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ELECTRONIC APPLICATION AND VALVE REPORT

Algob - 62

E IV 6201

LABORATORY: Development Gas-Discharge Tubes

GROUP : Electronic Tube Division

AUTHOR : P.H.G. van Vlodrop

DATE : 25.1.1962

TITLE : Self-counting circuit for the decade indicator tube Z 550-M.

Proj.nr.: 2013/52.

SUMMARY

The present report describes a circuit in which the decade indicator tube Z 550 M is used as an active counting tube.

The maximum counting speed for this simple self-counting circuit is 1 to 2 kc/s. Scalers with a high counting rate may now be designed in the following way.

a) With transistor decades with the Z 550 M, merely acting as indicator tube for all decades with a counting speed $>$ 1 kc/s.

b) With self-counting circuits for the Z 550 M with only one transistor as a pulse-amplifier for all decades with a counting speed $<$ 1 kc/s.

P.H.G. van Vlodrop

Appr.:

Ir. D.A. v.d. Berg

Self-Counting Circuit for the Decade Indicator Tube

Z 550 M

(Group Notebook 1961 J. Thaens - sheets 64-67.)

Introduction

The Z 550 M is a cold cathode gas-filled decade numerical indicator tube with figures 0 to 9 in red neon colour. The tube is developed for use as an indicator that requires a bias of less than five volts at 50 μA to switch the discharge. The tube will be used in solid-state scalers, and industrial counting devices and operates directly off commonly used low voltage transistors without intervening circuits or costly high voltage transistors. The max. counting frequency is determined by the scaler elements and is not influenced by the indicator tube. The tube is fed with a full-wave rectified unsmoothed voltage. This causes a periodic extinction of the discharge, which is essential to displace the discharge from one position to another. It is immaterial whether or not the tube can follow a rapid counting operation, because upon the next reignition after the completion of the counting operation, the tube always ignites at the position corresponding to the final result of the count.

It is, however, also possible to use the tube in a simple circuit as an active counting element. The resolution of the tube is then limited by the deionisation time of the discharge. The maximum speed in a self-counting circuit is about 1 - 2 kc/s.

Description of the Tube

The tube contains an anode, a cold cathode and ten starters. The cathode is ring-shaped and has ten evenly spaced holes into which the starter electrodes are placed. The anode consists of a ring above and a ring below the cathode. The upper anode is provided with cut-out figures 0 to 9 that can be read through the dome of the glass-envelope because of the glow behind them. The molybdenum cathode ring is divided into ten sectors by means of a material with a higher work function. If the discharge current is not higher than Ik max. only one cathode sector is covered.

Operating Circuit for the Z 550 M used for Indication

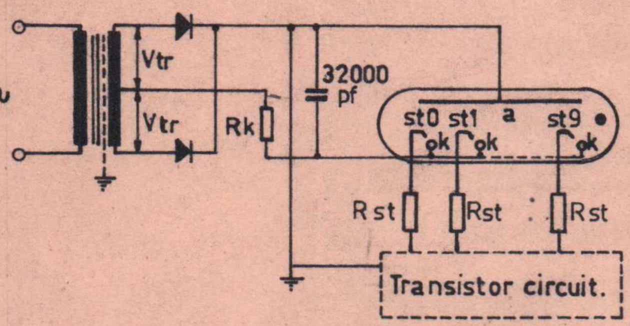

FIG.1.

Fig. 1 shows the circuit. The tube is fed with a full-wave rectified unsmoothed a.c. voltage. A discharge is initiated when the ignition voltage is reached and extinguished when the voltage drops below the burning voltage. Suppose the starters are at the same potential as the anode as long as there is no discharge present. The ignition voltage between a starter and cathode is lower than the ignition voltage between anode and cathode. Therefore the discharge is initiated between one of the starters and the cathodes. If that auxiliarly discharge is high enough, the anode takes over the discharge almost immediately. The cathode section in which the discharge occurs is selected by making the potential of the relevant starter at least 5 V higher than that of the other starters. As a result of this, the corresponding starter reaches the breakdown voltage earlier than the others and the discharge occurs at the required place. The common starter bias may deviate by a maximum of Vn = ± 5 V from the anode potential. When the anode voltage is more than 5 V higher than the common starter, there may be a breakdown directly between anode and cathode before one of the starters has reached its breakdown voltage. When the anode voltage is more than 5 V lower than the common bias of the starters, the anode may fail to take over when the starter discharge occurs. After a short delay other starters will ignite and the anode may take over at a wrong place. The capacitor C prevents the tube from being ignited by random pulses of the mains.

The Z 550-M as active counting Tube

Principle

The tube may be regarded as a combination of ten gas-diodes in one envelope. The starters may be used as anodes while the cathode ring is divided into ten sections. The difference between ignition- and burning voltage of a starter and the cathode is about 25 V. This voltage difference decreases to about 17 V due to priming for the diodes on either side of an ignited cathode section. A part of this voltage difference e.g. 9 V may be used as bias for the ignition of the next diode in a self-counting circuit. The principle is shown in fig. 2.

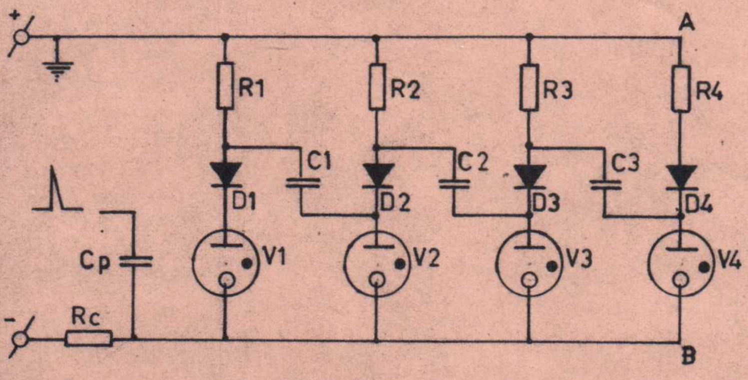

FIG. 2.

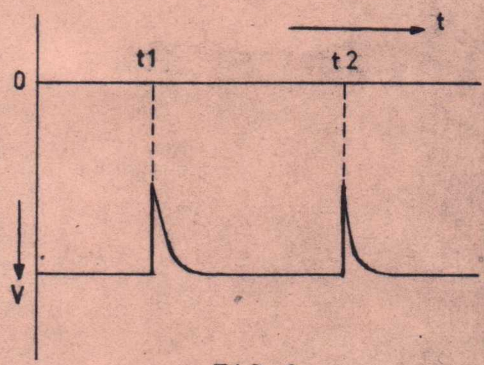

FIG. 3.

Each gas-diode is fed in series with a resistor and a germanium-diode. The common line A is connected to the positive terminal of the D.C. supply and the cathode sections are connected in series with a resistor Rc to the negative terminal. The interconnection of resistor and germanium diode is connected to the anode of the next gas-diode in series with a capacitor. Suppose tube V2 is ignited and the voltage drop across R2 becomes 9 V. Fig. 3 shows the voltage present between the lines A and B. At the moment t1 the tube V2 is extinguished by a positive pulse applied to the common cathode line via capacitor Cp. The amplitude of the pulse must be such that the voltage between lines A - B drops below the burning voltage of the tube. At the moment the tube is extinguished the voltage at the side of D2 increases about 9 V. This increase is also present at the anode of tube V3 due to capacitor C2. The voltage at the anode of V3 becomes +9 V in respect to line A. The diode D3 is reversed biased for this voltage and prevents discharging of C2. The same rise in voltage would be present at the anode of tube V1 but C1 discharges in series with the resistors R1 and R2. Meanwhile the voltage present between the lines A and B increases according to the time constant RcCp. Then the tube V3 will ignite, because the anode of V3 has a bias of +9 V in respect to the other anodes. At the moment t2, tube V3 will be extinguished and tube V4 will be ignited, etc. The inverse current (-Id) of the germanium diodes at higher temperatures will not easily influence the correct working for:

1. The bias is only necessary during the counting pulse. A pulse time of RcCp of 0,85 msec has proved to be a safe value.
2. The available bias is about 9 V, which is almost twice the value necessary for controlling the tube (min. bias +5 V).

Fig. 4 shows a circuit for forward and backward counting.

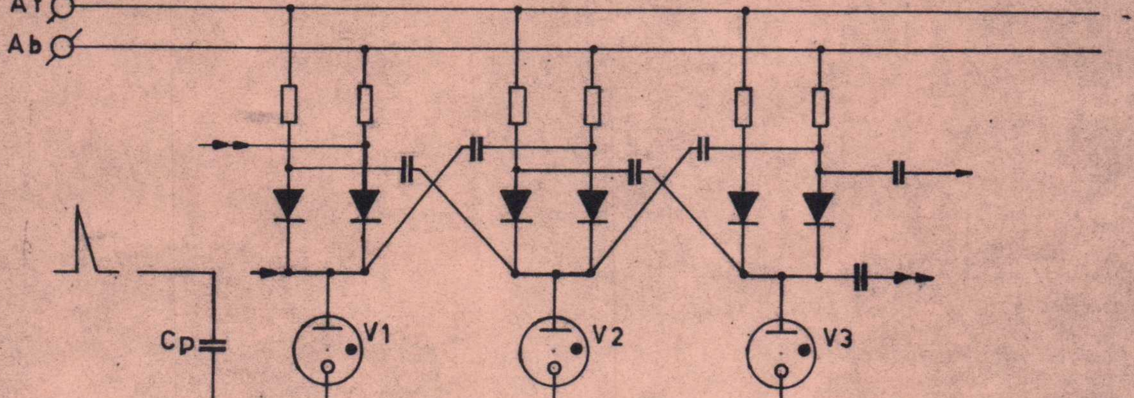

FIG.4.

For forward counting the voltage at line Af must be at least 9 V higher as the voltage at line Ab. During backward counting the voltage at line Ab is 9 V higher. In both cases counting takes place by applying positive going pulses to line B.

Self-Counting Circuit with Z 550 M

Fig. 5 shows the circuit with a transistor for coupling to the next decade. The counting circuit is equal to that of fig. 2. For counting the transistor is bottomed via a negative going pulse at the base. The voltage rise of the collector is applied to the cathode of the tube V, via the capacitor C1, which will be extinguished. As already described the next cathode section will ignite during the decreasing of the cathode voltage. The collector voltage is determined by the voltage divider of the resistors R2 and R4.

$$Vc = \frac{R4}{R4 + R2} \times Vb = 38 \text{ V}$$

The pulse time at the cathode may be expressed by the formula:

$$t_p = RC \ln \frac{Vo - Varc - Vbias + Vc}{Vo - Vign + V_{bias}} = 182 \,\mu\text{sec}$$

in which:

$R = R3 = 39$ Kohm

$C = C1 = 22$ KpF

Vo is the supply voltage (-250 V)

Vign is the ignition voltage between a starter and cathode (99 V)

Vbias is the voltage over a starter resistor (9 V)

Varc is the burning voltage between starter and cathode (80 V)

Vc is the collector voltage of the transistor immediately before bottoming (38 V)

The negative voltage at the cathode, originating from the collector when the transistor is cut off, is damped by the capacitor C2. The capacitor C2 is normally charged to a voltage equal to the burning voltage and the voltage drop across one of the starter resistors. Without damping the negative pulse at the cathode a false cathode section may ignite. A second function of capacitor C2 is to protect the transistor against high transient voltage during switching on.

Transients are also damped when a tube is taken off during the time the circuit is switched on.

Coupling to the next Decade and resetting

Resistor R7 is connected to the base of the transistor of the second decade in series with resistor R8. The decades are reset by applying a positive pulse to resistor R7. The amplitude and width of the reset pulse must be sufficient to ignite the relevant section and to produce a sufficient rise of the common cathode potential to extinguish the ignited section. The diodes D2 prevent the anodes of the decades from being coupled via the resistors R6.

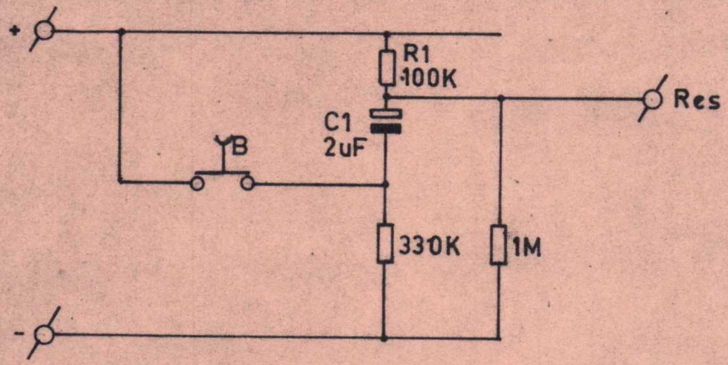

FIG.6.

Fig. 6 shows a reset circuit. When the button B is pressed the capacitor C1 discharges and a positive voltage is produced across resistor R1. Terminal Res. is connected to all reset terminals of the counting circuits.

Graphs

Figs. 7 - 10 show some graphs of a scaler with tubes Z 550-M in the self-counting circuits as shown in fig. 5. The graphs are taken at a counting rate of 1000 c/s. Fig. 7 shows the voltage present between point P and Q. At A the transistor is bottomed and the tube extinguished. The voltage drop is only 30 V instead of 38 V as calculated before because at a counting rate of 1000 c/s capacitor C1 is not fully discharged. At B diode D opens and the rise of the voltage across the tube increases at a lower rate. The voltage drop at the range C is caused by the ignition of the tube. A slight variation is present due to differences in ignition voltage and delay time.
Fig. 8 shows the voltage drop across resistor R7 (fig. 5). At A the

tube ignites (e.g. section 0) and at B the tube is extinguished. At C the tube ignites at section 1. The negative going pulse is passed via the coupling capacitor C4. At D the tube is extinguished again and the voltage rise at starter 1 is passed via the coupling capacitor C4. At E section 2 extinguishes and a smaller positive pulse is present across resistor R7 via two coupling capacitors C4 and C5 in series. The negative pulse at F is produced at the moment the foregoing section 9 ignites and the negative voltage drop across R17 is passed via C3 and D3 in series. The whole cycle is repeated each 10 pulses. Fig. 9 shows the voltage present across the tube in series with resistor R7 and diode D3 of the second decade. This graph corresponds with the graph of fig. 7, but now the positive pulse A for extinguishing the tube is followed by a smaller one B. This may be explained as follows. The input terminal of the second decade is connected to the pulse output of the first decade (shown in fig. 8). The second pulse B (fig. 9) is caused by a negative pulse (pulse C in fig. 8). The amplitude of pulse B (fig. 9) is not sufficient and the pulse duration is too short to cause failures.
Fig. 10 shows the voltage across collector-emitter of the transistor.

Technical Data

Freq.	:	1 Kc	
Supply voltage	:	250 V ± 10 %	
Input pulse	:	Amplitude	0,5 V ± 20 %
		Width	200 μsec ± 20 %

Conclusion

It is simplerto use the tube in a self-counting circuit for frequencies up to 1 Kc, than using a more complicated transistor scaler.

Due to the low voltage input pulse the circuit may be easily coupled to transistor scalers. Therefore a scaler may be designed with transistor circuits and the Z 550 M as an indicator tube for the high speed decades combined with selfcounting circuits for the low speed decades.

P.H.G. van Vlodrop

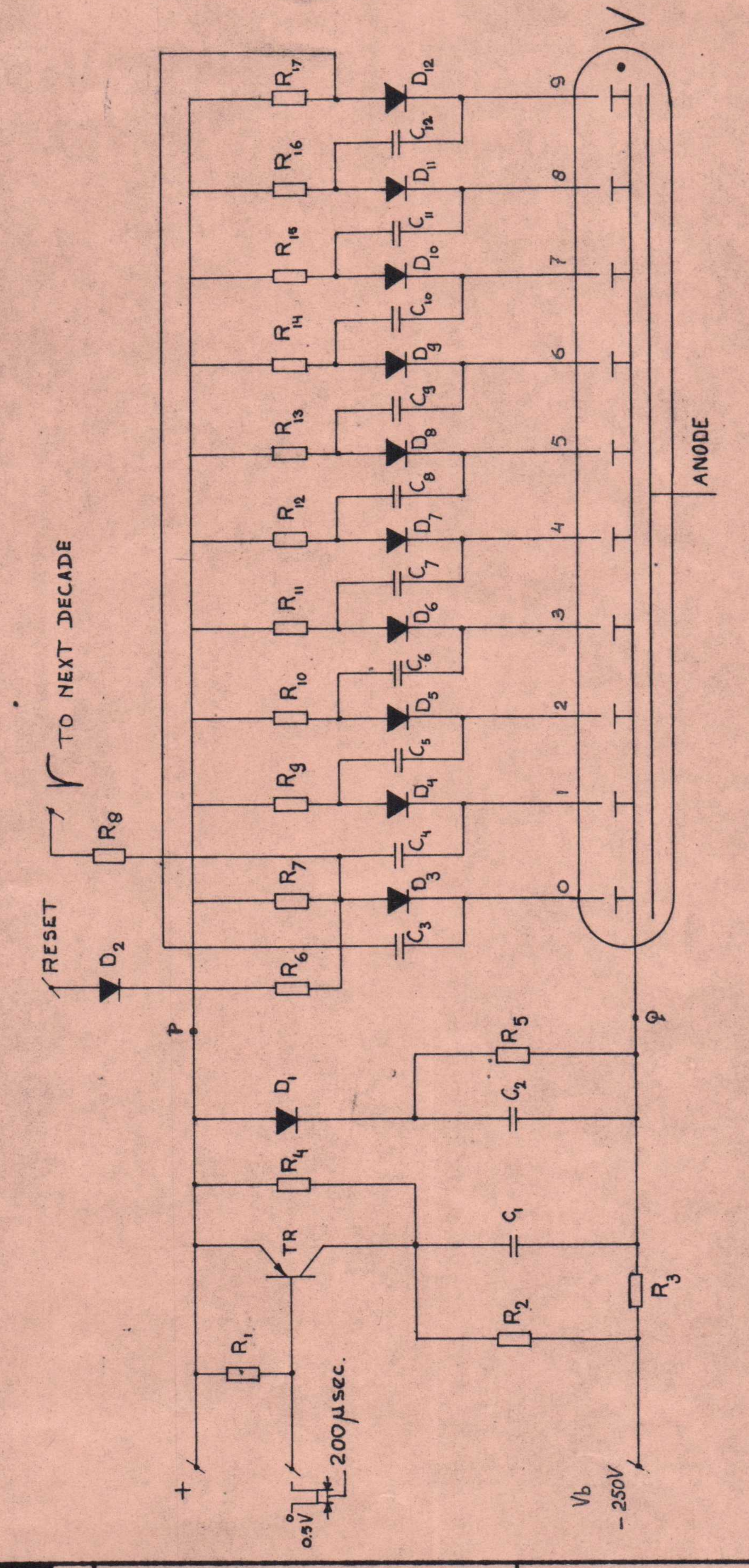

fig. 5.

Self-counting circuit for tube Z550M

1A 561 77

(2 BL. SH.P.) BL. SH.P. 1

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Circuit nr.	Description	Code nr.
R1	Carbon resistor 1,2 Kohm $\frac{1}{4}$W	B8 305 05B/1K2
R2	Carbon resistor 150 Kohm $\frac{1}{2}$W	B8 305 06B/150K
R3	Carbon resistor 39 Kohm 1W	B8 305 07B/39K
R4	Carbon resistor 27 Kohm $\frac{1}{2}$W	B8 305 06B/27K
R5	Carbon resistor 470 Kohm $\frac{1}{4}$W	B8 305 05A/470K
R6	Carbon resistor 10 Kohm $\frac{1}{2}$W	B8 305 06A/10K
R7	Carbon resistor 2,2 Kohm 0,1W	B8 305 00A/2K2
R8	Carbon resistor 22 Kohm $\frac{1}{4}$W	B8 305 05A/22K
R9–R17	Carbon resistor 2,2 Kohm 0,1W	B8 305 00A/2K2
C1	Polyester capacitor 22 kpF	C 296 AC/A22K
C2	Polyester capacitor 56 kpF	C 296 AC/A56K
C3–C12	Ceramic capacitor 10 kpF	C 318 BA/A10K
D1	Germanium diode	OA 95
D2	Germanium diode	OA 95
D3–D12	Germanium diode	OA 95
TR	Transistor	OC 77
V	Numerical indicator tube	Z 550 M

Self-counting circuit for tube Z550M.

1A 561 77

(2 BL. SH.P.) BL. SH.P. 2

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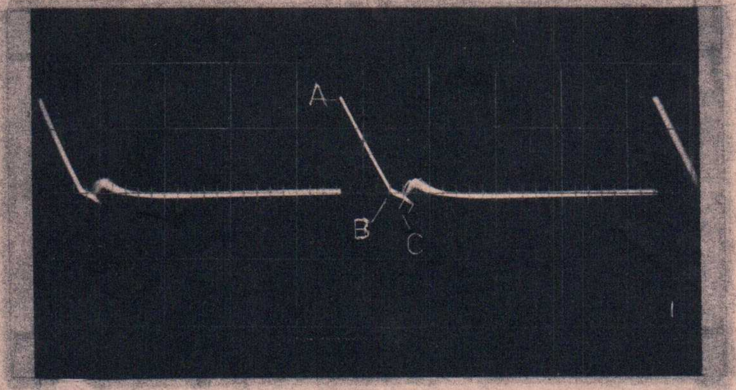

Fig. 7

Hor.: 0,2 msec/cm.
Vert,: 20 V/cm

The voltage present between point P and Q

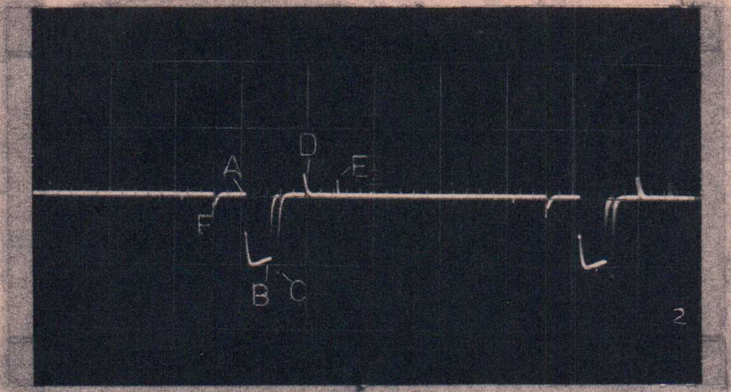

Fig. 8

Hor.: 2 msec/cm
Vert.: 10 V/cm

The voltage drop across anode resistor R7

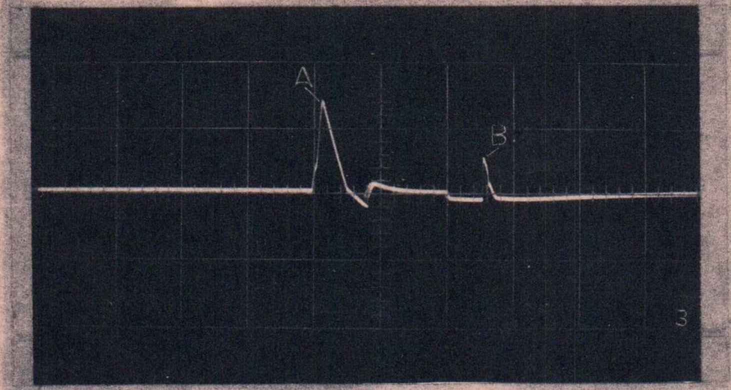

Fig. 9

Hor.:0,4 msec/cm
Vert.: 20 V/cm

The voltage across the tube in series with resistor R7 and diode D3 of the second decade.

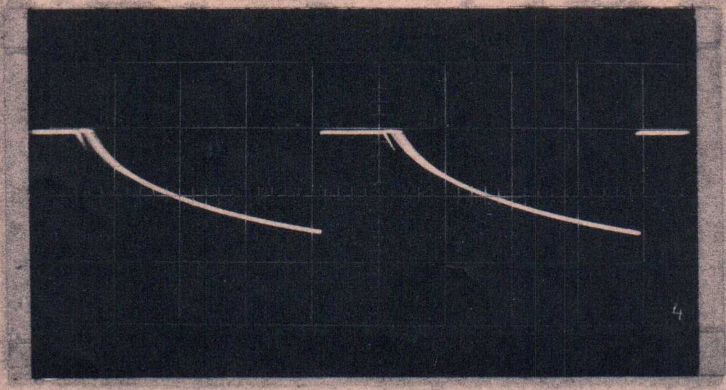

Fig. 10

Hor.:0,2 msec/cm
Vert.: 20 V/cm

The voltage across collector-emitter of the transistor. V_{CE}