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Distributed Control And Data Acquisition For The EUROGAM Gamma Ray Spectrometer

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Abstract

EUROGAM is an Anglo/French Gamma Ray Detector which will alternate between the Tandem Van der Graaf at Daresbury and the Vivitron at Strasbourg. Because of the need to conform to the standards of Laboratories in two different countries, and the very sensitive nature of electronics for Germanium Gamma Ray telescopes, the newly emerging VXIbus (VMEbus EXtensions for Instrumentation) was chosen as the basis for control and data acquisition. This entailed a major programme of development for both the signal processing front end modules for Germanium and Bismuth Germanate detectors, and also for the hardware and software management of resources from within the VXI environment. The paper will concentrate mainly on the latter areas.

I. INTRODUCTION

EUROGAM is a high resolution gamma-ray detector which is being constructed to answer the many exciting questions raised through recent discoveries in Nuclear Physics. Phase I of the EUROGAM array provides 45 Germanium (Ge) detectors with surrounding Bismuth Germanate (BGO) detectors being used to provide the suppression shields. A second phase is planned which will provide a 70 detector system. EUROGAM is a joint development project between Institut National de Physique Nucléaire et de Physique les Particules (IN2P3), France, and the Science and Engineering Research Council (SERC), UK. The array is expected to come into operation at the Nuclear Structure Facility at Daresbury Laboratory, UK, early in 1992 and will run for one year following which it will be transferred to France to operate on the new Vivitron accelerator which is being commissioned at Centre de Recherches Nucléaire, Strasbourg (CRNS).

II. TECHNOLOGY

To provide data acquisition, control and monitoring functions for EUROGAM, a mixed solution based on VXI, VME and UNIX workstations has been chosen with the overall system structure being arranged in a distributed computing architecture. Figure 1 shows the layout of the system and its component parts.

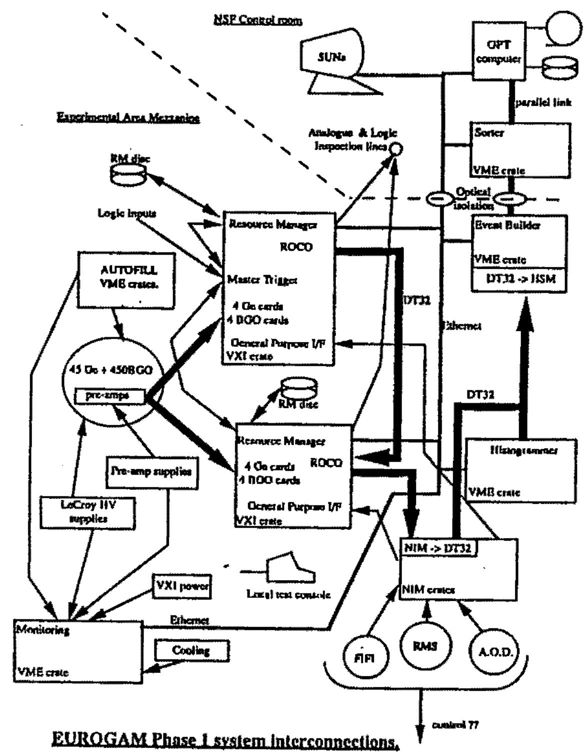

FIGURE 1.

VXI is used to front-end the system and has enough electric and magnetic shielding to allow the treatment of analogue signals to very low noise levels This permits a highly integrated approach to be taken in the electronics units designed for the processing of pulses from detector channels. VXI also minimises the inter-unit cable connections required and hence increases reliability. VXI also provides a full implementation of a 32 bit VME bus for general control of cards in the crate, read-out capability and multi-master processor access. The enhanced features contained in the VXI standard

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allow user definition of specific lines to suit individual system requirements, trigger implementation, clock facilities, and if higher speed data read-out is needed in the future, a 32 bit local bus is available.

Components of the system not requiring a very low noise environment are implemented in a number of standard VME crates for economy, commercial availability of many modules, and efficient use of space. Functions implemented in this form are Histogramming, Event Building, On-Line Sorting of Data, High Voltage Control and Autofill Systems for detector cooling. The overall system is set-up, controlled and monitored from UNIX workstations via an Ethernet LAN. A separate high speed data path is provided for data acquisition. Users of the system can also use the same workstation for visualisation of on-line and off-line data. VXworks has been used for the real time software components of the system and runs in all the VME/VXI based processors.

III. VXI SYSTEMS

The VXI front-end crates are dedicated to processing of analogue pulses from the detectors. Special components have been designed and manufactured for the Ge and BGO interface boards which accept the analogue output pulses from detectors and provide all the signal processing required to produce a digital output data stream which can be accessed over the backplane. A 6 channel Ge board is available and this is matched by a BGO card which provides signal conditioning, event vetoing and read-out from the suppression shields surrounding the Ge detectors. All adjustable parameters on the Ge and BGO cards are under control of the software via read and write access to registers over VME bus. Local trigger facilities are also provided on each board. Each VXI crate is controlled by a Resource Manager (RM) unit which also contains the Slot 0 module functions. The RM is modular in its construction and allows the integration of commercial VME processor boards offering an on-board Ethernet network interface with the 3 other RM boards which provide VXI/VME interfacing. Thus the architecture of the RM can be updated or tailored to meet other experimental requirements without complete re-design. The current RM has been developed by electronics engineers working on the EUROGAM project and engineering staff from Struck in Germany. The company are responsible for the manufacturing of this unit. Read-out for each crate is provided by a Read-out Controller (ROCO) which shares mastership of the VME bus with the Resource Manager. The ROCO collects data from each instrumentation card participating in a multi-parameter event and forms a data block for transmission via its output port which is a 32 bit ECL bus (DT32) capable of rates up to 4 Mbytes/sec. The DT32 bus is chained to all ROCOs in the system and read-out is performed sequentially from each VXI crate. A Master Trigger unit is required for the data acquisition system and this is also designed in VXI format and housed in one of the front-end crates. A small amount of trigger logic is associated with each detector channel and this is provided by the local trigger facilities on-board each instrumentation card. Master Triggers are produced when one of several pre-programmed multiplicity levels is reached (ie, a number of detectors involved in multiparameter event). This is done by summing current outputs provided by the local trigger of each active channel and combining this with logic inputs provided directly to the Master Trigger. The trigger unit is programmable and software access is again via registers on the VME bus.

IV. HISTOGRAMMER

The ability to histogram parameters from individual detector channels is a requirement of the system and this is achieved by inserting a Histogrammer into the DT32 chain. This is a single crate VME system which consists of a special interface together with commercially available memory and processor modules. The special interface unit spies on the data passing over the DT32 but does not participate in controlling the flow of data from the ROCO. Data to be histogrammed is loaded into a FIFO which acts as a de-randomising buffer between the 10 MHz burst rate on the DT32 and the average rate at which histogram updates are required. A software loadable look-up table is used to compare the address fields of each parameter passing over the DT32 with internal values to see if this parameter is to be histogrammed. If a match is found the look-up table also provides the base address of the area of memory assigned to this parameter. By summing the base address and current data value of the parameter the correct memory location is then incremented over VSBbus. Histograms are read out over the VMEbus and shipped by the crate control processor over the set-up and control Ethernet for visualisation at a user workstation. Such histograms are generally used to check the quality of data from an experiment and to monitor detector performance. If data rates exceed the capability of one histogrammer unit additional systems can be inserted into the DT32 bus and assigned different groups of parameters to monitor.

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V. EVENT BUILDER

The Event Builder (EB) is a multiprocessor VME system which is built entirely of commercially available modules, except for a small interface board (ROHSI) which terminates the DT32 bus and passes data to one or more CES HSM8170 units which are controlled by FIC8232CPU. The main task of the EB is to form self-contained events from the raw data stream for onward shipment, further processing and/or storage. The EB can also carry out simple functions such as individual/shared suppression filters, event filtering and simple arithmetic operations. The system must be capable of processing 100% of the data in real-time and it is therefore equipped with a number of MVME165 processors (4 initially) which are assigned to event processing and operate in parallel on the data stream. The EB is initially targeted to process about 1 Mbyte/sec of raw data but is expandable by the addition of further hardware modules. The output stream of formatted events is via a dedicated fibre optic link driven by a CES FIC8232 and CES ODL8142. The fibre optic link and its drive units are capable of operation at rates up to 6 Mbytes/sec. Control of the EB is via the Ethernet LAN and as the unit is fully programmable other software functions can be added as experience of user requirements is gained during operation of the array.

VI. DATA ROUTER AND SORTER

The Data Router and Sorter (DRS) is a VME system which sits at the remote end (ie outside the experimental area) of the fibre optic link driven by the EB. In addition to providing a high speed data path the optical link also provides an excellent means of isolating electrical noise and potential earth loop problems in the computing zone from the more sensitive experimental area.

Although contained in the same crate the functions of routing and sorting are to be seen as completely separate facilities. The Router forms part of the data acquisition path whereas passing data to the Sorter is optional and to be selected by the user.

The optical link is received by an identical pair of units to those in the EB (FIC8232/ODL8142). The Router software then allows all or some percentage of data to be sent to the Sorter or alternatively directly written to tape; if required, both paths can be accommodated in parallel. The Data Sorter consists of a number of MVME165 processors which are controlled and supervised by an MVME147 unit which also provides general network access to the DRS via its Ethernet port. The task of the Data Sorter is to provide on-line analysis of the data. Multi-dimensional histograms are built in global memory and can then be made available to the user for viewing at a workstation. The main data stream from the DRS is output via a parallel interface to the resource computer.

VII. RESOURCE COMPUTER

The Resource Computer which provides tape and disc drive facilities to the data acquisition system is a GEC4190 machine, one of a range of computers which have been used at Daresbury for several years with great success. Tape server software has been written for the GEC4190 which allows the event by event data received from the DRS to be written to one or more Exabyte 8500 drives. The server software supports different data streams and it is the responsibility of the user to select the event type to be assigned to a particular stream. At a later stage of the project a UNIX based system will be developed to provide tape and disc resources.

VIII. HIGH VOLTAGE CONTROL

The High Voltage (HV) supplies required for the detectors are provided by LeCroy 1440 high voltage units which are controlled and monitored via a LeCroy 1131 interface board and controlled by a VME processor unit connected to the Ethernet. The software allows interrogation of each HV mainframe to find unit type, the voltage setting for each channel, ramp rate, and current limits; it will also continuously monitor all channels to check for any irregularities.

A hardware interlock to the Autofill System has been provided so that any failure of the cooling system to an individual detector will cause shut-down of the appropriate HV channel. This condition is detected by the control task and reported back to the user. A local database of the current set-up state of all HV channels is maintained and is available to the user over the network for viewing and/or storage for use on a future experiment. The user interface to the HV system will be from the UNIX workstation.

IX. AUTOFILL

It is necessary for the Ge detectors in the EUROGAM array to be kept at liquid nitrogen temperature during operation and data taking. This is accomplished by means of an Autofill System which regulates a series of solenoid valves according to the cooling requirements of each detector as indicated by

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temperature monitoring. A VME system with local processing capability has been provided to control the operation and much of the controlling software runs in stand-alone mode. The VME system has a network interface onto the control Ethernet thus allowing monitoring information and error messages to be passed to remote terminals for viewing. The Autofill equipment has been designed with an optional manual mode of operation and as indicated in the section on HV control there is a hardware interlock to ensure the voltage supply is removed if the temperature of the detector exceeds its limits.

X. ENVIRONMENTAL MONITORING

To ensure the quality of the environment in which EUROGAM operates, the data acquisition system is built into water cooled racking systems. To prevent damage under fault conditions and to provide early detection of potential problems, the systems are monitored for temperature, fan failure, power supplies, etc. This information is fed back to the control system via VME interfaces which are accessed over the network.

XI. UNIX WORKSTATIONS

Networked workstations provide the user, and where appropriate, engineering support staff with an interface to the whole of the EUROGAM control, data acquisition and data analysis system. This is achieved by using a window system based on X11 which gives the user access to a series of purpose designed windows which provide visualisation and control to various areas of the system. The workstations also provide a programming environment for users in which they can develop their own software tools for analysis. Menus are provided to set up EUROGAM to meet individual experimental requirements and the current configuration status can be sorted for future use. Access to the system is not restricted to any single workstation and provides facilities for groups of users to work in parallel. Security features are built into the network system to prevent access to areas of the array software and hardware facilities which could be damaged in error.

XII. SOFTWARE ENVIRONMENT

The individual hardware components of the system have been described and form a networked set of distributed computing elements. It is the software environment which provides the integrated approach to EUROGAM control and data acquisition and offers the user complete control of his or her experiment, from set up and monitoring, through acquisition to analysis functions, all controlled from a UNIX workstation offering graphical menus in multiple windows to meet all general requirements. The software has been designed so that it is modular in its architecture thus providing for easier maintenance and the development of additional facilities in the future.

Whilst UNIX workstations were selected to provide the user interface, UNIX is not considered an appropriate operating system for the real time elements of the software which run in the VXI and VME processors and which provide various functions in the EUROGAM architecture. VxWorks was chosen as the real-time kernel and has proved to be very efficient in both its ease of development and run-time performance.

The software is designed around the client/server mode of working and Ethernet provides communications to all areas of the distributed system. Four main server programs have been developed to provide access to all data acquisition resources, these are a register server, spectrum server, tape server, and message/error logger. The main path for data from the experiment is kept separate and is as described in the hardware section. This path is not used for software commands and is uni-directional. Figure 2 (overleaf) shows the overall software structure and how it relates to the hardware components.

XIII. SOFTWARE COMPONENTS

Communications

Common network software is used to access all components of the system and Ethernet is used as the carrier LAN. CPUs which are attached to the Ethernet can also act as gateways for communication with other processors in the same crate using the backplane as a network.

The protocols used for communication are:

1. NSF (Network File System).
2. RPC (Remote Procedure Calls).
3. XDR (eXternal Data Representation).
4. UDP/IP (User Datagram Protocol/Internet Protocol.)
5. IP (Internet Router).

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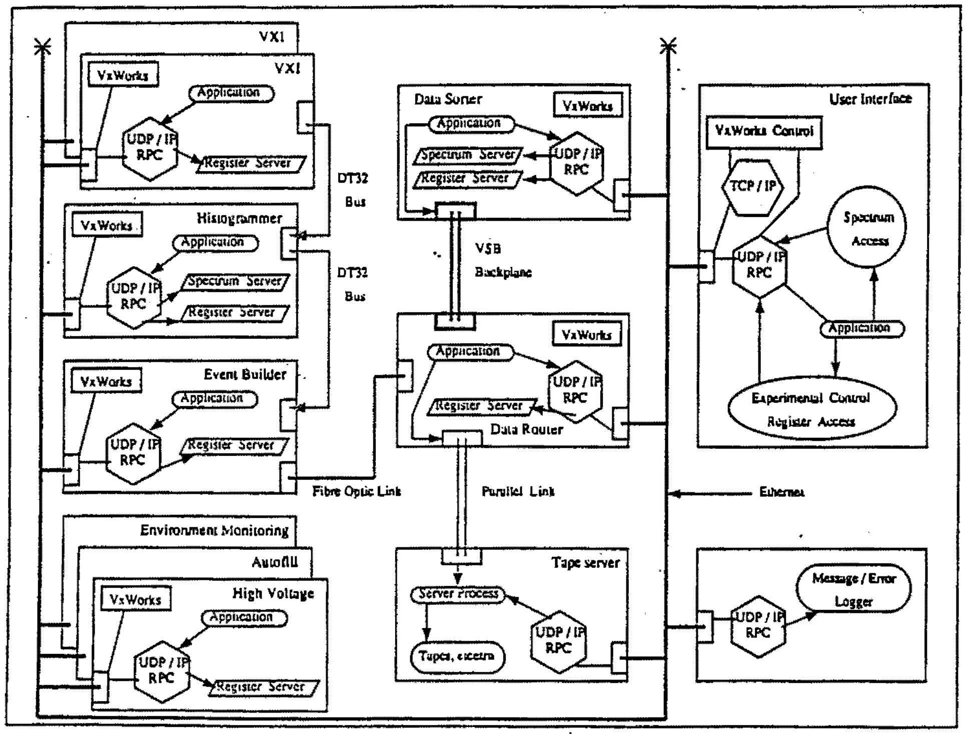

FIGURE 2.

Communications between clients and servers use RPC to pass requests for control, monitoring and read-out functions. Fixed UDP/IP ports are used by servers to avoid delays which the use of dynamic ports would involve. To offer facilities which are more suited to the data acquisition and control environment the standard Sun Microsystems RPC library has been extended to provide:

1. Asynchronous RPC to improve response to user interface requests.
2. Multiple RPC requests to different servers.
3. Variable RPC timeouts for specific applications.

XIV. VXWORKS

The decision to run VxWorks as the real-time kernel was based on the following criteria:

1. Offers a multi-tasking environment designed to meet the need of real-time control and data acquisition.
2. Software is designed and developed using UNIX workstations and is UNIX source compatible.
3. BSD networking available.
4. Performs well in the areas of task scheduling and interrupt handling.
5. Remote debugging facilities are available.
6. Support is provided for a wide range of manufacturers products

XV. REGISTER SERVER

The Register Server allows client programs to communicate with server processes anywhere within the EUROGAM system. It is a general purpose communications package which can be tailored to fit a particular application environment When the system is initialised, each server process is loaded with the application specific processes it requires to carry out its designated task which can be viewed as a set, or, in some cases, sequence of writable and readable registers within the VXI and VME systems for which it is responsible. Registers are defined dynamically by clients using the Register Server protocol and specify the local procedure to be invoked when the register is subsequently accessed. The Register Server also

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provides for data to be passed between client processes and server applications.

The Register Server Primitives are: a) Read, b) Write, c) Initialise, d) Read Attribute, e) Write Attribute. Attributes are additional pieces of information required by application procedures, for example the offset address of a register in an individual VXI or VME card. For reading and/or writing sequences of registers wild-card techniques have been implemented based on the register name. This allows many registers to be accessed with a single RPC request.

XVI. SPECTRUM SERVER

The Spectrum Server is responsible for the handling of all spectra and provides access to data in the Histogrammer and Sorter units and is also able to access off-line spectra held on disc. The server controls and allocates memory in the Histogrammer as required to meet user demand and will pass the address of an individual memory area assigned to a parameter to be histogrammed to the Histogrammer look-up table via the client workstation using the Register Server. In response to user requests spectra can be named and created and then read back for on-line display at the workstation or for off-line storage.

XVII. TAPE SERVER

As previously mentioned in the section on the Resource Computer the server software provides access to tape storage devices. Data striping has been implemented to permit data to be written to several units in parallel when higher data rates are required than can be accommodated by one drive. Alternatively the same data stream can be written to multiple tapes simultaneously which is a useful feature when several users in an experimental collaboration wish for their own copy to take to their home institute.

XVIII. MESSAGE & ERROR LOGGER

When problems or errors occur in the system a report is passed to this process. Such items would be HV malfunction, Autofill problems or an environmental failure. Clients programmes can declare that they are interested in receiving messages from a particular area of the system and these message types are then forwarded to the client in addition to being logged by the server.

XIX. OTHER SOFTWARE

EUROGAM provides facilities such as Event Building and Data Sorting described in the hardware section. These functions are controlled and accessed in the same way as other VXI and VME devices and use the VxWorks kernel. In order to perform their designated scientific function each system has specific application code which is tailored to meet experimental needs. This software is not described in the paper. To provide the graphical scenes required for the user interface the Open Look Window Manager is used together with DEV Guide to provide the development environment. To complete the software system several small application routines are provided to meet specific requirements, these routines use the software infrastructure described.

XX. ACKNOWLEDGEMENTS

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