A Fast Pulse-Height Ratio Circuit

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A fast pulse-height ratio circuit suitable for position sensitive radiation detector is presented. The circuit is based on the linear to logarithmic conversion method using three semi-conductor diodes. By flowing constant standing current through these diodes in quiescent state, the circuit performance is, in principle, independent of temperature. The accuracy of the circuit is almost less than $\pm 1.5\%$ of full scale for input voltage range of 20-420 mV at a temperature between 0°C and 50°C.

1. Introduction

Many of position sensitive radiation detectors produce two energy dependent position signals, V_A and V_B , and the energy independent position information is obtained by taking the ratio, $V_A/(V_A + V_B)$. The denominator, $V_A + V_B$, is proportional to the energy deposited to the sensitive volume of the detector, and hence it is some times called "Energy signal".

With recent development of the position sensitive detectors, many authors have developed various pulse-height ratio circuits^{1)~5)}. These include the use of special characteristics of diodes, transistors or field effect transistors (FET), the use of pulse-height to time conversion, and the use of linear to logarithmic conversion.

This paper describes a ratio circuit suitable to the use with a position sensitive proportional counters for β - or X-rays, in which a large dynamic range in energy signal is required. The circuit principle is based on the linear to logarithmic conversion by using semiconductor diodes, and the design criteria are large dynamic range, fast response, small temperature dependency and variable sampling time.

2. Circuit principle

A blockdiagram of the whole system is

shown in Fig. 1. Two input signals are amplified and summed to produce energy signal, $V_A + V_B$, which is proportional to the energy deposited to the sensitive volume of the detector. The energy signal is applied to a single channel pulse-height analyzer (dotted line) which consists of "Fast Pick Off", "Variable Delay", "Gate", "Lower Discriminator", "Upper Discriminator" and two "Uni-Vibrators".

The ratio circuit (broken line) is designed so as to produce a voltage output pulse proportional to $V_A/(V_A + V_B)$ at a variable sampling time determined by "Variable Delay" circuit if the energy signal passes the single channel pulse-height analyzer. The diodes D_1 and D_2 are linear to logarithmic conversion elements and the diode D_3 is a logarithmic to linear conversion element. These diodes are biased by constant currents, I_{01} , I_{02} , and I_{03} respectively, in the quiescent state. When an energy signal exceeds the lower discriminator level, a negative rectangular pulse from "Uni-Vibrator" ($3 \mu\text{sec}$) cuts the bias currents, I_{01} and I_{02} , off by the switching action of transistor Q_1 and Q_4 , and the signal currents, I_1 and I_2 , flow through D_1 and D_2 , respectively, by the action of the operational amplifiers "A₁" and "A₂", where I_1 and I_2 are given by

$$I_1 = (2V_A + V_B)/R \text{ and } I_2 = (V_A + V_B)/R \quad (1)$$

If the currents, I_1 , I_2 , I_{01} and I_{02} are suffi-

Fig. 2 Complete circuit diagram of the ratio circuit.

3. Performance

The performance test was made with a specially designed double pulse generator and a 200 channel pulse-height analyzer. The pulse generator is controlled by a precise mercury pulser, and produces a pair of pulses having the same waveform as that of the mercury pulser. The ratio of their

amplitudes can be changed in ten steps keeping the sum of them at a constant amplitude which is equal to that of the pulses from the mercury pulser.

The linearity, the dynamic range and the temperature dependency are shown in Figs. 3-5. *A* and *B* in the figures indicate the pulse-heights of signals at the input terminals of the amplifiers. The single channel pulse-height analyzer was set at the widest position, and the amplifier gain was set at about 10. The solid lines in these figures show the ideal characteristics. The deviation from the ideal is within 1.5% of the

Fig. 3 Linearity of output vs. input pulse-height. *A* and *B* indicate the pulse-heights of two input signals at the input terminals of the amplifiers.

Fig. 4 Constancy of output for various input signals having constant ratio.

Fig. 5 Temperature dependence of the circuit for three input levels.

full scale for the input voltage range from 20 to 420 mV, and for 0°C~50°C, except for 20 mV at 0°C.

The rise time of the output from the operational amplifier "A₄" is a function of the input voltage, and it ranges from about 0.5 μsec for the smallest pulse to 0.1 μsec for the largest pulse in the usable dynamic range. The high count rate performance was tested with random pulses from a scintillation detector. The pulse-height of output of the system was decreased by 1.5 %, 2 %, 3 %, and 4 % at 15, 20, 35, and 60 kcps, respectively.

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要 旨

高 速 パ ル ス 比 回 路

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放射線位置検出器に適する高速パルス比回路について報告する。この回路は3個の半導体ダイオードを使用した「直線—対数」変換法に基づくものである。パルス信号のない期間中3個のダイオードに一定の直流電流を流しておくことにより, この回路の動作は温度変化の影響を原理的に受けない。この回路の精度は, 温度0°C~50°Cの範囲で20 mV~420 mVの入力信号にたいし, フルスケールのほぼ±1.5%以内である。