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HAND-HELD PULSE-TRAIN-ANALYSIS INSTRUMENT*

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Summary

A portable hand-held pulse-train-analysis instrument uses a number-oriented microprocessor sequenced by a single component microprocessor. The incorporation of new CMOS integrated circuits makes possible complex analysis in a small, easily operated, battery-powered unit. The instrument solves an immediate problem with threshold setting of plastic scintillators and promises numerous other applications.

Introduction

The Advanced Nuclear Technology Group of the Los Alamos National Laboratory has designed, developed, and tested a hand-held pulse-train-analysis instrument. The need for such an instrument grew from working with plastic scintillators in Nuclear Safeguards. As stated in a companion paper,¹ the plastic scintillator system with the lowest threshold provides the best performance; however, lowering the threshold can introduce noise. The noise increases the false-alarm rate by broadening the signal count variance. By measuring the variance and comparing it to that expected for a Poisson count distribution, one can adjust the bias to the minimum without introducing the unwanted noise. Thus, the display of the difference between the standard deviation and the square root of the mean count permits the user to optimize the threshold setting.

Instruments with calculational power have been developed in the neutron correlation work reported in other papers.^{2,3} Miniaturizing the circuitry and replacing the bipolar integrated circuits with CMOS equivalents produced a small, portable, battery-powered unit. Figure 1 shows the compact packaging. The instrument weighs 310 g and is 3.2 cm thick, 9.1 cm wide, and 14.6 cm long.

Function

The pulses from the plastic scintillator system are applied to the K-loc connector on the front panel of the analyzer (Fig. 1). When the power is turned on, the instrument is initialized. The measurement begins with acquiring 30 count intervals of 0.50 s each. The counts per interval are stored in the external memory. On completion of the last count interval, the values listed below are calculated and displayed.

$$\bar{c} = \frac{\sum_{i=0}^{30} c_i}{30} \quad (1)$$

on display No. 1 with mode switch 1 in the down position.

$$\text{Variance} = \frac{\sum_{i=0}^{30} (c_i - \bar{c})^2}{20} \quad (2)$$

on display No. 2 with mode switch 2 in the down position.

$$\text{Difference} = \frac{\sqrt{\text{var}} - \sqrt{\bar{c}}}{\sqrt{\bar{c}}} \quad (3)$$

on display No. 1 with mode switch 1 in the up position.

$$\text{Difference Average} = \frac{\sum \text{Difference}}{N} \quad (4)$$

on display No. 2 with mode switch 2 in the down position, where N = number of 30 interval samples.

The two displays are monitored slowly. Thus time-sharing the displays with four values is practical. Two mode switches control the content of each of the four-digit liquid crystal displays (LCDs). Thus, the operator can sequence the switches to read out each value calculated from the equations above. The mean is presented on the lower display, No. 1, when mode switch one is in the down position. The same display presents the difference when the switch is up. The top display, No. 2, presents variance with its mode switch down. The difference average is available on the same display with the switch up. If a new bias has been set, cycling the power off and on resets the unit.

Fig. 1. Hand-held pulse-train-analysis instrument.

*This work was supported by the US Department of Energy and the US Defense Nuclear Agency through the US Naval Electronics Systems Command.

Hardware

A number-oriented microprocessor (National MM57109) sequenced by a central processor single-component microcomputer from the 8048 family enables both data acquisition and analysis (Fig. 2). The central processor is an 80C35 with a 27C16 providing the program memory. The 27C16 is a CMOS erasable programmable read-only memory that has a 2-k by 8-bits organization. This device provides a large program memory with very low power consumption. An ultraviolet light source can erase the memory to permit re-programming. An external random access memory furnishes storage area for the data. Two Harris 6514's provide a 1-k by 8-bit storage that is more than adequate and uses little power.

The National MM57109 number-oriented microprocessor provides the calculation ability with reverse Polish notation data format. The 64 program commands include arithmetic, trigonometric, and logarithmic functions as well as square, square root, and y^x . The microprocessor contains five internal 12-digit registers. Operational commands include number entry, decimal point, change sign, enter, roll stack, output number, etc. The commands are entered by the central processor into a 6-bit latch that stores the control word for the number-oriented microprocessor.

This microprocessor interface design varies slightly from those described in other papers.¹⁻³ Substitution of the 741CXX series components for the 74LSXX equivalents

decreases power consumption with no degradation of performance.

The single-component microcomputer sequencing the microprocessor is a 80C35 that boasts an instruction set of 96 commands with extensive bit-handling capability. An 8-bit on-board timer/counter allows the signal input to be handled directly. In the plastic scintillation application, the counter mode was used; however, for other applications, a timer mode is available. Such flexibility should make the system valuable in numerous other applications. The central microcomputer also controls the input to the liquid crystal display drives. The drivers, Intersil's ICM7211A, provide the storage, decoding, and multiplying for the 4-digit, 7-segment LCDs. Requiring a single 5-V bias, the integrated circuit drivers use less than 50 μ A of current. Designed to interface simply with a microprocessor, the display drivers enable clear display of data with very little power consumption. The two mode switches control input lines (to the control microcomputer) that indicate which values in Eqs. (1) through (4) to display.

A single 9-V transistor radio battery that will operate for over 8 hours provides the power for the system. When not in use, the calculator microprocessor is turned off to conserve energy. This cuts the system current to 20 mA, lengthening battery life. The central microcomputer control line drives a single transistor stage to enable software control of the system power consumption.

Fig. 2. Functional block diagram.

Software

The microcomputer program was written in ASM-48 assembly language, the highest level language available for the 8748 family. The flow chart (Fig. 3) shows the structure of the program for the plastic scintillator application. After the power switch is turned on, an initialized program resets all the microcomputer control lines, displays "HI" to the user, sets N equal to 1, and sets the interval counter to 0. The counter is cleared and a 0.50-s delay is executed. The counter contents are read and stored in external random access memory. The displays are updated if values have been calculated. If the interval count is not 30, the counter is reset and the interval count is incremented. The program loops back to the "start counter" point. When the interval counter is equal to 30, the program branches to the calculate subroutine.

The calculate subroutine turns on the number-oriented processor and, using the data stored in the external memory, calculates Eqs. (1)-(4). The displays are updated, N is incremented, and the interval count is set to 1. The program returns to the reset counter point and continues as before. Thus, the main program is a continuous cycle that is reset only by power switch operation.

The calculate subroutine is written so that the programmer need only point to a command table, which is a list of the calculator entries needed to solve the desired equation. Thus, the programmer creates a table of the keystrokes to solve the desired equation and to load the accumulator with the table address before calling the calculator subroutine.

Similarity of the microprocessor operation with that of hand-held calculators such as the Hewlett-Packard HP-21 or the National Semiconductor Novus 4520 (the Scientist) allows the user to develop calculation sequences without detailed knowledge of microcomputers. One only develops the table of keystroke entries to solve the equation on one of the calculators, and the table can be programmed directly into the program memory. The ease of program development encourages a wide range of potential users.

The flow chart in Fig. 4 shows the operation of the calculator subroutine. The basic 64 commands of the calculator microprocessor require only 8 of the 8 bits available in program memory. Therefore, the two most significant bits indicate noncalculator actions accomplished during the calculator subroutine. Such actions can be the transfer of data from external memory to the microprocessor or from external memory to internal memory. At the end of the table, a byte (FF hexadecimal) signals the calculator subroutine that control is returning to the calling program.

Fig. 3. Plastic scintillator algorithm flow chart.

Fig. 4. Calculator subroutine flow chart. This structure allows programming controlled with a table of keystroke-like commands.

The plastic scintillator program requires slightly over half of the 2k bytes of the program memory. Thus, nearly 2k bytes of additional programming are available. Because each byte is equivalent to a keystroke, there is room for many more calculations with no hardware change. In one of the multiplication instruments that does an error analysis, equations with hundreds of keystroke entries are solved.¹ Thus, complex data analysis previously requiring an hour or more is accomplished automatically in a few minutes. Numerous other applications for the hand-held pulsed-train-analysis instrument will stem from its easily used programming capacity.

Acknowledgment

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