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Arithmetic Box for Enrichment Meter and Neutron Assay Instruments

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T. R. Van Lysest

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ARITHMETIC BOX FOR ENRICHMENT METER AND NEUTRON ASSAY INSTRUMENTS

by

E. R. Martin and T. R. Van Lynsel

ABSTRACT

This report documents the construction and operation of the arithmetic unit developed by Group A-1 for use with the gamma enrichment meter and the neutron monitor nondestructive assay systems. The generic equation, $ASSAY = A \cdot C_1 - B \cdot C_2 - D$, is solved automatically on line while the data are being taken; the final answer is presented directly on LED displays; and the time of day, scaler counts, and final answer are also printed on a teletype unit.

I. INTRODUCTION

The generic equation, $ASSAY = A \cdot C_1 - B \cdot C_2 - D$, occurs frequently in the course of nondestructive monitoring of fissionable materials by the enrichment meter instrument or neutron counting. Group A-1 has designed and reported in detail¹ the principles behind instrumentation which permits direct calculation of this equation while the data are being received. This report will serve to document the construction and operation details of an arithmetic unit built by Group A-1 to implement these principles. The rack-mountable unit described here is relatively inexpensive, reliable, and simple to operate, replacing two scalars, a time-of-day and day-of-year clock and calendar, a teletype interface, two discriminators, and a great deal of tedious hand calculation.

II. PHYSICAL DETAILS

The finished unit is shown in Figs. 1, 2, and 3, which show the front, back, and top views respectively, indicating clearly the basic elements

of construction. As is apparent, we have chosen to implement the electronics on small printed circuit cards, which permit simpler mass production, rapid debugging, and easier troubleshooting and repair. Our unit was constructed to be rack-mountable, since it will be used in conjunction with equipment not normally portable in operation. It derives its power from the standard 115-volt ac power line, and is capable of driving several teletypes in parallel through cables up to several hundred feet in length. Clearly, this unit will find application in fixed point situations where long data runs with hardcopy output are being made. Several identical units could be used, for example, in the "hybrid" counter system, where one unit would be used with the gamma monitor and the other with the neutron instrument. The unit is entirely self-contained and requires only power connections and a teletype for complete operation.

Fig. 1. Front view of arithmetic unit.

Fig. 3. Top view of arithmetic unit.

Fig. 2. Back view of arithmetic unit.

III. ELECTRONIC DETAILS

The schematic details of individual printed circuit boards are shown in Figs. 4 through 16. Figure 4 is the input circuit. Three input modes are switch selectable from the front panel as shown in Fig. 1. In mode 1 the input is directed into a discriminator which will discriminate positive input signals down to 100 millivolts. This discrimination level is screwdriver adjustable from the back panel (Fig. 2) for each of the two input channels. Mode 2 expects positive-going 0- to 3-volt

input signals of arbitrary length. Mode 3 is simply reverse polarity from mode 2; i. e., negative-going 3- to 0-volt pulses are accepted. Note that the risetimes of these input pulses are not critical since signals are received in the unit by Schmitt-trigger circuits. Both inputs are terminated in 50 ohms to eliminate line ringing and noise associated with high-impedance circuits. If daisy-chaining of the input signal is desired with the termination elsewhere, the 51-ohm input terminator can easily be removed, yielding an input impedance over 1 k Ω .

Figure 5 shows the scaler with input gating. Two of these boards are used for each input channel, providing six-digit capacity for each scaler. Each of these six-digit scalers is provided with its own LED display as shown in Fig. 1. These scalers do not contribute in any way to the calculated answer, but serve merely to indicate to the

user when counts are being received, and to permit simpler calibration on known standards. The "X-out" signal from these scalers is routed into the digital rate multipliers for on-line multiplication by the selected constants.

Figure 6 shows the details of the digital rate multiplier circuit, which is quite straightforward. The numbered input lines to the SN74167 integrated circuits come from the thumbwheel switches on the front panel of the unit for constants A and B. These thumbwheel switches are used for setting in the A and B multiplication constants in the calculation. Constant D is set into the up-down counter (Fig. 8) in a manner to be described presently. The number of output signals from this multiplier circuit is equal to the number of input signals multiplied by the constant set into the thumbwheel switches and divided by ten.

The up-down counter for each channel is also a six-digit scaler consisting of two boards for each channel. Each board is constructed according to the diagram of Fig. 7. The preset inputs to this scaler are not used in this equipment, but are brought out on the board for general purpose use elsewhere. For our use, the "load" input is grounded, and "carry" and "borrow" lines are provided for cascading purposes. Note that the data lines are a four-wire data bus with wire-ORed connections to individual decades.

Figure 8 is a single-board six-digit up-down counter with zero detect output. The general logic diagram of the arithmetic unit¹ shows that the down counting operation is stopped at the correct answer when the multiplied inputs of channel B are counted to zero. This board provides the stop signal for the down count. It is here also that the constant D is set into the system. The preset lines on the SN74192 ICs are used for this purpose, with the thumbwheel switches provided on the front panel for operator ease in changing constants. The "load" pulse is used as a strobe pulse for this constant, so that it is set into the counter at the

commencement of each counting interval. Since this counter will be zero at the end of the calculation, it is not necessary to bring out its data lines.

Resetting after a counting interval has been completed and the data printed out can be accomplished in two ways: (1) if the automatic mode is chosen (see front panel mode switch in Fig. 1), another counting interval will be started automatically after the data printout on the teletype, so that continuous runs can be made without operator intervention; (2) if the switch is in the manual position, the reset pulse will be generated only when the operator presses the "reset" button. Figure 9 shows the details of this circuit. The "shift", "sr clr", "sr out", and "sr clk" pulses are associated with the teletype interface in a manner which will become apparent as we turn attention to the details of the teletype-driving circuitry.

The time-of-day clock shown in Fig. 10 is self-explanatory, except perhaps for the strobe delay generated by the SN74123. This is necessary because of the very slow risetime of the MOS output pulses from the clock chip, since the hours ten digit is used for incrementing the day counter as each 24-hour period elapses. The clock has its own front panel display (Fig. 1) and its own setup switches on the back panel (Fig. 2). Since it is desired to print out on the teletype this time-of-day information for each analysis interval, it is necessary to gate and store the day information to prevent possible ambiguous data from being printed. This function is performed by the board detailed in Fig. 11.

The day-of-the-year calendar simply stores for printout the number of the day of the year. It consists of a 3-stage scaler shown in Fig. 12, which is incremented as each 24-hour period expires, or can be incremented manually by a pushbutton switch on the backpanel for initial setup. Once again, the output from this counter goes onto the common data bus as shown.

The interval timer shown in Fig. 13 permits the operator to choose intervals of one, two, or five minutes duration as shown in Fig. 1. We used a crystal oscillator (C0238) operating at 8 MHz for this interval timer, since the short-term accuracy of the ac line frequency is not good enough for interval timing on a very accurate measurement. This timer provides input gating as well as down counting for the final calculation. The detailed drawing of the circuit makes its operation fairly apparent.

The teletype interface is shown in Figs. 14, 15, and 16. It is a straightforward parallel-to-serial interface. Worthy of mention, perhaps, is the fact that the oscillator period specified in Fig. 14 is for the standard 110-baud data transfer to a

Teletype Model 33 printer. This frequency is easily changed for other printing units by simply changing the value of the 33-microfarad tantalum capacitor and readjusting the 500-ohm potentiometer on the board.

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REFERENCES

1. E. R. Martin, "A Direct Reading Arithmetic Unit for NDA of Nuclear Materials," Nucl. Inst. & Meth. 109, p. 439 (1973).

Fig. 4. Input Circuit.

Fig. 5. Three-Decade Scaler.

Fig. 6. Multiplier Circuit.

Fig. 7. Up-Down Counter.

Fig. 8. Up-down counter with zero detect.

Fig. 11. Time-of-Day Data Latches.

Fig. 12. Day-of-Year Calendar.

Fig. 13. Interval Timer.

Fig. 14. Teletype Interface Board #1.

Fig. 15. Teletype Interface Board #2.

Fig. 16. Teletype Interface Data Gates.