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AUTOMATIC DATA ACQUISITION USING
A DESK CALCULATOR

T. L. Futrell

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OAK RIDGE Y-12 PLANT
OAK RIDGE, TENNESSEE

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Oak Ridge Y-12 Plant

P.O. Box Y, Oak Ridge, Tennessee 37830

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ABSTRACT

A system has been designed that permits automatic data acquisition and processing using a programmable electronic desk calculator. By using a calculator which is not promoted for its interfacing capabilities, but which has provisions for remote entry of data, a relatively simple, inexpensive system has been fabricated. The unit is now in production use on an X-ray spectrometer which has been updated with solid-state nuclear instrument module system counting equipment.

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SUMMARY

A significant improvement has been made, at the Oak Ridge Y-12 Plant,^(a) in the method of data acquisition and processing on an X-ray spectrometer. The previous method required hand transcription of data and manual operation of a desk calculator by the analyst to produce the desired analytical result. To eliminate several possible sources of error, a relatively inexpensive programmable desk calculator was interfaced to the X-ray instrument, thus providing automatic data acquisition and processing. The interface permits the calculator to accept data directly from a dual counter/timer when requested by the program. The analytical result is provided automatically when the last data are fed from the scaler to the calculator. Several analyses have been programmed for use on the calculator system. Use of the system is believed to improve the overall efficiency of the X-ray spectrometer operation.

(a) Operated for the US Atomic Energy Commission by the Union Carbide Corporation's Nuclear Division.

INTRODUCTION

When previously performing a sample analysis on the X-ray spectrometer, the analyst was required to set the goniometer at various angles and take a scintillation count at each angle. The scintillation count was read from a dual counter/timer, and each count was written on paper as it was taken. After all necessary readings were taken, the analyst performed the necessary calculations on a desk calculator and reported the results. The calculation for a particular analysis is given in Appendix A.

Several possible sources of error in the procedure just described, particularly in transcription, could be eliminated by instituting a system of automatic data acquisition and processing. Since this application did not justify a computer, thoughts were turned to a programmable desk calculator. However, a system employing a desk calculator which is promoted for its interface capabilities would typically cost several thousand dollars. The idea was then conceived to adapt a less expensive desk calculator (one not promoted for interfacing) to the data system.

This report discusses the development and fabrication of a significantly less expensive automatic data acquisition and processing system that employs a relatively inexpensive programmable desk calculator.

AUTOMATIC DATA ACQUISITION

THE CALCULATOR

The calculator selected for the data system has a calculation capacity of sixteen digits, ten memory registers, and a programming capacity of 144 steps. The program is stored on a magnetic card for instant retrieval. A rear-panel connector on the calculator provides access to many of its internal functions. Most important of these connections are four lines used to input binary coded decimal (BCD) information into the operating register. The multidigit information must be serially strobed onto the four BCD input lines, and the standard 8421 BCD code must be altered such that any "0" digit is replaced by a "12". The $\pm$ key on the calculator is used to start execution of the program. It was necessary to run two wires from the $\pm$ reed switch to two unused terminals on the rear panel connector to provide remote starting of the program. This modification was the only one made to the calculator, and it does not affect the normal operation of the calculator.

THE INTERFACE

Requirements

To be compatible with the overall data system of Figure 1, the interface must serially scan the dual counter/timer, convert the transistor/transistor logic (TTL) levels to metal oxide

Figure 1. X-RAY DATA SYSTEM.

semiconductor (MOS) levels, strobe each digit into the calculator, and execute a program START command. In addition, the interface must contain the zero correction circuit previously mentioned. The MOS logic levels used by the calculator are:

Logic One = 0 volt,
Logic Zero = -24 volts.

Thus, to apply a Logic one to any calculator input line, that line is simply grounded. Internal pullup resistors keep the input lines held at Logic zero. To convert to these MOS levels, the field effect transistor (FET) switch with TTL driver outlined in Figure 2 was chosen.

Figure 2. FIELD EFFECT TRANSISTOR (FET) LEVEL CONVERTER.

Circuit Description

To fulfill the electrical requirements of the interface, the circuit presented in Figure 3 was designed. Reference should be made to this circuit in the discussion which follows.

Initially, the interface is in the "ready" state, with the mode switch in the AUTO position. IC 7B is in the "set" condition. When the dual counter/timer reaches a preset condition, Pin 9 of CN 1 and CN 2 goes low, sending a negative pulse to Pin 13 of IC 7B, thereby resetting the flip flop. This action begins the transfer of data from the scaler to the calculator. The flip flop immediately sends a PRINT command to the scaler by taking Pin 5 of CN 1 and CN 2 low. After a delay controlled by IC 6A, the scan oscillator starts and a PREVIOUS MODULE FINISHED signal is sent to the scaler by taking Pin 7 of CN 2 high. The scan oscillator sends PRINT ADVANCE pulses to the scaler through Pin 6 of CN 1 and CN 2, and gates the four BCD lines through Delay IC 8B. After all decades of the scaler have been scanned, the scaler issues a THIS MODULE FINISHED signal to the interface by taking Pin 7 of CN 1 high. A negative pulse sets the flip flop, and Q_5 is strobed to start execution of the program. The interface is once again in the "ready" state. The digital timing diagram for the sequence is given in Figure 4. With the mode switch in MAN, the interface is disabled and the calculator may be used independently.

Several integrated circuits serve special purposes in the interface. IC 6B and IC 4D form the scan oscillator whose frequency is controlled primarily by the 100-microfarad capacitor. IC 2A gates the FET switches OFF when no BCD code is applied to the input (all lines are high). IC 3 and IC 4A form the zero correction circuit and turn Q_3 and Q_4 on when all four BCD input lines are low.

Fabrication

The interface was fabricated in a double-width nuclear instrument module (NIM) for compatibility with the already existing counting equipment. Standard NIM voltages were also used in the circuit design. A photograph of the interface is seen in Figure 5; a view of the complete data system is provided in Figure 6.

Figure 3. CALCULATOR INTERFACE.

Figure 4. LOGIC TIMING DIAGRAM.

Figure 5. CALCULATOR INTERFACE ASSEMBLY.

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Figure 6. X-RAY DATA SYSTEM ASSEMBLY.

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SYSTEM OPERATION

One of the simplest analyses performed on the X-ray spectrometer is governed by the equation given in Appendix A. The calculator program for this analysis, recorded in Appendix B, is used to determine the percent weight of a single unknown by taking a scintillation count for both the unknown and an internal standard. The scintillation counts and two previously determined constants, K_1 and K_2 , are used with the equation to calculate percent weight of the unknown element. These two constants represent the y intercept and slope of the response for the element used as an internal standard, and are typically determined once per shift.

In performing the analysis, the analyst would do the following:

1. Enter the program in the calculator from the magnetic card.
2. Enter K_1 and K_2 in the proper memory registers.
3. Enter the sample weight and depress the $\pm$ key.
4. Set the angle for the internal standard and start the timer.
5. Set the angle for the unknown and start the timer.
6. Record the analysis result from the calculator display.

If this same analysis is run consecutively, Steps 1 and 2 are omitted after the first run.

While the analysis just described is a relatively simple one, it serves to demonstrate how the calculator system reduces to a minimum the number of analyst operations. Programs have been written for several more complex analyses, yet the operational procedure remains basically the same as that just outlined.

CONCLUSIONS

The automatic data acquisition system now in operation on the X-ray spectrometer has eliminated the need for hand transcription of data, eliminated the manual operation of a desk calculator by the analyst, and standardized the calculation of analytical results. The time saved per sample analysis varies from thirty seconds to three minutes, depending upon the type of calculation required. The time saved by eliminating reruns due to incorrect data transcription cannot be measured. The possibility of transcription and calculation errors has been virtually eliminated, and the efficiency of the X-ray spectrometer operation has been improved by the use of simplified, concise operational procedures.

ACKNOWLEDGEMENTS

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APPENDIX A

EQUATION FOR SAMPLE ANALYSIS

$$\text{Percent Weight of the Unknown Element} = \frac{\left(\frac{\text{Count 2}}{\text{Count 1}} \times K_2 \right) - K_1}{\text{Sample Weight}},$$

where:

Count 1 is the scintillation count for the internal standard, and

Count 2 the scintillation count for the unknown element.

K_1 represents the y intercept of the count ratio $\left(\frac{\text{unknown}}{\text{internal standard}} \right)$ versus the concentration plot, and

K_2 the slope of the count ratio versus the concentration plot.

APPENDIX B

CALCULATOR PROGRAM FOR A SAMPLE ANALYSIS

Store K_1 in Memory 1Store K_2 in Memory 2

Step	Operation	Note
0	Enter Weight	Places sample weight in display register.
1	CM	
2	3	Clears Memory 3.
3	CM	
4	4	Clears Memory 4.
5	M+	
6	3	M3 = sample weight.
7	H	Halt program. Wait for entry of Count 1.
At this time, interface enters Count 1 and starts execution.		
8	M+	
9	4	M4 = Count 1.
10	H	Halt program. Wait for entry of Count 2.
At this time, interface enters Count 2 and starts execution.		
11	÷	
12	MR	
13	4	
14	x	
15	MR	
16	2	
17	$\boxed{+}$	
18	MR	
19	1	
20	$\boxed{-}$	
21	÷	
22	MR	
23	3	
24	$\boxed{+}$	
25	END	

$$\text{Percent Weight} = \frac{\left(\frac{\text{Count 2}}{\text{Count 1}} \times K_2 \right) \cdot K_1}{\text{Sample Weight}}$$

Record analysis result from the calculator display.

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