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### **Author**

Wiegand, Clyde

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DISTRIBUTED COINCIDENCE CIRCUIT

Clyde Wiegand

June 28, 1950

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DISTRIBUTED COINCIDENCE CIRCUIT

Clyde Wiegand

June 28, 1950

Abstract

A coincidence circuit using the traveling wave principle as applied to distributed amplification is described. The resolving time is about  $10^{-8}$  sec. when the device is used in connection with scintillation detectors.

## DISTRIBUTED COINCIDENCE CIRCUIT

Clyde Wiegand

June 28, 1950

An electronic coincidence circuit employing the traveling wave concept as applied to distributed amplification<sup>1</sup> has been developed and used in the Radiation Laboratory. When the circuit is used in connection with scintillation crystal detectors, photomultiplier tubes and distributed amplifiers the resolving time is about  $10^{-8}$  sec. The response to single pulses in either channel is satisfactorily small and is quite independent of the height of the single pulses.

The circuit employs conventional miniature pentagrid converter tubes (type 6BA7) and makes use of the fact that their plate current can be practically cut off by biasing either of the two control grids a few volts negative with respect to their cathodes. Consequently a positive pulse on either grid alone will not allow plate current to flow, whereas if positive pulses are applied simultaneously to both control grids plate current will flow during the time both grids are sufficiently less negative with respect to the cathode.

The principle of distributed amplification is applied by using a series of tubes and connecting separate artificial transmission lines to each set of control grids. The schematic circuit is shown in Fig. 1. The grid to other tube elements (ground) capacitances serve as the shunt capacitances of the transmission line sections. The plates are connected to a third transmission line in the usual manner of distributed amplifiers.

Type 6BA7 tubes were chosen because the two control grids and the plate

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<sup>1</sup>Ginzton, Hewlett, Jasberg, and Noe, Proc. I.R.E., 36, 956 (1948)



are quite well shielded from each other and thus interaction among the grid and plate lines is minimized. The type 6BA7 was preferred to type 6BE6 because of the higher current and transconductance ratings and only slightly increased capacitances.

A coincidence circuit for particle counting should ordinarily have the two input channels equal to each other. The circuit is thus required to be symmetrical so that its behavior is unchanged upon interchanging the two input leads 1 and 2. However, the input capacitances of the two control grids are not equal and their effectiveness in controlling the plate current is different. Therefore the staggered connection is used as indicated in the schematic diagram where one input grid line is shown connected alternately to grids #1 and #3 and the capacitances are made equal by adding external condensers to the #1 grids.

Two other requirements should be met to assure effective traveling wave amplification. These are that the velocity of the waves be equal on the grid and plate lines and that there should be no discontinuities in the value of the impedance upon which the waves are incident. Neglecting losses the velocity of propagation of the waves will be equal when

$$L_{g1} C_{g1} = L_{g2} C_{g2} = L_p C_p$$

where  $L_g$  refers to the series inductance and  $C_g$  the shunt capacitance of the grid line sections and likewise  $L_g$  and  $L_p$  refer to the plate line.

The corresponding impedances are

$$Z_{g1} = \sqrt{\frac{L_{g1}}{C_{g1}}} \quad Z_{g2} = \sqrt{\frac{L_{g2}}{C_{g2}}} \quad Z_p = \sqrt{\frac{L_p}{C_p}}$$

In order for the circuit to be symmetrical we must have  $Z_{g1} = Z_{g2}$ . It is not

necessary that  $Z_{g1} = Z_p$ , since the plate line will generally work into an arbitrary impedance such as a pulse height discriminator stage.

The coincidence circuit has thus far been used in connection with distributed amplifiers having output impedance values of 200 to 400 ohms. The grid lines should be designed to match the output impedance of the amplifiers. The coincidence circuit can then be coupled directly to the amplifiers. Present designs incorporate the amplifiers and coincidence circuit on a common chassis.

A typical design makes use of m-derived<sup>2</sup> filter networks as suggested in reference 1. The coils are wound on 1/4 inch diameter pregrooved polystyrene rods with bare copper wire of about 0.015 inch diameter. The coil constants were calculated by the formula for the inductance of a single layer solenoid (Handbook of Chemistry and Physics). The values of the shunt capacitances are those of the tube manufacturer plus an allowance of 1  $\mu\text{fd}$  for socket capacitance. Effort was made to maintain inductances to  $\pm 10$  percent of the calculated values.

A sample of the coil data is presented in Table I.  $L_1$  refers to the inductance of half of the coil,  $L_2$  to the whole coil.  $n$  is the total number of turns and  $m$  is the parameter of the m-derived filter.  $Z_0 = \sqrt{L_2/C}$  is the nominal iterative impedance.

TABLE I

	C $\mu\text{fd}$	$L_1 \mu\text{H}$	$L_2 \mu\text{H}$	n	turns/inch	m	$Z_0$ ohms
grid line	10.5	0.25	0.63	12	40	1.27	250
plate line	9.3	0.31	0.76	14	40	1.24	290

<sup>2</sup>See for example: L. C. Jackson, Wave Filters, Methuen and Co. Ltd., London, 1950

The lines should be terminated by a resistance equal to their iterative impedance. Ordinary carbon resistors are satisfactory, although some improvement might be realized by using half sections at the terminations. Satisfactory operation has resulted for grid biases of -2 to -4 volts when using a minimum pulse input level to the coincidence circuit of about 10 volts. The non-linearity of the coincidence circuit provides sufficient discrimination against small pulses.

For further discussion of the design and adjustment of distributed amplifiers the reader is referred to a paper by G. G. Kelley<sup>3</sup> on the construction of a high speed synchroscope.

This work was performed under the auspices of the Atomic Energy Commission.

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<sup>3</sup>G. G. Kelley, Rev. Sci. Instr. 21, 71 (1950)

