

Laboratori Nazionali di Frascati

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C. Infante: PULSE HEIGHT DISCRIMINATOR EMPLOYING DISTRIBUTED  
AMPLIFICATION.

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Summary

An integral pulse-height discriminator employing distributed amplification is proposed. The discriminator accepts 0.5 - 12 volts positive input pulses with a maximum repetition rate in excess of 20 mc. Dead time is less than 25  $\mu$ sec and threshold uncertainty is 30 mV. The circuit uses 20 vacuum-tubes in an arrangement believed to be new.

Introduction:

The problem of fast integral discriminators has received considerable attention in recent literature (1), (2), (3): this is due mainly to the inadequateness of older fast discriminators (e.g. those employing secondary emission type tubes (4) ) and to the increasing trend to-

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- (1) - F.J.M. Farley: Rev. Sci. Instr. 29, 595, (1958)  
(2) - J. Mey: Rev. Sci. Instr. 30, 282, (1959)  
(3) - D.V. Swift and V. Perez-Mendez: Rev. Sci. Instr. 30, 1004, (1959)  
(4) - N.F. Moody, G.J.R. McLusky and M.O. Deighton: Elect. Eng. 24, 214, (1952).

wards fast circuitry in conjunction with high-intensity pulsed accelerators. Instantaneous counting rates experienced with these machines may easily be as high as  $10^7$  pps: in other words speed is at a premium. It often turns out that the resolving time of the discriminator is the limiting factor in the speed of an electronic counting system: the dead time of a typical fast coincidence circuit may be as low as 5  $\mu$ sec (5), while the resolving time of the discriminator following it is more often in the 0.1  $\mu$ sec range (2).

With these facts in mind the design of the present discriminator was undertaken: the apparatus is bulky and expensive, difficult to align and to repair, but its performance is so superior to the abovementioned circuits that the effort was deemed worthwhile.

The principles and operation of distributed amplifiers have been known for some while (6), (7), their main advantage being in the very large gain-bandwidth products available: this would make them ideally suited for fast trigger circuits, except that their large inherent delay makes them useless in regenerative-type circuits (8). In the present application a distributed amplifier is employed to amplify the signals coming from a diode comparator: the amplified signal is sufficient to turn a vacuum tube off, thus producing a signal of constant amplitude. If the gain of the amplifier is large enough, the threshold uncertainty will be reduced to

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- (5) U. Pellegrini, B. Rispoli and A. Serra: N. Cim. Ser. X, 2, 171, 1959.
- (6) E. L. Ginzton, W. R. Hewlett, J. H. Jasberg and J. D. Noe: Proc. I.R.E.: 36, 956, (1948)
- (7) W. H. Horton, J. H. Jasberg and J. D. Noe: Proc. IRE, 38, 748, (1950)
- (8) M. Brown: Rev. Sci. Instr.: 30, 169, (1959)

an acceptably low value (in the present case about 30 mV). The principle outlined above (i.e. that of straightforward amplification without positive feedback) while giving up the advantages of positive feedback (e.g. that of very large gains with few tubes) provides one important advantage in that the delay of input-to-output is not a function of pulse height. It is a well-known fact (9) that any positive feedback circuit with a threshold  $V_S$  introduces a delay that depends on much the input exceeds  $V_S$ . Strictly speaking a regenerative triggered device may be thought of as an amplifier and a positive feedback loop containing a non-linear element such as a diode or a vacuum tube at or near cutoff. If one employs piece-wise linear approximation of the non-linear element by postulating that its transfer function is zero for signals lying below the threshold and unity for signals lying above it, one can easily show that the time  $T$  necessary for the output voltage to reach a specified value  $V$  is given by

$$T = \frac{\theta}{\ln F} \ln \frac{V}{\epsilon} + \theta$$

where  $F$  and  $\theta$  denote loop gain and delay respectively, while  $\epsilon$  is the portion of the input pulse exceeding the threshold.

#### Circuit description

The discriminator consists of three parts: a comparator circuit, a distributed amplifier and an output or pulse-shaping circuit (fig. 1).

The comparator is of the differential-amplifier-derived type as proposed by J. Mey (2) with a few modifications

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(9) - J. Mey: L'onde électrique 38, 622, (1958)

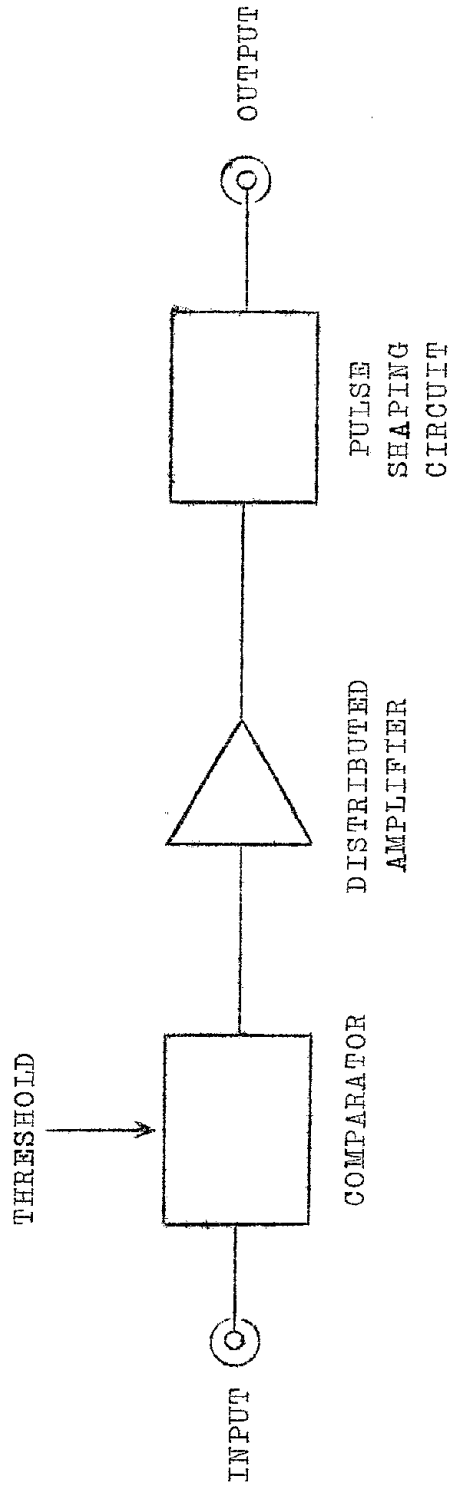


FIG. 1 - BLOCK DIAGRAM OF DISCRIMINATOR

which consist essentially in the use of low-capacitance pentodes instead of triodes and in the use of limiting diodes  $D_3$  and  $D_4$ . Use of pentodes instead of triodes brings the gain-bandwidth product between grid of  $V_1$  and plate of  $V_2$  from 24 for the Mey circuit to 40 Mc/sec for the present circuit. Use of high-speed diodes  $D_3$  and  $D_4$  (10) was made necessary to avoid overloading the following amplifier: limiting action is quite sharp and takes place at about 0.4 volts amplitude. The circuit diagram of the comparator is given in fig. 2: it should be borne in mind that the effective plate impedance 'seen' by  $V_2$  is the grid-line impedance of the distributed amplifier, i.e. 150 ohms.

The distributed amplifier is made up of four identical stages one of which is shown in fig. 3; grid and plate-line impedances are 150 ohms, while total gain and rise time are  $\times 150$  (43 dB) and 5  $\mu$ sec respectively. Alignment had to be of course quite accurate to avoid double pulsing.

The diagram of the pulse-shaping circuit is given in fig. 4:

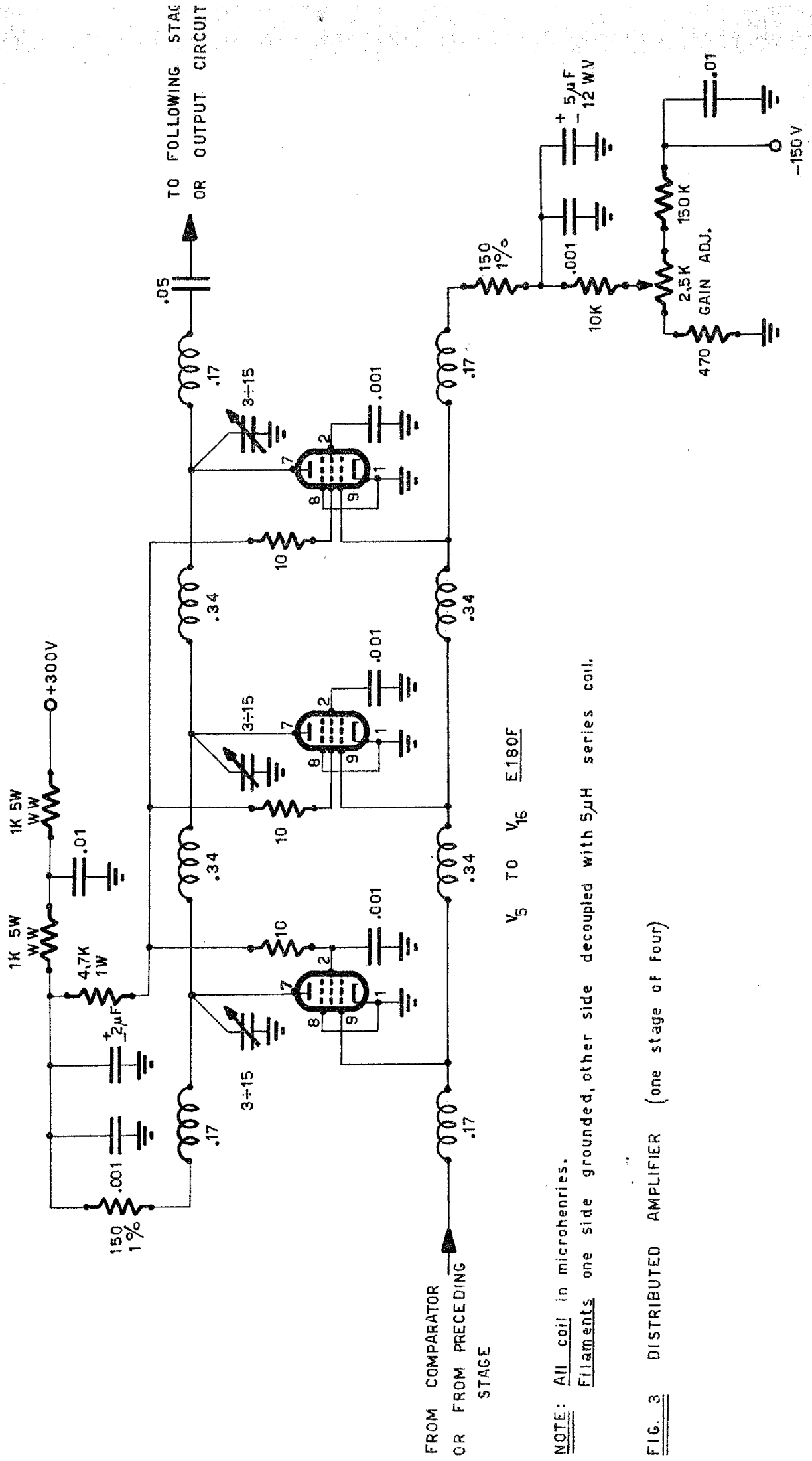
Diode  $D_5$  (11) eliminates small reflections and noise coming from the amplifier and is biased by cathode follower  $V_{18a}$ : the other half of  $V_{18}$  provides a low impedance d.c. source for the screen grids of tubes  $V_{17}$  and  $V_{20}$ . A positive pulse coming from the amplifier makes  $V_{17}$  conduct strongly, thus turning  $V_{19}$  off, and allowing a constant-amplitude positive pulse to reach output terminals.  $V_{20}$  in turn is switched on, thereby producing a standard negative pulse. Both positive and negative output are 2 volts in amplitude when terminated in 125 ohms:

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(10) - made by Qu-Tronic Semiconductor Corp.

(11) - Made by Transitron Electronic Corp.





FROM COMPARATOR  
OR FROM PRECEDING  
STAGE

$V_5$  TO  $V_{16}$  E180F

TO FOLLOWING STAG  
OR OUTPUT CIRCUIT

NOTE: All coil in microhenries.

Filaments one side grounded, other side decoupled with 5 $\mu$ H series coil.

FIG. 3 DISTRIBUTED AMPLIFIER (one stage of four)



NOTE: One side of filament grounded. Filament of V<sub>17</sub> and V<sub>20</sub> bypassed by .005 μF capacitor. 2 μH

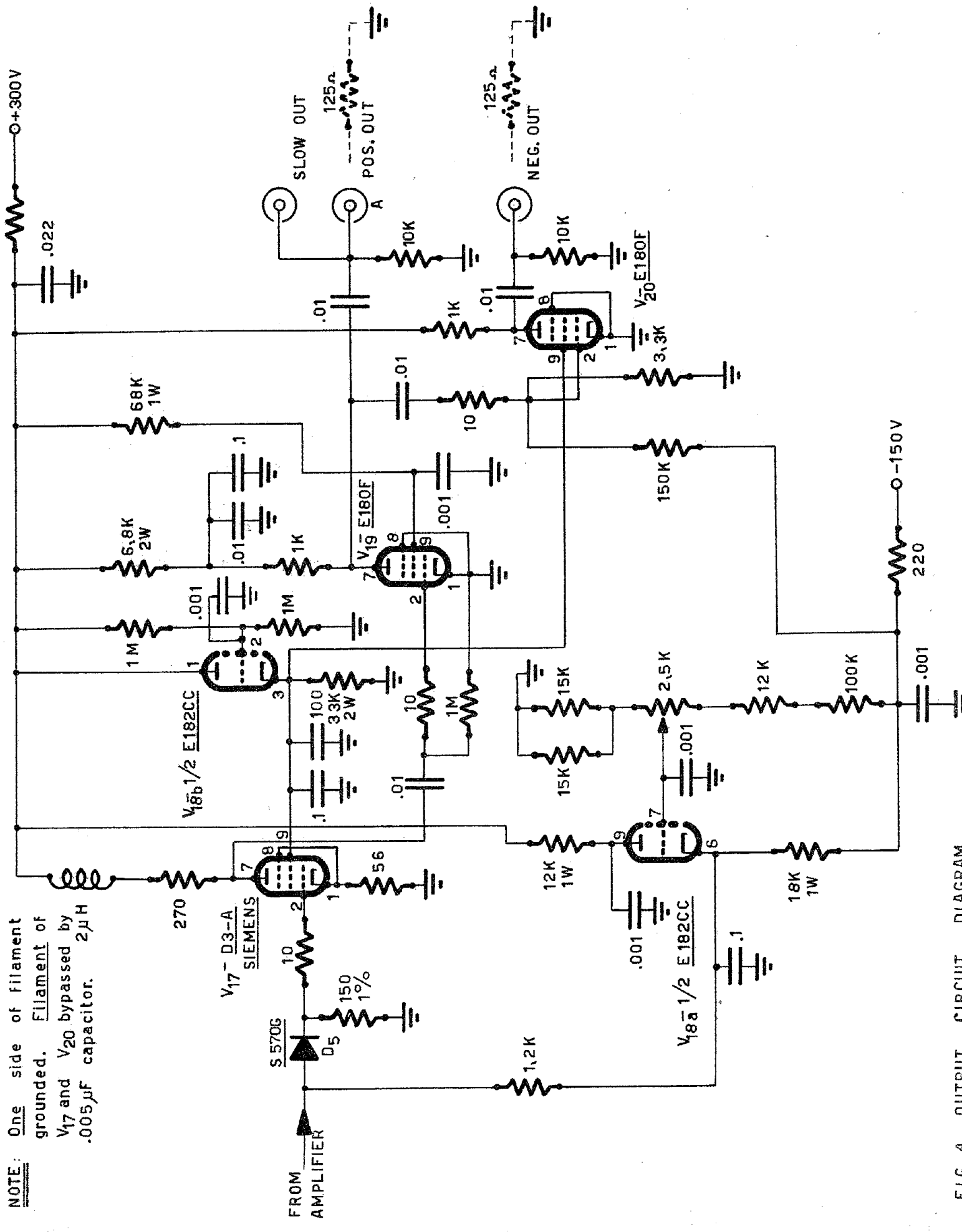


FIG. 4 OUTPUT CIRCUIT DIAGRAM

e.g. the former for triggering fast scalers (12), the latter for coincidence work. The output pulse duration is dependent mainly on the duration of the input signal: due to rise-time deterioration, minimum pulse-width at full amplitude is of the order of 10  $\mu$ seconds. A larger slower output pulse is also available for triggering slow scalers when output A is unterminated.

### Performance

The threshold linearity in the useful range of 0.5 to 12 volts is better than 3% for pulses whose duration lies between 10 and 100  $\mu$ seconds as evidenced by fig. 5. The lower limit is due to uncertainty in diode break-point, while the upper limit (due to diode breakdown) is ample considering the dynamic range of present-day photo-multipliers and fast amplifiers. With 25  $\mu$ sec rectangular pulses the absolute value of the threshold increases by 15 mV, while with 10  $\mu$ sec pulses the absolute value increases by 0.3 volts maximum. The resolving time is less than 25  $\mu$ sec, in the sense that two 10  $\mu$ sec rectangular pulses, 25  $\mu$ sec apart are handled independently with no loss in accuracy or in threshold definition. The discriminator has been triggered at repetition rates as high as 20 Mc without threshold variations higher than 0.1 volts. 20 Mc is the limit of available pulse generators (13), (14), (15), but probably still below the limit of the discriminator. The delay between input and output is of about 40  $\mu$ sec and does not change by

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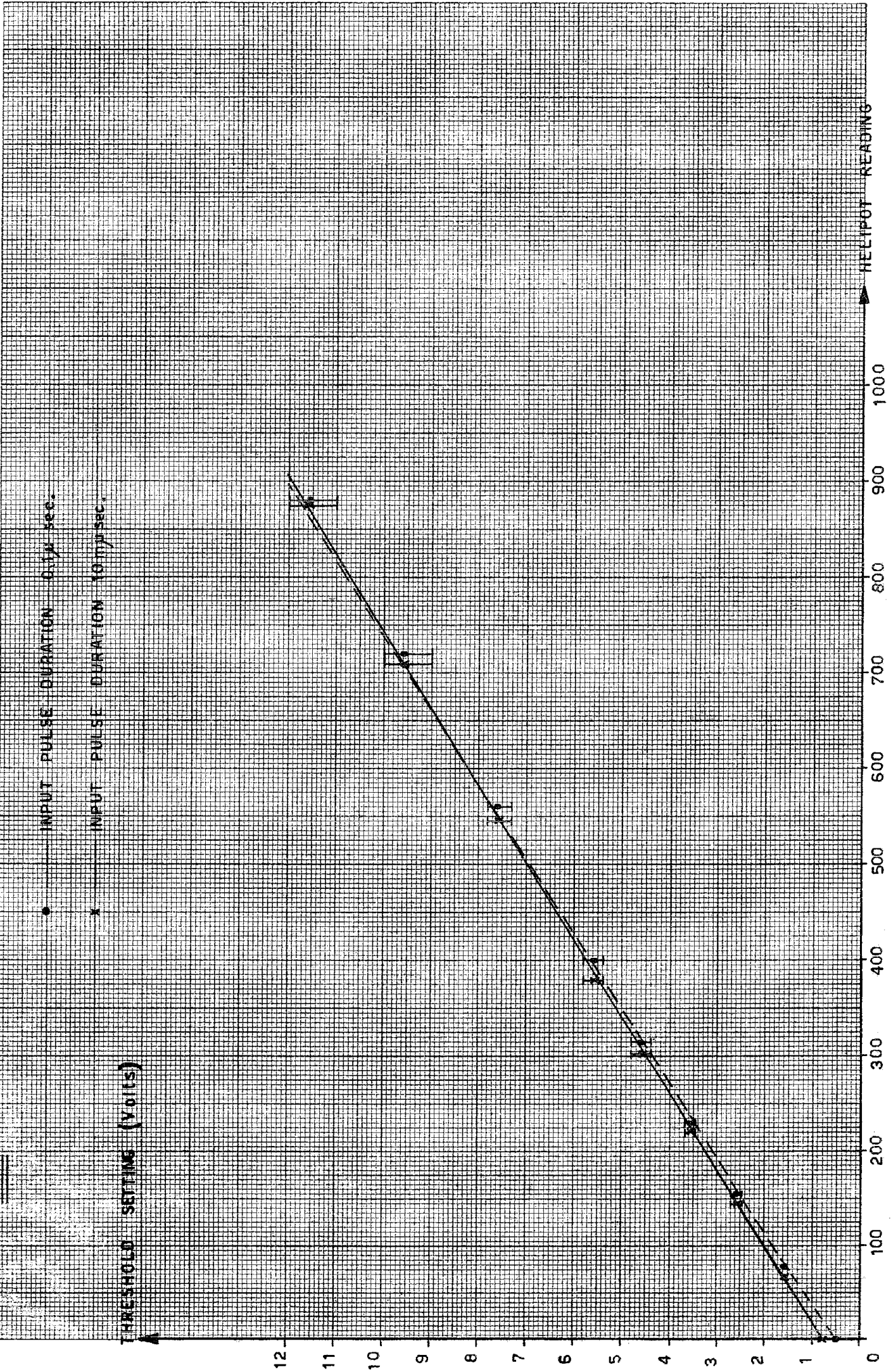
(12) - The 40 Mc scaler described by M. Nakamura (Rev. Sci. Instr. 28, 1015, (1957) ) will trigger with a 2 V pulse.

(13) - C.C. Cutler: Proc. IRE 43, 140, (1955)

(14) - U. Polleggrini: N. Cim. Ser. X, 9, 533, (1958)

(15) - M. Nakamura: Rev. Sci. Instr. 30, 778, (1959)

FIG. 5 DISCRIMINATOR CALIBRATION



more than 2 msec as the input exceeds the threshold by 0.03 to 10 volts. Long term (8 hrs) drift was found to be about 20 mV.

### Conclusion

The proposed circuit is novel in the sense that it employs distributed amplification and no positive feedback in an integral discriminator. Although it uses a large number of tubes (twenty) it is felt that instances may arise in which its superior performance as regards to speed may outweigh the disadvantages of added cost and complexity. An example of this could be a recently proposed multichannel analyzer (16) employing only one discriminator and whose total dead time is equal to the discriminator dead time multiplied by the number of channels.

### Acknowledgments:

The advice and support of Profs. A. Alberigi-Quaranta and I.F. Quercia are gratefully acknowledged. The Author wishes likewise to express his thanks to Mr. R. Rizzi who carried out most of the tests.

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(16) - A. Alberigi-Quaranta, C. Bernardini and I.F. Quercia:  
Nucl. Instr. 3, 201, (1958).