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A FAST MULTIPLE CHANNEL COINCIDENCE AND ANTICOINCIDENCE CIRCUIT

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Abstract. A multiple channel coincidence circuit is described whose resolving time is about 10^{-8} sec. This circuit is suitable for use with arrays of scintillator - photo multiplier tube counters to detect sub-atomic particles. The input channels can be transformed into anticoincidence channels by a simple switching operation. Details of construction are given.

Introduction. In recent months many observers have begun to use scintillating crystals (and liquids) in conjunction with photomultiplier tubes as detectors of fast charged sub-atomic particles. In many important ways these detectors are not essentially different from gas counters, and the conventional coincidence and anticoincidence techniques which have been worked out for gas counters can be and often are successfully applied with them. In one very significant way, however, the scintillation counter is different from a gas counter; namely, the output electrical pulse from the photomultiplier tube has a very short rise-time, of the order of 10^{-9} sec. or less, whereas for a gas counter pulse the rise-time is seldom less than 5×10^{-7} sec. Furthermore, this short rise-time is accompanied by a very much smaller absolute fluctuation in the time delay between the passage of the particle through the counter and the onset of the output pulse than is the case with the conventional types of gas counters. Hence with scintillation counters one may hope to investigate physical phenomena in which very short time intervals of the order of 10^{-8} sec. or even less, are of importance. Investigations of this kind require coincidence and anticoincidence circuits with resolving times of the order of 10^{-8} sec. or less, whereas conventional coincidence and anticoincidence techniques have in the past been limited to resolving times of the order of 10^{-6} sec.

In seeking a fast coincidence circuit, our particular interest has been to devise a circuit of resolving time 10^{-8} sec. or less which will accommodate a large number of input channels (at least four or five), and which will have at the same time the possibility that any one (or even several) of these channels may be quickly and easily transformed by a simple switching operation into an anticoincidence channel without loss in time resolution. This paper briefly reports our development of a satisfactory circuit possessing these features.

<u>The Coincidence Circuit</u>. The basic idea of this multiple channel fast coincidence circuit is very simple. The input pulses are each limited to a definite standard height and then added together. Thus the height of the output sum-pulse becomes a direct and easy measure of the number of pulses occurring coincidentally in the input channels. By feeding this output pulse into a properly set voltage level discriminator, one can expect to obtain a circuit capable of responding to coincidence events of a given multiplicity, and of rejecting coincidence events of lower multiplicity. More precisely, if there are N input channels, each producing a pulse of standard height V, and if the discriminator is set to reject sum-pulses of height (N-1)V or lower, than an N-fold coincidence is required to produce an output pulse; if the discriminator is set to reject sum-pulses of height (N-2)V or lower, then both an N-fold and an (N-1) fold coincidence can give output pulses; etc.

Thus the problem reduces to the following electronic operations: a) limiting the input pulses to a standard height; b) adding these pulses without increasing their time duration; c) making a voltage level discrimination on the sum-pulse.

We have investigated several ways of limiting the input pulses to a standard height. Our most successful method is to apply the pulses in the negative direction to the grid of a sharp cut-off pentode (6AH6). This tube may conveniently be run with the grid biased about 1/2 volt above cut-off, so that the input pulses are effectively limited to an amplitude of (minus) 1/2 volt. One such tube is located in each input channel.

A very convenient method of adding together the limited pulses is to use a single plate load resistor in common for all the limiter tubes. (An actual circuit for 4 input channels is shown in Fig. 1). Thus the sum of the plate currents flows in the plate load. When several of the limiter tubes are cut off simultaneously, the output voltage rises by an amount equal to the plate resistor multiplied by the total change in current through it, which is clearly proportional to the total number of tubes which are simultaneously cut off.

The positive output sum-pulse may next be amplified (without inversion) by a sufficiently broad band amplifier to prevent serious distortion of the pulse, (e.g., a distributed amplifier with a pass-band of roughly 100Mc), and is then impressed on the grid of the discriminator tube (Fig.2). The voltage level discriminating action is achieved because the grid of the tube is biased below cut-off by a definite amount; hence unless the sum-pulse is sufficiently high to raise the tube into the conducting state no output pulse is obtained from the discriminator. The output pulses from the discriminator may be used, for example, to operate a conventional scaling circuit.

The Anticoincidence Circuit. In order to transform a coincidence channel into an anticoincidence channel, a non-amplifying (unit gain) inverting stage (Fig.3) can be switched into the desired input channel ahead of the limiter-adder circuit of Fig. 1. Then the (inverted) pulse in this channel is subtracted from, instead of added to, the other input pulses, and so its presence prevents the resultant output pulse from passing the discriminator. If the pulse in this channel is absent, however, the discriminator can respond to the sum-pulse arising from coincident pulses in the other channels.

Discussion. In connection with the design and successful operation of this circuit, several points should be mentioned. First, all the components must be chosen to ensure a pass band of about 100 Mc from the input cables to the output discriminator; in particular, a fast amplifier of the distributed type with a 100 Mc band-width must be used between the limiter-adder and discriminator circuits. Second, the input pulses must be clean and free from "overshoot", since overshoots in either direction can give spurious results. Overshoots can easily arise from improper termination of transmission lines both at the inputs and also between the limiter-adder and discriminator circuits. Very large input pulses can be troublesome, because even relatively small overshoots on very large pulses can be large enough to give spurious effects. Third, as in all high frequency circuits, care must be exercised in correctly shielding tubes and circuit elements and in decoupling plate power, filament power and ground impedances.

With some care in laying out and constructing the circuits given here we have been able to get reliable results in both coincidence and anticoincidence at measured resolving times of 2×10^{-8} sec. using liquid scintillator-photomultiplier pulses generated by fast random protons (340 Mev). Using electronically generated pulses of uniform height and duration, we have, with the same equipment, reliably obtained resolving times of 3×10^{-9} sec. in both coincidence and anticoincidence.

Acknowledgements. It is a pleasure to thank Mr. Gerald Essex of the electronics group of this laboratory, who designed and constructed the distributed amplifier (gain = 50x, band width $\cong$ 100 Mc, maximum output voltage swing $\cong$ 30 volts) which we used between the limiter-adder and discriminator. We have also benefited from the cooperation, interest and advice of Mr. Alex Stripika of the electronics group. The work was supported by the Atomic Energy Commission.

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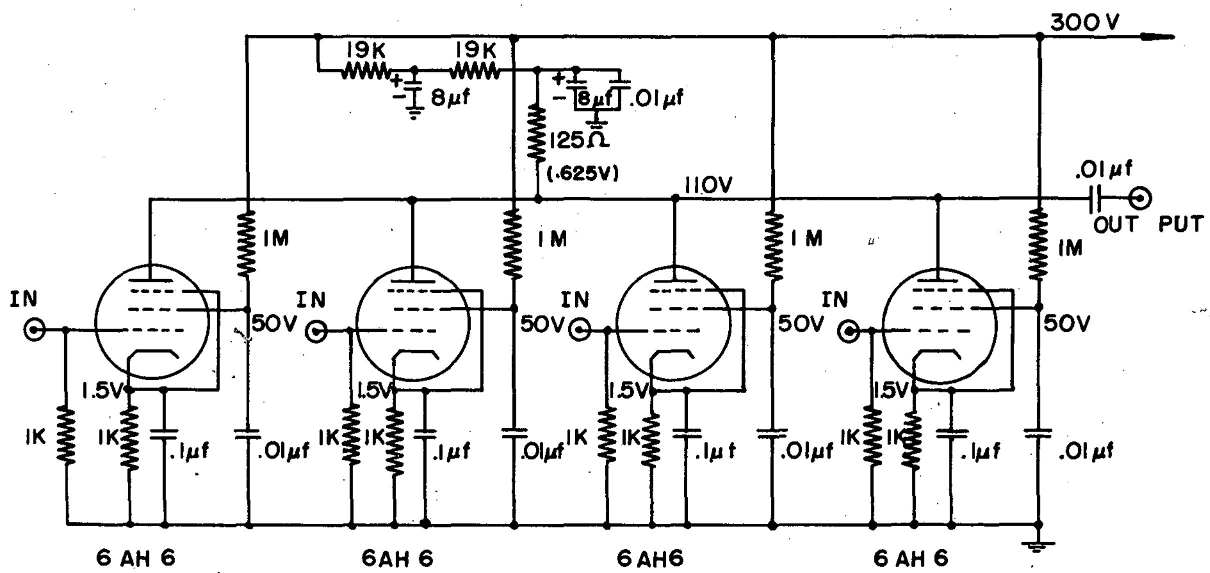
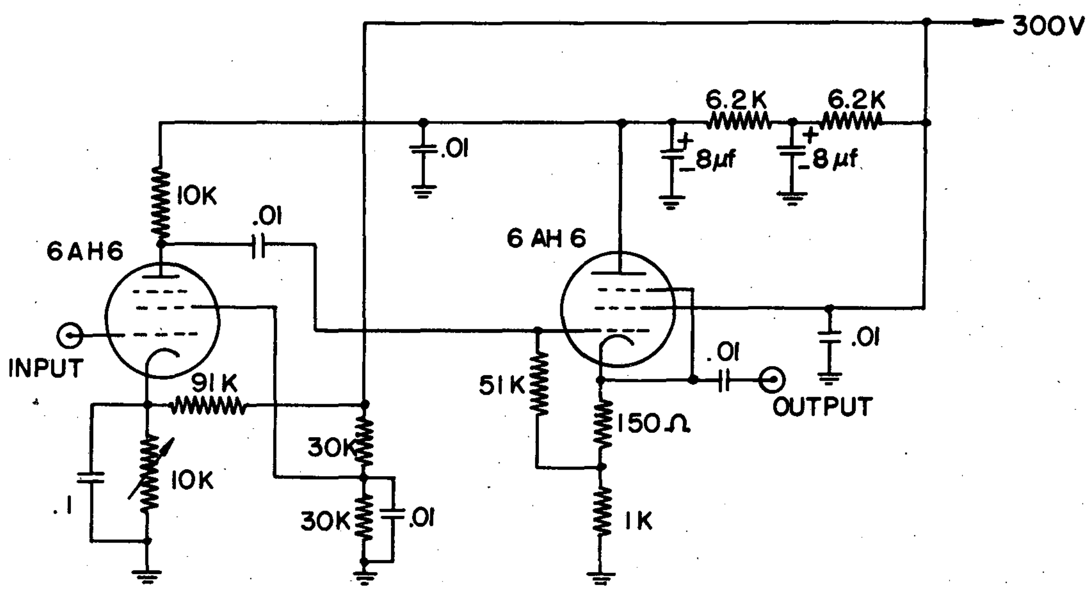


LIMITER ADDER

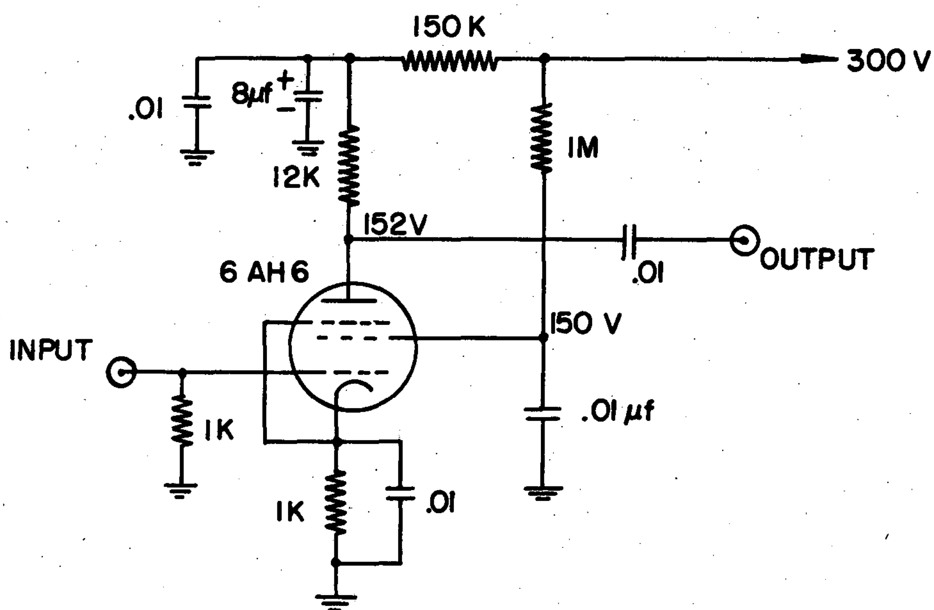
FIGURE I

MU 2616



DISCRIMINATOR
FIGURE 2

MU 2617



INVERTER

FIGURE 3

MU 2618