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GROUP COINCIDENCE DISCRIMINATION

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ABSTRACT

A gated discriminator of wide flexibility is described wherein selective discrimination is achieved by grouping desired circuit functions in a mixer unit composed of diode elements. The method is suitable for sorting single and coincident events originating among a multiplicity of separate signal sources and is shown applied to a seven-channel discriminator excited from Geiger tubes. Performance of this equipment is not critically dependent upon wave shape or amplitude of the exciting pulses. No adjustments are required and the equipment is suitable for long periods of continuous operation.

PROBLEM STATUS

This is an interim report on this problem; work is continuing.

AUTHORIZATION

NRL Problem P07-04R

GROUP COINCIDENCE DISCRIMINATION

INTRODUCTION

In some cosmic ray investigations a contiguous bundle of Geiger tubes is used as a means for detecting and separating highly ionizing cosmic radiation from poorly ionizing gamma radiation. The separation is usually predicated upon the ability to sort out single from coincident firing events. Such a method is widely applied and the equipment used frequently employs some form of amplitude discrimination, as for example, a diode biased level selector. Because of the need for maintaining wave-form consistency and critical voltage relationships between control signals and the discrimination reference level, the use of amplitude discrimination is often objectionable. Particularly is this the case where equipment must perform continuously over long periods of time with a minimum amount of necessary attendance. Gated discrimination is more suitable for use under such conditions, as operation is not dependent upon the preservation of critical amplitude and wave-form relationships. However, gated discrimination is generally suitable for simple discriminating functions and is not readily adaptable for use with multiple signal sources requiring selective discrimination. To avoid this difficulty, a method of group discrimination has been developed, which generalizes the application of gated circuits and yields a discriminator of great flexibility, combined with a high degree of performance dependability. This report reviews the fundamental discriminator types, from which the method of gated-group discrimination is evolved. It also describes a practical multichannel group discriminator which has given excellent performance during many months of continuous operation in this Laboratory. This seven-channel discriminator has a resolving time of 50 microseconds, but for special applications this figure may be reduced by one order of magnitude or more by the use of well known design techniques.

COINCIDENCE DISCRIMINATION

The method of coincidence discrimination involves the technique of signal gating a network, so that transmission is made contingent upon the coexistence of one or more independent signal sources. This concept has found wide usefulness in cosmic ray studies and in nuclear physics investigations.[1-5]* Discriminators may be broadly classified on a basis of the essential circuit function involved in the switching process.

VOLTAGE DISCRIMINATION

If the on-off switching operation is dependent upon whether a signal is less than or whether it exceeds a reference voltage level, such performance may be termed voltage

* References appear at end of report.

(or amplitude) discrimination. Voltage discrimination involves: 1) the superposition of a number of independent signal sources upon a common feeder line to yield an amplitude modulated resultant, and 2) a comparison of the resultant with a reference voltage to establish the criterion for signal transmission or rejection.

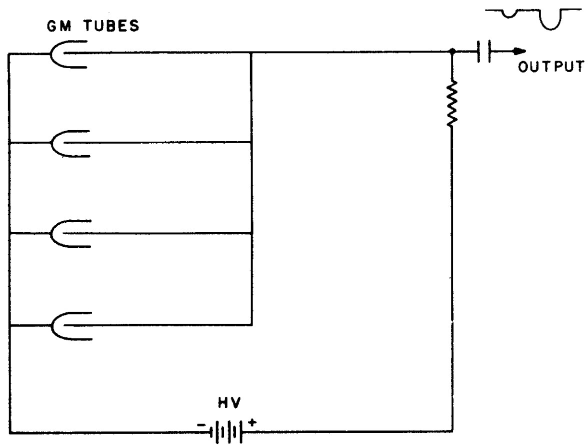


Fig. 1 - GM tube amplitude modulator

A simple type of amplitude modulator is shown in Figure 1. Separate GM tube pulse sources are wired in parallel and are connected through a common resistor to the high voltage supply. If the individual pulse sources are identical, then the resultant voltage drop across the series resistance element will vary directly with the number of active sources present at one time. Although this arrangement is one of utmost simplicity and will accommodate a large number of separate signal sources, it possesses a number of undesirable features. Some of these lie in the fact that the GM tubes must have nearly identical pulse characteristics, as all tubes are energized from the same high voltage supply. Ageing must be gradual and identical, since this affects the reference threshold voltage adjustment and the modulation contribution from each tube. Paralleling of the GM tubes raises the combined circuit capacitance, and thereby the input RC time constant. The use of separate feed lines for each GM tube, where permissible, is preferred over the more simple parallel arrangement, as this improves the isolation of the individual Geiger tubes and thereby contributes to more dependable operation.

In one version of the familiar Rossi arrangement,[1] a separate coupling tube is used with each GM tube source. The source coupling impedance is thereby raised and made independent of the number of GM tubes employed. The plates of the coupling tubes are wired in parallel and are connected through a series resistance element to the plate voltage supply. This resistance element, as in the previous example, comprises the modulation impedance to which discrimination is applied for distinguishing the order of coincidence.

It is evident that both methods distinguish single from multiple firing phenomena by developing a signal which is proportional in amplitude to the number of events that occur at the same time. Identification regarding the order of coincidence is then made by means of a detector with a predetermined voltage threshold sensitivity, plus such additional refinements as are required for obtaining satisfactory coincidence discrimination.

In order to distinguish amplitude levels between a single firing event and coincident firings, the voltage discriminator must delay transmission of the pulse by an amount equal, at least, to the rise time of the individual signal pulses. This is necessary to prevent transmission of the leading edge of the pulse before the pulse as a whole has been adequately appraised by the detector. Voltage discriminating detection, therefore, inherently requires delay in the order of the pulse rise time, which value establishes the minimum realizable resolving time. Such a time delay, together with the constant voltage requirements from the source, make it necessary that the separate signal sources be of identical wave form and amplitude level, a condition normally realized in practice by the use of wave form and amplitude equalizers for the individual sources. A typical voltage discriminating detector is shown in block diagram form in Figure 2.

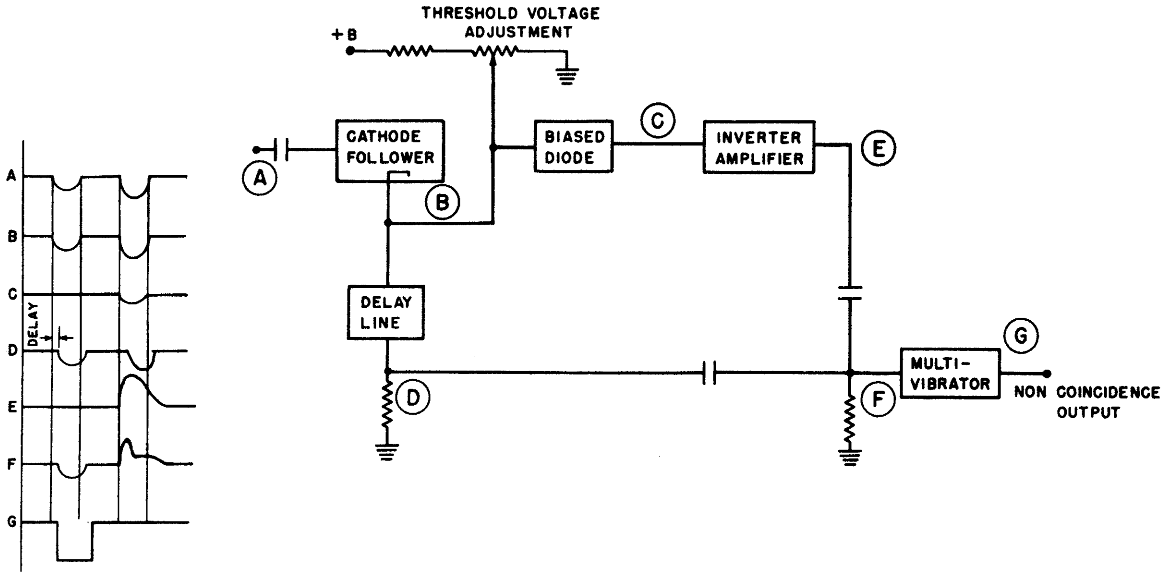


Fig. 2 - Amplitude modulating detector

GATED DISCRIMINATION

If the on-off signal switching is dependent upon conduction and non-conduction operation of an electronic tube, this action may for convenience be termed gated discrimination. Figure 3 is an example of a gated discriminator which utilizes a multiple element tube. The tube, as shown, is normally biased to plate current cut-off conditions. The operation is such that a positive polarity signal pulse applied to one of the grid elements (transmit channel) is communicated to the output load, provided that no signal of negative polarity is present at the same time on a second grid element (reject channel). The presence of such a concurrent signal on the reject grid maintains cut-off conditions and thereby suppresses the transmit channel signal. Switching action will occur if the impressed signal voltages are sufficient to satisfy the amplitude requirements of the discriminator tube for conduction and cut-off operation. The performance is in other respects independent of the signal wave form and amplitude level. This is a decided advantage over voltage discrimination.

It may be observed at this point that either voltage or gated discrimination is obtainable with the Rossi circuit by a suitable choice of plate load resistance. The former condition is attained for a low resistor value and the latter condition is approached as the resistor is made increasingly large. Both modes of operation are illustrated in the plate current static characteristic for a typical triode in Figure 4, with low and high load impedances plotted to show the effect upon performance.

GATED-GROUP DISCRIMINATION

As a further breakdown of discriminator types, the reject channel grid of a gated discriminator, as in Figure 3, may be excited from a mixer unit. The mixer may in turn

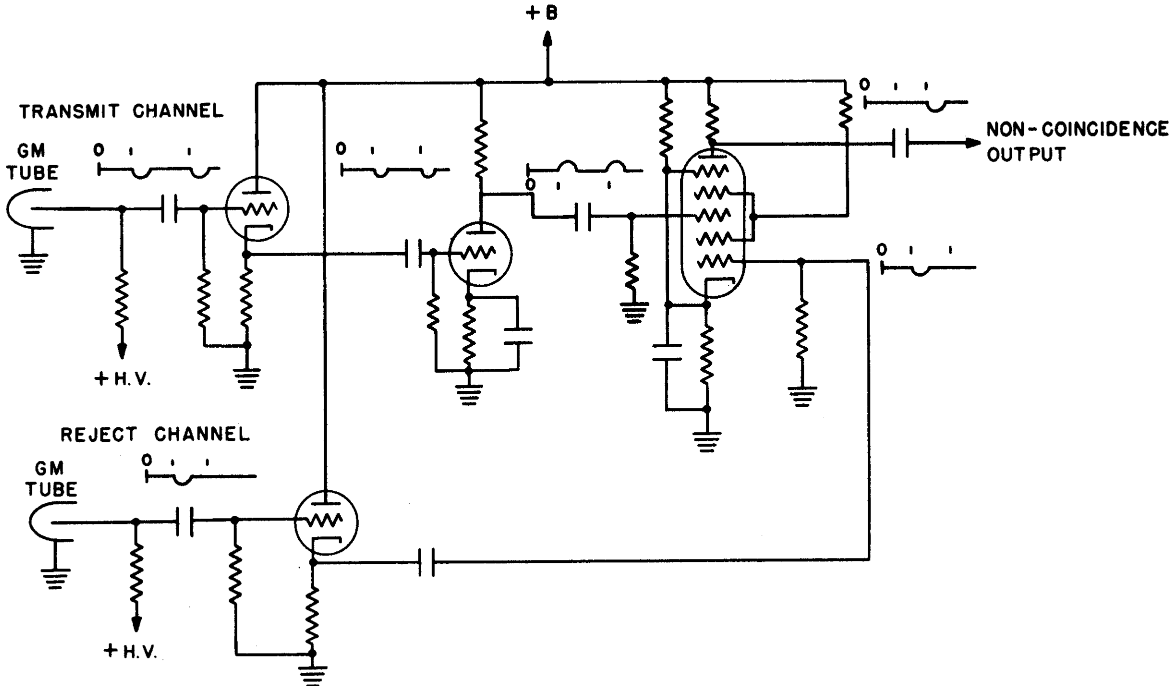


Fig. 3 - Gated discriminator using multiple-element tube

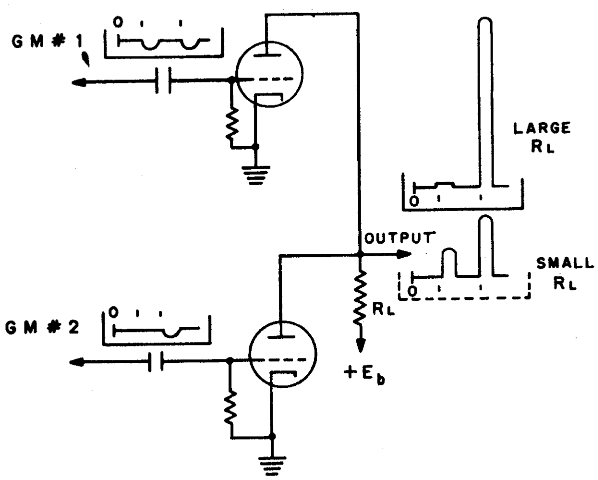
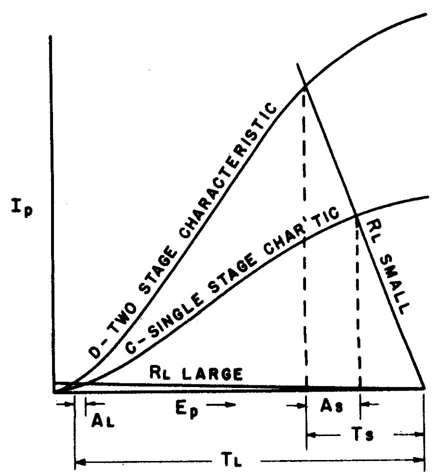


Fig. 4a - Typical Rossi circuit



A_S — Plate pulse increment for one active stage with small load resistance.

T_S — Plate pulse increment for two active stages with small load resistance.

A_L — Plate pulse increment for one active stage with large load resistance.

T_L — Plate pulse increment for two active stages with large load resistance.

Fig. 4b - Load line performance of Rossi circuit

be connected to a group of separate signal sources chosen in such a manner as to furnish the desired gating action; this will be referred to hereafter as "gated-group discrimination" or simply "group discrimination." Advantages of this type of operation are those of the gated discriminator, i.e., wide circuit indifference to pulse amplitude and wave form, plus a high degree of performance flexibility.

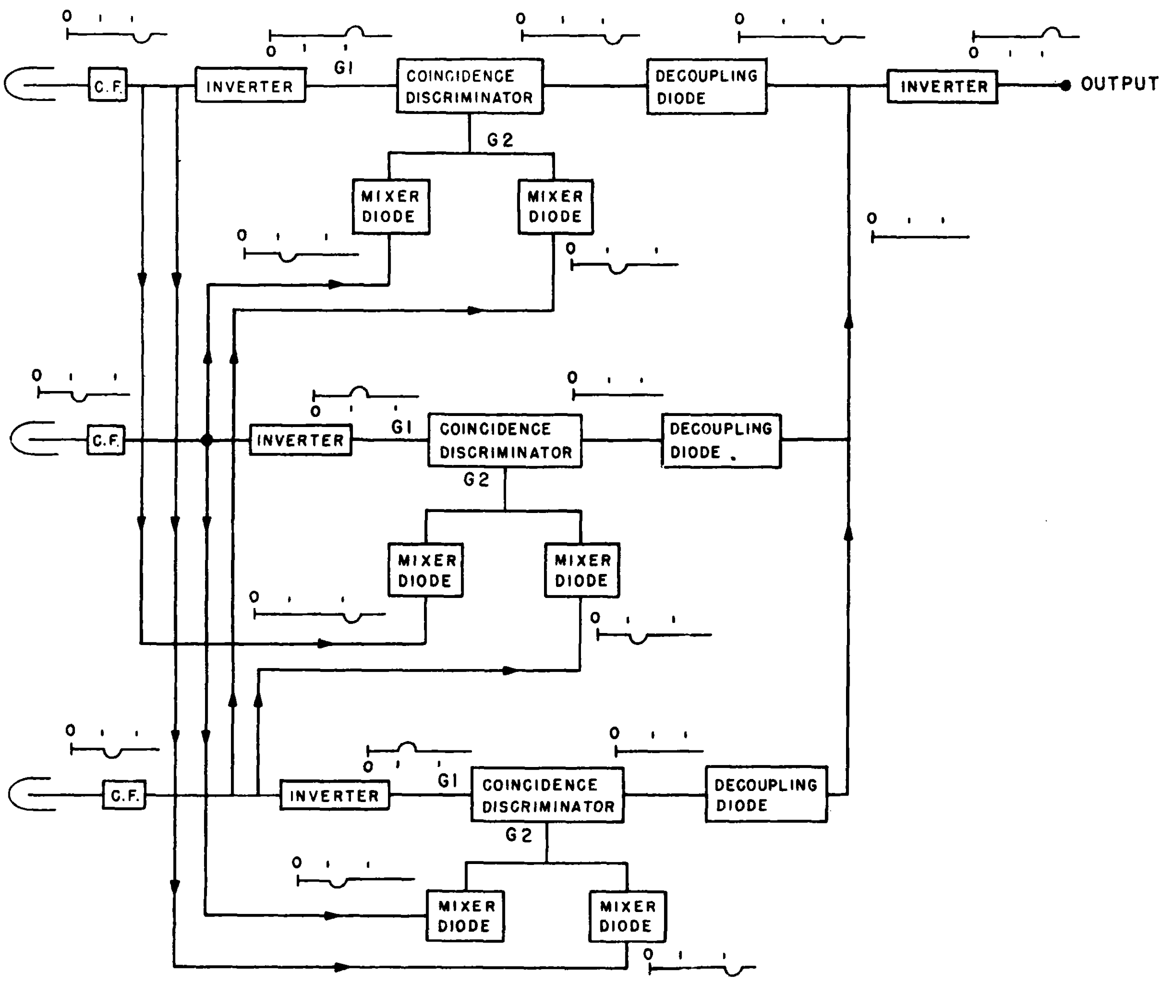


Fig. 5 - Three-channel group discriminator with non-coincidence output

Figure 5 shows, in block diagram form, a three-channel group discriminator for rejecting coincidences and transmitting single counts only. The circuit utilizes three identical channel strips, one for each of the GM tube sources. Each channel employs a multiple-element coincidence-discriminating tube, of the type shown in Figure 3. A negative pulse from each Geiger tube passes through a cathode follower, then through an inverter stage from which it is applied as a positive pulse to the transmit element of the discriminator stage. In the absence of a simultaneous negative pulse on the reject grid, the pulse is freely transmitted to the output terminals after passing through a diode decoupler and an inverter stage. The mixer unit, associated with each coincidence discriminator, is excited from the remaining signal channels. It impresses a negative polarity pulse upon the reject grid of the discriminator tube, thereby maintaining cut-off conditions and suppressing transmission of any signal which may be concurrently present on the transmit channel grid. The decoupler stages are used to permit the paralleling of all output channel pulses on a common line, without mutual interaction.

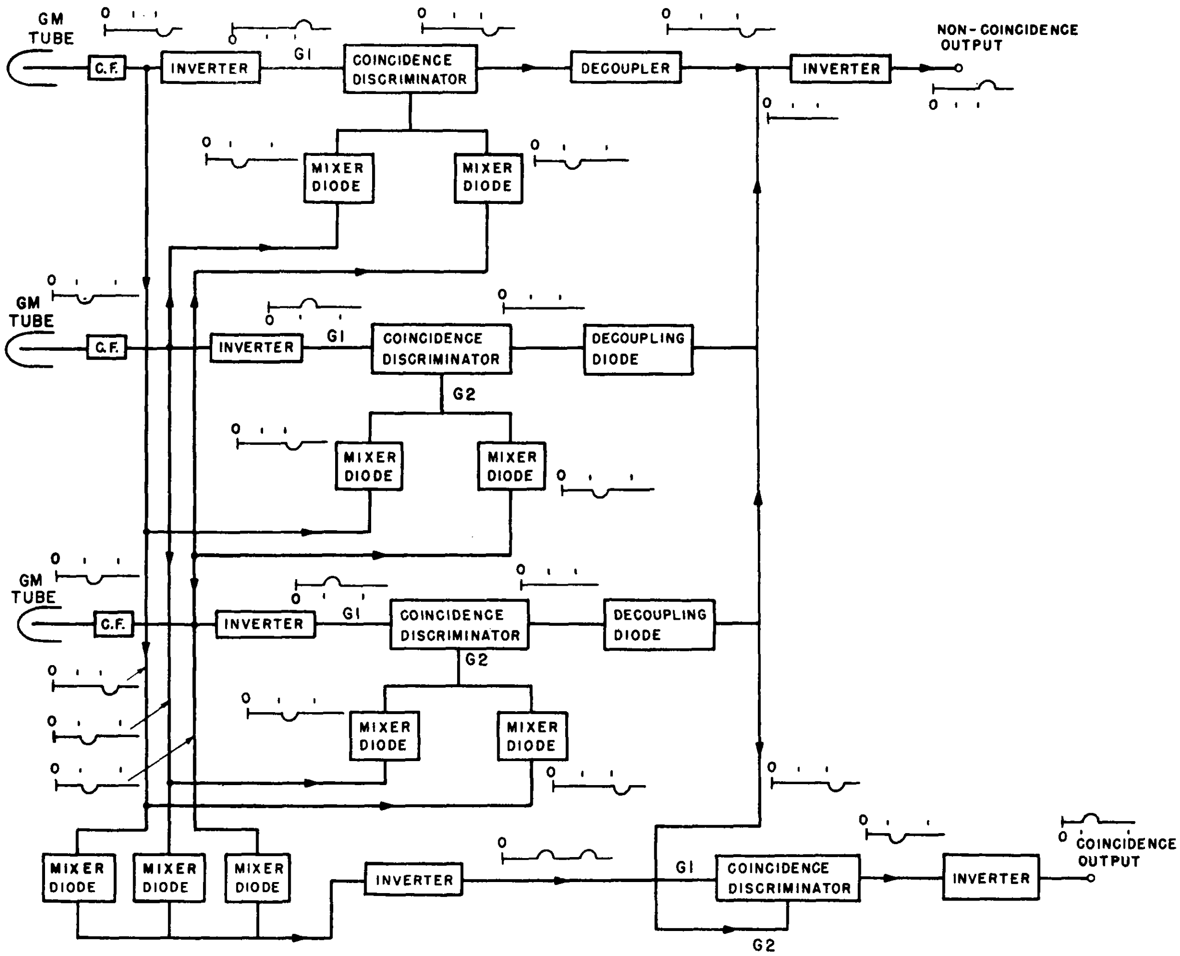


Fig. 6 - Three-channel group discriminator with coincidence and non-coincidence output

The three-channel group discriminator is shown in the block diagram of Figure 6 combined with additional circuitry to make available single as well as coincident counts at separate output terminals. This is accomplished by coupling all input circuit signals first to a mixer unit, then to an inverter, and finally applying these signals as a positive pulse to the transmit grid element of the discriminator. The pulse amplitude is sufficient to produce tube conduction, provided no signal is present on the reject element. Such a condition exists only if no pulse is present at the single count terminal. Otherwise a pulse of negative polarity, from the single count circuit, is applied to the reject line of the coincident pulse discriminator, which maintains cut-off conditions and prevents signal transmission. In this manner only one of the two output terminals can be active at any given time.

SEVEN-CHANNEL GATED-GROUP DISCRIMINATOR

The method of Figure 6 is shown extended to seven channels in the block diagram of Figure 7. Each of the Geiger tubes is coupled to a discriminator stage by means of a

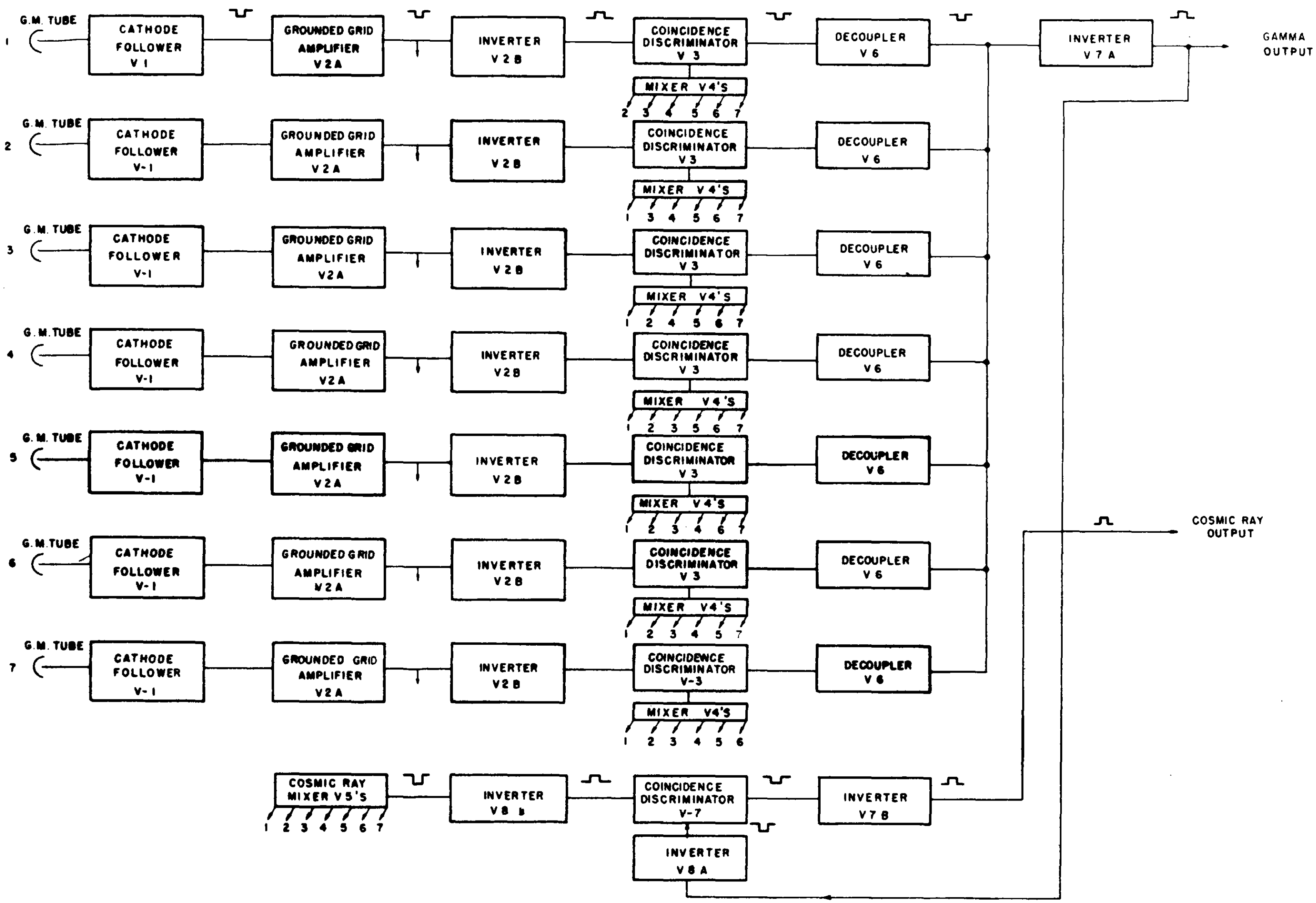


Fig. 7 - Seven-channel coincidence discriminator, group type - block diagram

cathode follower and grounded grid amplifier combination. This type of coupling has been used to enable the Geiger detector tubes to be situated remotely from the basic electronic equipment. It is thereby possible to realize the best location for the detector tubes with regard to radiation exposure, and the placement of the associated electronics, such as the discriminator, rate meter, power supplies and recorders, favorable to dependable performance and convenient access to the apparatus. Finally, this coupling means is suitable for use with low-impedance coaxial cable.

A schematic diagram of the circuitry beyond each cathode follower GM tube coupler is shown in Figure 8. The diagram contains the circuits for sorting out the single and the coincident counts originating in a bundle of seven Geiger tubes. Only one of the single-count (gamma) channels is shown, as these are all essentially alike.

SINGLE COUNT (GAMMA) OUTPUT

In operation, a negative polarity pulse from the GM tube cathode follower is impressed upon the grounded grid amplifier. This is amplified and made available at the plate of V2A without inversion, as a low-impedance driving point, for exciting the various mixer diodes. The negative polarity plate pulse is also inverted in V2B and is impressed as a positive polarity pulse on an outer grid element of the gated discriminator tube V-3. If this is the only pulse impressed upon V-3, the normally biased to cut-off discriminator tube will be raised to the conducting state. A negative polarity pulse is thereby produced in the anode of V-3 and passes through a diode decoupler (V-6). It is then inverted in V7A and finally appears as a pulse of positive polarity at the single count (gamma) output terminal. Coincident operation of the Geiger tubes is prevented from appearing at this output terminal by the arrangement of the group mixer units. Each channel mixer unit is made up of tube diodes V-4, and each of the diodes is connected to the anode element of one of the grounded grid amplifiers associated with the remaining channels. An inner grid element of the discriminator tube (V3) is connected to a mixer unit. This results in the application of a negative polarity pulse on the inner grid of V3 whenever any of the remaining channels are active, which prevents conduction and suppresses transmission of a concurrent pulse that may be present on the transmit element of V3.

The transmit channels are identical to each other with the exception of the manner in which every channel group mixer is excited by the remaining channel input signals. The coincidence discriminators, V-3, are combined at a common junction to the grid of inverter tube, V7A, by the diode decouplers V-6. The decouplers are used for the purpose of eliminating mutual interaction between the discriminator stages and for making the circuits non-critical with regard to selection of the discriminator tubes.

The pulses appearing at the gamma terminal of Figure 8 are therefore due to single-count events alone, all effects caused by concurrent excitation of the channels being effectively eliminated.

COINCIDENT COUNT (CR) OUTPUT

The coincident count output is obtained from discriminator stage V-9 which is controlled by a signal produced at the single count (gamma) output terminal and a pulse signal derived from excitation of any of the channels. Input pulses appearing at the anode of each grounded grid amplifier are combined in diode mixers, V-5, which are effectively paralleled at the grid of inverter tube V8B. This results in the application of a positive polarity pulse on an outer grid element (transmit grid) of V-9 whenever any of the input circuits are active.

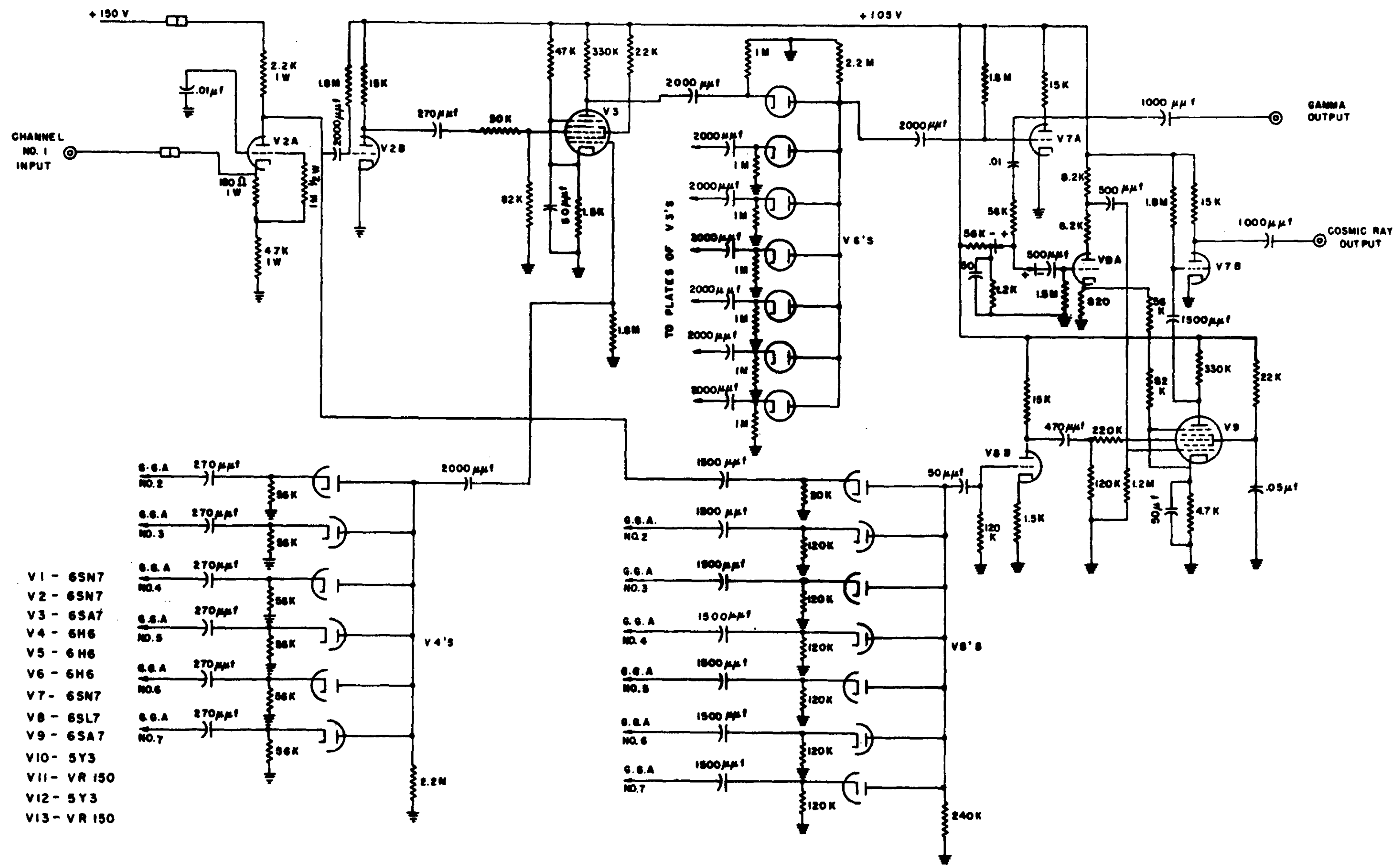


Fig. 8 - Seven-channel coincidence discriminator, group type-schematic diagram

Tube V-9 is thereby made conductive, provided no signal is simultaneously present at the gamma output terminal. This produces a negative polarity pulse at the anode of V-9 which is inverted in tube V7B and is presented as a positive polarity pulse across the CR output terminal of Figure 8. The presence of a pulse on the gamma output line is applied to inverter tube V8A and then, as a negative polarity pulse, it is impressed upon an inner grid (reject element) of V-9, thus preventing conduction. In this manner only one of the two output terminals can be active at one time. The gamma terminal yields single counts only and the cosmic ray terminal furnishes coincident counts.

RESOLVING TIME OF THE SEVEN-CHANNEL GROUP DISCRIMINATOR

The resolving power τ of the coincidence discriminator may be determined as usual by counting the accidental coincidences between two channels.[6-8] If the rate of independent pulses for each channel is respectively N_1 and N_2, then the number of random coincidences for one pair of channels is

$$\begin{aligned} A &= 2\tau N_1 N_2 \\ &= 2\tau N^2, \text{ for } N_1 = N_2. \end{aligned} \qquad (1)$$

For seven channels there are 21 channel-pair combinations. The combined rate of accidental coincidences A_O for all seven channels, each operating at the rate of N pulses is therefore

$$A_O = 42\tau N^2. \qquad (2)$$

Let M represent the total rate for all channels, then M = 7N, and

$$A_O = \frac{6}{7}\tau M^2. \qquad (3)$$

For $\alpha = 100 \frac{(A_O)}{(M)}$, equation (3) becomes

$$\frac{\alpha}{M} = \frac{600}{7},$$

or

$$M = \frac{7}{10}\frac{(\alpha)}{(\tau)} \text{ in counts per minute.} \qquad (4)$$

The application of equation (1) to the seven-channel discriminator yielded a τ value of approximately 50 microseconds. When this is substituted in equation (4) it is found that for one percent accidentals ($\alpha = 1$), the total rate must not exceed 1.4×10^4 cpm. This figure was adequate for the application of this apparatus. However, if necessary, the resolving time obtained could be reduced by one or more orders of magnitude through the application of well known pulse circuit design techniques.

CONCLUSIONS

The method of gated-group discrimination furnishes a convenient and dependable basis for obtaining selective-circuit discrimination. Examples have been furnished to illustrate application of the method to the problem of continuously separating single and coincident firing events originating within a bundle of Geiger detector tubes. The seven-channel group discriminator described has proven to be stable in operation and dependable in performance during many months of uninterrupted service. There are no critical adjustments or critical circuit parameters involved and the principle of gated-group discrimination is particularly well suited for applications requiring long periods of continuous operation with a minimum amount of maintenance.

* * *

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