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ABSTRACT

A transistor coincidence-discriminator circuit of better than 10^{-8}-sec resolution and 0.25-v sensitivity has been designed for use where large numbers of such circuits are required in a single system. The experience gained in operating 168 units in a physics experiment, and the methods developed for testing the sensitivity and resolution of the circuits during both initial checkout and operation in the experiment show the approach used to circuit design to be highly feasible.

A TRANSISTOR COINCIDENCE-DISCRIMINATOR CIRCUIT FOR 10^{-8}-SECOND PULSES*

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INTRODUCTION

For several years, multiple-counter experiments have been performed at this Laboratory using two-fold coincidence circuits in which each channel receives pulses from a scintillation counter and a common gate pulse. The gate pulse, usually generated by a counter system, indicates the passage of a particle with a particular time of flight or momentum. Thus all coincidence channels are sampled for the gate period whenever the desired event is detected.

A pulse-amplitude discriminator follows the coincidence circuit to accurately determine which events produce signals above a predetermined threshold level and should be recorded. To relax the bandwidth requirements of the system after a coincidence has been detected, a memory circuit is employed to preserve the response of each event until further logical operations are completed.

Multiple-diode coincidence circuits whose outputs are appropriately delayed and mixed for display on an oscilloscope have been used in numerous experiments.[1] A permanent record is then made on photographic film for later analysis.

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When a 168-channel system was proposed, it became evident that the experimental data should be acquired and preserved in a form suitable for immediate entry into a computer.[2] The coincidence-discriminator circuit described here was developed to accept pulses directly from multiplier phototubes without preamplification and to store the coincidence patterns electrically instead of photographically.

Development specifications for the unit are the following: The minimum input-amplitude sensitivity must be 0.25 v into an impedance of 125 ohms, but 10 v signals must not cause adverse effects. The memory must accept information at a rate of at least a 100 kC; however, 10 v non-coinciding pulses at either the phototube or gate inputs occurring with a frequency of 10 Mc must not cause accidental output signals. The time resolution of the coincidence circuit should be 5 nsec or less. The unit must operate satisfactorily up to an ambient temperature of 55°C. Since more than one coincidence circuit would be operated from each phototube signal, a means of operating units in parallel should be provided. The output of the coincidence-circuit portion of the unit must be monitored without affecting the operation of the remainder of the unit.

CIRCUIT DESCRIPTION

At the time of development, the most economically feasible transistors with a sufficient gain-bandwidth product (i.e. $f_T > 100$ Mc) were PNP types. A diffused base, mesa unit, type 2N1143, was selected for use in the fast circuits. It has a minimum gain-bandwidth product (f_T) of 250 Mc at a collector potential of 10 v at 10 ma. Using PNP transistors meant that coincidence-circuit limiters had to receive positive base signals to cut off their collector currents.

A block diagram of the coincidence discriminator that was developed is shown in Fig. 1, and the schematic circuit diagram in Fig. 2.

The minimum acceptable input signal turned out to be 200 mv, which gave an adequate margin in sensitivity over the specified value of 250 mv. A phase-splitting stage, transistor Q-1, was used to provide isolation between the portion of the signal fed to the coincidence circuit and that part which might be used to drive another unit or a phototube-signal monitor. For proper operation, the monitor jack is terminated in an impedance of 125 ohms. The input stage Q-1 inverts negative phototube signals in order to apply positive pulses to the coincidence limiters.

The gate pulse, which is applied in common to each coincidence unit, is externally shaped to a specified height and width. Careful design was required in the gate distribution system to drive two groups of 84 coincidence units with a minimum delay and pulse lengthening. Distribution was made by first splitting the gate into three channels driven by a complementary PNP - NPN emitter follower. Each of these channels is then multiplied into six more channels in another emitter-follower unit. These channels are finally separated into five more to provide the gate signals to drive each coincidence unit.

A schematic circuit diagram of the last 5-channel gate driver is shown in Fig. 3. A type 2N1143 emitter follower drives five grounded-emitter amplifiers in parallel. The gain is 0.5 for each channel loaded with 125 ohms. It provides a positive output signal 0.5 v in amplitude and 20 nsec long.

The coincidence circuit selected was a Garwin circuit[3] modified to include a clipping stub on one channel. The gate input signal is already shaped and needs no attention; the phototube input signal might have considerable variation in pulse length, however. A 5-nsec clipping stub on the collector of Q-2 provides the necessary pulse clipping. Diode D-2 isolates the clipping action to only the phototube signal and not the gate signal. Diode D-1 is the one normally associated with the Garwin circuit; it draws 55% of the combined collector currents of limiters Q-2 and Q-3. Both transistors Q-2 and Q-3 must be cut off before D-1 unclamps and allows an output signal. The output is directed to both a coincidence-output monitoring jack through emitter follower Q-4 and to an amplitude discriminating diode D-3. The coincidence ratio (doubles-to-singles) is approximately 10/1.

Several other coincidence circuits were investigated, but this one proved to be best suited to our needs. In other circuits degenerating resistors in the emitters of the limiters caused the input impedance to be much higher and allowed a better termination for a transmission line than could be obtained with the circuit actually employed. This, however, increased the pulse height needed for limiting. Decreased sensitivity was undesirable, while matching impedances was not a great problem, and so unbypassed emitter resistors were not used.

To obtain more output signal, the circuit of Fig. 4 was tried, in an attempt to get a good coincidence ratio without sacrificing half the output current, as is done with the Garwin clamp diode. When one transistor in Fig. 4 cuts off, the other side assumes the whole current; when both sides are cut off, the whole bias current is available as a pulse in the output. This worked well and provided the same resolution time as the Garwin circuit, but again the loss of sensitivity was too disadvantageous. This loss is, of course, due to the presence of the emitter resistor.

Amplifier Q-5 and blocking oscillator Q-6 serve to convert signals with an amplitude greater than the threshold bias on diode D-3 into a 4-v, 0.8-μsec pulse. A blocking oscillator was chosen to generate this pulse, because it needs only one transistor and possesses a very sensitive triggering action. When biased beyond cut off, it exhibits good threshold stability. The pulse produced has a very stable width, and operation is good over a wide range of temperature.

To make sure that transients produced by the blocking oscillator did not feed back into the sensitive portion of the circuit, the power supplied to the trigger circuit had to be well-bypassed.

The capacitance loading by the memory flip-flop Q-7 and Q-8 reduces the input sensitivity of the blocking oscillator. Diode D-4 provides some isolation for the blocking oscillator during its regenerative period.

Memory for coincident events is provided by an Eccles-Jordan bistable circuit. Two output connections are buffered by emitter followers Q-9 and Q-10. The flip-flop is reset by a positive pulse applied to diode D-6 after the necessary logic functions have been completed by the rest of the readout system.

Each unit was constructed on a glass-epoxy-laminate, printed-circuit board measuring 3 by $10\frac{1}{2}$ in. A photograph of this unit is shown in Fig. 5. Ten coincidence-discriminator units and two gate-circuit driver boards were plugged into a frame measuring $3\frac{1}{2}$-in. high by 19 in. wide. Phototube-signal and coincidence-output connections were made to a front panel on each unit; all other connections were made through connections at the rear of the board.

During initial line-up as well as during the running of multichannel experiments it was desired to check the operation of the unit--especially the threshold sensitivity.[4] A test signal (introduced in parallel with the phototube input and in time coincidence with a test gate pulse) provided a means of making this measurement. A pulser was constructed to allow test signals to be introduced in this manner by either a single pulse or at a 800 cps rate. The pulses were shaped to resemble the actual phototube signals.

OPERATION

The amplitude threshold of the coincidence-discriminator circuit was found to be a strong function of the dc supply voltages. The -5 v bias potential had to be kept within 0.1% to keep the threshold variation within 1%. The sensitivity to the -15-volt supply line was not as great; it had to be maintained within 1% to hold the threshold within 1%. These voltages were monitored by a 2% full-scale recorder during operation.

The drift of the threshold level with time was quite acceptable. At the Bevatron without temperature control during a normal 8-hr period, four or five of the 168 units would drive outside of a ± 5% range. This was measured by the checking system previously mentioned.[4] It was a simple matter to periodically readjust the threshold levels of these units that had drifted outside the prescribed range.

During the early part of the experiment, approximately 12 transistors were burned out in the input amplifier Q-1. It was found that switching on the high voltage for the phototubes caused a large positive transient on the signal line. A protective diode is now placed across the input circuit.

ACKNOWLEDGMENTS

The circuit and package design was done in cooperation with H. G. Jackson. Stuart Wright checked and maintained each circuit both before and during operation.

REFERENCES

1. See, for example, Fig. 5 of C. A. Coombes, B. Cork, W. Galbraith, G. R. Lambertson, and W. A. Wenzel, Phys. Rev. 112, 1303 (1958).

2. S. C. Baker, F. A. Kirsten, D. A. Mack, and C. E. Wiegand, An Electronic Data-Aquisition System for Use with a Complex Nuclear Physics Experiment, UCRL-9271, December 1960; submitted to Nuclear Instruments.

3. R. L. Garwin, Rev. Sci. Instr. 24, 618 (1953).

4. S. C. Baker, Q. A. Kerns, F. A. Kirsten, D. A. Mack, and T. A. Nunamaker, Test Routines and Monitoring, UCRL-9273, December 1960; submitted to Nuclear Instruments.

Figure Captions

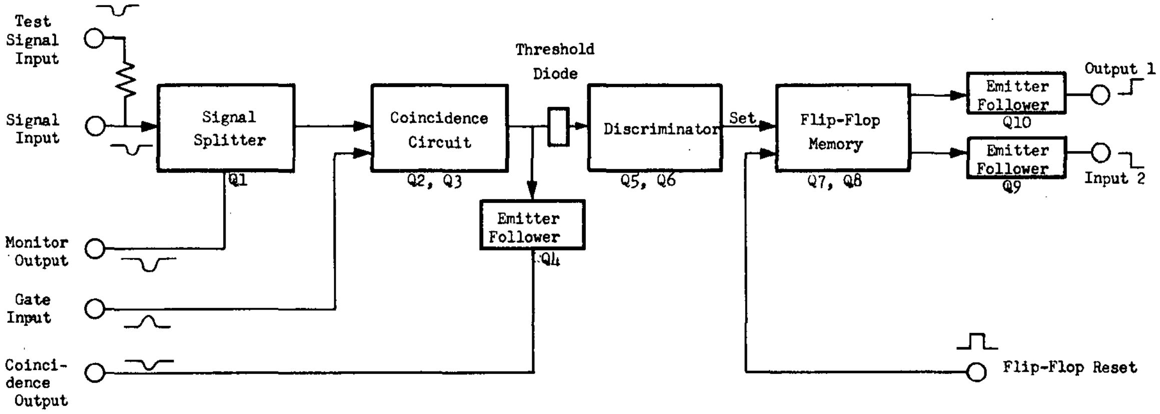
Fig. 1. Block diagram of the coincidence-discriminator circuit.

Fig. 2. Schematic diagram of the coincidence-discriminator circuit.

Fig. 3. Schematic diagram of the five-channel driver unit.

Fig. 4. Alternate coincidence circuit.

Fig. 5. Coincidence discriminator unit.



MU-21847

Fig. 1.

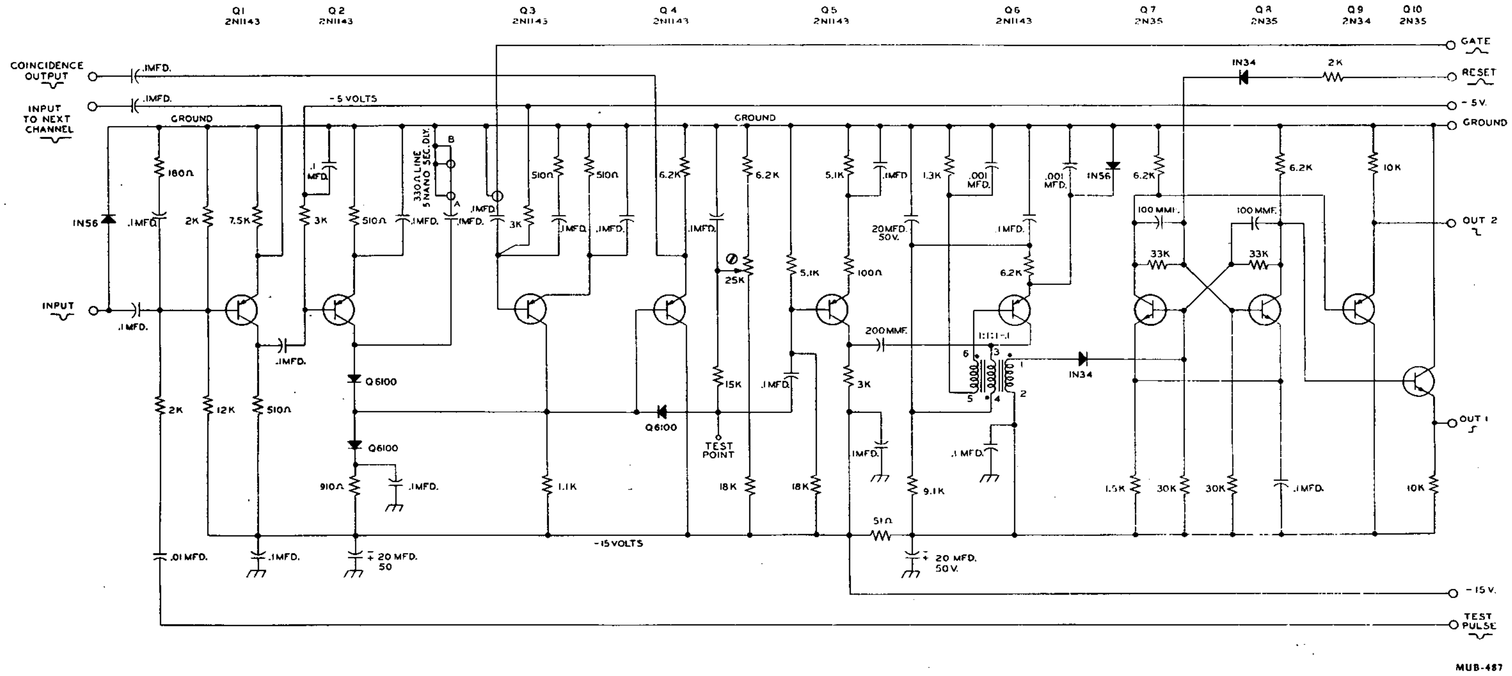
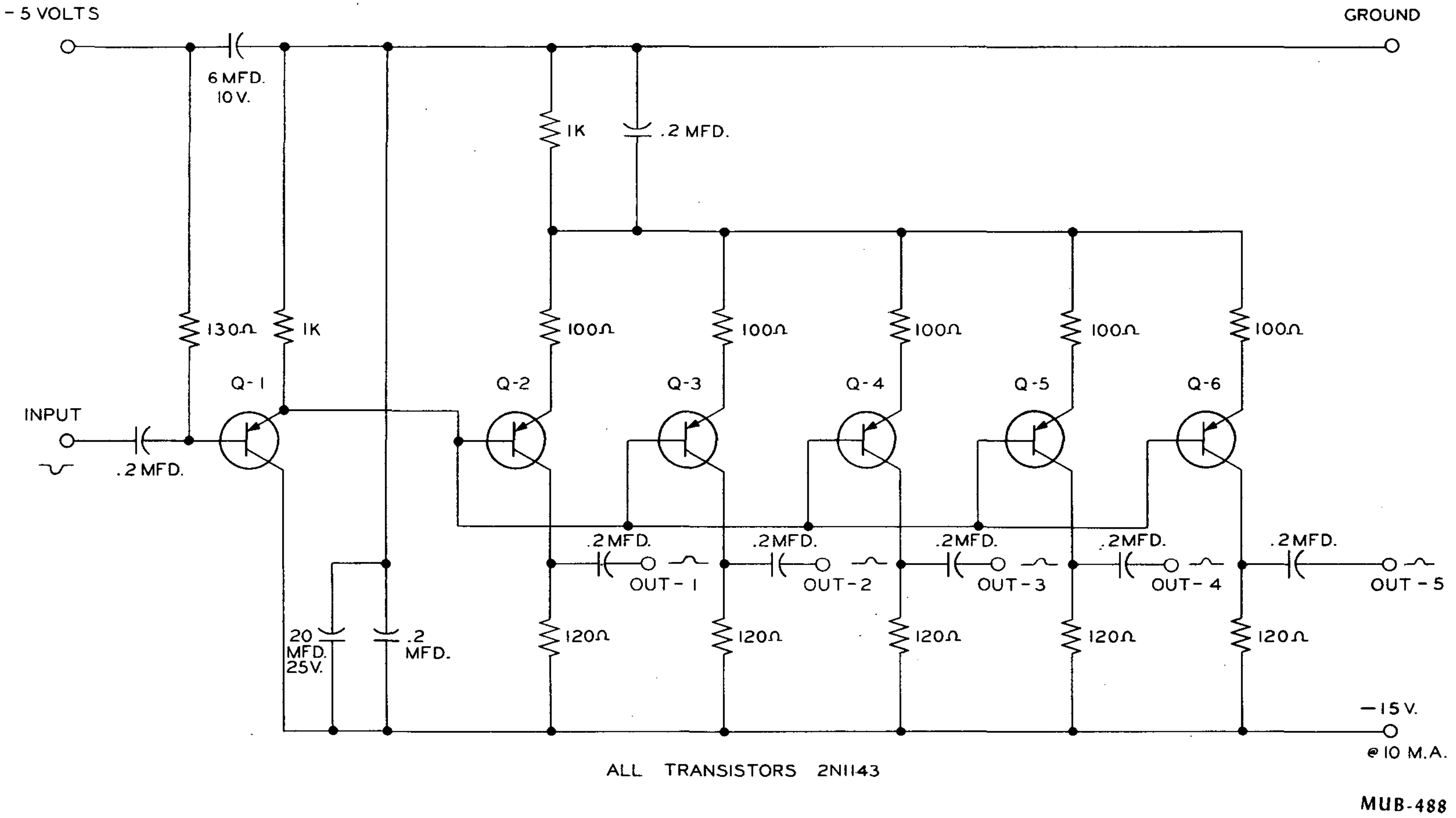

Q1 2N1143
Q2 2N1143
Q3 2N1143
Q4 2N1143
Q5 2N1143
Q6 2N1143
Q7 2N35
Q8 2N35
Q9 2N34
Q10 2N35
COINCIDENCE OUTPUT
INPUT TO NEXT CHANNEL
INPUT
GROUND
-5 VOLTS
-15 VOLTS
330Ω LINE 5 NANO SEC. DLY.
A
B
IN56
IN34
Q6100
180Ω
2K
7.5K
3K
510Ω
12K
910Ω
1.1K
6.2K
25K
15K
18K
5.1K
100Ω
3K
51Ω
9.1K
1.3K
1.5K
30K
33K
10K
.IMFD.
.01 MFD.
.1 MFD.
20 MFD. 50
20 MFD. 50V.
.001 MFD.
200 MMF.
100 MMF.
TEST POINT
GATE
RESET
-5V.
GROUND
OUT 2
OUT 1
-15 V.
TEST PULSE
MUB-487

Fig. 2.



ALL TRANSISTORS 2N1143

Fig. 3.

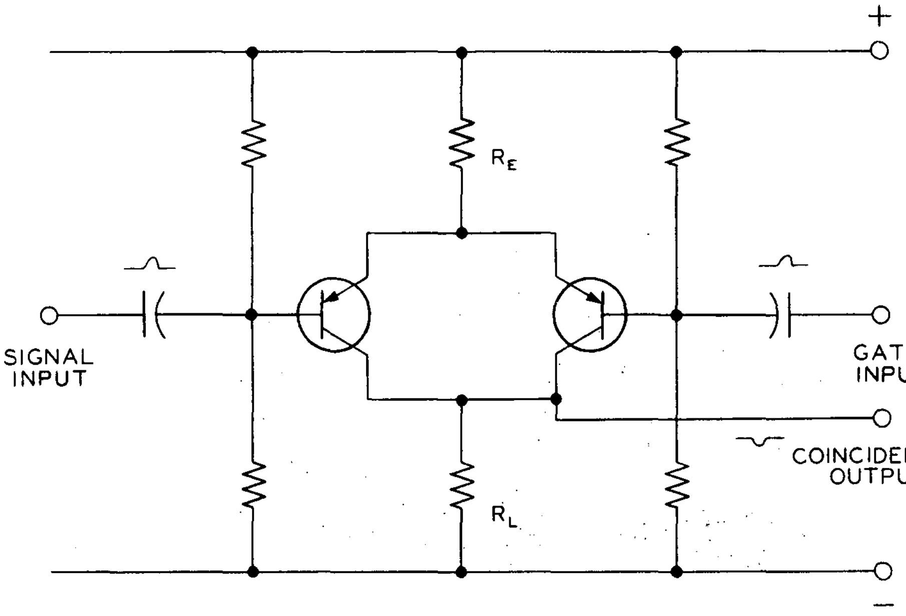


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Fig. 4.

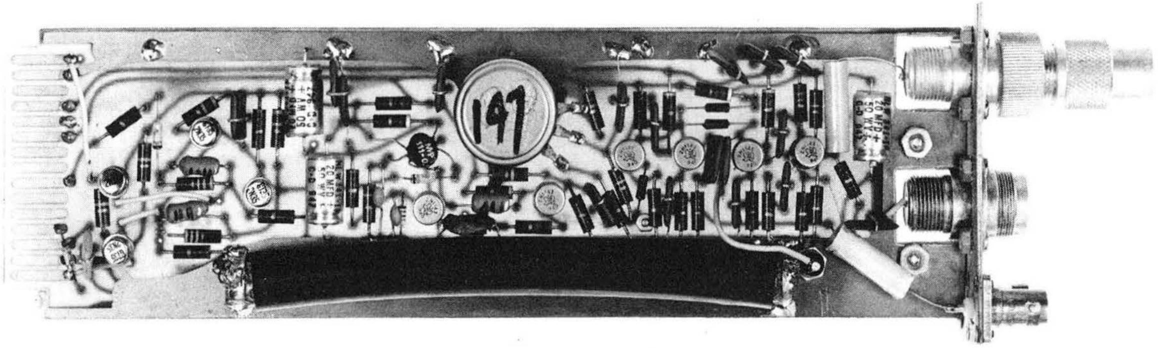

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Fig. 5.

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