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PULSE HEIGHT DISCRIMINATOR EMPLOYING DISTRIBUTED AMPLIFICATION

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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 mμsec and threshold uncertainty is 30 mV. The circuit uses 20 vacuum-tubes in an arrangement believed to be new.

1. Introduction

The problem of fast integral discriminators has received considerable attention in recent literature[1,2,3]: this is due mainly to the inadequates of older discriminators (e.g. those employing secondary emission type tubes[4]) and to the increasing trend towards 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 mμsec[5], while the resolving time of the discriminator following it is more often in the 0.1 μsec 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 cricuits, 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 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

1) F. J. M. Farley, Rev. Sci. Instr. 29 (1958) 595.
2) J. Mey, Rev. Sci. Instr. 30 (1959) 282.
3) D. V. Swift and V. Perez-Mendez, Rev. Sci. Instr. 30 (1959) 1004.
4) N. F. Moody, G. J. R. McLusky and M. O. Deighton,—Electr. Eng. 24 (1952) 214.
5) U. Pellegrini, B. Rispoli and A. Serra, N. Cim. Ser. X, 9 (1959) 171.
6) E. L. Ginzton, W. R. Hewlett, J. H. Jasberg and J. D. Noe, Proc. I.R.E. 36 (1948) 956.
7) H. W. Horton, J. H. Jasberb and J. D. Noe, Proc. IRE 38 (1950) 748.
8) M. Brown, Rev. Sci. Instr. 30 (1959) 169.
9) J. Mey, L'onde Électrique 38 (1958) 622.

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

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

where F and θ denote loop gain and delay respectively, while ε is the portion of the unit pulse exceeding the threshold.

2. 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 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

[10]) Made by Qu-Tronic Semiconductor Corp.

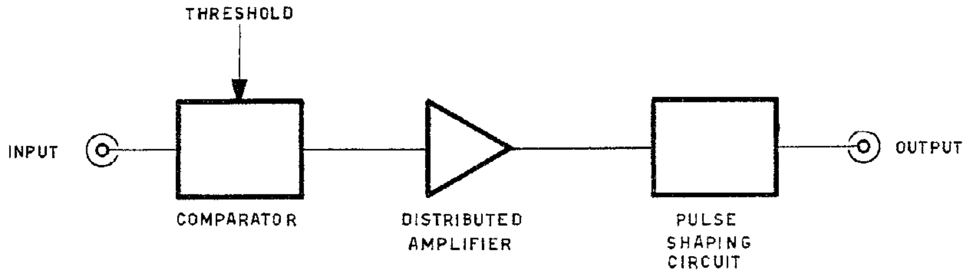

Fig. 1. Block diagram of discriminator.

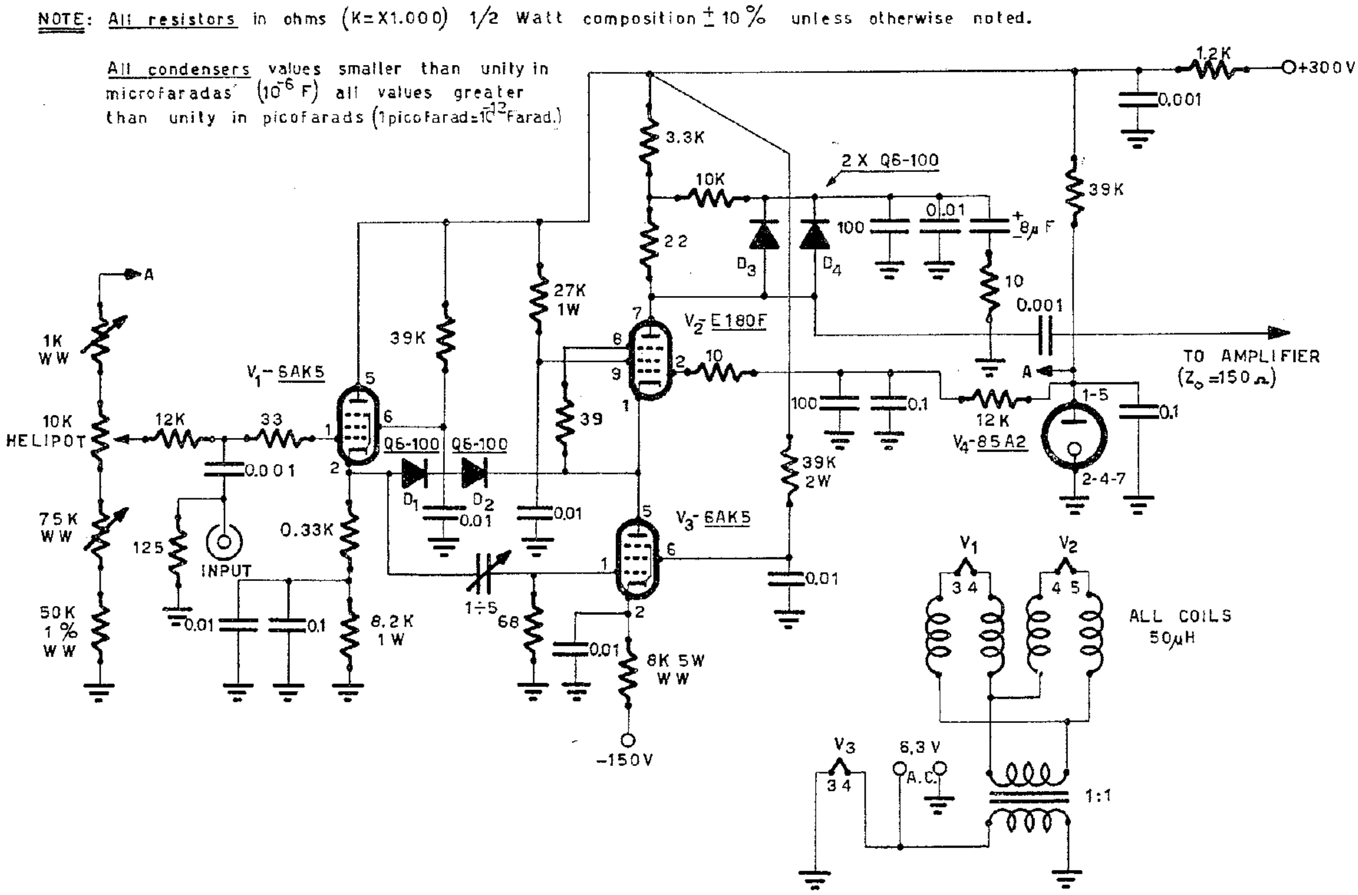

Fig. 2. Comparator circuit.

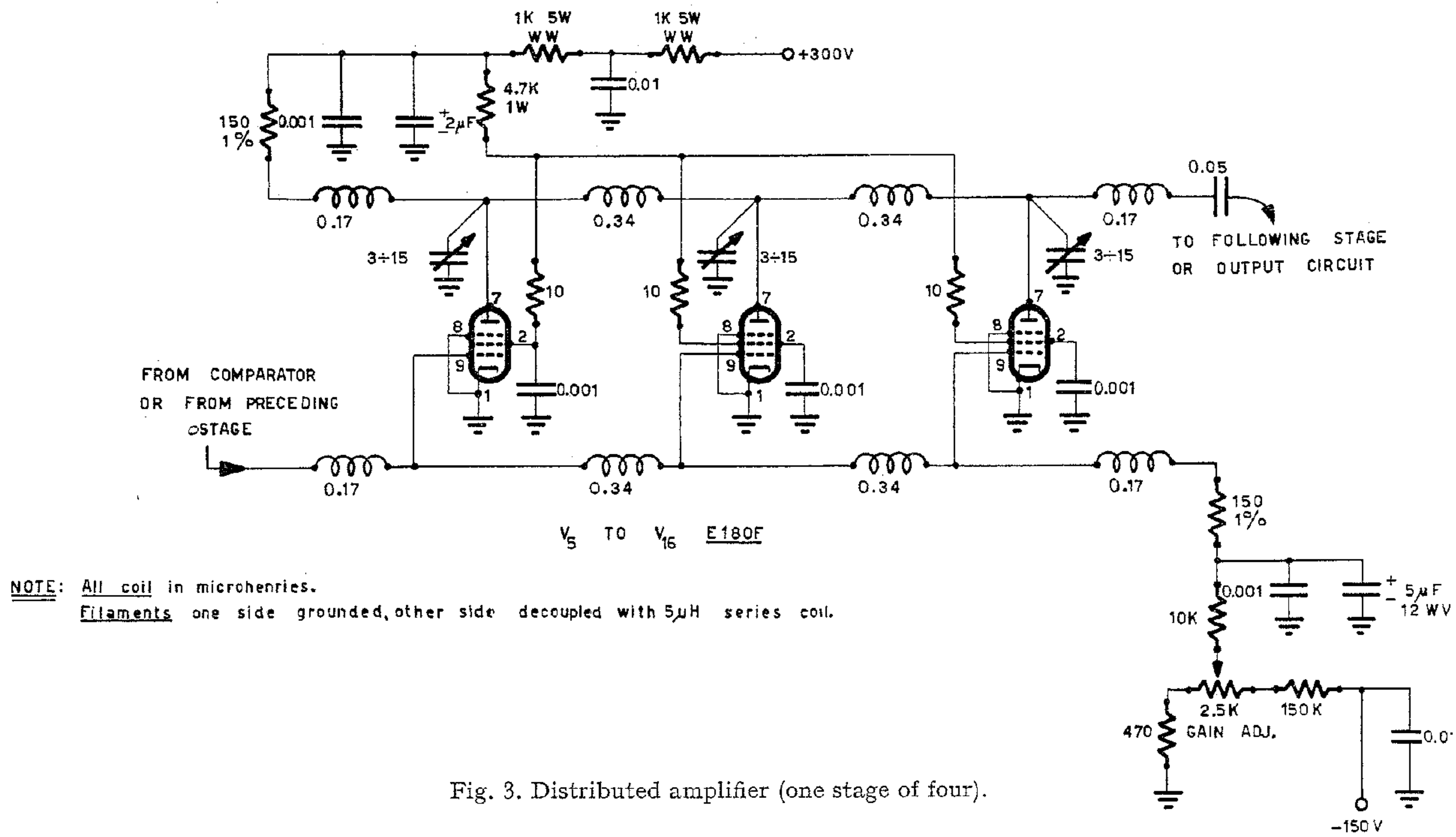

Fig. 3. Distributed amplifier (one stage of four).

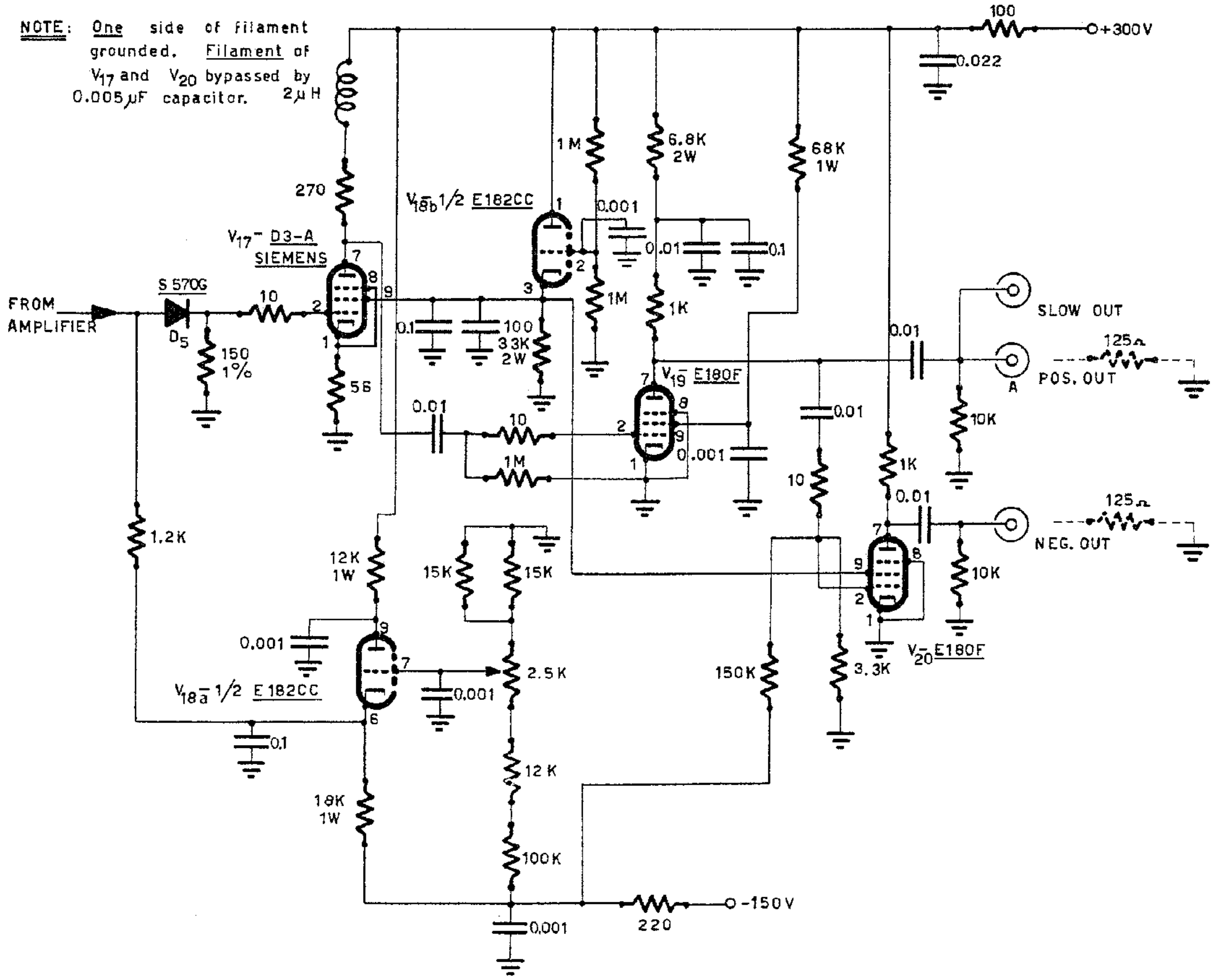

Fig. 4. Output circuit diagram.

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 × 150 (43 dB) and 5 mμsec 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: 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 mμsec. A larger slower output pulse is also available for triggering slow scalers when output A is unterminated.

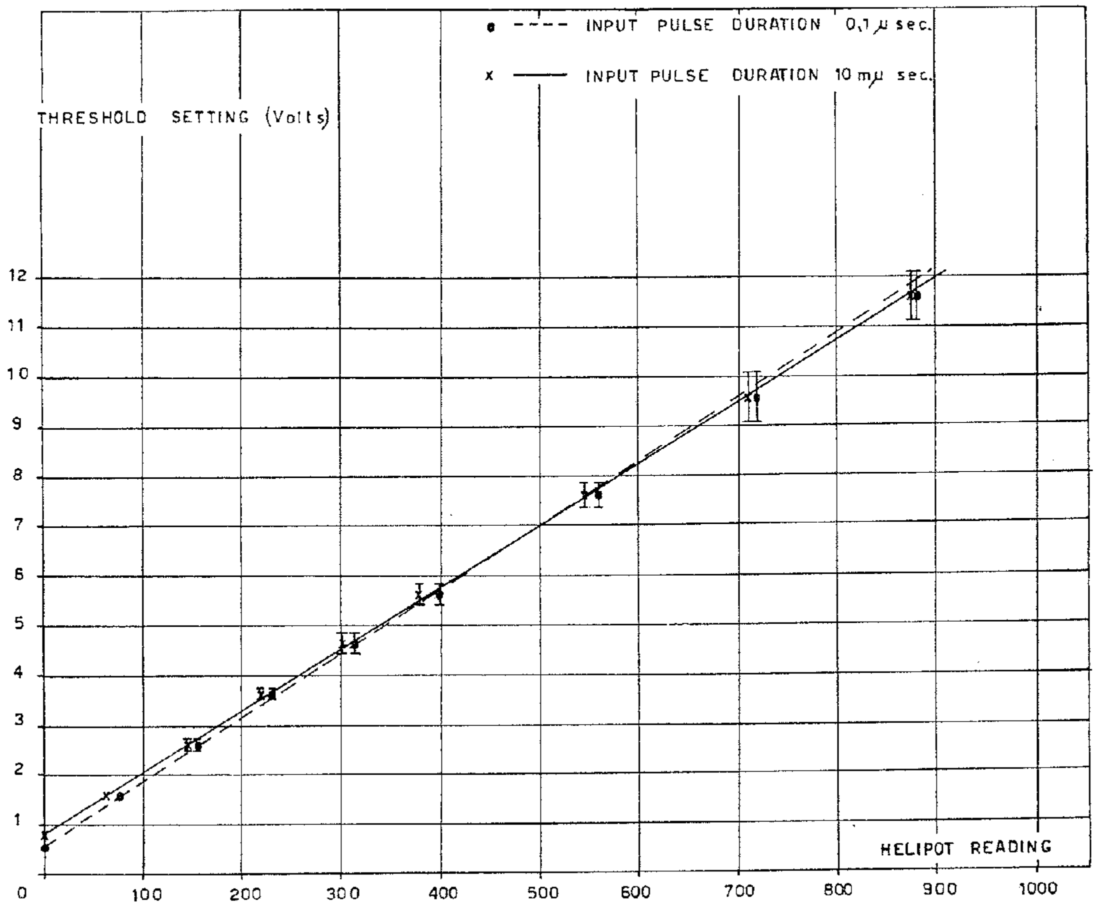

Fig. 5. Discriminator calibration.

3. Performance

The threshold linearity in the useful range of 0.5 to 12 volts in better than 3% for pulses whose duration lies between 10 and 100 mμ seconds as evidenced by fig. 5. The lower limit is

[11]) Made by Transitron Electronic Corp.

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

due to uncertainty in diode break-point, while the upper limit (due to diode break-down) is ample considering the dynamic range of present-day photo-multipliers and fast amplifiers. With 25 mμsec rectangular pulses the absolute value of the threshold increases by 15 mV, while with 10 mμsec pulses the absolute value increases by 0.3 volts maximum. The resolving time is less than 25 mμsec, in the sense that two 10 mμsec rectangular pulses, 25 mμsec 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/s without threshold variations greater than 0.1 volts. 20 Mc/s 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 mμsec and does not change by more than 2 mμsec as the input exceeds the threshold by 0.03 to 10 volts. Long term (8 hrs) drift was found to be about 20 mV.

[13]) C. C. Cutler, Proc. IRE **43** (1955) 140.

[14]) U. Pellegrini, N. Cim. Ser. X, **9** (1958) 533.

[15]) M. Nakamura, Rev. Sci. Instr. **30** (1959) 778.

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

4. 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.

Acknowledgements

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