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AEC RESEARCH AND DEVELOPMENT REPORT

A SOLID-STATE CIRCUIT FOR A REACTOR PERIOD SIMULATOR

J. S. BYRD

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Aiken, South Carolina

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A SOLID-STATE CIRCUIT FOR A REACTOR PERIOD SIMULATOR

by

J. S. Byrd

Approved by

D. E. Waters, Manager
Laboratory Operations and Services Division

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E. I. DU PONT DE NEMOURS & COMPANY
SAVANNAH RIVER LABORATORY
AIKEN, S. C. 29801

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ABSTRACT

A solid-state circuit has been constructed that provides an exponentially rising or falling electric current from 10^{-12} to 10^{-4} amp. This circuit is used in a convenient and reliable period simulator that tests the electronic response of instruments monitoring the neutron flux level in a nuclear reactor.

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INTRODUCTION

In many nuclear reactors, neutron sensitive ion chambers are used as primary monitors. These chambers drive linear and logarithmic electrometer circuits, which in turn trip safety switches and indicate power levels. Power levels in a reactor characteristically change exponentially when the reactor multiplication is changed. The electrometer circuits must follow these changes closely, both to ensure accurate monitoring and to provide proper input to the reactor period meters, which display the e-folding times of the power changes. Accordingly, it is customary to test the response of the electrometer circuits with a reactor period simulator before each reactor startup. Ideally the simulator should reproduce the reactor signal with a very accurate exponential current output extending over the full range of possible ion chamber outputs.

Previous reactor period simulators were electromechanical devices using motor-driven logarithmic potentiometers to provide an exponential current output in increments of two or three decades with overlapping steps. These simulators were cumbersome and required precise mechanical and electrical adjustments to obtain acceptable accuracy.

The simulator described in this article is an all-electronic, solid-state device that is reliable, accurate, compact, stable, and easy to use.

THEORY OF OPERATION

The short-circuit collector current of a silicon transistor changes exponentially with a linear change in its base-emitter voltage. The background theory and the proof of this result are presented in detail by Gibbons and Horn.[1] This transistor logarithmic transfer characteristic was used as the basis for an all solid-state log n-period meter.[2] The application for the period simulator is just the reverse of that for the period meter: the transistor collector current is the output for the period simulator and the input for the period meter.

CIRCUIT DESCRIPTION

The simulator circuit is shown in Figure 1. The output transistor Q-2 is a silicon planar epitaxial type. The emitter-base junction of Q-2 is driven by a summing amplifier stage consisting of an SA-2 type operational amplifier; a 0.1 multiplication is performed in that stage. The emitter-base voltage of Q-2 varies in decade steps (SW-4) from approximately 150 to 630 mv for output collector currents from 10^{-12} to 10^{-4} amp.

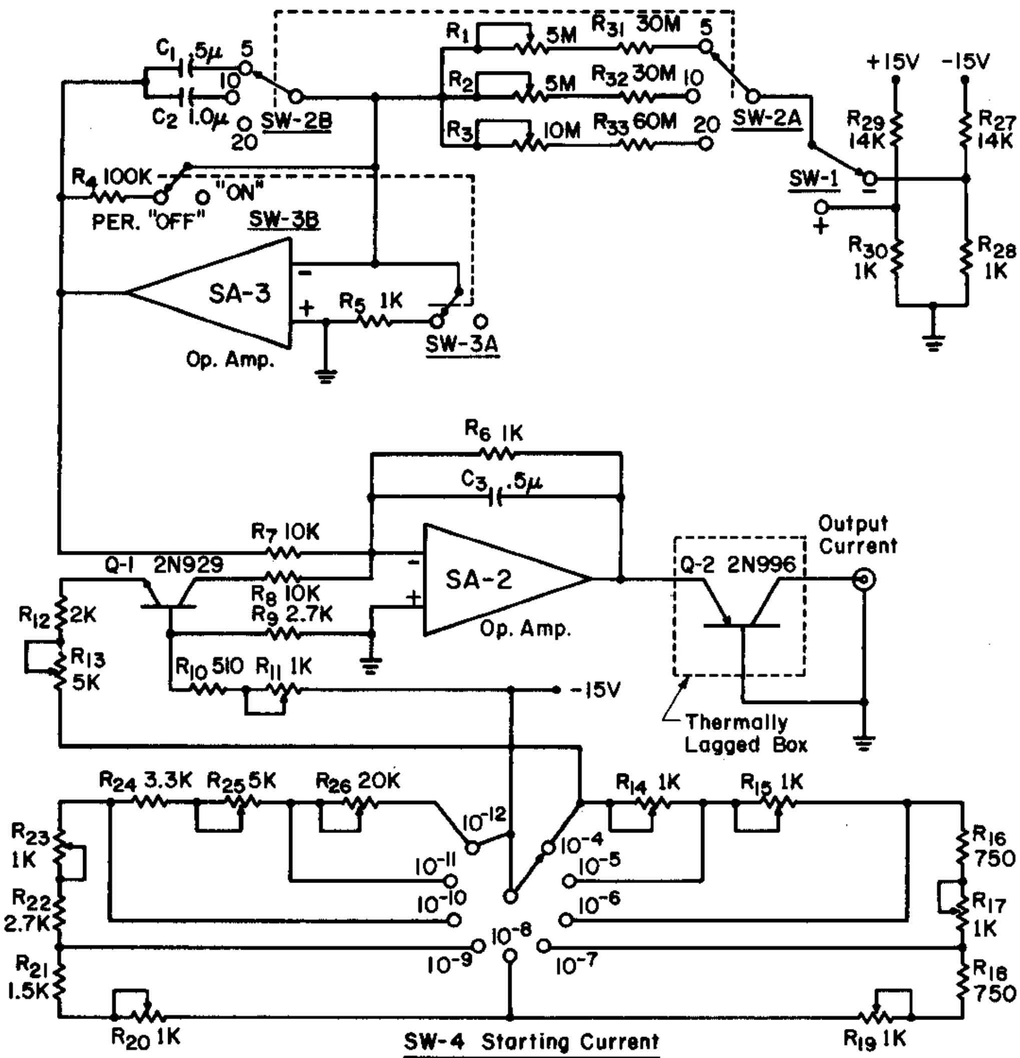

FIG. 1 PERIOD SIMULATOR CIRCUIT

An exponentially increasing reactor period is simulated by applying a controlled ramp voltage to the emitter-base of Q-2 via the SA-2 stage. The ramp voltage is generated by an SA-3 operational amplifier integrator. One of three time constants can be selected with SW-2A for output currents representing periods of 5, 10, or 20 seconds. The period polarity is selected with SW-1. The negative or positive period can be started at any fixed current level set by SW-4.

PERFORMANCE

The collector-base junction of Q-2 should be short-circuited, or the collector-base voltage (V_{CB}) should be zero. However, when the output of the simulator is connected to the input of an electrometer, a small collector-base potential does develop at Q-2. This potential must be less than 10 mv for good period accuracy of 10^{-11} amp, and less than 1 mv for good accuracy around 10^{-12} amp. At these low currents, as V_{CB} is increased the saturation current becomes a significant part of the total collector current. Usually, this is no problem since most electrometer circuits, when properly balanced, will have input potentials of 1 mv or less. This simulator is used only with electrometer circuits which have these low input potentials. An error of 10% at 10^{-11} amp was measured with an electrometer input potential of 10 mv.

The prototype simulator was designed to be used as a laboratory instrument at a relatively constant ambient temperature; therefore, Q-2 was not installed in an oven. Tests revealed that a change from 15 to 37°C caused the "starting current" (selected by SW-4) to change over one decade, but the period changed less than 10%. Q-2 was installed in a thermally lagged compartment to integrate small ambient temperature fluctuations.

CONCLUSION

The solid-state period simulator performed very satisfactorily. Its accuracy, stability, and compactness are adequate for testing reactor instruments. The circuit can be easily modified to provide a desired range of fixed or adjustable periods. As power requirements are small, a battery supply can be used to make the instrument portable.

REFERENCES

1. J. F. Gibbons and H. S. Horn. "A Circuit with Logarithmic Transfer Response over 9 Decades." IEEE Trans. CT-11, 378 (1964).

2. J. S. Byrd. "Solid-State Log n-Period System." Nucl. Instr. and Meth. 48, 296 (1967).