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Summary

A system for automatically measuring and displaying the thresholds of many channels of nanosecond-speed discriminators is described. It is used in high-energy physics experiments in which the results depend critically upon the stability of the discriminator thresholds. Measurements are made in the dead time between accelerator beam spills. The system includes a programable pulse generator, a 20-channel pulse distribution transformer, and a multichannel coincidence array which is sequentially addressed. Since the distribution transformer is constructed as a through-line, matched-impedance element, it remains permanently connected in the signal lines from the phototubes, and no cables whatever need be disturbed to allow threshold measurement.

Introduction

The Problem

Accurate setting and repeated monitoring of discriminator thresholds during a complex physics experiment can be a laborious and time-consuming operation. The problem of maintaining known settings over a period of time was recently encountered in a physics experiment in which the discriminators in question were to be used with fast phototube pulses from plastic scintillators for neutron detection. The neutrons are observed indirectly, i. e., the recoil protons produced when a neutron interacts in the scintillator cause the scintillation. Such recoil protons have a variety of energies, and consequently the percentage of recoil protons observed (the counter's efficiency) depends on the discriminator's threshold. This efficiency may be continually observed by monitoring the discriminators, provided the phototube gain and optical path are constant or are monitored. In this paper, I discuss only the problem of the discriminator threshold monitoring.

Definition of Threshold

A plot of the ratio of discriminator average output rate (DAOR) to the average input pulse rate (AIPR) vs the amplitude of pulses to the discriminator would result in a graph similar to that of Fig. 1.

Thus we may define threshold where:

Threshold pulse voltage = amplitude (on x axis of Fig. 1) for which $\frac{\text{DAOR}}{\text{AIPR}} = 0.5$.

This is the generally accepted concept of threshold and is so used throughout this paper.

System Description

Block Diagram

A simplified block diagram of the threshold detecting system is given in Fig. 2. Examination of the diagram shows the following component blocks: a programable pulse generator and pulse distribution network, a multichannel coincidence array which is sequentially addressed, and a bidirectional scaler and digital-to-analog converter (DAC). The amplified output of the DAC provides the programing feedback voltage to the pulse generator, closing a digital control loop whose action is further described below.

Operating Cycle

During the "on" time of the threshold-determining system, interrogating test pulses of 10-nsec duration and of amplitude controlled by the programing feedback voltage are generated at a 100 kHz clock rate in the programable pulse generator. The cycle of operation includes varying the test-pulse amplitude in steps of one part in 2048 until the discriminator under test fires 50% of the time (on the average), at which point the test-pulse amplitude stabilizes. This amplitude stabilization is brought about by the fact that the bidirectional scaler counts the clock pulses up in the normal fashion until the test-pulse amplitude is sufficient to trigger the discriminator. When the discriminator triggers, the associated clock pulse is subtracted or counted down in the bidirectional scaler. Thus, the test-pulse amplitude is reached at which the discriminator triggers (on the average) as often as it misses, and a leveling off or stabilized count is achieved in the scaler. This stabilized binary count is a function of that particular discriminator threshold and is displayed on a four-digit Nixie-tube indicator panel. The display for that discriminator remains on for observation, then terminates and the next discriminator threshold is displayed. Adjacent to the threshold display is an address display, indicating which discriminator is being read at the time.

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*Work done under auspices of the U. S. Atomic Energy Commission.

Programable Pulse Generator and Test Pulse Fanout

The programable pulse generator provides up to 30-volt (maximum amplitude) pulses at a 50-ohm level. Examination of Fig. 3 (which is a detailed description of programable pulse generator block as shown in Fig. 2) reveals that it is a line-type pulser that provides two fast pulses in coincidence. One of the output pulses (lower output) is distributed to and arrives simultaneously at the inputs to the multichannel coincidence array. The other output of the pulse generator (upper output of Fig. 3), which is variable, is also distributed (via the Test Pulse Fanout) and arrives simultaneously at the inputs to the various discriminators in the system. The programable pulse generator is driven by the clock, which, of course, must receive externally supplied "turn on" gates in the dead time between accelerator beam spills.

Figures 4 and 5 show the construction details of the Test Pulse Fanout chassis. Distribution transformers are used to distribute the pulse at a lower level to the total number of channels included in the test system. In the present device, the maximum pulse amplitude out of the test pulse fanout has been chosen as 3 volts. The test pulse increments are therefore 3/2048 or about 1.4 millivolts. As well as distributing the test pulses, the Fanout serves as the junction where the phototube pulses and test pulses are mixed at the input to the discriminators. Fanout construction is such that it is a through-line, matched-impedance element remaining permanently connected in the phototube signal lines; no cables need be disturbed to allow threshold measurement.

Sequential Shift Register and Three-Input Coincidence

It is required that not all channels be permitted to operate simultaneously, but rather stepped sequentially. Reexamination of the block diagram, (q. v., Fig. 2) indicates that during the gated on-time of the programable pulse generator, any or all of the discriminators may be triggered, thus providing simultaneous inputs to the coincidence circuits of all 20 channels. The shift register steps the channels along in the proper sequence, selecting one but blocking interfering pulses from the other nineteen channels.

The shift register provides sequential dc levels to the transistor collectors in the coincidence circuit of Fig. 6, typical of 20 such circuits used. An output pulse from the triple coincidence in the channel under test triggers the one-shot, thus subtracting that particular count pulse from the three-stage averaging scaler. (To be discussed below.)

Bidirectional Scaler and DAC

Early design specifications called for at least a 2% threshold detection accuracy over a dynamic range of 30 to 1. This requires that the programable pulse generator be capable of producing 1500 distinct levels; an 11-bit bidirectional scaler[1] and DAC were used, thus producing 2048 steps. The 11-bit scaler is preceded by a three-bit reversible scaler, which does not drive the DAC. The averaging effect of these three stages is one solution to the noisy readout problem that would otherwise occur, i. e., the DAC changing level needlessly and continuously merely because of the statistical uncertainty of discriminator firing. With the circuit as shown, the DAC will not change level unless there is an unbalance of eight pulses all of one sign, i. e., eight "count up" or eight "count down." Thus a persistent unbalance is corrected, but fluctuations within the three-stage count capacity do not result in a pulse-height change.

The selection of three-stage averaging was an estimate made with a view to changing it if in practice another number was required, but operation has been satisfactory, with no overshoot apparent on the readout. Stable readings are typically obtained in a time of about 1 to 2 sec after switching from one channel to the next.

It should be noted that although the present device does measure and read out discriminator thresholds, it does nothing to control them should they drift. Various workers[2] have attacked the problem of digital stabilization, and the interested reader is directed to their papers for discussion of stabilization.

Conclusions

A system for multiple discriminator threshold detection and monitoring has been used quite successfully in a recently completed experiment at the Lawrence Radiation Laboratory Bevatron. It has been used to monitor 20 discriminator thresholds, one between each Bevatron pulse. In the next experiment using this monitor, we will probably examine two or three discriminators per pulse by making slight modifications to speed up the shift register. Presumably one could go even faster with a typewriter or computer readout.

After working with the system we have developed several peripheral uses in addition to the original monitoring function:

(a) The device can be used as a pulser and detector to rapidly set a series of specific thresholds.

(b) It can be used as a synchronized pulser. Setting one threshold higher than the others, and monitoring this threshold, one can rapidly make adjustments of fast timing and output pulse shape for a large number of identical discriminators.

Acknowledgments

I wish to express my appreciation to Kai Lee for his help with the shift register. I am indebted to Mr. Frederick Kirsten for his original contributions and to Dr. Robert W. Kenney for his continued interest and support.

References

1. Don Fleming, Bidirectional Counting, EDN Magazine, Feb. 1967.
2. J. M. Ferguson, The Statistics of Digital Stabilizers, Nucl. Instr. Methods 58[2], 318 (1968).

Figure Captions

Fig. 1. Typical curve of ratio of discriminator output average rate to average input pulse rate vs amplitude of pulses to discriminator.

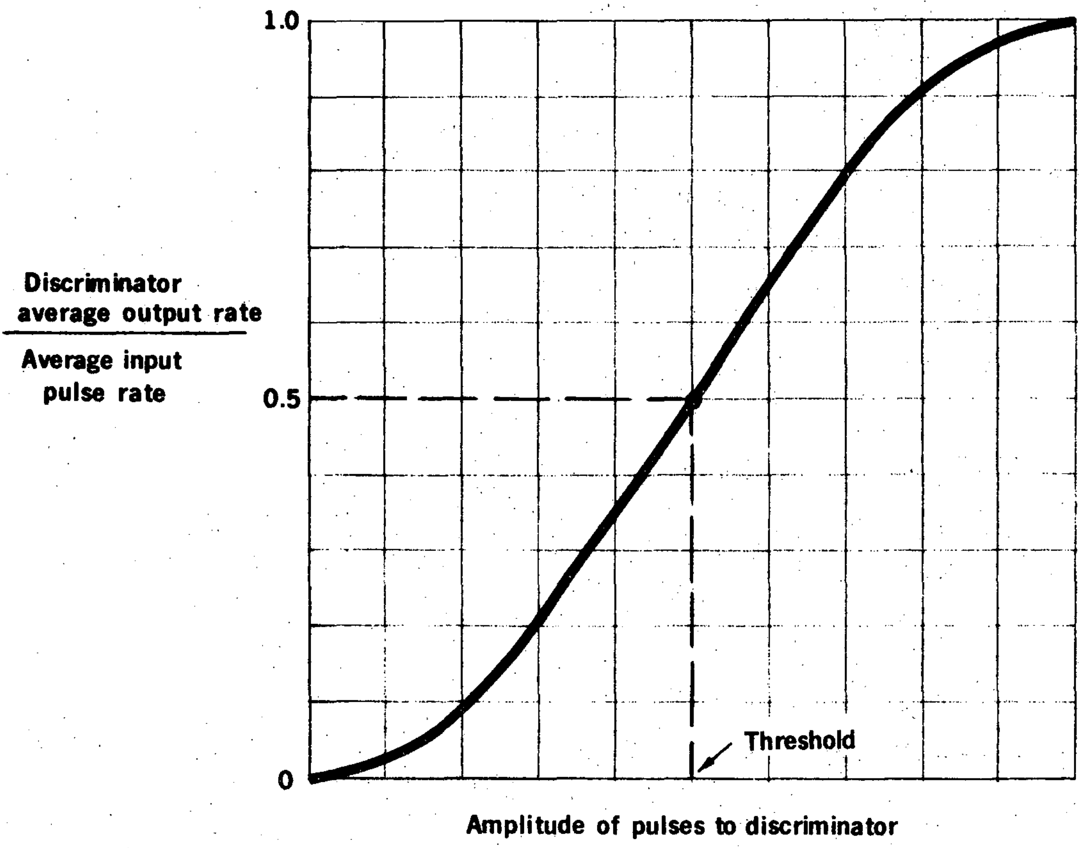
Fig. 2. System block diagram.

Fig. 3. Schematic of programable pulse generator.

Fig. 4. Rear view of test pulse fanout chassis.

Fig. 5. Front panel view of test pulse chassis.

Fig. 6. Triple coincidence circuit—typical of 20 circuits.



Threshold pulse voltage = Amplitude (x-axis) for which $\frac{\text{DAOR}}{\text{AIPR}} = 0.5$

XBL 6810-6006

Fig. 1

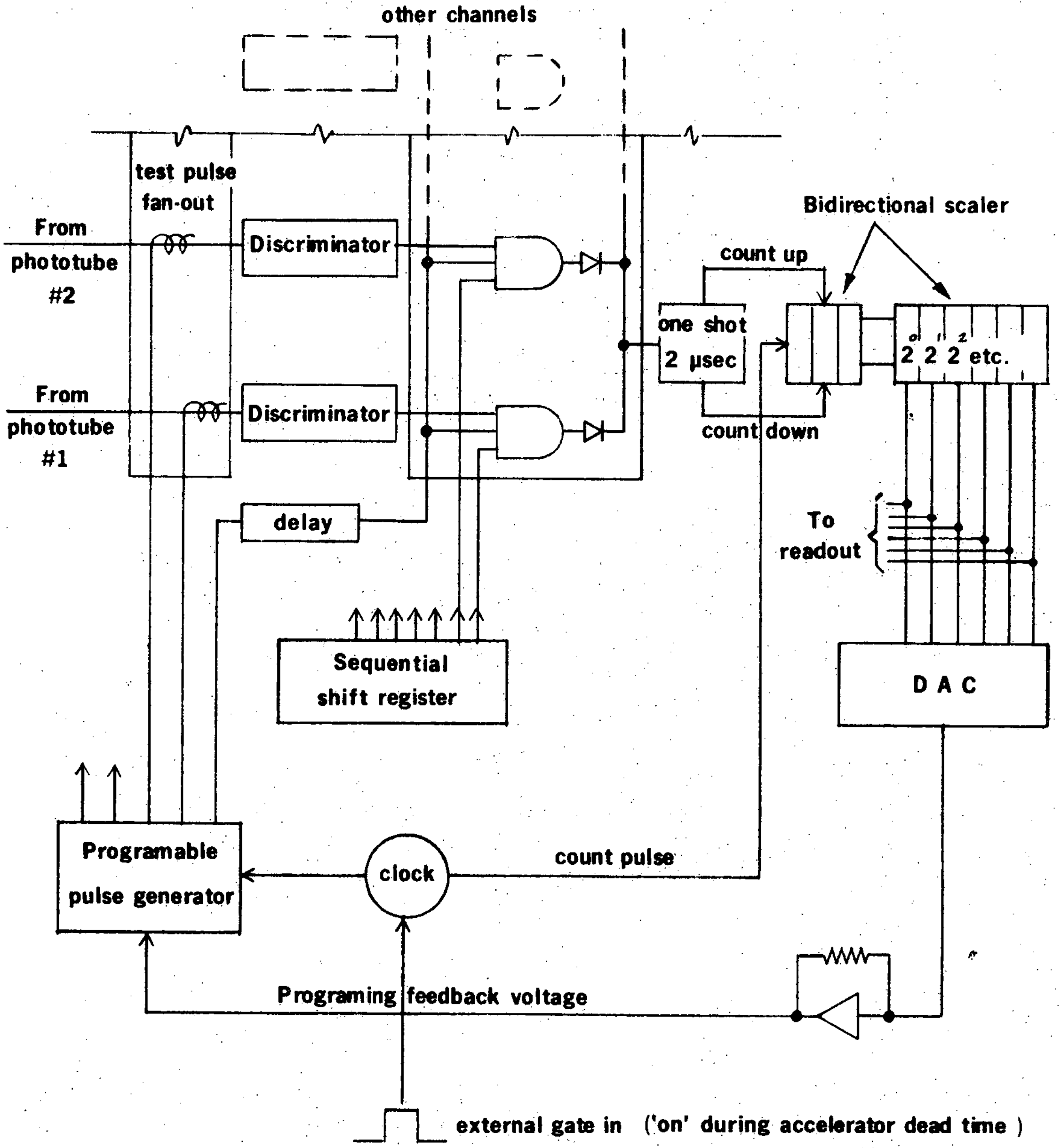


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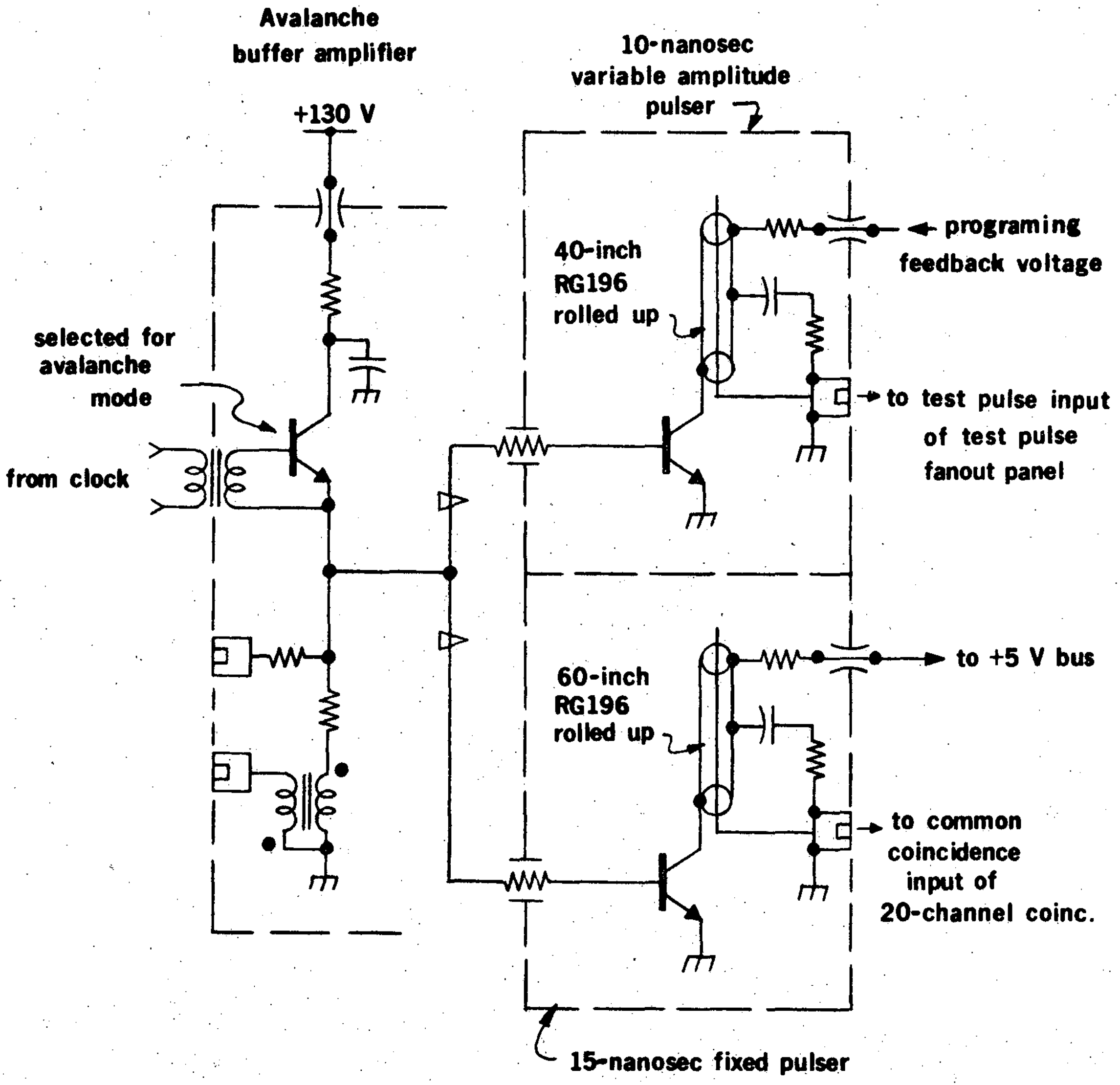
Fig. 2



Programable pulse generator
Ref: 12X 7020-S3 (Schem.)

XBL 6810-6008

Fig. 3

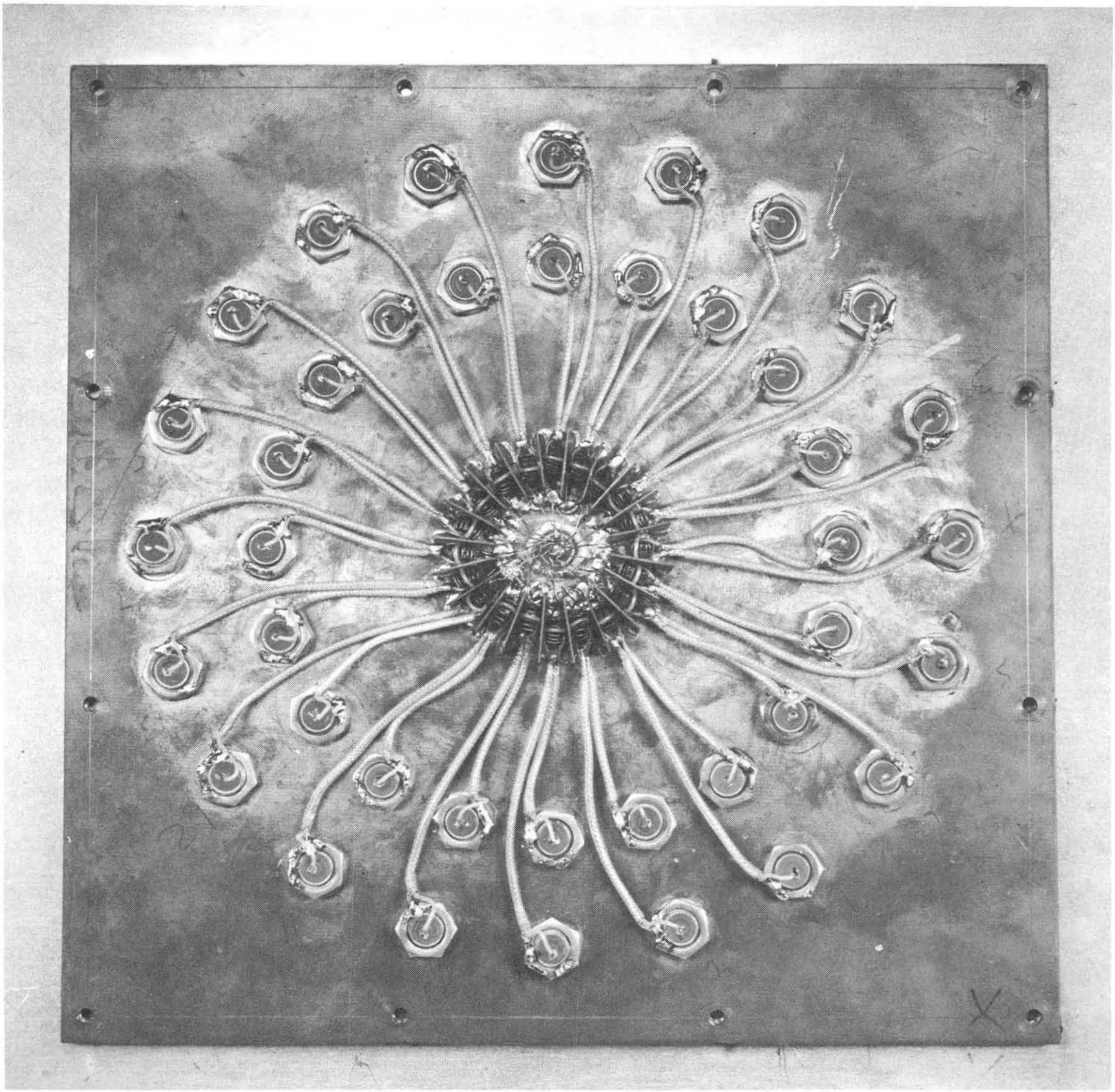


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Fig. 4

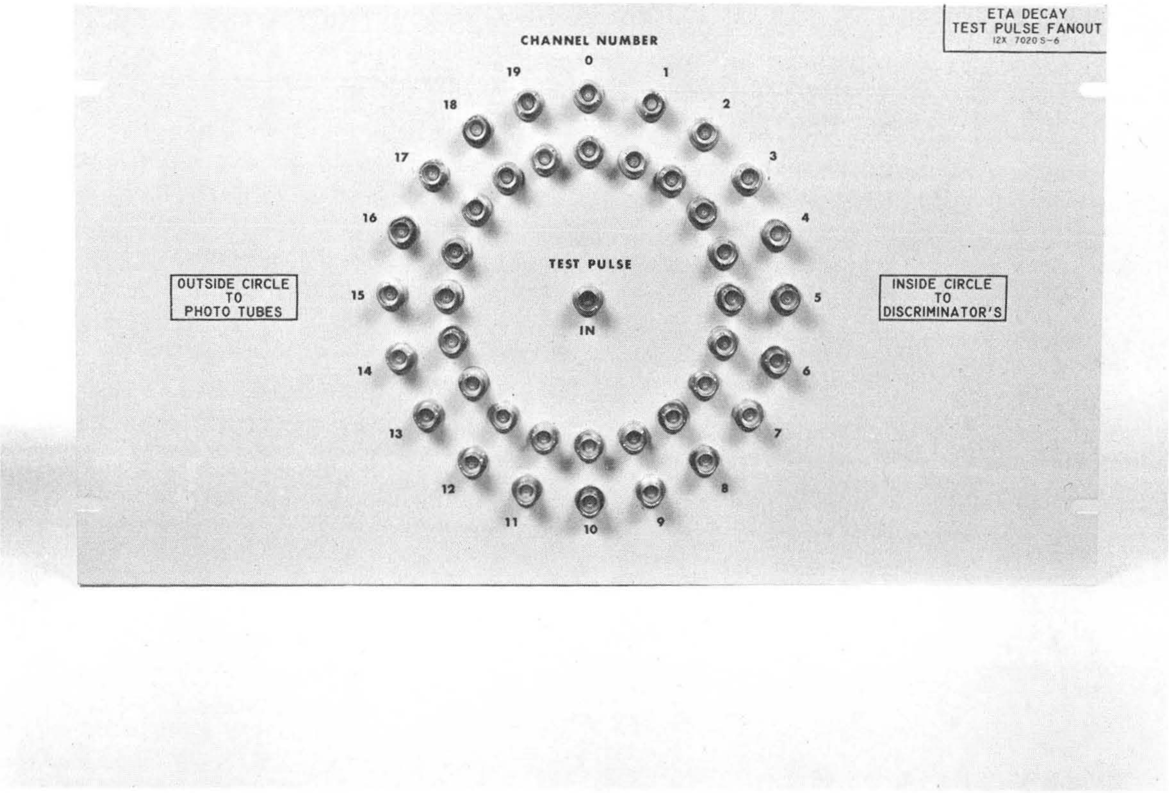

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Fig. 5

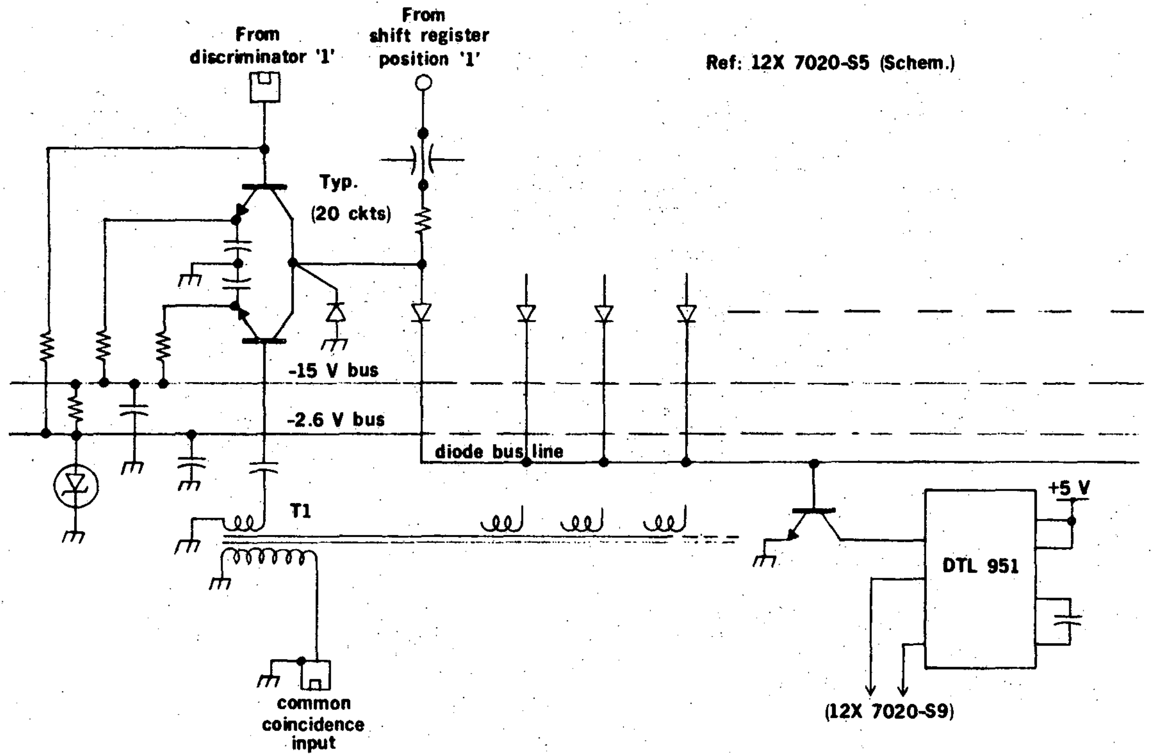

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Fig. 6

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