Laboratori Nazionali di Frascati

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C. Infante, C. Solimani, I. F. Quercia: A FAST 20-CHANNEL PULSE HEIGHT ANALYZER EMPLOYING LINE CODING.

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Introduction

The problem of multi-channel analyzers to be used in conjunction with pulsed accelerators becomes more challenging and intriguing as time goes by. Apart from the usual requirements of channel stability and overall reliability, low resolving times are also necessary. It is the aim of this work to present an analyzer posessing the absence of drift usually encountered in much slower amplitude-to-time converters, coupled with speeds usually obtained only with 'stacked discriminators' designs.

The basic idea of the analyzer has appeared in the litterature some time ago[2] and is summarized in fig.1.

If a pulse is injected into an open circuited delay line, multiple reflections occur resulting in a train of equally spaced amplitude-decreasing pulses. Hence if this pulse train

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(1) Now at Columbia University, N.Y.

(2) A.Alberigi Quaranta, C.Bernardini, I.F.Quercia: Nuclear Instr. and Meth., 3, 201 (1958)

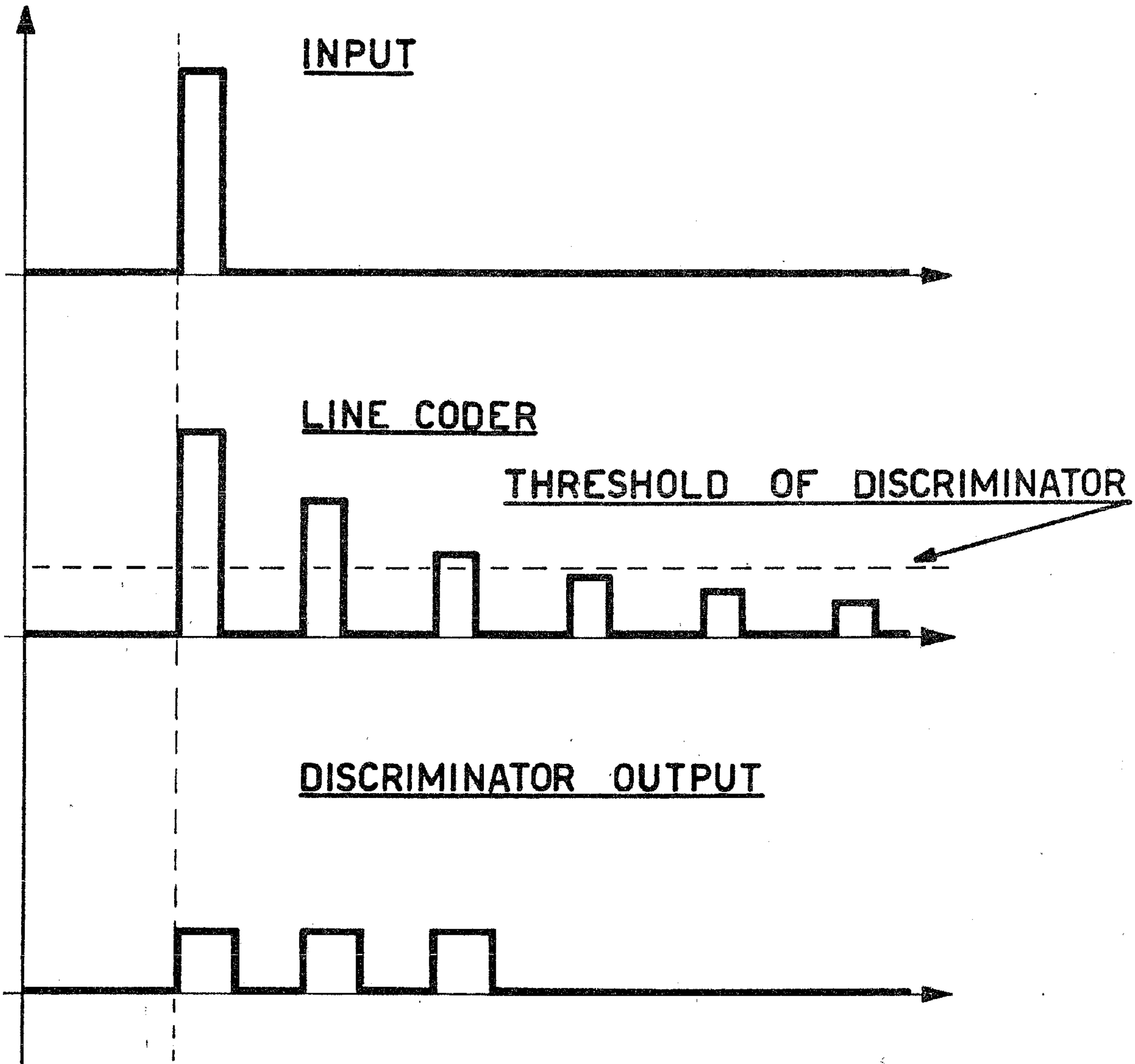

FIG. 1

BASIC IDEA OF ANALYZER

is fed to an integral discriminator, the number of discriminator output pulses obtained will depend on the amplitude of the original pulse. Single-channel analyzers employing this principle have already been built using vacuum tubes[3] or transistors[4]. A multi-channel device based on the above principles has also been built elsewhere[5].

The analyzer about to be described employs 20 channels with an overall dead time of the order of 3 μsec. Channel width is of course quite stable since it is mainly determined by the attenuation characteristics of the delay line, a passive device.

Block diagram of pulse height analyzer

The block diagram of the analyzer is shown in fig.2 and its idealized waveforms in fig.3.

Input pulses are gated and amplified and then branch out to a fast trigger and to the line coder where the pulse train is formed. Discriminator output is fed to an anticoincidence both directly and through a delay τ equal to the spacing between pulses in the pulse train. Inspection of fig.3 shows that this ensures the selection of the last pulse in each train. This 'last pulse' is compared with the pulse generated by the fast trigger that has been delayed by successive steps (all equal to τ). Channel selection is thus accomplished by coincidence circuits. Finally the paralysis generator prevents input pulses from reaching the delay line coder while an input pulse is being analyzed.

RG-63U, 125 Ω, coaxial cable is used extensively in the 'fast' part of the analyzer (i.e. in the delay line coder and

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(3) A.Alberigi Quaranta, C.Bernardini, C.Infante, I.F.Quercia: Nucl. Instr. and Meth., 5, 120 (1959)

(4) A.Alberigi Quaranta, B.Righini: In course of pubblication.

(5) I.M.Akimov, A.S.Kusnetzov: Joint Inst. for Nuclear Research, Dubna, Report R-436 (1959).

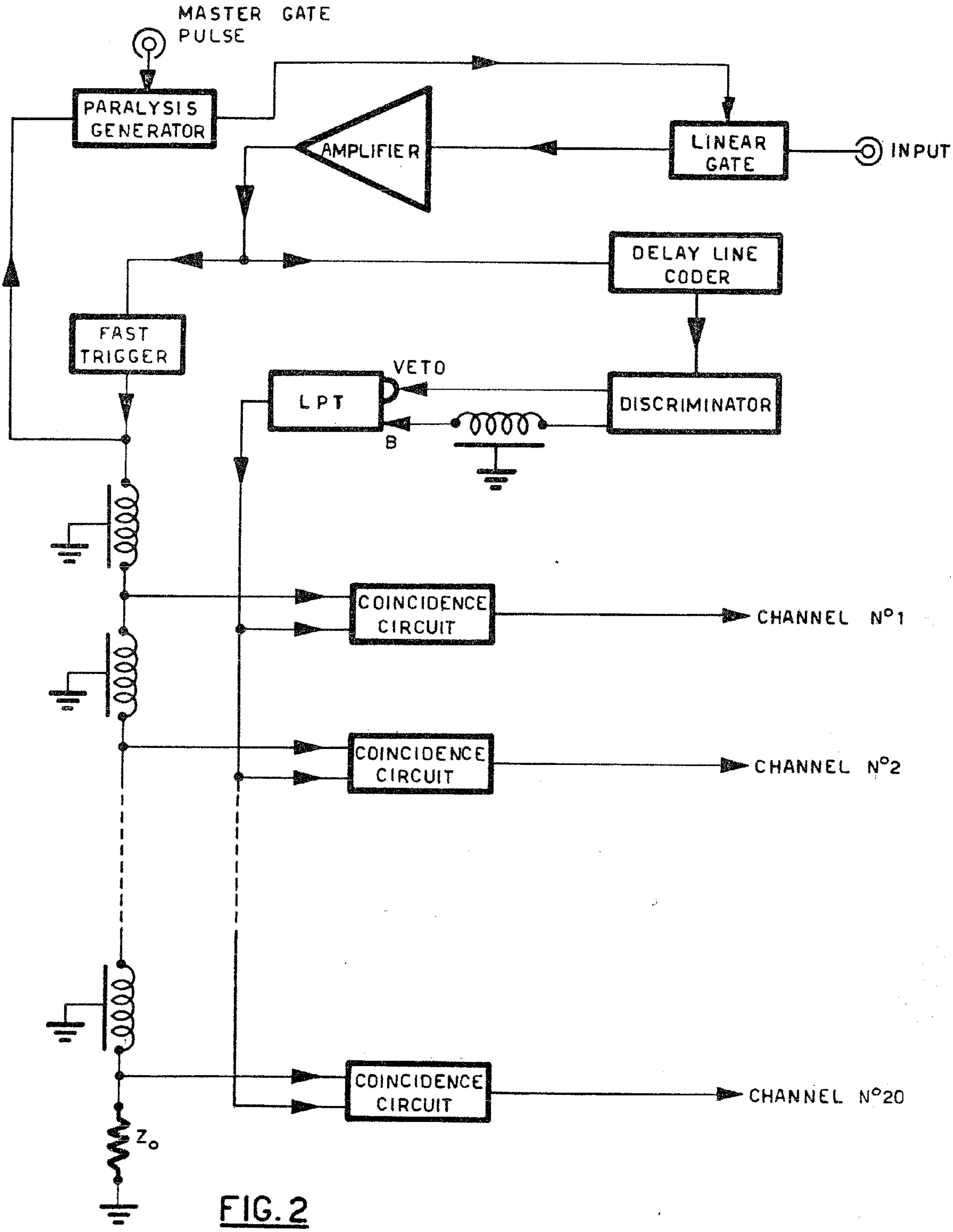

FIG. 2

BLOCK DIAGRAM OF PULSE HEIGHT ANALYZER

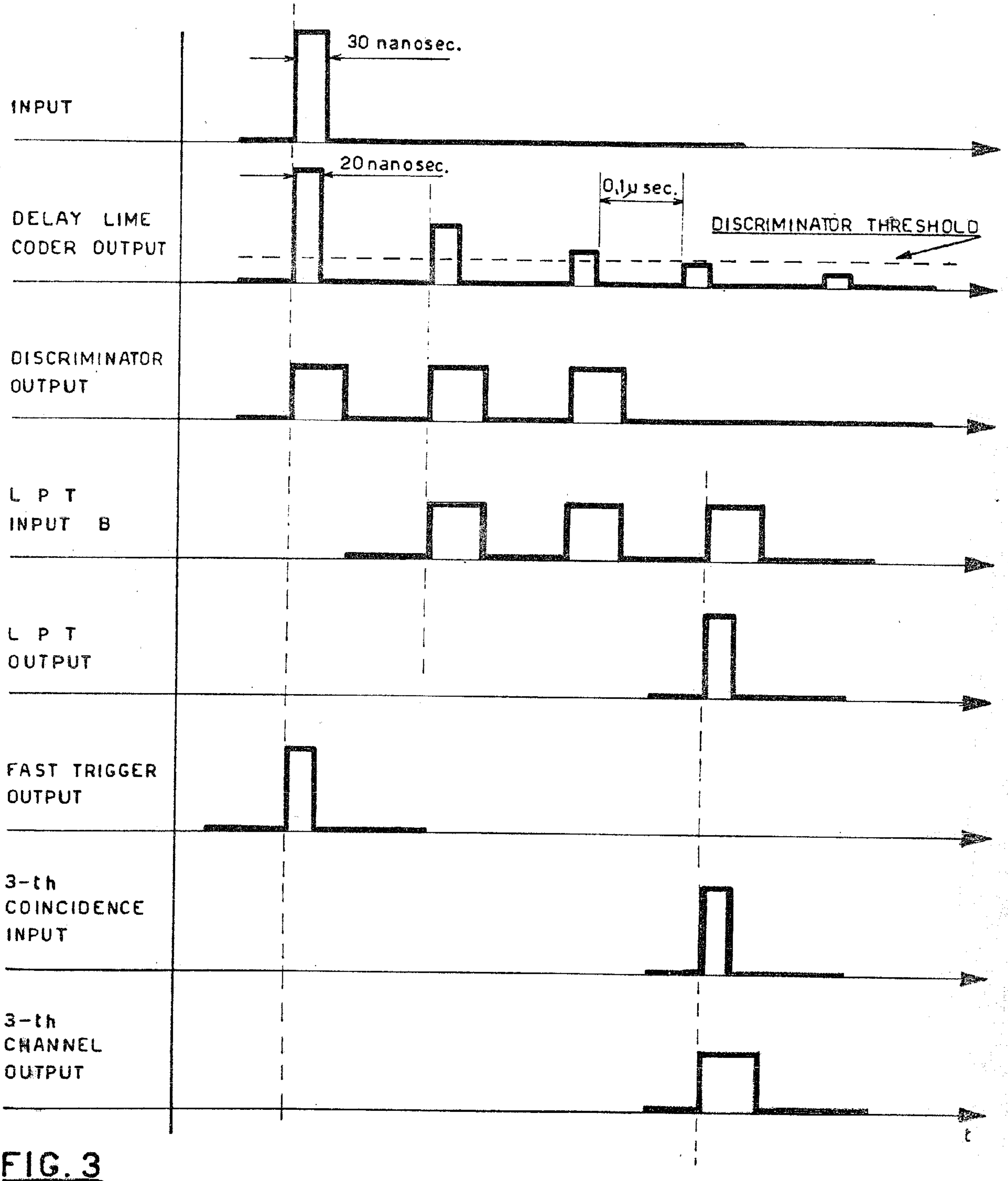

FIG. 3

WAVEFORMS IN PULSE HEIGHT ANALYZER

in all the circuits up to the fast trigger and the LPT circuit). In the 'slow' part (i.e. in the time-to-channel selection circuits) 1 kΩ delay line is used, due to its greater delay per unit length (0.1 μsec/m).

Circuit description

a) Linear Gate (see fig.4)

It consists of a semiconductor diode drawing heavily through tube V2 and thereby short circuiting input pulses. A positive pulse applied to the grid of V1 turns V2 and its associated diode off, allowing input pulses to reach the output. Pedestal is a few tenths of a volt in amplitude, while non linearity is quite small ($\leq$ 25% up to 6 volts) and is limited by diode backward characteristics.

b) Amplifier (see fig.5)

The amplifier is a conventional constant-k distributed design[(6)] employing 8 power tubes ensuring a ± 30V linear swing on a 125 Ω load. Gain is about 6 (16 db) while rise time is about 3 nsec. Gain stability is ensured through a large amount of D.C. feedback (feedback factor is about 3) and through use of stabilized filament supply.

c) Delay Line Coder (see fig.6)

The input diode separates the preceding circuit (with its associated low output impedance) from the coding cable. Pulses in each train are cathode followed, clipped by a shorted stub and again cathode followed. A semiconductor diode S570G is added to clip undesirable undershoots.

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(6) E.L.Ginzton, W.R.Hewlett, J.H.Jasberg and J.D.Noe: Proc. Ire, 36, 956 (1948)

FIG. 4

LINEAR GATE

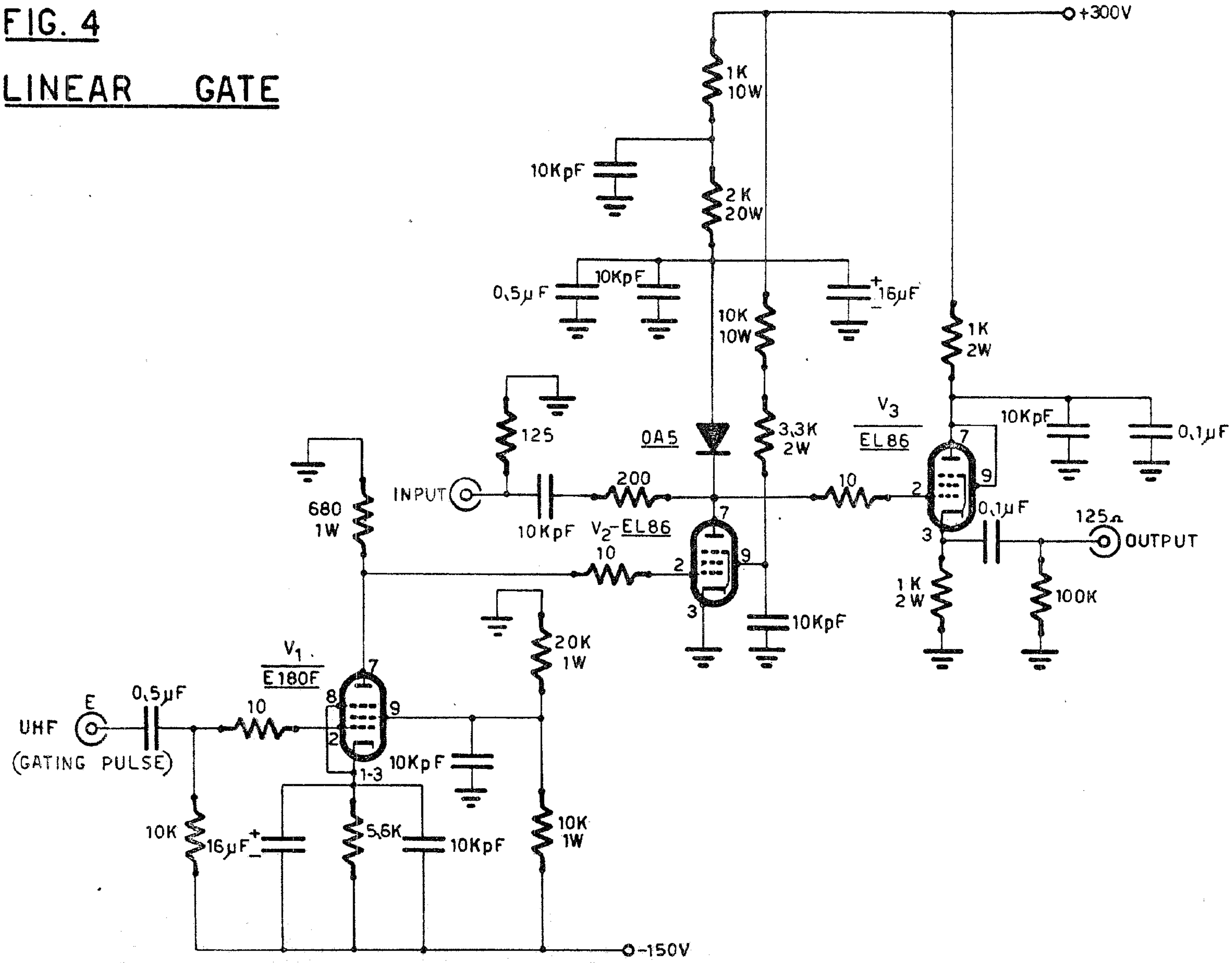


FIG. 5

AMPLIFIER

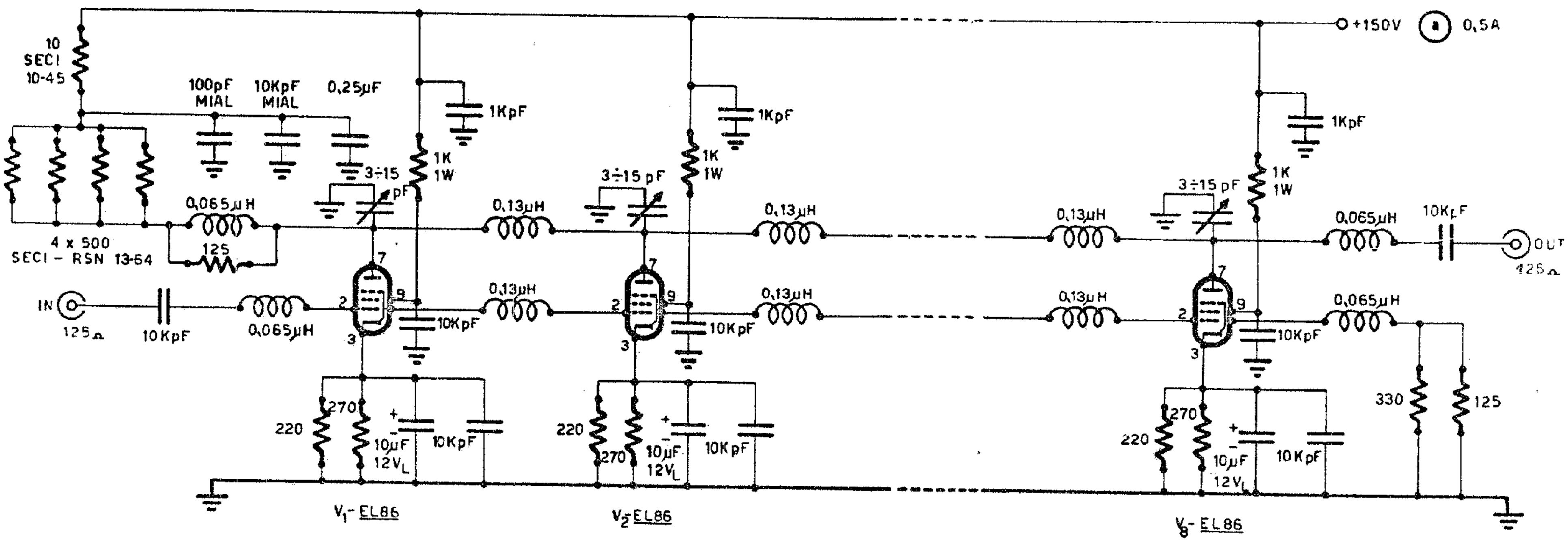
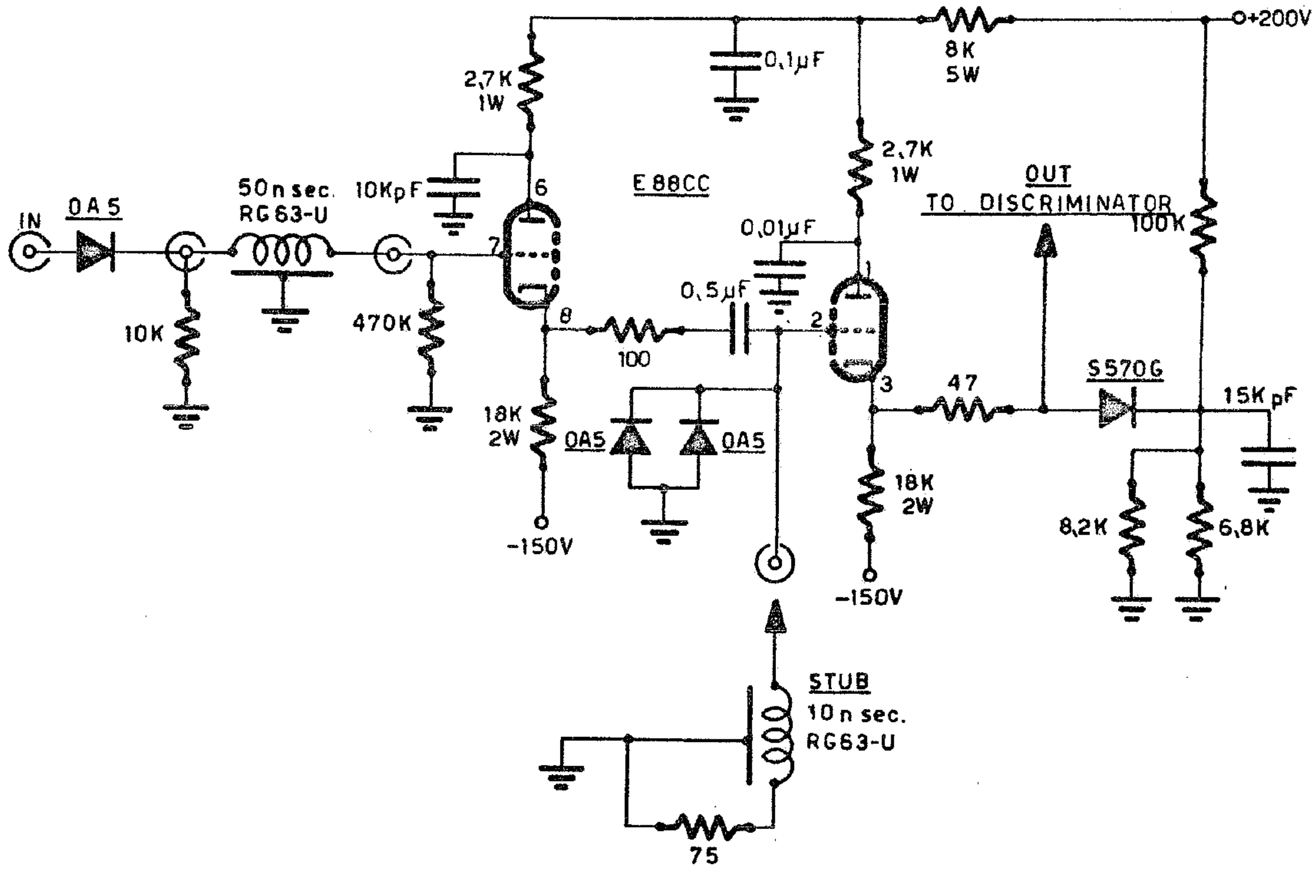


FIG. 6

DELAY LINE CODER



d) Discriminator (see fig.7)

As the input-to-output delay of the discriminator must be constant to ensure satisfactory operation of the following circuits, a discriminator employing a distributed amplifier as the pulse shaping element was chosen[7]. This allows pulses separated by 0.1 μsec to be handled with relative ease (discriminator dead time is less than 25 nsec.

e) L.P.T. (Last Pulse Trigger)

This circuit is a conventional anti-coincidence whose inputs are suitably delayed: the circuit is derived from the well-known Garwin[8] coincidence circuit with obvious modifications and is shown in fig.8.

f) Fast Trigger (see fig.9)

Once again the requirements on input-to-out delay were such (i.e. the delay should not be a function of pulse height) as to prohibit the use of regenerative trigger circuits[9]. Since the speed of the device was not so important as in the case of the discriminator, conventional R-C amplifier stages were used. The device gives constant output for input pulses ranging from 0.2 to 80V in amplitude.

g) Decoder (Delays and coincidence units)

As mentioned before in the 'slow' part of the analyzer HFK 5614 delay lines are used to generate suitable delays.

The coincidence circuits have been designed so as to employ a minimum number of tubes and of standby current, the positive pulse generated by the fast trigger travels down the delay lines

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(7) C.Infante: in course of pubblication on Nucl.Instr.and Meth.

(8) R.L.Garwin: Rev. Sci. Instr., 24, 618 (1953)

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

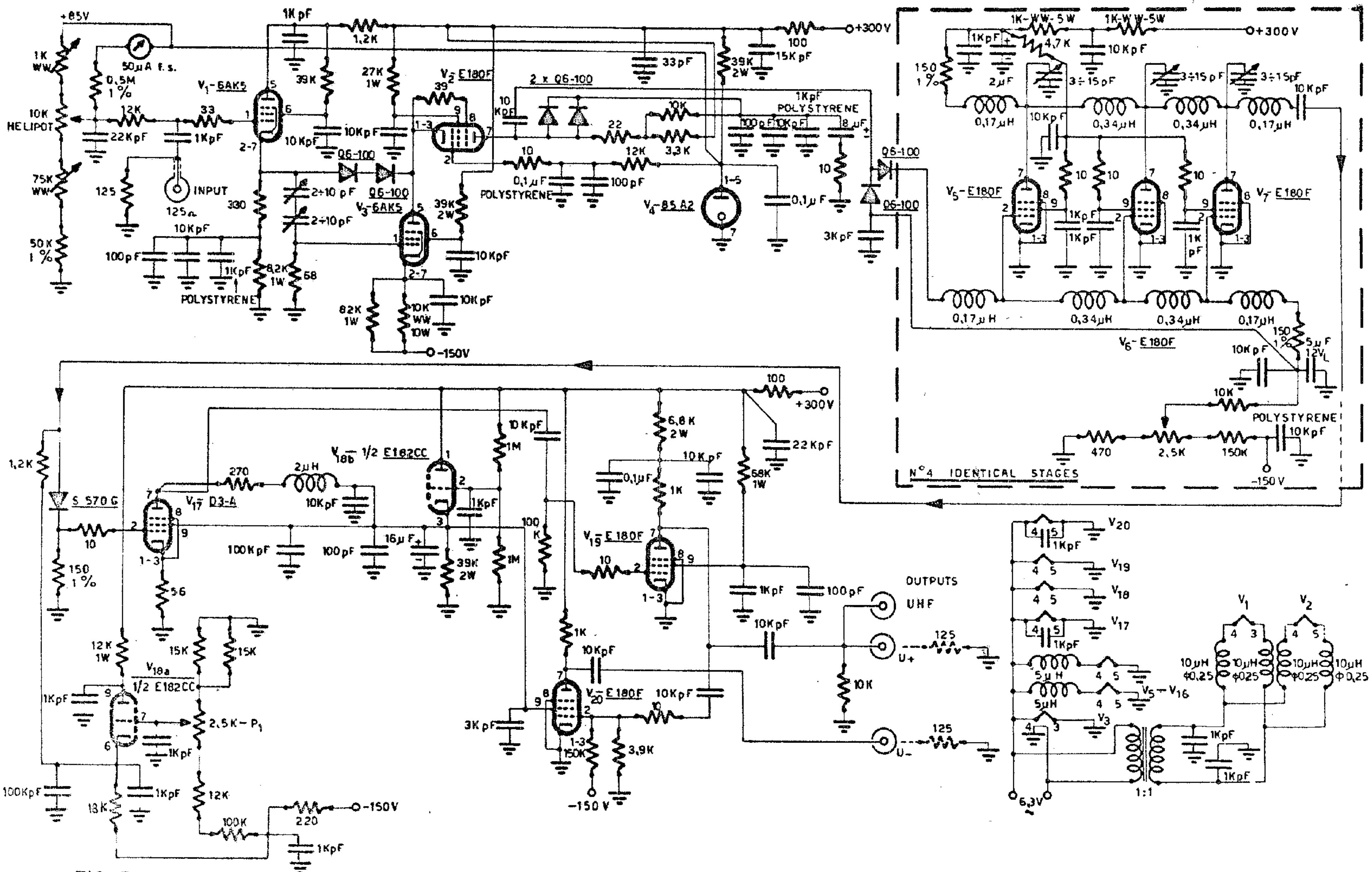


FIG. 7
DISCRIMINATOR

FIG. 8

LAST PULSE TRIGGER (LPT)

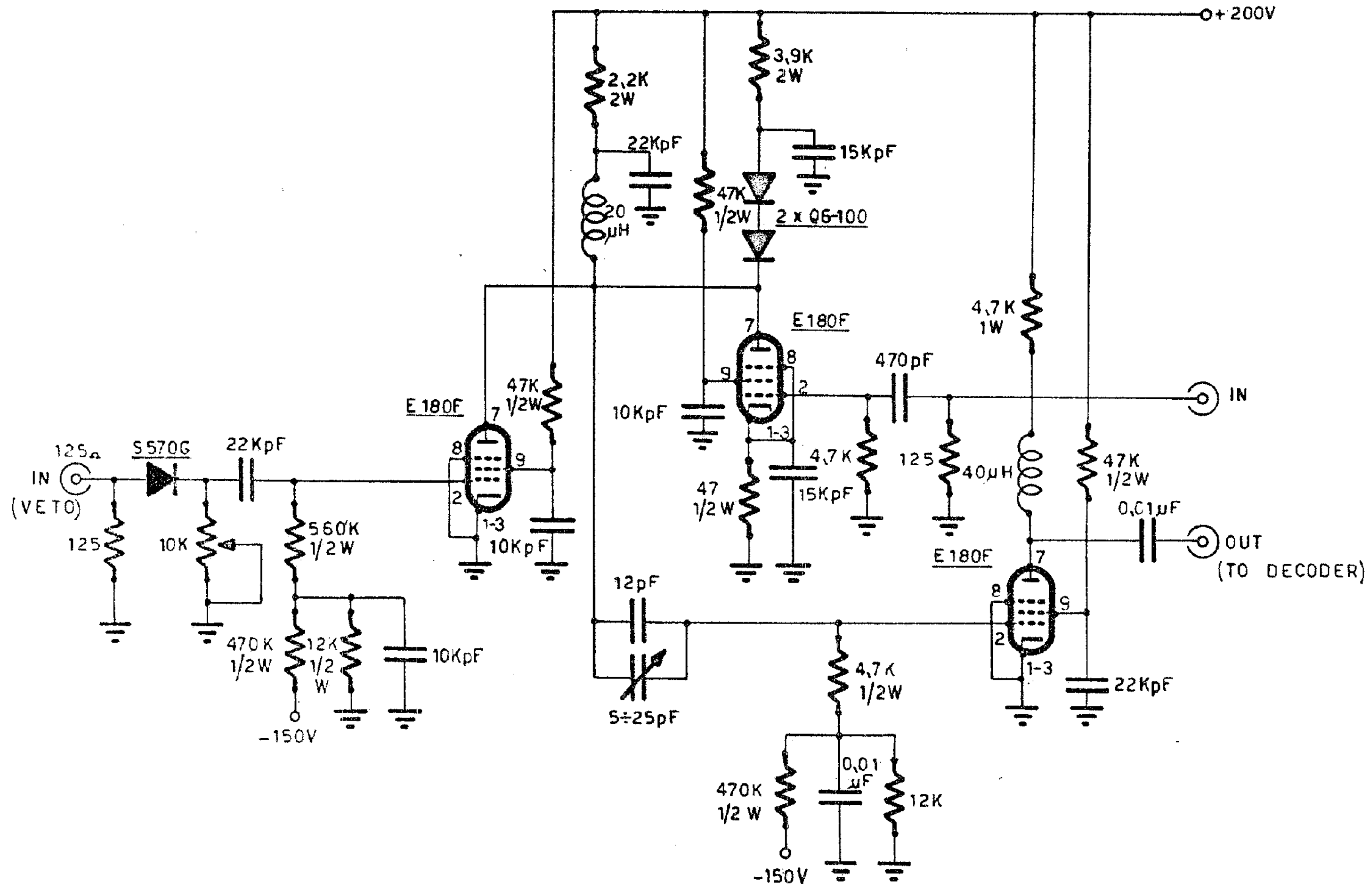
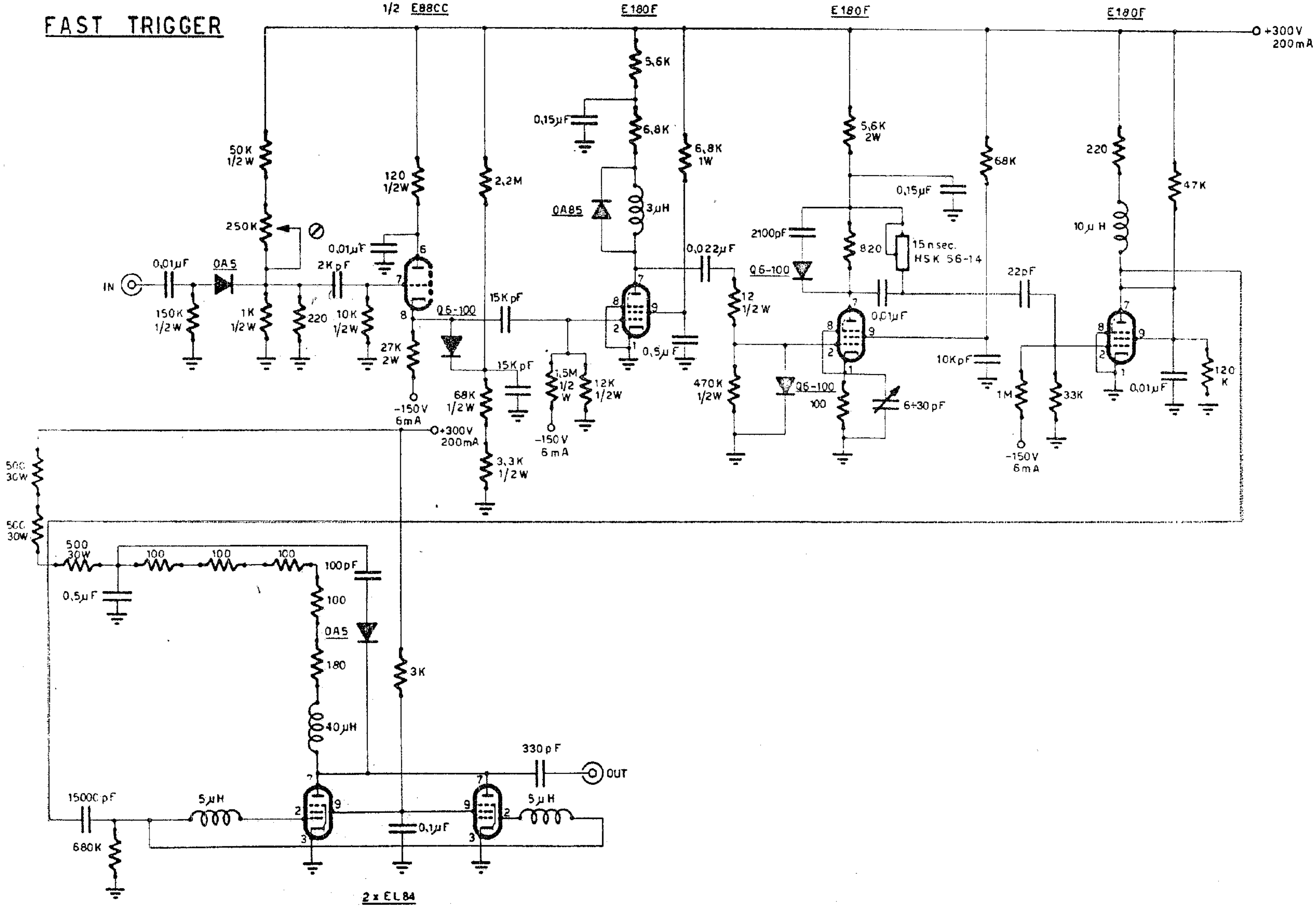


FIG. 9

FAST TRIGGER



and is repeatedly cathode followed (see fig.10). By itself it can not have any effect due to the limiting action of semiconductor diode S570G biased by cathode follower V2. A negative pulse from the LPT circuit turns V1 and all the diodes off. It is therefore necessary that two pulses be present (e.g. at the grid of V3 and at the cathode of its associated diode) before an output may be produced (at terminal U1).

Vacuum tubes V23 + V42 are used to cut off non coincident pulses and to amplify and invert the pulses so as to drive the output scalers.

h) Paralysis Generator (see fig.11)

Upon receipt of an external gating signal this circuit clears the linear gate for a time equal to the duration of the signal itself, then effectively blocks the linear gate for a time equal to the analyzer dead time (3 μsec). This is done with an anticoincidence circuit fed by a monostable multi and by the gating signal. The monostable is triggered by the analyzer's fast trigger and inhibits gating signals from reaching the linear gate for the duration of its quasi-stable state. This circuit employs a secondary emission tube (V2) normally biased well below cut off with a length of delay line (Hackethal HH 2500) as the pulse shaping element. This ensures an excellent stability of the pulse duration and a very low recovery time (about 0.2 μsec).

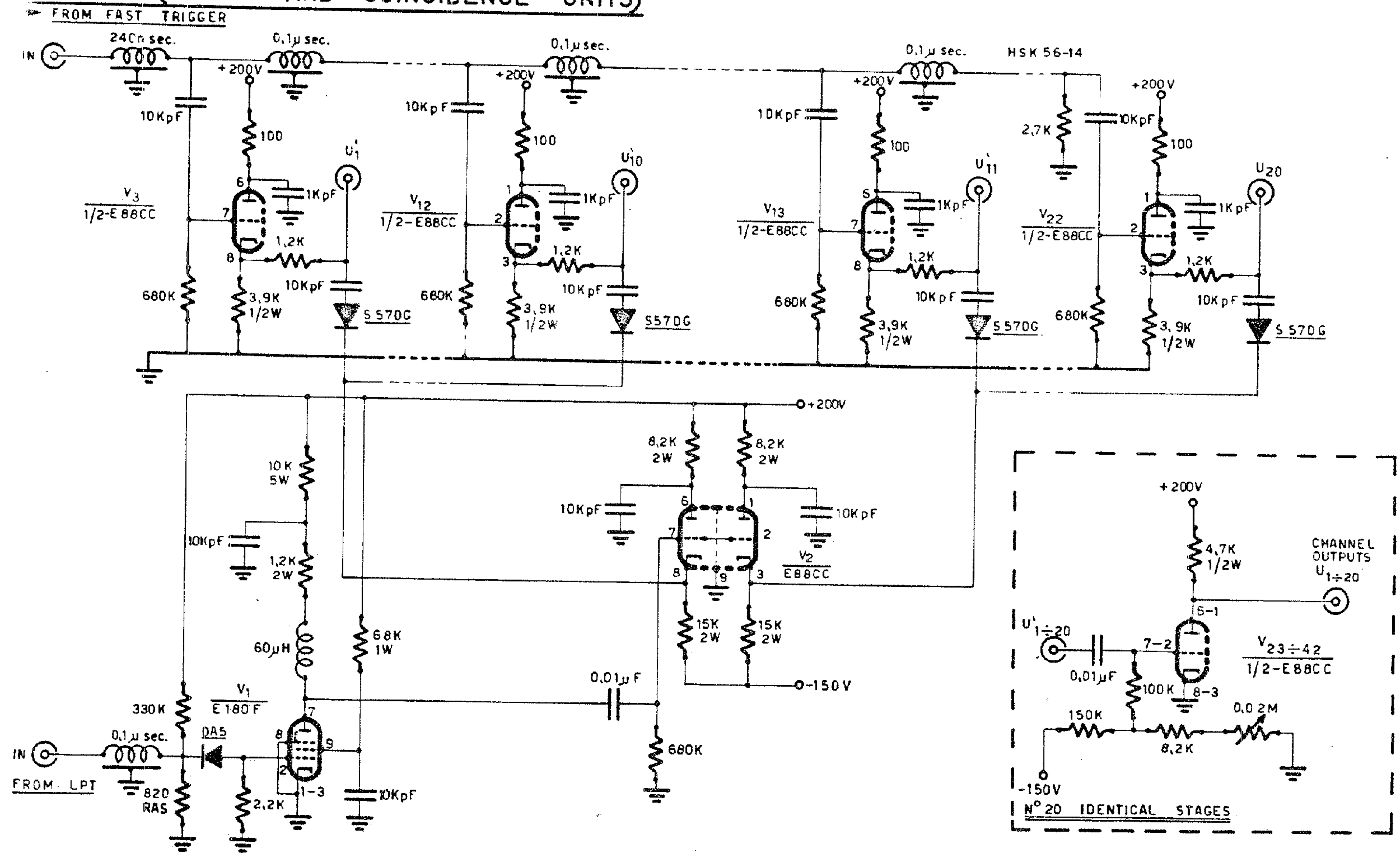
The anticoincidence is a conventional difference amplifier (V4).

Performance

The tests and performance figures to be stated are only preliminary and are therefore not to be taken as definite: they may be taken however as indicative of circuit performance.

FIG. 10

DECODER (DELAYS AND COINCIDENCE UNITS)



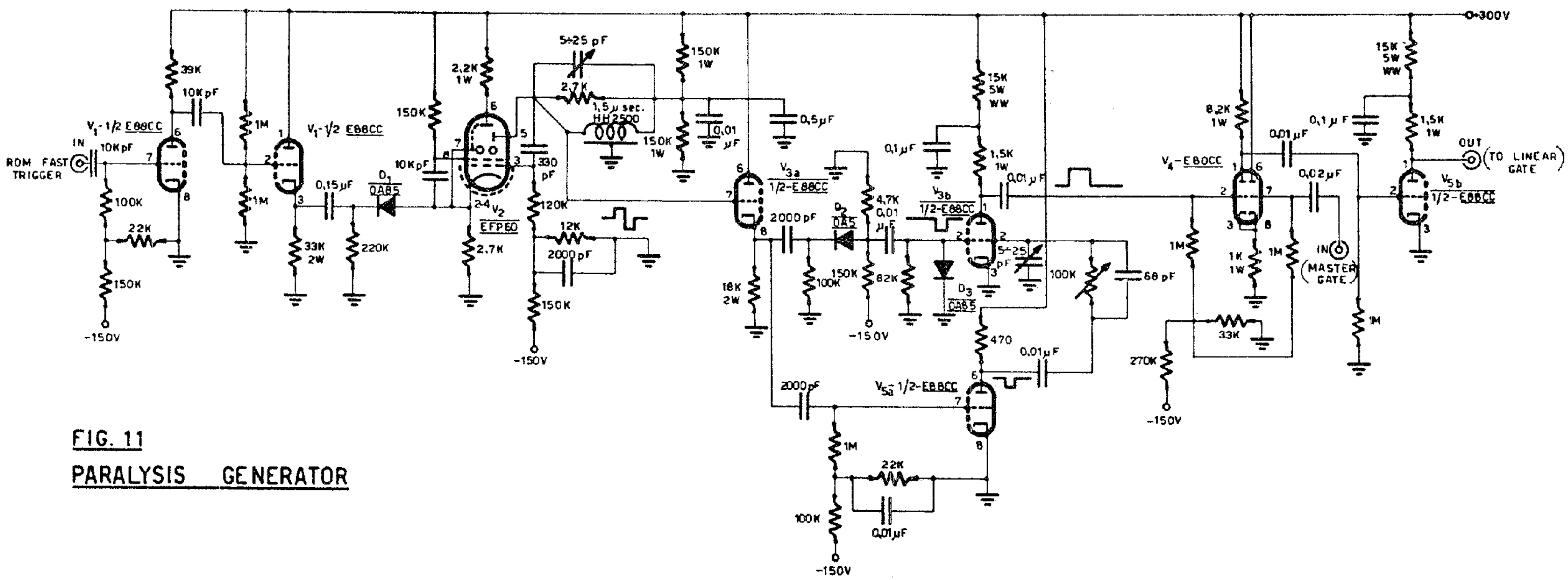


FIG. 11

PARALYSIS GENERATOR

The fig.12 shows the calibration curve of the analyzer, taken with 25 nsec pulses generated by a mercury relay generator.

It is quite evident that channel width is not constant but varies logarithmically with channel position. This may be an advantage in certain cases (e.g. it allows detailed examination of a part of a spectrum) but renders certain calculations necessary in going from channel contents to spectrum. Specifically it is necessary to divide the number of pulses counted by each channel by a number proportional to channel width so that a flat spectrum is reproduced as a flat graph. These calculations could of course be done automatically by suitably processing each channel's data.

The fig.13 shows a spectrum plotted with this technique. Inserting suitable attenuators the peak of the spectrum was moved to the lower channels thereby showing greater detail.

Fig.14 shows the same spectrum taken at different times. It is apparent that the position of the peak of the spectrum changed by only one channel.

Finally fig,15 shows the dependence of analyzer calibration on input pulse width.

The errors introduced for very short pulses are probably due to the excessive length of the shorting stub in the delay line coder, to pulse deterioration effects in the coder itself and to ballistic effects in the discriminator.

Acknowledgements

The authors wish to acknowledge the help of Mr. C.Dardini in building and testing the circuits just described.

FIG. 12

CALIBRATION OF ANALYZER

25 n sec. PULSES

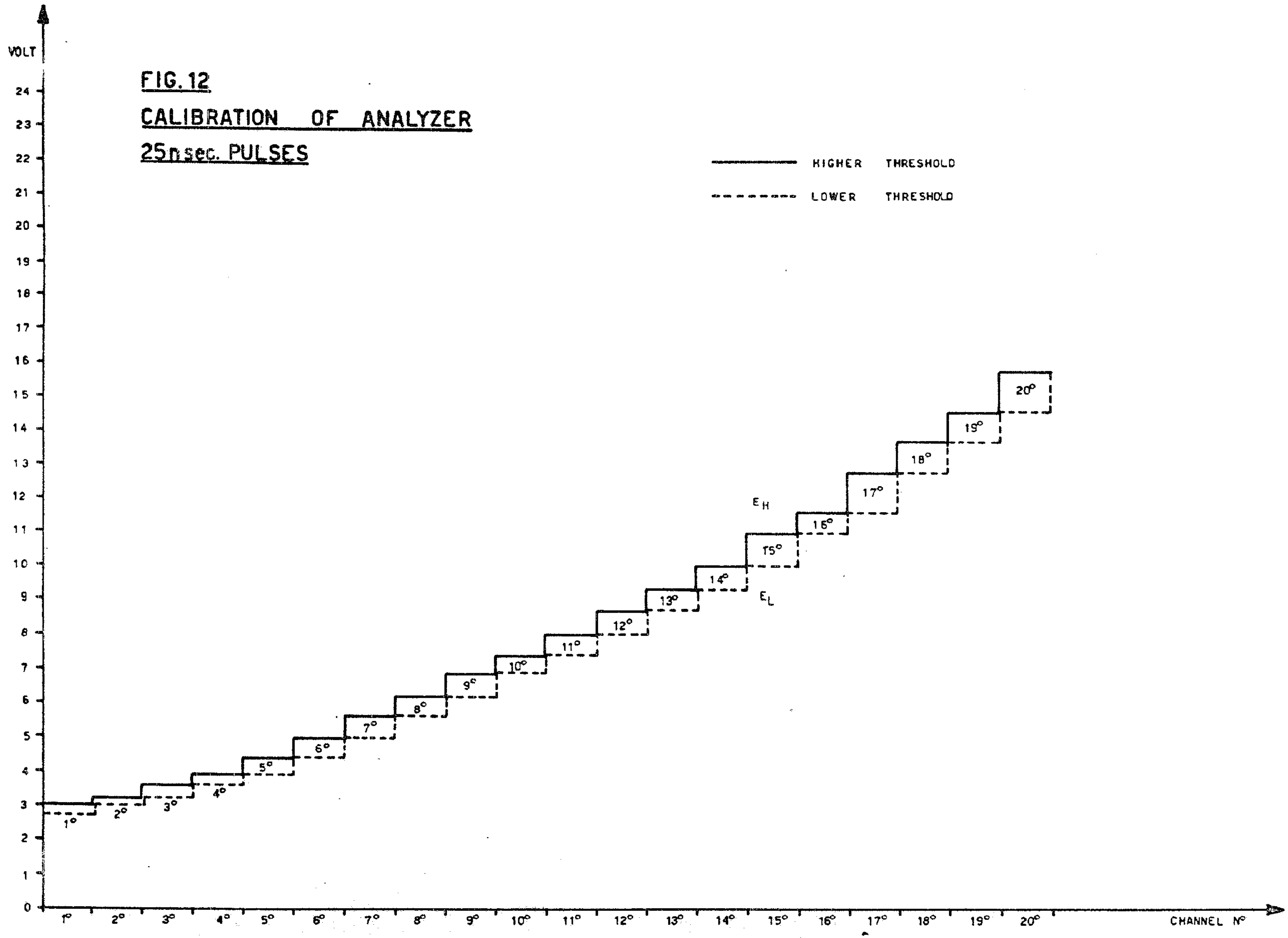


FIG. 13

α - SPECTRUM OF RADIOACTIVE SOURCE

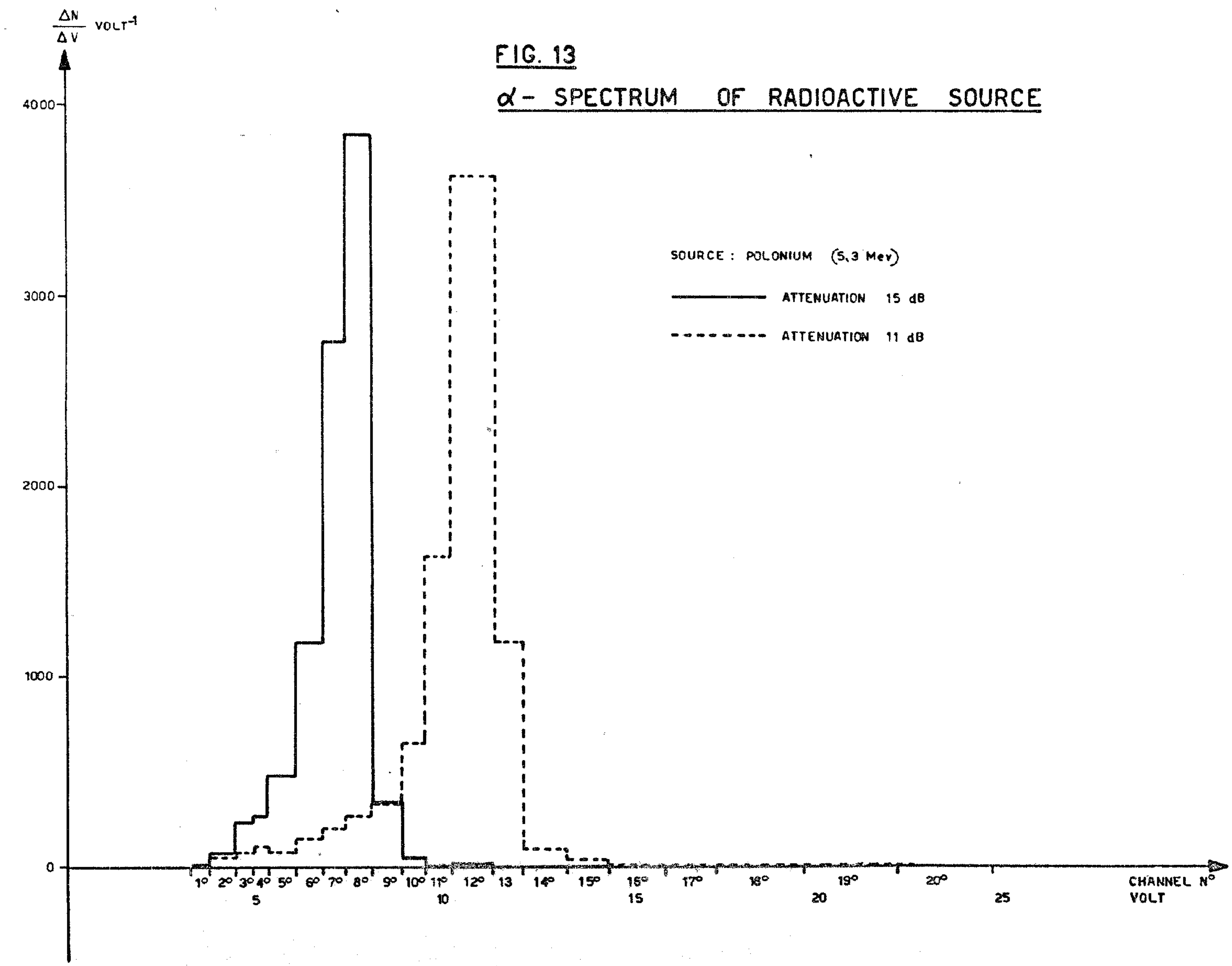


FIG. 14
α- SPECTRUM OF RADIOACTIVE SOURCE (POLONIUM)

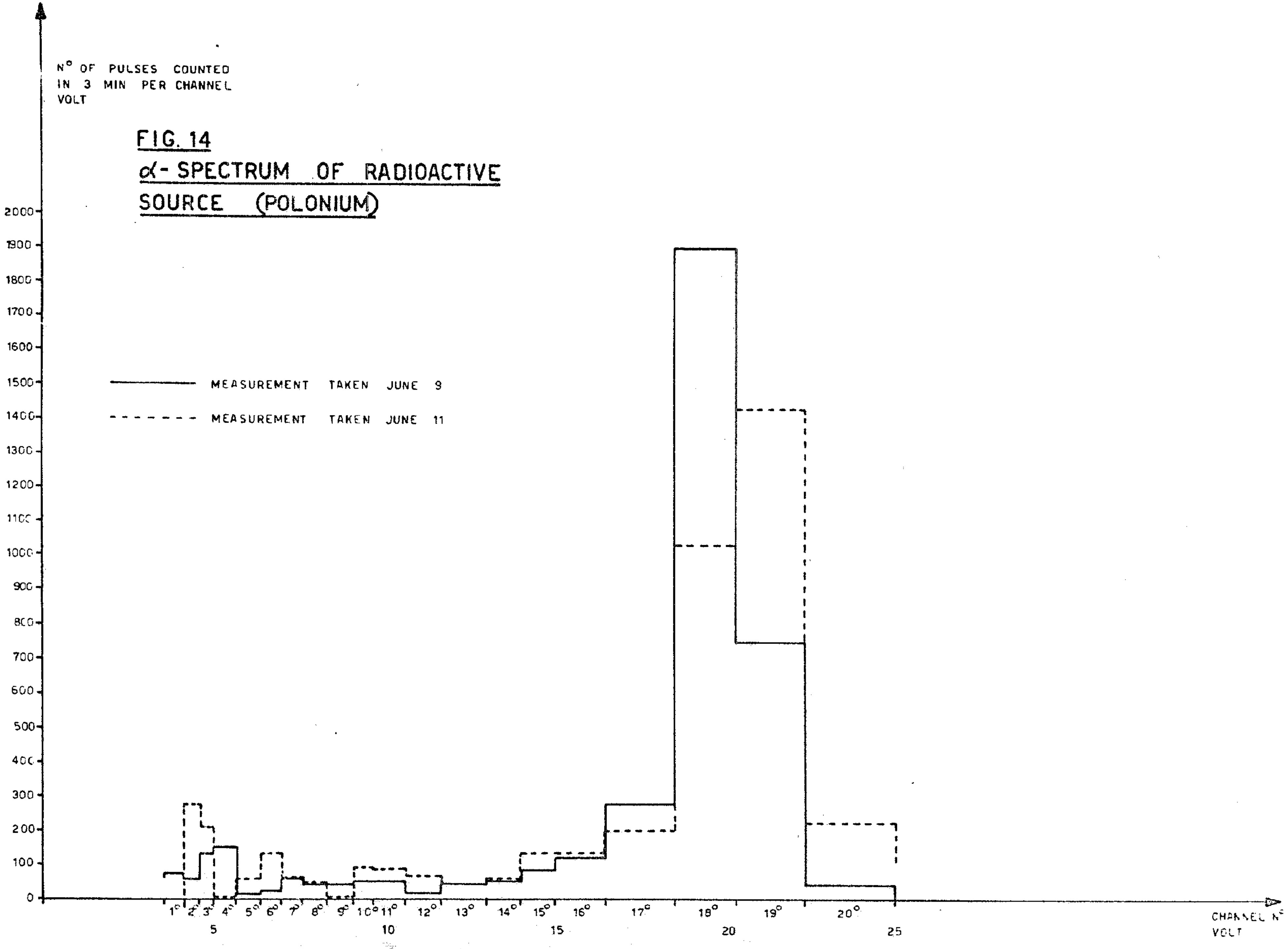


FIG. 15
ANALYZER CALIBRATION VS. INPUT PULSE DURATION