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TUNNEL DIODE PULSE SHAPE DISCRIMINATOR*

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Abstract

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A pulse shape discriminator with wide dynamic range is described. The discriminator has been used for separating the scintillation signals from particles with different specific ionization, in connection with fast 56 AVP and RCA 7267 photomultiplier tubes. For the signal amplitudes in the range from 50 mV to 5 V, the time shift of the output discriminator pulse for a given sort of particles is about ± 1 nanosec. The circuit has also been used for neutron spectrometry, using proportional counters, and for separation of thermal neutrons, with glass beads-plastic scintillators.

Introduction

Scintillation counters have been used for a long time for measuring the specific ionization of exciting particles through variations in signal pulse shape. A considerable number of circuits have been developed for distinguishing particles of different specific ionization. The most frequently used is the zero-crossing technique, used to provide a time invariant fiducial point from a

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variable amplitude pulse of a constant shape. In the nanosecond time spectrum at least two possible sources of timing error are present. First, under overload conditions, the input pulse will be distorted by the photomultiplier or the discriminator circuitry, causing the output pulse to shift in time. Secondly, if a photomultiplier is used as the event detector, the trailing edge of the signal is not of constant shape, due to statistical processes in the tube, and this will shift the zero-crossing point in time. The pulse shape fluctuations depend on the energy of particles detected, and hence on the number of photoelectrons emitted by the photo-cathode. The fluctuation is small at high energies, increasing gradually with decreasing energy.

The present instrument incorporates three tunnel diode discriminators in coincidence. The first discriminator is used to reject pulses of very small amplitude which could not be measured accurately. The second discriminator fires on the fast leading edge of accepted pulses. The third discriminator fires at the zero-crossing point of pulses which are previously integrated and differentiated to diminish statistical fluctuations. Discriminator outputs are connected to a simple nanosecond time-to-amplitude convertor.

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Circuit Description

Figure 1 shows the circuit diagram of the discriminator. The discriminator has three channels, connected to the input through common base stages T_1 , T_7 , and T_{10} .

Channel I is an amplitude discriminator. If the input pulse is larger than the triggering level preset with potentiometer P_1 , tunnel diode monostable D_1 fires and removes biases from tunnel diodes D_2 and D_3 . The period of the monostable is controlled by the value of the small inductor.

Channel II receives a delayed input signal, which triggers tunnel diode monostable D_2 , determining the leading edge of the output.

Channel III integrates and differentiates the signal in a filtering network between transistors T_1 (high output impedance) and T_2 (high input impedance). The zero-crossing point of the signal triggers tunnel diode monostable D_3 , determining the trailing edge of the output.

Such an arrangement has the following advantages: diodes D_2 and D_3 are quiescently biased into a noise insensitive state. They are unbiased to the sensitive state, very near to the peak current point, only a few nanoseconds before receiving signals whose timing information is to be extracted. The current in the diode D_3 , after unbiasing, can be equal to the diode peak current, or even slightly higher, since it is compensated by a negative

part of the signal before zero-crossover point. Such biasing enables high timing accuracy.

Signals from the three channels are amplified and connected to the simple time-to-amplitude converter. When tunnel diodes D2 and D3 fire, the bases of transistors T_8 and T_{11} receive an immediate flood of 5 mA, allowing the transistors to saturate fast. Fast pulses of 6 V amplitude are connected to diode "and" gate which controls the flow of a current from constant current source T_{13} into condenser C_3 , changing time information into amplitude information. The main pulse shapes and their time relationships can be seen in Fig. 2.

Linearity and Timing Test

The linearity and timing accuracy of the discriminator has been checked by applying a simulated photomultiplier pulse to the input, using a nanosecond pulse generator (Berkeley Instrument Co.). A pulse generator and discriminator outputs have been connected to the X and Y inputs of a two-dimensional analyzer. Results are shown in Fig. 3. The presented curves are obtained with pulse lengths approximately 80, 110, 120, 150 and 180 nanosec (from left to right). Amplitudes of input pulses cover the range from 50 mV (bottom) to 5V (top).

Experiments

The discriminator has been intended for three kinds of experiments: with stilbene scintillators, with glass beads mixed in a plastic scintillator, and with proportional counters. Results of a few experiments are shown in Figs. 4, 5 and 6. Figure 4 shows the separation of neutrons and gamma rays using stilbene and fast photomultiplier RCA 7264 (anode pulse rise time 3 nanosec), at 1800 V anode voltage. Radiation sources used have been Pu-Be (Fig. 4a) and Na^{22} (Fig. 4b).

Figure 5 shows separation of gamma rays and thermal neutrons, using a scintillator composed of boron glass beads mixed into plastic. Design and operation of such a scintillator will be described elsewhere. The photomultiplier used was a 56 AVP (anode rise time 2 nanosec) at 2100 V. The radiation source was Pu-Be.

Figure 6 shows the separation of gamma rays and neutrons using a hydrogen filled proportional counter. Pulses from the counter were amplified in a charge-sensitive, low noise, fast FET preamplifier. The radiation source was Pu-Be.

For the experiments with the proportional counter, timing determining elements in the discriminator were increased to match longer rise times from the counter.

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Figure Captions

1. Circuit diagram of the discriminator.
2. Main pulse shapes of the discriminator, triggered by the nanosecond pulse generator. Time scale 50 nsec/cm.
 - a) input to channel I
 - b) output from channel I
 - c) input to channel II
 - d) output from channel II
 - e) integrated and differentiated signal at the base of T_2
 - f) output from channel III
 - g) output of the time-to-amplitude converter.
3. Linearity test. Abscissa: output from discriminator; ordinate: output from pulse generator.
4. Separation of gamma rays and neutrons in stilbene. a) radiation source Pu-Be. b) Na^{22} .
5. Separation of gamma rays and thermal neutrons in boron glass beads mixed with plastic scintillator. Unblanking levels a) 8000 counts, b) 4000 counts, c) 1000 counts.
6. Separation of gamma rays and neutrons from a proportional counter. a) distribution of rise times of gamma rays, measured with a discriminator. b) distribution of rise times of gamma rays and neutrons. c) rise time - energy plot for gamma rays and neutrons.

FIGURE 1

FIGURE 2

a

b

FIGURE 3

a

b

FIGURE 4

a

b

c

FIGURE 5

a

b

c

FIGURE 6