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# A HIGH RESOLUTION SCALE-OF-FOUR

by

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## DISCLAIMER

# A B S T R A C T


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A high resolution scale-of-four has been developed to be used in conjunction with the nuclear particle detection devices in applications where the counting rate is unusually high. Specifically, it is intended to preceed the commercially available medium resolution scaling circuits and so decrease the resolving time of the counting system. The circuit will function reliably on continuously recurring pulses separated by less than 0.1 $\mu$ sec. It will resolve two pulses (occuring at a moderate repetition rate) which are spaced at 0.04 $\mu$ sec. A five-volt input signal is sufficient to actuate the device.

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## Introduction

The development of wider-band amplifiers and the use of inherently faster detection devices in the nuclear physics laboratory has emphasized the need for higher resolution counting systems. In particular, counting equipment capable of resolving several events per microsecond is highly desirable in experiments performed with such pulsed particle accelerators as the Columbia synchrocyclotron. The present scale-of-four was devised to meet such a requirement. Accepting signals from a pulse height discriminator or "level-setter," the circuit, with its resolution time of less than 0.1 $\mu$sec, will normally provide sufficient "smoothing" of random pulse inputs[1] to drive the commercially available 5 to 10 $\mu$sec scaling units with a low counting loss. While designed primarily for use with nuclear particle detectors, the basic scale-of-two circuit is useful in other counting applications, e.g., counter chronographs, electronic computers, etc.

## Circuit Considerations

The scale-of-two is a version of the familiar Eccles-Jordan trigger circuit. The selective diode switching which Higinbotham found highly successful is utilized.[2] To enhance the performance of the device at higher frequencies design considerations center around the basic ingredients of fast regeneration and appropriate "memory." The circuit must, on receipt of the initiating signal, revert quickly to the opposite stable condition and assume quiescence before the succeeding signal arrives. However, in any scaler there is one point in the regenerative cycle when the circuit must be informed as to the direction the action should proceed. To enable the circuit to continue to the opposite conducting position, some device is necessary to recall the previous situation and make conditions favorable for conduction starting in the proper tube. The minimum resolution obtainable will depend to a high degree on the relative success of providing this memory. The memory must last sufficiently long after the triggering pulse to insure return of the circuit to the opposite regime. In addition, it must be arranged for the circuit to have "forgotten" the previous switching operation by the time the next triggering pulse arrives.

In the original Higinbotham circuit, the memory is achieved through the use of capacitors in parallel with the plate-to-grid cross-over resistors that are considerably larger (at least a factor of two) than is necessary for a frequency independent compensation. The duration of the memory is determined by this RC time constant, and congruous with the comparatively slow regeneration inherent in such a triode circuit the time constant is made quite long.

In the present scaling circuit a fast regeneration is achieved by the standard wide-band techniques of using relatively low plate resistors (compensated) and high transconductance tubes. With reference to the accompanying circuit diagram, the switch tubes, $V_{2A}$ and $V_{2B}$, and the cathode followers, $V_{3A}$ and $V_{3B}$, comprise the first scale-of-two. The cathode followers employed in the plate-to-grid coupling network minimize the capacitive loading on the anodes of the switch tubes and hence speed the flip-over action. The crystal diodes in the grid circuits prevent overdriving the switch tubes and so limit their plate voltage excursion.

Memory, however, is provided not only through capacitive but also by inductive effects. The capacitors in parallel with the cross-over resistors are comparatively small. To provide the additional memory necessary for reliable operation, the anode resistors are over-compensated considerably with 50-microhenry inductors.

The succeeding scale-of-two is identical to the first and is driven by the buffer tube $V_4$. The rectangular wave from the last scaler is RC differentiated with a 1-μsec time constant presented as the output through a cathode follower. The amplitude of the output signal is approximately 10 volts.

Testing and Adjustment

Fifteen scale-of-four units have been constructed and tested in this laboratory. They exhibited nearly identical characteristics, and the following remarks apply to their performance.

A measure of the reliability of a circuit is the allowable tolerance in components. The scale-of-four was found to operate despite a rather wide deviation from preferred values. Unfortunately, in a circuit of this general type it is inevitable that minimum resolution is a function of the "balance" of the components. To facilitate compensation for unbalance in the fixed resistors, a linear potentiometer is provided as part of the crossover network. A rough balance setting may be obtained with an ordinary high-impedance voltmeter. The voltmeter is connected so as to measure the potential between ground and the cathode of the switch tubes; e.g., $V_{2A}$ and $V_{2B}$. The circuit is then flipped from one stable regime to the other by alternately touching to ground momentarily the grids of the two cathode followers. The potentiometer is adjusted such that there is no change in this voltage when the circuit switches to the opposite conducting position. Using the cathode of one of the cathode followers as a point of observation, the flip-over action may be verified with an additional voltmeter.

Response of the circuit to signal inputs may be checked with a sine wave or pulse generator and an oscilloscope. The amplitude of the sine wave should be at least 5 volts (rms) and the frequency higher than 3 megacycles. Pulse inputs may range from 5 to 20 volts with a duration less than 0.1 $\mu$sec. The first scale-of-two is checked with an oscilloscope by observing the plate signal of the buffer tube $V_4$; the second, by observing the output. Final setting of the balance potentiometer is effected by increasing the frequency until the scaling action falters (at 11 or 12 megacycles for the units tested) and then readjusting. When properly balanced, the circuit responded to 13 or 14 megacycle signals. Tube replacement was found to have little effect on this resolution and did not necessitate readjustment.

Normal precautions should be taken in construction to minimize stray capacitance. The performance of the device is probably dependent on the arrangement of parts. Layout and wiring details of the units constructed in this laboratory are shown in Fig. 2. Five per cent components should be employed throughout, and preliminary matching of the crossover resistors (as noted in the circuit diagram) is suggested. The 50-$\mu$henry inductors are RF chokes of the iron core variety.

The scale-of-four requires an external power supply, preferably regulated, which will provide 60 ma at 300 volts.

## Acknowledgments

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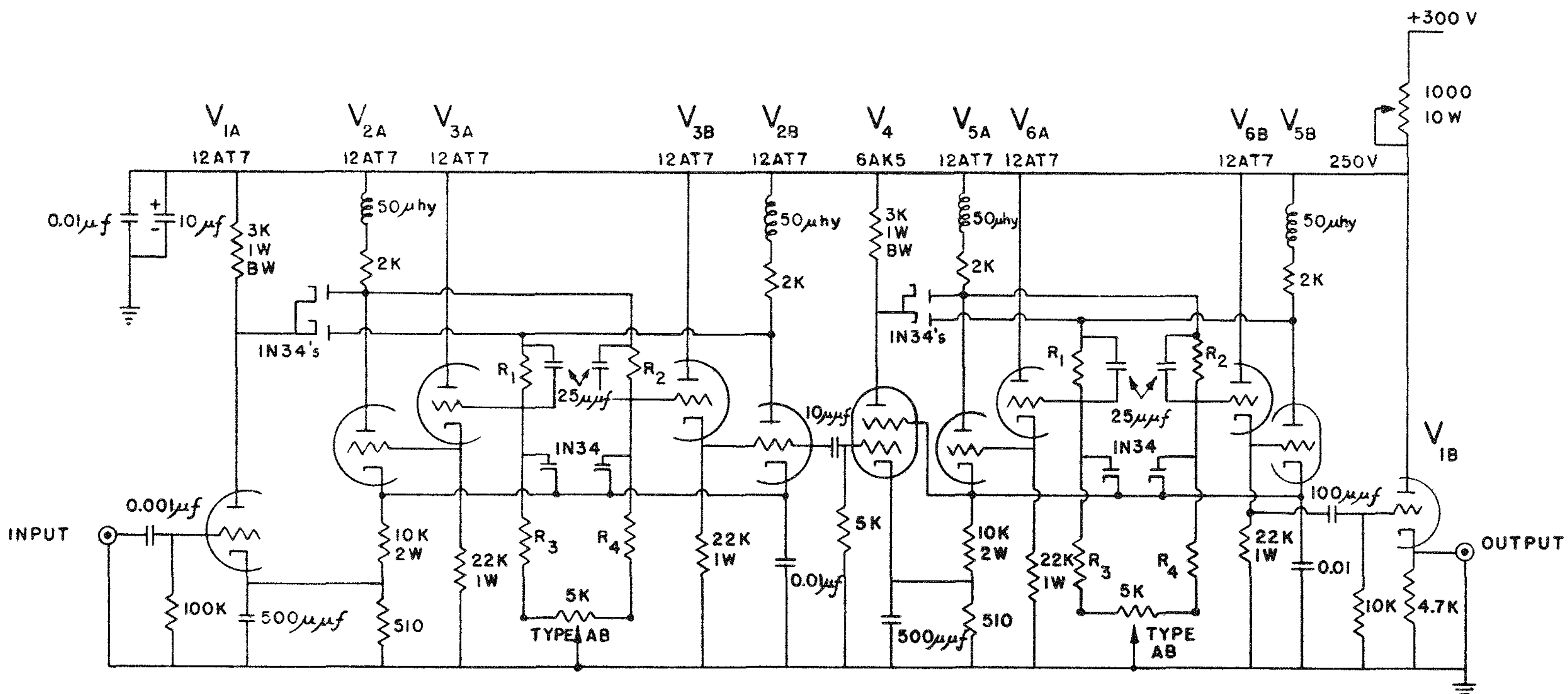
## REFERENCES

(1) L. J. Rainwater and C. S. Wu, "Applications of Probability Theory to Nuclear Particle Detection," Nucleonics, Vol. 1, No. 10, October 1947.

(2) W. A. Higinbotham, J. Gallagher and M. Sands, The Model 200 Pulse Counter, Revs. Sci. Instruments, Vol. 1, No. 2., October 1947.




$R_1 = R_2 \cong 27K$ 1W

$R_3 = R_4 \cong 27K$ 1W

ALL RESISTORS $\frac{1}{2}$ W UNLESS OTHERWISE NOTED

Figure 1: Circuit diagram of scale-of-four.

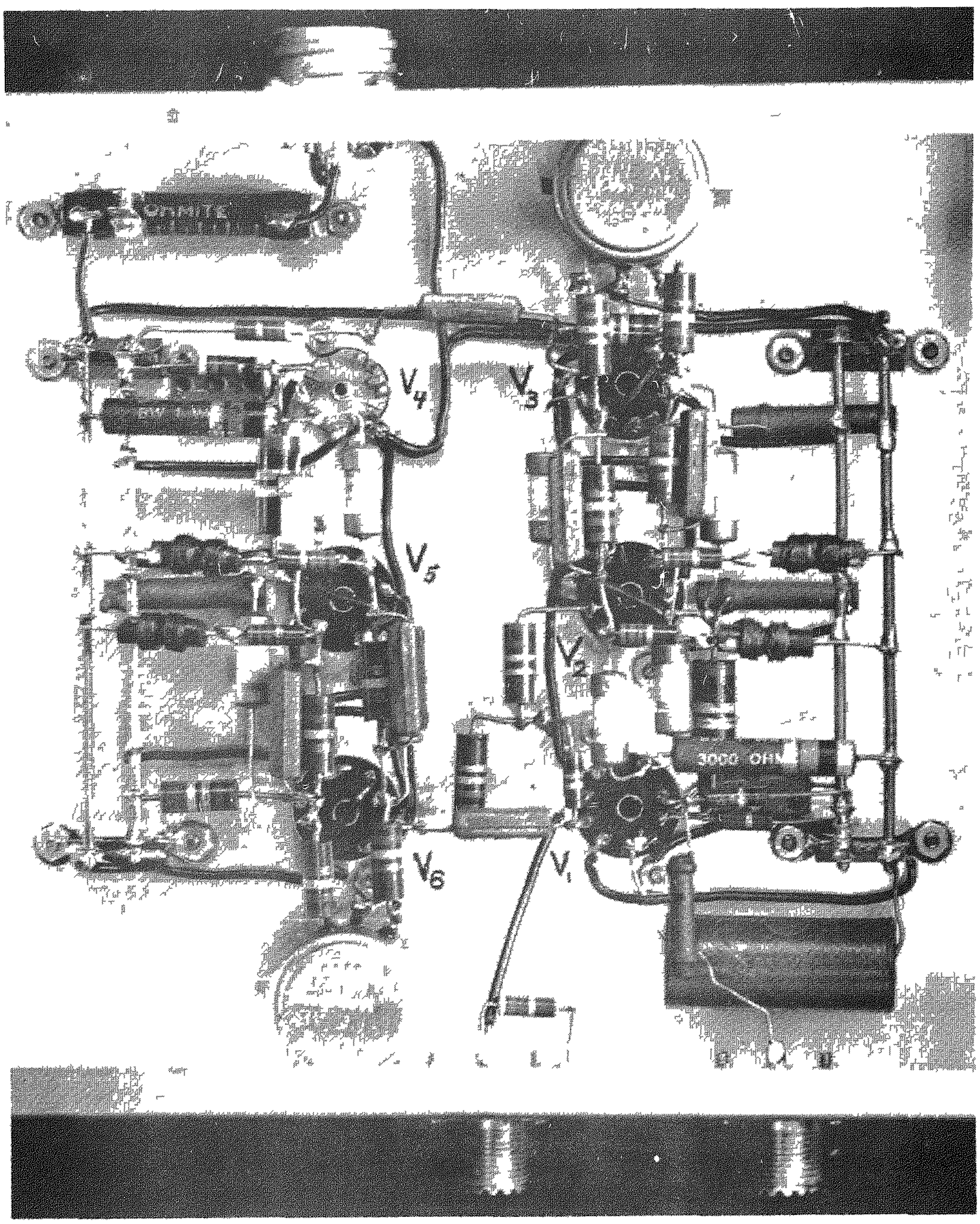



Figure 2: Photograph showing layout and wiring on 7″ × 7″ chassis.