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TITLE: NEUTRON-MULTIPLICATION MEASUREMENT INSTRUMENT

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NEUTRON-MULTIPLICATION MEASUREMENT INSTRUMENT

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Summary

The Advanced Nuclear Technology Group of the Los Alamos National Laboratory is now using intelligent data-acquisition and analysis instrumentation for determining the multiplication of nuclear material. Earlier instrumentation, such as the large NIM-crate systems, depended on house power and required additional computation to determine multiplication or to estimate error. The portable, battery-powered multiplication measurement unit, with advanced computational power, acquires data, calculates multiplication, and completes error analysis automatically. Thus, the multiplication is determined easily and an available error estimate enables the user to judge the significance of results.

Introduction

The technique used, to measure multiplication, analyzes the time correlation of neutrons emitted by the fission process. If neutron detection events are uncorrelated (that is, random in time), the distribution of counts during an interval of fixed size is a Poisson distribution. However, because neutrons detected from a fissioning system exhibit time correlation stemming from the nature of the fission process, we expect a broader distribution than that of Poisson. We measure this deviation from a Poisson distribution using the first two moments of the distribution and relate this deviation to the neutron multiplication of the fissioning system. This theory is discussed in another paper.[1]

Operation

The instrument is controlled by switches and pushbuttons on the front panel. START, STOP, and RESET pushbuttons control the acquisition of data (Fig. 1). Analysis is automatic when acquisition is complete, and results are stored in the external memory. A 16-position thumbwheel switch selects which value will be displayed on the 16-character liquid crystal display (LCD). In conjunction with the ENTER pushbutton, another thumbwheel switch provides manual entry of constants such as deadtime or livetime. If the appropriate values are not entered manually, the microprocessor assigns default values for the constants.

The operator begins a typical measurement sequence by connecting the instrument to a neutron detector pod with a random neutron source, such as ^{241}AmB, placed near the pod. He places the function switch at 0, tau, and pushes the START button. This measurement determines the value of tau, deadtime. After 10^6 intervals are counted, tau is calculated and stored in the external memory. The neutron source is replaced with a spontaneous fission source, ^{252}Cf, and the operator begins the acquisition with the function switch either in position 1 or 2. At the completion of 10^6 intervals, Y_s is calculated and stored in the external memory. If these values are known from earlier measurement, the user can omit this sequence and manually enter tau and Y_s from the front panel. The operator turns on the STANDBY switch to maintain the values of tau and Y_s and turns off the instrument.

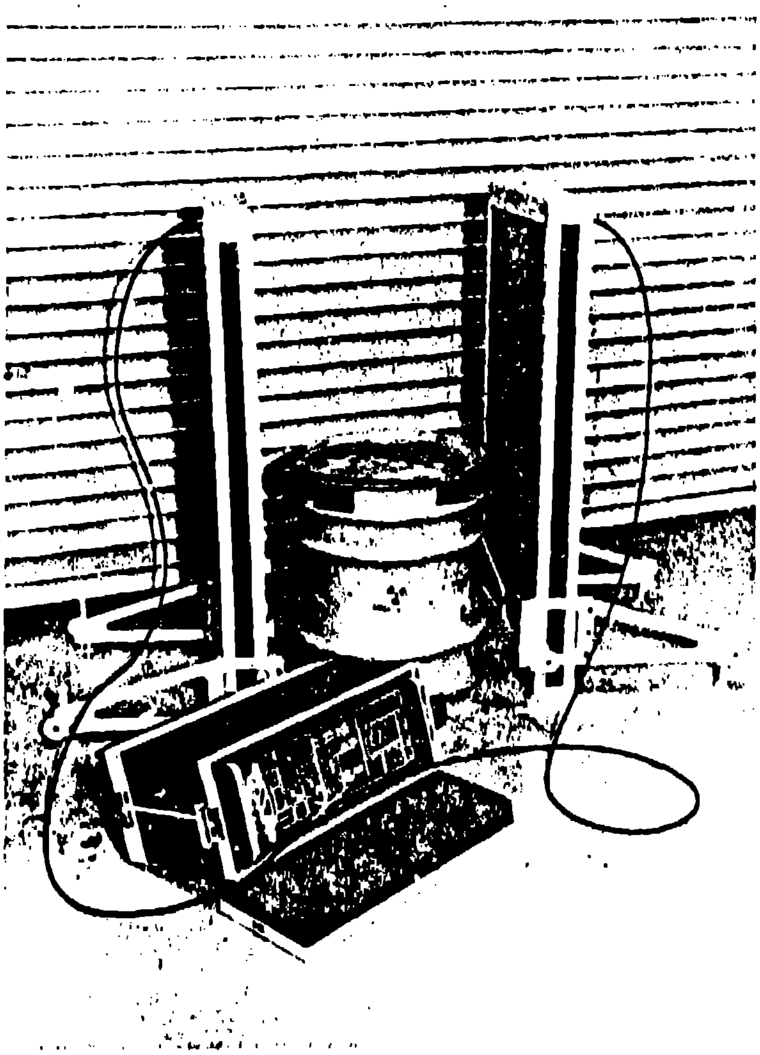

Fig. 1. Multiplication measurement instrument in operation.

After the detector pod and instrument are taken to the measurement location, the user positions the detector next to the nuclear material. The operator turns on the power and pushes the START button with the function switch in position 4. After 10^6 intervals are acquired, the value of the multiplication and the associated error estimates are calculated and stored in the memory. If the printer is connected, the microcomputer prints the original data and the calculated results at the end of each measurement. If only LCD display is preferred, the user moves the function switch to position 3.

Hardware

Figure 2 shows the functional block diagram of the multiplication measurement instrument. The NS80P50, a member of the 8048 family of single-component microcomputers, is a central processor that controls the operation of the entire instrument. This microcomputer allows the program memory in the form of a 2732 erasable, programmable, read-only memory (EPROM) to be attached piggyback style. Thus, 4096 bytes of program memory are provided in the small and convenient package.

The microcomputer provides for 256 bytes of internal random access memory indirectly addressable as working registers. Two 6514 microcomputers provide an external 1024-by-3-bit random access memory and supply the needed storage of the large histogram (256 channels by 24 bits). The first three stored pages constitute the histogram memory; the last page, calculated values, such as tau, multiplication, and mean. This memory has a 3.6-V back-up voltage when the stand-by switch is on and the power switch is off. The back-up system enables retention of the calculated values while draining a maximum of 2 mA from the battery. Thus, the measured values of tau and Y_s can be stored whenever the instrument is turned off and relocated at a target object.

Interfaced with the central processor by low-power, small-scale, integrated circuits, a number-oriented microprocessor, MM57109, provides calculational power.[1] Commands from the central processor are latched for continuous input into the number-oriented microprocessor. The calculator output is multiplexed onto the data bus, and circuitry provides a handshake style of data exchange.

Input from the START, STOP, RESET, and ENTER DATA control buttons causes an interrupt to the central processor and sets an associated bit in a latch. The microcomputer polls the latch to determine the appropriate subroutine. These interrupts and all other switch signals from the front panel are input to the microcomputer through Intel 8243 input/output expanders. These devices provide the I/O expansion that consists of four 4-bit bidirectional static I/O ports. Thus, a single 4-bit master control port provides the many I/O control lines for the microcomputer.

The 5- by 7-in. dot-matrix LCD, EPSON MA-B955B, comes with the low-power circuitry needed to furnish the drivers and multiplexers for the dot matrix. The character generator, two 6654 CMOS EPROMs, furnishes a custom set of characters that includes the standard ASCII upper- and lower-case alphabet, some of the Greek alphabet, exponentials, and other characters used to display scientific data.

The serial port provides the data to be produced on the printer or transmitted over the RS232 link to remote locations. The serial port consists of a 6402 universal asynchronous receiver/transmitter and some discrete components to shift the logic levels to those compatible with RS232. The 6402 is now an industry standard and interfaces directly with the single-chip microcomputer.

The input signal from the neutron pod is provided at the front panel through a standard high-voltage (SHV) connector. A single printed circuit card furnishes the preamplification, amplification, and discrimination. This unit also sums the high-voltage output with the signal input, allowing a single cable to the detector pod. This arrangement eliminates the need for external preamplifiers and multiple cables that are difficult to deploy for field measurement. The discriminator output is a standard digital logic signal connected to an INTEL 8253 counter/timer. This integrated circuit furnishes three 16-bit timer/counter registers that are used for the data scaler and the interval timer. The 8253 interfaces directly with the central processor through the multiplexed data bus and allows efficient and convenient program control.

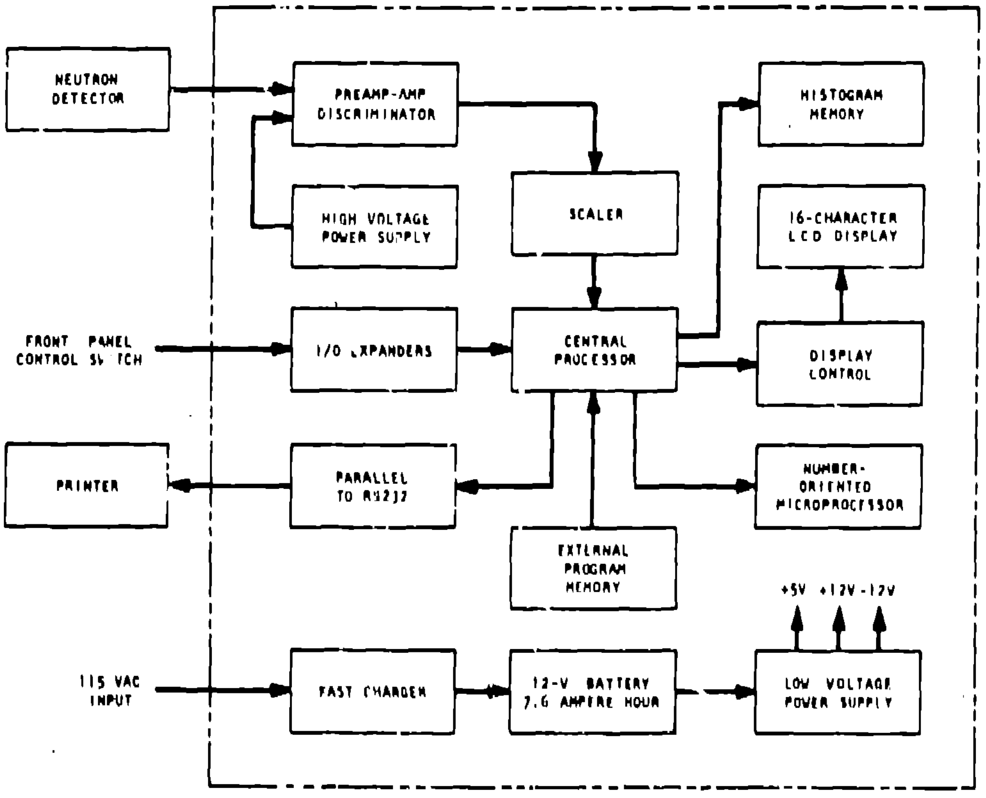

Fig. 2. Functional block diagram.

Software

The program was written with ASM-48 assembly language, the only language available with the 8048 family microcomputers. A 4096-byte program memory was designed to accommodate extensive analysis. Over three-fourths of the program memory is used, which allows some expansion and indicates the size of the programming effort. The modular software is efficient for development and testing and enables the transfer of useful subroutines to other instruments under development.[8]

The flow charts (Figs. 3-5) show the program structure. After the POWER ON RESET is complete, the microcomputer control lines are initialized and READY is printed on the display (Fig. 3). The program waits for an interrupt; when interrupt recognition occurs, the program identifies which of the four possible subroutines to service. If the DATA ENTER button is pushed, the control computer reads the manual data thumbwheel switches. If the FUNCTION switch is at 0, the value of the data switches is read as 0 to 9.99 μs and is stored in the tau location in the memory. If the FUNCTION switch is at 1, the data switches are read as X.XX for the mantissa of Y_g and stored in that location. The exponential of Y_g is entered when the FUNCTION switch is at 2. The lifetime (L) of the pod is manually entered as XXX μs when the FUNCTION switch is at 4. When the MANUAL DATA button is pushed, all other values for the FUNCTION switch trigger the LCD signal FC SWITCH WRONG.

A RESET interrupt clears the interval counter and the histogram in the same manner as does a POWER ON RESET. The START interrupt clears the histogram and begins the data acquisition. Acquiring data continues until 10^6 intervals are counted and stored or until the STOP interrupt is activated (Fig. 4). These actions cause the program to transfer to the COUNT END subroutine, which calculates tau, Y_g, or multiplication (Fig. 5). The calculated values are stored in the memory for LCD retrieval or serial port printout.

The CALCULATE subroutine requires only that the programmer point to a command table, a list of calculator keystroke entries necessary for solving the desired equation, before calling the calculator subroutine. The microprocessor operation is similar to that of hand-held calculators, such as the Hewlett-Packard HP-21 or the National Semiconductor Novus 4520, the Scientist. The user develops calculation sequences without detailed knowledge of the design or of microcomputers. Once a table of keystrokes to solve the equation has been developed and tested on the calculator, it can be entered directly into the program memory. Figure 6 shows the structure of the CALCULATE subroutine. Notice that besides the 64 calculator commands, memory-to-calculator inputs or calculator-to-memory outputs are possible. The hexidecimal byte FF indicates the end of the table and signifies that control will be passed back to the calling routine.

The multiplication unit, tested and proven to be a versatile and easily used instrument that saves the operator analysis time, contrasts sharply with earlier systems.[9] Furthermore, because error analysis is available at the scene, the user can quickly judge the accuracy of the answers.

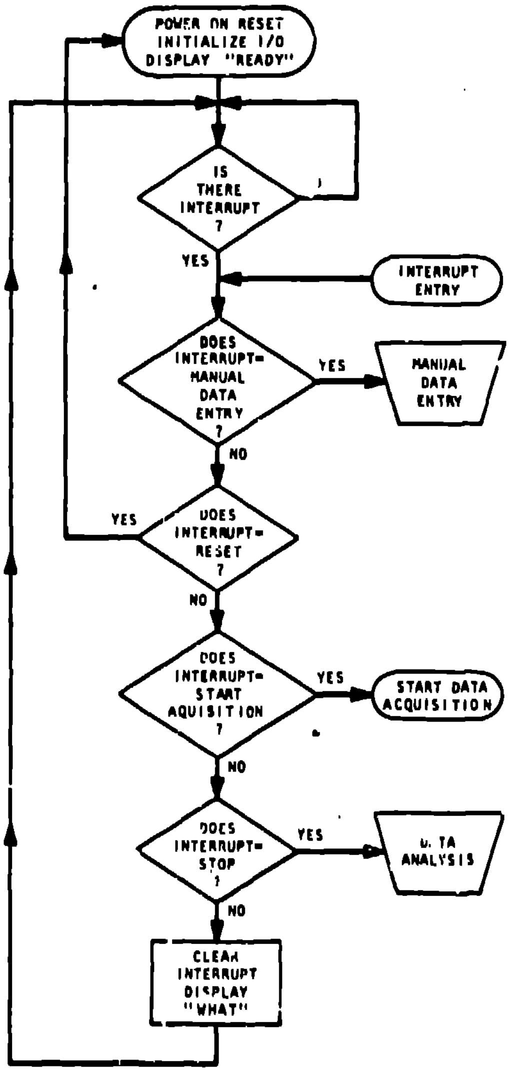

Fig. 3. Interrupt software flow chart.

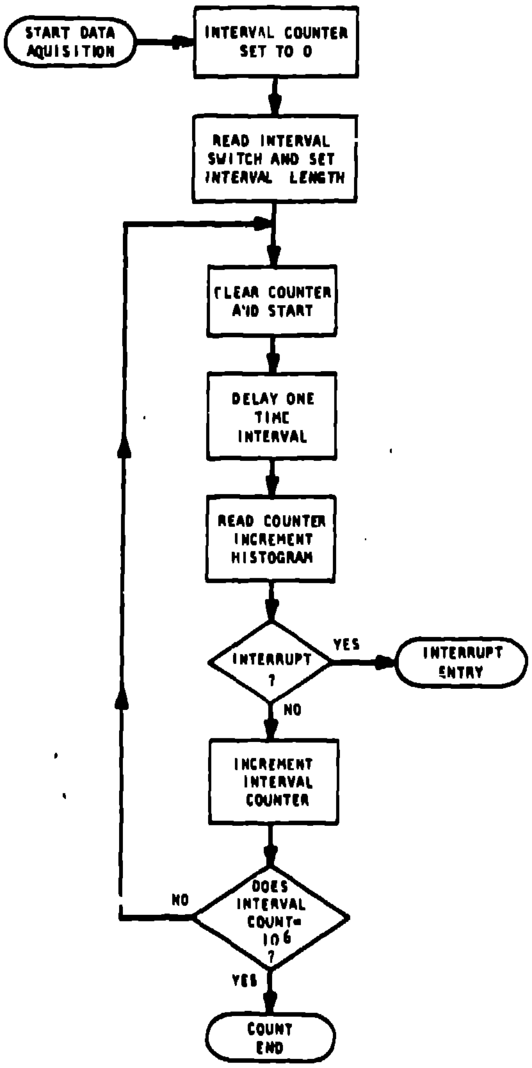

Fig. 4. Acquisition software flow chart.

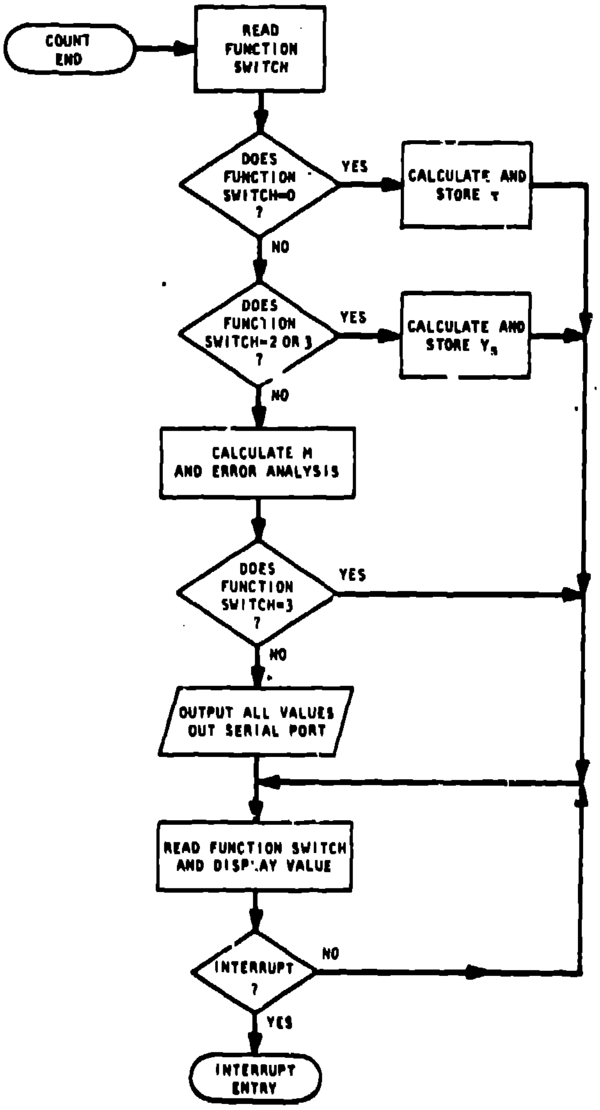

Fig. 5. Count END software flow chart.

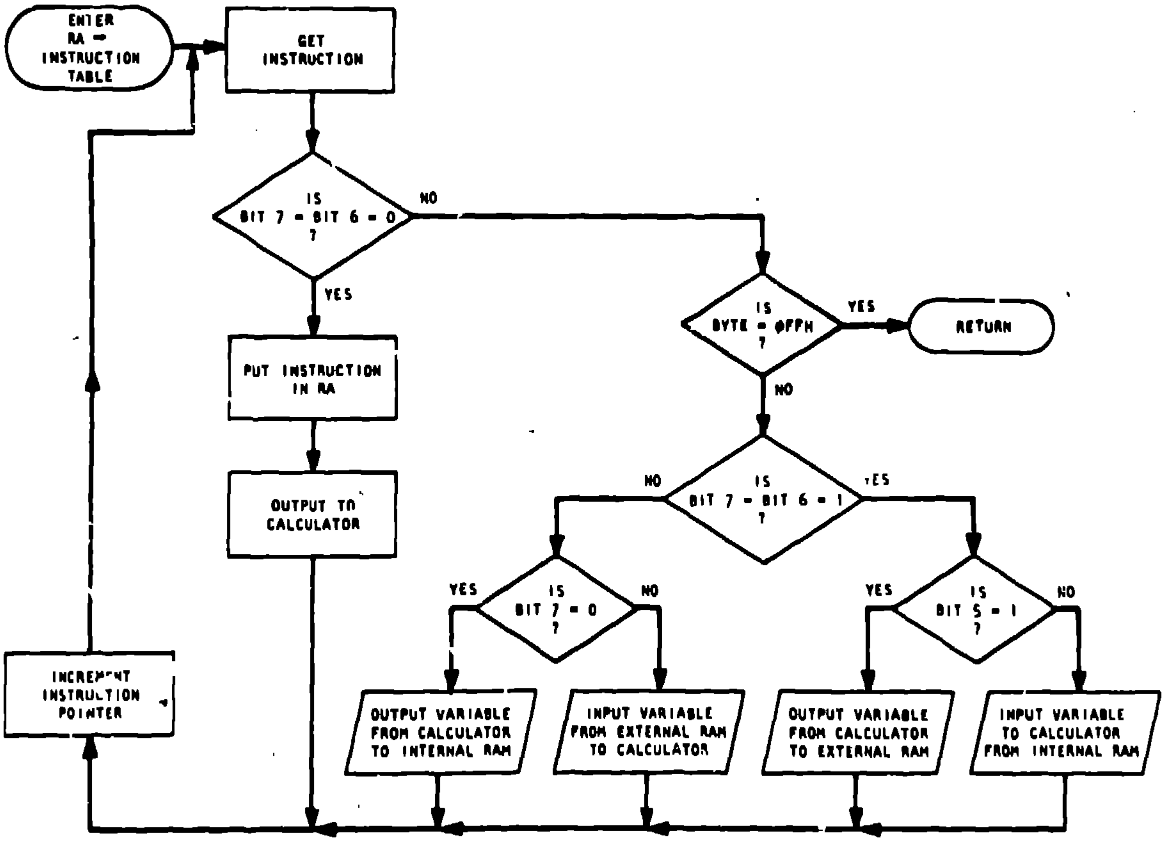

Fig. 6. Calculator software flow chart.

Acknowledgment

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References

1. A. [illegible] Robba, E. J. Dowdy, and H. F. Atwater, "Neutron Multiplication Measurements Using Moments of the Neutron Counting Distribution," submitted to Nuclear Instruments and Methods, October 1982.

2. S. N. Kim, "Number Cruncher (MM57109) Interface to Microprocessor," Application Note AN-180, IM-B2077, National Semiconductor Corporation, July 1977.

3. K. V. Nixon and C. Garcia, "Hand-Held Pulse-Train-Analysis Instrument," IEEE Transactions on Nuclear Science, February 1983.

4. C. D. Ethridge, E. J. Dowdy, C. N. Henry, and D. R. Millegan, "A Microprocessor-Based Neutron Count Moments Logic Module for Special Nuclear Material Assay by the Neutron Fluctuation Method," First Symposium on Safeguards and Nuclear Material Management, April 1979, Brussels, Belgium, LA-UR-78-3174.