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AN INCREMENTAL DATA RECORDING SYSTEM FOR LOW LEVEL SPECTROMETRY

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by

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and
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ABSTRACT

An incremental data recording system has been applied to low-level single and multiparameter gamma and x-ray spectrometry. The system hardware includes three ADC's (analog to digital converters) with coincidence logic circuits. The digitized pulse height of an accepted event from each ADC is punched on paper tape. Time and identification information are automatically punched on paper tape at the beginning of each pre-set live time period. The punched paper tape is converted to computer-compatible magnetic tape. Various detector assemblies can be used with the converters and recording system.

The system software includes a paper tape to magnetic tape conversion routine, an analysis and file maintenance program, a printed display program, a channel summing program, and a weighted least-squares routine used for quantitative analysis of the spectra. All programs are written for use with an IBM-7090 computer.

The system has been used for various low-level radiochemical analyses involving x-ray-gamma, gamma-gamma, and beta-gamma coincidence techniques.

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INTRODUCTION

The availability of modestly-priced multichannel/pulse height analyzers has greatly aided the application of gamma-ray spectrometry to a large variety of problems. Most users consider 100 to 400 channels necessary if full advantage is to be taken of available detector resolution. The recent availability of 4096 channel multiparameter pulse height analyzers has lead to the use of multidimensional gamma-ray spectrometry as a radio-analytical technique⁽¹⁾. Unfortunately the various configurations possible with 4096 channels do not always allow full advantage to be taken of the detector resolution. The cost of analyzers with even larger memory capacities limits their application⁽²⁾.

For low-level gamma spectrometry NaI detectors of large dimensions are desirable in order to obtain high counting efficiencies. As the detector size is increased, however, the background also increases. By requiring an alpha, x-ray, or beta event in coincidence with a gamma event the background can be reduced several orders of magnitude. A typical detector arrangement used in low level beta-gamma-gamma coincidence spectrometry is shown in Figure 1. The background reduction obtained is shown in Figure 2. Very long counting times per sample are necessary when the activity levels to be measured require the use of such low level coincidence techniques. The investment in NaI(Tl) detectors required for such measurements can be reduced by multiplex operation using several beta detectors⁽³⁾.

At low counting rates incremental event recording can be used for data storage^(4,5). A relatively economical multiparameter incremental data recording system has been assembled for use with such low-level detector assemblies.

Because it is not restricted to 4096 channels and can easily be adopted to multiplex operation, it has some advantages over the more costly multiparameter analyzer systems.

DESCRIPTION OF HARDWARE

A block diagram of the incremental data-recording hardware is shown in Figure 3. The heart of the system is a commercially available triple ADC (analog to digital converter) unit* with amplifier and coincidence logic circuits. Various beta, gamma, and x-ray detectors have been used with the system. The coincidence logic allows the operator to require a coincidence between ADC #1 and (ADC #2 and/or ADC #3) before an event is accepted. The digitized pulse height of an accepted event from each ADC can be punched on paper tape. Although each ADC is capable of up to 1000 pulse height divisions or channels our present data analysis system is limited to 100 channels from each of two ADC's. Each accepted event results in a two-digit X coordinate, a two-digit Y coordinate, and an end-of-data character punched on paper tape. Because of the slow punching rate a dead time of 1/10 sec is required during the recording of each event. A 1000 foot reel of paper tape can store 24,000 events which require a minimum of 40 minutes.

A 400-channel magnetic core analyzer has been modified to accept the output from any one of the ADC's. It is used for gain and zero adjustment of the ADC's prior to an experiment. It can also be used to monitor one of the ADC's during an experiment or can operate with its own ADC and detector when not required with the incremental data recording system. Figure 4 is a photograph of the assembled equipment.

The automatic punching of time and identification information on the paper

* RIDL Model 22-101 Three Parameter Data Acquisition System

tape is controlled by the SND (serial number device) pictured in Figure 5. The complete serial number of 36 or 45 characters is punched on the paper tape prior to each counting period. The serial number includes the live time, the laboratory time, which is obtained from a built-in 10^{-4} day clock, various control parameter codes, equipment identification codes, and sample identification number as listed in Table 1.

A live timer which can be pre-set between 0.1 and 999.9 minutes operates in conjunction with the SND and a total event scaler. Both single and recycle modes of operation are possible. In the single mode the serial number is punched on tape and events are recorded for the preset live time. In the recycle mode the serial number is punched initially and after each live time period has elapsed. Thus the start time, end time, and live time are all recorded on the paper tape. The total events scaler is useful for estimating tape usage.

Multiplex operation and three parameter 1000 x 1000 x 1000 analyses have been allowed in the design of the equipment. Operation with incremental magnetic tape rather than paper tape has also been anticipated in the SND design.

DESCRIPTION OF SOFTWARE

The MJL data analysis system as outlined in Figures 6, 7, and 8 will accumulate, maintain, and retrieve a file of multidimensional radiation measurement data. The programs are written for use with an IBM-7090 computer. In addition to parameter control cards the input to the program consists of punched paper tape from either the event recording equipment or a 4096 channel magnetic core analyzer. The paper tape is initially converted to computer compatible magnetic tape. The data from the event recording equipment is accumulated in a 100 x 100 array in the computer memory. A provision has been made in the program to allow the array to be in terms of a function of the coordinate rather than the coordinate itself in order to compensate for the variation in resolution with energy associated

TABLE I

SERIAL NUMBER FORMAT FOR INCREMENTAL
DATA RECORDER

<u>Character</u>	<u>Contents</u>
<u>Time and Identification Information (Every Live Time Period)</u>	
1	Start Character (PI-1)
2 - 5	Live Time (0.1 Minutes)
6 - 7	Instrument Number
8	Multiplex Code
9	Spare Digit
10 - 17	Laboratory Time (10^{-4} Days)
18 - 19	Parameter Code ADC #1
20 - 21	Parameter Code ADC #2
22 - 23	Parameter Code ADC #3
24 - 26	Spare Digits
27 - 28	Detector Number
29 - 30	Mode Code
31 - 35	Sample Number
Used in (36 - 37	Detector Number
Multiplex (38 - 39	Mode Code
Operation (40 - 44	Sample Number
Only 36 or 45	End Character (PI-2)

Each Event Recorded as Follows

1 - 2	X Coordinate
3 - 4	Y Coordinate
5	End Character (PI-2)

with NaI(Tl) detectors. This feature can also be used to reduce arrays greater than 100 x 100 to storable dimensions.

The number of live time periods to be accumulated as one spectrum for each sample number and mode code is under parameter control.

The following errors are checked and listed during the accumulation:

1. Parity errors
2. Improper identification
3. No accumulation instructions
4. Invalid number of characters

After accumulation the specified spectrum with its time and identification information is written to a master file tape. For more compact storage of the spectrum, only the non-zero channels of the 100 x 100 matrix are written to the master file tape. Each channel is limited to about 10^5 counts since each word in the file must also contain the channel number. The selection of one of several master files is under parameter control as is an optional printed display of the accumulated spectra. At each updating of the master file old records can be deleted and a master file content report is generated. The program requires 0.2 minutes to accumulate about 7500 events from the incremental recorder or to accumulate a 4096 channel spectra from a 64 x 64 magnetic core analyzer.

A selected spectrum or combination of spectra can be retrieved from the master file in several forms. Selection of spectra to be retrieved is specified by parameter cards containing the sample number, mode code, and optionally a range of start times. The display program (Figure 7) presents a printed 100 x 100 array of multiparameter data obtained by adding together one or more spectra and optionally subtracting background or other spectra. The spectra to be subtracted are normalized to the same live time as the positive spectra. An example of a portion of a typical display is shown in Figure 8. All negative

values are reported as dashes to simplify interpretation. Non-coincident events on the X axis are listed separately to conserve space on the print out. The following sums are also computed and printed:

1. Total counts observed by Y as a function of X
 - a) Including $Y = 0$
 - b) Not including $Y = 0$
2. Total counts observed by X as a function of Y
 - a) Including $X = 0$
 - b) Not including $X = 0$
3. Total single parameter data as a function of $X + Y$
 - a) Including channel 0
 - b) Not including channel 0
4. Total number of counts in spectra.

Figure 9 shows an example of the printed tables.

When the number of counts observed is small it is often difficult to locate peaks due to the large number of channels. The 100 x 100 displayed array can be reduced to a display array of smaller dimensions as specified by parameter input to the program. An additional display option replaces the displayed matrix of counts by a matrix of single characters. The character used for a specific channel is based on a logarithmic scale. Thus the digits 0 through 9 or the letters A through J can be used for a ten cycle logarithmic display. Gray scale displays can be generated using characters such as . , / X W &.

The summing program (Figure 10) performs channel summations of selected spectra as required for further computations. The channels of selected spectra to be summed into a single channel group are specified by one or more rectangular portions of the 100 x 100 array. Each rectangle is specified by the X and Y coordinates of the lower left hand and upper right hand corner. Up to 101 channels

groups can be obtained for a single specified spectrum. The program checks for overlap of channel groups. The computed channel groups are listed and punched on cards for use in further computations. In addition to a listing of the summing instructions a printed display of the summing instructions is presented as shown in Figure 11.

A previously reported⁽⁶⁾ weighted least squares program (GEM) for estimating the contribution of individual radionuclides in multicomponent time dependent pulse-height spectra can be used with the summing program card output. The GEM program has been modified to accept up to 10 spectra and 10 backgrounds of 100 channel groups each and solve for 30 nuclides.

The summing program card output can also be used as input to a decay curve plotting routine.

CONCLUSIONS

The principle advantages of the incremental data recording system are its small equipment cost, large number of channels, many coincidence configurations with up to three parameters and relative ease of data handling program modifications. Among its disadvantages can be listed long dead times, poor economy for large total counts due to required computer time, delays in data presentation, and limited capacity of paper tape.

The system has been used for beta-gamma-gamma, x-ray-gamma, and gamma-gamma multiparameter measurements as well as single parameter measurements of low activity sources. Figure 12 is a typical multiparameter x-ray-gamma coincidence spectrum. A gamma-gamma coincidence spectrum is shown in Figure 13.

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FIGURE 1

**GENERAL PURPOSE LOW LEVEL BETA-GAMMA
DETECTOR**

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FIGURE 2

**GAMMA BACKGROUND FOR TWO
OPPOSED 8" DIA. X 4" NaI
(TI) CRYSTALS WITH 4" THICK
LEAD SHIELDING**

Counts per Minutes per 10 Kev

10^2

10^1

10^0

10^{-1}

10^{-2}

10^{-3}

10^{-4}

Gamma

Gamma-Gamma
Coincidence

Beta-Gamma
Coincidence

Beta-Gamma-Gamma
Coincidence

Gamma Energy - Mev

UNCLASSIFIED

0

1

2

3

4

BLOCK DIAGRAM
INCREMENTAL DATA RECORDER

FIGURE 4

INCREMENTAL DATA RECORDER

FIGURE 5
SERIAL NUMBER DEVICE

FILE MAINTENANCE FLOW CHART

SPECTRUM DISPLAY FLOW CHART

Spectra
File

FIGURE 8

MULTI-DIMENSIONAL DISPLAY

FIGURE 9

MULTI-DIMENSIONAL DISPLAY

SPECTRUM SUMMING FLOW CHART

FIGURE 11

SUMMING INSTRUCTION DISPLAY

FIGURE 12

Zn-65 X-RAY-GAMMA SPECTRUM

FIGURE 13

Co-60 GAMMA-GAMMA SPECTRUM