

# DOT SCANNING USING LOGARITHMIC TAPPER AND ADJACENT AREA AVERAGING

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Approaches to data presentation of radioisotope scans have been many and varied (1-3). The identification of small variations of counting rate within an organ is made difficult because the eye cannot easily differentiate small changes in dot spacing or film density (4). Previous studies have shown that computer averaging of adjacent areas improves the statistics and consequently improves the display of results (3,5). Use of a "de-randomizer" or buffer-storage interface with a low-frequency clock simulates averaging of incoming counts (6). By "de-randomizing" the incoming counts using digital-to-analog-to-frequency techniques and mechanically averaging adjacent scanning lines, instrumentation has been designed which more closely matches density changes to the requirements of the eye.

## INSTRUMENT DESIGN

Figure 1 is an over-all block diagram of the complete circuit. Incoming 0.7- $\mu$ s 3-volt positive pulses from the pulse-height analyzer go into the "de-randomizer." To provide maximum averaging and minimum loss of counts, a clock frequency of from one and one half to twice the expected incoming counting rate is required. Providing the necessary clock frequency necessitated that this interface be constructed to have available frequencies of from 100 to 600 cycles/sec in 100 cycle switch-controlled steps. The negative-going 10  $\mu$ s pulse output of the interface is the input to a digital-to-analog converter.

The block diagram in the upper part of Fig. 2 is the diagram of the converter with its emitter followers and resistor ladder network. Its input stage is a pulse amplifier whose positive-going 10  $\mu$ s output pulse triggers the least significant stage of a seven bit binary counter with a capacity of 127 counts. For each 0.1 in. or multiple of scanner probe travel, a pulse is generated photoelectrically by the scanner control circuits. When connected to the

proper input, positive or negative pulses can be used to trigger pulse amplifier #2 to provide a 10  $\mu$ s shift pulse. Seven flip-flops (bistable multivibrators) are connected as a shift register to the seven bit counter. Upon command of this shift pulse, the accumulated data in the counter is shifted into the register. The trailing edge of the shift pulse triggers pulse amplifier #3 for a 10  $\mu$ s pulse which resets the counter to zero. Because the data pulses and the shift pulses are both 10  $\mu$ s, only one data pulse could possibly come through to the counter while shifting. Therefore gating at the counter input was not necessary. The schematics of the pulse amplifiers and flip-flops are not shown because government surplus 100 kc/s computer printed circuit boards were used. Nearly any commercially available substitutes should function in this design.

The register and counter use negative logic which indicates that if the "0" side of a flip-flop is at negative 12 volts, then it is in the "0" state. If the opposite is true, and the "1" side is at negative 12 volts, then it is in the "1" state. Each flip-flop in the register has its own emitter follower whose output is either zero or plus 3 volts depending on whether its base terminal potential is minus 3 or plus 3 volts. This base terminal potential is determined by the base being connected to the center termination of two series-connected 10K ohm resistors. At one end of the resistor string there is a constant 6 volts. The other end can be at ground or minus 12 volts depending on the condition of the flip-flop to which the other 10K resistor is connected. If the flip-flop is in the "1" state, the "0" side is at ground and the voltage divider action of the two resistors places a positive 3 volts at the base of the emitter follower. The emitter followers and associated resistor ladder network provide a positive analog voltage which has

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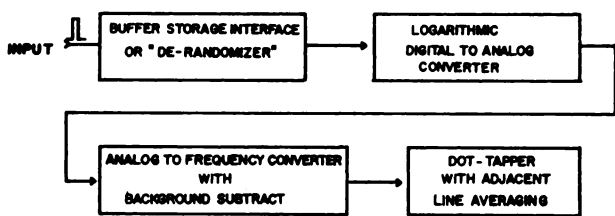


FIG. 1. Over-all block diagram of complete circuit.

a logarithmic relation to the register contents. For example, doubling the counts in the register will more than double the analog output. This is accomplished by selecting the value of the resistors in the ladder network. In this case, the most significant bit resistor is 1,000 ohms, next most significant bit resistor is 2,500 ohms, seventh or least significant bit resistor is 250 K ohms. Each resistor is 250% of the value of the previous one. In a linear network the values would increase by 200%.

In order to control the output of the ladder network, one end of each of the resistors in the network terminates on a 10-turn, 2,000 ohms, potentiometer which could be called a "gain" control. At the slider of the potentiometer is available the analog output of the digital-to-analog converter. The logarithmic relationship could have been obtained by using a logarithmic analog-to-frequency converter. Selection of this method would have increased the cost of the system. Also, in the logarithmic digital-to-analog converter in this design, the density relationship desired by the user can be obtained by installing the proper resistors in the resistor ladder network.

Pulses are required to drive a "dot-tapper." Therefore, the logarithmic analog voltage is the input to a linear voltage-to-frequency converter. The bottom part of Fig. 2 is the diagram of the modified converter that is in use (7). Capacitors C1 and C2 were selected according to instructions in the manual. The modifications were primarily caused by the cost and availability of the original components. Positive-going pulses are the output of the converter and these are the input to the "dot-tapper." Adjustment of R3 can be used to provide background subtract.

The achievement of adjacent line averaging required the construction of a special "dot-tapper" tip with an over-all width of  $\frac{5}{16}$  in. and the selection of  $\frac{3}{16}$  in. as the distance between scan lines. As shown in Fig. 3, the tip was first made to form a thin line  $\frac{5}{16}$  of an inch long on pressure sensitive paper. Then two  $\frac{1}{16}$  in. slots were filed so that upon contact with the paper, three narrow  $\frac{1}{16}$  in. lines were formed with  $\frac{1}{16}$  in. spaces between the inner mark and the outside marks. Thus, when scan-

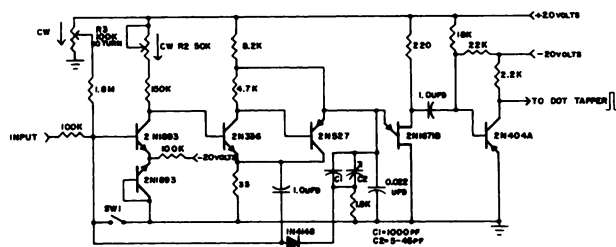
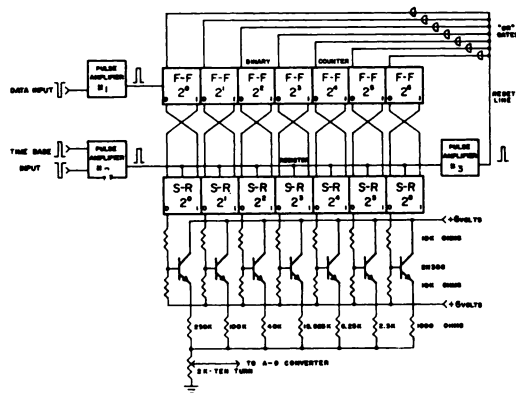


FIG. 2. Top figure is diagram of logarithmic digital-to-analog converter. Three main parts of circuit are binary counter in upper portion, shift register in middle, and 2N388 transistors with associated resistors as emitter followers in lower portion. Bottom figure is diagram of analog-voltage-to-frequency converter.

ning a line, three rows of dashes are imprinted on the paper. The blank rows are filled in by the overlap of the adjacent lines when they are scanned.

An offset between adjacent lines would be apparent in the record because the data that is counted during one spatial interval on a scan line is imprinted on the record during the following period. A longer period of counting will yield better statistics; thus 0.2 in. instead of 0.1 in. was selected for the distance of probe travel per counting period. A lag

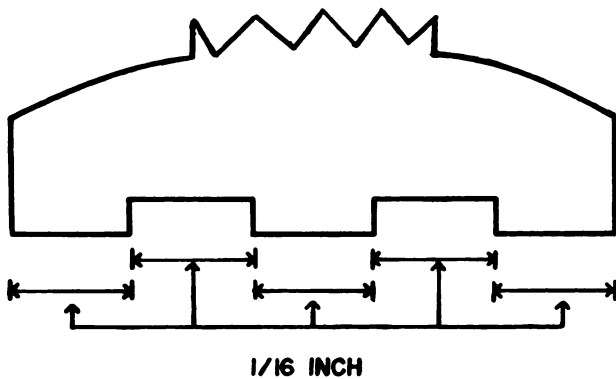


FIG. 3. Special dot-tapper tip.

of 0.2 in. is required when scanning in one direction and an additional 0.2 in. is necessary when traveling in the opposite direction. The tapper was mounted on a short track which allowed the 0.4 in. of movement. The track was in turn mounted on the x-y recorder head. When the scanner is moving in one direction, a spring pulls the tapper against the stop on the end of the track opposite to the direction of

scanner motion. Upon reaching the end of the line, the scanner controls energize a solenoid which pulls the tapper the required 0.4 in. to the other end of the track.

## RESULTS

A seven-pointed star-shaped phantom of blotter paper with a 2.2-cm round hole in the center was constructed and as nearly as possible evenly impregnated with  $^{86}\text{Rb}$ . A conventional  $6 \times 6$ -in. scan with  $\frac{3}{16}$  in. line spacing was made on a rectangular scanner. Approximately 3 min were required for the scan and the highest count per 0.2 in. of detector travel was 40. The record that resulted is shown in the upper part of Fig. 4. Using the same phantom and scanner speed with the electronic design that has been described resulted in the record shown in the lower part of Fig. 4. While making this latter record, the data were recorded and later entered into a digital computer for nine-point averaging. The resulting three-dimensional model that was constructed revealed the same areas of higher isotope concentration as is shown in the darker areas around the hole in the lower record. Thus the isotope was not homogenous throughout the phantom and this is indicated by the record.

With appropriate modifications, such as a prism or triple lens system with neon light source, the principle should be adaptable to photorecording.

## ACKNOWLEDGMENT

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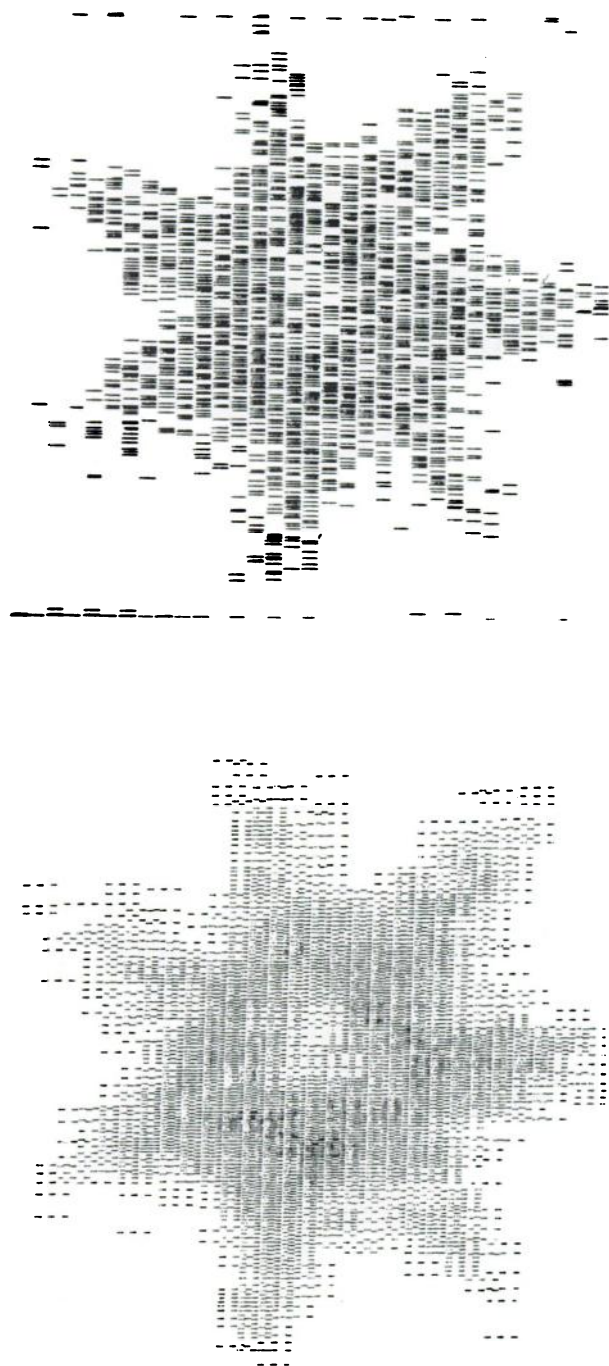


FIG. 4. Top figure is dot record made with regular  $\frac{3}{16}$ -in. tip. Lower figure is record made with special tip and electronics.