the processing part is carried out on the client machine, it gives freedom to the user to process the data according to their algorithms. This also reduces load the on the acquisition servers and indirectly boost the performance.

**Performance**

System with 96 and 128 channels was tested and following is the summary of the performance achieved. The system was evaluated for Continuous acquisition, Single-shot application, Multi-triggering (where triggers are occurring at regular intervals) and changing of sampling rate in between the triggers. The module used had 32 analog channels and supports a maximum of 1.25MS/sec. Four such modules aggregating 128 channels were used for the performance measurements. In the case of continuous acquisition the system acquires data from 128 channels @ 10 KHz sampling rate and pushes all the 128 data channels on to the network whilst simultaneously writing to the hard disk. Sampling rate can be increased to 30 KHz, if we do not put the data on network. The performance was observed on windows2000. A client utility has also been developed to view the data from any network node. It generated total data of about 3 GB over a period of 1200sec. In case of 30KHz sampling rate it generated volume of about 9 GB of data. In the case of event based sampling, 100 events with a time gap of 70ms can be acquired with simultaneous plotting of the data. Without plotting, the time gap between triggers can be reduced to 15ms. This was tried with the pre/post trigger facility. The channel handling capacity of an acquisition unit predominantly depends upon the host system performance and performance is enhanced with better configurations. The Plug & Play nature simplifies the hardware installation compared to other bus architectures. The rich library supporting routines for dual buffer mode, single shot and event detection routines makes the system flexible for different applications.

**TABLE -1**

<table>
<thead>
<tr>
<th>Samp Rate</th>
<th>No. Of Channel</th>
<th>Writing to Disk</th>
<th>Data on Network</th>
<th>Acq. Time sec.</th>
<th>Volume of Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>10KHz</td>
<td>128</td>
<td>Yes</td>
<td>Yes</td>
<td>1200</td>
<td>3.07GB</td>
</tr>
<tr>
<td>25KHz</td>
<td>128</td>
<td>Yes</td>
<td>No</td>
<td>1200</td>
<td>5.76GB</td>
</tr>
<tr>
<td>30KHz</td>
<td>96</td>
<td>Yes</td>
<td>No</td>
<td>1000</td>
<td>9.00GB</td>
</tr>
</tbody>
</table>

**ACKNOWLEDGMENT**

The author expresses his sincere thanks to all the members of the Data Acquisition Group for their contributions.

**REFERENCES**
