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²⁵²Cf Source "Shuffler"**

by

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SYSTEM CONTROL FOR THE MODULATED ^{252}Cf SOURCE "SHUFFLER"

by

Melvin M. Stephens

ABSTRACT

This report documents the design and theory of operation of the control chassis for a ^{252}Cf nondestructive assay system. This system repetitively transfers a ^{252}Cf source from the irradiation region to a shielded position before measuring the delayed neutrons. The design criteria for the system were: rapid movement and precise positioning of the ^{252}Cf source, precise positioning of the sample, and very accurate timing of the irradiate and count cycles. To achieve these results crystal oscillators were used for timing, and stepping motors were used to position the sample and the source.

I. INTRODUCTION

Californium-252 has proven to be a useful source in neutron interrogation of fissionable material. Californium-252 can provide a high intensity of neutrons with a relatively long half-life. To measure the induced-delayed neutrons without the background of neutrons from the ^{252}Cf itself, the "Shuffler" concept evolved; that is, the ^{252}Cf source is moved from a shielded area out to irradiate a sample, then back in the shield tank before counting the delayed neutrons. To take advantage of the short half-life groups of delayed neutrons, it was desirable to keep the transfer time from the irradiate position to the count position as short as possible. Transfer times of less than 0.5 s were achieved. Accurate assay dictated that both transfer speed and source positioning be precise.

To achieve flexibility for research purposes, the source speed and position, the elevator positions, and the irradiate and count dwell times were made variable. This is the reason stepping motors were used to drive both the elevator and the

Teleflex cable which transports the source. Figure 1 shows a schematic diagram of the Shuffler unit, and Fig. 2 shows the complete system including shield tank, irradiation chamber, and electronics rack.

II. THEORY OF OPERATION

The Shuffler control chassis shown in Fig. 3 has two modes of operation--manual and auto. These modes are described in Secs. II.A and II.B.

The source speed, anticipation position, and stop position are switch-selectable on the integrated circuits (IC) wire wrap boards.

The irradiate and count dwell times, along with the number of cycles and sample elevator position, are thumbwheel-selectable on the front panel. Front panel light-emitting diodes (LEDs) display the dwell times in seconds, as well as the number of cycles completed.

A. Auto Mode

1. The start push button energizes the sample elevator stepping motor, and the elevator descends to the first irradiate

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Fig. 1. Modulated ^{252}Cf assay system, "Shuffler," showing the shielding tanks and fast-neutron irradiation chamber.

thumbwheel setting.

2. The source transfer stepping motor ramps up to the switch-selected speed (100-10,000 steps/s) and runs for a selected number of steps. When the source reaches the selected anticipate position, the stepping motor ramps down and stops at the selected

stop position.

The source remains in this position (irradiate position) for a time which has been thumbwheel-selected on the front panel. At the end of this time, the source transfer stepping motor ramps up to speed in the reverse direction, and the source is

Fig. 2. Complete ^{252}Cf assay system including electronics rack.

transferred back into the shield tank. It remains there for a thumbwheel-selected number of seconds (referred to as the count time). This process repeats for a selected number of cycles.

3. When the preset number of cycles is reached, the source shuffling stops and the sample elevator descends to the selected lower irradiate position. The procedure described in step two is repeated for the selected number of cycles.

4. After the selected number of cycles has been completed, the source shuffling stops and the sample elevator returns to the initialize position, and the control chassis goes to stop. This signifies that the operation has been completed.

B. Manual Mode

The start push button starts the sample elevator descending to the selected upper irradiate position. After the elevator has reached this position, the source can be transferred manually from the shield tank to the irradiate position without being under the control of the irradiate and count dwell-time settings.

III. ^{252}Cf SYSTEM BLOCK DIAGRAM DESCRIPTION

Figure 4 shows the block diagram of the ^{252}Cf Shuffler system. The source motor

Fig. 3. Control chassis for the ^{252}Cf system.

drive control, cycle counter control, and the sample elevator drive and control are the main parts of the control chassis shown in Fig. 5. The circuitry within each part is rather straightforward, but the interconnection and interlocks may cause some confusion. The most important signals are included in this block diagram and will be discussed below.

Fig. 4. Block diagram of electronic circuitry for ^{252}Cf assay system.

Fig. 5. Wire wrap IC board layout for 252Cf control system.

A. Source Motor Drive Inputs

1. Source initialize position originates from a slotted optical device which senses the end position of the Teleflex source drive.

2. Source motor encoder pulses are generated by an optical device attached to the end of the stepping-motor shaft.

3. The personnel interlock is on the cover to the sample input compartment to prevent the source from leaving the shield area when the cover is removed. The source interlock is a switch closure at the end of the source tube to prevent the source from overrunning its stop position. Both interlocks cause the control chassis to go to the stop mode.

4. The manual source transfer push buttons control the source position in the manual mode.

5. The system start-stop push buttons control the system in both the manual and auto modes.

6. The auto start source motion originates from the elevator control when the sample elevator is in position.

7. The auto stop to the source drive control is produced by the cycle counter, completing the selected number of cycles.

8. The source motor speed is digitally-selected by toggle switches on the IC boards.

9. The anticipate position for the ramp-down and the stop position of the

source are also toggle switch-selectable on the IC board.

B. Source Motor Drive Outputs

1. The source motor steps to the sigma stepping-motor translator are controlled by the source motor drive logic.

2. The direction control is originated in the source motor logic.

3. The scaler gate logic disables the scalers when the source leaves the shield area and does not start the count dwell time until the source is back at the shield position.

C. Cycle Counter Control and Elevator Motor Control

The cycle counter control and elevator motion control are less complicated, and the signals are self-explanatory.

IV. ELECTRONIC CIRCUIT DESCRIPTION

Figure 6 shows part of the control and interlock circuitry. The "system start-stop" flip-flop is set by the start push button, provided that the interlocks are clear. The "start-stop" flip-flop is a system "go" gate which triggers the "start-stop one shot" causing the elevator to descend and clear the cycle counters. It also enables the dwell-time counters and opens two gates for the stepping-motor pulses which drive the sample elevator and source Teleflex cable.

The "system start-stop" flip-flop is cleared by the stop push button or the interlocks which close the "go" gates. It is also reset at the completion of a run by the sample elevator returning to its initialize position.

The interlock flip-flop is initially set by the power-on reset circuitry. If it is reset by either interlock, the interlock must be cleared before the "start-stop" flip-flop can set it again.

The "elevator start-stop" flip-flop is set to the elevator "go" state by the "system start-stop" flip-flop or at the end of a cycle-complete signal to cause the elevator to go to the lower irradiate position.

Fig. 6. "Shuffler" system control and interlock circuitry.

The elevator is stopped when the "elevator start-stop" flip-flop is reset. The reset can be caused by either the elevator reaching its selected position or by the system-stop push button.

The sample elevator-stepping-motor translator receives its pulses from the oscillator and associated gating circuitry shown at the bottom of Fig. 6.

The source drive Teleflex cable and sample elevator both have an initialize position detected by a slotted photo-coupled pair. Figure 7 shows the initializing circuitry. The slotted pair, MCA-8, drives the Schmitt triggers (7414's), which are gating levels that are used throughout the control chassis. The signal locations are denoted by the six-digit row, card, IC, and pin code.

The "go" or "no go" and direction of the stepping motor which drives the teleflex cable with the ^{252}Cf source attached originates from the control logic in

Fig. 7. Source-transfer and elevator-position initialize logic.

Figs. 8 and 9. The speed and distance which the source travels will be covered later.

The auto-manual switch has a front-panel indicator to denote which mode is selected. In the manual mode, the gates

Fig. 8. Californium-252 source-transfer logic (auto-manual and direction).

Fig. 9. Californium-252 source-transfer logic (start, anticipate, stop motion).

associated with the front-panel push button are enabled so that if the source is in the count position, it may be transferred to the irradiate position with the irradiate push button.

In the auto mode, the front-panel push buttons are disabled and the source is set in motion when the sample elevator reaches its selected position or at the end of a dwell time.

All of these gates are "ored" together at IC 1313, then "anded" with the "system start-stop" flip-flop to trigger the "start-delay one shot." The purpose of the start delay is to assure that the stepping-motor translator has received its direction logic prior to stepping the motor. The start-delay pulse sets the "start-motion" flip-flop shown in Fig. 9.

The "multiplex" flip-flop "looks at" the source anticipate and the source-stop position switches, as shown in Fig. 11, at a 64-KHZ rate. The "multiplex" flip-flop has other functions such as "clocking" the "source-direction" flip-flop.

The source direction is determined (see the bottom of Fig. 8) by the state of the "source-direction" flip-flop through a buffer-driver to the source-transfer

stepping-motor translator. The direction of the source is determined by the source-initialize slotted pair; or if the source has inadvertently overrun the stop position, the stepping motor is immediately reversed.

The "anticipate" flip-flop shown in Fig. 9 programs the phase-lock loop to low speed when the stepping-motor pulse counter exceeds the number set into the anticipate switches.

The anticipation circuitry is necessary because the source-transfer motor has been ramped up to 3200 steps/s and needs to be slowed to less than 500 steps/s before it can be stopped precisely at the stop position. When returning the source to the shield tank, the "anticipate-to-high-speed one shot" enables the source stepping motor to return to high speed while in the anticipate area.

The "source-motion" flip-flop enables the pulse synchronizer, IC 1535, when it is cleared by the "start-motion" flip-flop, which is set by the "start-delay one shot."

The source stepping motor is stopped when the "source-motion" flip-flop is set either by the source reaching the stop position in the forward direction, or the source reaching the initialize position in the reverse direction.

The source stepping motor encoder pulses and the elevator stepping motor encoder pulses enter identical circuitry, shown in Fig. 10. The source-position pulses then go to the source-position up-down counter (see Fig. 11). The elevator encoder pulses go to the elevator-position up-down scaler shown in Fig. 15.

The circuitry shown at the top of Fig. 11 reduces the 1 KHz to 1 Hz to be used by the source dwell-time counter. The source-transfer-motor encoder pulses are counted in the three divide-by-16 up-down counters in Fig. 11. The output of the counters is compared with the output of the data-selector multiplexers which alternately "look at" the anticipate, then at the stop-position switches at a 64-KHZ rate. When

Fig. 10. Source and elevator-stepping-motor-position encoder.

the output of the source encoder counters matches the anticipate position switches, the "anticipate" flip-flop is set and the source-transfer stepping motor starts ramping to low speed. Some number of steps later the stop-position switch setting will become equal to the source-position counter and the "source-motion" flip-flop is set, stopping the motor. When the source-transfer motor is returning the source to the shield tank, the switch settings are ignored; and the motor is stopped when the "source-initialize" flip-flop is set by detecting the teliflex cable end with the slotted pair.

Figure 12 contains the 16.384-KHZ oscillator reduced to 64 KHZ for the multiplexer frequency, then reduced further to 1 KHZ for the reference to the phase-lock loop. The voltage-controlled oscillator output of the phase-lock loop is fed into the count-down input of the divide-by-N counters.

If a borrow occurs, the number that is loaded into the divide-by-N counter

Fig. 11. Californium-252 source anticipate and stop-position circuitry.

depends on the setting of the source-speed toggle switches.

The range of the divide-by-N counter is 1-100. This means that the range of the phase-lock-loop oscillator output is 1-100 KHZ.

The divide-by-10 counter, between the voltage-control oscillator and the

Fig. 12. Californium-252 source-transfer speed and ramping circuitry.

source-motor step, limits the motor-step frequency to 100-10,000 steps/s in 100 step/s increments.

An active low-pass filter is used between the phase-II output and the voltage-control oscillator input. This active filter allows a larger variety of controls on the ramping of the stepping motor.

The range may be changed while the ramp-up and ramp-down time is held constant with the equalizing control. The damping adjust prevents "hunting" when the phase-lock loop "locks" on frequency.

The 1-HZ pulses originating from the logic shown in Fig. 11 are counted in the dwell-time counter shown in Fig. 13. The dwell-time counter is held on reset until the source is in the desired position. The output of the dwell-time scaler is compared with the thumbwheel settings on the front panel. The set of thumbwheels that the comparator "looks at" through the multiplexing circuitry is determined by the position of the source. The output of the comparator triggers the "dwell-time-complete one shot" (see Fig. 8) which, in turn, enables the source to be transferred.

Each time the source returns to the source shield tank, the cycle counter shown in Fig. 14 is advanced. The output of the cycle counter is compared with the thumbwheels on the front panel. When the se-

Fig. 13. Circuit for irradiate and count dwell-time selection.

Fig. 14. Circuit for thumbwheel select number of irradiate and count cycles.

lected number of cycles has been completed, the "cycle complete" flip-flop is set, which enables the "cycle-complete one shot" to be triggered at the end of a completed dwell time. The "cycle-complete one shot" starts the sample elevator to its next position. The cycle counter is initially reset by the "system-start one shot," then reset again when the sample elevator reaches its lower irradiate position.

The pulses from the sample elevator-stepping-motor encoder are counted in the up-down decade scalars shown in Fig. 15. The measurement (to tenths of an inch) recorded

Fig. 15. Thumbwheel select, sample irradiate positions, and control logic.

by the elevator-position counter is compared with front-panel thumbwheel settings for the upper and lower irradiate position. The correct set of thumbwheels to be compared are selected by the elevator-position detector through the multiplexers into the comparators.

When the correct elevator position has been reached, the comparator sets the "elevator-in-position" flip-flop which triggers the "elevator-in-position one shot." This stops the elevator by clearing the "elevator start-stop" flip-flop. In addition to selecting the correct set of

elevator-position thumbwheels to be fed to the position comparator, the elevator-position detector controls the direction of the sample elevator stepping motor and drives the front-panel position indicators.

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