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Fusion Energy 2000 (Proc. 18th Int. Conf. Sorrento, 2000), IAEA, Vienna (2001).

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ABSTRACT.

A large memory VME data acquisition system was developed for the JET heterodyne radiometer upgrade, which is capable of acquiring/storing 576 Mbytes of data per JET pulse. The implementation of the system integration software which includes a CGI based control interface and the data acquisition software is described as well as the development and architecture of the transient recorders. The system maximum data throughput is 288 Mbytes/s when all the 48 channels acquire at the maximum rate of 3 MSPS. The system hardware is composed by the following components: (i) A VME controller module, with a Pentium III processor running Linux, 128 MB of RAM, 100 Mbits/s Ethernet channel and a 40 GB disk; (ii) Six on-site developed transient recorder modules, each having 8 input channels, 12 bit resolution, 6 MSample/channel of memory and sampling rate up to 3 MSPS. Optimal VME device drivers were developed to minimise the data transfer time to the local disk, to be available through a HTTP server. The system has been reliably in operation since January 2003.

1. INTRODUCTION

The Electron Cyclotron Emission (ECE) diagnostic system on JET, named KK3, performs localised measurements of electron temperature (T_e) at various radial positions. Measurements of changes in T_e at higher frequency (above ~10kHz) when correlated with other diagnostics (e.g. magnetic or soft X-ray signals) allows us to localise and identify the structure of the various forms of Magnetohydrodynamics (MHD) activity which can occur in the plasma. The existing data acquisition capability on JET for this system was limited to only 4 channels for high frequency extended duration measurements or to short time periods (<200ms) and limited band width (<100kHz) for 48 channels.

To overcome these limitations a new multiple-channel data acquisition system, named KK3Fast, was developed to allow performing localised MHD analyses in the JET plasmas during the machine operation intervals of physics interest, at a fast signal acquisition rate.

This paper describes VERSA Module Eurocard (VME) [1] data acquisition system and the in-house developed modules which provides 48 input channels, 12 bit resolution, sampling rate up to 3 MSPS and 6 Msample of memory per channel capable of acquiring/storing 576Mbytes of data per JET pulse. A web server running on the host computer allows a remote Hyper Text Transfer Protocol (HTTP) client to run custom developed Common Gateway Interface (CGI)-bins [2] scripts which control the system and perform the data collection.

2. SYSTEM DESCRIPTION

2.1 INTRODUCTION

The KK3Fast includes the following components:

- One CPU module, with a Pentium III processor running Linux (RedHat 7.3), 128 MB RAM, one RS232 port terminal, one 100Mbits/s Ethernet channel and one 40GB hard disk.
- Six fast transient recorder units, each one with 8 input channels.

Figure 1 presents the system architecture and the hardware interface. The analog input channels are sampled on the rising edge of the 6 digital clock inputs. Three types of acquisition modes can be used:

(i) A synchronous mode, where all 48 channels signals are acquired at the same time during up to 6 seconds at a rate of 1MSPS.

(ii) An asynchronous mode, where 8 signals connected to 8 groups of 8 channels in parallel, can be acquired in different moments for up to a total of 36 seconds at the same rate.

(iii) A combination of either modes, e.g. 16 channels of data during 18 seconds or 24 channels of data during 12 seconds.

The acquisition time can be continuous or time sliced depending on the clock generators and timing system. New modules can be easily inserted in the system to enhance/change the system configuration and modes. Figure 2 depicts interface for using the different configuration modes using the 6 installed modules.

The 6 Transient Recorder Modules (TRM) can achieve an overall acquisition rate of 96Mbytes/s (6 modules x 8 channels x 1 Msample/s x 2 bytes/sample). Such transfer rate from the acquisition boards to the local disk is impossible to sustain over the standard VME bus, therefore in-board memory was included. To minimize the transfer time between acquisitions of the total amount of data, which is up to 588 Mbytes, optimization of the control software and hardware was a priority. This was accomplished by implementing VME Block Transfer mode support on the transient recorder modules and by choosing a CPU module which includes an industry leading VME bridge.

2.2 TRANSIENT RECORDER MODULE DESCRIPTION

Each transient recorder module includes 72 Mbytes of inboard memory; a settable analogue input amplifier and fixed passive input signal filtering with 500KHz bandwidth. The module has external clock, trigger and gate inputs which allows several combinations of timing control including a software programmable trigger delay. Figure 3 presents a block diagram of the transient recorder module.

To control the data flow from the ADC to the channel memory and to VME bus, an address generator was implemented in a Complex Programmable Logic Device (CPLD), along with all the control logic. This CPLD also controls the clocking and the triggering of the module which can be internal or external.

The 8 channels, labeled CH1 through CH8, are grouped in pairs: CH1 with CH5; CH2 with CH6, CH3 with CH7 and CH4 with CH8; each group is associated with a 24-bit by 6 MSPS memory block composed by 9 static memories of 16 Mbit each. A switching circuit allows these blocks to be read from the VME bus, written by the ADC or cleared by software specification of one of these states of operation. Three front-panel LED’s indicate the state of operation of the module.

The specifications of the transient recorder module include:

a) Data storage: 6 MSamples per channel.

b) Analogue inputs: (i) 8 simultaneous sampling differential channels; (ii) LEMO differential connectors; (iii) 60 dB CMRR differential inputs; (iv) Bipolar ±5 V, ±2.5 V, ±1.25 V, ±0.625

V selectable ranges; (v) High input impedance of 1MΩ for all ranges except ±5 V (10kÉ∂); (vi) Non-multiplexed - one ADC per input; (vii) Over-voltage protection (±50 V); (viii) Fixed anti-aliasing 500 kHz continuous 3rd order passive Butterworth filter.

c) ADC: (i) LTC1412, successive approximation, sampling; (ii) 12-bit resolution, no missing codes; (iii) High speed - up to 3.0 MSPS; (iv) Signed binary output code; (v) No pipeline delay.

d) Digital inputs: (i) External Clock, External Trigger, Clock Gate; (ii) LEMO single-ended connectors; (ii) Low-true TTL compatible inputs with pull-ups; (iii) Signal ringing over-voltage protected.

e) Clock input: (i) External, via LEMO connector (TTL levels); (ii) Clock is synchronous in all channels; (iii) Maximum sample rate up to 3 MSPS.

f) Trigger input: (i) Acquisition on all channels initiates with selected trigger's ascending edge; (ii) Internal, with programmable delay – 333ns resolution; (iii) External, via LEMO connector (TTL levels).

g) Gate input: External, via LEMO connector (TTL levels); it enables synchronously the acquisition clock.

h) Signalling: Three programmable LED's (Red, Green, Blue) which indicate the Initialization, Acquisition and Transfer operation phases. i) Power specs: Current consumption: <1A (5V). j) Mechanical specs: Standard 6U, 4HP (single width) front panel dimensions.

2.3 SOFTWARE AND NETWORK INTERFACE

The JET central control and the data acquisition system are linked by a 100 Mbits/s Ethernet network, which transports data, commands and parameters. The data acquired during one JET pulse is stored in the JET database after the end of all diagnostic activities, the end of a JET pulse or the end of the day. The diagnostic configuration is obtained from the central control before the beginning of the discharge. The communication is performed as described:

- The supervisory software sends the configuration parameters to the acquisition system before the acquisition starts, using the HTTP protocol [3]. All configurable parameters of the system are defined in this HTTP Post.
- The supervisory software sends an 'init' command to the system, informing that the pulse will start.
- The JET timing system starts the acquisition and the KK3Fast system acquires the data to files which names indicate the discharge and channel numbers. All the data nodes are generated in the HTTP Server.
- The supervisory software sends an end-of-pulse command to the system, informing that data collection will follow.
- When the pulse is over, the supervisory software gets the files from the KK3Fast system using HTTP protocol by issuing a data-archive command to the system.

Besides all the above-mentioned actions the HTTP server allows the remote monitoring of the state variables and status of the machine, logger interface and pulse control. This service is responsible for checking all the hardware and software status to ensure that the available information is accurate and updated.

The Linux operating system (RedHat distribution) [4] and the Apache HTTP server [5] were used to implement the support network services. The developed software is divided into two blocks: (i) the acquisition software that controls the system modules and reads out the data from the hardware modules through the VME bus; (ii) the HTTP interface software composed by the Apache server and several binary CGIs [6].

Figure 4 presents the communication flow and software structure of the system. The Acquisition Software controls the hardware modules by: (i) initializing it and start data acquisition; (ii) reading the size of the data collected; (iii) reading out the memory of all channels to disk.

The binary CGIs scripts which were developed are:

- ***Control*** – This receives the control data from JET receiving commands such as init; abort; end-init; end-of-pulse; data-archived.
- ***Parameters*** – This was developed to receive system configurable configuration parameters. In this system this feature is not being used because no pre-initialization parameters were necessary.
- ***Log*** – This sends XML text with log information according to three severity domains Info; Warning; Error.
- ***Monitor*** – This sends the global state of the machine that can be on or off.
- ***State-variables*** – This sends the system defined state variables that can be shown in displayed in the control room. These state-variable are defined for each system.
- ***Data-nodes*** – This sends the data acquired and stored in the system disk according to the Jet pulse number and the name of the data node.

A hardware test and commissioning software was also developed to help the installation, test all module hardware circuits and simulate the complete data acquisition process. It provides several testing options such as: test LEDs; read status; print acquired data on screen; test memory; start acquisition; read channels data; write channels data to disk. The memory test function was of special importance to test the large number of Ball Grid Array (BGA) memory chips used which totalize 1728 soldering joints per board.

To ease the maintenance and system backup processes, a remote boot procedure was implemented to permit storing all system files on a remote server. The VME controller has support for the Etherboot [7] remote boot protocol. During boot this client searches a BOOTP or Dynamic Host Configuration Protocol (DHCP) server to get the network configuration and the address of a Trivial File Transfer Protocol (TFTP) server. This server supplies the boot file containing the OS kernel which subsequently mounts and accesses the entire file system on an Network File System (NFS) server. The RedHat kernel [8] was recompiled to provide NFS kernel support. The boot file was created using the ‘mknbi’ tool (make network bootable image) tool.

CONCLUSION AND FUTURE WORK

After the preliminary offline tests the system was installed in the JET facilities, and is in operation since January 2003 with the expected good performance and reliability. Performance tests revealed that the data collection of the full memory takes less than 2 minutes, which results in a data transfer rate of about 5Mbytes/s. This result shows that the choice for the Linux operating system running Apache Server and CGI technology has led to a good performance. The interface software was designed as a generic platform and can be ported easily to other diagnostic acquisition systems, even with different data acquisition modules. Future work on low cost data acquisition systems based on the PCI [9] bus, SDRAM high capacity memory modules and real-time digital signal processing is under development [10, 11, 12]. This architecture introduces a significant cost reduction of large memory transient recorder modules with the advantage of including real-time processing power.

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REFERENCES

[1]. Wade D. Peterson, The VMEbus Handbook – Third Edition, VITA Publication, 1993.

[2]. http://hoohoo.ncsa.uiuc.edu/cgi/intro.html

[3]. Colin Hogben and Sverker Griph, “Interfacing to JET Plant Equipment Using the HTTP Protocol”, CODAS Document Centre, March 2002.

[4]. http://www.redhat.com

[5]. http://www.apache.org

[6]. Shishir Gundavaram, CGI Programming with Perl, 2nd Edition, O’Reilly, June 2000.

[7]. http://etherboot.sourceforge.net/

[8]. Alavoor Vasudevan, The Linux Kernel HOWTO, Linux Documentation Project, June 2003.

[9]. T. Shanley e et al., PCI System Architecture, Fourth ed: Addison-Wesley Pub Co, 1999.

[10]. J. Sousa, et al., A PCI time digitizer for the new JET time-of-flight neutron spectrometer, presented at 4th IAEA Technical Meeting on Control, Data Acquisition and Remote Participation for Fusion Research, San Diego, 2003.

[11]. A. Combo, et al., “A PCI transient recorder for the magnetic proton recoil neutron spectrometer at JET”, presented at 4th IAEA Technical Meeting on Control, Data Acquisition and Remote Participation for Fusion Research, San Diego, 2003.

[12] M. Correia, et al., “A Low-Cost Galvanic Isolated Fast PCI Transient Recorder with Signal Processing Capabilities”, presented at 4th IAEA Technical Meeting on Control, Data Acquisition and Remote Participation for Fusion Research, San Diego, 2003.

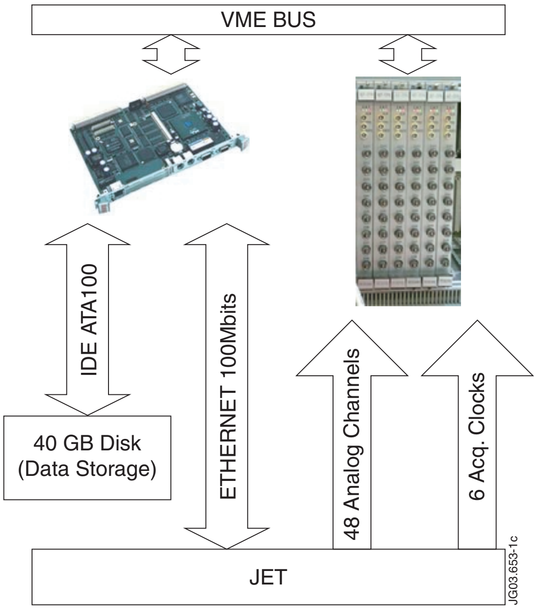
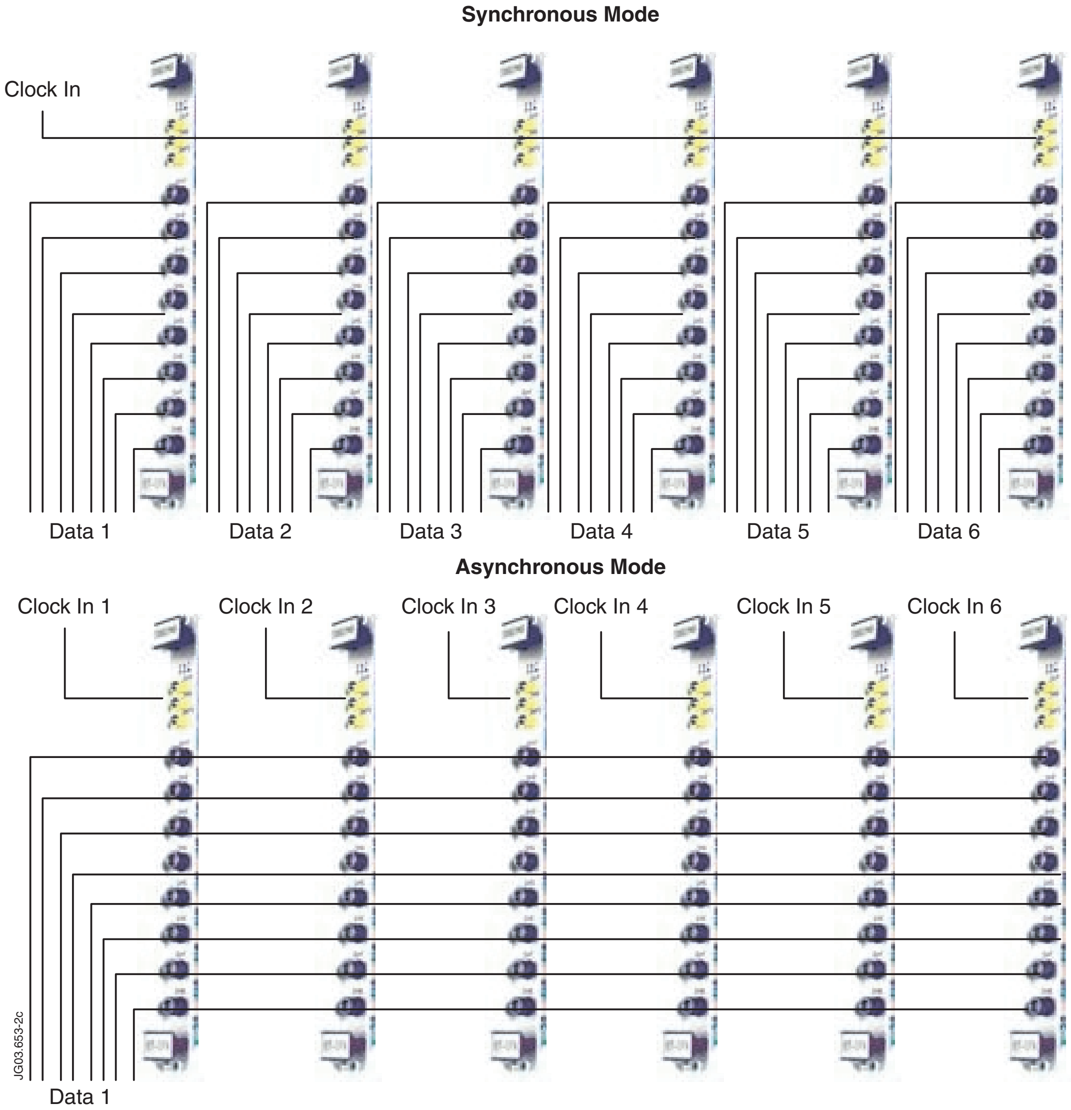


Figure 1: System architecture and interface


Synchronous Mode

Asynchronous Mode

Figure 2: Acquisition Configuration Modes

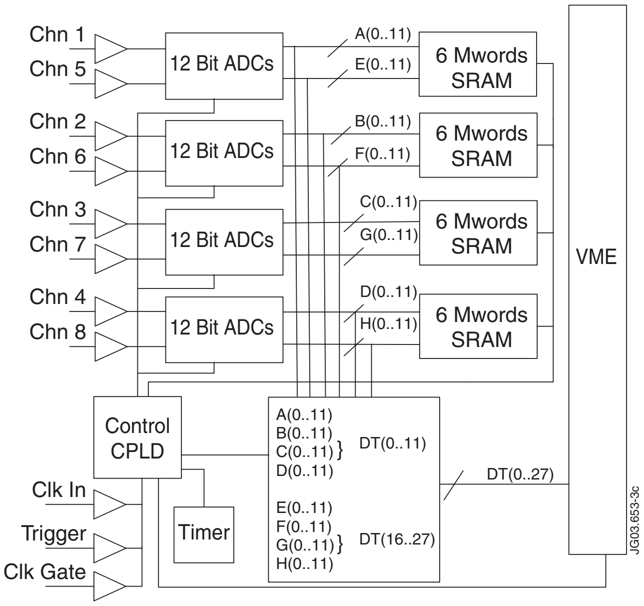


Figure 3: VME-8-300-6M Block Diagram

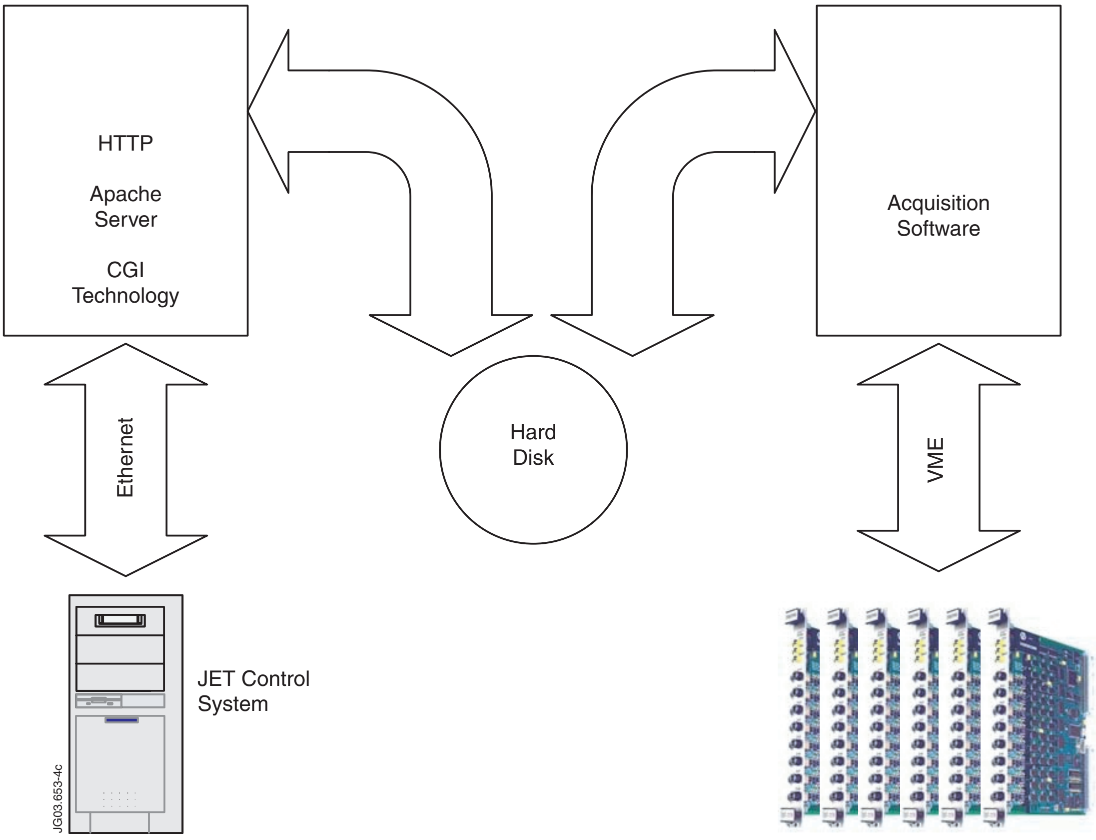


Figure 4: Communication flow and Software Structure