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ABSTRACT

We describe an acquisition system based on a network (Ethernet/DECNET) of MicroVAX's running under the VAXELN operating system. VAXELN is a Digital Equipment software product for the development of dedicated real time systems for VAX processors.

A central VAX running under the VAX/VMS operating system is used as file server and as an interface with respect to the user's world.

This acquisition system has been realized for the MACRO Experiment (Monopole, Astrophysics and Cosmic Ray Observatory) at the INFN Gran Sasso Laboratory.

1. INTRODUCTION

The MACRO Experiment has been designed for the study of cosmic rays and for the search of GUT monopoles, dark matter and neutrino stellar collapses. Briefly, the detector, installed underground at the Gran Sasso Laboratory, consists of six equal and almost independent entities (supermodules). Each supermodule has streamer tubes and liquid scintillators as active devices. The tracking is done by using streamer tubes.

The most relevant requirements to the acquisition system of the experiment are not related to the cosmic ray rate, expected to be rather small, but to the other searches, since the background due to the local radioactivity can increase substantially, in this case, the total trigger rate.
This fact is particularly true for the GUT monopoles and for the dark matter searches in which are expected particles with very low velocity (down to 10^{-4} c); this means that the trigger gates should be opened for a long time, and therefore, that the trigger needs sophisticated circuitries in order to have rates compatible with the acquisition system capability. In MACRO we expect trigger rates that could be of the order of several tenths of Hz. An additional trigger reduction will be done in software after the event readout.

Even the amount of information for each trigger is relevant. In fact, each detector is equipped with a Wave Form Digitizer with very long recording times (up to 500 microsec).In total, MACRO will have about 580 Wave Form Digitizers connected to the photomultiplier subsystem and 720 Wave Form Digitizers connected to the streamer tube subsystem. There will be about 100,000 digital readout channels for the streamer tubes, about 580 channels of TDC's and 1160 channels of ADC's for the scintillators.

The time schedule for the installation of the apparatus spans over two years with the first supermodule taking data in few months. The total amount of information to be read for the first supermodule is expected of the order of 100 Kbytes. Data reduction is necessary in order to skip the zero values and record only the the significant quantities. For the first supermodule this reduction will be done 50% in the front-end readout circuits and 50% in the online program; for the other supermodules the electronics has been designed to perform this operation fully in the front-end readout circuits.

Another requirement to the acquisition system is the capability to insure remote accesses for monitoring the data taking. This is particularly important since the Collaboration is formed by a large number of Institutions, part of them from USA.

2. MACRO ACQUISITION SYSTEM

The acquisition system has been designed taking into account the following requirements:

1) The system must be modular and must consist of a network of microcomputers to match the apparatus modularity. In this way the system size can be tailored to the real necessities.
2) The system must allow an easy access from remote locations to each computer or microcomputers in order to control the apparatus even from large distances (i.e., USA).

3) The system must be largely based on commercial products, both for software and for hardware, in order to be easily maintained.

Taking into account these requirements, we have chosen a system based on a MicroVAXII network (Ethernet/DECNET). The MicroVAX's are running a VAXELN system. VAXELN is a Digital Equipment software product for the development of dedicated, real time systems for VAX processors. A central VAX, running under VAX/VMS operating system, is used as file server and interface with respect to the user's world.The "CERN-Fisher CAMAC system crate", that uses the CES 2280 Qbus-CAMAC interfaces with the DMA controller 2281, has been chosen as the main hardware standard.

The general layout of the acquisition system is shown in Fig.1). Three MicroVAX's will control three groups of two supermodules each. Each MicroVAX is connected to two CAMAC parallel branches. A fourth MicroVAX will act as the supervisor for the neutrino events from a stellar collapse.

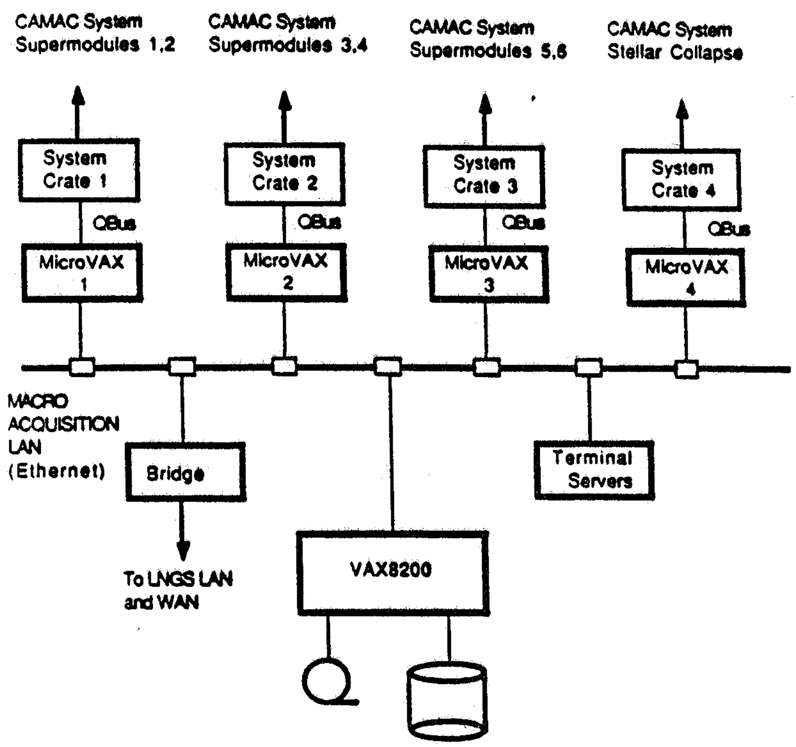


FIG. 1 - General layout of the MACRO Data Acquisition System.

All the computers are connected via Ethernet under DECNET protocol. This choice does not imply any limitation on the data throughput that, in our case, is due the CPU used. We obtained, in absence of high software overload, a data throughput of more than 300 Kbytes/sec between two MicroVAX's in VAXELN, and more than 150 Kbytes/sec between a MicroVAX in VAXELN and the VAX8200. A big advantage of this network solution consists in the reduction of cables, due to the fact that is not necessary to have all the CAMAC crates in the same location.

The tasks that each MicroVAX has to perform are: CAMAC readout, event filtering, data reduction and data forwarding to the VAX8200. Ancillary utilities have been implemented to help the control and the debugging of the apparatus; in fact during the acquisition an user from any DECNET node can:

1) require a copy of the raw data buffer from a given MicroVAX;
2) require the execution of CAMAC operations by using Remote Procedure Calls utilities for the CAMAC handling.

3. VAXELN SYSTEM FOR THE MICROVAX's

VAXELN has the following advantage respect to the VMS operating system:

1) optimized performances for real time operations due to the small overload of the operating system;
2) powerful and efficient message exchange facilities that are useful to build multi-jobs applications, even if the jobs are running onto different machines;
3) easiness to write device drivers and to work with peripherals. Device drivers can be written using high level languages (Epascal or C).

A machine running a VAXELN system is dedicated to a particular application and it is not possible to perform any operation that was not planned at the building time.

The VAXELN system for MACRO consists of six user jobs running with different priorities.The system includes four system jobs like the Ethernet driver. In each job many concurrent subprocesses can run with different priorities; in our system more than fifteen subprocesses run concurrently: the number of subprocesses depends on the number of activated DECNET connections.

The software has been written in EPASCAL, the VAXELN PASCAL version.

The exchange of data between jobs is done using the VAXELN message facilities, useful in the handling of the event data.

The CAMAC input/output can be done using a list of CAMAC operations, contained in a file on VAX8200. This is the normal way to handle CAMAC during the data taking. Moreover, the access can be done by using a standard ESONE CAMAC library[1], either directly inside VAXELN, or from a computer of the DECNET network via remote access routines.

The time needed to perform a 16-bit word CAMAC operation (CSSA routine) is 74 microsec, to be compared with times of the order of 1-2 msec obtained with drivers under VMS. This time becomes 16 msec for a CSSA operation executed from VAX8200 using the MicroVAX as a server. The

execution of a single word operation via CAMAC list takes about 30 microsec.
A DMA transfer takes an offset time of about 1.08 msec using the ESONE library and 0.8 msec using the CAMAC list; the transfer rate due to the hardware is of the order of 3.2 microsec/word.
A centralized job handles the commands coming from the central VAX and routes the commands to the appropriate VAXELN jobs.

4. THE VAX/VMS ACQUISITION SYSTEM FOR THE VAX8200

The VMS part of the acquisition system performs, at this moment, the following functions:

1) Network server and I/O server with respect to the ELN systems running on the MicroVAX network;
2) router of the directives to the MicroVAX network;
3) router of the user directives to the subprocesses components of the VMS system;
4) handler of the general histogramming;
5) spooler of complete event data to other VAX/VMS computers in the network;
6) collector of the alarm conditions.

This part is constituted by several parallel subprocesses scheduled according to a prefixed scheme of priorities and synchronized via Event Flags.
Other multiple processes, substantially decoupled from the core of the system, are the interfaces toward the users (Consoles, Histogram Presenters).

The data sharing among the processes is performed via mailboxes and global sections, while the raw data flow among the different components of the system is arbitrated by the Model Buffer Manager(2).

The network service is performed by the use of the DECNET communications. The system implements synchronous DECNET transparent communications in the subprocess that routes the directives to a companion process of the ELN systems (send commands/wait for the completion) and asynchronous DECNET nontransparent communications in the subprocess that handles unsolicited data coming from the ELN systems (messages containing event data, alarms, etc.). The asynchronous Net Server subprocess includes a procedure that builds the event data structure starting from the information (fragmented due to the transmission protocol) received from the network and originated from different MicroVAX's (more than one MicroVAX can be involved in the acquisition of the same event).

5. OVERALL PERFORMANCES

The performances has been studied using a random trigger generator.
The data flow related to a trigger is shown in Fig. 2. The performances obtained with events involving only one MicroVAX are shown in Fig. 3: in Fig. 3.a the CAMAC list generated only one DMA transfer and 40 word program transfers for a total buffer length of 2.18 Kbytes; in Fig. 3.b the CAMAC list generated 10 DMA transfers and 80 word program transfers for a total of 13.07 Kbytes. The data logging was done on disk. At 10% of dead time a throughput of about 40 Kbytes/sec has been obtained (for a buffer length of 13 Kbytes). This value corresponds to about 30 tapes/day (a tape is supposed to contain 120 Mbytes). The limitation is due to the VAX8200 CPU that is saturated for this data throughput. We think that the current Ethernet hardware could support a data throughput at least a factor three higher, if a CPU more powerful than the VAX8200 is used. However, this is not required for the MACRO Experiment.

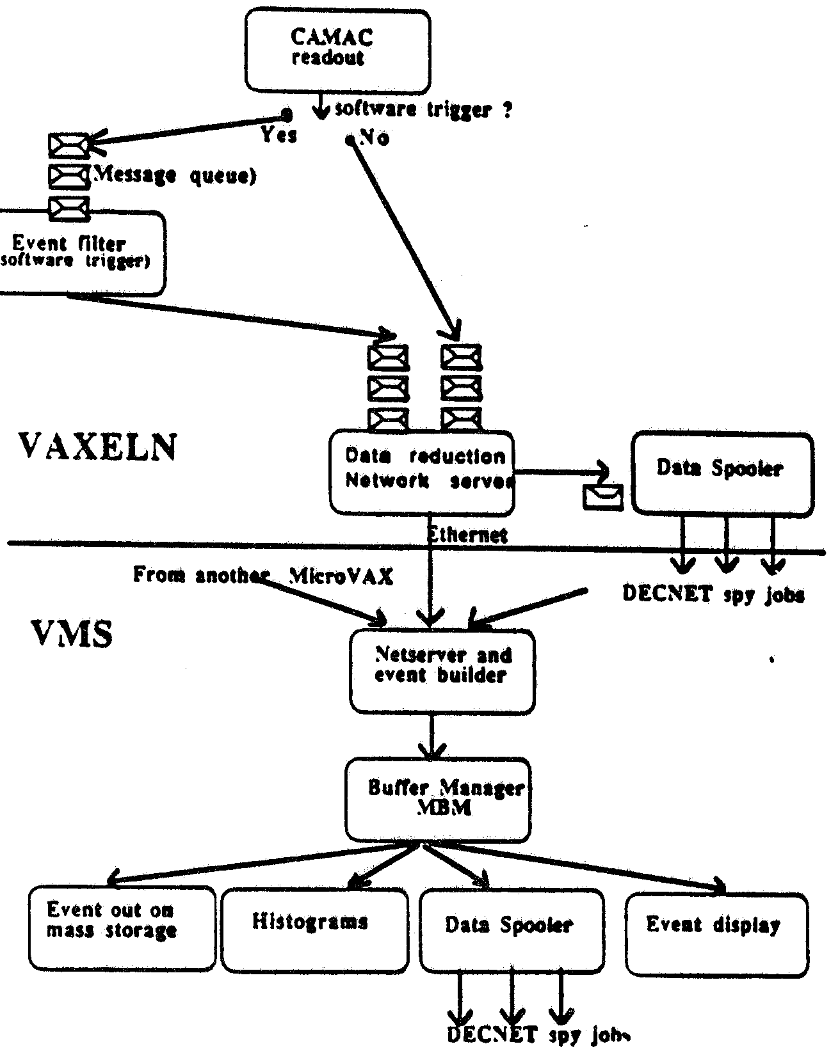
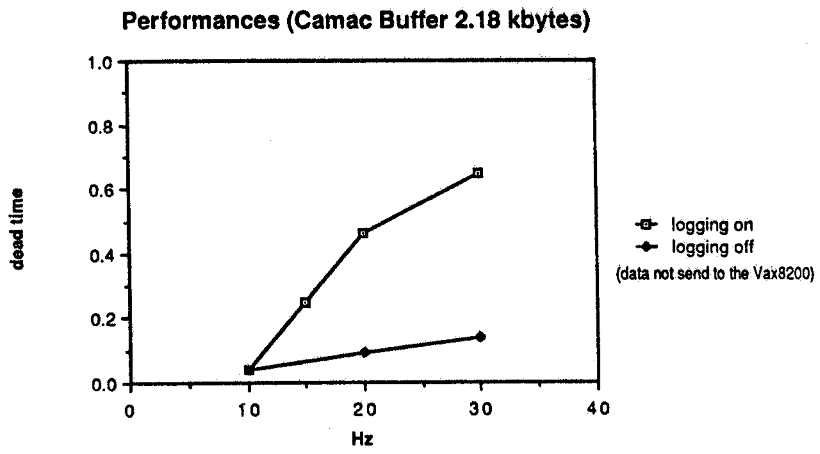


FIG. 2 - Event flow from a MicroVAX to the VAX8200.



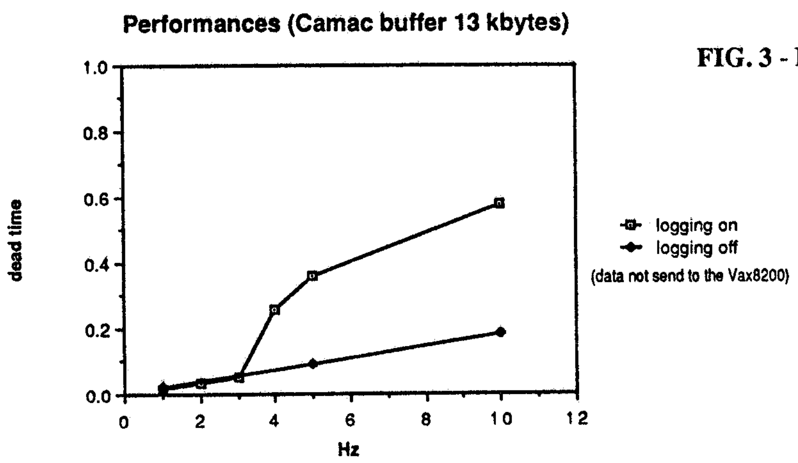


FIG. 3 - Performances for random triggers.

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2. Vande Vyvre, P.; The MODEL Buffer Manager, CERN Mini and Micro Computer Newsletter, No. 17, pag.13, December 1987; and The MODEL Buffer Manager User's Guide, CERN, May 1987.