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DATA ACQUISITION AND ANALYSIS : A FORWARD LOOK

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1 INTRODUCTION

Improved neutron detector technology now enables neutron scattering instruments with many thousands, or even tens of thousands, of detectors to be built. This increase in detector numbers will have significant effects on the associated data acquisition systems for time-of-flight instruments and in this paper we attempt to identify some of the problems that are likely to arise over the next two to five years. Having posed the problem we will look at one or two solutions.

Over the next few years anger cameras will enter service with around 16,000 detector elements per camera. Single crystal instruments can quite sensibly employ 3 such cameras per instrument making a total of 48,000 detector elements on a single instrument. Using 700 time channels implies a total of 33 million time/position channels.

Similarly, new powder instruments with up to 10,000 individual scintillator tiles may be built which, when combined with the need to employ 4,000 time channels requires a total of 40 million channels storage.

Even instruments with more modest storage requirements, can quickly multiply them by the need to store time-dependant data.

2 THE EXISTING ISIS DATA ACQUISITION SYSTEM

To see how these developments will affect data acquisition systems we will examine the particular case of the ISIS PUNCH system. This is shown in figure 1.

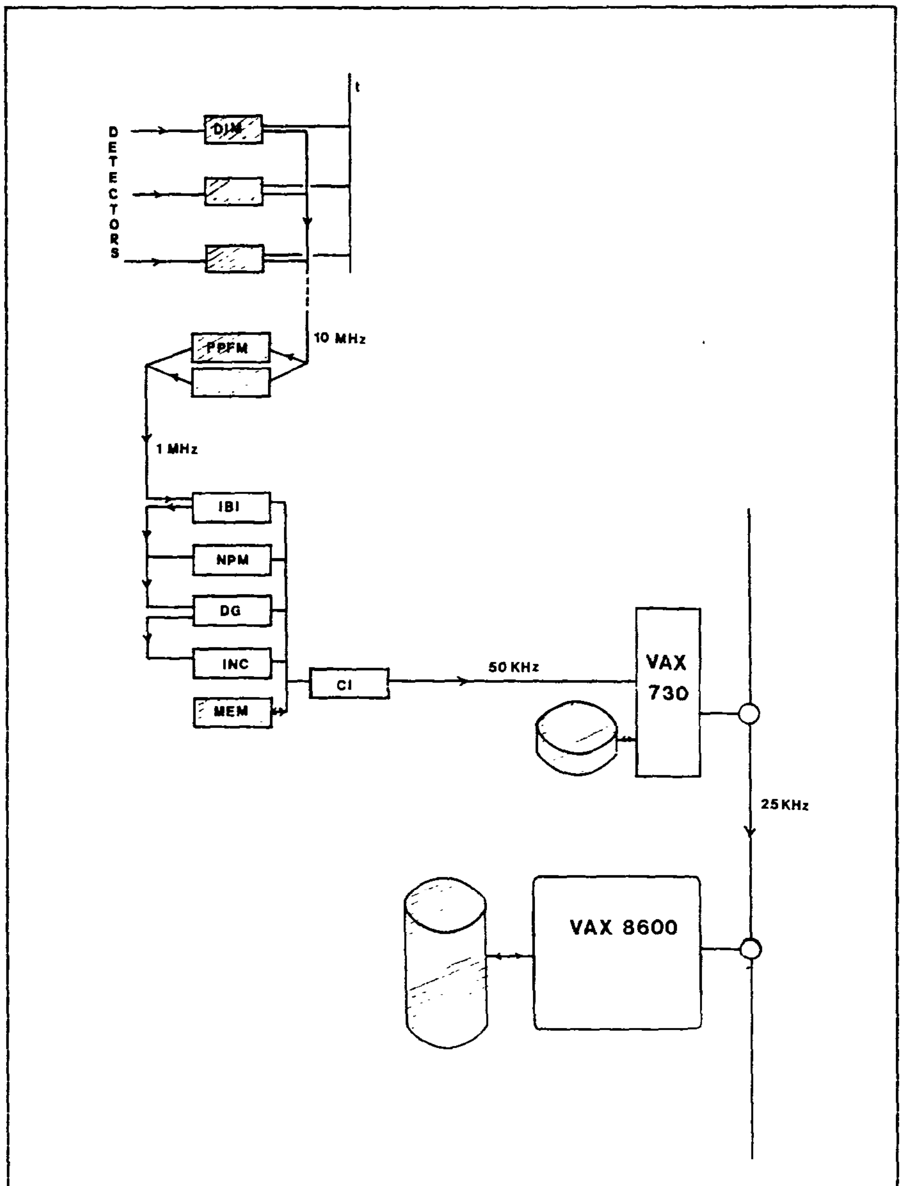


Fig. 1

The shaded components indicate the points at which data is stored. In the DATA INPUT MODULES (DIM) the neutron event is time stamped and the time descriptor stored for up to 5μs before being read out on the 10 MHz instrument crate bus. It is then stored for one frame (20ms) in the PING PONG FRAME MEMORY (PPFM). This is to ensure that the data is not corrupted by any incorrectly taken data during the frame. Following compaction from 40 to 24 bits in the DESCRIPTOR GENERATOR (DG) the event descriptor is finally recorded by incrementing the appropriate word in the BULK STORE memory (MEM) , where it effectively remains for one run. The histogram of events is then copied to the FRONT END MINI COMPUTER disk, where it may reside for one or two days, and on to HUB computer where it may last for some tens of days for further analysis. Notice that data is stored for increasing lengths of time at subsequent locations and each pathway between storage points must be fast enough to remove all the data in the storage time of the 'up-stream' location. The transition rates within the existing ISIS PUNCH system are shown in FIG.1. In particular the transfer between the DAE memory (MEM) and the Front End Minicomputer (VAX 730) is at an effective rate of 50 Kbytes/s, and the transfer rate over the Cambridge Ring is 25kbytes/s. Thus a run using a total of $0.5\ 10^6$ time-of-flight channels that requires 2 Mbytes of memory storage in the bulk store can be transferred to the FEM computer in a total elapsed time of 40 seconds. Since most runs have a duration well in excess of 40s, no major problems arises from this combination of run size and transition speed.

3 THE PROBLEM

For the data sets described in §1 the memory storage requirement is obviously a lot higher. An experiment using 40.10^6 time-of-flight channels will require 80 or even 160 Mbytes of memory depending whether two or four bytes of memory are used for each channel. Figure 2 shows a simple modification to the existing data acquisition electronics which shows the MEM module converted to a memory controller and large numbers of new memory cards introduced in a separate crate. This overcomes the present limit of 16Mbytes on the capacity of the bulk store, and with memory prices as low as £200/Mbyte a total memory configuration of 100 Mbytes is entirely feasible.

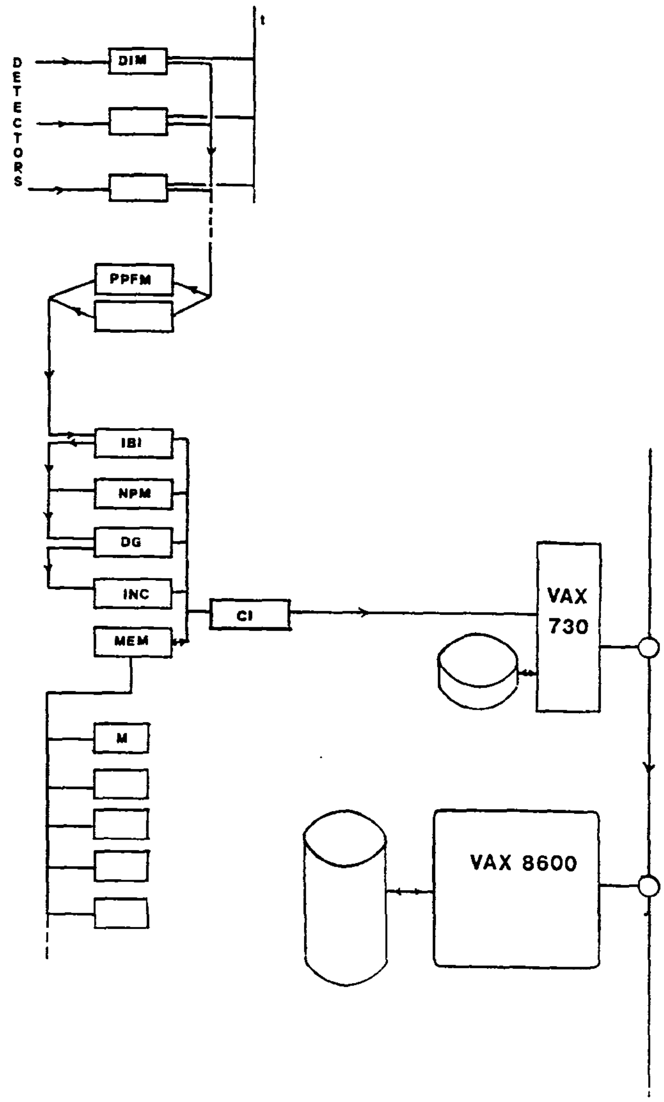


Fig. 2

However, with data sets of 80 Mbytes, the existing transfer speeds imply a transfer time of ~30m to the FEM computer and ~60m to the HUB computer. Clearly runs may last less than 1 hour and hence the transfer time will become a serious problem. This could, in principle, be solved by improved transfer speeds between the DAE-FEM and FEM-HUB , although many of the limits to these transfer rates are determined by VAX system software and may prove difficult , in practice, to change by orders of magnitude.

More than the transfer time, there is also the problem of the shear bulk of data to be stored and the problem in displaying the entire data in some useful form. The elegant solution therefore resides in some form of data compression that may be applied either before, or at the histogramming memory stage.

4 POSSIBLE SOLUTIONS

So far two types of data compression have been identified. The first applies to single crystal instruments where the data is sparse and consists of regions of intensity in a 3-d histogram. The data may be compressed by factors of 1000 or more by extracting the integrated peak intensities and positions of the discrete Bragg reflections. The second technique applies to powder and LOQ instruments where the data compression takes the form of a transformation of the time coordinates before the spectra from different detectors may be added together. The data may also have to be corrected for wavelength dependent effects before the transformation.

4.1 Incrementer Solution

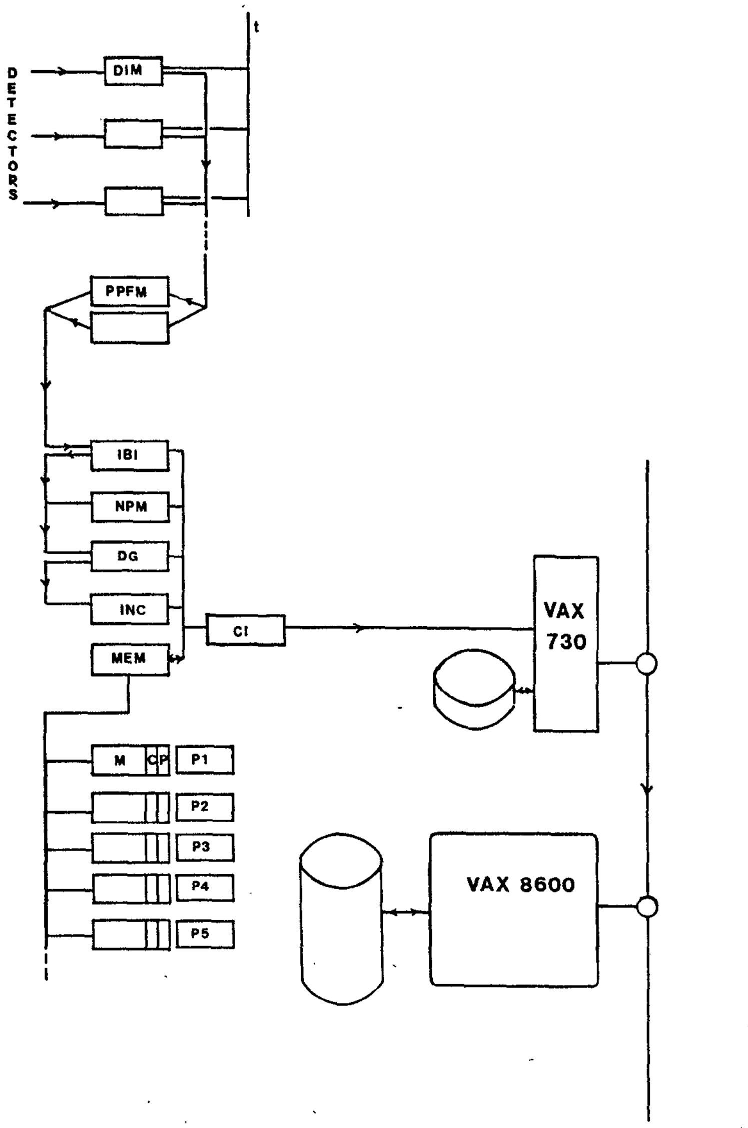
In the case of single crystal data it is conceivable that an 'intelligent incrementer'[1] (INC figure 2), provided with knowledge about the sites of high intensity in the single crystal data, could be used to assign short words to background and long words to the high intensity regions. This has two disadvantages. It is inflexible, in that you have to know the structure and orientation of the crystal beforehand, and there is the danger of missing weak reflections. Alternatively, short words could be assigned to all regions and overflows stored as a list in a separate area of the bulk store. However, in either case, the methods would only save a factor 2 or 3 in the data storage requirement.

4.2 Descriptor Generator Solution

In the case of powder diffraction it is conceivable to shift this intelligence to the descriptor generator (DG in Fig.2) and by providing the information necessary to shift the x coordinate on the fly a large number of individual detector elements could be summed together before the descriptors reach the memory components. For an intelligent descriptor generator to run at speeds required of a powder instrument (i.e. around 1 MHz) special signal processing chips would have to be used whose logic was essentially hard wired. This again has the disadvantage that it is inflexible. If 32 bit processor chips were used in their place this would give complete flexibility in the transformation of the descriptor on the fly but would reduce the data acquisition rate to around 10 KHz. A drawback for both DG solutions is the fact that subsequent wavelength dependent corrections would have to be performed on averaged data, with the possible erroneous assignment of weights to the correction factor.

4.3 Intelligent Memory Solution

A third possible solution is shown in figure 3. In this solution the large memory array is segmented into a number of individual memory boards each equipped with its own processor, shown as p1, p2, p3 etc. in figure 3. Programs would be down loaded via the CI interface into program storage areas (P). By a suitable choice of processor/memory board size, the data could be processed in between 10 and 100s to compress the data from the large area of memory (M - Fig.3) to the compressed area (C). This would be especially suitable for peak intensity determination in SXD type machines and the same architecture could be employed in powder machines and low Q machines. The use of the incident spectrum in the data analysis process would present no inherent difficulties since the incident spectrum would be available in part of the memory at the time of analysis. It is further possible that the compressed areas of memory could be directly connected to display systems in order to provide fast real time displays for the experimenter who is trying to determine the course of the run. Clearly in the case of powder analysis if processor p1 wishes to access memory allotted to processor p4 there is considerable advantage is the processors could be linked and it is in this way that the transputer with its inter-processor link could provide an additional advantage.



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DETECTORS
DIM
PPFM
IBI
NPM
DG
INC
MEM
CI
VAX 730
M
CP
P1
P2
P3
P4
P5
VAX 8600

Fig. 3