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DEVICE FOR DETERMINING THE MEAN VALUE AND DISPERSION OF THE DISTRIBUTION OF PULSE AMPLITUDES

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Pulse amplitudes having a zero dispersion can be measured with a pulse-type voltmeter [1]. There do, however, exist voltage or current pulse-generators, the amplitude of which is distributed according to a specific law (for example, scintillation counters and other detectors of nuclear radiation). In this case, we may speak of measuring the mean pulse amplitude. Below, we give a description of a device for measuring the mean value of the amplitude distribution of pulses. More precisely, this device can be used to determine the median of the distribution, i.e. it can find a level that divides all pulses into two equal parts, namely those amplitudes which are above or below this level. If the distribution is symmetrical, the median coincides with the mean value. If, moreover, the distribution is normal, the device can be used to determine also the degree of dispersion. For convenience, we shall, when speaking of this equipment, use the term "pulse-type voltmeter".

Figure 1 is a block diagram of the voltmeter;
figure 2 gives time-diagrams for the block diagram. The voltmeter consists of two amplitude discriminators having a common input. Discriminator 1 has a low, fixed threshold. The threshold of discriminator 2 is determined, through the buffer circuit, by the potential on the capacitance C and is measured on a pointer-type instrument.

It is assumed that the threshold of discriminator 2 is always higher than that of discriminator 1. The set-up includes a trigger-controlled current generator 1, which is switched on and discharges the capacitance C with a current i_1, if the trigger is in the "1" state, and is switched off if the trigger is in the "0" state. The set-up also includes a non-controlled current generator 2, which charges the capacitance with a current i_2. If the input pulse is higher than the threshold of discriminator 2, the trigger is tripped in the "0" state by the pulse from discriminator 2. If the input pulse is lower than the threshold of discriminator 2, but higher than the threshold of discriminator 1, the trigger is tripped in the "1" state by the pulse from discriminator 1. To prevent the pulse of discriminator 1 from reaching the trigger, if there is a pulse from discriminator 2, an anti-coincidence circuit is used. The device will operate if the threshold of discriminator 2 also increases when the potential on the capacitance rises.

During measurement, the potential value on the capacitance remains stationary, the average value of the current i_i being equal to the current i_2 ($\bar{i}_i = i_2$). The threshold of discriminator 2 will correspond to the median of the amplitude distribution if $i_2 = 0{,}5 i_1$, i.e. the threshold of discriminator 2 will split all the pulses into two equal parts, according to whether the amplitudes are above or below it. If the pulse amplitude distribution is normal, which is the usual case, and $i_2 = 0{,}16\ i_1$, the stationary state of the thereshold of the discriminator 2 will be less and, with a current $i_2 = 0{,}5\ i_1$, will be separated from the threshold by a value corresponding to a single standard deviation. For a current of $i_2 = 0{,}34\ i_1$ the stationary state of the threshold of discriminator 2 will be higher and, with a current $i_2 = 0{,}5\ i_1$, will be separated from the threshold value by a value which also corresponds to a single standard deviation.

Since the input of the pulse-type voltmeter is likely to receive not only the pulses whose amplitudes are to be measured, but also extraneous pulses (e.g. the background from the photomultiplier), a control system was included.

Figure 3 is a schematic diagram of the discriminators; figure 4 gives the time diagrams for the case in which the input pulse has an amplitude which exceeds the threshold of discriminator 2.

The basis chosen was the differential discriminator discribed in /2/. In the schematic diagram, discriminator 1 is at the top. The circuits for both discriminators are identical. Below, the components of discriminator 2 will be given in brackets.

In discriminator 1 (discriminator 2), use is made of two tunnel diodes TD1 and TD2 (TD3 and TD4), separated by an inverted gallium arsenide diode OD1 (OD2). One tunnel diode TD1 (TD3) serves as a current discriminator, the other tunnel diode TD2 (TD4) shapes the output signal in respect of its amplitude and duration. The input pulse branches out and reaches the tunnel diodes after passing through the transistors T_1 and T_2 (T_5 and T_6) in the form of current pulses. The threshold of discriminator 2 is determined by the feed-back current which arrives at point d on the circuit. The tunnel diodes of both discriminators return to the initial state by the discharge pulse formed in discriminator 1: T_3, T_9, T_{10}, T_{11}, the delay line LZT - 0.05 - 600. The pulses from the tunnel diode TD_2 (TD_4) enter the differential amplifier on transistors T_3 and T_4 (T_7 and T_8), are then shaped by a short-circuiting cable in the collector of transistor T_4 (T_8) and are fed to the differential amplifier on transistors T_{12} and T_{13} (T_{14} and T_{15}).

The last mentioned differential amplifier serves two purposes: it amplifies the positively polarised pulses which have been shaped in respect of their duration and acts as a gating circuit, since it can be switched over by the input pulse, provided that the 10mA current which arrives at point a of the circuit is switched off. The bases of transistors T_{13} and T_{15} are connected, i.e. the differential amplifier on transistors T_{14} and T_{15} also acts as a gating circuit, but only for pulses from discriminator 2.

The pulses of opposite sign from the collectors of transistors T_{12} and T_{15} arrive at the tunnel diode TD_6 on which is mounted an anti-coincidence circuit. To ensure the reliable operation of the anti-coincidence circuit, the pulses reaching TD_6, are shaped in respect of their length and are appropriately delayed in time (see the time diagrams). At the outputs of discriminator 1, the anti-coincidence circuit and discriminator 2 are amplifiers which are fitted on transistors T_{16} - T_{21}.

The transistors used in the circuit were:
pnp type G T313, npn type GT 311, tunnel diodes TD_1 - TD_4 type AI 301G, TD_5 - TD_7 type AI 301V.

The negative polarity pulses from the amplifier outputs can be fed to counters, and this is essential when tuning the voltmeter. It is always necessary to fulfil the equation $N_1 = N_{AC} + N_2$, and when the median is measured, the equation $N_{AC} = N_2$ must also be fulfilled throughout the entire working range of the voltmeter. Here, N_1 is the count from the output of discriminator 1, N_{AC} is the count from the output of the anti-coincidence circuit, N_2 is the count from the output of discriminator 2. The positive polarity pulses control the trigger operation.

Figure 5 is a schematic circuit diagram of the trigger, the current generator 1, the current generator 2, the buffer circuit and the switching circuits of the pointer-type instrument. The schematic circuit diagram matches the block diagram, and the time diagrams have therefore not been given.

The trigger is mounted on transistors T_{22}, and T_{23}. This is the trigger from the decade scalers designed on the basis of /3/ and made at the central experimental workshop of the Joint Institute for Nuclear Research. The positively polarised pulse from the output of discriminator 2 enters the base of transistor T_{23} and, if the transistor is open, closes it. The negative voltage drop in the collector of T_{23} switches over, through the emitter repeater T_{24}, the differential amplifier on transistors T_{25} and T_{26}. The positive voltage drop in the collector of transistor T_{25} switches off the current i_1 of the current generator 1 mounted on transistors T_{27} and T_{28}. The current generator 2 is mounted on transistor T_{29}. The direction of currents i_1 and i_2 is shown by arrows. Current i_1 is 10 mA, current i_2 is 5 mA when the median is measured. To measure the dispersion of the amplitude distribution the current i_2 must be varied by means of the switch.

The potential on the capacitance C varies within ~ 6 V. The limits of this range are fixed by the diodes D310.

The buffer circuit consists of an emitter repeater T_{30}, a phase-inverter T_{31} and a transistor T_{32}, the collector current of which determines the threshold of discriminator 2. There are no stability requirements placed on the buffer circuit. In the event of a variation in the transmission factor of the buffer circuit the only change is in the range of the pulse amplitudes that can be measured with the voltmeter.

The threshold of discriminator 2 is determined by the voltage drop on the resistor $R_1 = 20\ \Omega$ in the collector of transistor T_{32}. Resistors R_3 and R_8 are selected to ensure that the characteristics of the device tend to zero. The resistor R_2 serves to compensate the minimum current of the collector T_{32}.

The following transistors were used in the circuit: T_{22} - T_{26}, T_{29} and T_{32} (type GT 308 V), T_{27} and T_{28} (type GT 311), T_{30} and T_{31} (type P38).

Figure 6 shows the dependence of the readings of the pointer-type measurement instrument of the voltmeter on the amplitude of the input pulses from the generator. The dashed lines show the non-operative region.

Figure 7 shows the dependence of the N_{AC} count, for $N_1 = 10^4$, on the amplitude of the input pulses from the generator. It can be seen from the graph that the fixing diodes D 310 are switched from the non-conducting state to the conducting state when the voltage is varied by 0.1V. It can also be seen that, when the amplitude of the input pulses varies, the N_{AC} count varies by $\pm$ 2%, which is explained almost completely by the variation in the current of the base of the emitter repeater T_{30}

when the potential on the capacitance is varied. If the standard deviation of the amplitude distribution of input pulses $\sigma = 0,5\ \bar{u}$, this variation in the N_{AC} count may produce a systematic error of no more than 1% in the measurement of the median; this error may be taken into account after measurement of the dispersion by this same apparatus.

We should point out that when measurements are made of pulse amplitudes having a zero dispersion, the i_2 current may have any value as long as it does not exceed the current i_1.

The readings of the voltmeter do not depend (within 1%) on the following-frequency of the input pulses, starting from 15 - 20 Hz. Measurements were made with a generator having a stable amplitude up to a frequency of 1,5MHz.

A check was made of the dependence of the readings of the voltmeter on the frequency whilst the input was being fed with pulses from a photomultiplier; a light diode was used for irradiation of the latter's photo-cathode. The mean amplitude of the pulses from the photomultiplier was 3V; the width at the half-height was determined by this same apparatus and found to be 42%. At a frequency of 1400 Hz, aperiodic oscillations of the pointer of the measurement equipment were observed in the region of 0,05 V; at a frequency of 250 Hz, in the region of 0,1V and at a frequency of 25 Hz, in the region of 0,5V.

The readings of the voltmeter do not depend (within 1%) on the duration of the input pulses in the 15-75 nsec range. Pulses shorter than 15 nsec were not used.

The readings of the voltmeter remain unchanged when the delay of the control pulses is varied within 75 nsec.

The pulse-type voltmeter was used for about a year to control the stability of pulses from photomultipliers with the aid of light diodes. It remained switched on for several hundred hours and was periodically calibrated by means of pulses from a G5 - 13 generator. The calibrations coincided to within 1%.

In conclusion, the authors wish to thank V.G. Zinov for his valuable discussions, Yu. G. Budyashov for his technical advice, L.L. Nemenov for the support he gave to this work and V.A. Smirnov for his assistance in setting up the equipment.

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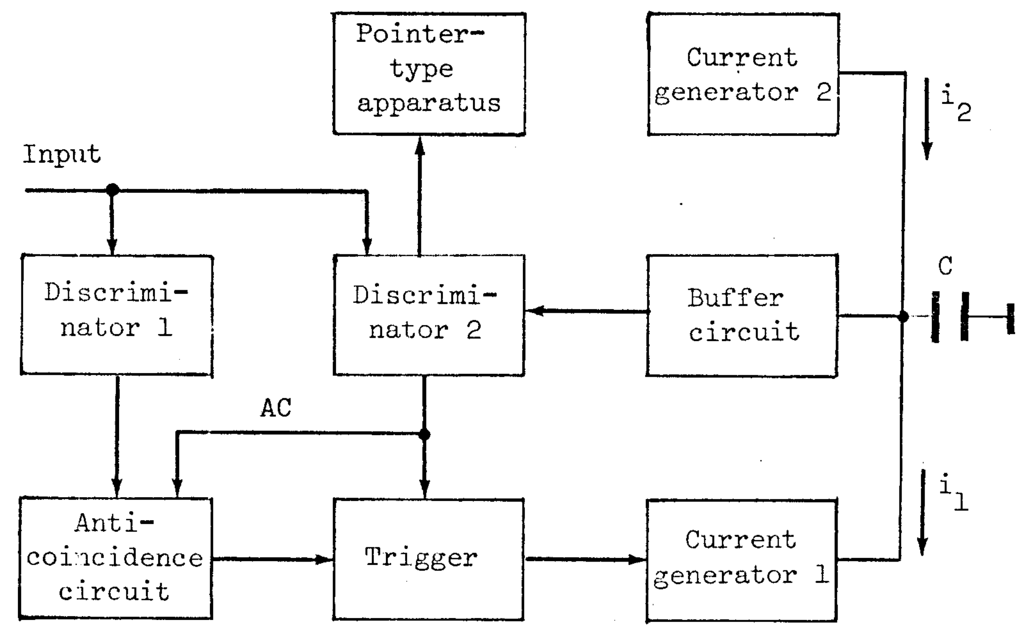

Fig. 1 Block-diagram of the pulse-type voltmeter

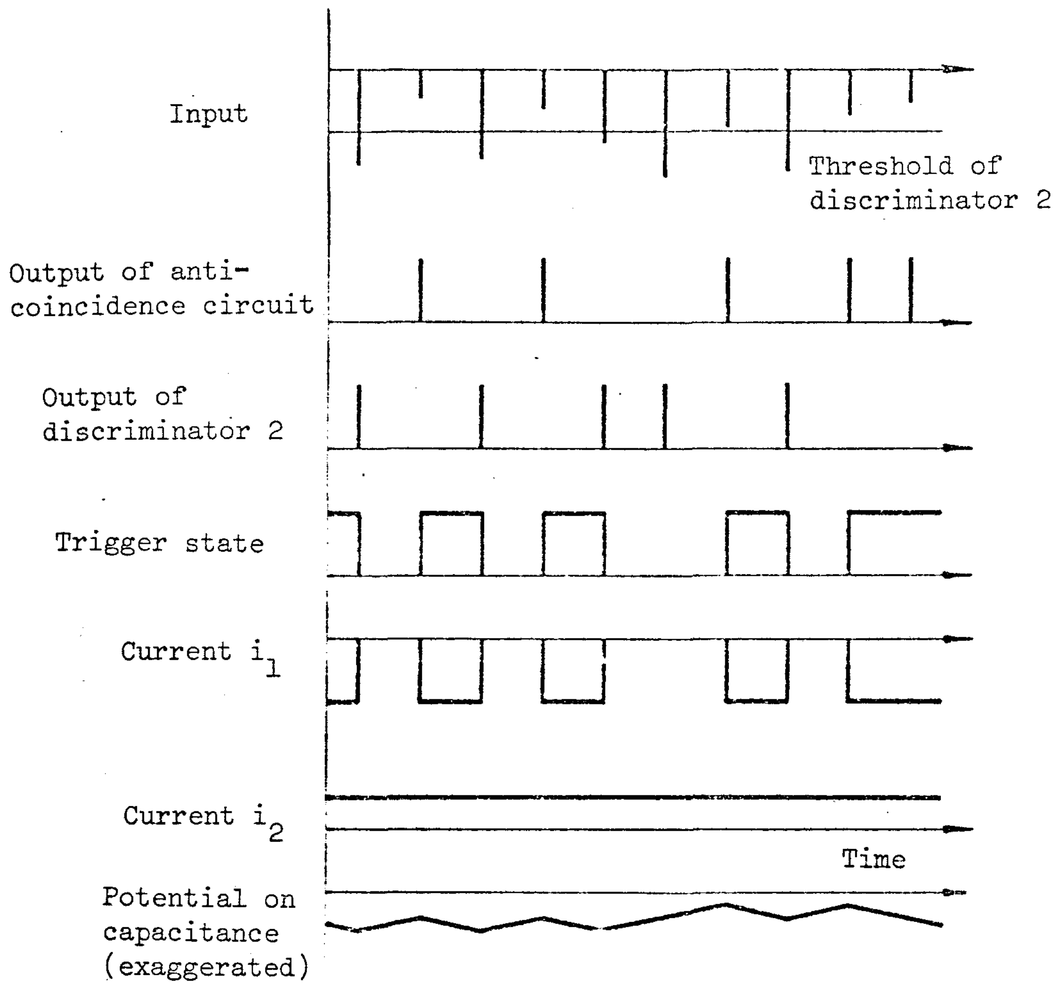

Fig. 2 Time diagrams corresponding to the block-diagram.

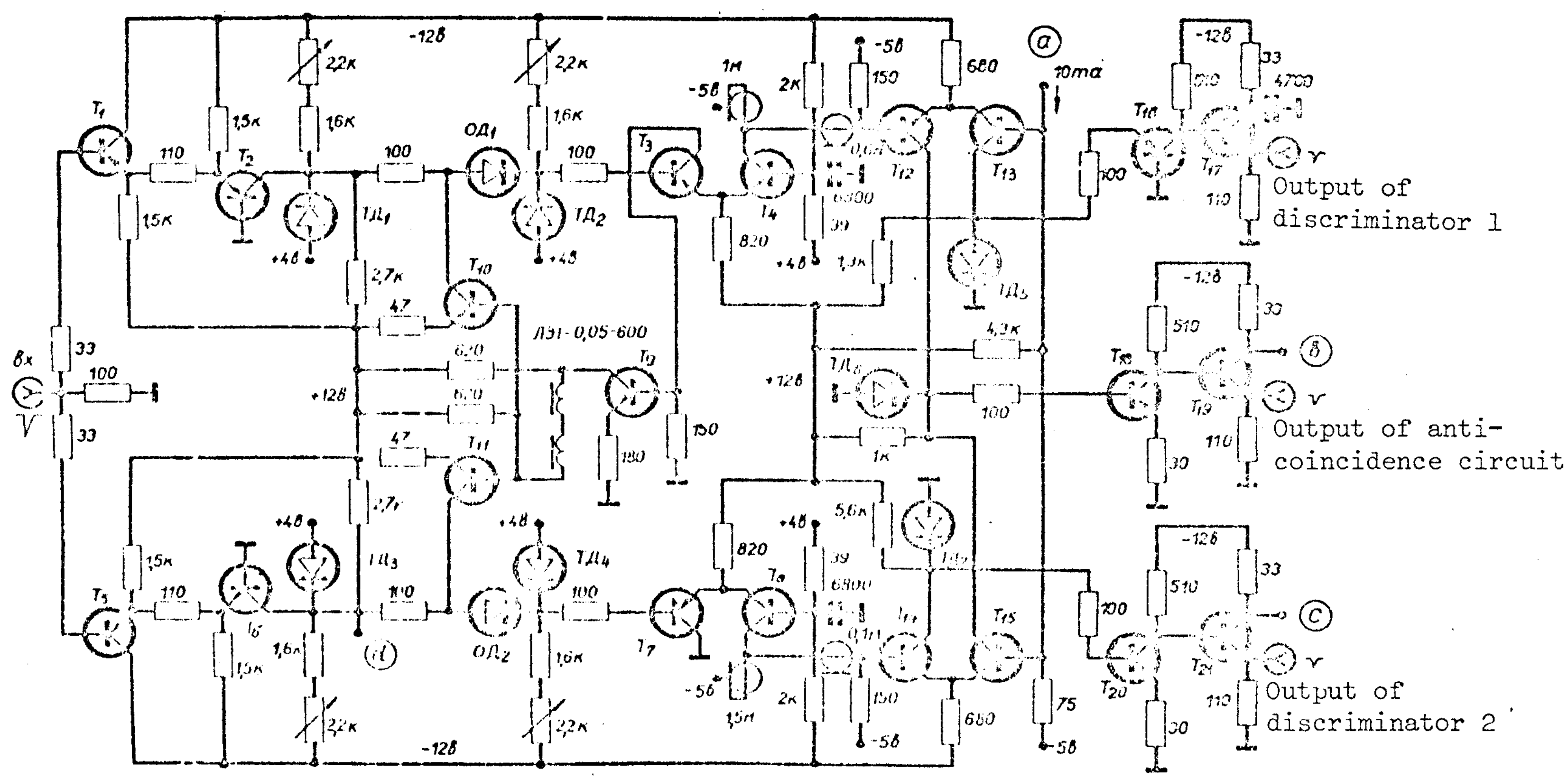

Fig. 3 Schematic diagram showing the circuits of discriminators 1 and 2 and the anti-coincidence circuit.

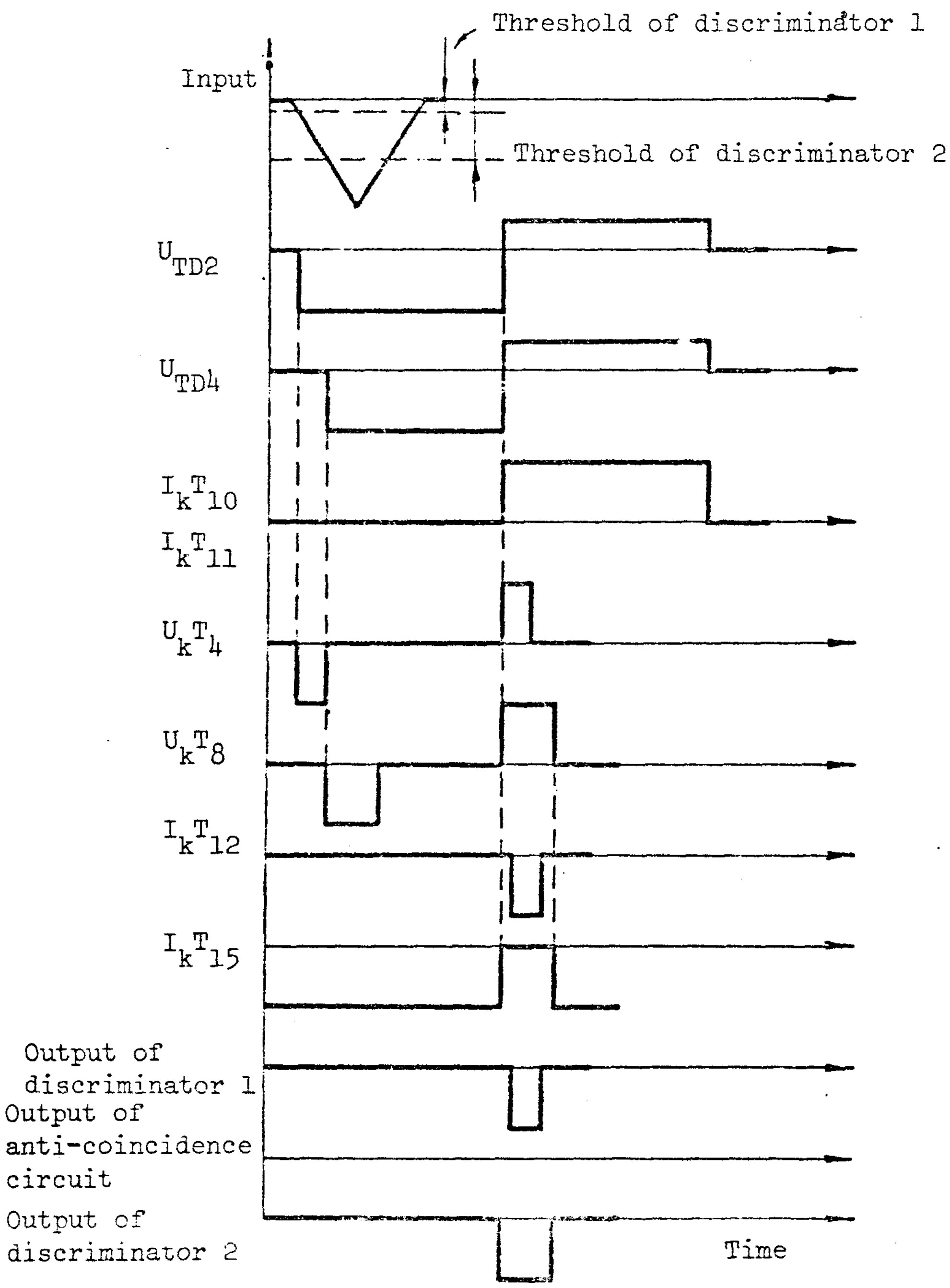

Fig. 4 Time diagrams for Fig. 3.

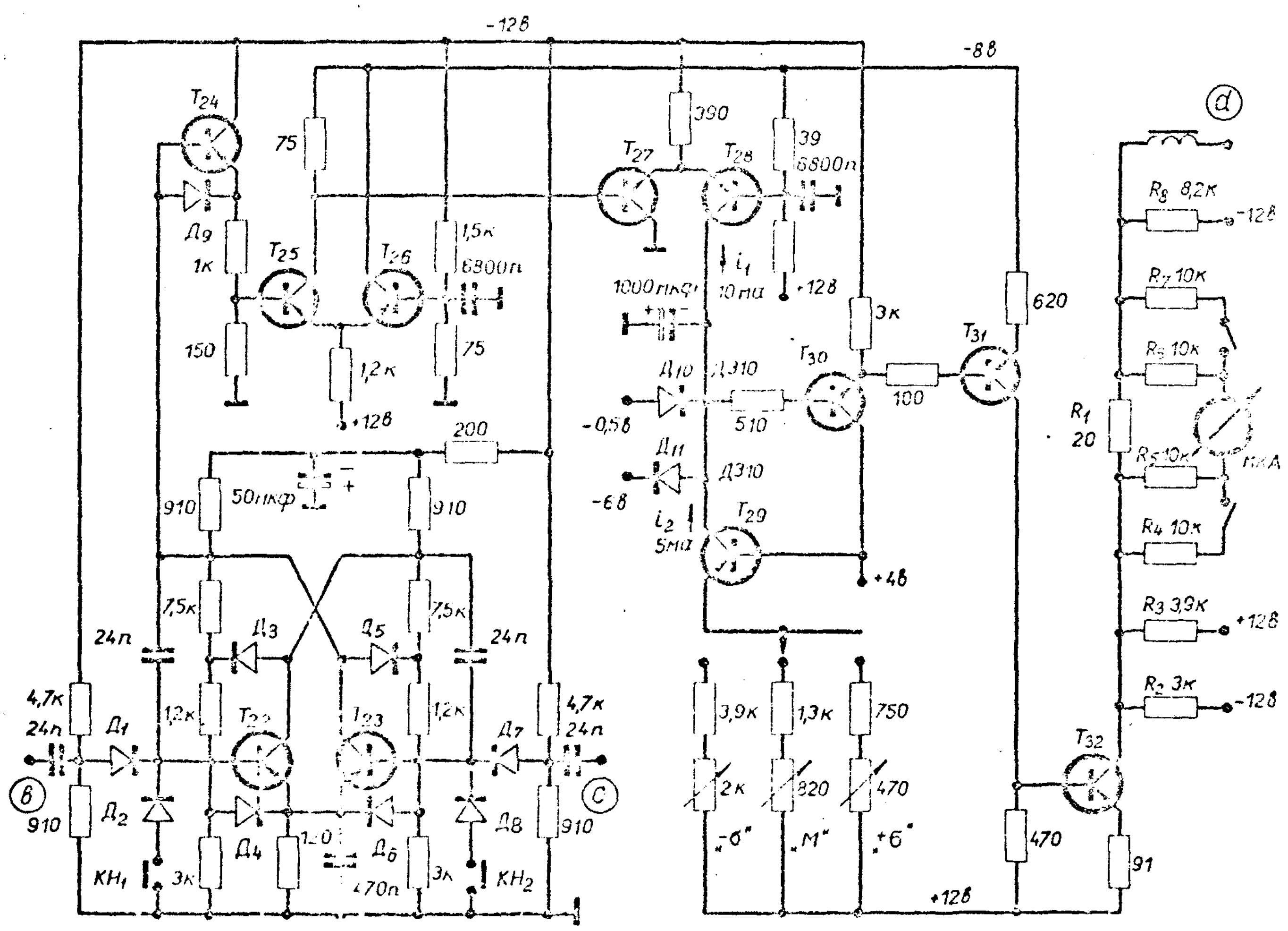

Fig. 5 Schematic circuit diagram for the trigger, current generators 1 and 2 and buffer circuit.

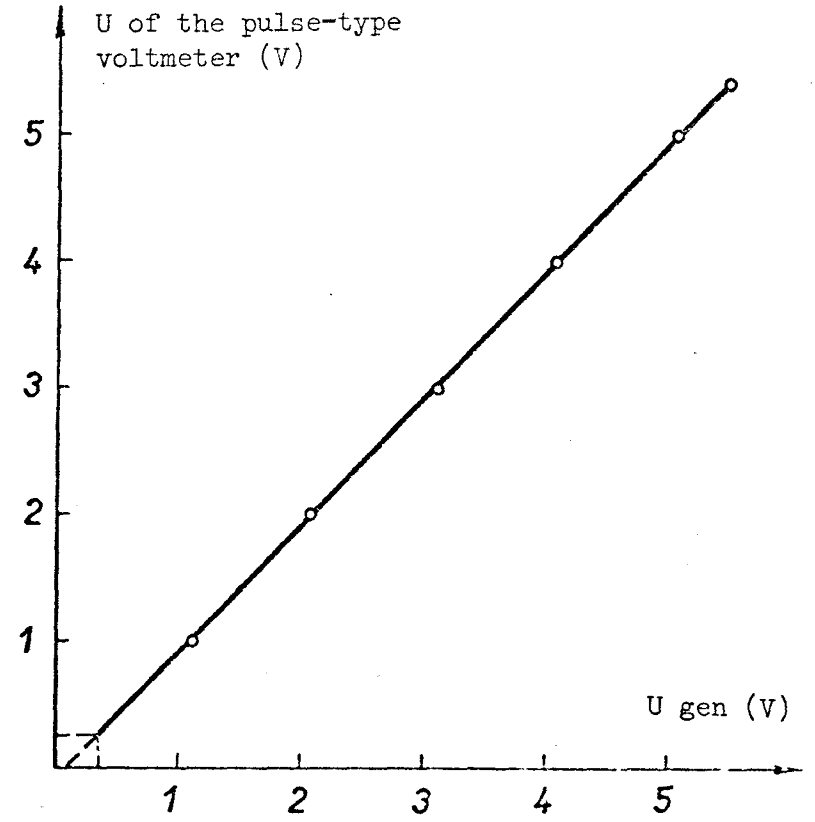

Fig. 6 Dependence of the readings of the pulse-type voltmeter on the amplitude of the input pulses.

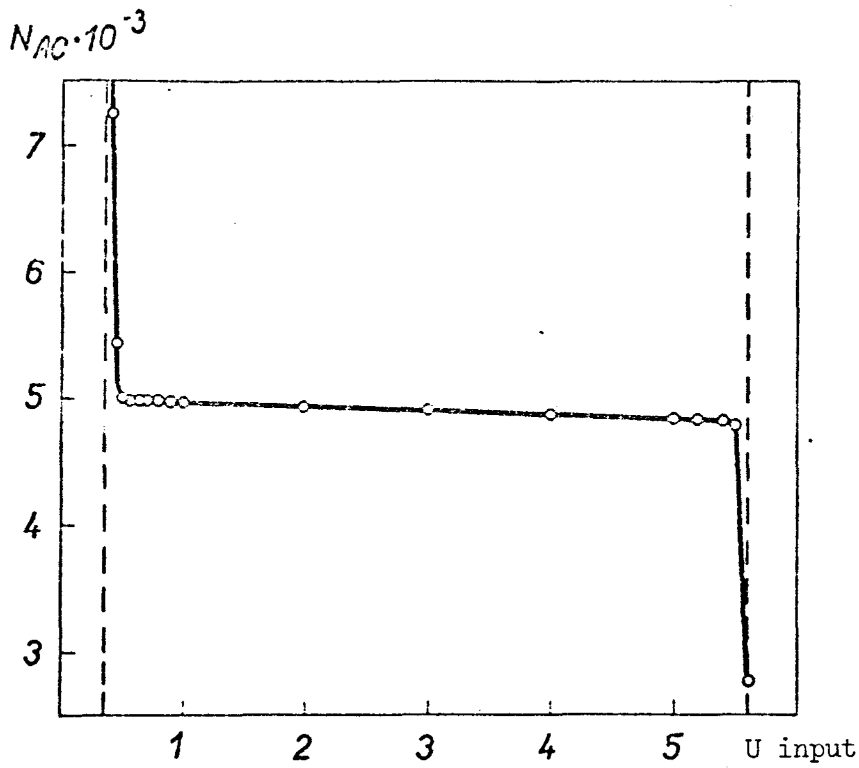

Fig. 7 Dependence of the count, at the output of the anti-coincidence circuit, on the amplitude of the output pulses.