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REAL-TIME MULTIPLE NETWORKED VIEWER CAPABILITY OF THE DIII–D EC DATA ACQUISITION SYSTEM

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ABSTRACT

A data acquisition system (DAS) which permits real-time viewing by multiple locally networked operators is being implemented for the electron cyclotron (EC) heating and current drive system at DIII–D. The DAS is expected to demonstrate performance equivalent to standalone oscilloscopes. Participation by remote viewers, including throughout the greater DIII–D facility, can also be incorporated.

The real-time system uses one computer controlled DAS per gyrotron. The DAS computers send their data to a central data server using individual and dedicated 200 Mbps fully duplexed Ethernet connections. The server has a dedicated 10 krpm hard drive for each gyrotron DAS. Selected channels can then be reprocessed and distributed to viewers over a standard local area network (LAN). They can also be bridged from the LAN to the internet. Calculations indicate that the hardware will support real-time writing of each channel at full resolution to the server hard drives. The data will be re-sampled for distribution to multiple viewers over the LAN in real-time.

The hardware for this system is in place. The software is under development. This paper will present the design details and up-to-date performance metrics of the system.

1. INTRODUCTION

Operating the gyrotrons of the electron cyclotron (EC) system on the DIII–D tokamak requires the monitoring of various dynamic signals in near-real time. This is currently done in a traditional way with oscilloscopes. These signals are made available to remote users by archiving them to the DIII–D database using digitizers on a CAMAC highway. There are two significant limitations with these methods of viewing signals. First, is a physical limitation. Although control can be passed to any of the networked consoles, the oscilloscopes are in fixed locations. Therefore, the monitor and control functions can be separated physically. Second, remote monitoring and participation, even from the nearby DIII–D control room, is encumbered by the slow response of the CAMAC data acquisiton. It can take minutes for signals to appear in the database.

During a recent upgrade of the EC system, these issues were addressed by including CompactPCI (cPCI) digitizers which are accessible from a high speed local area network (LAN). These digitizers are currently deployed in parallel with the oscilloscopes and CAMAC digitizers. The goal for their implementation is to make them more useful to the gyrotron operators than the oscilloscopes and to eliminate the need for the CAMAC modules.

2. HARDWARE CONFIGURATION

Adequate replacements for the CAMAC digitizers are readily available as the current usage is non-strenuous. The typically used sampling frequency is 5 kHz and the maximum sampling time is 10 sec. The most critical requirement is that the data be streamed out within seconds after acquisition.

It is more difficult to find affordable direct replacements for the 200 MHz oscilloscopes. For most waveforms, a resolution of 0.1 ms is adequate. To examine fault events, 1 to 0.1 μs resolution is required. Faster sampling yields diminishing returns because of varying delays between signal origins and the digitizers. One of the most significant delays, on the order of 1 μs, is introduced by the fiber optic transceivers that are used to provide isolation and to minimize electromagnetic interference. These delays distort the timing relationship among signals and lessen the value of higher resolution acquisition.

A related concern is whether signals delivered to a multi-channel digitizer module are sampled simultaneously. Multi-channel modules often employ a single analog to digital converter. As channels are switched sequentially to the one converter, a phase shift is introduced between the sampled signals. Each signal should be fed to its own sample and hold circuit prior to conversion to avoid this phase shift.

Three models of digitizers were chosen for three acquisition speed ranges. Signals acquired for fault analysis will be wired to a 4 channel module sampling at 20 MHz. Fast dynamic signals, such as gyrotron beam voltage and current, will be acquired with an 8 channel, 1.25 MHz digitizer. When synchronized to a simultaneous sample and hold front end, this digitizer can acquire each channel at about 70 kHz. Finally, slow dynamic signals, most of which are used for calorimetric analysis, will be acquired with a 16 channel, non-simultaneous 250 kHz digitizer. This module can acquire each channel at over 15 kHz, but 1 to 100 Hz will be adequate in most cases.

The set of digitizers for each gyrotron is controlled by a computer dedicated to that system. These computers are equipped with dual network ports. One port is connected to the local area network and is used for control, status, and general network traffic. The other port is used to download the acquired signals and is run directly, with a full duplex Ethernet connection, to a multi-port data server computer. The data server computer is responsible for archiving the acquired signals and preparing them for dissemination to the DIII–D database and to the EC system operators.

Calculations suggest that the fast dynamic signals can be streamed to the EC operators at sufficient resolution in near real time (Fig. 1). Transferring data from the eight channel digitizer to the computer memory at 70 kHz requires 1.1 megabyte per second (MB/s) bandwidth, well under the 120-132 MB/s bandwidth of the computer’s PCI bus. Buffering ten seconds of signals requires 11 MB, a small percentage of the computer's memory. The dedicated full duplex Ethernet connection that carries the data to the server has a rated bandwidth of 200 megabits per second (Mb/s). Assuming the data from eight systems will be fed to one server, that server's PCI bus will be handling about 9 MB/s. Dual ultra wideband SCSI channels, with a total capacity of 160 MB/s, carry the data to multiple 10 krpm hard drives. One drive, with an internal transfer rate of 152-231 Mb/s, is installed per gyrotron system to minimize drive head seek times. Simultaneously streaming these 8 channels of data at a reduced resolution of 10 kHz to, as an example, four operators on the local 100 Mb/s network requires 5.1 Mb/s. The hardware should be able to handle the data flow with insignificant delays. The challenge will be to produce software which can also support the data flow.

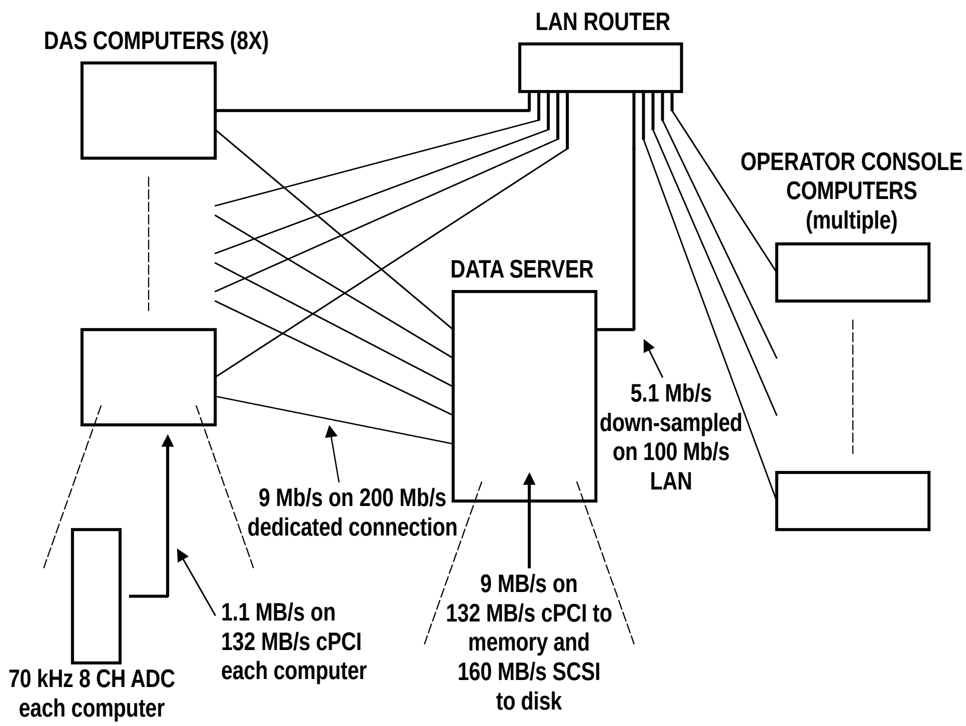

Fig. 1. Network topology and data stream rates.

3. SOFTWARE DESIGN

A first step to achieving the goal of providing the EC operators with remotely accessible digitizer data was accomplished using the remote control application VNC, as in virtual network computing [1]. This program allows any computer on the EC LAN to view and interact with the desktop on any other computer on the LAN running the VNC server. Thus a digitizer acquisition and charting application running on the individual gyrotron computers is remotely accessible to the operators (Fig. 2). Multiple operators can interact with the same computer. Adding additional clients requires direct access to the host or first client computers, however, which is not always convenient.

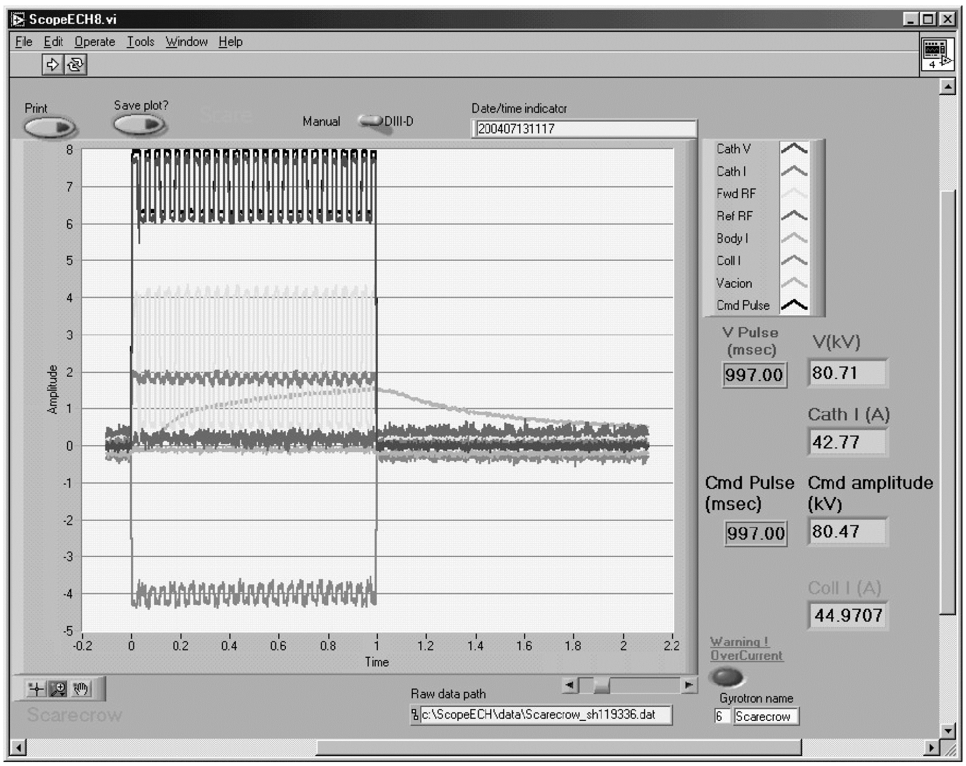

Fig. 2. Screenshot of ScopeECH application. Signals sampled at 1 kHz.

While VNC is an attractive solution for accessing computers remotely to casually change parameters or for maintenance, it is not ideal for some specific tasks such as remotely distributing the digitizer signals. A major drawback is that the host desktop becomes a resource that is shared among the operators. Each operator does not have independent control over what is displayed. Thus, a dedicated application is still desired.

Designing a software application to display high resolution signals in near real-time obviously requires high performance. To realize this, several aspects of the implementation have to be evaluated. These include the absolute maximum acquisition frequency, the maximum acquisition frequency while streaming to disk, network speed streaming signals to the data server, the rate at which signals can be streamed to the data server hard drives, transfer latency versus decimation or re-sampling while streaming from the data server to viewer clients, and the merits of data compression.

Preliminary tests have been conducted on a development system. Test signals were sent to a National Instruments (NI) SC-2040 8 channel simultaneous sampling differential amplifier, followed by a NI PXI-6070E 12-bit digitizer. These were controlled by an older computer with an AMD-K6/450 3D processor and 256 MB of RAM running Windows 98SE. The programming language was National Instruments' LabVIEW 7.0. An example application included with LabVIEW was used as a starting point for the evaluation.

The test results using this application indicate that the software needs to be optimized to achieve the desired performance. Attempting to download the acquisition buffer at the highest available resolution took about ten times the acquisition period itself. Even at marginally acceptable resolutions, the download time was about two times the acquisition time. Surprisingly, adding the additional task of streaming the data to disk while downloading the buffer did not significantly contribute to these poor results.

It was found that the maximum acquisition frequency was close to that expected, 66.8 kHz versus a quoted 70 kHz. At this frequency, 10 kHz square wave signals were sufficiently well represented (Fig. 3). Storage requirements at this frequency for eight channels were also examined. One-tenth of a second of data required 420 kB as expected for storing the data scaled and formatted as double precision real numbers, twice that required to store the data in binary as acquired by the digitizers. However, this is still within the storage capacity of the computer.

Network performance has not been tested yet; however discussions on a LabVIEW user's forum are encouraging [2]. Users have reported achieving 56.13 Mb/s passing a 32 kB buffer multiple times on a 100 Mb/s Ethernet system. Paying attention to the buffer size has been found to be important for the built-in LabVIEW TCP/IP routines. The estimated throughput requirement for this application is 9 Mb/s.

Important aspects of the software architecture remain to be decided. Most interesting is how signals will be streamed to several users on the LAN while emulating the performance of an oscilloscope. It is expected that the signals will be decimated, or digitally re-sampled, for quick views and then filled in should the user desire to view the signal in higher resolution. It will also be interesting to see if there is a benefit to applying a compression algorithm at different points of the data stream.

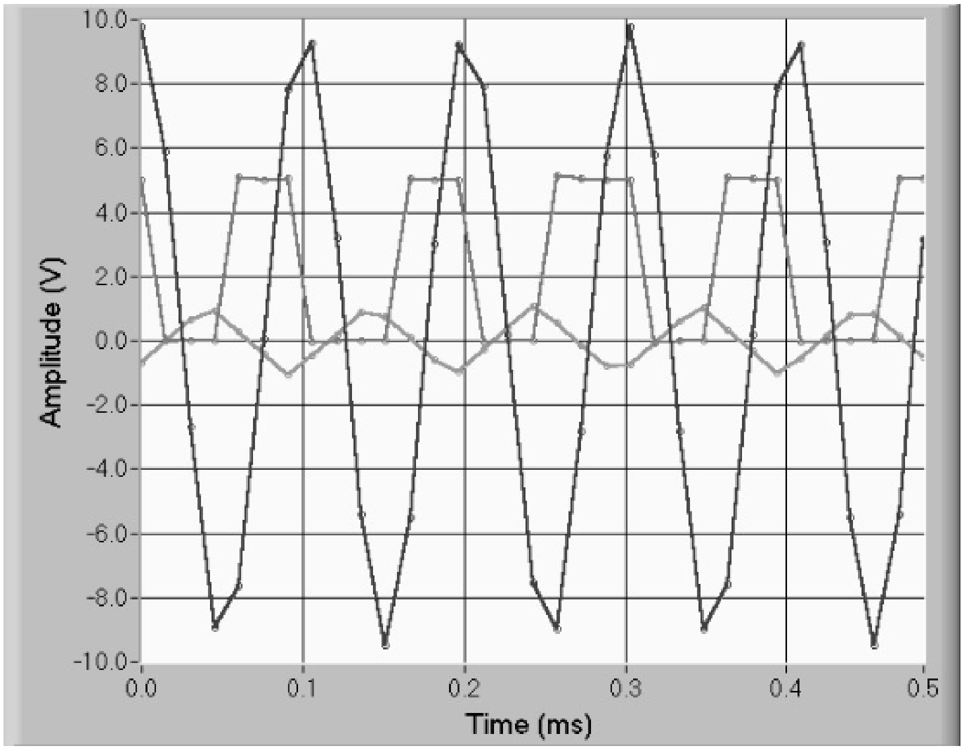

Fig. 3. 10 kHz sine, square, and triangular signals are sufficiently well represented when sampled at 66.8 kHz.

CONCLUSIONS

The hardware chosen appears capable of performing in near real-time without stress. Conversely, it is evident that the software will have to be optimized to achieve the desired performance. But even with non-optimized software, early results indicate that the CompactPCI system will perform faster than the present CAMAC-based system.

REFERENCES

[1] http://www.realvnc.com/, RealVNC Ltd., Cambridge, UK

[2] http://exchange.ni.com/, Optimizing network throughput over Ethernet with TCP/IP.

ACKNOWLEDGMENTS

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