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A FLEXIBLE WIDE-BAND ANALOGUE NETWORK FOR DIRECT SIGNAL DISPLAY ON OPERATOR CONSOLES

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Summary

Observation of analogue signals coming directly from the processes remains an indispensable tool in Particle Accelerator operation. The system presently used in the new CPS control system, allows analogue signals to be selectively routed at the operator consoles: (i) 32 out of 1600 signals to oscilloscopes, (ii) 10 out of 40 triggers for these oscilloscopes and (iii) 8 out of 80 video signals for TV monitors. These signals can also be observed on local oscilloscopes. An optimised multiplexing structure is used, the transmission range is several hundred meters and the bandwidth is from DC to 25 MHz. The switch network is controlled by a computer program which directs signals requested to the console oscilloscopes and, where required by the optimised nature of the network, reroutes previously chosen signals without disturbing the observer. A central interactive database is used and signals are chosen through a tree-structure from touch panels on the operator consoles.

Introduction

In the CPS, analogue signals come from areas situated up to 1 km from the main control room. The central observation of these signals was formerly done individually for each accelerator equipment. The new control system had to realise a uniform network so that from each of the 5 central consoles any 8 analogue signals can be observed simultaneously; these signals can also be observed locally. The trigger selection for the oscilloscopes and the selection of the video signals are made through the same type of switching network.

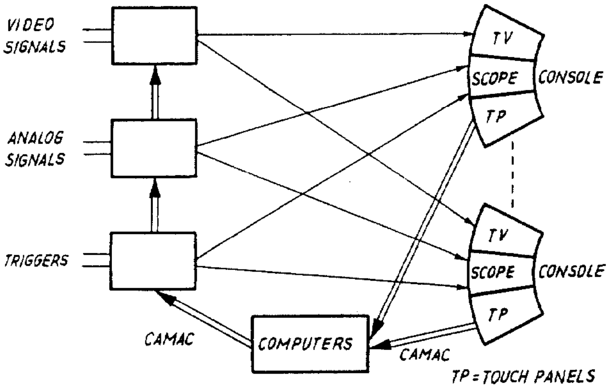

Fig. 1 OVERALL SYSTEM

The switching network for analogue signals, being the most important, will be described here.

This "Signal Observation System" (SOS) is mainly composed of
- the analogue network
- the control system of the network.

Analogue Network

The network allows the connection of any signal of the CPS complex to any trace of the scopes - and on each scope simultaneously. Its topology allows the possibility of increasing the number of scopes and signals and the overall number of transmission channels, without modifying the equipment installed or the overall structure. It optimises the following parameters:

- cost
- decoupling of material
- modularity of material
- the variety of material (standardisation).

Network Topology

The network is composed essentially of matrices linked by transmission channels. To reduce the number of elementary switches, the number of output transmission channels for each matrix has to be minimized.

The basic operational considerations to choose the topology are the following:
- the maximum number of transmission channels needed is 40 (5 consoles, 8 signals per console); this number is reduced to 32 because of the use of general utility signals on several consoles simultaneously. These 32 channels are divided in two groups: 16 are used for general utility signals and 16 for signals coming from specific operational processes.
- Because one operational process is normally controlled from one console and this in turn receives a maximum of 8 signals, the number of output channels of a matrix that groups the signals of an operational process has to be 8; but the geographical position of signals and other technical considerations must also be taken into account, increasing the number of channels required. The local observation of signals also needs at least 4 channels. In total, the number of output channels chosen for the basic switching matrix is 16.

The signals coming from the specific operational process are first premultiplexed in matrices called "villages", 8 to 12 channels from these are sent to a central "town". The general utility signals are sent directly to a second town or to a village, 12 to 16 channels from there also being sent to this second town.

The 32 output lines of the 2 towns are distributed to matrices called "districts", each of these having 4 output channels supplying one oscilloscope. The only general node of the system is the "distributor" which allows the distribution of each signal to each osscilloscope simultaneously.

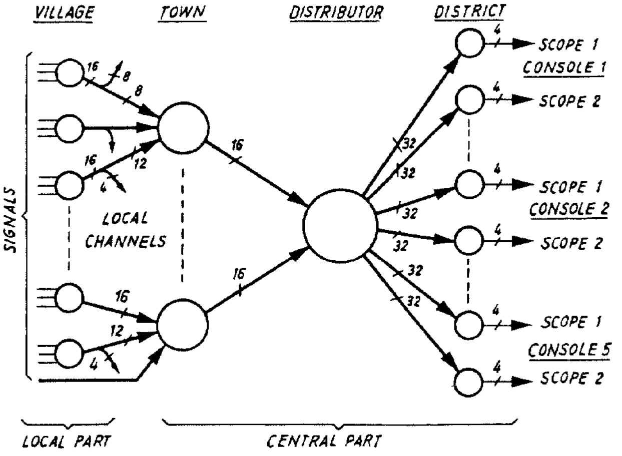

Fig. 2 NETWORK TOPOLOGY

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Matrices Structure

To reduce the matrices cost, the structure of villages and towns is optimised. A fully combinatorial structure matrix is composed of two stages of elementary matrices: a first stage which distributes each input to m outputs and a second stage which collects the s inputs at each output. To optimise this structure a third stage is introduced which distributes the outputs of a smaller fully combinatorial matrix to the m output channels of the bus. In a structure of this type the number of switches needed per input is $k = (s + m/s)$ and the minimum number is obtained for $s = s_o = \sqrt{m}$. This reduction factor is $\sqrt{m}/2$; so the signals are grouped in quarters having s_o signals each. Due to the first two stages of fully combinatorial structure, any combination of these signals can be selected, and because of the third stage they can be connected to any output channel. In our case the quarter has 4 inputs and 16 output channels, and the number of switching elements is 32, instead of 64 in the case of the fully combinatorial structured matrix. The cost is thus reduced by a factor of 2. This structure is also compatible with the desired modularity.

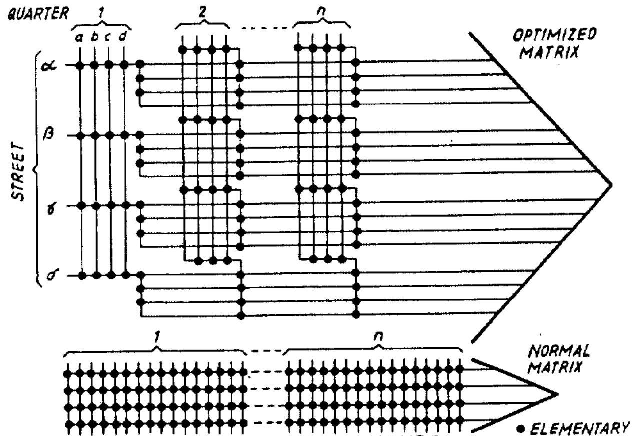

Fig. 3 MATRICES STRUCTURE

The penalty of using this structure is that signals may need to be rerouted. Example: if the 3 signals a b c of quarter 1 occupy the 3 streets α, β, γ, the 4th signal d can be put only in the street δ. And so one of the 4 lanes of this street must be free. Thus it can happen that one signal of another quarter which occupies one of these lanes must be rerouted onto another lane of another street. This rerouting is executed by an algorithm in the software switching routine. The execution duration is of a few milliseconds and the phenomenon is imperceptible by the operator. Because of the possibility of rerouting, the district must have a fully combinatorial structure to permit a rerouted signal, in all cases, to continue to be connected to the original oscilloscope trace.

Realisation

In order to reduce the cost, the towns and villages are made up of two types of switching module : one low frequency and one high frequency, depending on the bandwidth needed for the signals conveyed.

- These modules are put on 5-unit crates, each of them producing one reference signal which can be selected in each quarter and enables one to check the attenuation, the CMRR and the offset of the transmission.
- In the distributor, the attenuation and the bandwidth of the transmission are computer-controlled.
- The transmission characteristics are
  - . floating from the source to the oscilloscope
  - . bandwidth (3dB) = DC to 25 MHz
  - . attenuation 1/5
  - . signal range = 60 dB maximum
  - . CMRR = > 60 dB for F < 1 MHz

- Overall size: the system now contains 6 villages, 2 towns, 8 districts; later on it will contain 20 villages, 2 towns, 10 to 14 districts.
- The practical limit given by the installation realised is 3 towns and 16 districts, which enables up to 48 independent transmission channels to be used simultaneously, and 16 oscilloscopes. There is no real limitation to the number of villages; each village accepts up to 760 signals.

Network Control

The overall control system of the CPS contains one computer for each console, one front-end computer for each process and some other special-purpose computers such as the TREES computer, which houses the operational trees.[1,2] These computers are linked together by the "Message-Handling Computer" (MHC).

The SOS network is controlled, via a serial CAMAC link, by the TREES computer, so as to be independent of the processes and accessible from all consoles. A number of local terminals are linked to the TREES computer.

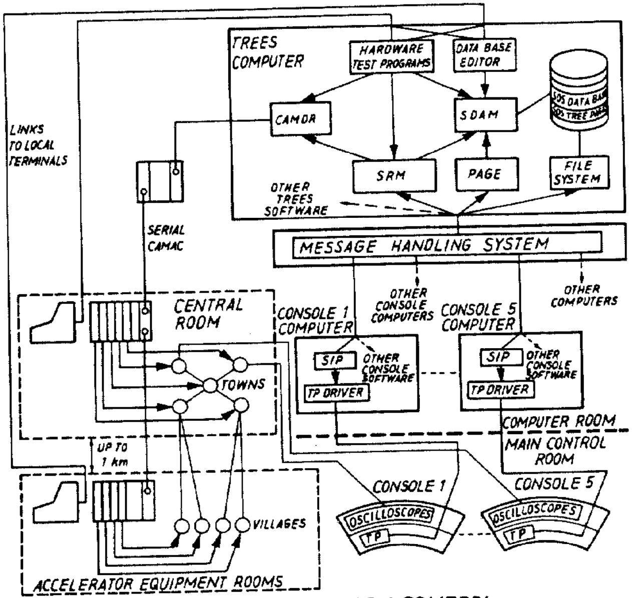

Fig. 4 SOS NETWORK CONTROL

Only one type of CAMAC module is used to control the matrices. One matrix is driven by one CAMAC module. This module memorises the complete status of the 16 possible connections in the matrix.

The SOS control software contains three main components:

- the SOS Interactive Program (SIP), which runs on each console computer, translating the operator's requests from the console Touch-Panel (TP) for:
- the switching routine "SOS Routing Module" (SRM), which resides on the TREES computer, controlling the SOS hardware;
- the SOS Database, resident on the TREES computer's disc, which contains various information for SRM and SIP.

SOS Interactive Program

SIP is presently written in the interpretive language NODAL and fulfils three main functions:

(i) Tree walking. Through the TP, the operator selects

first the set of signals he wants to observe, by descending a 4-level tree structure, each level being a "page" displayed on the SOS TP. The pages are fetched from the "SOS tree pages" on disc through the network file system. When reaching level 4, SIP instead calls for a "signals page", through a dedicated routine "PAGE" that extracts from the SOS database the names of all signals to be displayed as buttons of that page.
(ii) Connection and disconnection of signals. When at level 4, the operator may require a new signal to be displayed on one of the eight oscilloscope traces of his console; this is performed by pressing successively 1 of the 24 possible signal names displayed on the TP buttons and then 1 of the 8 trace buttons which have a dedicated place on the TP. The request is then sent to SRM, which acts accordingly. To disconnect, the operator presses the corresponding trace button again.
(iii) Status display. SIP displays the result of the required action, if successful, by changing the trace button legend: e.g. successful connection of a signal to a trace is shown by replacing the trace button legend by the name of the signal. For an unsuccessful action, SIP displays, on the TP, a detailed message indicating the nature of the error, e.g., computer network problem, disc access error, bad operator action, SOS Database problem, SOS hardware error, etc.

If the TREES computer should go down while SIP is in use on a console, further commands from the operator must be rejected by SIP with an explanatory message. However, the existing connections are unaffected, and, when the TREES is then restarted, the operator may continue using SIP as normal.

SOS Routing Module

SRM, written in PASCAL, is housed in the TREES computer, to which the SOS hardware is connected. It is remotely called by SIP with parameters that describe the action required. SRM is protected by a "semaphore" to prevent concurrent access by more than one console's SIP. Possible actions are:
- connect a specified signal to a specified oscilloscope trace, via any appropriate "route" through village, town, distributor and district, "re-routing" existing connections if necessary
- disconnect such a route, thus clearing the corresponding oscilloscope trace
- replace a connected signal by a "reference" signal (for calibration)
- "reserve" a route, so that "re-routing" is prohibited: SIP automatically requests reservation of a route when an operator asks for a "reference" signal to be connected
- "release" a reservation
- exchange the signals on two oscilloscope traces (e.g. to allow easier visual comparison): only the relevant district(s) are affected.

All SRM actions, apart from "reserve" and "release", result in SOS hardware control through the CAMAC driver, "CAMDR", and any change of connections in the SOS hardware is memorised by SRM, to facilitate break-down recovery after, e.g., a CAMAC crate power failure.

SOS Database

The SOS Database resides on the TREES computer disc, in order to avoid duplication of data in the consoles, and to allow stand-alone access from a local terminal. It contains three types of information:
- description of the SOS matrices, e.g., name, type (village, town, distributor or district), hardware address, destinations of the output lanes
- description of the available signals; e.g., input address, name to be displayed on the console TP, specific characteristics
- the layout of signal buttons on the "signal pages".

To provide a common "access method" for the database, there exists a set of PASCAL procedures, the "SOS Database Access Module" (SDAM), through which programs may access the information held in the database without knowing its actual physical structure. Currently, three programs access the database via SDAM:

- SRM
- PAGE, which is remotely called by SIP to provide the "signals pages", for display on the TP
- the SOS Database Editor, which allows interactive modification of the database contents, and can produce various printouts useful to the SOS hardware engineers.

Hardware Test Programs

In addition to the "operational" routines, there exist some specific SOS hardware test programs for use by the SOS hardware specialist, either from a local terminal or from one of the main consoles. These programs were first used to test each of the SOS modules during installation and now help in the search for hardware troubles and their repair. They may also be used for connecting SOS signals to a local oscilloscope.

Final Remarks

The SOS has been in use now for over 3 months, and has worked satisfactorily. The decoupling of hardware material has proved invaluable in the localisation of control failures, and the built-in reference signal generators have allowed rapid diagnosis of analogue transmission failures. The natural extendability of the network facilitates the addition of new signals, whenever these are needed.

The completion time for all operations requested at the console TP, is of the order of 1 second. Various possibilities exist for further optimisation of the SOS control software, so as to reduce the load on the console computers, and to increase the speed of SIP operation. It is intended, for example, to rewrite SIP in PASCAL, so as to remove the overhead of interpretation.

Another possible future development is the addition of analogue-to-digital conversion at the district, to allow, for example, completely automatic testing of the transmission.

Acknowledgements

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