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A VXI SYSTEM FOR THE OBSERVATION OF DISTRIBUTED ANALOG SIGNALS

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A VXI system for the observation of distributed analog signals

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Abstract

To replace an aging multiplexed observation system of about 1500 analog signals originating in 5 machines of the CERN PS Complex a VXI system consisting of various oscilloscope and multiplexer modules housed in local crates has been developed. The crates are linked together via an Ethernet cable and run under the VxWorks operating system. An on-line Oracle database allows for reference signals and observation settings to be saved and restored. The signals are displayed within a hundred millisecond after their capture on virtual oscilloscopes on DEC workstations; these oscilloscopes include all the usual features plus the specific controls related to the CERN context. A first slice, correlated with the PS-SL controls rejuvenation project was delivered in March 1993, consisting of 2 crates accessing about a hundred signals. This paper will describe the hardware and software structure, the current and expected performances as well as costs and forecasts.

I. ENVIRONMENT PRESENTATION

The CERN PS Complex machines produce various lepton and hadron beams in sequences called "Supercycles" that repeat every 10 to 20 sec. As several machines are always involved in the processing of any beam, touchy synchronization is necessary and the evolution of lots of parameters according to time and energy has to be closely scrutinized. This explains the vital need for the operation crew to have, besides a sophisticated control system, a large stand-alone system to observe and correlate analog signals delivered by all the types of pulsed and programmed equipment. This system, running since 1981 and known as S.O.S. (Signal Observation System) links more than 1500 signals to any of the 8 operation consoles in the PS Main Control Room [1].

Because of the obsolescence of the FEC computers driving the control system and the SOS, a rejuvenation project was launched in 1991 based on VME distributed crates driving the hardware linked to workstations via an Ethernet network [2].

II. THE EXISTING SYSTEM

A. Description

The SOS is a CAMAC-driven custom-designed analog multiplexing equipment structured in three layers (Fig.1):

- local crates called "Villages" concentrate up to 88 signals quite near to their origins and multiplex them onto 8 output cables,
- beside the Main Control Room, central multiplexers called "Towns" receive the village cables plus direct "essential" signals that would not be sufficiently available otherwise ; these towns deliver 16 output signals to a distributor called the "Capital" which delivers 8 signals to the C_i consoles.

Fig. 1. Structure of the existing multiplexing system.

Fifty timing pulses originating in the different CERN-PS machines are multiplexed with the same equipment as the analogue signals to bring two triggers to each console.

Thus, on every operation console 8 signals can be observed on 4 digitizing oscilloscopes using 2 trigger pulses. These triggers are gated with a selectable beam-type information (referred to as PLS telegram) in order to display only signals relative to one type of beam at a time.

An "SOS routing module" written in RT-Pascal drives the hardware in relation with "SOS Interactive Programs" running in each console computer to handle the operator requests. An Editor running on any console allows the modification of the access tree to the signals.

B. Performances and limitations

Despite the care which was brought into the implementation of the system, long cables - mainly between "villages" and "towns"- and multiple multiplexing layers are responsible for a limited bandwidth (<25 MHz) and for serious noise problems (10 to 20 mV). The original amplitude of the signal is reduced by ~2 or by ~4 which makes amplitude checks difficult. The correlation in time of different signals is nearly impossible as soon as the observation proceeds in the microsecond range. Comparisons with reference print-out or pictures are necessary to diagnose a faulty situation from a healthy one.

Any precise observation requests a complete resetting of the oscilloscopes and of its triggers which can need a lot of time when the signals are only repeated once per supercycle (i.e. every 10 to 20 sec.).

On the other hand this system did work with a high

availability and provided the analog information to the operators in real time, as soon as the digitizing oscilloscopes had built up their displays..

III. NAOS GENERAL DESCRIPTION

To improve both bandwidth and signal to noise ratio, the digitization is to be brought close to the sources of the signals.

To restore meaning to the amplitude of the observed signals, a single passive multiplexing layer and a fixed routing of the analog signal is the simplest solution.

To speed up the setting up procedure and to ease the retrieval of reference signals and comparison of current signals with these references, an on-line database is the way to go.

The system should also exhibit short transmission delays to stick to real time and an amplitude resolution better than 1%.

The possibility to observe the signals from other places than the Main Control Room would also be appreciated.

At last, the cost should not be prohibitive.

A proposal was made in 1990 of a structure which is shown on Fig.2.. It was decided in 1991 to produce a first test slice. This system was named nAos (new Analog observation system).

Fig. 2. Structure of the proposed VXI system

- As for the remainder of the distributed controls for the PS machines an Ethernet Local Area Network (LAN) is used to link the different parts of the system. This LAN has to be dedicated when the system reaches its full extension since a data rate of about 0.5 Mbytes/sec is needed to provide 64 signals every second (8kbytes / signal).

- The local crates : they physically replace the current SOS "villages" close to the equipment and make use of the existing cables to minimize the cost. They contain multiplexing units, oscilloscope modules, a multiple trigger generator and an intelligent controller linked to the LAN. They can process the 12 digitized signals which might be requested every second with the shortest possible delay.

- The database : The new control system makes use of an on-line ORACLE database. This database is used by the system to store the access structure of the signals, the signals in use, the users, the characteristics of the hardware modules, the reference waveforms and default oscilloscope settings for each signal.

- Workstations : DEC workstations are the tools used by the operators to access all the control parameters and the instrumentation of the 3 already upgraded PS machines. Additional workstations of the same type are then naturally used to emulate the user interface of the nAos system : signal and trigger selections , signal displays, recall of stored settings or adjustments of the data taking conditions are thus all performed through DEC workstations.

IV. THE LOCAL VXI VILLAGES

A. Hardware aspects

The C-size VXI has been chosen as the standard because

- commercial modules exist which cover the requested functionalities,
- the computing power which can be housed in the crate is adequate for our real-time requirements,
- it comes as a natural extension of the VME environment in which the new controls are developed,
- the crate size is the same as the size of the SOS crates they are replacing.

The VXI crates have 13 slots available. To handle a maximum number of signals in conjunction with a maximum number of output channels, single-slot units have been selected whenever possible. Thus besides the slot-0 controller and the trigger generator units, 11 slots remain to accommodate the MPX and oscilloscope modules. Depending on operational requirements the number of output channels can be 4, 6, 8 or 12 and the number of analog input channels inversely varying from 162 to 90. Hewlett-Packard E1400B crates have been used up to now and Racal 1261 crates are also considered.

A.1. The multiplexer units

18 input / 12 output custom-built units have been implemented as single-slot VXI modules. They house one digital board and one piggy-back RF-relay board. The analog outputs are linked to a common front-panel bus.

The digital board is a register-based device which makes use of 4 Altera® EPLDs 5128. One of these interfaces the module with the VME bus and deals with the VXI logical address assigned by the Resource Manager in the A24 range. The remaining circuits drive the switches insuring the consistency of the configuration and the communication of the status to the Controller.

The analog board (Fig. 3.) carries 108 Teledyne-712 RF relays (half of what would be needed to get the full combinatory) arranged in 2 layers. The output channels can be put in parallel to fit the number of digitizer channels available in the crate so that 18x4, 18x6, 18x8 and 18x12 configurations can be realized. The first generation of these boards currently installed presents a bandwidth of 25 MHz. A new 50Ω analog switch board aiming at 50 to 100 MHz bandwidth is under development. Commercial switch units are also being considered either with higher bandwidth

requested trigger and a free oscilloscope channel are available, a new "client" is declared. A token system is started to insure that the client is and remains alive.

- Dispatcher : it receives the answers of the modules to former commands in its input pipe, checks for the concerned client, encodes the data (XDR) and transmits them onto the LAN (UDP).

B.1.2.2. The functionality tasks

These tasks of lesser priority transmit the properties to the Module Drivers and the resulting data issued by the Drivers towards the Dispatcher pipe. The WAVE-AQN task is a bit special : upon a Signal produced when a trigger occurs on one of the oscilloscopes, it acquires the waveform data using a DMA in the adequate A24 memory field of the oscilloscope module; then the data is re-arranged in a nAos standard format and sent to the Dispatcher.

B.1.2.3. The drivers

A driver is a software interface (Fig.5.) to a specific hardware module which translates the standard nAos messages into

Fig.5. The driver layout

commands that can be understood by the module, whether it is "register-based" or "message-based", in COMP (for HP modules) or SCPI.

V. THE ORACLE DATABASE

Using functions written in SQL+, the user of the nAos ORACLE database can choose, read or record data in the different fields which have been created; this information is devoted to :

- operators : signal names, reference settings and waveforms,
- VXI local software : hardware addresses (INET), module characteristics, etc
- specialists : cable and patch-panel numbers, etc.

The different tables stored in ORACLE are presented on Figure.6. :

They list The PS machines (T1), the machine processes (T2), the machine sub-processes (T5), the signal acquisition parameters (T7) and locations (T6) plus the possible triggers (T4). The so-called PLS_lines table (T3) contains cycle-type information used to filter the acquisition on a single beam type at a time.

Figure.6. nAos ORACLE database

VI. THE VIRTUAL OSCILLOSCOPES

The current user interface has been designed to be both friendly and fast in displaying the waveforms. It displays on workstations as many oscilloscope frames as there are "oscilloscope" modules in the concerned VXI crate. Each of the frames consist of a graphical area mimicking a CRT with its graticule plus information pads displaying the timebase and amplitude settings of the parameters. An optional extension can be opened which gives access either to the signal list or to a set of tools.

It should be added that any workstation linked to the PS Ethernet cable can access the nAos system. On top of that the PC office network of the PS Division is interfaced to the controls network and can also be hooked to nAos. The net result is that hundreds of clients can have access which requires a careful priority assignement as well as some clearing facilities for the top priority users.

A. The graphical display

Two signals can be displayed on each frame (Fig.7.) with different colors. 500 points are shown either as dots or linked in a linear interpolation. Three different graticules are available and the contrast between the signals and the graticule can be controlled. A zoom can also be activated from the "Tools" panel. The bit-to-pixel relation is always set as an integer.

Fig.7. : One virtual oscilloscope with the "Tools" extension opened

Whenever the settings (time or amplitude) are changed the display presents provisionally a waveshape elaborated from the already acquired data until the signal is re-acquired with the new time/amplitude settings.

B. The information pads

As can be seen on Figure.7., 3 pads give complete information on the 2 channel settings and on the trigger. Clicking on any of these 3 parts opens the corresponding set-up panel.

C. The set up extensions

Two types of extension are available : Signals and Tools.

C.1. The signal selection

A tree-like structure (Machine/process/sub-process/signal) accesses the parameters which are then allocated to one channel of the selected oscilloscope. Each signal comes with its default amplitude and trigger/timebase settings. Whenever the selected signal is already used by another operator, a message warns the second user that he can only observe the signal in a slave mode according to the settings defined by the first user, as long as this user is "alive". Other restrictions raise also alarm messages : multiplexer limitations, lack of available "oscilloscope" channels, discrepancy of default triggers of the 2 signals processed by the same oscilloscope.

C.2. Tools

Apart from the Zoom facility already mentioned, tools are provided to :

- call back the reference settings and display the stored reference signals beside the actual signals,
- display and position amplitude and time cursors plus the corresponding Δv and Δt values,
- print out the analog display with all the relevant parameters,
- access to a Help on how to use the system,
- change the data presentation and the type of frame.

Two other tools are also provided to store a waveform and its settings as reference signal in ORACLE or, inversely to recall the reference settings from the database.

A last facility is provided to give information to any user about the signals and users currently alive. It gives also to the few priority users the possibility to delete "clients".

VII. FIGURES AND FUTURE PLANS

A. Figures

The current equipment has been installed as a test system without all the functionalities of the complete system. For instance, the 2 "villages" that have been implemented make use of the same Ethernet network than the remaining of the controls system (no dedicated network); the data blocks are limited to 521 bytes (including headers). Based on the result of this test-slice, and depending of the available budget, the system is to be extended to replace completely the current SOS.

These results are the following :

- the system is used permanently in the Main Control Room and in the local Linac control room,
- the signal availability is greater than 90% mainly limited by the number of oscilloscopes installed,
- the down time of the system since beginning of March 1993 (over 3 months) is of the order of 0.2 %, only due to general mains breakdown,
- the average response time measured as the inverse of the number of acquisitions/displays of the same signal within one second is less than 100 ms (using a HP 1428A oscilloscope module and a DEC 5000 Workstation).
- the cost per installed signal (with CERN-made MPXs) is about 800US\$, excluding the analog cabling which was already installed and the workstation + network costs. Half of this cost comes from the oscilloscope modules (HP E1428A)

B. Future plans

B.1. Produce the future slices

Because of reduced budget, the aim for 1994 is limited to the realization of a single extra "village" for the PS-Booster machine. Nevertheless, since the PS-Booster is a synchrotron this realization needs the implementation of the full trigger handling and of the cycle-gating facilities.

Besides, the availability of higher bandwidth MPXs (from 50 to 250 MHz) and the introduction of lower-priced VXI oscilloscope modules will allow to modulate the costs according to the performances needed.

B.2. Extend the functionalities

The virtual "super" scopes are to be realized, independant of the physical VXI modules and able to

present in the same frame signals acquired in different "villages". This implies the necessity to transfer longer data blocks (8kbytes) which requires the dedicated Ethernet cable.

The other steps which are to perform :

- to switch to LynxOS operating system whenever it becomes available on suitable commercial controllers,
- to produce drivers for other VXI modules (oscilloscopes, multiplexers).

B.3. Other possibilities

The new nAos system is developed as a stand alone diagnosis system with very few links to the controls system of our machines. Nevertheless a lot of digital information elaborated in nAos could be used in the controls application programs further than pure observation (waveform analysis, correlations and on-line optimizations).

At the opposite, whenever empty slots are available in the "village" crates, these slots could be used to plug all sort of beam instrumentation, making use of the whole VXI environment, provided a multi-user operating system is used.

VIII. REFERENCES

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