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ABSTRACT

In this paper a large memory fast data acquisition system is presented, giving special attention to the architecture and suitability of Linux for use in this type of applications. The system will be used to acquire data from JET's new correlation reflectometers composed by four microwave channels of four analog signals each. The sixteen signals will be acquired by fast acquisition 12-bit channels at 2Msamples/s achieving a data rate of 60Mbytes/s. These sixteen signals will also be acquired by slower acquisition channels, with 16-bit resolution and sampling rates up to 250kSPS. Two Digital Signal Processors will run an algorithm over this data to avoid the use of the old KG8B RMS analog circuits as well as control and generate all the timing and acquisition clocks needed by the system.

1. INTRODUCTION

Correlation reflectometry with high temporal (<1us) and spatial (<1cm) resolutions is an adequate tool for the study of electrostatic turbulence on improved regimes and in particular during internal transport barriers. The JET X-mode correlation reflectometry will have four microwave channels, each one delivering four analog signals. During the full JET discharge ten to twenty correlation measurements shall be performed, each one corresponding to the acquisition of ten to twenty frequency plateaus at a sampling rate of 2MSPS and having each plateau at least 1 ksample acquired data. Real-time plasma monitoring at a slower sampling rate is also needed to detect the turbulence.

This paper describes the VME data acquisition system that fulfils the above-mentioned requirements. It must have 16 fast and 16 slow input channels with large local memory as well as to provide data transfer rates of 60Mbytes/s to accomplish a dead time equal to the duration of the measurements.

2. SYSTEM DESCRIPTION AND ARCHITECTURE

The dedicated VME data acquisition system is composed by:

- One CPU module, with a Pentium III processor running RTLinux, 256MB RAM, four RS232 ports, one 10/100Mbits/s Ethernet channel and a 4GB disk.
- Two on-site developed intelligent transient recorder modules, each one having a Digital Signal Processor TMS320C31 running at 80 MHz and 8 input channels, with 16-bit resolution, sampling rates up to 250kSPS and 64kWords memory.
- Two on-site developed fast transient recorder modules (TRMs), each one having 8 input channels, with 12-bit resolution, 1.5Msample memory and sampling rate up to 3MSPS.

Figure 1 shows the architecture of the system and the interface signals. The components in this architecture, as well as the way they interface with each other are described in the reminder of this session.

2.1 THE INTELLIGENT TRANSIENT RECORDER MODULE

Figure 2 presents a block diagram of the intelligent transient recorder modules. The main functions of these modules are:

1. To provide the system acquisition clock up to the 3MHz, counting time with resolution of 1ms for controlling the measuring duration;
2. To acquire the 16 channels at a slow rate for real time plasma monitoring needed to detect the turbulence.
3. To run a digital signal-processing algorithm over the acquired data to avoid the use of RMS analogue circuits.

Providing the system acquisition clock and counting time with a high resolution is achieved using DSP internal timers and software Interrupt Service Routines (ISRs). The two DSP timers are programmed to run at different frequencies: the highest is the acquisition clock that may go up to 3MHz (the maximum sampling rate of the fast acquisition modules ADCs), the lowest is programmed with the time unit desired to count time. Each clock cycle of the slowest timer generates an interruption to the DSP. The ISR that serves this interruption increments a counter (Time Stamp), which is used to start and stop the first timer for each measure.

Eight channels are acquired in each intelligent module and data is processed by the local DSPs and stored in local memory. The algorithm that is under development is used to avoid the current analog configuration and circuits. A schematic view of the current RMS circuits is shown in figure 3.

2.2 THE FAST TRANSIENT RECORDER MODULE

Figure 4 depicts a block diagram of the fast Transient Recorder Module (TRM).

The function of the fast data acquisition TRMs is to digitise and store the analogue signals coming from reflectometers at a rate of 2MSPS.

The two fast TRMs can generate an overall acquisition rate up to 96Mbytes/s, which cannot be sustained when data is transferred from the acquisition boards to some other system resource due to VME bus performance. Optimal VME interfaces are requested to minimise dead time between acquisitions. For this reason transient recorders slave modules support Block Transfer Accesses and the master CPU module use industry leading VME controller. The software controlling this device lets the user configure acquisition periods compromising the number of measurements, its duration and the available memory. A set of working modes for different quantity of data is presented in section 4.

2.3 JET NETWORK AND SYSTEM INTERFACES

The communication between the JET control and the dedicated reflectometry data acquisition system will be made using a 100Mbits/s Ethernet channel, which is used to receive commands and send the acquired data. This choice was made based on the standardisation, performance and low cost of this technology.

The data acquired during one JET discharge is placed in the JET database after all diagnostic activities are over, at the end of the JET pulse. The diagnostic configuration will also be obtained from JET computers via the network before the pulse starts. This communication will be performed as described:

- Supervisory software writes a configuration file in the acquisition system using FTP protocol, before the acquisition starts. In this file are all configurable parameters of the system.
- JET trigger starts the acquisition and the VME system acquires the data to a directory named after the pulse number, to files named after the channel numbers.
- When the acquisition is over, supervisory software will get the files from VME system using FTP protocol.

The dedicated acquisition system will have a service running with a TCP/IP port where the status of the machine can be remotely checked. This service is responsible for checking all the hardware and software status so that all information available is accurate and updated.

3 REAL TIME AND OPERATING SYSTEM CONSIDERATIONS

During the last years Linux has found increasing use in instrument-control applications, mainly due to its stability, integrity, versatility and low cost. An effort has been made to use Linux-based PCs controlling CAMAC crates and VME buses. Moreover, because Linux implements the same POSIX specification as commercial versions of UNIX, it supports a full range of features such as multi-user, protected-mode and multitasking. [1] One of the projects using VME and Linux is the VMELinux project [2]. It aims at building a Kernel Level Linux Device Driver that interfaces between the Unix Shell environment and the VMEbus. This driver is compatible with the Tundra Universe PCI-VME bridge integrated circuit and supported by various manufacturers and the device drivers developers themselves [3].

This software is governed by the GNU Free Software Foundation [4] license and includes:

- VMELinux Device Driver, which interfaces the user programs with the system device. The driver uses a standard set of calls, being familiar to most programmers.
- VMEUtils Program, which runs in an Unix shell which communicates directly with the Device Driver. It is an example to the programmer of how to interface the driver and what are its main features.
- VMEShell Utilities, which are a set of routines to be called from Linux shell and that may be used to read data directly from VMEBus as well as to use as examples to the programmer.

Another problem that usually comes with fast data acquisition systems is the need for a Real Time Operating System. “Real-time” is an overused word that is used to mean “very fast”, “as soon as possible” or “almost at the same time” (like real-time stock quotes over the internet) among others.

This system is designed to run in a soft real-time environment. This means that there are timing deadlines that cannot be overcome in any circumstances, risking the loss of data. No mater how fast is usually the system, if it doesn’t read a buffer before it is full, even if it is only one time, all data may be compromised.

The choice of using RTLinux [5] [6] was made since it is a real-time variant of Linux that makes it possible to control data acquisition systems and other time sensitive instruments and devices with accuracy. This system is being tested in our application and results will be available soon.

4 RESULTS AND SYSTEM PERFORMANCE

This system is capable of acquiring 16 channels with rates up to 3Msamples/s directly to its internal memory at a rate of 96Mbytes/s. This data rate cannot be sustained when data is transferred from the acquisition boards to some other system resource, due to VME bus performance. In spite of this particular constraint, several important cases can be described in which the overall performance of the system can be accessed and prove to be adequate to the envisaged application.

A few meaningful hypothetical application cases are described to illustrate the capabilities of the system.

Let us define a measure as the acquisition of all frequency levels. The data length acquired for each measure is attainable multiplying the number of frequency levels by the data length acquired in each level. A measure that uses 10 levels of frequency of 8Kbytes each, will have 80Kbytes of data length.

4.1 CASE 1 – ACQUISITION TO THE CHANNEL MEMORY

Let the acquisition rate be 2Msamples/s. 18 measures of 40ms each (80ksamples/measure) can be done with no dead time between them. This is possible due to the large internal memory associated to each channel (1.5Msamples).

This memory can be used to make a number of measurements with virtually no dead time between them. Some numeric examples are given in the following list:

- 18 measures of 40ms each (80ksamples/measure);
- 36 measures of 20ms each (40ksamples/measure);
- 72 measures of 10ms each (20ksamples/measure);
- 180 measures of 4ms each (8ksamples/measure).

4.2 CASE 2 – ACQUISITION TO CPU MEMORY USING THE VME BUS STANDARD ACCESS

This case shows the possibility of acquiring large amounts of data during extended periods of time.

Again, let the acquisition rate be 2Msamples/s, and time periods from 4ms to 40ms for each measure. Based on a standard VME transfer rate (using A24/D32 Standard Access) of 4 Mbytes/s or 2Msamples/s, table 1 can be build.

In table 1, T1 is the time of each measure, DATA1 is the amount of data per channel for each measure, DATA2 is the total amount of data for 16 channels for each measure and T2 is the time necessary to read DATA2 using VME Bus. T2 is the dead time between measures. Only the CPU DRAM that is 256 Mbytes limits the amount of data to be acquired.

4.3 CASE 3 – ACQUISITION TO CPU MEMORY USING THE VME BUS BLOCK TRANSFER

The system was developed to support VME D32 Block Transfer that enhances the data transfer rate in the VMEBus to 16MB/s. The sample rate is 7.5Msamples/s, which enables the reconstruction of the previous table.

The time between the beginning of two consecutive measures is given by T1 + T2.

This data rate is tested and was achieved, however it is not sustained for long periods of time. It is still under development to achieve longer periods avoiding the PCI latency of the CPU board.

5 CONCLUSION AND FUTURE WORK

In reflectometry diagnostics very large amounts of data must be acquired in very small amounts of time. This fact leads to very high data rates of acquisition and to the need of very large storing devices and quantity of memory.

The need of simplifying analogue circuits that are a potential cause of system errors and malfunctioning leads to the development of digital processing units in substitution of the old circuits. The easy reprogramation and capacity of using different settings and algorithms for different occasions is another of the advantages of digital signal processing.

The use of GPL software like RTLinux and VMELinux Device Driver provide low cost solutions keeping high quality standards and performance.

In this project all this features and technologies were gathered to develop a large memory, high transfer rate VME data acquisition system for the JET correlation reflectometer. This system will be installed in January 2002 in JET facilities and some tests are still to beperformed. However, the choice for standard technologies with large use in industry, as well as the experience attained when developing previous VME modules foresees a high performance system.

ACKNOWLEDGEMENTS

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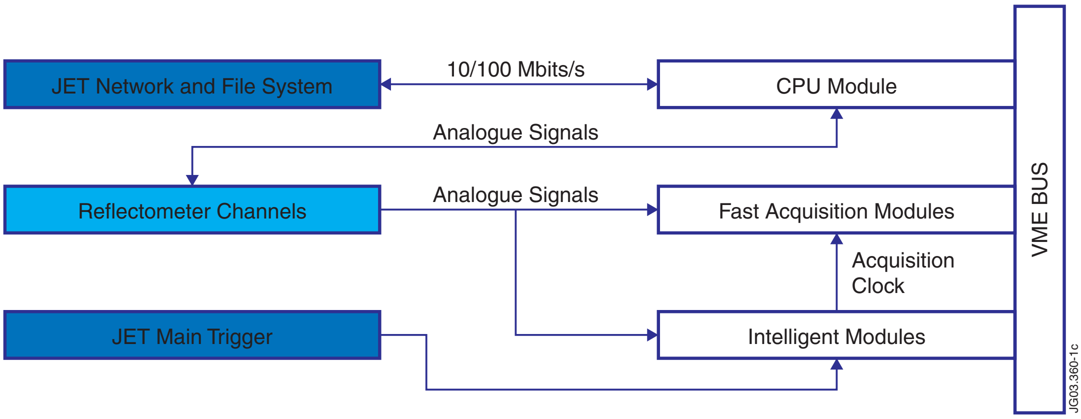

Figure 1: System architecture and interface signals.

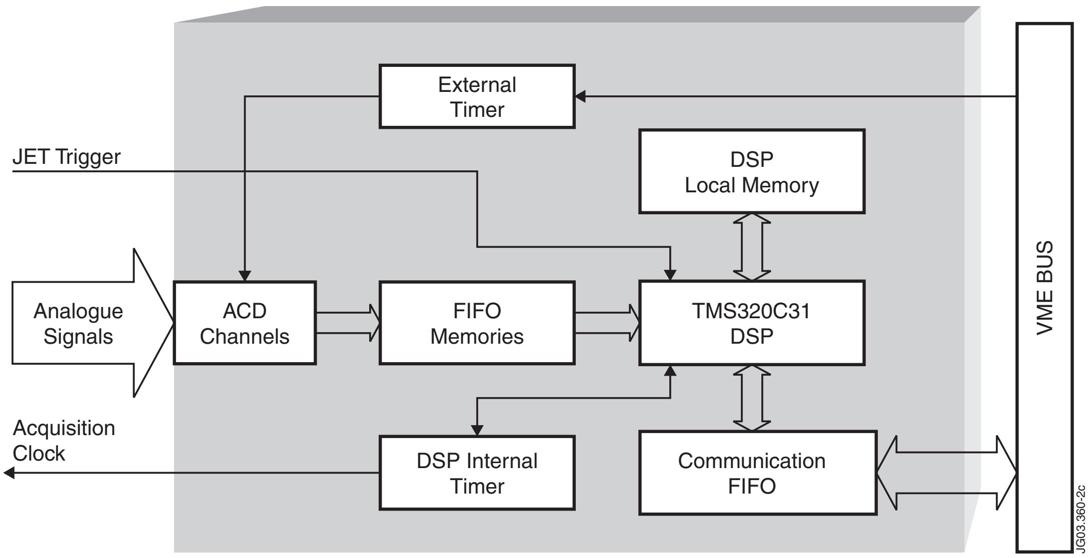

Figure 2: Intelligent Modules Block Diagram.

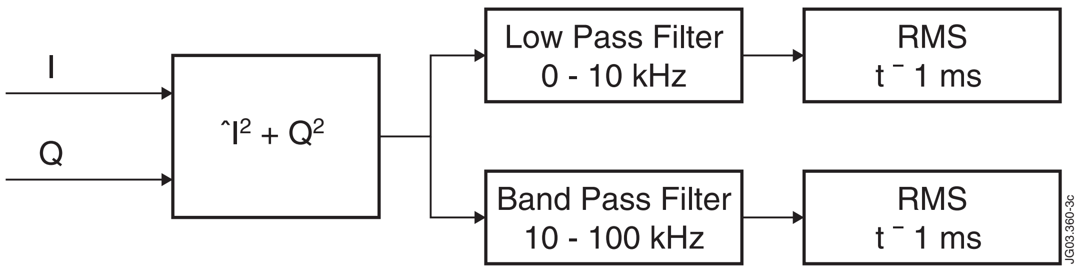

Figure 3: Block Diagram of RMS Circuits.

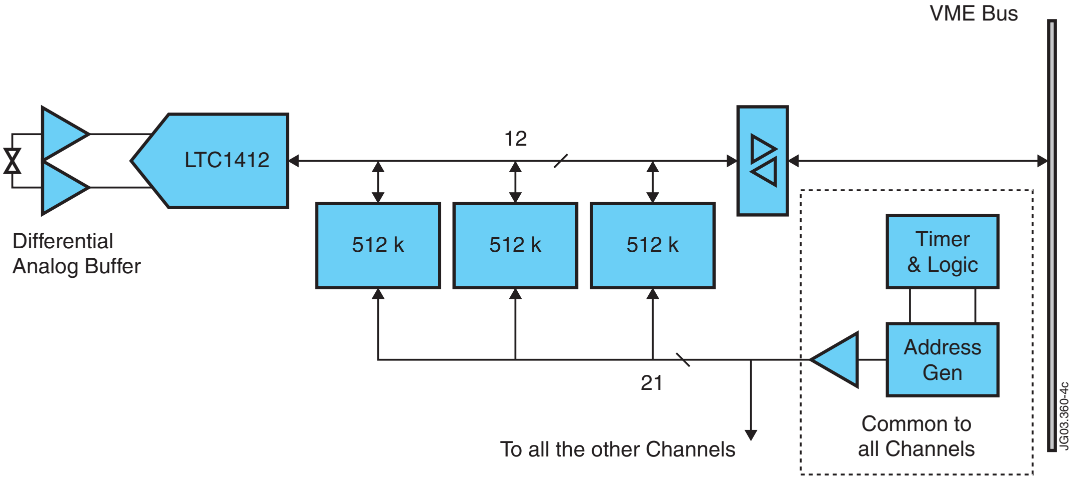

Figure 4: Block Diagram of the fast transient recorder module.

T1 (ms)	DATA1 (ksamples)	DATA2 (ksamples)	T2 (ms)
40	80	1280	640
20	40	640	320
10	20	320	160
5	10	160	80
4	8	128	64

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Table 1: Dependence of dead time between measures (T2) with the time of each measure (T1), using A24/D32 VME Standard Access.

T1 (ms)	DATA1 (ksamples)	DATA2 (ksamples)	T2 (ms)
40	80	1280	170
20	40	640	85
10	20	320	43
5	10	160	22
4	8	128	17

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Table 2: Dependence of dead time between measures (T2) with the time of each measure (T1), using VME D32 Block Transfer.