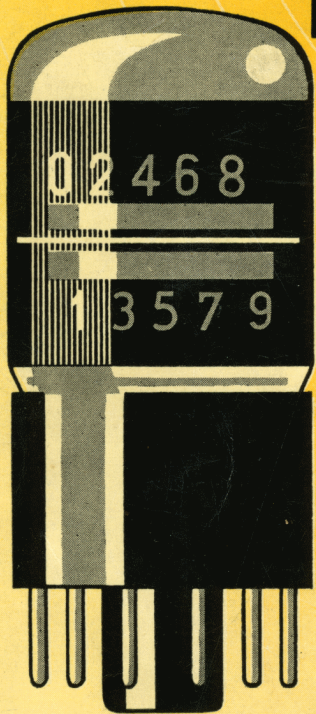
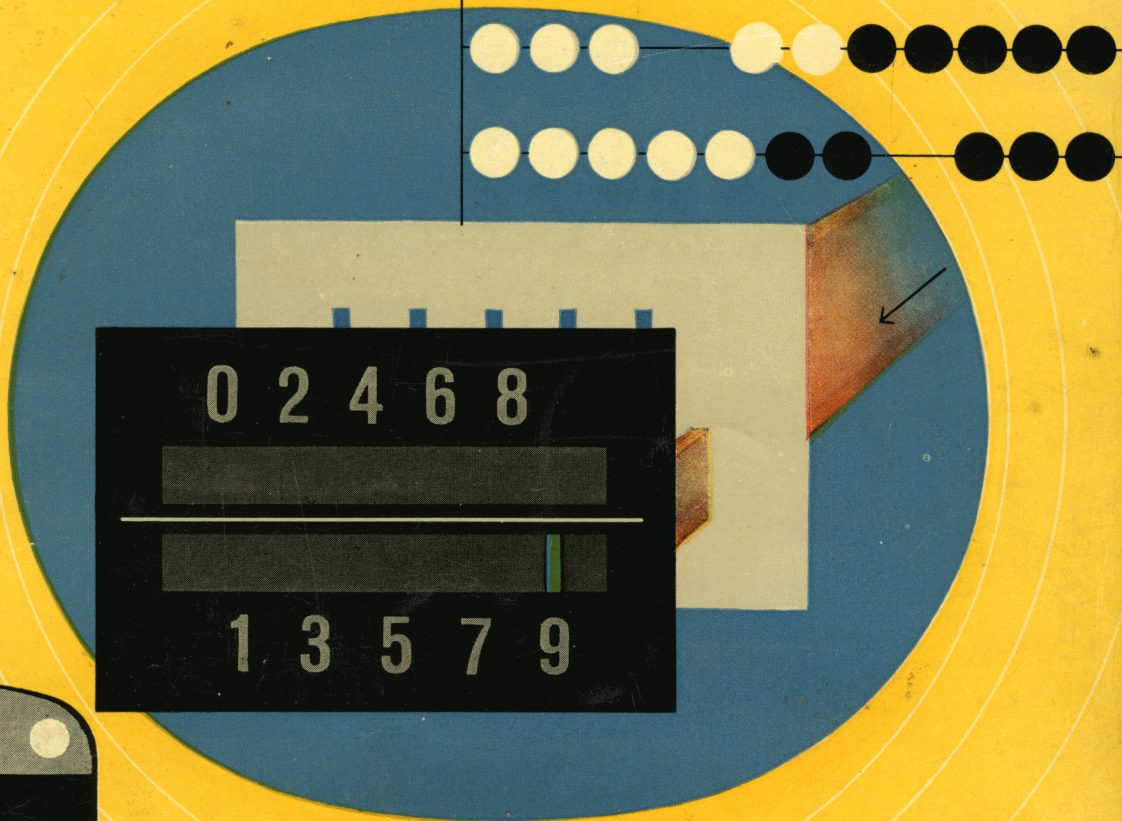


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# PHILIPS



# E1T

## Decade Counter Tube



The E1T Decade Counter Tube

*The information given in this  
Bulletin does not imply a  
licence under any patent*

# THE E 1 T DECADE COUNTER TUBE

## INTRODUCTION

*The E 1 T decade counter tube is a typical example of an electronic tube that has been specially designed for solving a particular problem, namely the counting and indicating of electric pulses, replacing in this way a considerable number of tubes with their accessory components, indication devices, etc.*

*The E 1 T is, in fact, a cathode-ray tube having roughly the dimensions of a radio receiving tube and operating with a supply voltage of 300 V only. According to the number of counting pulses applied, its ribbon-shaped electron beam is shifted in a horizontal plane and passes in succession through the ten apertures of a cylindrical anode, thus impinging on the fluorescent layer with which the envelope is lined. The number of pulses can thus be read on the outside of the envelope, a rectangular luminescent spot appearing opposite one of the figures 0 to 9 indicated on the circumference of the bulb.*

*As the last position is passed, the beam is reset to its zero position and a counting pulse is applied simultaneously to the following tube. With several E 1 T tubes in cascade, any number can thus be directly read, the first tube counting the units, the second the decades, the third the hundreds, etc.*

*The features of the E 1 T render this decade counter tube particularly suitable for those applications where small dimensions, high counting speeds and reliability of operation are required, such as in telecommunication, in modern computers, in radiation counter apparatus, in industrial counting devices and for indication, control and memory purposes.*



## DESCRIPTION

### Constructional details

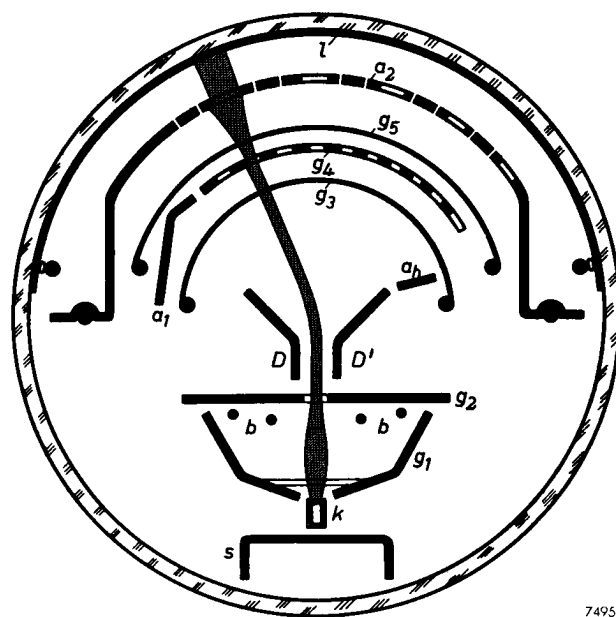
Fig. 1a shows the cross-section of the tube and fig. 1b the diagrammatic representation. The letter references are as follows:

- f* = heater,
- k* = cathode
- s* = screen,
- g*<sub>1</sub> = control grid,
- b* = beam-forming electrodes,
- g*<sub>2</sub> = accelerating electrode,
- D* = left deflection electrode,
- D'* = right deflection electrode,
- a*<sub>h</sub> = auxiliary anode,
- g*<sub>3</sub>, *g*<sub>5</sub> = suppressor grids,
- g*<sub>4</sub> = slotted electrode,
- a*<sub>1</sub> = reset anode,
- a*<sub>2</sub> = anode,
- l* = conducting layer coated with fluorescent material.

The 6.3 V, 0.3 A heater *f* is mounted in a rectangular cathode *k*, the front of which is oxide-coated. The electron beam is given the required shape by the action of the control grid *g*<sub>1</sub>, the internally connected beam-forming electrodes *b* and the accelerating electrode *g*<sub>2</sub>.

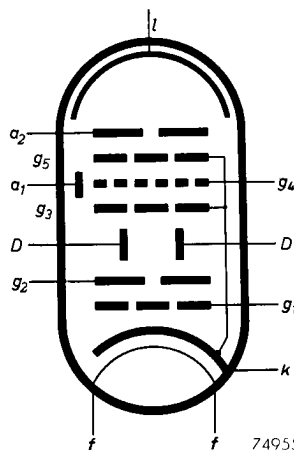
Since the deflection of the electron beam should take place in the horizontal plane only, the use of a narrow, ribbon-shaped beam of relatively great height offers substantial advantages. Space-charge effects are greatly reduced, for it will be clear that at given operating voltages the required total beam current and resolving power of the beam can be obtained at a much smaller current density with a ribbon-shaped beam than with a beam having a circular cross-section. A large current intensity is desirable because the duration required for an "electronic event" is, in general, proportional to the ratio  $VC/I$ , where  $V$  is the potential difference traversed by the electrons,  $I$  the current intensity and  $C$  the interelectrode capacitance. In order to keep this duration short, it is thus favourable that with a ribbon-shaped beam  $V$  can be kept relatively small, whereas  $I$  may assume a fairly large value. The small dimensions of the electrode system are, moreover, conducive to keeping the interelectrode capacitances small.

It has in this way proved possible to obtain a beam current of about 1 mA at a voltage of 300 V only, and to give the tube dimensions similar to



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a



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b

Fig. 1. (a) Cross section of the EIT counter tube. (b) Diagrammatic representation of the electrode system. For the letter references see text.

those of normal receiving tubes (max. diameter 36 mm and max. height 83 mm). A further advantage of using a ribbon-shaped beam is that the electrode system need only be aligned accurately in one dimension, namely in the direction normal to the plane of the beam.

The beam, which is shifted from its initial position at the extreme right (position 0) to the left by applying positive pulses to the left deflection electrode *D*, has ten stable positions in each of which it passes through one of the ten apertures of the slotted electrode *g*<sub>4</sub>. In these circumstances some of the electrons pass also through one of the corresponding narrow slots in the anode *a*<sub>2</sub> and impinge on the fluorescent material with which the

envelope is lined, so that a luminescent mark appears opposite the corresponding figure on the mask fixed on the outside of the envelope.

When the beam is deflected beyond the last stable position (marked "9") it strikes the reset anode  $a_1$ . The reset anode current pulse thus produced triggers a monostable (one-shot) multivibrator, by means of which the beam is reset to its zero position and a counting pulse is fed to the following EIT tube.

The suppressor grids  $g_3$  and  $g_5$  and the screen  $s$ , which are internally connected to the cathode, serve for suppressing any disturbing effects which might otherwise be caused by secondary emission from the slotted electrode and the anode. The auxiliary anode  $a_h$ , which is internally connected to the accelerating electrode  $g_2$  (+300 V), serves for capturing undesired stray electrons. In order to prevent the fluorescent screen from being charged by the impinging electrons, it is applied to a conducting layer  $l$  which should be connected to the H.T. line.

### Tube characteristic

When in the circuit shown in fig. 2 the anode current  $I_{a2}$  is plotted as a function of the anode and right-hand deflection electrode voltage  $V_{D',a2}$ , the static  $I_{a2} = f(V_{D',a2})$  characteristic is obtained.

In order to explain the significance of this characteristic and the principle on which the opera-

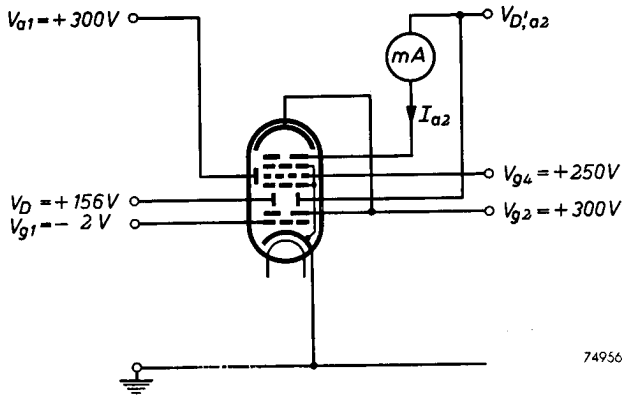


Fig. 2. Circuit for measuring the  $I_{a2} = f(V_{D',a2})$  characteristic.

tion of this tube is based, the influence of the various electrodes on the electron beam will be discussed.

It will be assumed that the following voltages are applied in the circuit shown in fig. 2: slotted electrode voltage  $V_{g4} = 250$  V; reset anode voltage  $V_{a1} = 300$  V; left deflection electrode voltage  $V_D =$

156 V; control-grid voltage  $V_{g1} = -2$  V. The variable voltage  $V_{D',a2}$  on the anode and right deflection electrode (these electrodes are externally interconnected) is assumed to have an initial value of 300 V. The anode current  $I_{a2}$  can be read on the milliammeter.

Provisionally it will be assumed that the slotted electrode  $g_4$  is provided with a number of identical and equidistant, rectangular slots, as shown in fig. 3. In its initial position the beam  $b$  will be

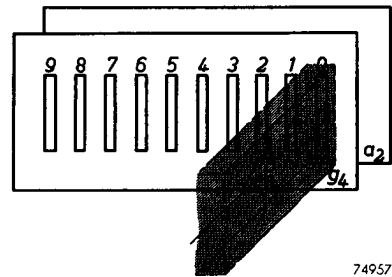


Fig. 3. Diagrammatic representation of a ribbon-shaped beam  $b$  sweeping over a slotted electrode  $g_4$  interposed between the cathode and the anode  $a_2$ .

focused on slot number 0, so that most electrons proceed towards the anode, and  $I_{a2}$  is at a maximum. A decrease of the right deflection electrode and anode voltage  $V_{D',a2}$  will cause the electron beam to be less attracted by the right deflection electrode  $D'$ , so that it will move to the left and a steadily increasing number of electrons will be intercepted by  $g_4$ . When the beam impinges on the centre of the area between slots number 0 and 1, the anode current  $I_{a2}$  is at a minimum, since only comparatively few electrons can now pass  $g_4$ . A further decrease of the voltage  $V_{D',a2}$  will shift the

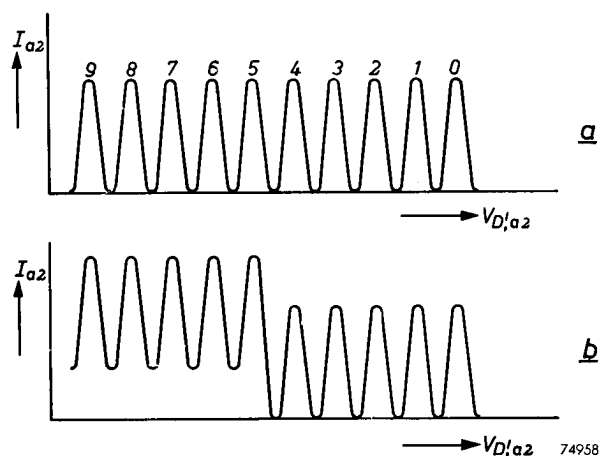


Fig. 4. (a) Hypothetical  $I_{a2} = f(V_{D',a2})$  characteristic of a tube provided with a slotted electrode  $g_4$  with identical, equidistant slots according to fig. 3. (b) As fig. 4a, but taking into account the presence of a horizontal slot at the bottom left.

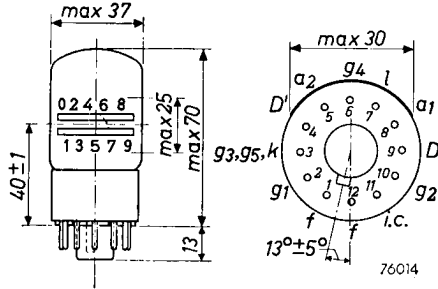
beam further to the left, so that the electrons can pass slot number 1, and  $I_{a2}$  again increases.

Proceeding further on its way to the left the action would be repeated as represented in fig. 4a. However, owing to a horizontal slot at the bottom left in  $g_4$ , the anode current will not actually drop back to its initial minimum value once it has passed slot number 5, since some of the electrons will then

always pass through the horizontal slot, so that a curve similar to that shown in fig. 4b is obtained. To avoid trouble being experienced as a result of the asymmetrical deflection ( $V_D = \text{constant}$ ,  $V_{D'} = \text{variable}$ ) and the unavoidable defocusing which occurs when the beam is deflected, the slots in  $g_4$  are given different widths and the actual characteristic assumes a somewhat different form.



# TECHNICAL DATA



- f* = heater,
- k* = cathode,
- g*<sub>1</sub> = control grid,
- g*<sub>2</sub> = accelerating electrode,
- D* = left deflection electrode,
- D'* = right deflection electrode,
- g*<sub>3</sub>, *g*<sub>5</sub> = suppressor grids,
- g*<sub>4</sub> = slotted electrode,
- a*<sub>1</sub> = reset anode,
- a*<sub>2</sub> = anode,
- l* = conducting layer,
- i.c.* = internally connected.

## TUBE OUTLINE AND ELECTRODE CONNECTIONS OF THE E 1 T COUNTER TUBE

### Heater data

#### Supply

Heater voltage . . . . .  
 Heater current . . . . .

Indirect by A.C. or D.C.;  
 series or parallel supply  
 $V_f = 6.3 \text{ V} \pm 10\%$   
 $I_f = 0.3 \text{ A}$

### Operating characteristics

Supply voltage . . . . .  
 Cathode current . . . . .  
 Cathode resistor . . . . .  
 Control grid voltage . . . . .  
 Accelerating-electrode voltage . . . . .  
 Left deflection electrode voltage . . . . .  
 Slotted-electrode resistor . . . . .  
 Conducting-layer voltage . . . . .  
 Anode resistor . . . . .  
 Reset-anode resistor . . . . .  
 Accelerating-electrode current . . . . .

$V_b = 300 \text{ V}^*)$   
 $I_k = 0.95 \text{ mA}$   
 $R_k = 15 \text{ k}\Omega \pm 1\%$   
 $V_{g1} = 11.9 \text{ V}^*) \pm 0.15 \text{ V}$   
 $V_{g2} = 300 \text{ V}^*)$   
 $V_D = 156 \text{ V}^*) \pm 1.5 \%$   
 $R_{g4} = 47 \text{ k}\Omega \pm 5\%$   
 $V_l = 300 \text{ V}^*)$   
 $R_{a2} = 1 \text{ M}\Omega \pm 1\%$   
 $R_{a1} = 39 \text{ k}\Omega \pm 10\%$   
 $I_{g2} = 0.1 \text{ mA}$

### Capacitances

Anode capacitance . . . . .  
 Left deflection electrode capacitance . . . . .  
 Right deflection electrode capacitance . . . . .  
 Reset anode capacitance . . . . .  
 Control grid capacitance . . . . .  
 Slotted electrode capacitance . . . . .

$C_{a2} = 10.5 \text{ pF}$   
 $C_D = 3.5 \text{ pF}$   
 $C_{D'} = 3.8 \text{ pF}$   
 $C_{a1} = 4.9 \text{ pF}$   
 $C_{g2} = 6.8 \text{ pF}$   
 $C_{g4} = 7.7 \text{ pF}$

\*) All voltages are quoted with respect to the chassis. Provided the ratios of the supply voltages are strictly maintained by using a suitably designed voltage divider consisting of 1% precision resistors, there is no need to stabilize the supply unit, voltage fluctuations of  $\pm 10\%$  then being permissible. It should be borne in mind however that during life a change may occur as a result of lack of stability of the resistors.

### ***Sensitivity to magnetic fields***

Care should be taken to prevent magnetic fields from upsetting the operation of the counter tube, the electron beam being sensitive to the influence of external fields. The flux density of these fields should not exceed  $2 \times 10^{-4}$  Wb/m<sup>2</sup> (= 2 gauss) in any direction.

### ***Ambient illumination***

In order to obtain a clear reading, the ambient illumination should range from 40 lux to 400 lux, to be measured by means of a luxmeter, set up vertically. At too low a value of the ambient illumination it may become difficult to read the figures on the masks of the counter tubes and some inconvenience may occasionally be experienced by the

two neighbouring spots showing some fluorescence. When, on the other hand, the ambient illumination exceeds 400 lux, it may become difficult to discern the luminescent spot.

### ***Mounting position***

Any, except with the tube horizontal and the fluorescent screen downward.

### ***Transport position***

Any, except with the tube horizontal and the fluorescent screen downward.

### ***Socket***

Philips duodecal socket type 5912/20.

## GENERAL CONSIDERATIONS ON THE APPLICATION

### Stability of the beam

The operation of the tube will be explained on the basis of the circuit shown in fig. 5, in which a load resistor  $R_{a_2}$  of 1 M $\Omega$  is included in the common anode and right deflection electrode lead. The load line of this resistor has been drawn in the actual tube characteristic plotted in fig. 6a, which is valid for the voltages stated at the beginning of the preceding section, the H.T. supply voltage being 300 V.

It will be assumed that the beam is in the position corresponding to point *a* of fig. 6a and the voltage on the left deflection electrode *D* is increased so slowly that the influence of the capacitance *C* shown in fig. 5 can be disregarded. This capacitance represents the sum of  $C_{a_2}$  (capacitance of the anode with respect to all other electrodes),  $C_{D'}$  (capacitance of the right deflection electrode with respect to all other electrodes) and the unavoidable wiring and stray capacitances. The electron beam will then tend to move to the left, but this results in the beam being intercepted to a greater extent by the slotted electrode  $g_1$ , so that the anode current decreases, and the anode voltage (and thus also the voltage on the right deflection electrode  $D'$ ) increases by

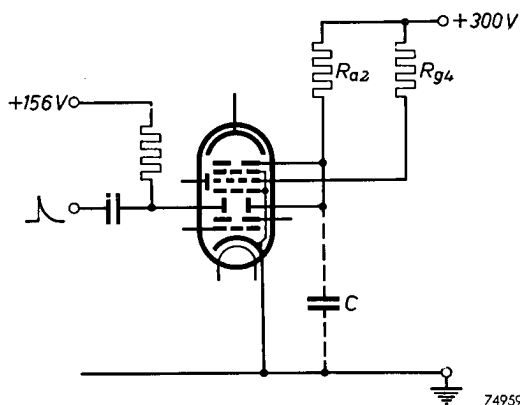


Fig. 5. Circuit for explaining the operation of the EIT counter tube, positive voltage pulses being applied to the left deflection electrode. *C* represents the sum of the capacitance of the anode and of the right deflection electrode with respect to all other electrodes and the wiring and stray capacitances.

practically the same amount as the voltage on the left deflection electrode *D*. The beam therefore remains at practically the same position, any gradual variation of the voltage applied to *D* being counteracted by a corresponding variation of the voltage on  $D'$  due to the stabilizing of  $R_{a_2}$ . This phenomenon may thus be regarded as a form of

negative feedback, the feedback factor being very high.

As a result of a gradual increase of  $V_D$  by, say, 14 V the characteristic will no longer be as depicted in fig. 6a (where  $V_D = 156$  V), but will be shifted in its entirety with respect to the system of coordinates, as shown in fig. 6b (where  $V_D = 156 + 14 = 170$  V). In fact, the position of the electron beam depends in the first instance on the voltage difference between  $V_D$  and  $V_{D',a_2}$ , all other voltages remaining constant.

The situation is fundamentally different when, instead of gradually varying the voltage applied to *D*, a positive pulse with a steep front is fed to this electrode, for now the capacitance *C* comes into play. Due to this capacitance by-passing the load resistor  $R_{a_2}$ , a positive pulse with a sufficiently steep front fed to *D* will no longer be accompanied by a corresponding decrease of the voltage across  $R_{a_2}$ . In fact, this voltage, and hence also the voltage on  $D'$ , cannot closely follow the sudden variation of the voltage applied to *D* and is maintained substantially constant\*) for a short interval (depending on the value of *C*). The beam is therefore displaced towards the left, over a distance corresponding to the amplitude of the pulse.

In order to shift the beam from one stable point of operation to the next, the shape of the pulse must be of the general form indicated in fig. 7. The amplitude of this pulse should be approximately equal to the voltage difference between two stable working points of the characteristic of fig. 6a, that is between the points *a*, *c*, *e*, etc. situated at the intersection of the load line with those parts of the characteristic which have a positive slope. The slope of the leading edge should be at least  $20 \times 10^6$  V/sec, that of the trailing edge should not exceed  $2 \times 10^6$  V/sec. Taking the average amplitude of the pulse to be 13.6 V, the time of rise should therefore have a maximum value of 0.7  $\mu$ sec and the time of fall a minimum value of 7  $\mu$ sec.

The delay with which  $V_{D',a_2}$  follows  $V_D$  due to the presence of the capacitance *C* is large compared

\*) This "stabilizing" effect of *C* on the voltage across  $R_{a_2}$  should not be confused with the stabilizing effect that  $R_{a_2}$  has on the position of the beam. Advantage is taken of the latter effect — which is suppressed during the steep front of the pulse by the presence of *C* — for maintaining the beam at the correct position after it has been displaced.

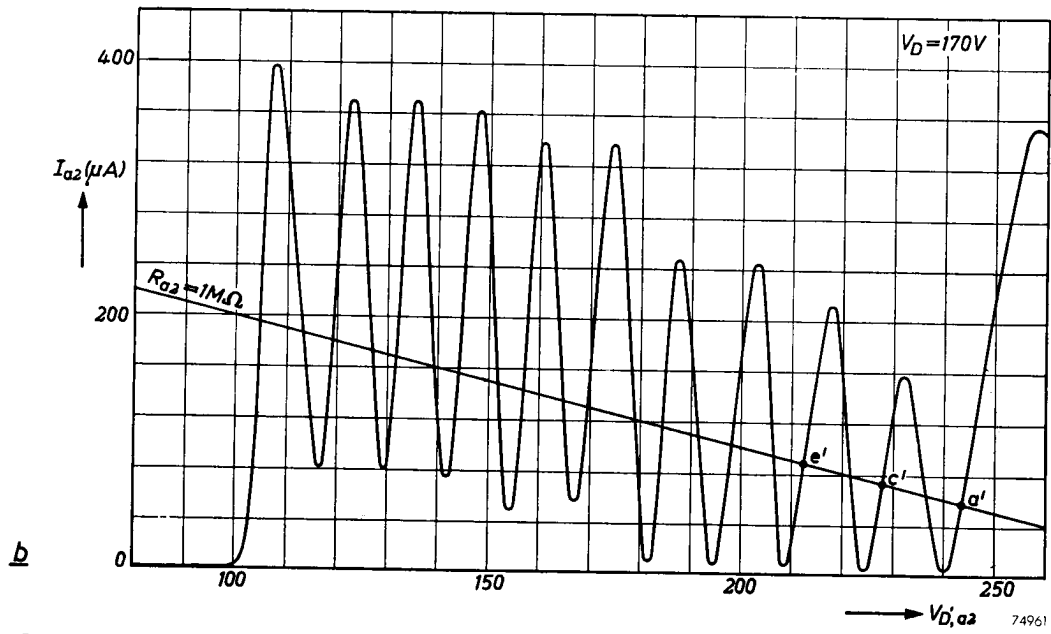
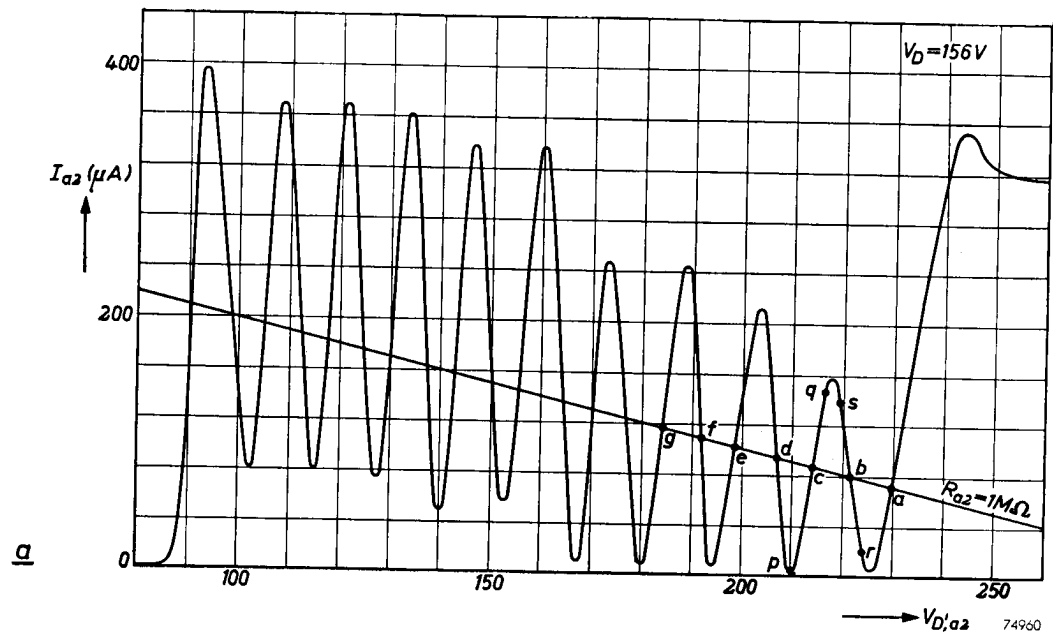


Fig. 6.  $I_{a2} = f(V_{D',a2})$  characteristic for a left deflection electrode voltage  $V_D = 156 V$  (a) and for  $V_D = 170 V$  (b).

with the time of rise of this pulse and small compared with the time of fall. The voltage across  $R_{a_2}$  therefore remains substantially constant during the build-up of the pulse to its maximum value.

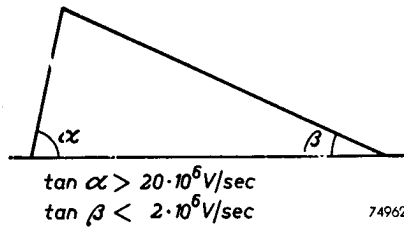


Fig. 7. Required form of the positive pulses to be applied to the left deflection electrode. The slope of the leading edge should be at least  $20 \times 10^6$  V/sec, that of the trailing edge should not exceed  $2 \times 10^6$  V/sec. The average amplitude of the pulse should be 13.6 V.

It is of interest to investigate this mechanism by means of the tube characteristics, fig. 6. It will be assumed that the beam is in its initial position 0, corresponding to point  $a$  of the characteristic, fig. 6a,  $V_{D',a_2}$  being about 230 V and  $V_D$  being 156 V. When  $V_D$  is suddenly increased by a pulse with an amplitude of 14 V to 170 V,  $V_{D',a_2}$  has no time to follow this variation, as explained above. The voltage  $V_{D',a_2}$  thus remains substantially constant at about 230 V, whereas  $V_D$  temporarily assumes a value of 170 V. The beam will thus be shifted to a position corresponding approximately to point  $c'$  in fig. 6b, the characteristic having been rapidly displaced to the right to such an extent that the metastable working point, maintained by the presence of  $C$ , is again situated on a part of the characteristic having a positive slope.

The beam has thus reached the new stable position 1. The decay of the pulse is so slow that the decrease of  $V_{D',a_2}$  can easily keep pace, notwithstanding the presence of  $C$ , and thus drops to about  $230 - 14 = 216$  V, corresponding to point  $c$  in fig. 6a.

Once this voltage has been reached, the tube is ready to receive another pulse by which the beam will be shifted to position 2, corresponding to points  $e'$  and  $e$  respectively in figs 6b and 6a.

It has been assumed so far that the pulse amplitude was such that point  $q$  was reached. When this amplitude is smaller, so that the peak of the pulse corresponds to point  $r$  in fig. 6, for example, the following situation will arise.

When point  $r$  has been reached, the current flowing through  $R_{a_2}$ , which is determined by the voltage drop across this resistor, exceeds the current

actually flowing through the tube, so that the charge of the capacitance  $C$  will increase. Consequently, the voltage drop across  $R_{a_2}$  will gradually decrease and  $V_{D',a_2}$  will rise. A pulse with an amplitude smaller than the voltage difference between the points  $a$  and  $b$  will therefore result in the beam returning to point  $a$ .

Theoretically, a voltage pulse which shifts the beam to a position corresponding to point  $s$  would suffice to displace the beam to point  $c$ , but due to the limited front slope and the trailing edge of the pulse, its amplitude should be slightly higher to ensure reliable operation. On the other hand, the amplitude of the pulse should not exceed the voltage difference corresponding to the distance between the points  $a$  and  $d$ , as can be readily understood. It is clear that point  $b$ , and thus also the points  $d$ ,  $f$ , etc. are unstable, since any small voltage fluctuations will return the beam to the nearest stable points  $a$ ,  $c$ , or  $e$ , etc.

It should be recognized that any tendency of the anode voltage to vary, due to such causes as supply voltage fluctuations, noise, etc. will be counteracted by a corresponding variation of the anode current, so that the position of the beam will not be influenced, once a stable point has been reached. If the supply voltage decreases, so that the beam would be shifted, for example, from the position corresponding to point  $c$  towards point  $p$ , the anode current will decrease, since point  $c$  is situated on a part of the characteristic having a positive slope. For the same reason the anode current will increase with increasing supply voltage. Since the fluctuations are usually relatively slow and of small amplitude, the capacitance  $C$  will have little effect and the current variation will be followed closely by a variation of the voltage drop across  $R_{a_2}$ , so that the beam remains at the position corresponding to point  $c$ .

### Interstage coupling

It has already been explained that there are ten stable points of operation. When suitable positive-going pulses are fed to the left deflection electrode  $D$  of the first counter tube, its beam will move from the right to the left in nine steps, starting from position 0. After nine pulses have been counted the beam will finally arrive at the last stable position. The next pulse will shift the beam to the reset anode  $a_1$ , from which it must be returned to the zero position, so that the counting action can continue. It is mainly the time required for this oper-

ation that determines the counting rate of the complete circuit.

In the circuit to be described in this Bulletin an interstage coupling consisting of a monostable (one-shot) multivibrator is used for rapidly resetting the beam to its zero position. This multivibrator is triggered by the sudden drop of the reset anode voltage caused by the electron beam impinging on this electrode.

A negative-going, trapezoidal, pulse is thus generated by the multivibrator and this resets the beam of the preceding counter tube to its zero position. Simultaneously a positive-going pulse is produced by which the beam of the next tube is advanced one position.

The beam of the preceding counter tube is reset by applying the negative-going pulse thus produced to the control grid  $g_1$ , so that the tube is temporarily cut off. It will be clear that this will result in the voltage on the anode and thus also on the right-hand deflection electrode rising to its maximum value. The anode voltage will, however, not rise suddenly but exponentially, due to the presence of the capacitance  $C$ , and the duration of the pulse cutting off the tube should obviously be so long that at the instant when this pulse ceases, the anode voltage has risen to at least the value corresponding to the zero position of the beam.

If the duration of the pulse cutting off the tube is insufficient, the beam may be reset to any position, so that a safety margin within the minimum duration should be observed. Too long a pulse, on the other hand, increases the reset time.

The minimum reset time  $t$ , which determines the maximum pulse frequency and thus the counting rate, is calculated as follows. When the beam is in position 9 the anode voltage is at the lowest value  $V_{a_2 \min}$  and this should rise to a value  $V_{a_2 \text{ init}}$ , slightly exceeding the value of  $V_{a_2}$  at position 0 of the beam. This gives:

$$V_b - V_{a_2 \text{ init}} = (V_b - V_{a_2 \min}) \cdot \exp. - \frac{t}{R_{a_2 \max} C_{\max}},$$

where  $V_b$  denotes the H.T. line voltage (300 V) and  $C_{\max}$  is the maximum capacitance (16.5 pF) by-passing  $R_{a_2}$  \*).

\*) This capacitance should be reduced to the minimum by keeping the wiring as short as possible and minimizing the stray capacitances, especially the capacitances with respect to  $a_2$  and  $D'$ . The anode load resistor ( $R_{a_2}$  in fig. 5). should be soldered directly to the socket contacts  $a_2$  and  $D'$ .

It is recommended to use a Philips duodecal socket 5912/20. When a different type of socket is used, care should be taken that the capacitance of contact 5 (or 4) of the unmounted tube socket to all other contacts connected together should not exceed 1.3 pF.

Setting  $V_{a_2 \text{ init}} = 240$  V and  $V_{a_2 \min} = 95$  V, which are the extreme values that may occur in practice, and taking  $R_{a_2 \max}$  to be  $1.02 \text{ M}\Omega$  \*\*), this expression gives  $t = 20.7 \mu\text{sec}$ , so that a maximum counting rate of 30 000 pulses per second can easily be achieved, allowance being made for spread in the tube characteristics, etc.

The mechanism of operation will be explained by means of the circuit given in fig. 8. There is only one stable position of the multivibrator, with the left triode section ( $T_1$ ) conducting, and the right section ( $T_2$ ) biased beyond cut-off. When a negative-going triggering pulse is fed to the grid of  $T_1$  its anode current will decrease and the voltage at point  $A$  will rise, taking along the grid potential of  $T_2$ . Tube  $T_2$  then becomes conducting, and the cathode potential  $V_k$  suddenly assumes a high value, which now definitely cuts off  $T_1$ . The charge of  $C_s$  is subsequently increased, so that the grid potential of  $T_2$  decreases exponentially. Since  $T_2$  is in fact connected as a cathode follower, its cathode follows the grid potential very closely, as a result of which  $V_k$  also decreases exponentially. As  $V_k$  continues to decrease, the cut-off value of  $T_1$  (the anode voltage of which is fairly high) will rapidly be reached, so that this tube again becomes conducting.

The voltage at point  $A$  then decreases and this voltage drop is communicated to the grid of  $T_2$ , cutting off this tube. The capacitor  $C_s$  then starts to discharge, the stable position of the circuit thus being reached again.

In the circuit shown in fig. 8 the values of the electrode potentials have been indicated for the stable position. The negative potential at the grid of  $T_2$  is seen to be  $45 - 20 = 25$  V, which is ample for cutting off  $T_2$  at an anode voltage of  $300 - 45 = 225$  V.

The anode load  $R_{12}$  of  $T_1$  is  $39 \text{ k}\Omega$ . This value is in fact too high to permit a pulse with a sufficiently steep leading edge to be taken from the cathode resistor for feeding to the next counter tube. A lower value of  $R_{12}$  would, however, result in a greater drain on the H.T. line. This difficulty has been overcome by shunting the main part of the cathode resistor by the capacitor  $C_6$ , so that only the resistor  $R_{15}$  of  $1 \text{ k}\Omega$  is operative for abrupt

\*\*) The rated value of this load resistor is  $1 \text{ M}\Omega$ . Since in the actual circuit a  $1 \text{ M}\Omega$  resistor is used, connected in series with a  $10 \text{ k}\Omega$  resistor required for checking purposes, the permissible tolerance of the  $1 \text{ M}\Omega$  resistor must be  $\pm 1\%$  to obtain the quoted value of  $1.02 \text{ M}\Omega$  for  $R_{a_2 \max}$ .

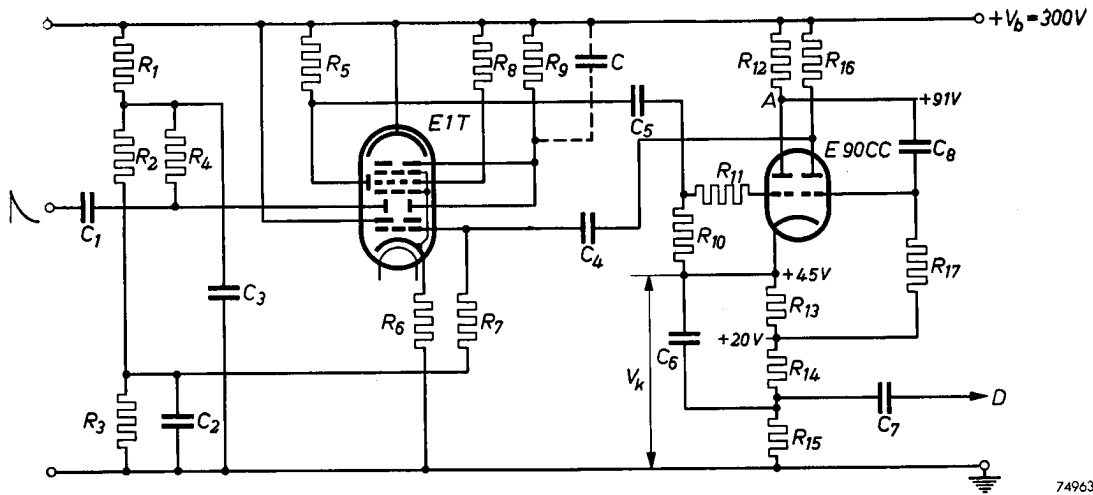


Fig. 8. Circuit diagram of an interstage circuit preceded by an E1T tube. The interstage circuit is equipped with an E90CC double triode, acting as a monostable multivibrator.

Component values

$R_1 = 68 \text{ k}\Omega \pm 1 \%$	$R_{10} = 0.56 \text{ M}\Omega \pm 10 \%$	$C_1 = 680 \text{ pF} \pm 5 \%$
$R_2 = 68 \text{ k}\Omega \pm 1 \%$	$R_{11} = 5.6 \text{ k}\Omega \pm 10 \%$	$C_2 = 0.39 \mu\text{F} \pm 20 \%$
$R_3 = 5.6 \text{ k}\Omega \pm 1 \%$	$R_{12} = 39 \text{ k}\Omega \pm 2 \%$	$C_3 = 0.15 \mu\text{F} \pm 20 \%$
$R_4 = 15 \text{ k}\Omega \pm 2 \%$	$R_{13} = 4.7 \text{ k}\Omega \pm 2 \%$	$C_4 = 0.0068 \mu\text{F} \pm 10 \%$
$R_5 = 39 \text{ k}\Omega \pm 10 \%$	$R_{14} = 2.7 \text{ k}\Omega \pm 2 \%$	$C_5 = 220 \text{ pF} \pm 10 \%$
$R_6 = 15 \text{ k}\Omega \pm 1 \%$	$R_{15} = 1 \text{ k}\Omega \pm 1 \%$	$C_6 = 68 \text{ pF} \pm 2 \%$
$R_7 = 0.33 \text{ M}\Omega \pm 10 \%$	$R_{16} = 3.3 \text{ k}\Omega \pm 2 \%$	$C_7 = 680 \text{ pF} \pm 5 \%$
$R_8 = 47 \text{ k}\Omega \pm 5 \%$	$R_{17} = 0.15 \text{ M}\Omega \pm 2 \%$	$C_8 = 68 \text{ pF} \pm 2 \%$
$R_9 = 1 \text{ M}\Omega \pm 1 \%$		

changes. The large value of the cathode resistor, combined with the fairly large value of  $R_{12}$ , renders the circuit extremely stable, resulting in a pulse amplitude and duration of high constancy, and insensitivity to spread in the tube characteristics.

Fig. 9a shows the negative-going pulse at the anode of  $T_2$ , for resetting the beam of the preceding counter tube, while fig. 9b shows the positive-going pulse at the cathode resistor of the multivibrator for operating the next counter tube.

The minimum amplitude of the negative-going pulse is 20 V, which ensures complete suppression of the beam; its duration of 27  $\mu\text{sec}$  is ample for

resetting the beam to the zero position without unduly increasing the reset time.

The cathode resistor has been so tapped that the positive-going pulse assumes the correct value to be fed to the left deflection electrode of the next counter tube. Because of the unilateral deviation of  $V_k$  from its stable value, there is no need for adding a clipping diode.

To ensure reliable operation of the circuit, it is of particular importance that the amplitude of the positive-going counting pulse fed to the next counter tube and the duration of the negative-going pulse required for resetting the beam of the preceding counter tube remain well within the limits to be observed. Experiments have shown that at extreme spread in the tube characteristics, a variation of all resistors and capacitances of 2% in an unfavourable sense results in the amplitude of the pulses changing by 8% and in their duration changing by 7.5%.

At an average value of 13.6 V the amplitude of the positive-going pulse may thus vary between 12.5 V and 14.7 V, which is well within the limits of 11.5 V and 16 V given by the characteristics of the tube.

As calculated previously, the duration of the

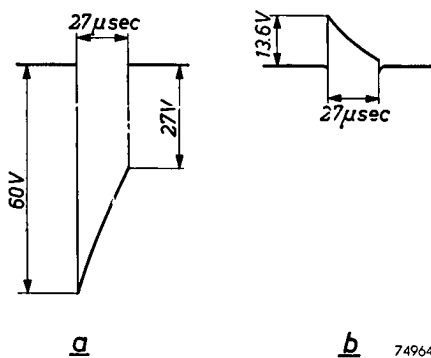


Fig. 9. Negative-going pulse (a) and positive-going pulse (b) derived from the multivibrator shown in fig. 8.

pulse for resetting the beam of the preceding counter tube should be at least  $20.7 \mu\text{sec}$ . To remain on the safe side, the required minimum value will be taken to be  $23 \mu\text{sec}$ . Taking the same safety margin for the pulse duration as that for the pulse amplitude, this gives for the average value of the duration  $(13.6/11.5) \cdot 23 = 27.2 \mu\text{sec}$  and for the maximum value  $(16/11.5) \cdot 23 = 32 \mu\text{sec}$ . Allowing for another  $1.3 \mu\text{sec}$  for stabilizing purposes, the maximum duration of the pulse which may occur under unfavourable conditions thus becomes  $32 + 1.3 = 33.3 \mu\text{sec}$ , giving a pulse repetition frequency of  $10^6/33.3 = 3 \times 10^4$  pulses per second.

### Input circuit

The first counter tube must be preceded by a pulse shaper (see fig. 10). A monostable multivibrator similar to that used in the interstage circuit may be employed for this purpose, the only difference being the somewhat lower values of the coupling capacitor between  $T_1$  and  $T_2$  and of the grid leak of  $T_2$ . Reliable operation at the highest counting rate of  $3 \times 10^4$  pulses per second is thus ensured. The resulting reduction of the pulse duration is of no consequence, since no negative-going pulse for resetting the beam of a preceding counter tube is needed in this case.

The pulse shaper must, moreover, be preceded by a differentiating network because — particularly at

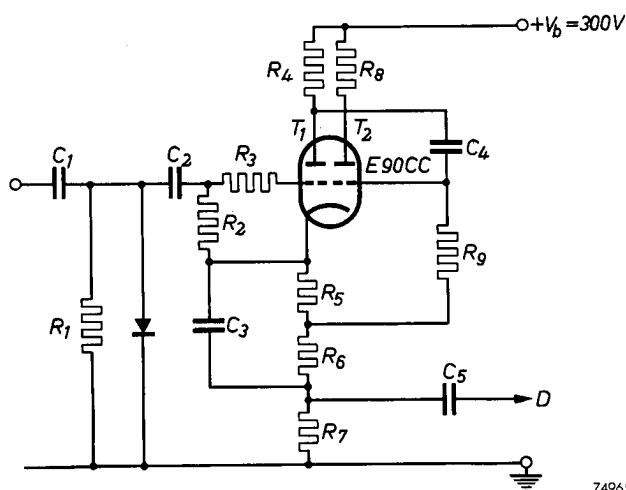


Fig. 10. Input pulse shaper for the first E1T tube.

#### Component values

$R_1 = 39 \text{ k}\Omega \pm 10 \%$	$R_8 = 3.3 \text{ k}\Omega \pm 2 \%$
$R_2 = 0.56 \text{ M}\Omega \pm 10 \%$	$R_9 = 0.1 \text{ M}\Omega \pm 1 \%$
$R_3 = 5.6 \text{ k}\Omega \pm 10 \%$	$C_1 = 470 \text{ pF} \pm 10 \%$
$R_4 = 39 \text{ k}\Omega \pm 2 \%$	$C_2 = 0.0068 \mu\text{F} \pm 10 \%$
$R_5 = 4.7 \text{ k}\Omega \pm 2 \%$	$C_3 = 82 \text{ pF} \pm 2 \%$
$R_6 = 2.7 \text{ k}\Omega \pm 2 \%$	$C_4 = 39 \text{ pF} \pm 5 \%$
$R_7 = 1 \text{ k}\Omega \pm 1 \%$	$C_5 = 0.0068 \mu\text{F} \pm 10 \%$

low counting rates — the duration of the counting pulses applied to the input might otherwise exceed the duration of the pulse produced by the multivibrator. In that case the trailing edge of the differentiated positive pulse would trigger the input shaper again and this might result in more than one count being produced per pulse applied to the input (The duration of the pulses derived from the reset anode of a preceding counter tube is only a fraction of a microsecond, so that this difficulty is not experienced in the interstage circuits).

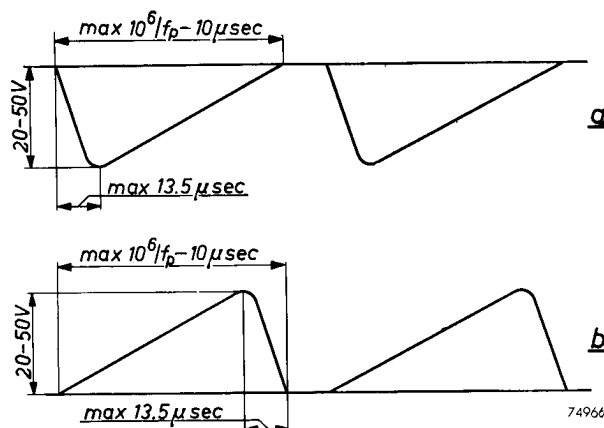


Fig. 11. Examples of a negative-going pulse (a) and a positive-going pulse (b) to be fed to input pulse shaper shown in fig. 10.

For triggering the multivibrator of the input circuit, the counting pulses, which are to be fed to the differentiating network, may be either negative-going with a leading edge duration not exceeding  $13.5 \mu\text{sec}$ , or positive-going with a trailing edge duration not exceeding this value. The total duration of the pulse must be equal to one cycle of the pulse repetition frequency  $f_p$  less at least  $10 \mu\text{sec}$ . At the highest frequency of  $3 \times 10^4$  pulses per second this duration may therefore not exceed  $33.3 - 10 = 23.3 \mu\text{sec}$ .

The amplitude of the counting pulses may range from  $20 \text{ V}$  to  $50 \text{ V}$ . Two examples of suitable counting pulses to be fed to the pulse shaper are schematically represented in figs 11a and b.

The purpose of the germanium diode OA 55 shunted across the resistor  $R_1$  of the differentiating network is to prevent positive pulses, caused by the trailing edge of a negative-going or the leading edge of a positive-going counting pulse, from being fed to the grid of  $T_1$ , thus producing faulty counts.

If the waveform of the signals to be counted is either sinusoidal, negative-going with a leading edge duration not exceeding  $13.5 \mu\text{sec}$  or positive-going



with a trailing edge not exceeding  $13.5 \mu\text{sec}$  the first counter tube should be preceded by an auxiliary pulse shaper. Figure 12 shows the circuit then to be used. With this circuit sinusoidal voltages down to 10 c/s can be counted provided the signal voltage is at least  $15 V_{\text{rms}}$ . The input voltage is applied to the terminal marked  $V_i$ .

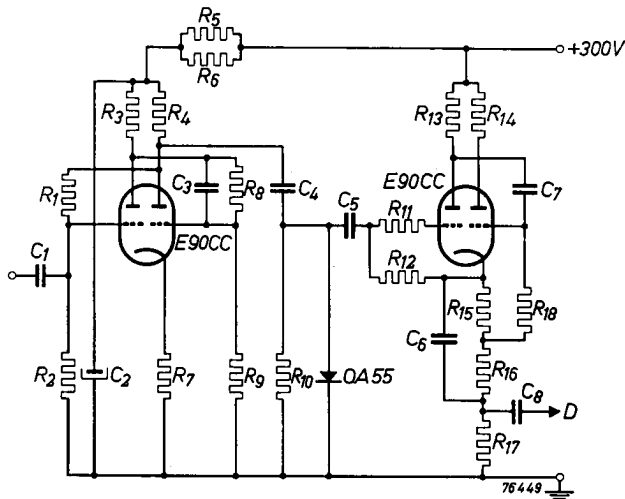


Fig. 12. Input pulse shaper with auxiliary pulse shaper.

If sinusoidal signals have to be counted with a frequency less than 10 c/s the input signal should have a higher amplitude and a clipper should be provided to render the waveform more suitable for triggering the auxiliary pulse shaper, i.e. to provide a signal whose positive and negative-going flanks have a sufficiently steep slope. Another pos-

sibility consists in increasing the value of the capacitor  $C_1$ .

Pulses produced by mechanical means, for example by closing a switch or operating a telephone dial across which a direct voltage is applied are likely to produce faulty counts. This is due to the fact that the decade counter might react on short interruptions during the time that the switch should actually be closed; such interruptions are apt to be produced by rebounding of spring contacts. It will in this case be necessary to connect filter circuits between the switch and the auxiliary pulse shaper.

Fig. 13 gives an example of a suitable filter network. The mechanical switch  $S$ , across which a voltage of approximately 40 V is applied by means of the voltage divider  $R_1R_2$  is followed by two RC filters. The output signal at terminal  $B$  should be fed to the input terminal of the auxiliary pulse shaper shown in fig. 12.

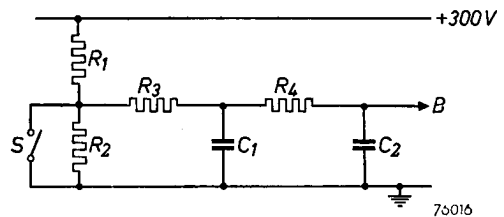


Fig. 13. Filter circuit for avoiding faulty counts which may be produced by rebounding of the spring contacts of mechanical switches.

$R_1 = 68 \text{ k}\Omega, 2 \text{ W}$	$R_1 = 3.9 \text{ k}\Omega, \frac{1}{4} \text{ W}$
$R_2 = 10 \text{ k}\Omega, \frac{1}{4} \text{ W}$	$C_1 = 0.47 \mu\text{F} \frac{1}{4} \text{ W}$
$R_3 = 390 \Omega, \frac{1}{4} \text{ W}$	$C_2 = 0.47 \mu\text{F} \frac{1}{4} \text{ W}$

## COMPLETE CIRCUIT OF A MULTI DECADE COUNTER

The circuit diagram of a complete decade counter will be explained by means of fig. 14, which shows the input pulse shaper, the first and second counter stages and the supply unit. The subsequent counter stages have been omitted in the circuit diagram, these being identical to the second counter stage.

The supply unit and the voltage divider consisting of the resistors  $R_{41}$ ,  $R_{42}$  and  $R_{43}$  have been designed for feeding up to 7 counter stages, the highest number to be registered then being 9 999 999. If a larger number of counter stages is required it is merely sufficient to change the supply unit and voltage divider accordingly.

There is no need to stabilize the supply unit, since mains voltage fluctuations will result in all voltages taken from the voltage divider to vary simultaneously by the same relative amount, and this has no noticeable effect on the performance of the counter tubes. Experiments have shown that reliable operation is still obtained at mains voltages ranging from 140 V to 270 V (nominal value 220 V). It is true that prolonged operation under these conditions may be harmful to the useful life of the tubes, but in practice such extreme fluctuations will hardly ever occur. Care must, however, be taken that the specified tolerances of  $\pm 1\%$  of the resistors  $R_{41}$ ,  $R_{42}$  and  $R_{43}$  of the voltage divider are strictly observed. The use of wire-wound resistors is highly recommended for this purpose.

The input circuit comprises a pulse shaper equipped with an E 90 CC double triode.

The counter stages, marked by the broken lines in fig. 14, are equipped with an E 1 T counter tube and a double triode E 90 CC. The counter tubes are connected as outlined in the preceding sections. Effective D.C. feedback is applied by using cathode resistors  $R_{12}$ ,  $R_{27}$  (cf. fig. 8); the cathode current is thus kept constant within narrow limits, which ensures reproducible sensitivity of the counter tubes.

During the intervals between the negative-going pulses fed to the control grid  $g_1$  of the counter tubes for resetting the beam, the potential of this electrode depends on the counting frequency. In the first counter stage, where the highest counting rate occurs, this would be objectionable, so that a germanium diode OA 56 is shunted across the resistor  $R_{14}$ , thus maintaining the direct voltage

level of  $g_1$  at a constant value. Apart from this diode all counter stages are identical.

In order to ensure that reliable operation at the counting rate of 30 000 pulses per second is obtained under the most unfavourable conditions, the rated values of the components of the counter stages should be as specified in the caption of fig. 14). \*) When the counting rate is lower, such as for example in the second and subsequent stages, normal  $\pm 10\%$  components may, however, be used in the multivibrator circuits, provided the rated values of the coupling capacitor  $C_{14}$  and the grid leak  $R_{39}$  are slightly increased, namely to 82 pF and 0.18 M $\Omega$  instead of 68 pF and 0.15 M $\Omega$  respectively. It is then necessary to adjust the amplitude of the positive-going pulse ( $V_p$  in fig. 14) with a diode voltmeter (slide-back peak meter for positive peaks) to  $13.6 \text{ V} \pm 2\%$  by connecting an additional correction resistor in series with or parallel to the 1 k $\Omega$  cathode resistor  $R_{38}$ . Since normal  $\pm 10\%$  resistors may show considerable drift during life, it may be necessary to readjust the setting of the correction resistor from time to time. It should be noted that it remains essential to use  $\pm 1\%$  precision resistors in the cathode and anode circuits of the counter tubes.

The press-button switch  $S$  in fig. 14 serves for resetting all tubes to zero by applying a negative voltage exceeding 10 V temporarily to their control grids. This voltage is obtained by means of the germanium diode OA 55 in the supply unit.

An oscilloscope may be connected to the points  $p$  in fig. 14 for checking each individual stage for reliable operation. Some marginal test may be made for example by raising and lowering the supply voltage around its average value. The oscillograms should be as depicted in figs 15a and b, with ten distinctive steps.

The counter stages may be built as small, interchangeable units as shown in fig. 16. These can be plugged into a chassis containing the input pulse shaper and supply unit. It is also possible to com-

\*) To cope with the variations to which the components may be subject due to ageing or temperature effects, a safety margin has been observed, but it should be noted that even after prolonged use and under working conditions, the deviations should never exceed twice the tolerances specified in the caption of fig. 12.

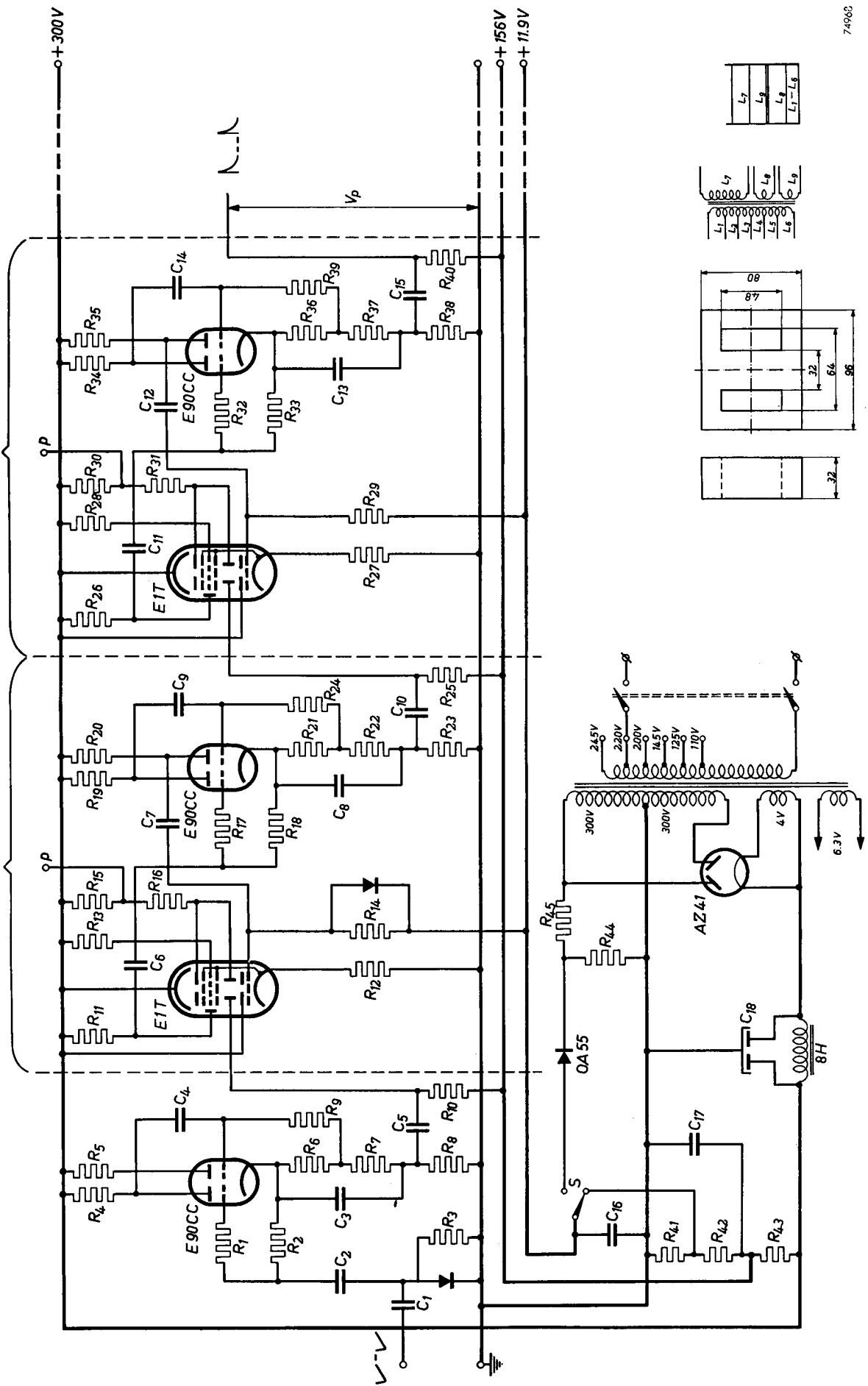


Fig. 14.

Fig. 14. Complete circuit of a decade counter. Only the first two counter stages have been drawn, the subsequent stages being identical to the second counter stage. The supply unit and voltage divider have been designed for feeding up to seven stages.

Component values

$R_1$	=	5.6 k $\Omega$	$\pm$ 10%,	1/2 W
$R_2$	=	0.56 M $\Omega$	$\pm$ 10%,	1/2 W
$R_3$	=	39 k $\Omega$	$\pm$ 5%,	1/2 W
$R_4$	=	39 k $\Omega$	$\pm$ 2%,	2 W
$R_5$	=	3.3 k $\Omega$	$\pm$ 2%,	1/2 W
$R_6$	=	4.7 k $\Omega$	$\pm$ 2%,	1 W
$R_7$	=	2.7 k $\Omega$	$\pm$ 1%,	1/4 W
$R_8$	=	1 k $\Omega$	$\pm$ 1%,	1/8 W
$R_9$	=	0.1 M $\Omega$	$\pm$ 1%,	1/4 W
$R_{10}$	=	15 k $\Omega$	$\pm$ 2%,	1/8 W
$R_{11} = R_{26}$	=	39 k $\Omega$	$\pm$ 10%,	1/2 W
$R_{12} = R_{27}$	=	15 k $\Omega$	$\pm$ 1%,	1/8 W
$R_{13} = R_{28}$	=	47 k $\Omega$	$\pm$ 5%,	1/2 W
$R_{14} = R_{29}$	=	0.33 M $\Omega$	$\pm$ 10%,	1/2 W
$R_{15} = R_{30}$	=	10 k $\Omega$	$\pm$ 10%,	1/2 W
$R_{16} = R_{31}$	=	1 M $\Omega$	$\pm$ 1%,	1/2 W
$R_{17} = R_{32}$	=	5.6 k $\Omega$	$\pm$ 10%,	1/4 W
$R_{18} = R_{33}$	=	0.56 M $\Omega$	$\pm$ 10%,	1/2 W
$R_{19} = R_{34}$	=	39 k $\Omega$	$\pm$ 2%,	2 W
$R_{20} = R_{35}$	=	3.3 k $\Omega$	$\pm$ 2%,	1/8 W
$R_{21} = R_{36}$	=	4.7 k $\Omega$	$\pm$ 2%,	1/4 W
$R_{22} = R_{37}$	=	2.7 k $\Omega$	$\pm$ 2%,	1/8 W
$R_{23} = R_{38}$	=	1 k $\Omega$	$\pm$ 1%,	1/8 W
$R_{24} = R_{39}$	=	0.15 M $\Omega$	$\pm$ 2%,	1/8 W
$R_{25} = R_{40}$	=	15 k $\Omega$	$\pm$ 2%,	1/8 W
$R_{11}$	=	5.6 k $\Omega$	$\pm$ 1%,	1/8 W
$R_{12}$	=	68 k $\Omega$	$\pm$ 1%,	1 W
$R_{13}$	=	68 k $\Omega$	$\pm$ 1%,	1 W
$R_{14}$	=	15 k $\Omega$	$\pm$ 10%,	1 W
$R_{15}$	=	0.33 M $\Omega$	$\pm$ 10%,	1 W

$C_1$	=	470 pF	$\pm$ 10%,
$C_2$	=	0.0068 $\mu$ F	$\pm$ 10%,
$C_3$	=	82 pF	$\pm$ 2%
$C_4$	=	39 pF	$\pm$ 5%
$C_5$	=	0.0068 $\mu$ F	$\pm$ 10%
$C_6 = C_{11}$	=	220 $\mu$ F	$\pm$ 10%
$C_7 = C_{12}$	=	0.0068 $\mu$ F	$\pm$ 10%
$C_8 = C_{13}$	=	68 pF	$\pm$ 2%
$C_9 = C_{14}$	=	68 pF	$\pm$ 2%
$C_{10} = C_{15}$	=	680 pF	$\pm$ 5%
$C_{16}$	=	0.39 $\mu$ F	$\pm$ 20%
$C_{17}$	=	0.15 $\mu$ F	$\pm$ 20%
$C_{18}$	=	$2 \times 50$ $\mu$ F,	400 V

Transformer data:

winding number	number of turns	wire diameter	voltage	current
$L_1$	470	0.50 mm	110 V	0.52 A
$L_2$	64	0.50 mm	15 V	0.45 A
$L_3$	86	0.45 mm	20 V	0.39 A
$L_4$	234	0.40 mm	55 V	0.29 A
$L_5$	86	0.35 mm	20 V	0.25 A
$L_6$	$2 \times 1420$	0.35 mm	25 V	0.23 A
$L_7$	108	0.25 mm	$2 \times 300$ V	0.07 A
$L_8$	30	2.0 mm	6.3 V	5.0 A
$L_9$	19	1.0 mm	4.0 V	1.1 A

bine the stages into a compact counter apparatus similar to that shown in fig. 17.

As the ambient illumination for a clear reading should range from 40 lux to 400 lux as indicated in the data it is of advantage to mount the E1T tubes at some distance behind the front panel of the apparatus thereby providing a light screen bringing the ambient illumination on the fluorescent coating to the desired value in a well lighted room.

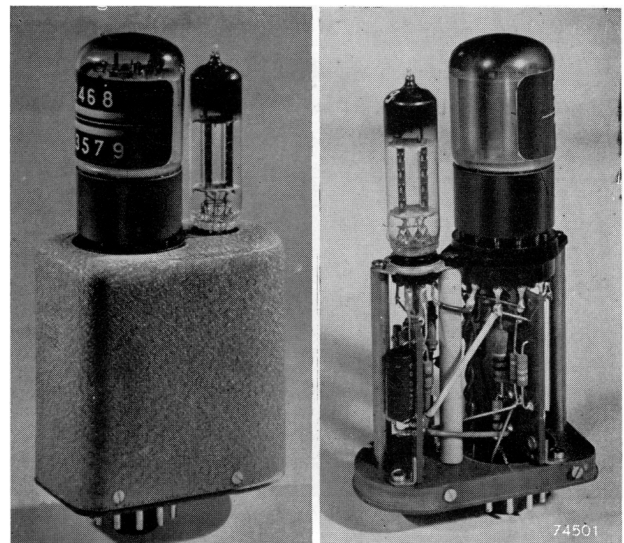
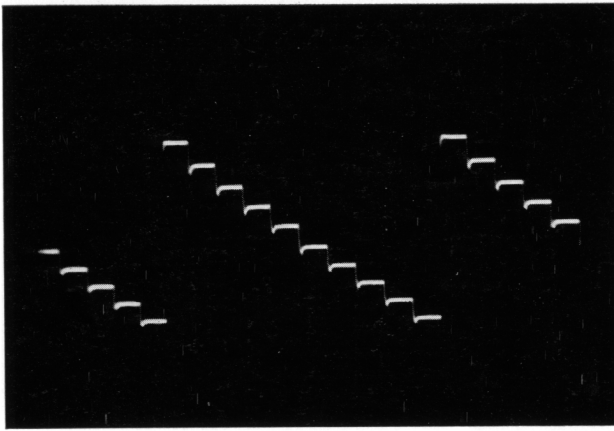
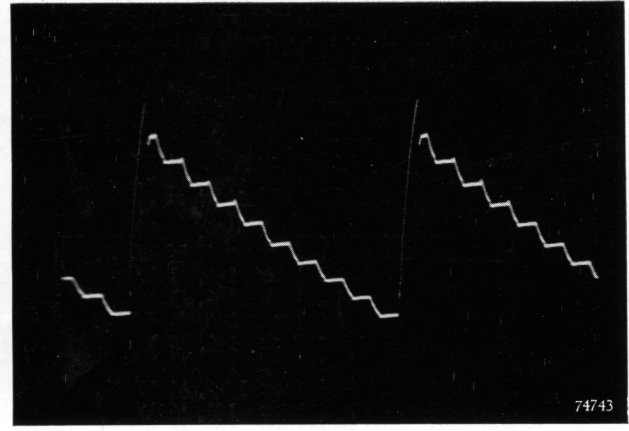


Fig. 16. Interchangeable counter unit comprising an E1T counter tube and an E90CC double triode. The cover of the right-hand unit has been removed to show the accessory components.



a



b

Fig. 15. Examples of oscillograms of the voltage at point *p* of the first counter stage (fig. 12). (a) at 3000 and (b) at 30 000 counts per second.

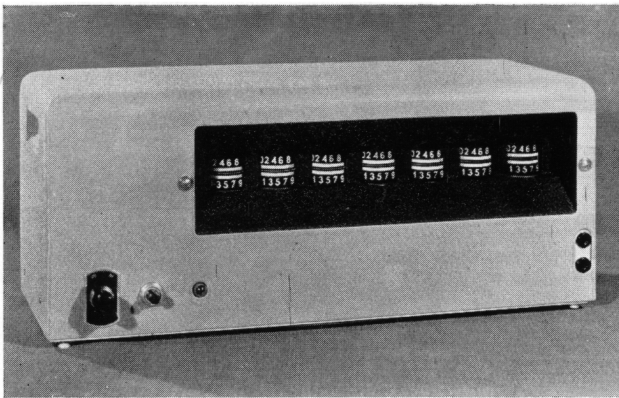


Fig. 17. Complete decade counter containing seven counter stages. The first counter tube at the left registers the millions, the second the hundred thousands, and so on. The press-button at the left serves for resetting all counter tubes simultaneously to zero. Cabinet dimensions: width 43 cm, height 17.5 cm. Depth 15.5 cm. Weight: 7.5 kg. Power consumption: 77 VA.

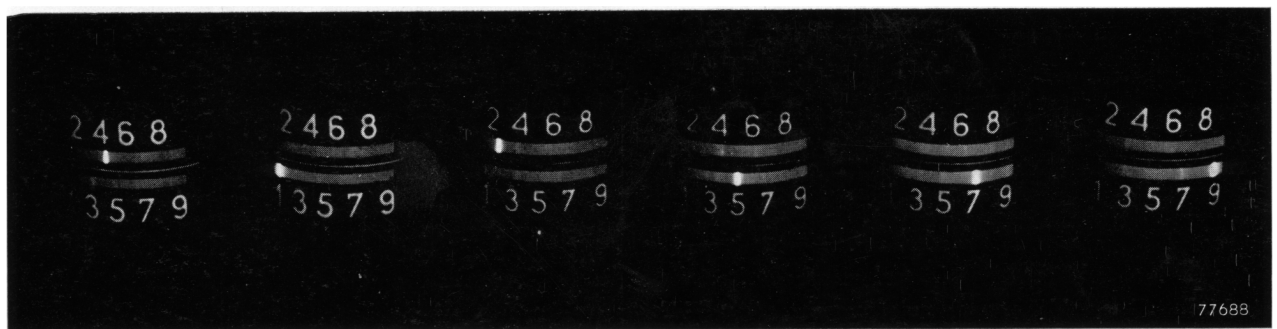


Fig. 18. Decade counter showing the number 412579.

# A MULTI-DECADE PREDETERMINED COUNTER

*In industry, particularly in mass production, it is often necessary to divide a continuous flow of products into specified quantities. When the counting rate is relatively low, mechanical means may give satisfactory results, but at high counting rates an electronic counter will provide the obvious solution.*

*A description is given of a fully automatic four-decade counter device which will count any predetermined number up to 10 000. Its construction is very similar to that of the multi-decade counter described, the main difference being the addition of two double diodes and one double triode. The number of counts registered can be read directly from the four E I T decade counter tubes with which the device is equipped. After the desired cycle of counts has been completed, the counter is automatically reset to its starting position and a pulse is produced which operates a relay by means of an additional output stage. The maximum counting rate is 12 500 counts per second, whilst the minimum duration of a complete cycle of counts is  $1/3000$  sec.*

## PRINCIPLE OF OPERATION

The explanation of the principle of operation of the predetermined counter will be based on the description of the multi-decade counter described above.

It will first be supposed that all counter tubes indicate zero in the four-decade counter the block diagram of which is given in fig. 19. After 9 counts have been applied to the input, the decade which counts the units will indicate number 9. The following count will reset this decade to zero and a pulse is fed to the following decade, counting the tens, which will thus be advanced one position, i.e. to the figure 1. In this way all decades may be brought to position 9. The 10 000th count will return all decades to zero. The resulting sudden voltage variation at the cathode of the counter tube in the last decade (which counts the thousands) is used for indicating that the cycle of 10 000 counts has been completed.

It will be clear that this principle can be used only for cycles of  $10^n$  counts, where  $n$  indicates the number of decades. This will serve little purpose since as a rule a signal should be produced after a number of pulses differing from  $10^n$  has

been applied. This can be achieved by presetting the counter to a number which is the complementary of the number that should be counted. When, for example, the signal should be produced after 7236 counts, the counter must be preset to  $10\ 000 - 7236 = 2764$ . After 7235 counts have been registered, all decades then indicate the figure 9 and the next count will reset all decades to zero, the pulse produced by the last decade indicating that the cycle of counts has been completed.

However, when all decades are returned to zero, the desired cycle of counts will be registered only once. Provision must therefore be made that the counter is returned to the initially selected, preset number each time this cycle is completed. This may be achieved in the following way.

As previously explained, an E I T decade counter tube is a small cathode-ray tube in which the electron beam may occupy any of ten discrete, stable positions. Each position corresponds to a definite voltage difference  $V_D - V_{D',a2}$  between the left deflection electrode voltage on the one hand and the voltage applied to the right deflection electrode (and anode) on the other hand.

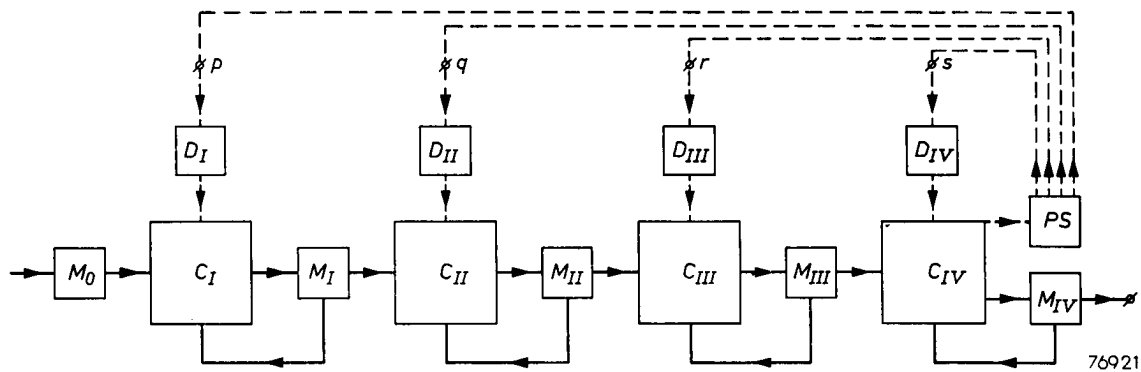


Fig. 19. Block diagram of a four-decade counter.  $C_I$  to  $C_{IV}$  — counter stages,  $M_0$  — input stage,  $M_I$  to  $M_{IV}$  — inter-stage pulse shapers. By adding the presetting stage  $PS$  and the four diodes  $D_I$  to  $D_{IV}$  the circuit can be converted into that of a predetermined counter.

By connecting the right deflection electrode and anode via the switch  $S$  to a variable voltage source as shown in fig. 20, the EIT tube can thus be adjusted to any desired figure, a fixed voltage of 156 V being applied to the left deflection electrode. When switch  $S$  is closed, the right deflection electrode and anode assume the same potential as the positive terminal of the voltage source. The lower the voltage  $V_{D',a_2}$  thus applied to the right

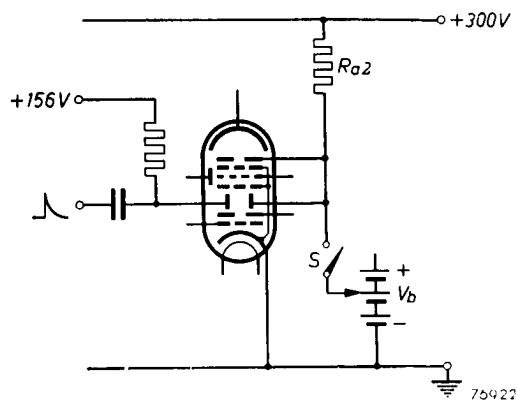


Fig. 20. Basic circuit for adjusting a counter tube to an arbitrary figure.

deflection electrode and anode with respect to the voltage  $V_D$  applied to the left deflection electrode, the further will the beam be deflected to the left and the higher will be the number indicated. When switch  $S$  is subsequently re-opened the beam will travel towards its nearest stable position due to the stabilizing effect of the resistor  $R_{a_2}$  and  $V_{D',a_2}$  will assume a value which is almost equal to that of the voltage temporarily applied. The counter tube will then work normally as if its

beam had been shifted to the preset position by applying a corresponding number of positive-going pulses to its left deflection electrode.

In practice the somewhat different circuit shown in fig. 21 is used. The right deflection electrode and anode of the counter tube are connected to the anode of an additional diode (level catcher), the cathode of which is connected to the slider of the potentiometer  $P_1$ .

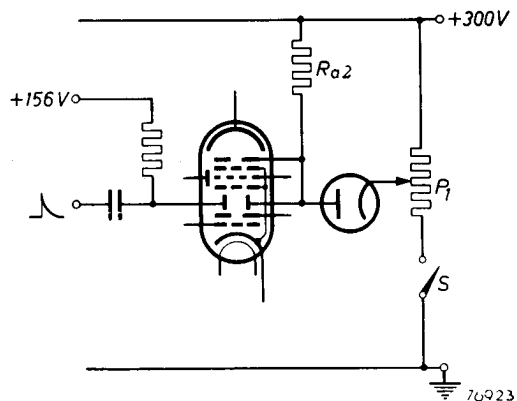


Fig. 21. Circuit similar to that shown in fig. 20 incorporating a diode acting as a level catcher.

When switch  $S$  is open the diode and potentiometer have no effect on the position of the beam, since the cathode potential of the diode is higher than its anode potential. Upon closing switch  $S$  the cathode voltage of the diode, is, however, reduced, and when it drops below the voltage at the right deflection electrode and anode of the counter tube, current starts to flow from  $+V_b$  towards  $-V_b$  via  $R_{a_2}$ , the diode and part of  $P_1$ . Since the internal resistance of the diode is very much smaller than

the resistance of  $R_{a2}$ , the right deflection electrode and anode voltage of the counter tube will drop almost to the potential at the slider of the potentiometer. The lower the position of this slider, the greater will be the resulting deflection of the beam towards the left, which corresponds to a higher number being indicated by the counter tube.

When switch  $S$  is re-opened the beam will travel towards its nearest stable position.  $V_{D',a_2}$  assuming a voltage that differs little from that which was present at the slider of  $P_1$  when switch  $S$  was closed. Since the cathode voltage of the diode now rapidly rises to  $+V_b$ , this tube becomes non-conducting and the counter tube again operates normally, starting from the preset position.

the beam of tube  $III$  from position 7 to position 8. After 7235 counting pulses have been applied, the beams of all tubes will thus occupy position 9 and the 7236 th pulse will have the following effects:

- (1) All tubes are reset to position zero.
- (2) As a result of the pulse produced at the cathode of the last counter tube  $IV$ , when it is reset to zero, switch  $S$  is temporarily closed. All tubes are thus advanced to their preset positions.
- (3) Switch  $S$  is subsequently re-opened after a short interval, so that the original condition is restored, the counter being ready to count the following cycle.

Instead of operating switch  $S$  mechanically, a presetting stage incorporating an electronic tube is

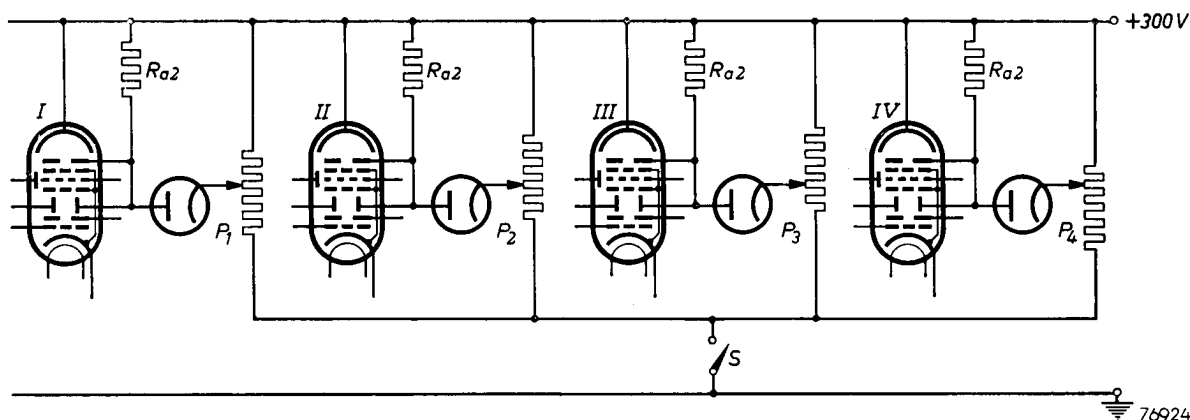


Fig. 22. Basic circuit of a four-decade predetermined counter. In order to obtain a cycle of 7236 counts (i.e. the complementary of  $10\,000 - 7236 = 2764$ ), the potentiometers  $P_1 - P_4$  must be so adjusted that the counter tubes  $I - IV$  are preset to figures 4, 6, 7 and 2 respectively.

The operation of a multi-decade predetermined counter will be explained by means of the basic circuit shown in fig. 22. It will again be assumed that a cycle of 7236 should be counted. The counter tubes must then be preset to the number  $10\,000 - 7236 = 2764$ . For this purpose switch  $S$  is temporarily closed and the beams of the tubes  $I$ ,  $II$ ,  $III$ , and  $IV$  are adjusted to the positions 4, 6, 7 and 2 respectively by means of the potentiometer  $P_1$ ,  $P_2$ ,  $P_3$  and  $P_4$ . Switch  $S$  is then re-opened.

After 5 counting pulses have been applied to tube  $I$  its beam will have advanced from its original position 4 to position 9. The next pulse resets the beam of this tube to position zero, as a result of which a pulse is fed to tube  $II$ , advancing its beam from position 6 to position 7. After 35 pulses have been applied, the beams of tubes  $I$  and  $II$  will both occupy position 9 and the next pulse will reset these tubes to position zero and advance

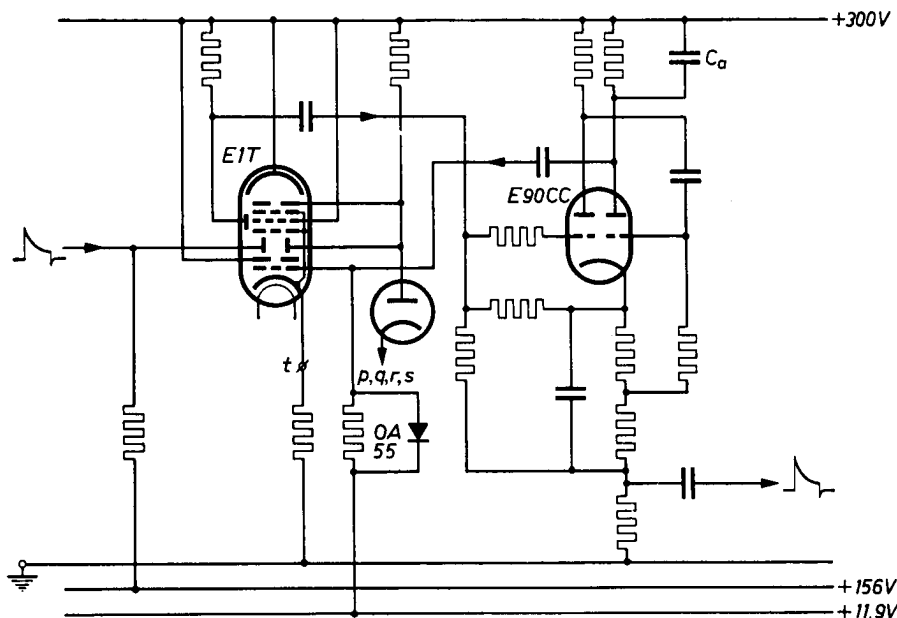
used, thus rendering the presetting after completion of a cycle of counts fully automatic. This presetting stage, which has also been drawn in the block diagram shown in fig. 19, will be dealt with later.

## THE COUNTER STAGES

The counter stages differ slightly from those of the decade counter described previously, the following changes being necessary (see fig. 23).

Additional diodes, consisting of one electrode system of the double diodes EB 91, are connected with their anodes to the right deflection electrode and anode of the counter tubes. The cathodes of the diodes are connected to the sliders of the potentiometers forming part of the presetting stage. It should be recognized that in view of the high value of the anode resistor it is not permissible to use germanium diodes, their back resistance being too low.





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Fig. 23. Circuit of one decade of the predetermined counter. The last decade differs from the preceding decades by the slightly increased value of the capacitor between the two triode sections of the E 90 CC (180 pF instead of 100 pF), whilst, moreover, the pulse required for operating the presetting stage is taken from the cathode of the counter tube (point *t*).

Some further changes are required to avoid the risk of difficulties being experienced when the counter tubes are preset to figure 9. This will become clear when it is realised that for presetting a counter tube to lower figures the slider of the potentiometer can easily be correctly adjusted by setting it midway between the positions at which the beam is preset to the adjacent figures, but when a tube should be preset to 9, the knob of the potentiometer will occasionally be turned too far\*). In that case the electron beam of the counter tube may be stabilized at a position at which it passes not only through the last aperture of the slotted electrode  $g_4$  (see fig. 1a), but also through the slit between this electrode and the reset anode  $a_1$ , impinging partly on this anode. The next counter pulse will then still advance the beam further to the left, so that it impinges in its entirety on the reset anode, but the negative pulse thus produced at the reset anode will not have the required amplitude and duration for completely triggering the monostable multivibrator which forms the following interstage circuit. This multivibrator will then operate merely as an amplifier, feeding the ampli-

\*) This cannot be prevented by connecting a fixed resistor in series with the potentiometers because in that case it would no longer be possible to cope with the unavoidable spread between individual counter tubes and it might therefore become impossible to preset the tubes beyond figure 8.

fied negative-going pulse back to the control grid  $g_1$  of the counter tube. As soon as the beam current is thus suppressed, the negative-going pulse at the reset anode will then cease, and so will the pulse at the control grid for suppressing the beam. The tube will thus remain at the preset position(9).

For this reason the anode resistor of 3.3 k $\Omega$  of the right-hand triode of the interstage circuit is shunted by a capacitor  $C_a$  of 270 pF. The suppression of the electron beam of the counter tube is thus delayed and the beam will continue its way towards the reset anode, giving the interstage multivibrator time to be completely triggered.

When the electron beam impinges partly on the reset anode at position 9, the amplitude of the pulse produced at the reset anode when the beam is further advanced will be approximately 3 V instead of 4 V. To ensure that the following interstage multivibrator is nevertheless triggered, its sensitivity is slightly increased applying a negative grid bias of 2.3 V to the grid of the left-hand triode by joining  $R_b$ .

The resistor of 47 k $\Omega$  originally connected between the slotted electrode  $g_4$  and the +300 V line gives rise to some negative feedback during the resetting of the beam, which may lead to difficulties in the modified circuit. This electrode is therefore connected directly to the +300 V line.

As a result of this resistor being omitted the amplitude of the counting pulses applied to the left deflection electrode must be slightly increased, the required limits being from 12.7 V to 16.9 V (average value 14.7 V) instead of from 11.5 V to 16 V (average value 13.6 V). The required increase of the pulse amplitude is obtained by shunting part of the cathode resistor of the input pulse shaper by a capacitor of 100 pF instead of by one of 82 pF. (In the interstage circuits there is no need to increase the corresponding capacitance; the pulse amplitude is already sufficiently increased by the capacitor of 270 pF which by-passes the anode resistor of the right-hand triode).

At high counting rates it is necessary to use a germanium diode OA 55 \*) in all counter stages to maintain the direct voltage level of the control grid  $g_1$  at a constant value. This is due to the fact that the counting rate of the second and subsequent decades may become fairly high when the preceding stages have been preset to a high number.

Due to the diode connected to the anode of the counter tube, the maximum capacitance at the anode is increased from 16.5 pF to 22.5 pF, which gives a minimum reset time  $t_{\min}$  of 29.1  $\mu\text{sec}$  instead of 20.7  $\mu\text{sec}$ . It should however be recognized that a tube may have been preset to position 9 so that its beam impinges partly on the reset anode; when this tube is reset the duration of the pulse produced by the corresponding interstage circuit will then be up to 7  $\mu\text{sec}$  shorter than normally. Taking moreover into account the possible spread in the circuit components, the first three decades must be so designed that under the most unfavourable conditions their reset times have a duration of  $t_{\max} = 48.5 \mu\text{sec}$ .

It will be clear that the time available for presetting the beams should always exceed the maximum duration of the reset time  $t_{\max}$ . This is necessary because the beams may otherwise not be returned to the desired preset positions but to a lower figure. Since the time available for presetting the beams depends on the time during which the beam of the last counter tube is suppressed when it is reset to zero, the multivibrator following this tube should be so designed that its pulse duration is at least 49  $\mu\text{sec}$ . Considering again that the counter tube may have been preset to position 9 so that part of its beam impinges on its reset anode, and taking into account the maximum spread that may occur

\*) In general all germanium diodes should be mounted in such a way that adequate cooling is provided.

in the circuit components, the maximum duration of the pulse produced by this multivibrator and serving for suppressing the electron beam of the last counter tube is 76  $\mu\text{sec}$ . Since the presetting tube is so connected that 4  $\mu\text{sec}$  are required for restoring the original condition at which this tube is cut off, there should be an interval of  $76 + 4 = 80 \mu\text{sec}$  between the counting pulses. The maximum counting rate is therefore  $\frac{10^6}{80} = 12\,500$  counts per second.

To obtain the longer pulse duration the triode sections of the first three interstage multivibrators should be coupled by means of capacitors of 100 pF instead of 68 pF. The coupling capacitor in the multivibrator following the last counter tube should be 180 pF.

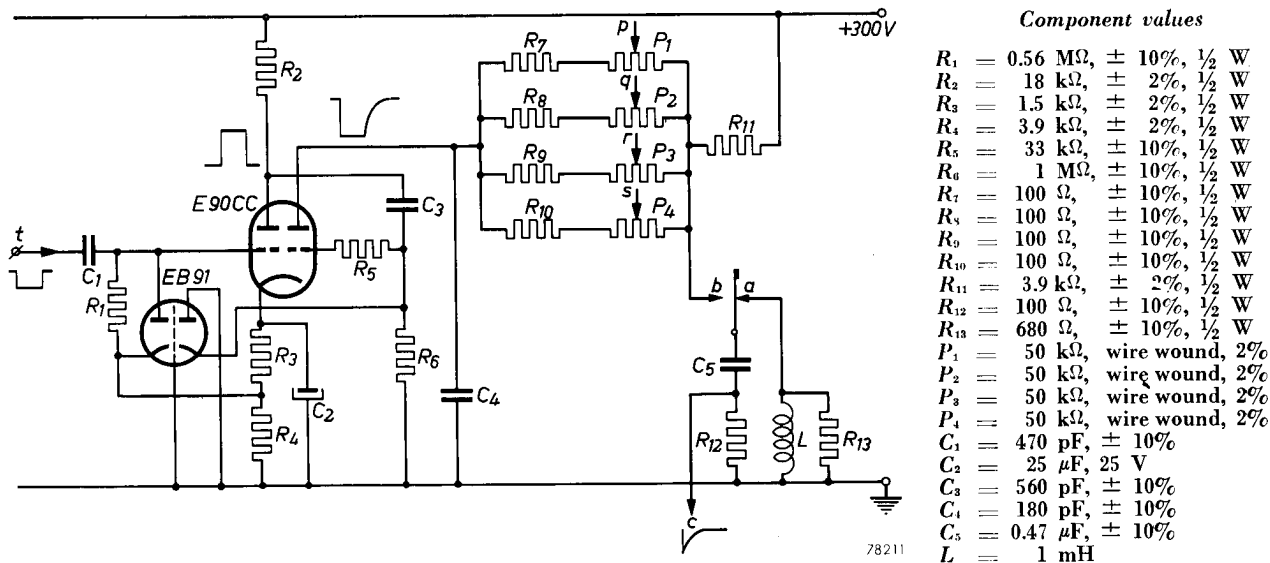
## THE PRESETTING STAGE

As previously mentioned, an electronic tube is used instead of the switch marked S in fig. 22. This tube is normally biased to such an extent that it is completely cut off, but when the last counter tube is reset to zero it is made conducting for a short interval, which corresponds to the switch being temporarily closed. This is achieved in the following way.

When the electron beam of a counter tube impinges in its entirety on the reset anode the following multivibrator stage is triggered and produces a negative-going pulse which is applied to the control grid  $g_1$  of this counter tube. The electron beam is thereby suppressed and the cathode current suddenly drops to zero until the multivibrator returns to its original condition.

The negative-going square-wave voltage pulse thus produced at the cathode of the last counter tube when the cycle of counts is completed, is amplified and reversed by the left section of the E 90 CC double triode shown in fig. 24 and subsequently applied to the grid of the right-hand triode section. The latter acts as the switch for presetting the counter tubes to the selected figures. For this purpose the four potentiometers  $P_1—P_4$  of 50 k $\Omega$  (cf. fig. 22) connected in parallel are incorporated in the anode circuit of this triode.

The square-wave voltage pulse applied to the left triode section has a duration ranging from 49  $\mu\text{sec}$  to 76  $\mu\text{sec}$ , according to whether the last counter tube has been preset to position 9 with part of the beam impinging on the reset anode or to a lower position.



Component values		
$R_1$	$= 0.56 \text{ M}\Omega, \pm 10\%, \frac{1}{2} \text{ W}$	
$R_2$	$= 18 \text{ k}\Omega, \pm 2\%, \frac{1}{2} \text{ W}$	
$R_3$	$= 1.5 \text{ k}\Omega, \pm 2\%, \frac{1}{2} \text{ W}$	
$R_4$	$= 3.9 \text{ k}\Omega, \pm 2\%, \frac{1}{2} \text{ W}$	
$R_5$	$= 33 \text{ k}\Omega, \pm 10\%, \frac{1}{2} \text{ W}$	
$R_6$	$= 1 \text{ M}\Omega, \pm 10\%, \frac{1}{2} \text{ W}$	
$R_7$	$= 100 \Omega, \pm 10\%, \frac{1}{2} \text{ W}$	
$R_8$	$= 100 \Omega, \pm 10\%, \frac{1}{2} \text{ W}$	
$R_9$	$= 100 \Omega, \pm 10\%, \frac{1}{2} \text{ W}$	
$R_{10}$	$= 100 \Omega, \pm 10\%, \frac{1}{2} \text{ W}$	
$R_{11}$	$= 3.9 \text{ k}\Omega, \pm 2\%, \frac{1}{2} \text{ W}$	
$R_{12}$	$= 100 \Omega, \pm 10\%, \frac{1}{2} \text{ W}$	
$R_{13}$	$= 680 \Omega, \pm 10\%, \frac{1}{2} \text{ W}$	
$P_1$	$= 50 \text{ k}\Omega, \text{ wire wound}, 2\%$	
$P_2$	$= 50 \text{ k}\Omega, \text{ wire wound}, 2\%$	
$P_3$	$= 50 \text{ k}\Omega, \text{ wire wound}, 2\%$	
$P_4$	$= 50 \text{ k}\Omega, \text{ wire wound}, 2\%$	
$C_1$	$= 470 \text{ pF}, \pm 10\%$	
$C_2$	$= 25 \mu\text{F}, 25 \text{ V}$	
$C_3$	$= 560 \text{ pF}, \pm 10\%$	
$C_4$	$= 180 \text{ pF}, \pm 10\%$	
$C_5$	$= 0.47 \mu\text{F}, \pm 10\%$	
$L$	$= 1 \text{ mH}$	

Fig. 24. Circuit of the presetting stage. Point  $t$  (input) is connected to the cathode of the last counter tube. The sliders of potentiometers  $P_1$ — $P_4$  are connected to the cathode of the corresponding diodes incorporated in the individual decades. By pressing the push-button switch at the right, all counter tubes are advanced to position 9; when the switch is subsequently released, so that it returns to position  $a$ , the negative-going pulse produced at point  $c$  is applied to the input stage, so that all tubes are reset to their predetermined positions.

When the beam of the last counter tube is reset to zero the voltage pulse produced at its cathode has an amplitude of about 15 V, so that the left triode section is completely cut off and the grid of the right-hand section is driven positive; as a result its anode potential suddenly drops from its initial value of 300 V to 95 V. The latter value is sufficiently low for the beams to be returned to position 9 when the sliders of the corresponding potentiometers occupy their lowest positions. (The voltage drop across the 100  $\Omega$  resistors  $R_7$ — $R_{10}$ , which serve only for preventing undesired interaction of the potentiometer settings as a result of the self-inductance of the wire-wound potentiometers, is negligible). Due to the presence of the 3.9 k $\Omega$  resistor  $R_{11}$  the highest potential available at the potentiometers, when the right-hand section of the E 90 CC is conducting, amounts to 240 V. This is ample for presetting the counter tubes to position 0.

The anode capacitance of the right-hand triode sections is increased by the capacitor  $C_4$ , thus reducing the slope of the trailing edge of the negative-going pulse. If this capacitor were omitted an inadmissibly large proportion of the high voltage pulse produced when this triode section is cut off would be transmitted to the right deflection electrode of the counter tubes via the anode-to-cathode capacitance of the additional diodes connected to points  $p$  to  $s$ .

The double diode EB 91 has been provided to restore the rest level of both grids at high repetition frequencies of the cycle of counts, thus ensuring that the anode potential of the righthand triode section is always exactly 95 V during the interval it is conducting.

The presetting switch at the right has been provided for static control. This should be a push-button switch and make reliable contact either with point  $a$  or  $b$  without rebounding or undue arcing being produced; moreover, there should be no possibility whatsoever of contact being made simultaneously with both  $a$  and  $b$ , since this would result in resistor  $R_{11}$  being seriously overloaded.

When the switch is pressed, establishing contact with point  $b$ , capacitor  $C_5$  will be suddenly charged. This results in the potential at the potentiometers dropping to such an extent that the beams of all counter tubes are advanced to figure 9, irrespective of the positions occupied by the sliders of the potentiometers. \*) When the switch is subsequently released, contact with point  $a$  is re-established, so that  $C_5$  discharges through the choke  $L$  shunted by the damping resistor  $R_{13}$ . The negative-going pulse thus produced at point  $c$  is fed to the input stage, which is thus triggered. As a result all counter tubes are successively reset to zero, the fourth decade brings the presetting stage into operation,

\*) If any of the counter tubes are not advanced to position 9 this is an indication that the switch makes poor contact.

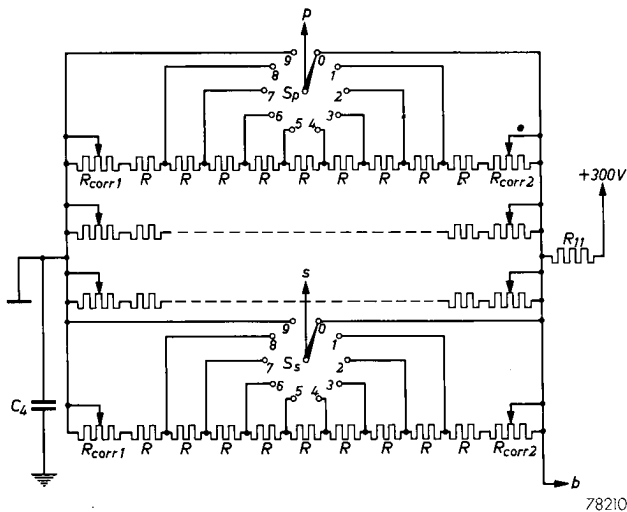


Fig. 25. Circuit for replacing the four wire-wound potentiometers  $P_1$ — $P_4$  and the resistors  $R_1$ — $R_{10}$  shown in fig. 6 by fixed resistors  $R$  ( $4.7\text{ k}\Omega \pm 2\%$ ,  $\frac{1}{4}\text{ W}$ ) and four ten-way switches  $S_p$ — $S_s$ . The variable resistors  $R_{corr}$  need be readjusted only when the tubes are replaced. They may be of the carbon type and should have a value of  $10\text{ k}\Omega$ . Only two of the four branches have been completely drawn. All resistors of this circuit should be mounted such that adequate cooling is provided, this may be done by drilling holes in the chassis above these resistors.

and the electron beams are thereby advanced to their preset positions.

In an alternative circuit the potentiometers  $P_1$ ... $P_4$ , which must be wire-wound, are replaced by fixed carbon resistors  $R$  and four ten-way switches  $S_p$ ... $S_s$ , as shown in fig. 25. In this way the counter can be preset to any number at a moment's notice without risk of inaccurate adjustment. The variable resistors  $R_{corr}$ , which may be of the carbon type, need be readjusted only when the corresponding counter tube is replaced. (In the circuit shown in fig. 24 it may be necessary to change the calibrated dials of the potentiometers when the counter tubes are replaced).

## THE OUTPUT STAGE

The trapezoidal voltage pulse produced at the lower tap of the cathode resistor of the last pulse shaper when a cycle of counts has been completed, can be applied to an output stage specially designed for the purpose in view. The circuit of a universal output stage, which operates an electromagnetic relay, is given in fig. 26. This circuit offers the advantage that the time during which the relay is energised can be adjusted from 20 milliseconds to 2 seconds.

Similarly to the interstage circuits this output stage consists of a monostable multivibrator and is

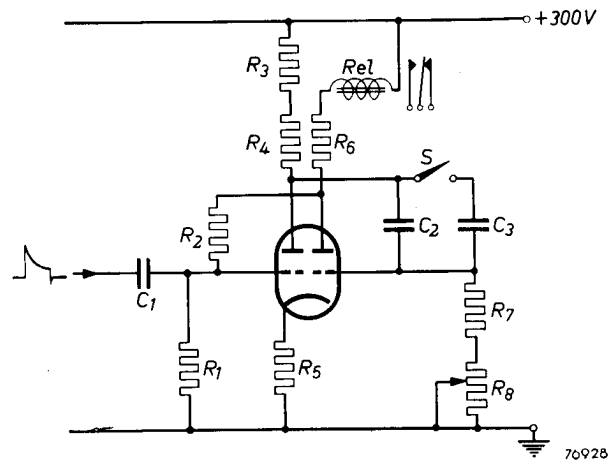


Fig. 26. Circuit of an output stage. The time during which the relay  $Rel$  remains energised when a pulse is fed to the input depends on the values of  $R_8$  and the coupling capacitance between the two triode sections of the E90CC.

### Component values

$R_1$	=	$0.1\text{ M}\Omega$	$\pm 2\%$	$\frac{1}{2}\text{ W}$
$R_2$	=	$1\text{ M}\Omega$	$\pm 2\%$	$1\text{ W}$
$R_3$	=	$15\text{ k}\Omega$	$\pm 5\%$	$\frac{1}{2}\text{ W}$
$R_4$	=	$47\text{ k}\Omega$	$\pm 5\%$	$1\text{ W}$
$R_5$	=	$10\text{ k}\Omega$	$\pm 2\%$	$\frac{1}{2}\text{ W}$
$R_6$	=	$6.8\text{ k}\Omega$	$\pm 5\%$	$\frac{1}{2}\text{ W}$
$R_7$	=	$0.33\text{ M}\Omega$	$\pm 10\%$	$\frac{1}{2}\text{ W}$
$R_8$	=	$2.6\text{ M}\Omega$	carbon	
$C_1$	=	$2.2\text{ }\mu\text{F}$	$\pm 10\%$	
$C_2$	=	$0.056\text{ }\mu\text{F}$	$\pm 10\%$	
$C_3$	=	$0.47\text{ }\mu\text{F}$	$\pm 10\%$	
$Rel$	=	$\left\{ \begin{array}{l} \text{resistance: } 3\text{ k}\Omega \\ \text{attracting current: } 8.5\text{ mA} \\ \text{releasing current: } 3.5\text{ mA} \end{array} \right.$		

fed by the common supply unit. The multivibrator is triggered by the negative-going flank of the differentiated pulse applied to the left triode section. The time during which the relay remains energised can be adjusted by means of the variable resistor  $R_8$  or by connecting the additional capacitor  $C_3$  by means of switch  $S$  across the coupling capacitor  $C_2$ . The maximum repetition frequency of this output stage is 20 cycles of counts per second, which is ample for most practical purpose. When it is required to take full advantage of the maximum repetition frequency of the predetermined counter (3000 c/s) an output circuit equipped with a thyatron instead of an electromagnetic relay may be used.

## THE COMPLETE CIRCUIT

Fig. 27 shows the complete circuit of the predetermined counter with output stage, built according to the principles outlined above. It is, moreover, preceded by an additional input pulse shaper ensuring reliable operation even when the input

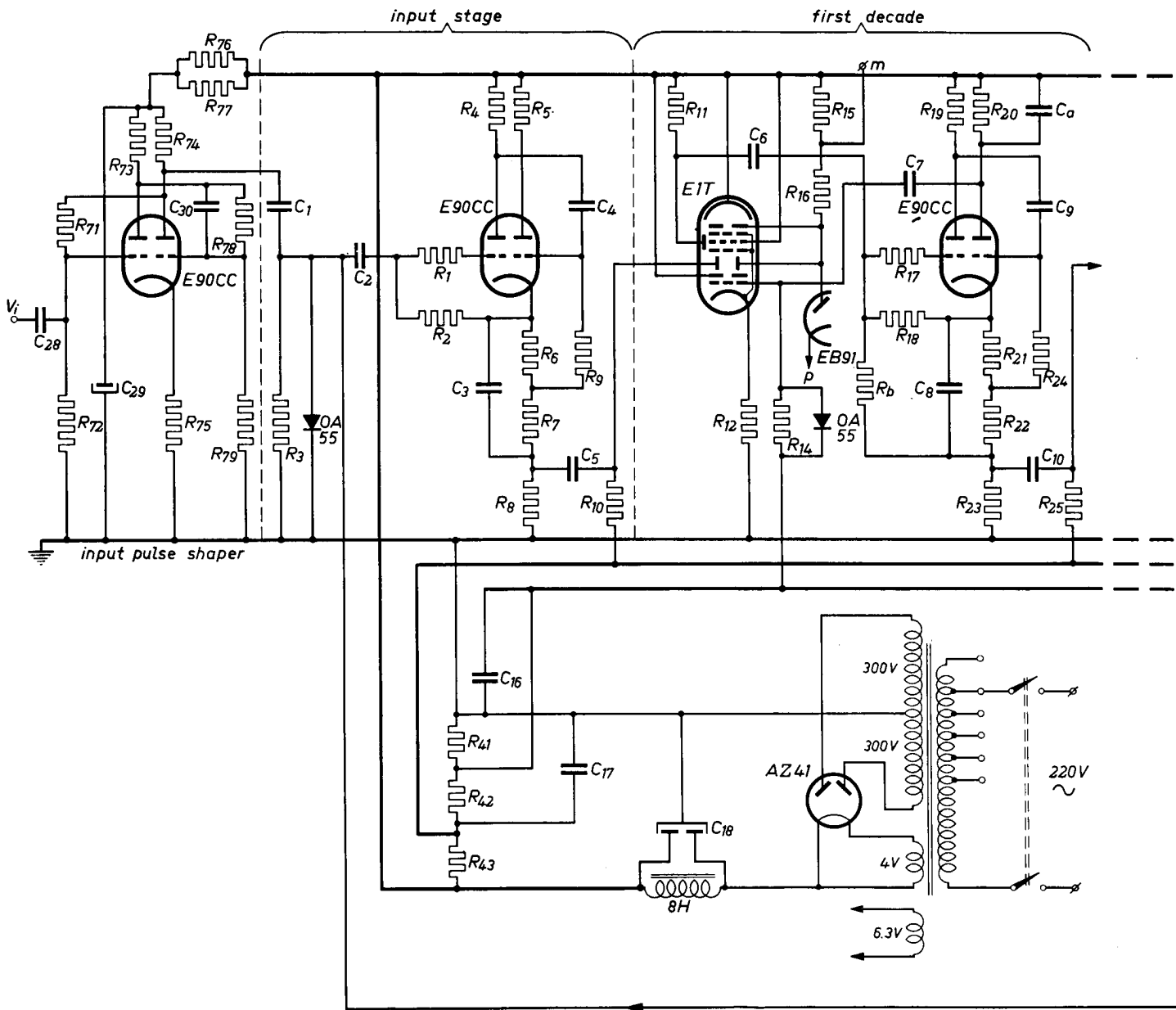
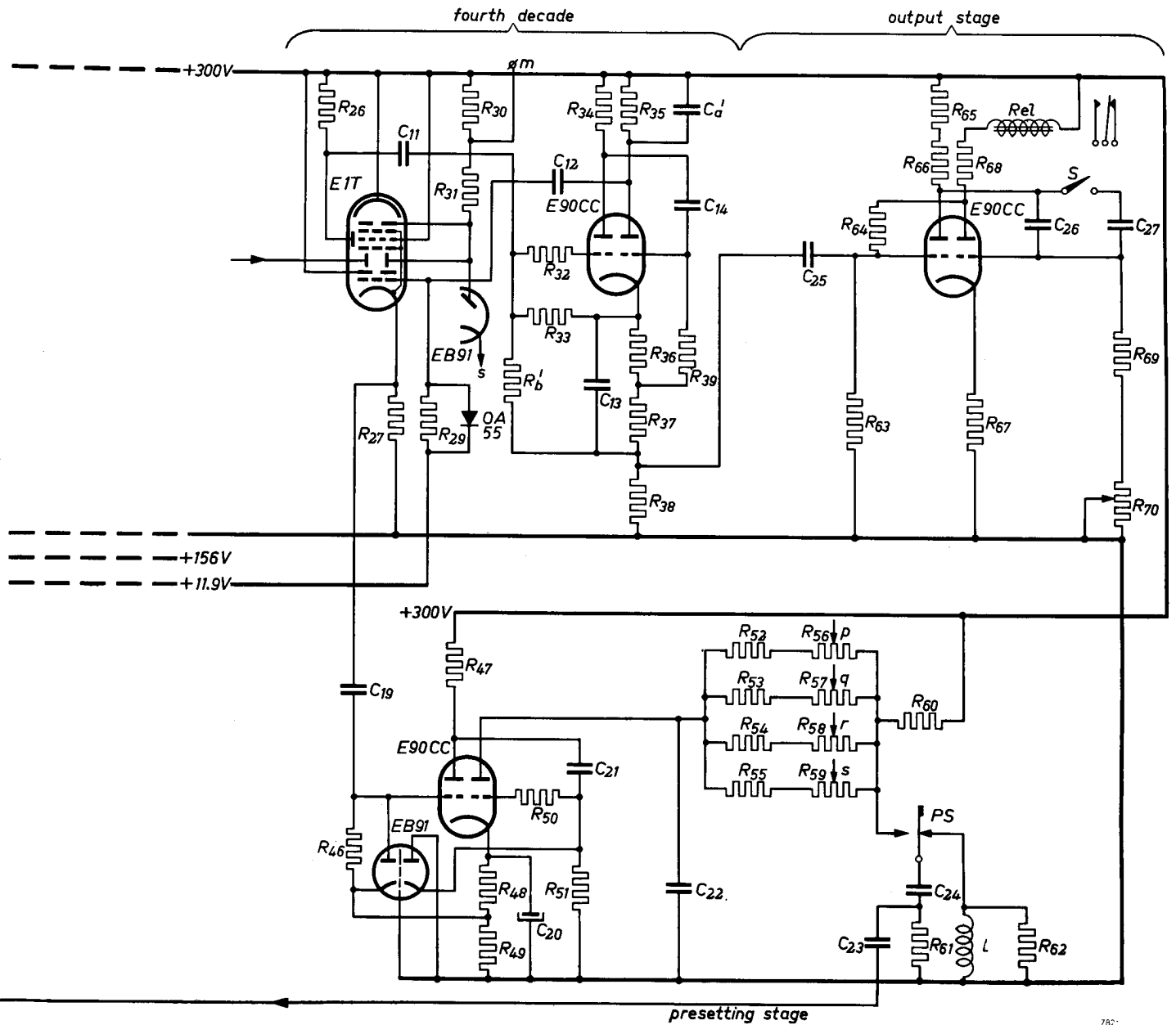


Fig. 27. Complete circuit of the predetermined counter with additional input shaper and

		Component	
$R_1$	$= 5.6 \text{ k}\Omega, \pm 10\%, \frac{1}{2} \text{ W}$	$R_{16}$	$= 0.56 \text{ M}\Omega, \pm 10\%, \frac{1}{2} \text{ W}$
$R_2$	$= 0.56 \text{ M}\Omega, \pm 10\%, \frac{1}{2} \text{ W}$	$R_{17}$	$= 18 \text{ k}\Omega, \pm 2\%, \frac{1}{2} \text{ W}$
$R_3$	$= 56 \text{ k}\Omega, \pm 10\%, \frac{1}{2} \text{ W}$	$R_{18}$	$= 1.5 \text{ k}\Omega, \pm 2\%, \frac{1}{2} \text{ W}$
$R_4$	$= 39 \text{ k}\Omega, \pm 2\%, 2 \text{ W}$	$R_{19}$	$= 3.9 \text{ k}\Omega, \pm 2\%, \frac{1}{2} \text{ W}$
$R_5$	$= 3.3 \text{ k}\Omega, \pm 2\%, \frac{1}{2} \text{ W}$	$R_{20}$	$= 33 \text{ k}\Omega, \pm 10\%, \frac{1}{2} \text{ W}$
$R_6$	$= 4.7 \text{ k}\Omega, \pm 2\%, 1 \text{ W}$	$R_{21}$	$= 1 \text{ M}\Omega, \pm 10\%, \frac{1}{2} \text{ W}$
$R_7$	$= 2.7 \text{ k}\Omega, \pm 2\%, \frac{1}{4} \text{ W}$	$R_{22} - R_{25}$	$= 100 \Omega, \pm 10\%, \frac{1}{2} \text{ W}$
$R_8$	$= 1 \text{ k}\Omega, \pm 1\%, \frac{1}{8} \text{ W}$	$R_{26}$	$= 50 \text{ k}\Omega, \pm 2\%, \text{ wire wound}$
$R_9$	$= 0.1 \text{ M}\Omega, \pm 1\%, \frac{1}{4} \text{ W}$	$R_{27}$	$= 3.9 \text{ k}\Omega, \pm 2\%, \frac{1}{2} \text{ W}$
$R_{10}$	$= 15 \text{ k}\Omega, \pm 2\%, \frac{1}{8} \text{ W}$	$R_{28}$	$= 100 \Omega, \pm 10\%, \frac{1}{2} \text{ W}$
$R_{11} = R_{26}$	$= 39 \text{ k}\Omega, \pm 5\%, \frac{1}{2} \text{ W}$	$R_{29}$	$= 680 \Omega, \pm 10\%, \frac{1}{2} \text{ W}$
$R_{12} = R_{27}$	$= 15 \text{ k}\Omega, \pm 1\%, \frac{1}{8} \text{ W}$	$R_{30}$	$= 0.1 \text{ M}\Omega, \pm 2\%, \frac{1}{2} \text{ W}$
$R_{14} = R_{29}$	$= 0.33 \text{ M}\Omega, \pm 10\%, \frac{1}{2} \text{ W}$	$R_{31}$	$= 1 \text{ M}\Omega, \pm 2\%, 1 \text{ W}$
$R_{15} = R_{30}$	$= 10 \text{ k}\Omega, \pm 10\%, \frac{1}{2} \text{ W}$	$R_{32}$	$= 15 \text{ k}\Omega, \pm 5\%, \frac{1}{2} \text{ W}$
$R_{16}$	$= 1 \text{ M}\Omega, \pm 1\%, \frac{1}{2} \text{ W}$	$R_{33}$	$= 5.6 \text{ k}\Omega, \pm 1\%, \frac{1}{8} \text{ W}$
$R_b = R_b'$	$= 8.2 \text{ M}\Omega, \pm 2\%, \frac{1}{4} \text{ W}$	$R_{34}$	$= 68 \text{ k}\Omega, \pm 1\%, 1 \text{ W}$
$R_{17} = R_{32}$	$= 5.6 \text{ k}\Omega, \pm 10\%, \frac{1}{2} \text{ W}$	$R_{35}$	$= 68 \text{ k}\Omega, \pm 1\%, 1 \text{ W}$
$R_{18} = R_{33}$	$= 0.56 \text{ M}\Omega, \pm 5\%, \frac{1}{2} \text{ W}$		
$R_{19} = R_{34}$	$= 39 \text{ k}\Omega, \pm 2\%, 2 \text{ W}$		
$R_{20} = R_{35}$	$= 3.3 \text{ k}\Omega, \pm 2\%, \frac{1}{8} \text{ W}$		
$R_{21} = R_{36}$	$= 4.7 \text{ k}\Omega, \pm 2\%, \frac{1}{4} \text{ W}$		
$R_{22} = R_{37}$	$= 2.7 \text{ k}\Omega, \pm 2\%, \frac{1}{4} \text{ W}$		
$R_{23} = R_{38}$	$= 1 \text{ k}\Omega, \pm 1\%, \frac{1}{8} \text{ W}$		
$R_{24} = R_{39}$	$= 0.15 \text{ M}\Omega, \pm 2\%, \frac{1}{8} \text{ W}$		
$R_{25}$	$= 15 \text{ k}\Omega, \pm 2\%, \frac{1}{8} \text{ W}$		
$R_{41}$	$= 5.6 \text{ k}\Omega, \pm 1\%, \frac{1}{8} \text{ W}$		
$R_{42}$	$= 68 \text{ k}\Omega, \pm 1\%, 1 \text{ W}$		
$R_{43}$	$= 68 \text{ k}\Omega, \pm 1\%, 1 \text{ W}$		



output second and third decades, which are identical to the first decade, have been left out.

values.

$R_{60}$	=	47 k $\Omega$ , $\pm$ 5%, 1 W	$C_1$	=	220 pF, $\pm$ 10%	$C_{16}$	=	$2 \times 50 \mu\text{F}$ , 450 V
$R_{61}$	=	10 k $\Omega$ , $\pm$ 2%, 1/2 W	$C_2$	=	220 pF, $\pm$ 10%	$C_{19}$	=	470 pF, $\pm$ 10%
$R_{62}$	=	6.8 k $\Omega$ , $\pm$ 5%, 1/2 W	$C_3$	=	100 pF, $\pm$ 2%	$C_{20}$	=	25 $\mu\text{F}$ , 25 V
$R_{63}$	=	0.33 M $\Omega$ , $\pm$ 10%, 1/2 W	$C_4$	=	39 pF, $\pm$ 2%	$C_{21}$	=	560 pF, $\pm$ 10%
$R_{64}$	=	2.6 M $\Omega$ , carbon	$C_5$	=	0.0068 $\mu\text{F}$ , $\pm$ 10%	$C_{22}$	=	180 pF, $\pm$ 10%
$R_{65}$	=	56 k $\Omega$ , $\pm$ 2%, 1/2 W	$C_6 = C_{11}$	=	220 pF, $\pm$ 10%	$C_{23}$	=	15 pF, $\pm$ 10%
$R_{66}$	=	56 k $\Omega$ , $\pm$ 2%, 1/2 W	$C_7 = C_{12}$	=	0.0068 $\mu\text{F}$ , $\pm$ 10%	$C_{24}$	=	0.47 $\mu\text{F}$ , $\pm$ 20%
$R_{67}$	=	8.2 k $\Omega$ , $\pm$ 2%, 1/2 W	$C_8 = C_{13}$	=	68 pF, $\pm$ 2%	$C_{25}$	=	22 pF, $\pm$ 10%
$R_{68}$	=	8.2 k $\Omega$ , $\pm$ 2%, 1/2 W	$C_9 = C_{14}$	=	180 pF, $\pm$ 2%	$C_{26}$	=	0.056 $\mu\text{F}$ , $\pm$ 10%
$R_{69}$	=	12 k $\Omega$ , $\pm$ 2%, 1/2 W	$C_{10}$	=	100 pF, $\pm$ 2%	$C_{27}$	=	0.47 $\mu\text{F}$ , $\pm$ 20%
$R_{70}$	=	56 k $\Omega$ , $\pm$ 2%, 1 W	$C_{11}$	=	680 pF, $\pm$ 5%	$C_{28}$	=	1 $\mu\text{F}$ , $\pm$ 20%
$R_{71}$	=	56 k $\Omega$ , $\pm$ 2%, 1 W	$C_{14}$	=	180 pF, $\pm$ 2%	$C_{29}$	=	25 $\mu\text{F}$ , 300 V
$R_{72}$	=	56 k $\Omega$ , $\pm$ 2%, 1/2 W	$C_{15}$	=	0.39 $\mu\text{F}$ , $\pm$ 20%	$C_{30}$	=	100 pF, $\pm$ 10%
$R_{73}$	=	56 k $\Omega$ , $\pm$ 2%, 1/2 W	$C_{17}$	=	0.15 $\mu\text{F}$ , $\pm$ 20%	$L$	=	1 mH
$R_{74}$	=	56 k $\Omega$ , $\pm$ 2%, 1/2 W						

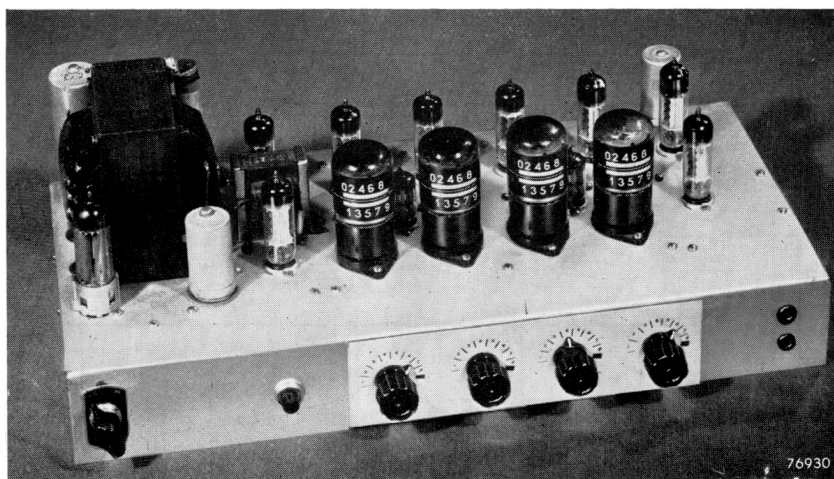


Fig. 28. Front view of the predetermined counter without hood. Length of the chassis 42 cm, height 6 cm, depth 20 cm.

signals do not comply with the specifications given. Sinusoidal voltages down to 10 c/s may thus be applied to the input, provided their amplitude ranges from 15 V to about 50 V. If there is a risk of random pulses being produced by rebounding of the spring contacts of mechanical switches, the additional input shaper should, moreover, be preceded by a low-pass filter.

The supply unit differs slightly from that of the multi-decade counter, which is attributed to the

fact that no auxiliary voltage source is required for resetting the tubes to position zero. The double diodes EB 91 from the decade stages must be fed from a separate filament winding (omitted in fig. 27), which should be connected to the + 156 V line. The double diode EB 91 in the preset stage should be fed parallel to the preset tube E 90 cc.

Fig. 28 shows the front view of the complete predetermined counter containing the additional input pulse shaper and the output stage mentioned above. At the front can be seen the four control knobs with calibrated dials for presetting the counter to the required number. At the right of the counter tubes is the E 90 CC double triode of the additional input pulse shaper and at the left that of the presetting stage. The relay is mounted behind the mains transformer to the left. The additional controls for adjusting the time during which the relay remains energised are mounted at the rear of the chassis next to a female plug to which the relay contacts are connected.

Fig. 29 shows the chassis seen from below. The four wire-wound potentiometers for presetting the counter tubes can be clearly seen. The wiring towards these potentiometers should be kept clear of the other wiring in order to avoid random pulses being induced capacitively into other leads. The double diodes EB 91 are mounted close to the corresponding counter to keep the wiring as short as possible and away from the chassis, undue increase of the stray capacitance at the right deflection electrode and anode thus being avoided. In order to prevent interaction between the two diode systems of the EB 91, the internal screen of this tube should be connected to the +300 V line.

## ADJUSTMENT AND CALIBRATION

### *Presetting by means of potentiometers*

The optimum settings of the potentiometers corresponding to the figures from 0 to 9 differ slightly for each decade and can be determined in the following way. A pulse generator having a frequency of up to 3000 c/s is connected to the input

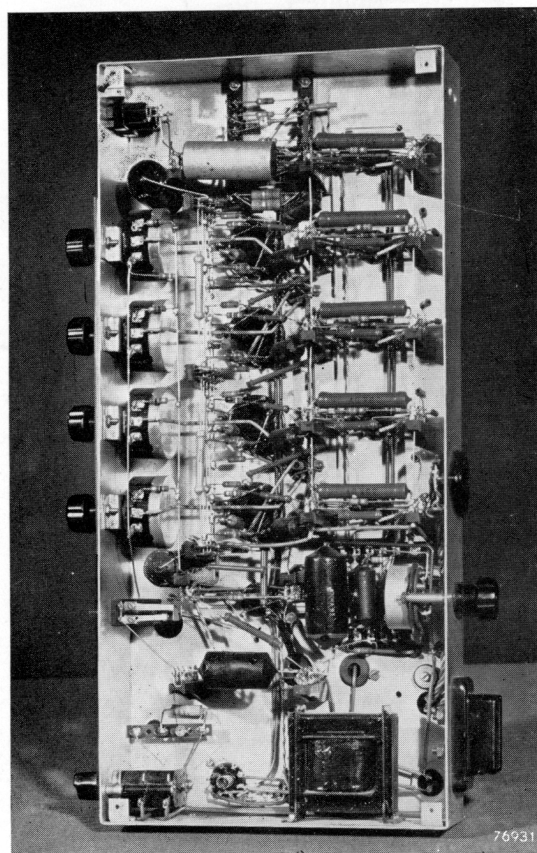


Fig. 29. The chassis depicted in fig. 28, seen from below.

terminals. First the potentiometer that presets the "unit" decade is calibrated, the other potentiometers being turned as far as possible in a clockwise direction \*). The transitional points at which the beam is preset to a next figure are sharply defined. The optimum positions are obviously those midway between these points. After this potentiometer has been calibrated, its knob is set to position 0 and the potentiometer by means of which

Due to the spread in the characteristics of the counter tubes the voltage at the anode and right deflection plate may range from 215 V to 240 V at position 0 and from 95 V to 115 V at position 9. When a counter tube is replaced it is therefore necessary to check the calibration of the corresponding potentiometer. As a rule there is no need to draw a new dial, it being sufficient to rotate the calibrated dial over a small angle.

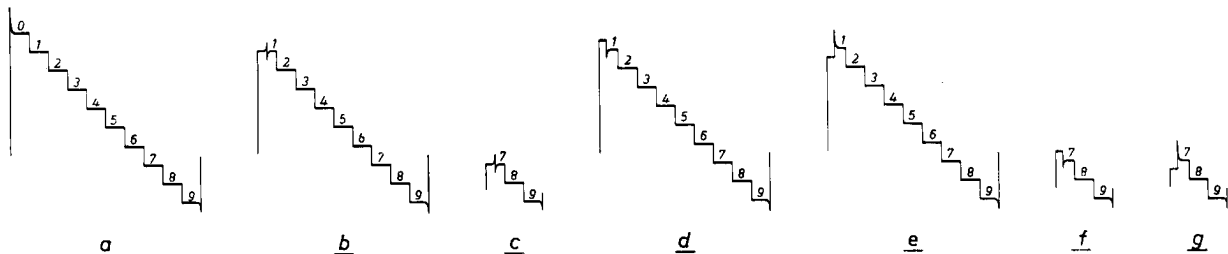


Fig. 30. Oscillograms of a decade incorporating a ten-way switch for the presetting. *a* — switch at position 0; *b* — switch at position 1,  $R_{\text{corr2}}$  accurately adjusted; *c* — switch at position 7,  $R_{\text{corr1}}$  accurately adjusted; *d* — switch at position 1,  $R_{\text{corr2}}$  too low; *e* — switch at position 1,  $R_{\text{corr2}}$  too high; *f* — switch at position, 7,  $R_{\text{corr1}}$  too high; *g* — switch at position 7,  $R_{\text{corr1}}$  too low.

the tens are preset is calibrated in a similar way; the knobs for presetting the hundreds and thousands should remain turned entirely to the right. The frequency of the pulse generator may now be increased to 12 500 c/s, which facilitates in particular the calibration of the potentiometers for presetting the hundreds and the thousands. \*\*). For calibrating the potentiometer that presets the hundreds, the knobs for presetting the units and tens should occupy position 0 and the knob for presetting the thousands should remain at its extreme right-hand position. Accurate calibration of the potentiometer for presetting the thousands — which is carried out with the other knobs still set to position 0 — takes a little more time. This is due to the fact that transitional points can no longer be clearly distinguished because the rate at which the electron beam travels over the fluorescent screen becomes fairly low even at the maximum frequency of 12.500 c/s.

\*) It is assumed that the potentiometers are connected so that, during the resetting, the highest potential (corresponding to position 0) is obtained at the slider when the knob is turned entirely in an anti-clockwise direction.

\*\*\*) It should be recognized that when the knob of the potentiometer which presets the "units" decade is adjusted beyond the position corresponding to figure 5 and the other potentiometers are turned as far as possible in a clockwise direction, it is no longer the maximum counting frequency (12 500 counts per second), but the maximum frequency of the cycle of counts (3000 c/s) that limits the counting rate.

### Presetting by means of ten-way switches

When ten-way switches and fixed resistors are used (see fig. 25) the adjustment of the variable resistors  $R_{\text{corr}}$  is preferably carried out with the aid of an oscilloscope connected to terminal *m* of the corresponding decade (see fig. 27). Adjustment should be carried out in the same sequence as described in the preceding section for predetermined counters incorporating potentiometers.

When the switch is set at position 0 the oscillogram displayed will be as shown in fig. 30*a*, consisting of ten distinct steps. When the variable resistors  $R_{\text{corr2}}$  and  $R_{\text{corr1}}$  are correctly adjusted the oscillograms will be as shown in fig. 30*b* and *c* at positions 1 and 7 respectively. If the value of  $R_{\text{corr2}}$ , which serves for correction of the lower positions, is too low the oscillogram will be similar to that shown in fig. 30*d* at position 1; if it is too high an oscillogram similar to that shown in fig. 30*e* is obtained. After  $R_{\text{corr2}}$  has been accurately adjusted, the switch is set to a higher figure, and the adjustment of  $R_{\text{corr1}}$  is checked. If its value is too high the oscillogram will be similar to that shown in fig. 30*f* at position 7, if it is too low the oscillogram will be as shown in fig. 30*g*.





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