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STUDIES FOR A DATA HANDLING INSTRUMENTATION SYSTEM IN THE CBNM

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H. MEYER

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Joint Nuclear Research Center
Geel Establishment - Belgium

Central Bureau for Nuclear Measurements - CBNM

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CONTENTS

Introduction

Studies are made to give a contribution from the instrumentation side to find out a suitable configuration of a data handling instrumentation system for nuclear experiments in the near future, especially in the CBNM.
Generally speaking, the to-days point of view about data handling systems is very strongly connected with the question, how far on-line analysis is possible directly with general purpose computers, i.e., should one use a computer not only for calculations, but also for recording and handling of data during an experiment?
It seems to be improbable that only such type of handling system will receive a predominant importance in the CBNM. An optimal system will depend very much on the type and quantity of experiments to be done and the equipment available because of different possible reasons.

Instead of using primarily a general purpose computer with program storage facility, it seems to be advantageous to have a flexible building block instrumentation system (1), for the measurement and handling of data on-line. Such system should allow to realize a great quantity of different wired experiment programs.

One final limit for on-line analysis with computers is their maximum storage capacity. (For medium priced computers the length of information words is limited to about 12-15 bits).
Another limiting factor for the use of computers on-line is the demand for high computer efficiency.

For experiments, as for instance high precision time-of-flight analysis and especially also multiparameter analysis, the necessary recording time is often high in relation to the calculation time for receiving final results. One can say, that for the most cases the recording time will increase very much more with the number of bits per information word than the calculation time.
Also, if several experiments are running in parallel, in the most cases a computer will probably be used with much higher efficiency for handling of data which are recorded beforehand on a suitable storage medium like magnetic tape.

For the probable future needs of the CBNM, the possibility of recording data with magnetic tape, before further handling off-line, should be available. But it will be necessary to have a suitable solution for monitoring an experiment. Monitoring should allow failure detections and preparation of final experimental conditions.

2. General lay-out

The instrumentation system shown in form of a block diagram (Fig.) is in principle similar to systems planned by others (see for instance (1)). It is a building block system which should allow an easy adaption to the specific needs of an experiment.
A part of the blocks does exist or will be available after minor modifications of existing units. Another part has been developed or is under development. A third part can be bought from industrial firms. Only some most significant interconnections between blocks are shown in the figure and discussed further on. Those are used for high precision T.O.F. and (or) multiparameter experiments. A high flexibility in the combination of blocks should be assured, also by the possibility of pure parallel binary data transfer between blocks.

3. General function

Radiation, detected with suitable radiation detectors and converted into electrical pulses, will be measured and the results then presented in parallel binary code. by use of coders (a). The code can be given by the measuring system itself (for instance, direct flight time measurement), or must be realized by special parts of a coder (for instance, pulse height converters of the serial mode - with or without preceding time-height converters - need an output register, counter chains need converters for coding their number). From coders the data will flow to an experiment handling programmer (b), where the regions of interest for different coders can be selected so far as this is not done by the coder itself.

For multiparametric analysis, the programmer should take care that the correlation condition for all parameters is fulfilled. The programmer should also adapt the arriving datas to the possibilities of the following block, mostly a buffer store (c). Such unit can accept directly only a maximum word length of datas. If the length is too big, series-parallel storage of data words into the buffer must be arranged.

The buffer store will regularize the mostly statistical distribution of the arrival time of data and allows therefore, that a maximum of time is available for further handling of an arriving data word, provided that losses of data must be kept low. The existence of a buffer store has special importance, if data are recorded on magnetic tape (e), before they will be further handled off-line. In this case the regularizing action of the buffer store makes a high packing density of datas on the tape possible and helps to increase the speed for further handling.

If the data are only recorded on-line, there must be a possibility the monitor the correct and faultless running of an experiment, but also to adjust final experimental conditions, mostly with the help of preliminary measurements of qualitative character.

A monitoring programmer (d_1) and a monitoring storage display (d_2) are planned for the last mentioned purpose.
The monitoring programmer should fulfill several functions, as for instance

α) selection of the display format, dependent on the number of given parameters of data and their dimensions, and on the type of storage display unit used;

β) selection of the type of display and of interesting parameter regions;

γ) automatic functions

In the simplest case a small core store with display function can be used as monitoring storage display, with reduced accuracy by selecting single parameters and/or the most significant bits of data words.
For having more optimal conditions concerning costs and possibilities, the application of display storage tubes is under study, to realize standard flexible monitoring equipment. The storage tubes shall store, sort and integrate arriving data, when they are only recorded on-line on magnetic tape.

Final sorting and integration of data, recorded on tape during an experiment, will be done by their fast readout (f) via a sorting programmer (g) into a sorting memory (h) during several running cycles of the tape. For each running cycle the sorting programmer selects a quantity data words (channels), which is adapted to the capacity of the sorting memory.

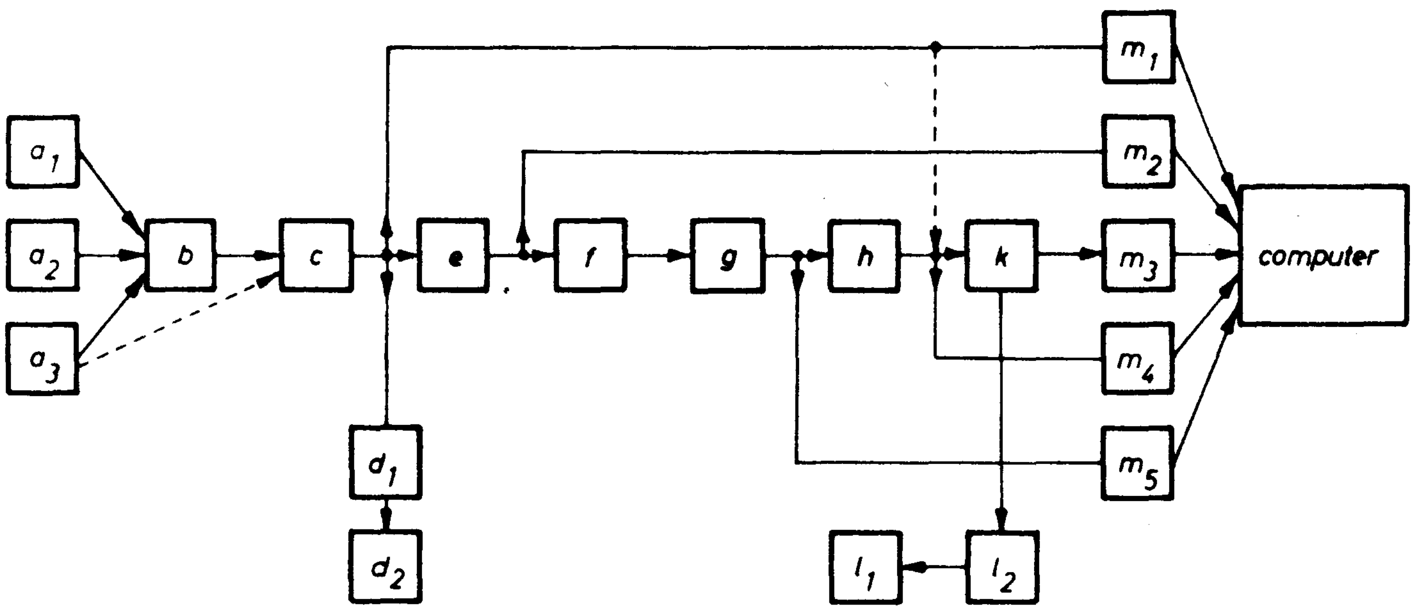

Fig.: General handling instrumentation system

a. Coders
b. experiment handling programmer
c. buffer storage
d. monitoring programmer with monitoring storage display
e. Magnetic tape recording equipment
f. Magnetic tape play-back system
g. Sorting programmer
h. sorting (computing) memory system
k. magnetic tape storage of sorted (integrated) information
l. multiparameter storage tube display
m. transfer functions to a general computer

After each running cycle the sorting memory must be read out from the sorting memory to allow sorting of another block of data words in a following running cycle of the tape. Readout of sorted information should be done preferably into a second magnetic tape (k), on which the whole experimental results can be stored for further handling in a computer (via m_5), or for display of the experimental results or interesting parts of them in a suitable standard display unit (l). Such system will contain a selection unit (l_1), the functions of which will be similar to those of the monitoring programmer (d_1). For the display itself, also a storage tube should be chosen, because a better intensity modulation for multiparametric display than with ordinary cathode ray tubes is possible. In addition, one is able to study a spectrum better in detail because a current repetition of long analysis cycles can be avoided. The analysis cycle may also run with low speed. The display unit will contain digital thresholds. The transfer function blocks (m), shown in the fig., which will allow the transfer of data of different state to a computer, will be adaption units, the necessity of which is dependent out on the type of available computer.

For multiparameter analysis, the tranfers via m_3, m_4, m_5 will be the most probable and in this case also functions, fulfilled by l_1, can be overtaken by a computer. Magnetic tape equipment for on-line recording can also be a part of a computer and in this case also the functions of d_1 can be fulfilled by an available computer; but the computer efficiency can be strongly limited, as mentioned earlier.

4. The main units of the data handling system and their characteristics.

A data handling system for the CBNM will be used mostly for neutron physics experiments in connection with a Van de Graaff generator and an electron linear accelerator. Planned and probable experiments for the near future determine the characteristics and variety of the different units.

Coding devices (a)

Five coders for flight time analysis, realized with development contracts by industrial firms, are available now. They allow channel numbers up to 65 000 (max. word length, 16 bits) and have a minimum channel width of 10 ns. They have been realised (2) for use as wired program analysers together with 4096-channel core memory systems. But a separate use of the units for on-line recording and off-line sorting is possible. One coder for high precision flight time analysis has been developed (3) with a maximum channel number of 130 000 (max. word length, 17 bits) and a minimum channel width of one nanosecond.

Pulse height coders of the serial type are included in the first mentioned system for two-parameter analysis. With the help of certain adaptions they could be used also for the general system. Parallel working pulse height coders, which will be available in the future and are under study now, can improve the conditions for certain experiments.

Experiment handling programmer (b)

The detailed characteristics of a handling programmer were not studied up to now, partly, because the momentary available coders include most of its features. In the simplest form such unit will contain only transfer registers and a gate function. But one should put into consideration for future plannings, that a central programming unit could simplify remarkably the lay-out of coders.

Buffer stores (c)

Buffer stores were developed and realised (4), especially for on-line recording of high precision time-of-flight measurements with magnetic tape. The word length is 20 bits and is adapted to the chosen form of magnetic tape equipment (24 parallel tracks with 20 tracks for the information).

One store uses magnetic cores as memory elements, has 10 words and a storage time of about 1 μsec. A second store uses tunnel diodes as memory elements, has 3 words and a storage time of 0.05 μsec.

It can be used as a prebuffer together with the first unit for time-of-flight experiments, where high differential data rates can exist because of intense neutron bursts from the linear accelerator. For multiparameter experiments only the slow buffer must be used. If the word length will extend 20 bits, the unit can be used also as a 40 bit, 5 word buffer by series-parallel storage of data words. The standard output characteristics of the buffer will allow its connection not only to magnetic tape- and monitoring storage display equipment, but also advantageously to a computer or memory with data reduction facilities.

Monitoring storage programmer with monitoring storage display (d)

A monitoring storage display will be of great importance when off-line analysis of long data words, recorded on-line on magnetic tape, will be done advantageously. The storage display will function as a qualitative sorting and integrating memory with display facility when display storage tubes are used in the right manner.
A special grid screen in the tube serves as memory in a two dimensional geometry. Each square inch of the screen can contain up to about 3000 separate storage cells, on which small charge increments will be stored and integrated.
For display, an electron beam will flow through the screen and introduce light points on the tube surface, the brightness of which is proportional to the stored charge. A stored spectrum will then be given in form of a contour display. Up to ten different brightness levels can be resolved. By varying the quantity of charge per increment, the sensitivity can be adjusted in a wide range. An adjustable display threshold will probably also be possible in a limited range.
In comparison with the "twinkle box" proposed by Chase (5) - photographic integration of light from a normal cathode ray tube - the storage tube will allow a current monitoring of a running experiment and a higher resolution. Detailed studies for the application of storage tubes have begun in our laboratory.

It will also be possible to use small capacity sorting memories with display facility for monitoring, generally by sufficient reduction of word resolution. A small memory system will be especially advantageous for the precise quantitative monitoring of single parameters.

But such a solution will be more expensive and will introduce great restrictions for multiparameter experiments, if only available.

The storage programmer will select out of the data presented by the buffer, and (or) compress, parameter regions of interest and distribute them among the dimensions of the display. In addition, it is planned to include the possibility of current automatic monitoring by making photos of the state of an experiment in suitable time distances. Only at that times the monitor will be shortly in the display mode. It is expected that about 500 words max. can be resolved per dimension (i.e. 250 000 words when contour display is used).

Magnetic tape handling equipment (e, f, g)

For the storage of data on magnetic tape an inexpensive tape deck unit (EMI-product) and one inch tape has been chosen.
For having a high information density on tape, 24 parallel tracks are available, from which 20 are used for information bits and 4 for control purposes, inclusive series parallel storage of words with a length greater than 20 bits and parity checking possibilities.

Besides the necessary electronic equipment for reliable and failureless function, modifications of the used tape deck equipment are under study, which will allow a reliable stepwise propagation of tape beside the continuous mode.
By this feature the tape speed can be completely adapted to the data rate for rates smaller about 300/sec., i.e., rates which are to expect for multiparameter experiments.
Preliminary results (6,7) have shown that for bit densities up to 300 20-bit-words / inch undetected failures because of skew and other mechanical influences of smaller 10^{-3} % can be expected.

Such high bit densities will allow, as known, a short analysis time for recorded events, especially in relation with the possible recording time. To give a typical worst case example: of the data rate is 20 words/sec. and 10^7 events are to be recorded into $2{,}5 \cdot 10^5$ channels (18 bit words), the recording time will be about five days. When a readout speed from tape of 120 inches/sec is used, and a 4096 channel sorting memory is available, then the sorting time will be about 5 hours (64 running cycles of tape), of the sorted information is read out fast on a second tape.
The sorting programmer (g) will be in the most cases an adaption unit to the sorting memory. During each running cycle of the magnetic tape, the unit will select a block of as many different data words (channels) as the memory can sort. At the end of one running cycle the programmer will initiate the readout of sorted information, clear the memory, change the selection code and start a new running cycle. Manually adjustable data reduction facilities can be inducted in such programmer.

If the experimental results, recorded on magnetic tape, are handled further directly in a computer (via m_5, fig.), the functions of the sorting programmer can be overtaken by the computer.

Sorting computing memory (h)

The reasons for the use of separate sorting computing memories, which have only simple computing facilities (addition and subtraction), instead of working directly with computers (via m_3, fig.) are mostly of practical nature. (What is available?).

In the CBNM, five 4096 channel (12 bit) sorting computing memories are available with several readout possibilities (tape punch, magnetic tape, recorders, c.r.t. display). They have been bought together with the flight time coders, mentioned earlier, as wired program analysers. No computer is directly available.

Technical reasons to use a separate memory for sorting and integrating may exist, if for instance multiparameter data with great word-length, which have been recorded on tape, must be completely sorted and if a high computer efficiency is asked.
For one million of channels for instance, one needs in the example given before, 20 hours to sort 10^7 words because of the limitation in memory capacity and tape speed; that is a mean distance of 7 milliseconds between two sorting processes. Available standard computers are by a factor up to 10^3 faster.

The mentioned five sorting computing memory systems are constructed for use in building block systems and therefore very flexible standard devices. The magnetic tape units delivered with the systems can serve for readout into a computer, which is done for the moment via a tele-processing system.

Magnetic tape storage of sorted information (k)

The magnetic tape unit shown in the fig. as a standard block for readout of datas from the memory unit can be used for the transfer to a computer (via m 5). Primarily such a unit is of advantage for fast readout of spectrum parts when a multiparameter spectrum will be sorted off-line in the memory unit during multiple cycles of the recording tape. Such type of readout is fast enough, also if the quantity of events per word-type or channel is read out several times for each channel to reduce the failure probability.

(One has to put into consideration that the sorted spectrum is stored on the tape, i.e. the intensity per channel instead of channel numbers and with the rejection of a storage, the information in one channel is lost).

The storage of the complete multiparameter spectrum on tape will allow a simple form of viewing the whole spectrum with a storage tube display unit.

The magnetic tape unit planned for readout will be similar to that used for recording, with the exception that stepwise propagation of tape and parity checking features will not be necessary.

Multiparameter storage tube display (1)

The basic unit (l_2) for the display of sorted spectra will be identical with the monitoring storage display unit (d_2) with the exception that for a contour display the charge stored during one storage process on one place of the storage screen will be proportional to the intensity in the channel belonging to that storage place. The digital to analog converters which convert the channel intensity, presented in digital form, into an analog signal will be preceded by variable digital thresholds to study a spectrum in more detail. With the programming unit (l_1) different types of display modes should be choosable (one parameter-, contour- and isometric display).

The selection of parameter regions of interest is to be done in a way already necessary for the monitoring storage display.

The maximum viewing time of a storage tube, we have in mind, is about 5 min. Then the picture should be erased and the storage

process repeated, what can be done in about one minute.
The programming unit may repeate the viewing cycle automatically.

5. Conclusions

The realisation and planning of suitable handling instrumentation will be a current work for best adaptation to different needs. Only the "red-line" should be fixed. It should be marked here that many institutions and also industrial firms are studying handling instrumentation usable as parts of a building block system (1) (8).
Own plannings should take this into account as much as possible to avoid that standard equipment, well adapted to own problems and available in the future, cannot be used because of interconnection problems.

Current contacts and discussions, also with firms concerning standardization of building block systems, will be advantageous.

If one tries to characterize the future trend in handling of data for nuclear experiments, one can say, that the application of computers will surely grow up. But the existence of instrumentation preceding and surrounding a computer in a handling system will always influence the practical possibilities and conditions for nuclear experiments remarkably.

The on-line use of computers and (or) computation devices for multiparameter experiments will receive an increasing importance, especially by the use of new memory configurations [1]. Also the modification of standard sorting memory systems with small word capacity for the on-line sorting of data from multiparameter experiments (10) could improve experimental conditions, especially for people who are not able to use always the most modern computer.

1) Associative memories with cryógenic storage cells (9)

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(3) KLOPF, MEYER, STUBER, VERELST "A nanosecond time coder with great analysis range for T.O.F. experiments"
EUR Report EUR. 491e (1963)

(4) STUBER "Studies and development of buffer storage systems for nuclear experiments
EUR Report (in press)

(5) R.L. CHASE "Nuclear pulse spectrometry"
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(9) Proc. 1962, Spring Joint Comp. Conf. - AFIPS, P.M. DAVIES, "A superconductive associative memory", p. 79 (plus other contributions: p. 89, 203)

(10) MEYER, STÜBER, "Use of standard memory systems as associative memories for integrating storage of multiparameter data by automatic data reduction"
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To disseminate knowledge is to disseminate prosperity — I mean general prosperity and not individual riches — and with prosperity disappears the greater part of the evil which is our heritage from darker times.

Alfred Nobel

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