THE NRL CYCLOTRON DATA ACQUISITION AND PROCESSING SYSTEM

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Summary

In order to make effective use of the NRL Isochronous Cyclotron we are designing an efficient multipurpose data collection and data handling facility. The central part of this system is a small general purpose computer with all digital data collection devices (examples are: timers, scalers, frequency meters, and digital voltmeters) feeding directly into the computer, thus eliminating a vast amount of time-consuming and error-causing paper work. The computer will also be used for multi-parameter and single-parameter multichannel analysis with ADC's feeding the computer memory directly. For rapid display of data, and any desired graphical display, a computer controlled CRT display will be used. A light pen will be used to select and modify information in the computer memory. The standard input-output equipment will consist of a typewriter, paper tape read/punch unit, two magnetic tape units, a graph plotter, and a fast on-line printer. The on-line time will be time shared between the (random) data collection and data processing and/or display. To make such concurrent operations possible a priority interrupt system will be used, with a higher priority system taking over computer control from a lower priority operation.

Introduction

The NRL Isochronous Cyclotron (for a detailed description see Paper EE14) will accelerate a variety of particles and heavy ions to high energies. In order to utilize fully these capabilities of the cyclotron, we are designing an efficient multipurpose data collection and data handling facility. This facility will serve the needs of many diverse experiments and experimenters. Since several experiments can be set up and tested simultaneously with an experiment in progress, the facility will be time shared among several users.

Experiments in nuclear physics have been changing rapidly in the last few years. Some experiments that even a few years ago seemed impossible have today been successfully completed. This, to a large extent, is due to the development of new experimental apparatus, data collection, and handling techniques. Since different experiments have different requirements for instrumentation, versatility and ease of modification of the support equipment in a basic nuclear facility is of paramount importance. The seemingly different requirements for instrumentation frequently can be reduced to a small number of instrumentation blocks; however, needless and costly duplication of equipment should be avoided as much as possible. Thus, it is desirable that a block type of instrumentation be adopted for the diverse and constantly changing experiments. Single purpose devices designed for a certain experiment can get very complex and very costly, frequently amounting to single purpose, wired-program computers. While they in general will fulfill the needs of a given experiment, they often are not adaptable to different experimental requirements without extensive modification. The time and effort spent in construction, as well as the expense of such devices, may influence the choice of experiment because the equipment is readily available, rather than choose an experiment on its own merits. Rapid interaction with the experiment also should be possible in order to guide the course of the experiment based on data already accumulated.

The Data Acquisition System

One of the most versatile general purpose instruments used in nuclear physics is a multichannel analyzer (single- or multi-parameter). An analysis of the function of such multichannel analyzers shows that a small general purpose computer with adequate input-output (I/O) devices can serve all the functions of several multichannel analyzers with far superior arithmetic capabilities. In addition, a general purpose computer because of its memory, arithmetic, and logical decision making ability is extremely versatile. With only a change in program, or the sequence of subprograms, a computer may be used for entirely different experiments; no internal or external circuit changes are needed. Thus, in order to overcome many data collection and data transfer problems, as well as to have a versatile facility, a small general purpose computer will be used as the central element of the data acquisition facility.

The choice of computer is determined by several considerations. Our requirements are for on-line operation with time sharing capabilities, coupled with the economic requirement to limit expenses. Since the demands on the computer will grow as the use of the computer develops, expansion of the facility in the field by adding more memory, additional data channels, and more I/O equipment, is left open. The system will consist of a fast central processor unit with adequate memory for multiparameter analysis coupled to diverse I/O devices to handle the rapid data flow. The computer will be capable of accepting data from a large number of different input devices, and will be able to address and interrogate a large number of external devices. Sufficient peripheral equipment for rapid communication with the computer will be provided.

The memory will initially consist of 8K words to provide for a multiparameter multichannel mode. In this mode of operation a conventional fast dual ADC unit will feed the computer memory directly. Coupled with a high resolution cathode ray tube (CRT) display and a light pen, immediate display of data and programmed interaction with the computer will be available. The desired speed (cycle time) of the computer is determined by the anticipated rate of data collection, and the desire for on-line time sharing. Data collection rates may be quite different from experiment to experiment. However, in many cases data will be accumulated through the ADC units whose data throughput capabilities, without introducing an excessive dead time, will be the determining factor on the maximum data accumulation rate. Faster ADC's are rapidly appearing on the market. If several detectors, for example in an angular distribution measurement, are feeding the computer through a multiplex channel, very fast data rates can be achieved. The rate at which the computer can accept data is determined not only by the memory cycle time, but also by the number of cycles it takes to increment a given memory location by one count. Thus, the fastest possible cycle time together with a minimum number of cycles for storing one count is needed. The computer will have better than a 2 microsecond memory cycle.

Since the arrival of a data pulse is a random process, some of the time the computer will not be busy with data collection. This time will be available for other operations. In particular, coincidence type experiments frequently have rather low counting rates, and thus leave the computer available to time share with other work. However, it is essential that only a negligible amount of data is lost because the computer is performing some other function, and does not attend to the needs of the data collection device. For true time shared operations, a priority interrupt system is essential. Some programs, such as data collection, must be able to interrupt other programs and therefore be given top priority while some programs, such as data display, have low priority, and are being used only when there is no higher priority program requesting attention. The occurrence of a signal on one of several interrupt lines forces the computer to execute a program specific to the line energized. A priority sequence is imposed on the interrupt lines. It is necessary that a higher order priority can interrupt a lower order priority. Upon serving the demands of a higher order priority, the computer will automatically go to the next highest priority. In other words, a complete staircasing of priority interrupts is provided. There will be a minimum of 16 priority levels with possible future expansion. The computer will respond to the interrupts as they arrive. This is needed because it is usually impossible to tell what input device will require attention at what time. For minimum delay between the occurrence of an interrupt signal and its execution, all interrupt lines will be looked at in parallel, rather than through some sequential routine.

All digital data collection devices (examples are: timers, scalers, frequency matters, ADC) will feed directly into the computer, thus eliminating a vast amount of time consuming and error causing paper work. The standard input-output equipment will consist of a typewriter, paper tape read/punch unit, two magnetic tape units, an on-line graph plotter, a card reader, and a fast on-line printer. In addition, a CRT for fast data display with a light pen for rapid communication with the computer, will be included.

Several programmed choices of data display will be available. In a single parameter display the X-axis is controlled by the address word (channel) and the Y-axis by the number of counts in the channel. It will be possible to break the memory display into several subgroups, displayed simultaneously and individually. For increased statistical accuracy several neighboring channels may be added before display. In a two parameter (X, Y) mode, the result appears in the form of a surface $N = f(X, Y)$. Here N is the number of events stored at address (X, Y) in the computer memory. A display of this surface $N = f(X, Y)$ is desired. The dual ADC will provide the following information: the signal output of the first detector will determine the X position, and the signal output of the second detector will determine the Y position. Both X and Y are fed into a buffer register, such that X occupies the first part of the register, and Y is stored in the second half. | X | Y | The combined output (XY) determines the memory location. In a contour display the intensity (brightness) of any point on the CRT is proportional to the number (N) stored at the given location. In an oblique isometric display the Y-axis is slightly tilted with respect to the X-axis, and the number of stored counts in a channel is indicated by vertical displacement of the channel from its row. The light pen will be programmed such that regions of interest may be indicated on the CRT and displayed in a "blown up" version. When multiparameter data will be accumulated with a resolution that is better than the storage capacity of the computer, all information will be stored on magnetic tape. This stored information will be run back through the computer and regions of interest analyzed in greater detail. To define proper regions of interest and to monitor the experiment, the multiparameter data will be simultaneously stored in the memory and displayed with a coarser resolution.

Programmed on-line uses of the computer besides data display will include background subtraction and spectrum stripping. The traditional way to analyze data is to transform it to a form that can be compared with theoretical predictions. With the advent of computers, however, it has become possible to simulate data. The computer is used to perform the inverse process, and present theoretical calculations in data (multichannel) form for easy and immediate comparison with experiment. Thus, it is possible to determine in advance what the experimental data should look like, given a particular model. In particular, processes involving the emission of several nuclear particles lead to rather complex kinematic relations that are not easily visualized without proper calculations and display. Computer simulated processes can be directly compared with experiment, thus keeping the experimenter informed about the progress of his experiment, as well as alerting him to any unusual features to be investigated more closely. Data simulation in the middle of an experiment can be used to simulate various experimental conditions and possible processes, thus helping to determine the best way to proceed, based on the data already accumulated. If so desired the light pen may be used to indicate background and channels over which a peak should be summed. In conjunction with data simulation, this will give a powerful tool for on-line hypothesis testing to guide the experiment. Simultaneous display of accumulated data with data simulated will be available. A direct data link to the NRL central computer is also envisaged. When this is realized frequently complete analysis of the data "on-line" will become possible. The feasibility of some feedback control for the cyclotron also is being investigated.