# PHILIPS

## SUBMINIATURE
## TRIGGER TUBES

## Z 70 U
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## Z 70 W
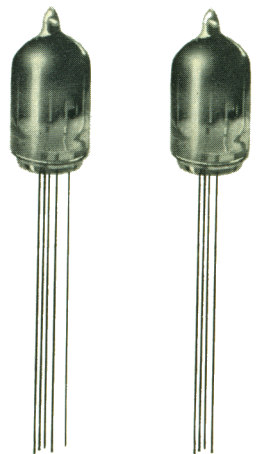
PHILIPS ELECTRON TUBE DIVISION

# Preface

For several years electron tubes have been successfully applied in all kinds of counting and computer circuits. With a few exceptions, all these tubes were of the hot-cathode type, which enabled the realisation of reliable circuits with a very high counting speed.

It has been found that in those cases in which the counting rate need not be very high, such as in many devices for industrial counting and control, cold-cathode tubes can be used to advantage, particularly with a view to their specific properties:

      very low current consumption;

      small heat dissipation;

      visible indication;

      long life;

      extended ambient temperature range.

In order to construct "manageable" and dependable circuits, however, cold-cathode tubes must meet very high demands. By making use of the well-known molybdenum sputtering technique, tubes have been developed that fully come up to all requirements, viz. the Z 70U and Z 70W.

The Bulletin in hand contains the latest data on these tubes, as also all application data which were worked out in our laboratories, which information will no doubt assist in examining into the possibilities offered by these tubes.

We are glad to be able to publish in this revised edition the tentative data of the Z 70W, being a Z 70U with two starters. The characteristics of the tube are similar to those of the Z 70U. The Z 70W will be very useful as a reset tube in circuits with the Z 70U, and in this way makes possible the easy construction of forward-backward counters with a small number of tubes. Some application data on the Z 70W are also included.

# Contents

# Introduction

The Z 70 U and Z 70 W cold-cathode tubes are the most recent types of a series of trigger tubes PL 1267/Z 300 T, 5823/Z 900 T, Z 71 U, Z 803 U, Z 804 U and Z 805 U, which, because of their special features, are suitable for a wide range of applications.

These features are:

(a) no heating power;
(b) long life;
(c) immediately ready for operation;
(d) visual indication;
(e) wide ambient-temperature range;
(f) short-time overloads permissible;
(g) narrow tolerances and constant characteristics;
(h) very long life, due to the plain molybdenum cathode;
(i) rapid ignition owing to very small ignition delay;
(j) high sensitivity;
(k) small dimensions and rugged construction.

The Z 70 U is suitable for all kinds of "on-off" applications for which a low current is required (up to 4 mA). Thus it can be used as an electronic switching element, e.g. in counter circuits and in logic units as employed for automation, etc. In decimal counter circuits counting speeds between 2 and 5 kc/s are possible with this tube. The power required is only 1.2 W per decade.

The Z 70 W has the same dimensions and electrical characteristics as the Z 70 U, with the additional advantage of two equivalent starters. It can therefore be used in more intricate circuits, such as forward-backward counters, reset positions, gates, etc.

Modern "sputtering" technique in the manufacture of the tube enables narrow tolerances to be obtained on the breakdown and burning voltages.

The tube is highly sensitive; within the narrow limits of the starter breakdown voltage (137-153 V) a starter current of only 30 $\mu$A is enough to ensure the main discharge at an anode voltage of 250 V.

By means of biasing the starter with 120 V when the tube is used in a normal counter circuit, ignition can be produced by a rectangular pulse of only 90 V and 20 $\mu$sec duration, or by a pulse higher than 90 V and at least 15 $\mu$sec with a sufficiently steep leading edge (rise time < 1 $\mu$sec). (For further requirements see section 8, "Starter pulse" on page 9).

The physical dimensions of the tube are extremely small, so that it can readily be used in printed wiring. One decade counter circuit with ancillary elements can, for example, be produced in a volume of 0.2 dm$^3$.

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# 1. Properties and Construction

GENERAL

Basically a trigger tube is a three-electrode tube filled with a rare gas, the electrons being released from the cathode by ion bombardment. With two-electrode tubes, such as for example voltage stabilisers, this action commences as soon as the voltage between the electrodes exceeds the ignition voltage. A trigger tube, however, is provided with an additional electrode, called the grid or "starter", by means of which the main discharge between cathode and anode can be initiated. During stand-by periods the anode operates at a voltage below the ignition voltage between anode and cathode, but high enough to maintain the main discharge once a discharge has been initiated between starter and cathode

Like most other gas discharge tubes, the trigger tube is essentially an "on-off" device. The starter loses control as soon as the main discharge between anode and cathode has been established. The most important fields of application are therefore found in switching equipment, e.g. relay and counting circuits, power switching apparatus, welding timers etc. For these applications the trigger tube has the following special advantages:

(1) Since no heating power is required, a mains transformer can often be dispensed with; there is also no power consumption during stand-by periods. This is of special importance in apparatus with battery supply or in mobile installations.

(2) No heating-up time is required, the tube being always ready for immediate operation.

(3) The main discharge can be initiated by a small energy pulse on the starter.

(4) A long life may be expected, independent of operating time.

(5) The amplitude of the starting pulse required for firing the tube is practically independent of the anode voltage.

PRINCIPLE OF OPERATION OF TRIGGER TUBES

Since the trigger tube has three electrodes, there are various ways in which the discharge may be initiated. Provided suitable voltages are applied, the discharge may take place from the anode to the cathode, from the anode to the starter or from the starter to the cathode, whilst in all three cases current flow is possible in two directions.

The cathode material of a trigger tube is, however, specially prepared so as to have a low work function.

For a given voltage the current flow in the direction from the anode or the starter to the cathode (direction of positive current) is therefore larger than in the reverse direction.

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It is possible to represent the breakdown characteristics between the various electrodes graphically. Such a graph is reproduced in Fig.1. For all combinations of anode starter voltages within the closed loop there is no discharge, unless the border line has been passed previously. In the latter case there is already a discharge and, depending upon the arc voltages between the electrodes concerned, this discharge is maintained also at voltages corresponding to part of the area within the loop.
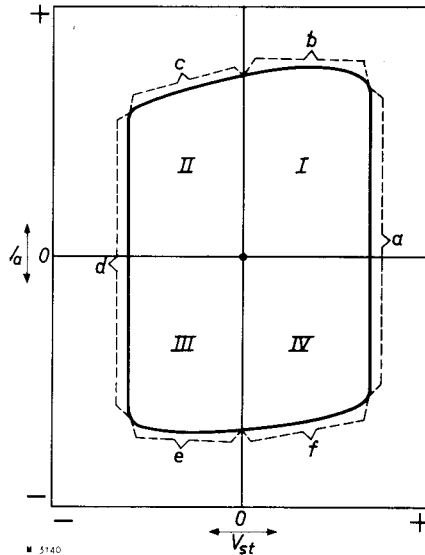
Fig.1. Typical breakdown characteristic of a trigger tube.

The section a of the loop refers to a discharge between starter and cathode (direction of positive current). It is seen that the ignition voltage required is practically independent of the anode voltage. A discharge from anode to cathode occurs when section b of the loop is passed. Section c refers to a discharge from anode to starter, section d from cathode to starter, section e from cathode to anode, and finally section f from starter to anode.

The discharge characteristic between either of these electrodes and the cathode has the typical form of any gas discharge. For the space between starter and cathode this is represented in Fig.2. As with the stabiliser tubes, distinction must be made between the
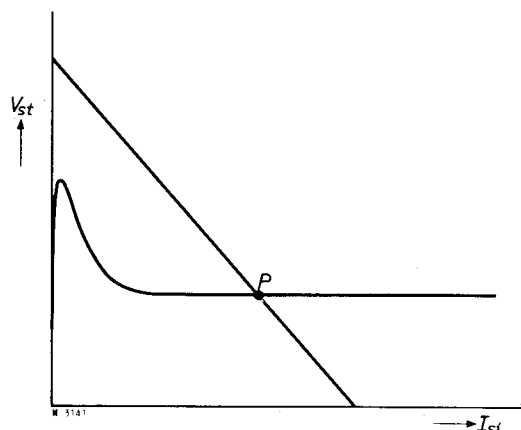


Fig.2. Typical discharge characteristic for the space between starter and cathode.

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"covered cathode" tubes (Z 900 T/5823 and Z 71 U) and the tubes manufactured according to the new "molybdenum sputtering technique" (Z 70 U, Z70W, Z803U, Z804U and Z805U.

In the first category of tubes the ignition voltage, which corresponds to the peak of the curve in Fig.2, lies between 70 and 90 V, whilst the anode-cathode voltage drop is approximately 60 V. The starting and operating voltages of the second category of tubes is roughly a factor 2 higher, viz. 140 to 160 V and 120 V respectively, and the molybdenum sputtering technique offers the advantage of ensuring very stable and uniform operating characteristics; moreover, it facilitates mass-production, which results in lower prices.

In series with the starter of all types a limiting resistor must be used; this is determined by the straight load line which intersects the discharge characteristic in Fig.2 in point $P$.
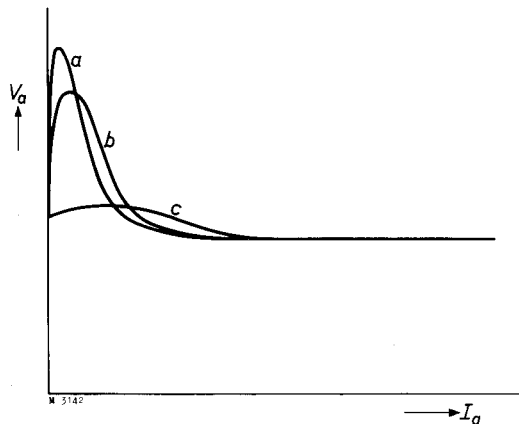


Fig.3. Typical discharge characteristic for the space between anode and cathode.

The discharge characteristic for the space between anode and cathode is represented in Fig.3. Different characteristics are shown here, each referring to one specific value of the current from starter to cathode. Curve $a$ refers to zero starter current. In this case a high voltage is required to initiate the discharge between anode and cathode.

Curves $b$ and $c$ refer to cases where current flows between the starter and the cathode. The positive ions formed by this current reduce the ignition voltage for the space between anode and cathode, i.e. the required ignition voltage decreases with increasing starter current. With curve $b$ the starter current is quite small, whilst curve $c$ refers to a larger current.

At any voltage between anode and cathode there is a minimum starter current required for obtaining transition from starter-cathode discharge to anode-cathode discharge. This is the so-called transfer current. The transition characteristic, i.e. the anode voltage as a function of the transfer current, is given in Fig.4. Under normal operating conditions at zero starter current the amplitude of the anode voltage is kept below $V_0$. Ignition may then be brought about by applying a pulse to the starter, so that sufficient current flows in this electrode to initiate the discharge between anode and cathode. For extinguishing the tube it is necessary to reduce the anode voltage below the burning voltage.

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In any case it must be ensured that ignition in one of the quad-
rants *II*, *III* or *IV* in Fig.1 is prevented, when tubes with a
starter as *anode* (such as the Z 70 U) are used, whereas ignition in
quadrant *II* is prescribed when a tube with a starter as *cathode*
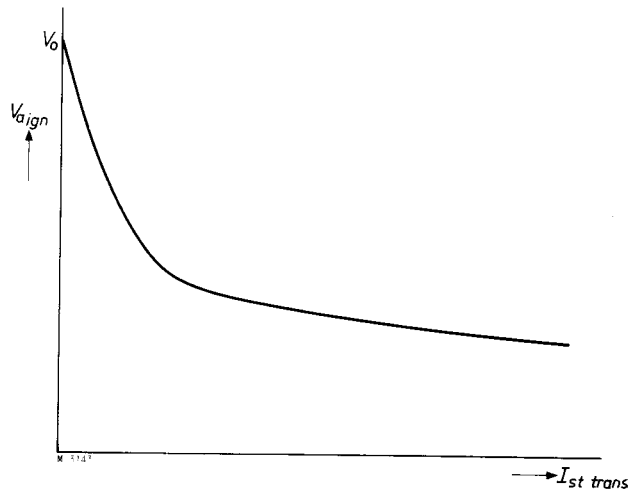(Z 804 U) is used.



Fig.4. Transition characteristic, i.e. breakdown charac-
teristic for the space between anode and cathode as a
function of the starter transfer current.


PROPERTIES OF THE Z 70 U

The various properties of the Z 70 U will be dealt with in the fol-
lowing paragraphs. In addition to the three electrodes discussed,
this tube possesses a fourth electrode, known as the priming cath-
ode. Between the anode and the priming cathode there should always
be a current of 1 to 10 $\mu$A in order to reduce ignition delay (see
sub-section 10).

1. VISUAL INDICATION

When the tube is in operation the neon gas which it contains is
seen to glow bright red. This produces a very clear visual in-
dication.

2. ELECTRICAL READING-OUT

As a rule a resistor will be connected in series with the tube, on
the cathode side. The voltage across this resistor can be used for
electrical reading-out. If reading-out is required with a drop in
voltage, an extra series resistor must be connected at the anode
side. (This is necessary, for example, in certain indicator tubes.)

3. TOLERANCES

In order to allow the widest possible tolerances in the supply
voltage and in the various circuit elements, the tolerances in the
electrical properties of the tube must be kept to a minimum. More-
over, there must not be any appreciable differences between the
properties of individual tubes or variations during their life.
The tube is filled with neon gas, among other things because of
the good indication it provides. The purity of the neon gas used
has a close bearing on the tube characteristics, and this point
therefore receives particular attention during the production
process.

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To maintain the same degree of purity during the life of the tube,
use is made of the "sputtering" technique, by means of which a
layer of molybdenum is deposited on a large area of the glass
envelope. The use of very pure neon gas and sputtering technique
results in narrow tolerances and good constancy. The discharge in
the tube helps to maintain these favourable properties. With this
in view, the quiescent current should preferably lie close to the
upper limit of the tube's loading capacity, so that the cathode
surface is used as. fully as possible.

## 4. ANODE BREAKDOWN VOLTAGE AND SUPPLY VOLTAGE

The anode voltage at which breakdown occurs depends on the gas
pressure, and on the geometry and nature of the tube electrodes.
In the Z 70 U the breakdown voltage lies in the region of 360 V and
is 325 V minimum when the primer is ignited. The supply voltage $V_b$
should therefore be lower than this breakdown voltage ( < 310 V),
and the stabiliser circuit must accordingly be so designed as to
prevent the supply voltage from exceeding this value. As the igni-
tion voltage of the priming discharge has a maximum value of 200 V,
the minimum value of the anode supply voltage is also 200 V.

## 5. STARTER BREAKDOWN VOLTAGE

Because the distance between the starter and cathode is so small,
the starter breakdown voltage is substantially lower than the anode
breakdown voltage, namely between 137 and 153 V. During the life
of the tube the individual variation in this value is generally
less than 3 V. When a tube is ignited for very long periods, draw-
ing negative starter current, a greater drift of the breakdown
voltage may occasionally occur; it is therefore advisable to design
the circuit for this application for. a breakdown voltage of 175 V.
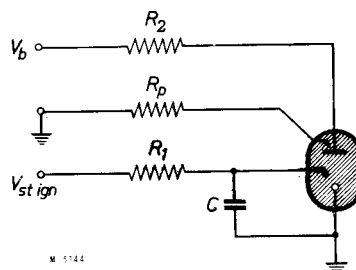


Fig.5. Circuit for measuring starter breakdown voltage.

| | |
|---|---|
| $R_1$ = 3.3 M$\Omega$ | $R_p$ = 18 M$\Omega$ |
| $R_2$ = 50 k$\Omega$ | $C$ = 100 pF |

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The starter breakdown voltage is measured in a circuit as shown in
Fig.5. The capacitor $C$ of 100 pF is connected close to the tube
base between starter and cathode, the reason being that the dis-
tance between these connections can influence the result of the
measurement. For the same reason the resistor $R_p$ is connected near
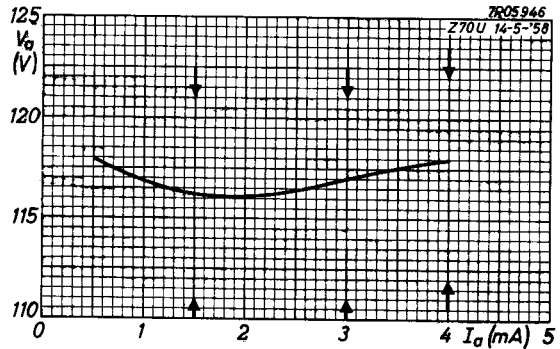to the tube base.

An external starter should not be used for igniting the tube, nor
is it advisable to mount conductive elements too close to the tube.

## 6. BURNING VOLTAGE

The burning voltage $V_a$ lies between 111 and 122 V at a cathode current between 2 and 4 mA (Fig.6).

Fig.6. Anode to cathode burning voltage.



## 7. CATHODE CURRENT

The maximum cathode current is 4 mA averaged over 1 sec. Peak currents up to 16 mA are permissible, and even higher values may be permitted in special cases, such as pulse-forming circuits, and other instances, where a high peak current during a short time may occur (e.g. 50 mA peak during 5 $\mu$sec). Having regard to the favourable effect of the discharge, the quiescent current should preferably lie near the permissible maximum.

## 8. STARTER PULSE

The input pulse must answer certain requirements. With a bias of, say, 120 V, a rectangular pulse of 90 V and 20 $\mu$sec duration or a pulse of sufficiently steep leading edge (rise time < 1 $\mu$sec) and an amplitude greater than 90 V, measured after 15 $\mu$sec (Fig.7), will be sufficient. In general, pulses with a steep leading edge and a slowly falling trailing edge are to be preferred to rectangular pulses of over 100 V. The trailing edge of these rectangular pulses may give rise to negative pulses on the starter, causing re-ignition of the tube. Pulses of pulse-forming circuits will have the shape as indicated in Fig.7, the steep front caused by the capacitor coupling, the tail being defined by the time constant of the circuit components (so-called differentiated pulse). The time constant should not be smaller than 50 $\mu$sec.

It will be clear that unbiased tubes can only be triggered with pulses greater than the normal starter ignition voltage.
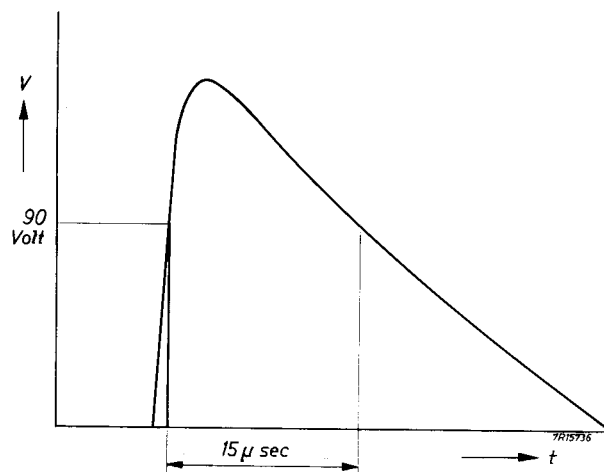


Fig.7. Pulse to trigger the Z 70 U.

The values of the starter ignition voltage as given in the published data are the values measured by slowly increasing the voltage applied to the starter. Ignition of the starter will cause starter current to flow. This current is increased by the capacitor between starter and cathode used in the measuring circuit. The ionisation of the starter-cathode gap enables the anode to take over, provided that the anode is at a sufficiently high potential. The time delay will influence the apparent ignition voltage of the starter and the take-over time of the anode. With pulses the apparent ignition voltage will be higher than with d.c. voltages. The amount of overvoltage depends on the values of the coupling capacitor and the starter resistor. With decreasing pulse width the overvoltage has to be greater than indicated in the published data.

The starter sensitivity, the so-called transfer current is more important for circuits using d.c. triggering. The starter current necessary for anode breakdown is max. 30 $\mu$A at 250 V. In most cases a much higher sensitivity can be reached by placing a capacitor parallel to the starter. Ignition of the starter to the cathode will cause this capacitor to discharge, as the burning voltage between starter and cathode is appreciably lower than the ignition voltage.

The transfer current pulse enables the anode to take over. The value of the capacitor should be at least 100 pF, but in real d.c. triggering circuits preferably higher, especially at lower anode voltages.


9. SMALL DIMENSIONS AND RUGGED CONSTRUCTION

The Z 70 U is a subminiature tube, which can readily be used in printed wiring. The "flying leads" allow the tube to be mounted in any position; no ambient lighting is needed. The tube can withstand vibrations of 2.5 g and 50 c/s for 96 hours, and is proof against the impact acceleration produced with the N.R.L. impact machine for testing electronic devices, the hammer being lifted over an angle of 30°.


10. RAPID OPERATION OWING TO ELIMINATION OF STATISTICAL DELAY TIME

There are two physical phenomena that can cause a time delay between the application of the pulse to the starter and the ignition of the tube. These are called *delay time* and *take-over time*. The first is the time needed for a discharge to build up between starter and cathode. The second is the time needed for the anode to take over this discharge from the starter.

The delay time depends partly upon whether or not there are electrons present in the space between the electrodes at a given moment. The electrons can be accelerated towards one of the electrodes and they then cause sufficient ionization in the gas to produce the discharge. Free electrons may be present in any gas owing to ionization, for example by cosmic radiation, but the number of electrons present per unit volume of gas can be substantially increased by various means:

(1) ionization by irradiating the gas with radioactive or ultra-violet rays;

(2) photoelectric effect on an electrode;

(3) stray ionization produced by an auxiliary discharge.

By these means it is possible to eliminate the so-called statistical delay time. Now the molybdenum cathode is insensitive to visible light, while ultra-violet rays, to which it is sensitive, are absorbed by the glass envelope. The Z 70 U therefore is fitted with a priming cathode, which maintains a current of 1 to 10 $\mu$A to the anode. This makes it possible to keep the tube in darkness, while on the other hand it is not affected by sunlight.

In this way the ignition delay is reduced to the time needed for the discharge between starter and cathode to build up and for it to be taken over by the anode.

To obtain a short take-over time the charge carriers present must be exploited, for which purpose a high field strength is necessary. In the Z 70 U a pulse voltage of 90 V is employed, which allows the total ignition delay to be reduced to a mere 5 $\mu$sec.

## 11. DE-IONIZATION TIME

The de-ionization time is the minimum duration of the negative rectangular pulse that must be fed to the anode to keep the tube extinguished when the supply voltage is subsequently applied again (starter and cathode being interconnected via a resistor). This time depends upon the voltage on the anode during the extinction time, on the recurrent anode voltage and on the current through the tube before the negative pulse is applied.
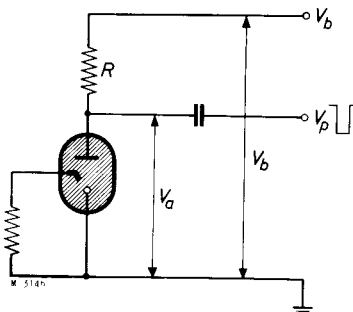


Fig.8. Circuit for measuring de-ionization time.

The de-ionization time is measured with the circuit shown in Fig.8. It is assumed that the tube is burning, so that the voltage on the anode is equal to the burning voltage $V_a$ at a current given by $I = (V_b - V_a)/R$. For this measurement $V_b$ is made equal to 90 % of the breakdown voltage $V_{a\ ign}$. A negative pulse having a duration $\tau_{imp}$ and an amplitude $V_p$ is applied to the anode, so that during the time $\tau_{imp}$ a voltage remains on the tube equal to $V_a - V_p = V_{res}$ (residual voltage). When $\tau_{imp}$ is long enough, the tube is extinguished.

We can now plot the minimum $\tau_{imp}$ needed to extinguish the tube at a given $V_{res}$. A curve of the form illustrated in Fig.9 is thus obtained. This curve shows a minimum at a value of $V_{res}$ approximately equal to 0.7 $V_a$. The time appertaining to this minimum is called the de-ionisation time; in the Z 70 U it amounts approximately to 200 $\mu$sec at an anode voltage of 280 V and a current of 4 mA.
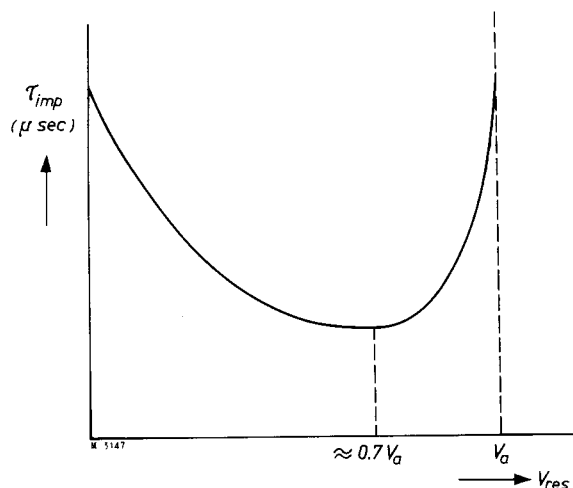
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Fig.9. $t_{imp}$ as a function of $V_{res}$.

The peculiar shape of the curve can be explained as follows. During the discharge each ion impinging on the cathode will liberate on an average $\beta_1$ electrons. Each electron in its turn will form on an average $\beta_2$ ions by collision with the gas molecules. As long as $\beta_1 \cdot \beta_2 = 1$ the discharge will be self-maintaining. When $V_{res}$ is approximately equal to $V_a$, the value of $\beta_1 \cdot \beta_2$ will be only slightly less than 1, and thus a relatively long time will have to elapse before the anode voltage can be applied again without causing the tube to ignite.

On the other hand, if $V_{res}$ approaches 0 the de-ionization will depend entirely on the diffusion, and in that case some time must again elapse before the space charge is sufficiently reduced. It is evident that a minimum in the de-ionization time will be found between these two extremes of $V_{res}$.

## 12. RECOVERY TIME

In the section of a counter circuit shown in Fig.10 the ignition of a succeeding tube causes the extinction of the preceding one. (The primer connections are omitted in this figure.) For example,
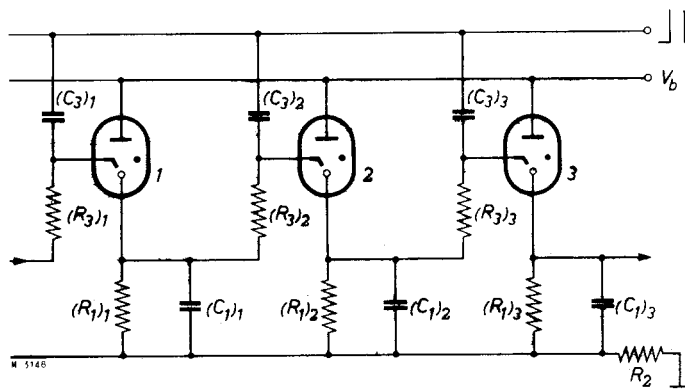


Fig.10. Section of a counting circuit.

when tube 1 is burning the voltage on the cathode is $V_{k1} = V_b - V_a$. Since the total series resistance is $R_1 + R_2$, the current flowing is $(V_b - V_a)/(R_1 + R_2)$.

The ultimate direct voltage across $R_2$ is thus $(V_b - V_a) \cdot R_2/(R_1 + R_2)$. We shall call this voltage $V_{20}$. The ultimate voltage across $R_1$,

which is also the voltage to which capacitor $C_1$ is charged, we shall call $V_{10}$, this being equal to $(V_b - V_a) \cdot R_1 / (R_1 + R_2)$.

Since the cathode of tube 2 is at the potential $V_{20}$, and since the voltage $V_{t2}$ on the starter of tube 2 is equal to $V_{k1}$, we find that the voltage $V_{tk2}$ between starter and cathode is equal to $V_{10} = (V_b - V_a) \cdot R_1 / (R_1 + R_2)$.

When, now, a pulse of 90 V is applied to the starter electrode, tube 2 will ignite, since the maximum starter breakdown voltage is exceeded. At the moment of ignition, $V_2$ suddenly rises to $V_b - V_a$, since capacitor $(C_1)_2$ constitutes a short-circuit at that moment, and $V_{k2}$ suddenly rises to $(V_b - V_a)$.

As a result of the rise in voltage over $R_2$ from $(V_b - V_a) \cdot R_1 / (R_1 + R_2)$ to $(V_b - V_a)$ the potential of all cathodes also increases, and hence $V_{k1} = (V_b - V_a) + (V_b - V_a) - (V_b - V_a) R_2 / (R_1 + R_2)$.

Now the values of $R_1$ and $R_2$ are so chosen with respect to $V_b$ and $V_a$ that $V_{k1}$ becomes approximately equal to $V_b$, so that tube 1 is extinguished.

Once tube 2 is ignited, the capacitor $(C_1)_1$ discharges with a time constant given by $\tau_1 = R_1 \cdot C_1$. At the same time capacitor $(C_1)_2$ charges up to $(V_b - V_a) \cdot R_1 / (R_1 + R_2)$ with a time constant given by $C_1 R_1 R_2 / (R_1 + R_2) = \tau_2$.

During the time in which $V_{k1}$ has fallen far enough for the burning voltage to appear over tube 1 again, this tube should be de-ionized. In practice we are concerned with this recovery time instead of with the de-ionization time. The dynamic de-ionization time or recovery time can be measured with the aid of a circuit operating as a bistable multivibrator, as shown in Fig.11.

Let us assume that the right-hand tube is burning. An applied pulse will reach both starters, but since the right-hand tube is already operating, the left-hand tube will ignite. The cathode potential of this tube then suddenly rises from earth potential to $(V_b - V_a)$, and this rise is passed via capacitor $C$ to the cathode of the right-hand tube, which is thereby extinguished, provided the value of the capacitor is high enough. A second pulse ignites the right-hand tube, and so on. The direct voltage on the starters is kept constant at about 100 V.

At a given value of the supply voltage $V_b$ and resistor $R$ a minimum value of $C$ is found at which the burning tube is extinguished and the other ignited. This measurement should be carried out at a fairly low frequency (e.g. 200 c/s). The time constant $\tau = RC$ is a measure of the recovery time or the dynamic de-ionization time. In a counter circuit the voltage $V_q$ of the quenching pulse at maximum is equal to the difference between $V_b$ and $V_a$, viz. $V_q = V_b - V_a$.

The quenching pulse is therefore fixed at this value. If the time $\tau$ is regarded as a function of the anode voltage, then within the practical range of this voltage it is virtually independent of it. As the magnitude of the quenching pulse was also dependent upon the anode voltage, $\tau$ remains only a function of the current.

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For designing circuits this value $\tau$ is highly practical since it imposes a lower limit on the time constants of the $RC$ elements at a particular current. This time is definitely not the only limitation for the switching speed, there being further factors in the
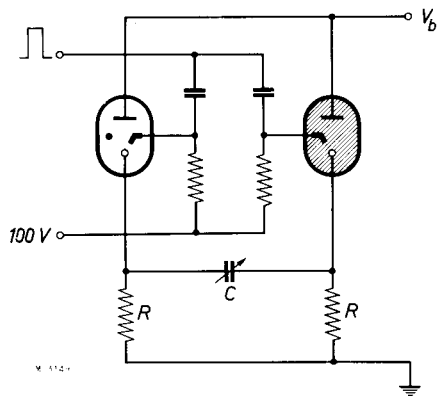
Fig.11. Circuit for measuring recovery time.

circuit, e.g. the interaction of $RC$ elements in the cathode and starter circuits, which restrict the speed. With the Z 70 U the value of $\tau$ changes from max. 115 $\mu$sec at 2 mA to max. 130 $\mu$sec at 4 mA.

## 13. COUNTING RATE

The maximum counting rate in the normal circuit is dependent on the extent to which the supply voltage is stabilised, and on the tolerances of the components. The higher the supply voltage, the higher the counting rate can be raised.
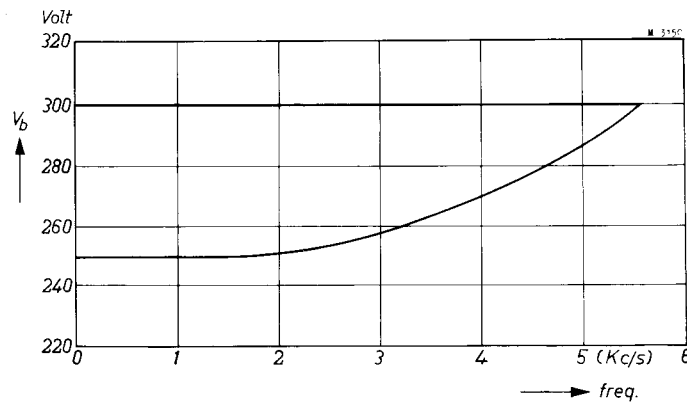


Fig.12. Permissible supply voltage variation as a function of counting frequency.

Since the circuit is also required to count accurately at very low frequencies, the supply voltage must not, however, exceed 310 V.

At low frequency, the maximum value of the anode supply voltage is limited by too high a value of the positive d.c. bias on the starter. In that case, tubes will be ignited even without pulses applied. Decreasing the anode supply voltage will decrease the bias until the moment at which the sum of bias and pulse is insufficient to ignite the tube. It will be clear that in this case the anode supply voltage can be lower as the pulse amplitude becomes higher, but an excessive pulse amplitude may ignite unbiased tubes.

At high counting rates, the RC time of the cathode-circuit and of the starter circuit prevents the respective capacitors from being fully charged and discharged. So the maximum bias will not be

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attained and the sum of pulse and bias will become too small at higher frequencies *) .

It can be seen from Fig.12 that the margin within which $V_b$ can be varied decreases as the counting rate is raised.

This characteristic gives a good insight as to the quality and tolerances of such a counter. Regular checking is rendered very simple by determining the limits of the supply voltage at which the counter just operates.

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*) By shunting the starter resistor with a diode, the influence of the $RC$ time can be greatly reduced so that the counting rate can be increased.

# Z 70 U

## 2. Technical Data

DESCRIPTION

The Z70U is a subminiature cold-cathode trig-
ger tube for operation at a positive starter
voltage, and chiefly intended for d.c. supply.
The tube is provided with a priming cathode,
so that it can be extinguished by a positive
cathode voltage without the priming discharge
being affected. Due to the priming discharge
the anode delay time is short, so that the
Z70U can be used in counters with a frequency
from 2-5 kc/s depending on the circuit, the
tolerances of the components and the stability
of the supply voltage.
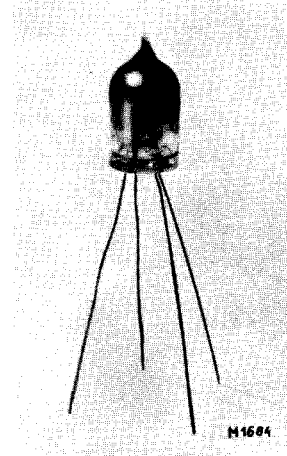
The Z70U has been made according to the molyb-
denum "sputtering technique". Therefore the
cathode consists of pure molybdenum and the inert gas filling is
also free of any contamination. The result is that the operating
characteristics are remarkably stable, for short periods as well as
during life. This renders the Z70U an attractive tube in those
applications where stability of the ignition voltage is essential,
such as in counters, timers, protective circuits, etc. The life
expectancy in counting circuits is longer than 30 000 hrs.

TYPICAL CHARACTERISTICS

(D.C. values; primer discharge ignited; valid during life)

| | | |
|---|---|---|
| Anode voltage | | 250 V |
| Starter ignition voltage | | 137-153 V[1]) |
| Temperature coefficient | | |
| of the starter ignition voltage | max. | -25 mV/°C |
| Starter current for transfer (see Fig.14b) | max. | 30 μA |
| Starter voltage during discharge | see Fig.14c | |
| Anode burning voltage at 3 mA anode current | | |
| (see Fig.14d) | | 111-121 V |
| Anode ignition voltage at zero starter voltage | | |
| minimum value (see Fig.14e) | | 325 V |
| Primer-to-anode ignition voltage | max. | 200 V |
| Primer-to-anode voltage at 3 μA primer current | | 155 V |
| Cathode current ⎫ | | 2-4 mA |
| Primer current ⎬ (recommended values) | | 1-10 μA |
| Primer series resistance ⎭ | | 18 MΩ |

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[1]) See Fig.14a. The individual ignition voltage drift during life in normal
applications is generally less than 3 V. When a tube is ignited for very
long periods, drawing negative starter current, a greater drift of the
ignition voltage may occur. It is therefore advisable to design circuits
for such applications for an ignition voltage of 175 V.

## DYNAMIC CHARACTERISTICS

| | | | | |
|---|---|---|---|---|
| Starter ignition voltage (duration of pulse 20 $\mu$sec) | | | 175 V[2] | |
| Pulse height plus starter bias voltage (recommended value) | | | 200 V | |
| Anode delay time | | | 5 $\mu$sec[3] | |
| Maximum counting frequency | | | 2-5 kc/s[4] | |
| Typical component values for self extinguishing pulse forming circuits | | | | |
| Anode resistance | 1.8 | 1.2 | 0.7 | M$\Omega$ |
| Capacitor | 300 | 600 | 2000 | pF |

## LIMITING VALUES (absolute limits)

| | | | |
|---|---|---|---|
| Anode supply voltage (with primer ignited) | max. | 310 | V |
| | min. | 200 | V |
| Cathode current (average time max. 1 sec) | max. | 4 | mA |
| Peak cathode current | max. | 16 | mA[5] |
| Negative starter current (tube ignited) | max. | 150 | $\mu$A |
| Negative starter current (tube extinguished) | max. | 0 | $\mu$A |
| Starter series resistance | max. | 20 | M$\Omega$ |
| Negative starter pulse voltage at 300 V supply | max. | -30 | V |
| at 200 V supply | max. | -50 | V |
| Ambient temperature | max. | 70 | $^{\circ}$C |

## MAXIMUM DIMENSIONS (in mm) AND BASE CONNECTIONS
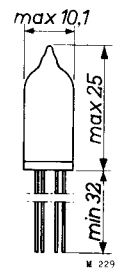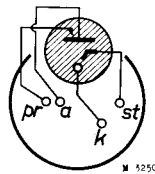


## OPERATIONAL NOTES

1. The Z70U is provided with flying leads. When soldering the tube in the circuit, care should be taken that the seals are not overheated and that the soldered connections should be kept at least 5 mm from the seals. Sharp bends in the leads should be avoided; bends should be kept at least 2 mm from the seals.

2. Starter and primer resistors should be mounted close to the tube.

3. The Z70U is sensitive to unintentional firing if the envelope is touched by conductive elements. Such elements should be kept at a distance of at least 2 mm from the envelope.

4. In capacitive starter circuits the capacitor should have a value between 50 pF and 1000 pF, the required value being in-

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[2]) Circuit Fig.13a.

[3]) Circuit Fig.13b.

[4]) Circuit Fig.13b: see also operational notes.

[5]) Higher peak currents are permissible in pulse-forming circuits.

versely proportional to the anode supply voltage. The starter series resistance should not exceed 20 MΩ if the priming discharge is established.

In special cases higher values of starter series resistance may be tolerated, it is then advisable to consult the tube manufacturer.

5. If the Z70U is ignited by pulses of short duration the total starter voltage (bias plus pulse) should exceed 175 V. A recommended value with a 100 pF starter capacitor is 200 V (see Fig. 13a).

6. If square starter pulses are used, attention should be paid to the trailing edge of the pulse at high amplitudes. When using the circuit of Fig. 13b with pulses of more than 100 V amplitude, a trailing edge as defined by a time constant of at least 50 μsec must be used. In special cases the tube manufacturer should be consulted.
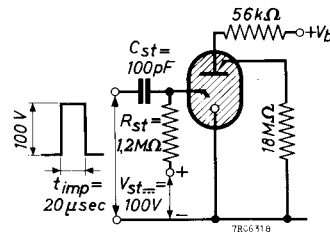


Fig. 13a. Recommended circuit with pulse ignition.
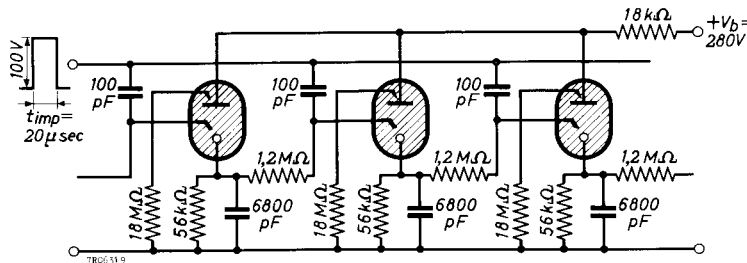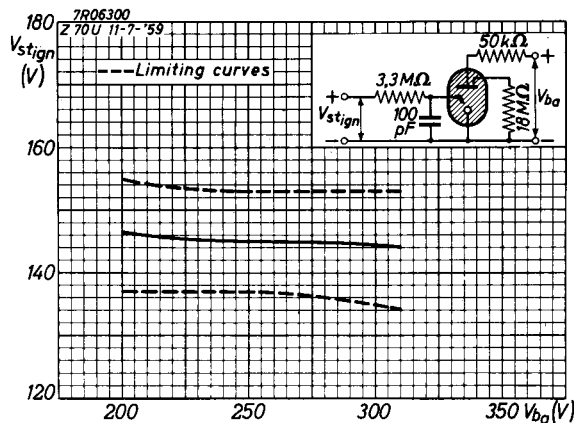


Fig. 13b. Recommended counting circuit.
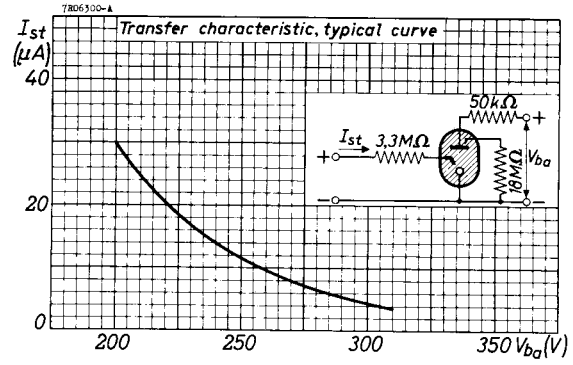


Fig. 14a. Starter breakdown characteristic.
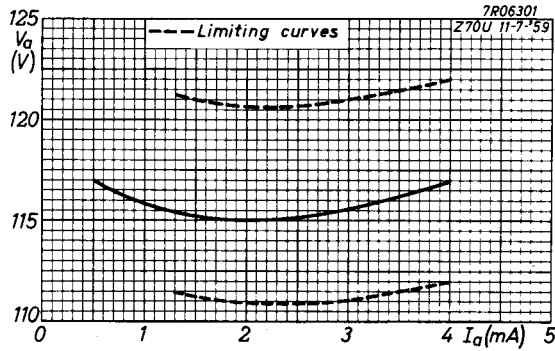
18

7R06300-A

$I_{st}$ ($\mu$A)

Transfer characteristic, typical curve

40

20

0

200      250      300      350 $V_{ba}$(V)

Fig.14b. Transfer characteristic.

125 $V_a$ (V)

120

115

110

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- - - Limiting curves

0      1      2      3      4 $I_a$(mA) 5

Fig.14c. Anode burning voltage char-
acteristic.

$V_{st}$ (V)

140

130

120

110

7R06301-A

0      50      100      150      200 $I_{st}$($\mu$A) 250

Fig.14d. Starter burning voltage
characteristic.

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$V_b$ (V)

400

200

II      I

-200      -100      0      100      200 $V_{st}$(V)

III      IV

-200

-400

In quadrant II high values of $-V_{st}$ should be avoided.
Quadrants III and IV should not be used.
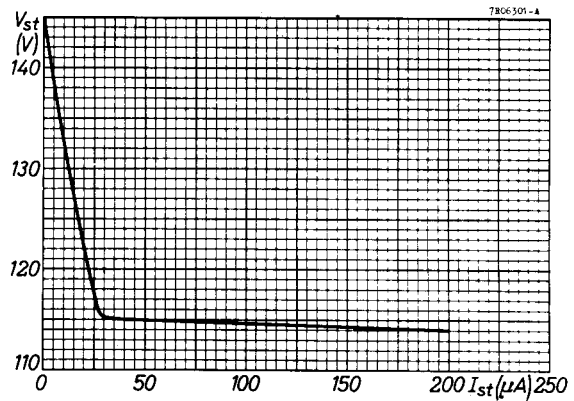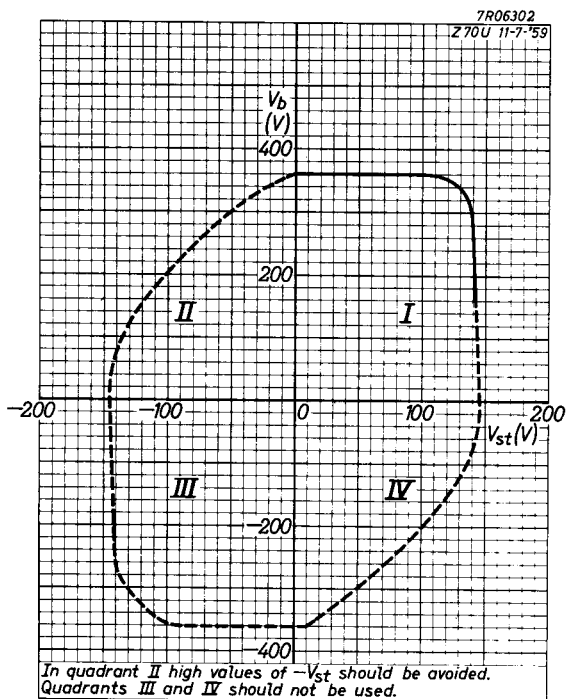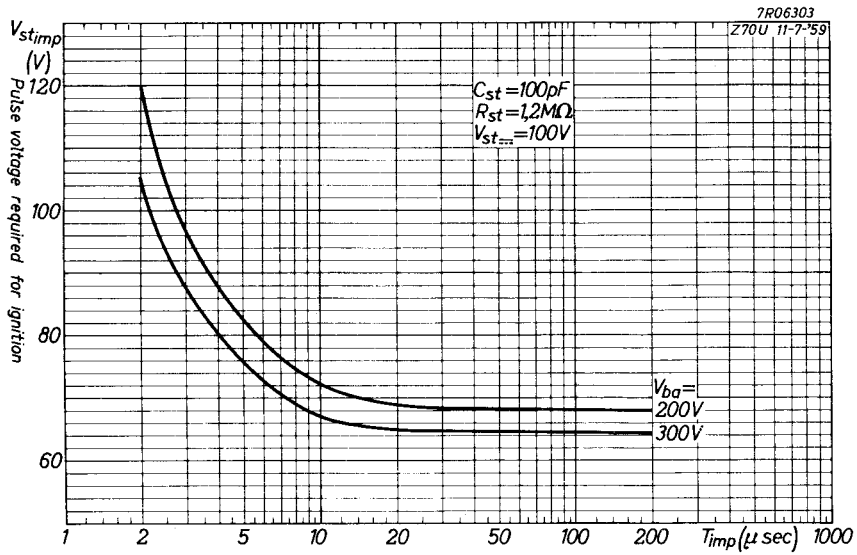
Fig.14e. Breakdown characteristic.

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Fig.14f. Starter pulse voltage required for ignition as a function of the duration of the pulse and the anode supply voltage as parameter (see Fig.13a).
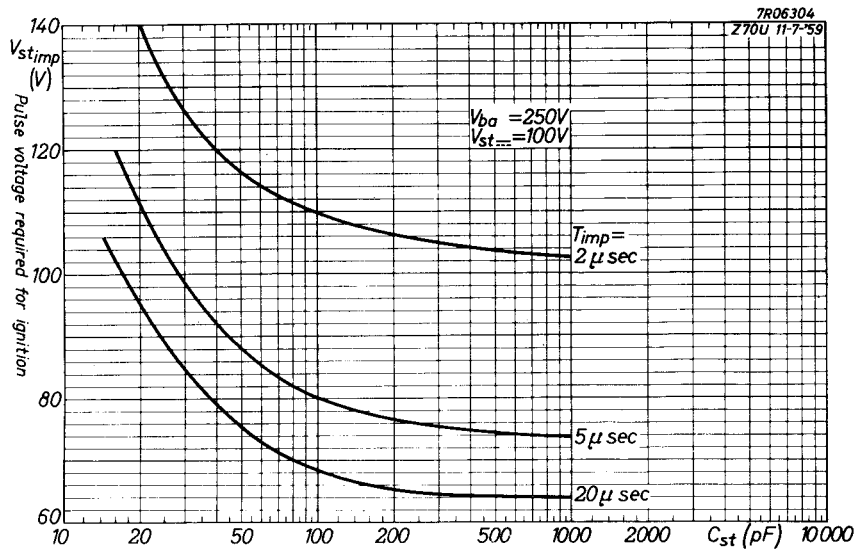


Fig.14g. Starter pulse voltage as a function of the value of the starter capacitor, with the pulse time as parameter (see Fig.13a).

## DESCRIPTION

The Z70W is a subminiature cold-cathode trig-
ger tube with characteristics identical to
those of the Z70U. The difference between the
two types is that the Z70W is provided with
two identical starters, so that the tube can
be used in forward and backward counting cir-
cuits. Another feature of the two starters is
that the second starter can be used for reset
of a counter, so that no additional tube is
required. In this way a saving in cost and
space is obtained.

The geometry in the discharge path of the
Z70W differs from the Z70U, which is caused by
the influence of the second starter on the
electrostatic field. The result is that the maximum starter cur-
rent for transfer is slightly higher than that of the Z70U, which
is the only difference in the characteristics of the two types. As
with the Z70U, the life expectancy of the Z70W is longer than
30 000 hrs.

The same operational notes and precautions apply to both types.
The circuit of Fig.15a is given for ignition with starter pulses
of 100 V or higher; for forward and backward counting the circuit
of Fig.15b may be used.
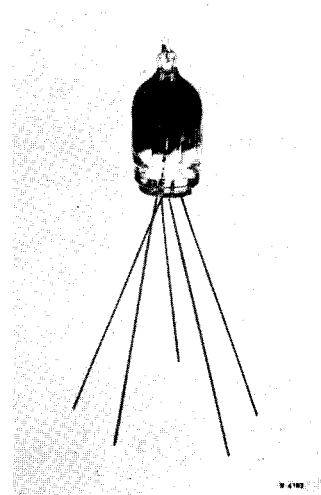
## TYPICAL CHARACTERISTICS

(D.C. values; primer discharge ignited; valid during life)

| | | | |
|---|---|---|---|
| Anode supply voltage | | 250 | V |
| Starter ignition voltage | | 137-153 | V[1]) |
| Temperature coefficient of the starter ignition voltage | max. | -25 | mV/°C |
| Starter transfer current (see Fig.16b) | max. | 50 | μA |
| Starter voltage during discharge | see Fig.16c | | |
| Anode burning voltage at 3 mA anode current (see Fig.16d) | | 111-121 | V |
| Anode ignition voltage at zero starter voltage minimum value (see Fig.16e) | | 325 | V |
| Primer-to-anode ignition voltage | max. | 200 | V |
| Primer-to-anode voltage at 3 μA primer current | | 155 | V |
| Cathode current | | 2-4 | mA |
| Primer current | | 1-10 | μA |
| Primer series resistor (recommended value) | | 18 | MΩ |

[1]) See Fig.16a. The individual ignition voltage drift during life in normal
application is generally less than 3 V. When a tube is ignited for very
long periods, drawing negative starter current, a greater shift of the
ignition voltage may occur. It is therefore advisable to design circuits
for such applications for an ignition voltage of 160 V.

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# Z 70 W

MAXIMUM DIMENSIONS (in mm) AND
BASE CONNECTIONS
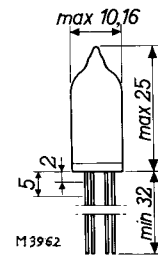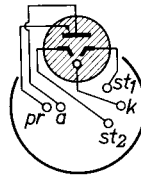


## DYNAMIC CHARACTERISTICS

| | | | | |
|---|---|---|---|---|
| Starter ignition voltage (duration of pulse 20 $\mu$sec) | | | 175 | V[2]) |
| Pulse height plus starter bias voltage (recommended value) | | | 200 | V[2]) |
| Anode delay time | | | 5 | $\mu$sec[3]) |
| Maximum counting frequency | | | 2-5 | kc/s[3]) |
| Typical component values for self extinguishing pulse forming circuits | | | see Fig.16 | |
| Anode resistance | 1.8 | 1.2 | 0.7 | M$\Omega$ |
| Capacitor | 300 | 600 | 2000 | pF |

## LIMITING VALUES (absolute limits)

| | | | |
|---|---|---|---|
| Anode supply voltage (with primer ignited) | max. | 310 | V |
| | min. | 200 | V |
| Cathode current (average time max. 1 sec) | max. | 4 | mA |
| Peak cathode current | max. | 16 | mA[4]) |
| Negative starter current (tube ignited) | max. | 150 | $\mu$A |
| Negative starter current (tube extinguished) | max. | 0 | $\mu$A |
| Starter series resistance | max. | 20 | M$\Omega$ |
| Negative starter pulse voltage at 300 V supply | max. | -30 | V |
| at 200 V supply | max. | -50 | V |
| Ambient temperature | max. | 70 | °C |
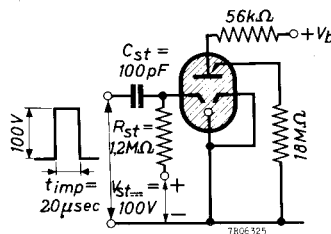


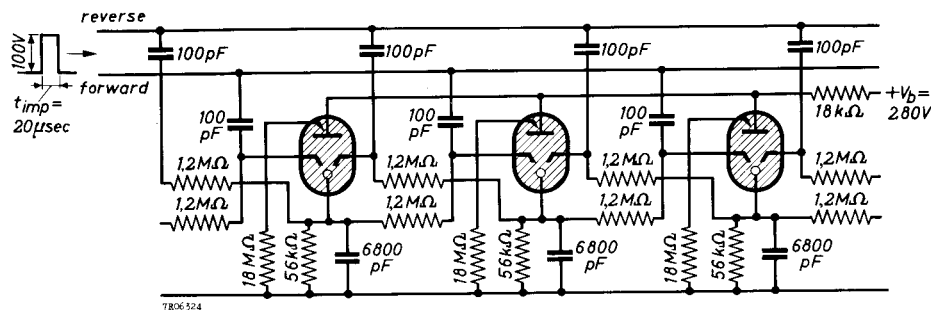Fig.15a. Recommended circuit with pulse ignition.



Fig.15b. Recommended circuit for forward and backward counting.

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[2]) See Fig.15a.

[3]) See Fig.15b.

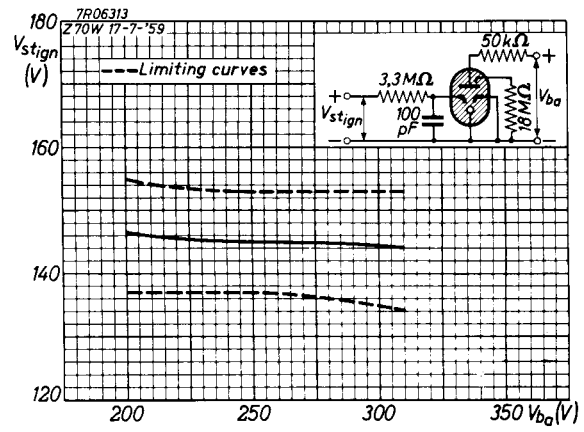[4]) Higher peak currents are permissible in pulse-forming circuits.
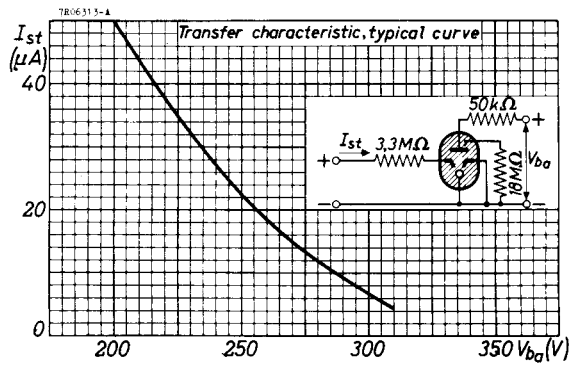
Fig. 16a. Starter breakdown charac-
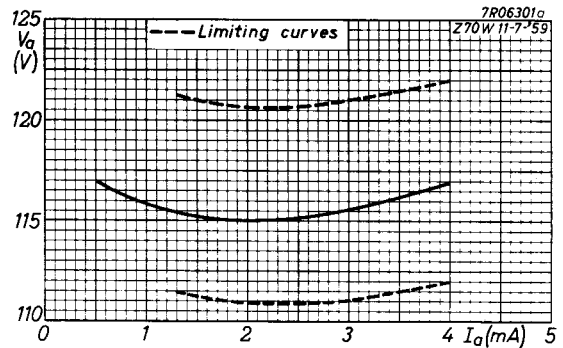teristic.

Fig.16b. Transfer characteristic.

Fig.16c. Anode burning voltage char-
acteristic.

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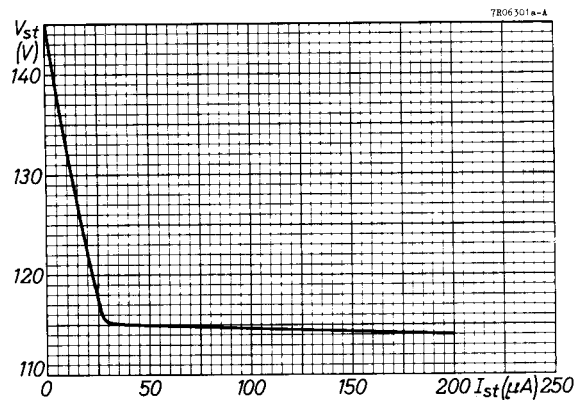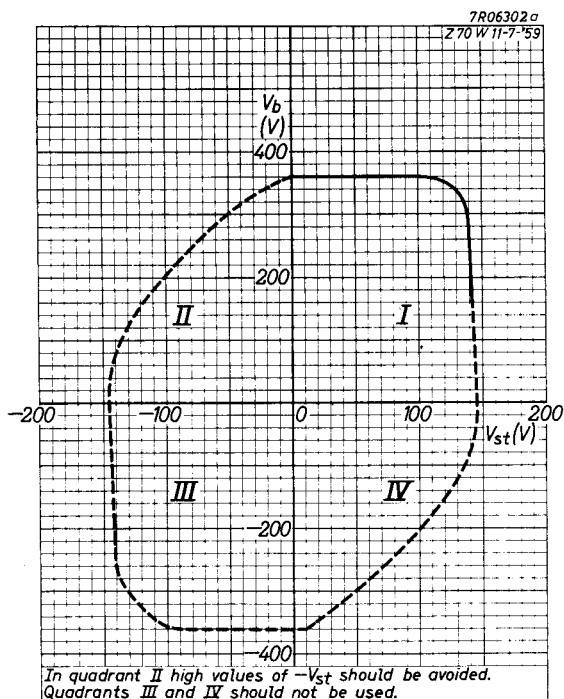Fig. 16d. Starter burning voltage
characteristic.

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In quadrant II high values of −V$_{st}$ should be avoided.
Quadrants III and IV should not be used.

Fig. 16e. Breakdown characteristic.

7R06303a
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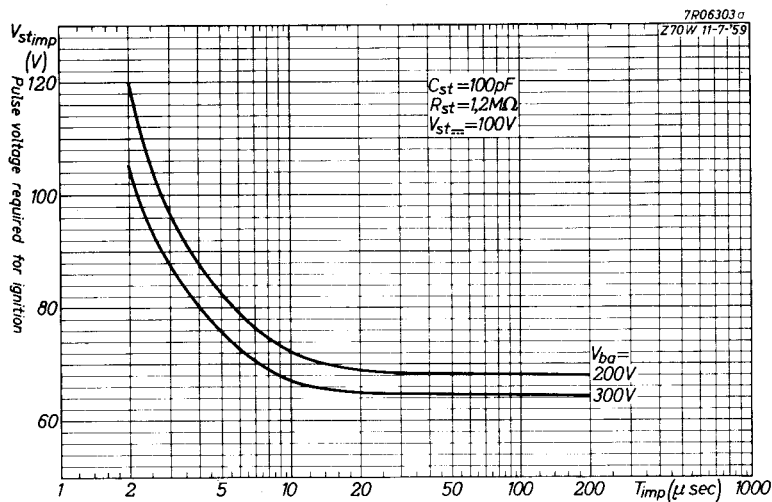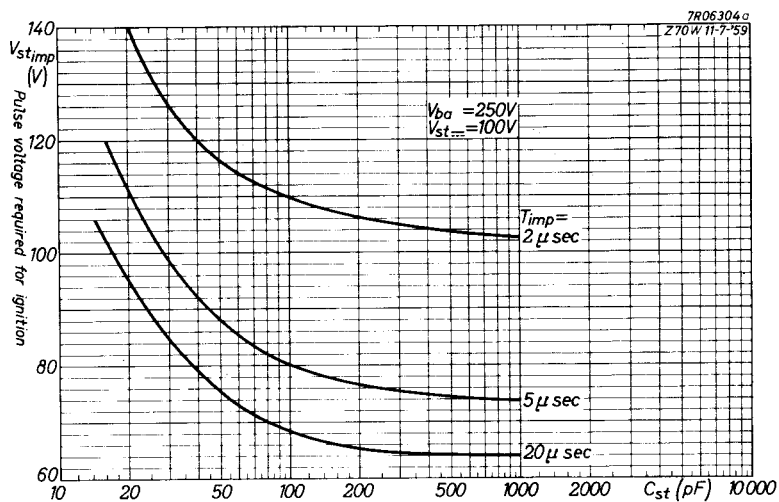$C_{st} = 100pF$
$R_{st} = 1,2M\Omega$
$V_{st=} = 100V$

$V_{ba} =$
200V
300V

Fig. 16 f. Starter pulse for ignition, as a function of the pulse time, with the anode supply voltage as parameter (see Fig. 15a).

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Z 70 W 11-7-'59

$V_{ba} = 250V$
$V_{st=} = 100V$

$T_{imp} =$
2 µ sec
5 µ sec
20 µ sec

Fig. 16g. Starter pulse height for ignition, as a function of the starter capacitor with the duration of the pulse as parameter (see Fig. 15a).

# 3. Applications

COUNTING CIRCUITS

The various kinds of counting circuit in use do not differ much in their fundamental operation. The pulses to be counted are always fed simultaneously to different tubes which are so interconnected as to be successively ignited and extinguished by successive pulses. Several tubes are connected in sequence, and the beginning of the chain is connected with the end, thus producing a ring circuit. The simplest ring of this kind consists of two tubes and constitutes a flip-flop circuit.

As a rule a counting circuit consists of several interconnected rings; in the counting process a pulse appearing at the output of one ring is fed to the input of the next (Fig.17).
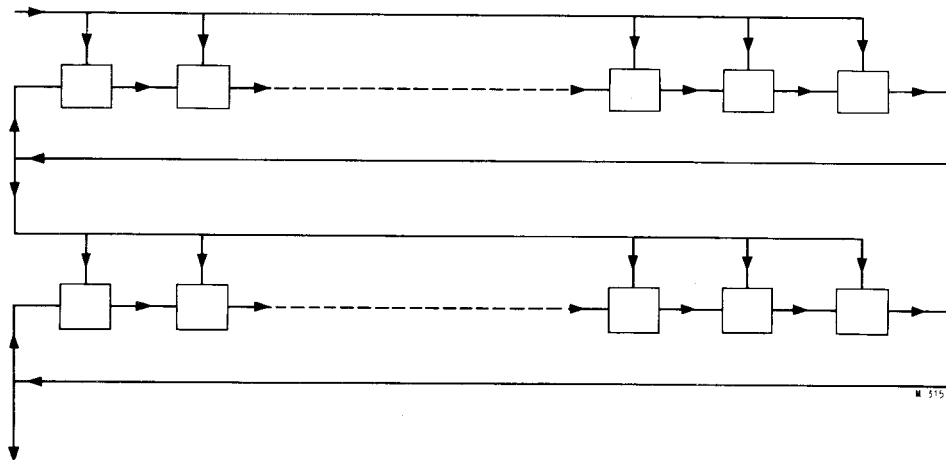


Fig.17. Basic arrangement of counting circuits with trigger tubes.

Counting circuits are distinguished from each other by the build-up of the units, the number of units per ring and the interconnection of the rings. The normal types of counter are the binary counters with flip-flop circuits and the decade counters consisting of rings of ten units each.

In the case of circuits with trigger tubes the separate units must be built up having regard to the following points:
(a) While one of the tubes is burning it must prepare the next tube for ignition so that the latter becomes conductive upon the arrival of the succeeding pulse.
(b) When one tube is ignited the preceding tube must be extinguished.

The first requirement is fulfilled by connecting the cathode of each tube via a resistor to the starter of the next tube. The voltage drop over the cathode resistor of a burning tube biases the starter of the next tube in such a way that a succeeding pulse ignites only the latter tube and not the others. It is a simple
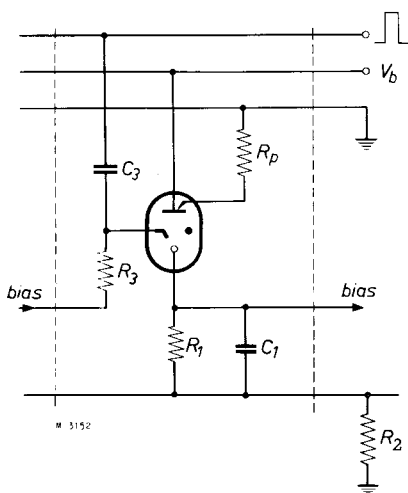
matter, when a tube is ignited, to generate a pulse which extinguishes the preceding tube, thereby fulfilling the second requirement.

Fig.18. Circuit of one tube from a ring.

| | |
|---|---|
| $V_b$ = 280 V or 300 V | $R_p$ = 18 MΩ ± 10% |
| $R_1$ = 56 kΩ ± 10% | $C_1$ = 6800 pF ± 10% |
| $R_2$ = 18 kΩ ± 5% | resp. 4700 pF ± 10% |
| resp. 27 kΩ ± 5% | $C_3$ = 100 pF ± 10% |
| $R_3$ = 1.2 MΩ ± 10% | |

Fig.18 shows the circuit of one tube with the appertaining resistors and capacitors. The starter bias is derived from the cathode of the preceding tube. When the latter is burning the voltage on the cathode $V_k$ is equal to the difference between the supply voltage $V_b$ and the burning voltage $V_a$, viz. $V_k = V_b - V_a$. This cathode voltage is now applied to the starter via resistor $R_3$, so that the tube ignites when a pulse is applied to it via capacitor $C_3$. At the moment the tube ignites the voltage over the common cathode resistor $R_2$ also rises to $V_b - V_a$, since the capacitor $C_1$ constitutes at that moment a short-circuit. Capacitor $C_1$ of the preceding tube, however, is charged to the voltage across $R_1$ while the tube is conductive, and as a result the cathode voltage of this preceding tube becomes so high as to cause the extinction of the tube. In this way, then, one pulse extinguishes the burning tube and ignites the succeeding one.

Depending on whether the supply voltage is 280 or 300 V, $R_2$ should be either 18 kΩ or 27 kΩ and $C_1$ either > 6800 pF or > 4700 pF (intermediate values are also possible).

The primer is connected to earth via a resistor $R_p$, so that the supply voltage is applied between anode and primer. In this way a priming current is maintained of 1 to 10 μA.

ELECTRICAL READING-OUT

The voltage produced across the cathode resistor of a burning tube can be used for electrical reading-out. When a common cathode resistor is used the voltage on the cathode will have the form shown
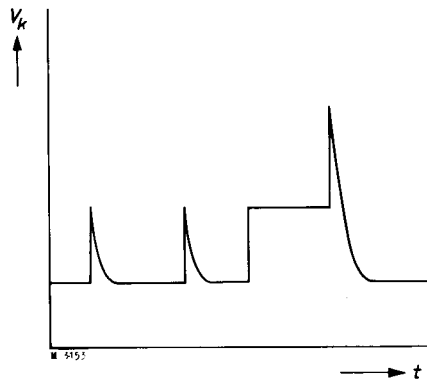
26



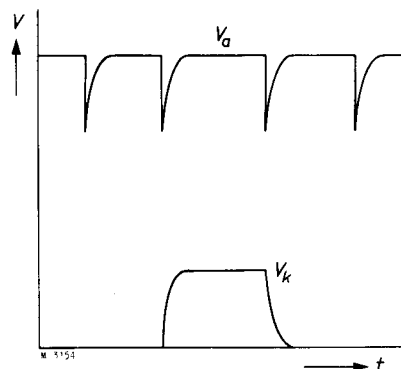Fig.19a. Voltage on the cathode of a tube in a circuit with common cathode resistor.



Fig.19b. Voltage on the anode $V_a$ and the cathode $V_k$ of a tube in a circuit with common anode resistor.

in Fig.19a. For the purposes of reading-out the principal objection to this form is that the sharp peaks (caused by the ignition of another tube) are troublesome. For this reason a circuit with common anode resistor is generally preferable in such cases. The resultant waveforms on the anode and on the cathode are as shown in Fig.19b.

RESETTING

When the apparatus is switched on, or after a series of pulses have been counted, the counters must be reset to zero. For this purpose the burning tubes must be extinguished and the tubes in position zero ignited.

In the circuit with common cathode resistor the burning tubes can be extinguished simply by removing the anode voltage. Naturally this also extinguishes the primers, and therefore special measures are needed to ensure that the primers are ignited first when the anode voltage is switched on again. Supply voltage remains, of course, applied to the anodes of the tubes in the zero position.

In the circuit with common anode resistor, the burning tubes can be extinguished by breaking the connection of the cathodes to earth. The anode voltage is thus maintained, and the voltage accordingly remains applied to the primers. In this case the connection between earth and the cathodes of the tubes in the zero position must be maintained.

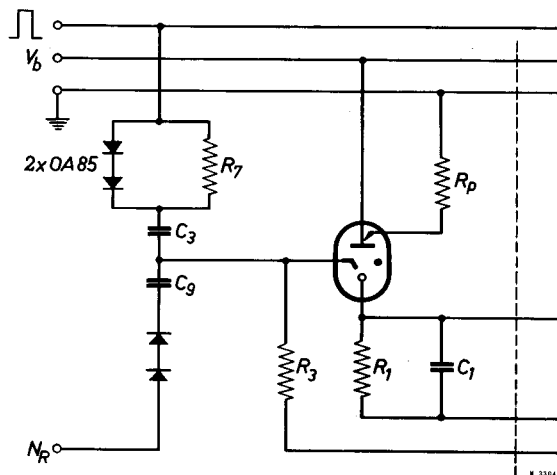There are several methods of igniting the tubes in the zero position:



Fig.20a. Reset method with diodes.

| | | | |
|---|---|---|---|
| $R_1$ = | 56 k$\Omega$ | $C_1$ = | 6800 pF |
| $R_3$ = | 1.2 M$\Omega$ | $C_3$ = | 100 pF |
| $R_7$ = | 100 k$\Omega$ | $C_9$ = | 220 pF |
| $R_P$ = | 18 M$\Omega$ | | |

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(1) With diodes. The circuit is as shown in Fig.20a. The supply voltage is applied to the anode of tube 0, possibly via the common anode resistor, and the ignition pulse is fed to point $N_R$. The disadvantage of this method is that it means reducing the counting rate. An advantage, however, is that tube 0 always ignites at "reset".
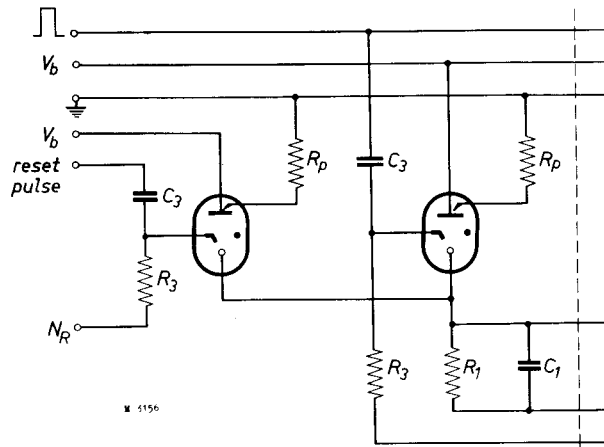
Fig.20b. Reset method with extra tube.

$R_1 = 56 \ \text{k}\Omega$ $\qquad\qquad$ $C_1 = 6800 \ \text{pF}$

$R_3 = 1.2 \ \text{M}\Omega$ $\qquad\qquad$ $C_3 = 100 \ \text{pF}$

$R_p = 18 \ \text{M}\Omega$

(2) With an extra cold-cathode tube. An extra reset tube is con-
nected in parallel to tube 0 as shown in Fig.20b. During the
reset this extra tube remains connected to the supply voltage
$V_b$, and via point $N_R$ a biasing voltage is fed to the starter.
The reset pulse thus ignites this tube and not tube 0. This
method does not adversely affect the counting rate, and makes
electrical resetting to zero possible.

(3) With a cold-cathode tube with two starters, the type Z 70 W. In
principle the same methods as mentioned under (2) can be used.
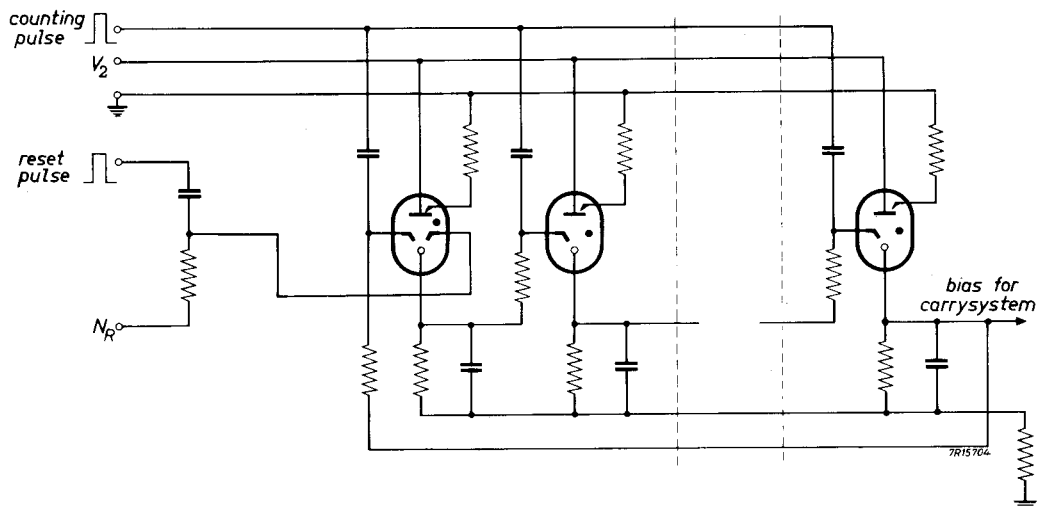The first starter is used in the normal counting circuit, the
second for reset.



Fig.20c. Basic arrangement of a ring circuit with Z70W for

reset and with bias for carry system.

(4) With a resistor. The tube 0 can also be ignited with a bias
which is applied to the starter via a resistor. This is a
cheap method, but if many ring circuits are used, a multi-
contact switch will be necessary.

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Fig.20c shows the basic diagram of a ring circuit with reset and bias for the carry system. The reset tube is connected to a separate anode lead and the bias for the starter $N_R$ is derived from a potentiometer circuit so designed that, after "reset", this voltage amounts to 140 to 160 V at a supply voltage of 280 and 300 V. Measures are also taken to prevent one of the tubes in the ring from going on burning or from igniting; this is done by reducing the anode voltage $V_2$ to earth potential (Fig.21a).
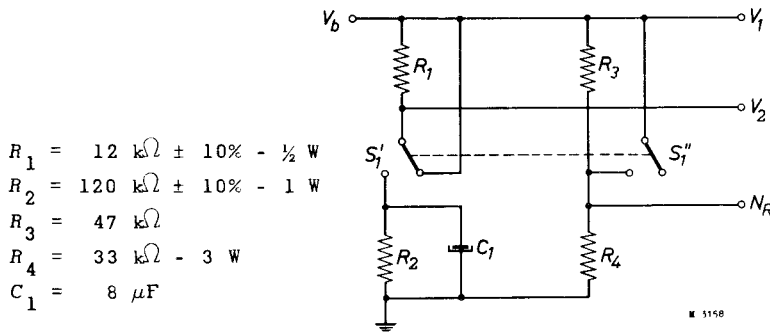


$R_1$ = 12 k$\Omega$ ± 10% - ½ W
$R_2$ = 120 k$\Omega$ ± 10% - 1 W
$R_3$ = 47 k$\Omega$
$R_4$ = 33 k$\Omega$ - 3 W
$C_1$ = 8 $\mu$F

Fig.21a. Reset circuit for a supply voltage of $V_b$ = 280 to 300 V.

To ensure that the primers ignite without at the same time one of the tubes igniting, the anode voltage is kept temporarily at 250 V. by holding the switch depressed for a few seconds. For this purpose a relay can also be used as indicated in Fig.21b.
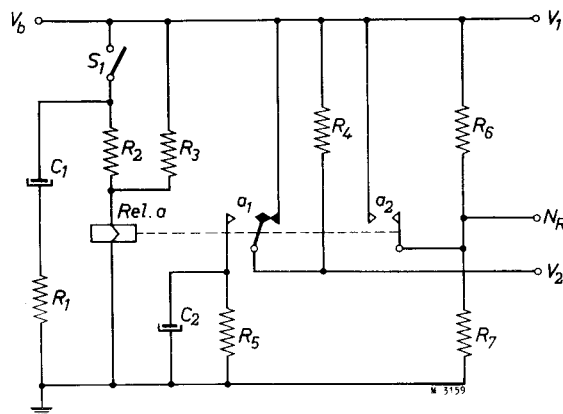


Fig.21b. Reset circuit with relay for a supply voltage of $V_b$ = 280 V.

| | | | |
|---|---|---|---|
| $R_1$ = 2.2 k$\Omega$ - | 1 W | $R_6$ = 47 k$\Omega$ - | 1 W |
| $R_2$ = 22 k$\Omega$ - | 5.5 W | $R_7$ = 33 k$\Omega$ - | 3 W |
| $R_3$ = 120 k$\Omega$ - | 1 W | $C_1$ = 50 $\mu$F | |
| $R_4$ = 12 k$\Omega$ - | 1 W | $C_2$ = 8 $\mu$F | |
| $R_5$ = 120 k$\Omega$ - | 1 W | 210 V $<$ $V_2$ $\leq$ 250 V | |

The closing of switch $s_1$ in Fig.21b energizes relay $a$ and closes contacts $a_1$ and $a_2$. The reset bias $N_R$ then rises to $V_b$, while the anode voltage on the other tubes drops to zero and subsequently rises with a time constant determined by $C_2$-$R_4$-$R_5$ to a value of approximately 250 V, whereupon the primers ignite. Even if switch $S_1$ is immediately opened again, the relay remains energised long enough for this process to take place.
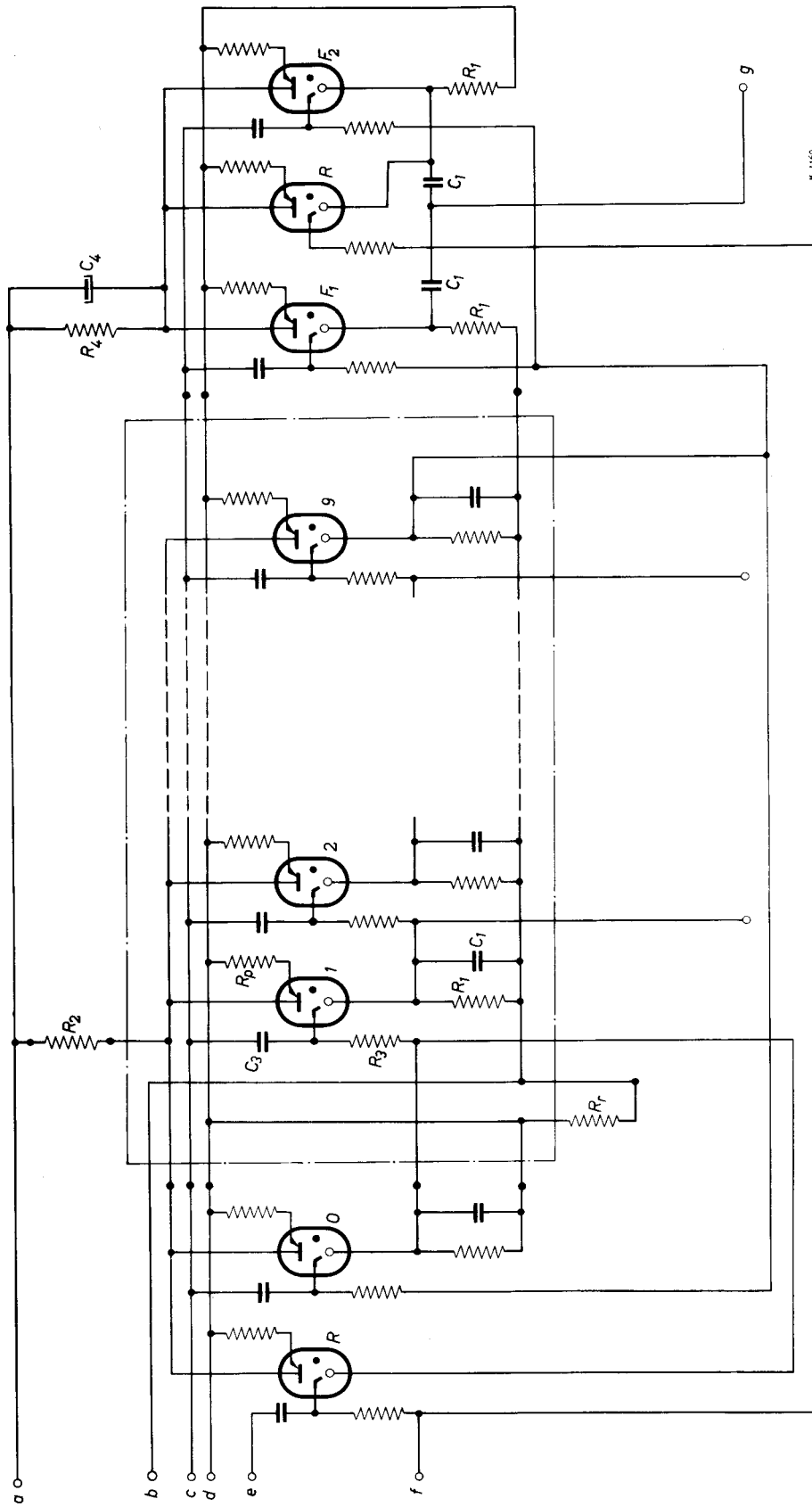
30



Fig. 22. Decimal counter with common anode resistor.

a = + 280 V
b = ground*
c = pulse input
d = ground
e = reset pulse
f = reset bias
g = output

$R_1$ = 56 k$\Omega$
$R_2$ = 18 k$\Omega$
$R_3$ = 1.2 M$\Omega$
$R_4$ = 18 k$\Omega$
$R_r$ = 1.2 M$\Omega$
$R_p$ = 18 M$\Omega$
$C_1$ = 6800 pF
$C_3$ = 100 pF
$C_3$ = 10 $\mu$F

Fig.23. Decimal counter with common cathode resistor.

a = + 280 V
b = + 280 V*
c = pulse input
d = ground
e = reset pulse
f = reset bias
g = pulse output

$R_1$ = 56 k$\Omega$
$R_2$ = 18 k$\Omega$
$R_3$ = 1.2 M$\Omega$
$R_5$ = 27 k$\Omega$
$R_p$ = 18 M$\Omega$
$C_1$ = 6800 pF
$C_3$ = 100 pF

31
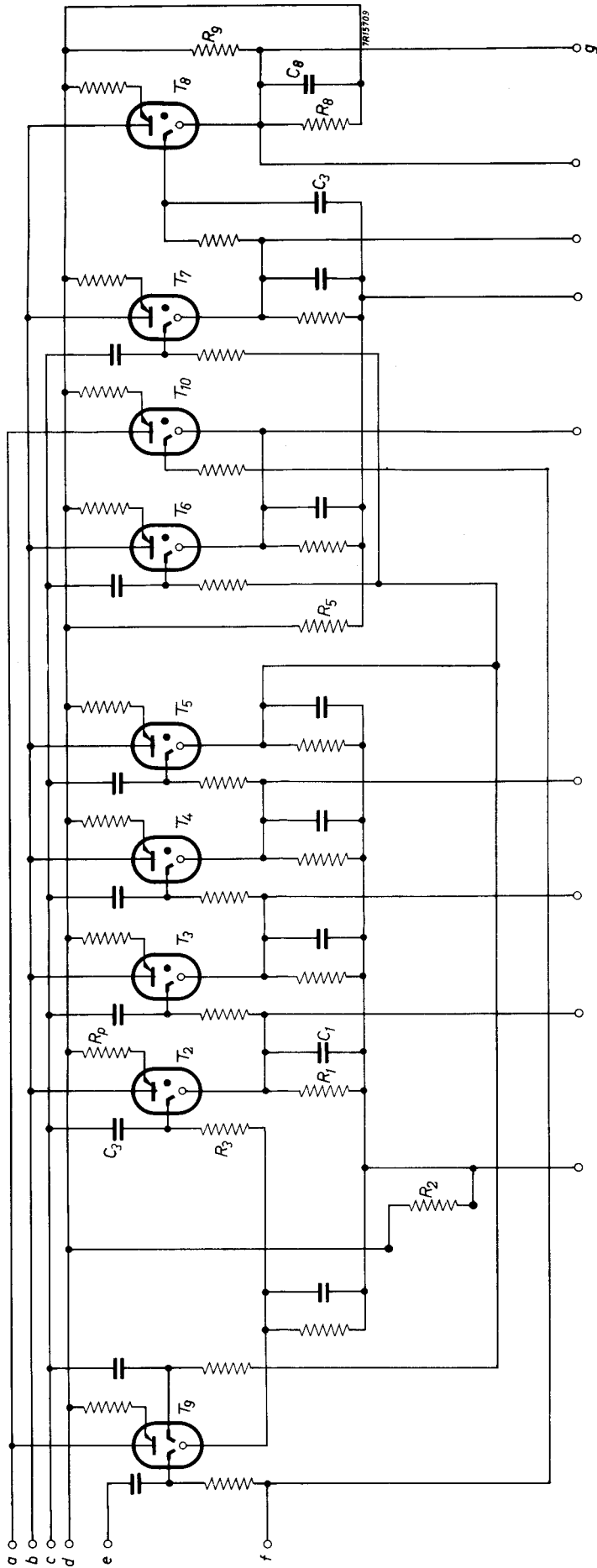
Fig.24. Biquinary decade counter.

a = + 280 V
b = + 280 V*
c = pulse input
d = ground

e = reset pulse
f = reset bias
g = pulse output

$R_1$ = 56 kΩ
$R_2$ = 18 kΩ
$R_3$ = 1.2 MΩ
$R_5$ = 27 kΩ

$R_8$ = 680 kΩ
$R_9$ = 100 kΩ
$R_p$ = 18 MΩ

$C_1$ = 6800 pF
$C_3$ = 100 pF
$C_8$ = 820 pF
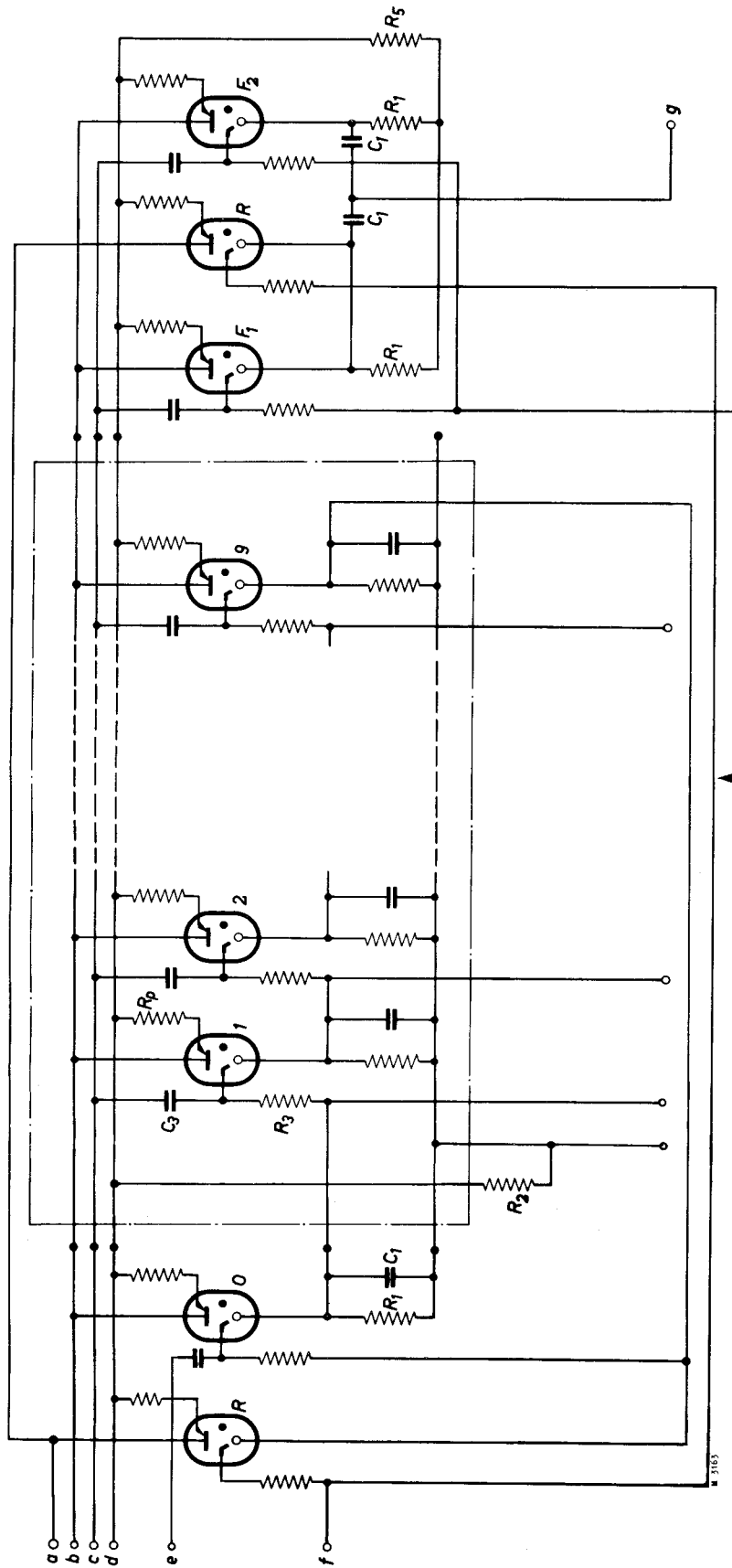
Fig.25. Pulse series generator.

a = + 280 V
b = + 280 V·
c = pulse input
d = ground

e = start pulse
f = reset bias
g = pulse output

$R_1$ = 56 k$\Omega$
$R_2$ = 18 k$\Omega$
$R_3$ = 1.2 M$\Omega$
$R_5$ = 27 k$\Omega$

$R_p$ = 18 M$\Omega$
$C_1$ = 6800 pF
$C_3$ = 100 pF

33

34
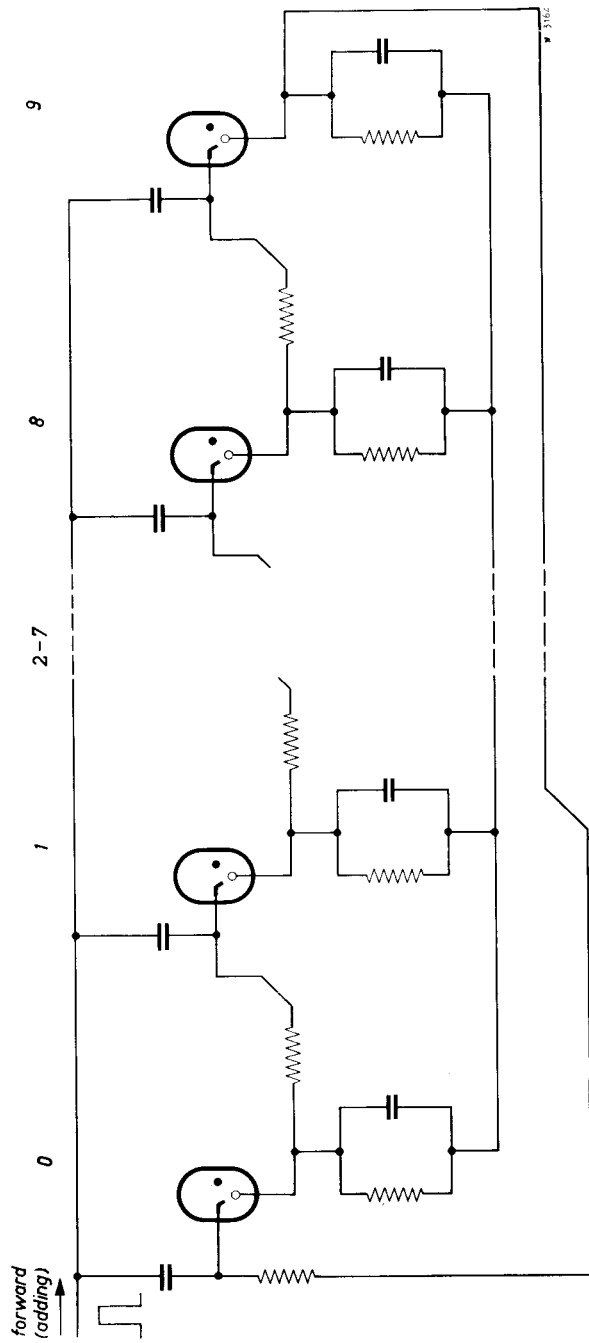
Fig.26. Forward counter.
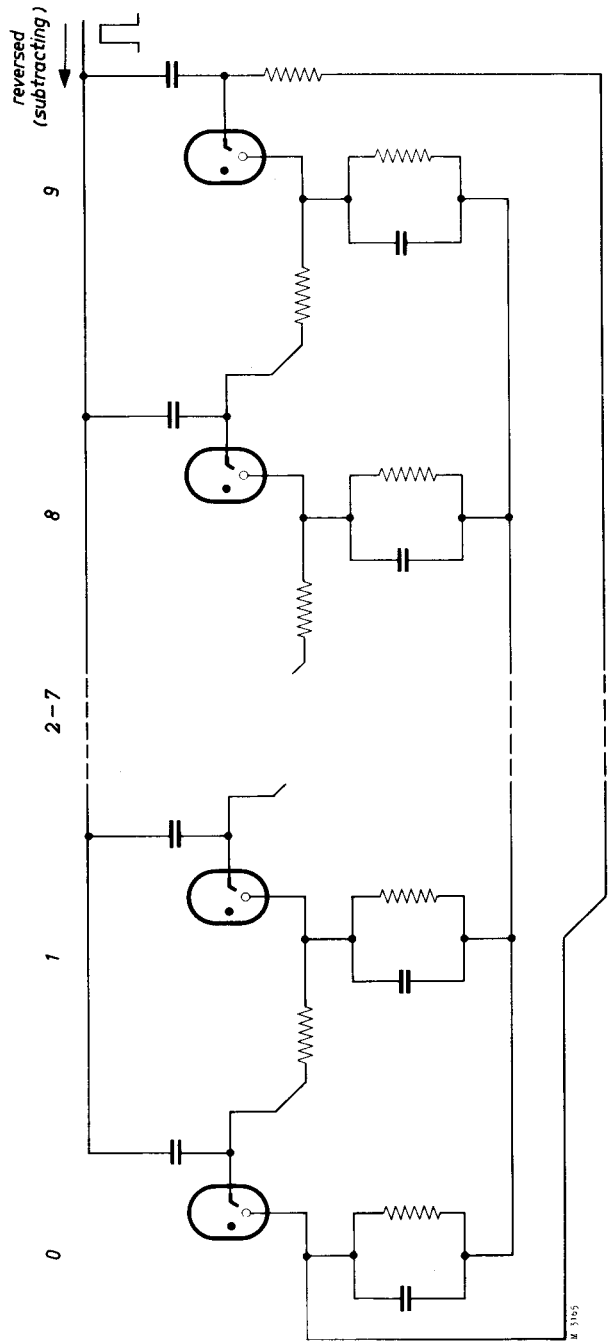
Fig.27. Backward counter.
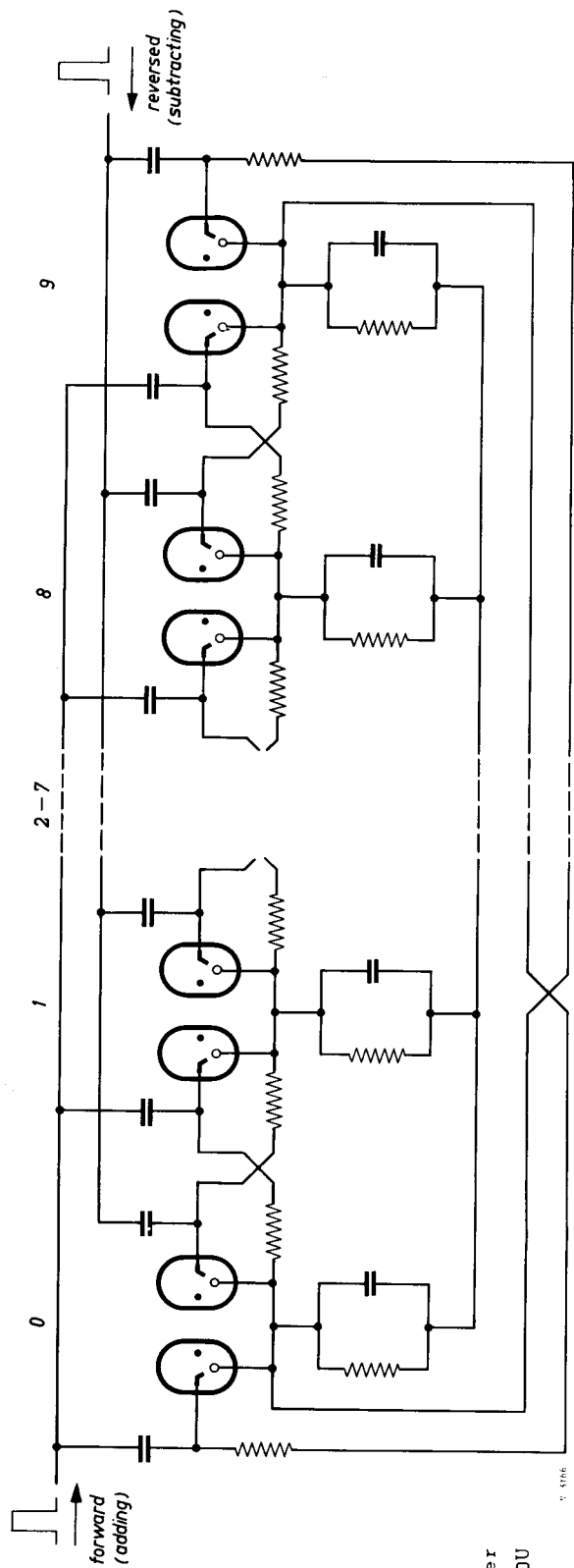
Fig.28a. Bi-directional counter
equipped with twenty tubes Z70U
per decade.
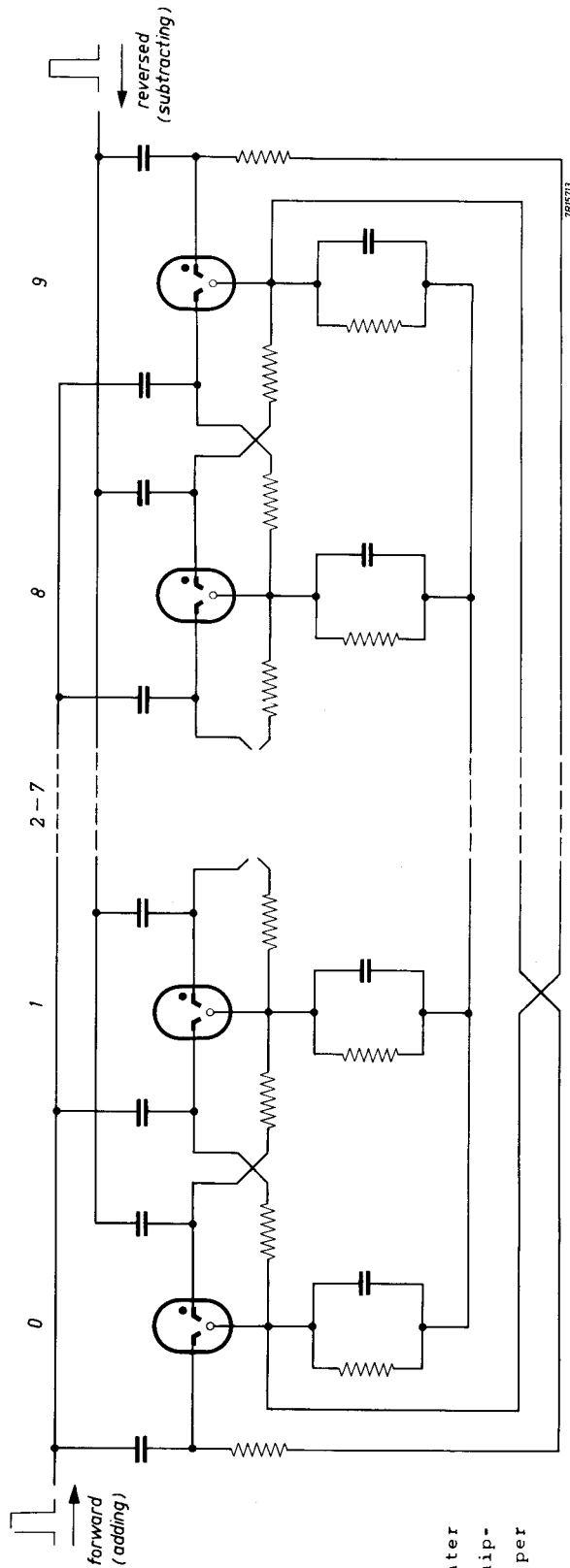


Fig.28b. Bi-directional counter
as shown in Fig.28a, but equip-
ped with only ten Z70W tubes per
decade.
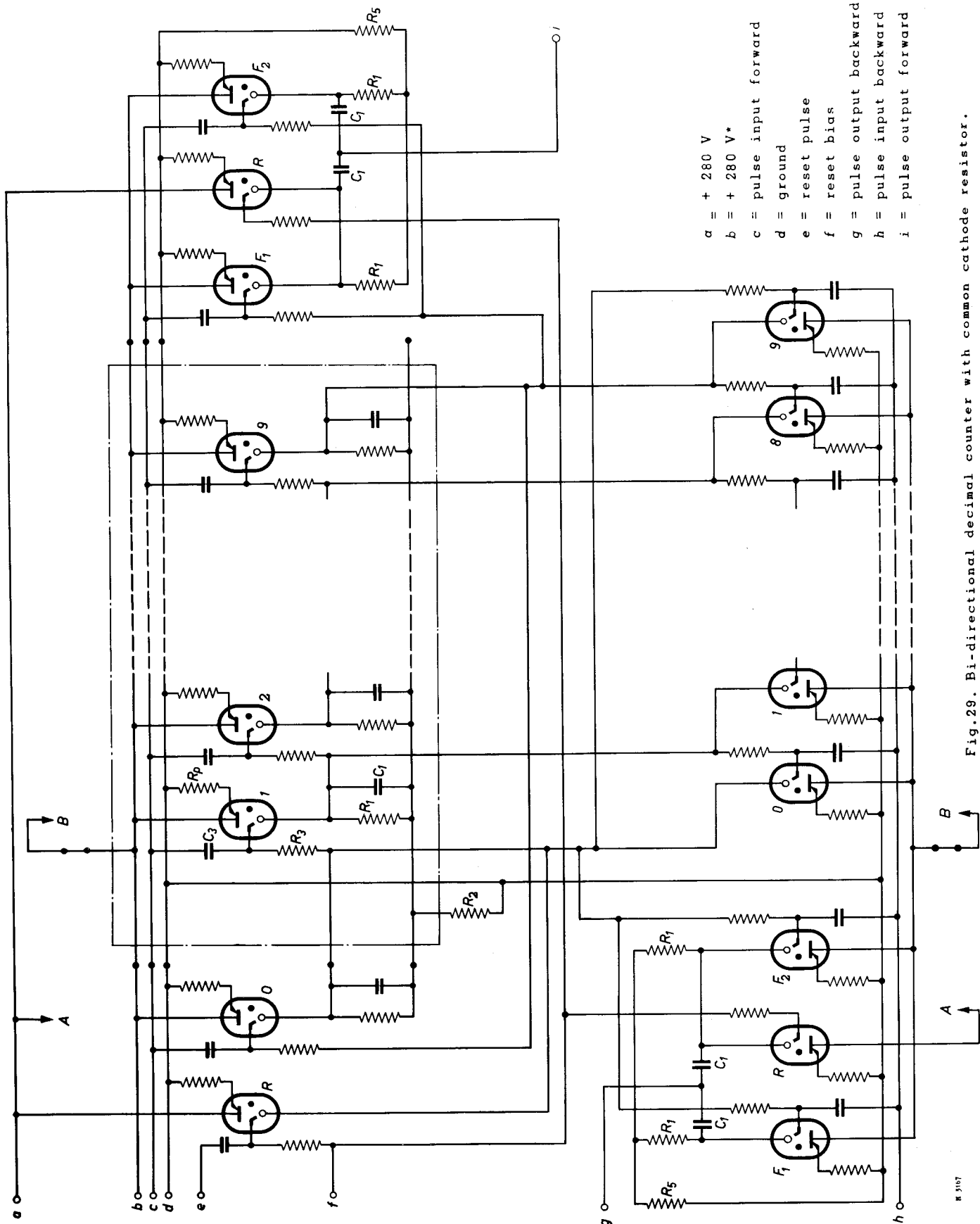
35

Fig.29. Bi-directional decimal counter with common cathode resistor.

a = + 280 V
b = + 280 V*
c = pulse input forward
d = ground
e = reset pulse
f = reset bias
g = pulse output backward
h = pulse input backward
i = pulse output forward

$R_1$ = 56 kΩ
$R_2$ = 18 kΩ
$R_3$ = 1.2 MΩ
$R_5$ = 27 kΩ
$R_P$ = 18 MΩ
$C_1$ = 6800 pF
$C_3$ = 100 pF

Fig. 30. Bi-directional decimal counter with common anode resistor.

$a = + 280 \text{ V}$
$b = \text{ground}^*$
$c = \text{pulse input forward}$
$d = \text{ground}$
$e = \text{reset pulse}$
$f = \text{reset bias}$
$g = \text{pulse output backward}$
$h = \text{pulse input backward}$
$i = \text{pulse output forward}$

$R_1 = 56 \text{ k}\Omega$
$R_2 = 18 \text{ k}\Omega$
$R_3 = 1.2 \text{ M}\Omega$
$R_4 = 18 \text{ k}\Omega$
$R_r = 1.2 \text{ M}\Omega$
$R_p = 18 \text{ M}\Omega$
$C_1 = 6800 \text{ pF}$
$C_3 = 100 \text{ pF}$
$C_4 = 10 \text{ }\mu\text{F}$

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# CARRY SYSTEM

Two systems can be used to produce the pulse to be carried to the succeeding ring counter.

(1) A single carry tube which receives its bias level from the last tube of the ring counter and thus is ignited by the same pulse that ignites tube 0. The ignition of this carry tube gives rise to a pulse which is sufficient to start the next ring counter. The maximum counting rate with this system is about 3 kc/s, which is ample for most purposes.

(2) A flip-flop which carries over the pulse in the same way when the carry tube ignites. The pulse to be fed to the next ring counter can then be derived via a capacitor from the cathode bias. The counting rate with this system is at least 3 kc/s, and it also provides relatively high energy pulses.

It is also possible with this system to distinguish between odd and even series of ten. For example, a scale-of-twenty counter can easily be constructed, and in the same way scales of 12-14-16 or 18 counters can be made.

With this flip-flop circuit, too, a reset tube can be connected in parallel which ignites when the ring counter is reset to zero by hand, for example, immediately after the apparatus is switched on.
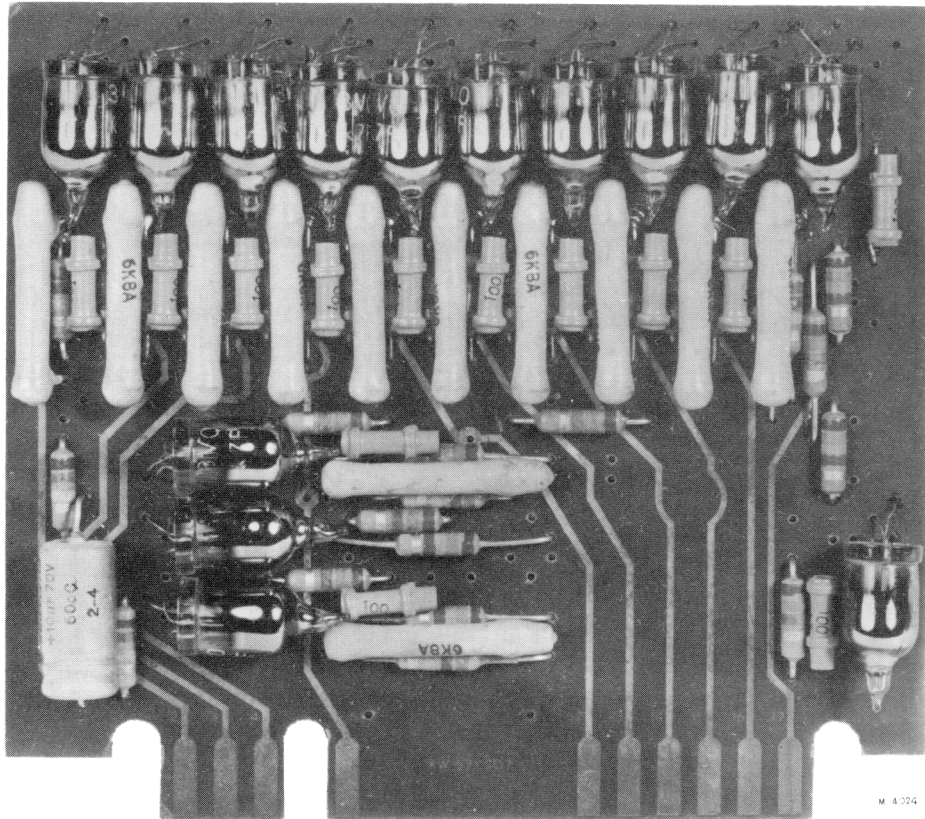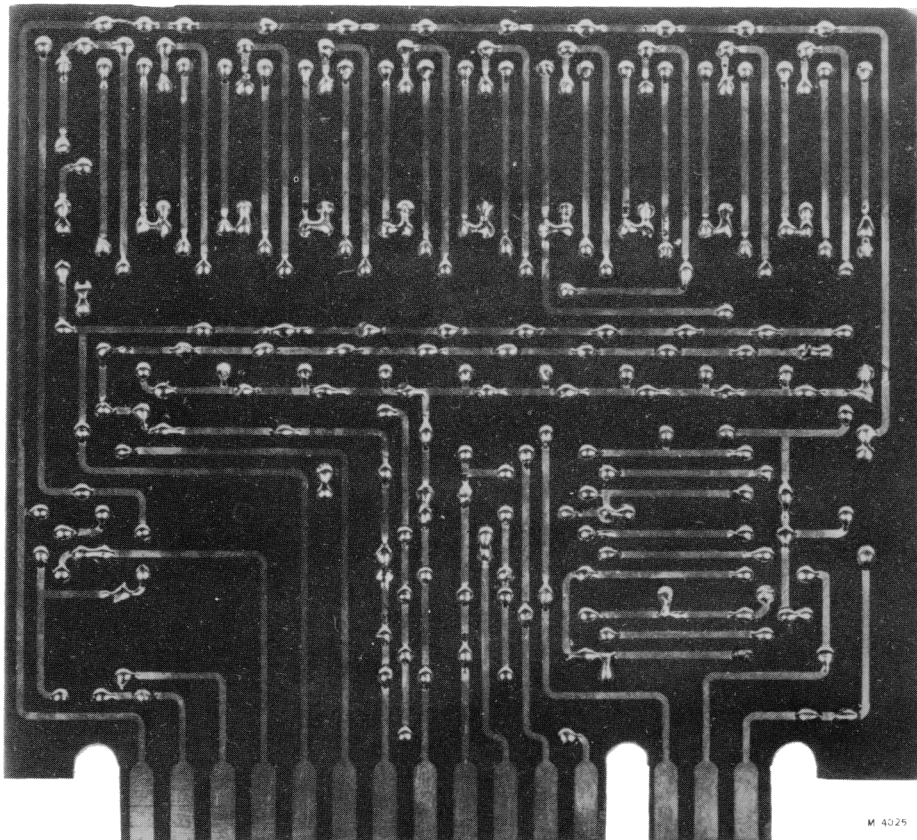
Sample of a universal counter according to the circuit of Fig.22
(decimal counter with common anode resistor).

# 4. Examples

Fig.22 shows a complete circuit in which a common anode resistor is used, thus allowing electrical reading-out from the cathode potentials. The resistor $R_r$ is included for the purpose of preventing the starter capacitors from being charged.

Fig.23 shows the same ring counter, but now with a common cathode resistor.

A scale-of-5 ring counter with a flip-flop circuit, which distinguishes between the first and second series of five pulses in each decade, is given in Fig.24. This biquinary counter, as it is called, contains a reset tube both for the ring and for the flip-flop circuit; tube 8 serves for the carry pulse. This circuit is explained in detail on page 36.

In the circuit shown in Fig.25 the reset tube is parallel to the ninth of the chain, so that after the start pulse is applied to the first tube, ten pulses are automatically counted and can be taken from the common cathode resistor $R_2$.

It is also possible to use any count pulse of any series of ten to actuate the carry flip-flop circuit, and this produces a carry pulse. This can be done by deriving the bias for the carry flip-flop circuit from one of the tubes in the chain instead of from the last tube.

The normal circuit for forward counting (Fig.26) can be reversed to form a circuit for backward counting (Fig.27). These two circuits can be combined as shown in Fig.28 to make both forward and backward counting possible; in this case two tubes are always used for each digit. A practical circuit of this kind with common cathode resistor is given in Fig.29, and one with common anode resistor can be seen in Fig.30.

In Figs 22 to 30 the indications 280 V* and ground* mean that these connections must be broken during resetting.

DEMONSTRATION COUNTER WITH 26 TUBES Z 70 U

A simple counter, built for demonstration purposes, will now be described. It operates either at the mains frequency or acts on an external pulse source. The mains voltage may be nominally 220 and 110 V. In both cases the input voltage may vary between wide limits.

POWER SUPPLY (FIG.31)

For the counter to work at a mains voltage of 110 V it is necessary to have at least a voltage doubler in the power supply. Since, however, stabiliser tubes are used in order to prevent difficulties arising from variations in the mains input voltage, it was in fact necessary to use a voltage tripler.

For switching over to 220 V, the most simple solution was to use a series dropping resistor. With the circuit as given in Fig.31 very large fluctuations in the mains input voltage are tolerable. At 220 V, for instance, the input voltage may even vary between 160 V and 260 V. At 110 V the figures are comparable.

The rectifying diodes used in the circuit were pre-production samples of a silicon diode.
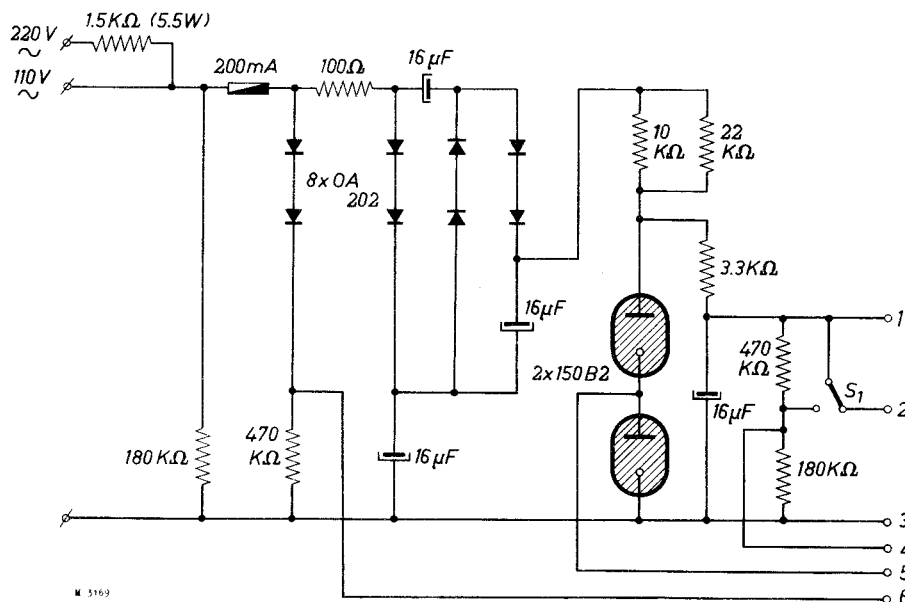


Fig.31. Power supply of demonstration counter.

NOTE

Terminal marked o n is an output terminal n.

Terminal marked $\phi n$ is an input terminal which should be connected to an output terminal n (input terminals 8 and 9, Fig.33, are to be connected to an external pulse source).

At the output terminal 6 (Fig.31) half sine-waves are available, obtained by means of two diodes and a resistor of 470 k$\Omega$. These half sine-waves are needed for the pulse generator.

Terminal 1 supplies the direct voltage for the tubes to be ignited during reset, while output 2 supplies the direct voltage to all other tubes. When switch $S_1$ (reset) is pushed in, this output is interrupted, to ensure that all tubes connected to it will be extinguished.

At output 4 a direct voltage is available which is fed to the starters of all tubes that are to be reset. This voltage is raised to the battery voltage when $S_1$ is pushed in. In this way all reset tubes are ignited, while at the same time all other tubes are extinguished, as already described.

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Switching over from 220 to 110 V is effected by means of a switch in the mains plug (the latter may be of the same type as used in the "Philishave" electric razor).

For the rest the circuit is self-explanatory.

## PULSE GENERATOR (FIG.32)

The pulse generator is built as a flip-flop circuit; its function is to deliver pulses to the counter. It is triggered by means of positive half sine-waves, these being used in order to avoid excessive negative starter current during the negative half-cycles.

A sinusoidal voltage is high for a relatively long time. This could mean, with an ordinary flip-flop circuit, that instead of one "throw-over" during the top of the sine wave, two "throw-overs" take place. In order to prevent this, the individual cathode impedances are given an adequately long time constant (0.56 msec). This is the more necessary as large fluctuations in input voltages have to be taken into account.

The pulses across the resistor of 18 kΩ (common cathode impedance) are fed to the counter.
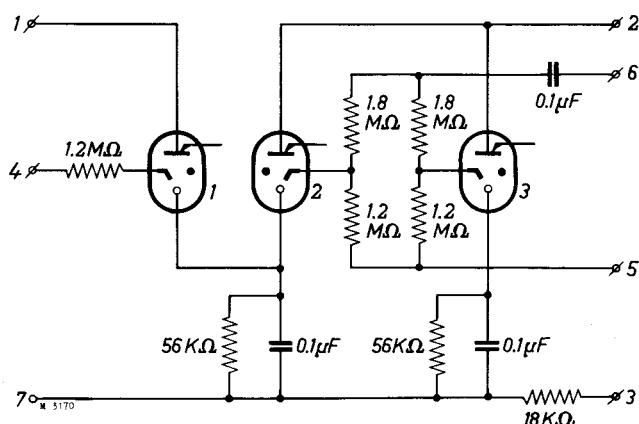


Fig.32. Pulse generator of demonstration counter.

In the circuit diagram a third tube is shown (at the left). This tube has its cathode connected to its neighbour, and acts as reset tube. The two right-hand tubes are connected to output terminal 2 of the power supply, which is interrupted during reset, whereupon these tubes are extinguished. The left-hand tube, however, is still connected to the battery voltage, while during hand-reset the starter voltage is raised to the battery voltage (input terminal 4 of the pulse generator is connected to output terminal 4 of the power supply). In this way the reset tube is ignited; after the reset knob is released, the circuit will function as a flip-flop, using the other two tubes.

## COUNTER CIRCUIT (FIG.33)

The circuit used is straight-forward. By means of switch $S_2$ it may be switched over from the internal pulse generator (input terminal 7) to an external pulse generator with a maximum pulse repetition frequency of 2 kc/s (input terminal 8). When no external pulse source is connected, $S_2$ may be used to switch off the internal generator to stop the counter. For stopping the counter when working on an external source, it is assumed that it is possible to switch off the pulses by means of a switch on this external pulse generator. The counter also contains an extra tube in both decades for reset (described under "Pulse generator").

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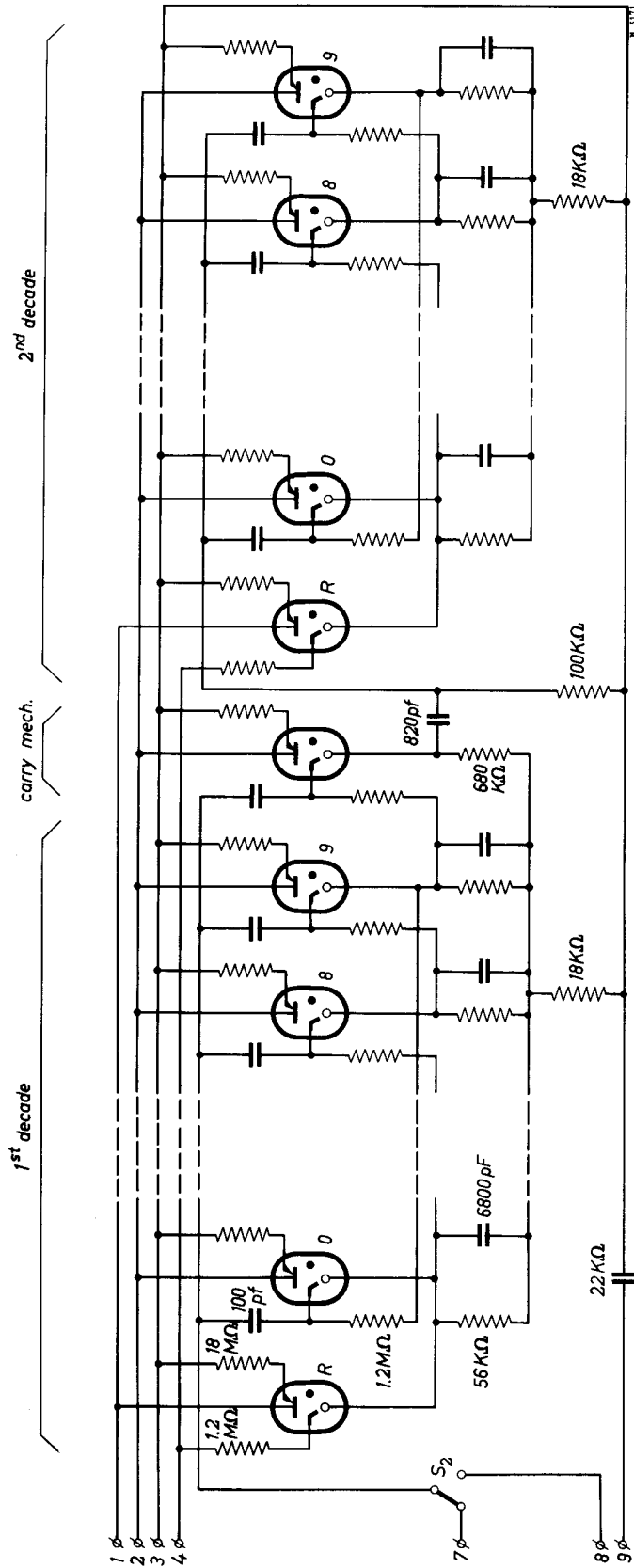
Fig.33. Counter circuit of demonstration counter.

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CONSTRUCTION

The construction of the demonstration counter appears from Figs 34, 35 and 36.

In Fig.34 can be seen:

(a) The units decade at the left-hand side.

(b) At the right-hand side from top to bottom:
   - the four smoothing capacitors and the rectifying diodes above (three times two in series);
   - the fuse and the push-button switch $S_1$ (for hand-reset);
   - the three tubes which form the pulse generator (the reset tube is the top one);
   - the tube for the carry over from the units decade to the tens decade.

In Fig.35 can be seen:

(a) At the right-hand side:
   - the printed wiring of the tens decade.

(b) At the left-hand side from top to bottom:
   - the two stabiliser tubes 150B2 in front of the smoothing capacitors, the switch $S_1$;
   - the capacitor of 0.1 $\mu$F, directly connected to the input terminal 6 of the pulse generator;
   - the switch $S_2$, for switching over from internal to external pulse source.

In Fig.36, which shows the completed counter, can be seen:
   - the indication system;
   - the input terminals 8 and 9 for the external pulse source;
   - the mains plug with switch.
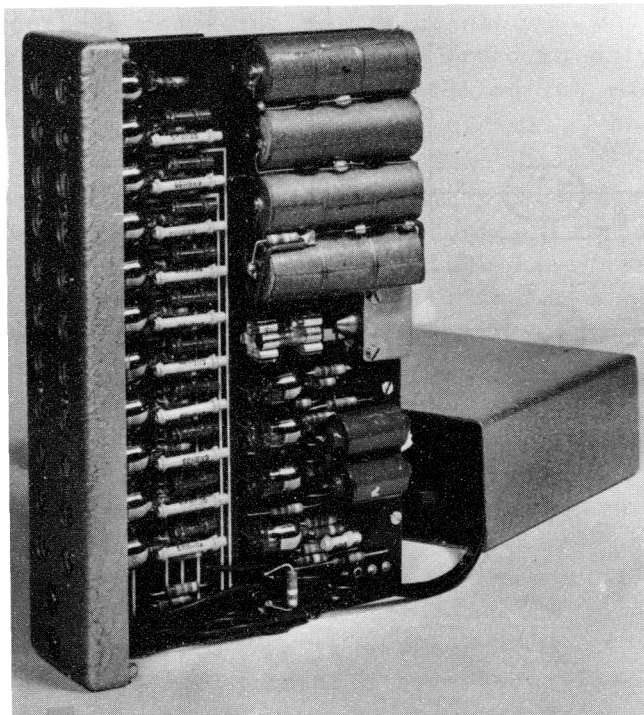
Fig.34. Demonstration counter, right-hand side.
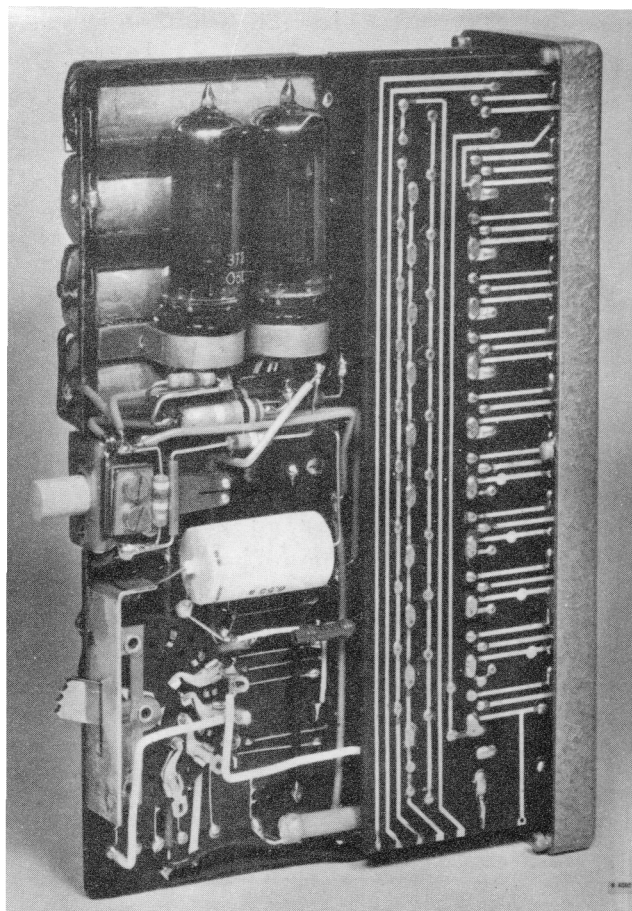
Fig.35. Demonstration counter, left-hand side.
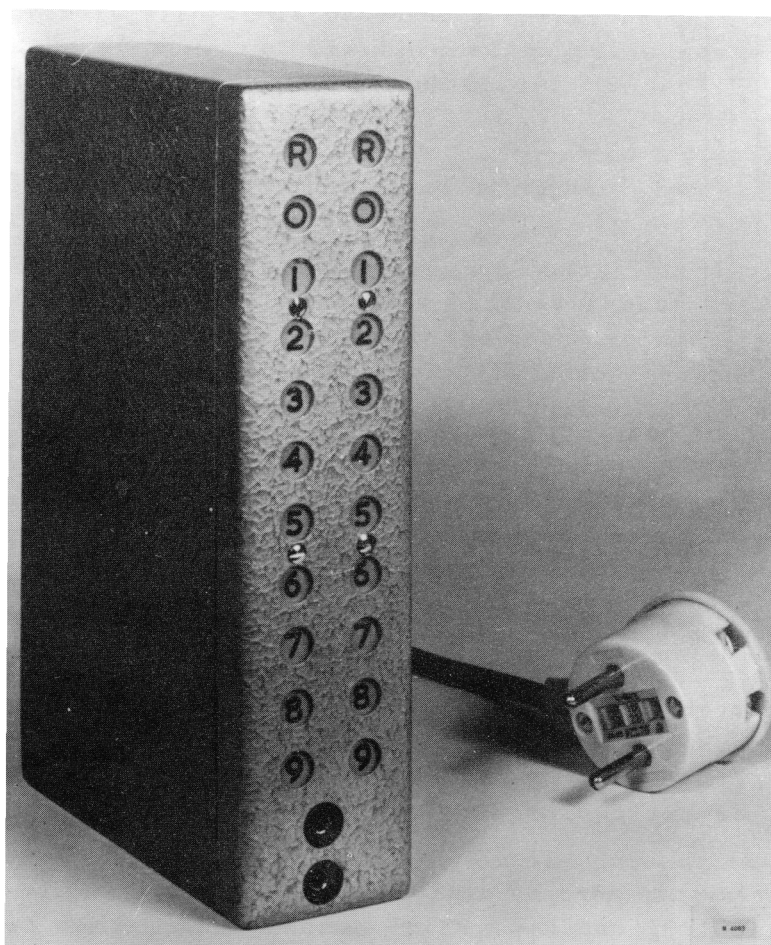


Fig.36. Demonstration counter, front.

# DECADE COUNTER WITH TEN TUBES Z 70 U

Fig.24 shows the circuit diagram of a biquinary decade counter equipped with ten tubes Z 70 U.

The circuit comprises a ring counter with the tubes $T_1$ to $T_5$ (scale-of-five circuit), a scale-of-two circuit ($T_6$ and $T_7$) and a pulse shaper ($T_8$), which supplies an output pulse to the following decade.

The principle of operation is based on the fact that each series of ten input pulses is divided into two groups of five pulses, the latter being counted by the scale-of-five circuit. The scale-of-two circuit discriminates between the first and the second group. As a consequence, any number of counted pulses between 0 and 9 is indicated by two tubes simultaneously, viz.: one of the tubes of the scale-of-five and one of the tubes of the scale-of-two circuit.

As shown in Fig.24, the tubes $T_1$ to $T_5$ have a common non-bypassed cathode resistor ($R_2$). $T_6$ and $T_7$ also have a common cathode resistor ($R_5$), and their starters are coupled to the cathode of $T_5$ via two resistors. The incoming pulses are applied simultaneously to the starters of $T_1$ to $T_7$. The circuit operates as follows (see Fig.37).

| number of pulses | tube number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| 0 | | x | | | | | x | | |
| 1 | | | x | | | | x | | |
| 2 | | | | x | | | x | | |
| 3 | | | | | x | | x | | |
| 4 | | | | | | x | x | | |
| 5 | | x | | | | | | x | |
| 6 | | | x | | | | | x | |
| 7 | | | | x | | | | x | |
| 8 | | | | | x | | | x | |
| 9 | | | | | | x | | x | |
| 10 | | x | | | | | x | | x |

In position zero the tubes $T_1$ and $T_6$ are ignited. When an input pulse is applied, $T_2$ ignites and $T_1$ is extinguished owing to the voltage drop across $R_2$. Tube $T_6$ remains ignited because its anode voltage is not changed.

Fig.37. Diagram showing the operation of the circuit of Fig.24. x = tube ignited.

After four pulses have been applied, $T_5$ and $T_6$ are ignited; $T_1$ and $T_7$ have a positive starter bias. The fifth pulse therefore ignites both $T_1$ and $T_7$, whereas $T_5$ and $T_6$ are extinguished. From the fifth pulse on, $T_7$ remains ignited until the tenth pulse (which arrives when $T_5$ is again ignited) causes $T_6$ to ignite, so that $T_7$ is extinguished. Now the initial condition is restored. When $T_7$ is ignited, $T_8$ has a positive starter bias. If, due to the arrival of the tenth pulse, $T_6$ ignites, the pulse appearing across $R_5$ is fed to the starter of $T_8$ via $C_3$. This additional voltage at the starter of $T_8$ causes the latter to ignite. A pulse is then produced across $R_8$, and fed to the next decade. $T_8$ is self-quenching and will be extinguished before the next tenth pulse arrives.

The counter can be reset to zero by applying a high positive voltage to the starters of $T_9$ and $T_{10}$, which causes these tubes to ignite.

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If a rectangular input pulse is applied, it should have an amplitude of approx. 90 V at a duration of 15 to 30 $\mu$sec.

The maximum counting rate with this counter is about 2.5 kc/s. When a carry flip-flop is used, the counting rate may be increased.

## PULSE SERIES GENERATOR

The pulse series generator delivers a series of $n$ pulses ($n$ ranging from 0 to 9) when a pulse is applied to input line number $n$.

### DESCRIPTION

The circuit to be described (see Fig.38) fulfils the following requirements:

(a) When a pulse appears on input line number $n$ ($n$ ranging from 0 to 9), a series of $n$ pulses will be delivered at output $A$. These pulses are synchronised to clock pulses having a repetition frequency of 80 c/s. (The input pulse appears at the same time as one of the clock pulses.)

(b) A pulse is delivered (at output $B$) one cycle after the appearance of the last pulse of the series of $n$ pulses. If $n = 0$, it is delivered the moment the input pulse appears on the line $n = 0$.

(c) A further pulse is delivered two cycles after the pulse mentioned under $b$ (output $C$).

To explain the working of the circuit three different cases will be considered: $n = 5$, $n = 1$ and $n = 0$. Reference will be made to Fig.38. In this figure the anodes and anode leads as well as the primers with their associated circuitry have been omitted for the sake of clarity. The hatched tubes indicate the tubes burning after a cycle has been completed.

*I. The case $n = 5$*

This case may be considered as typical for all values of $n$ from 2 to 9 inclusive.

When an input pulse arrives at input 5 (the circuit being in the state as indicated by the hatched tubes) tube $e$ will be ignited due to this input pulse and the incoming clock pulses. This implies that a pulse appears across the common cathode resistor $R_1$, this pulse causing tube $j_1$ to be extinguished. The same pulse, however, is also fed to tube $k_1$, tube $l_1$, gate $G_\alpha$ in the output lead A, and to $G_{b1}$. The starter of tube $k_1$ gets its bias (via a resistor of 1.2 M$\Omega$) from the cathode of tube $h$. Since this tube is non-conducting, however, the bias is low and tube $k_1$ will not be ignited. Tube $l_1$ is already conducting, so the pulse across $R_1$ will be inoperative for this tube. The cathode voltage of $l_1$ is fed to the gate $G_\alpha$; this voltage being high, this gate will be open, so the pulse arriving at the gate will pass on to output $A$. The pulse across $R_1$ will not pass gate $G_{b1}$, the latter being closed because the level $N_k$ is low (tube $k$ is not conducting). As soon as tube $e$ is ignited, its cathode voltage rises. This voltage is fed to the starter of tube $f$, which tube will therefore ignite the moment the next clock pulse appears. As in the case of the firing of tube $e$, the pulse across $R_1$ will appear at the output $A$, leaving the rest of the circuit unchanged. The same will happen again as soon as tube $g$ is ignited. The moment tube $h$ is ignited, however, the bias
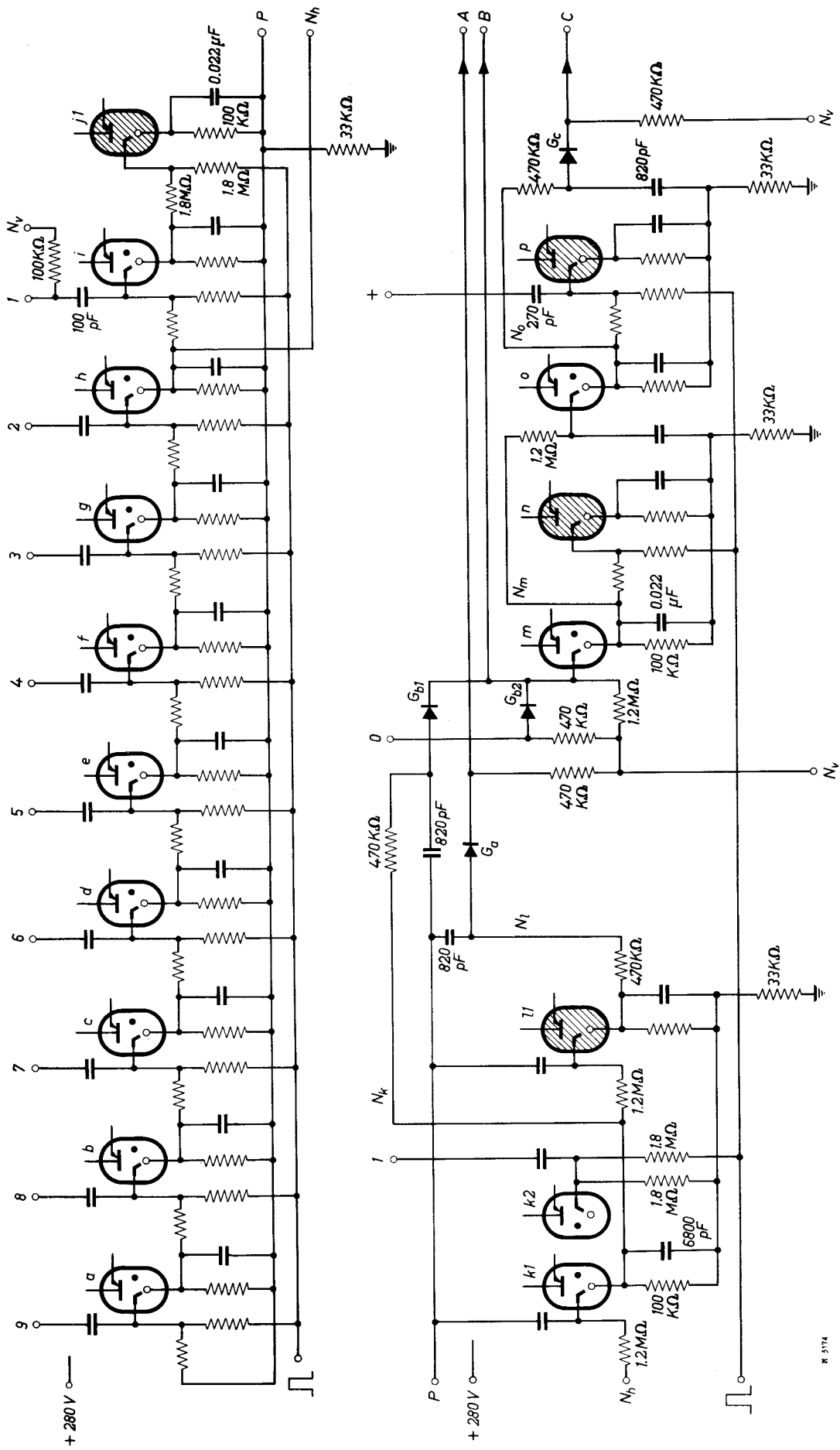
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Fig.38a. Pulse series generator.

voltage on the starter of $k_1$ will rise, so this tube $k_1$ will be ignited by the pulse appearing across $R_1$ when tube $i$ is ignited. The pulse appearing across $R_1$, when tube $i$ is ignited, will still, like its predecessors, pass gate $G_a$, being the fifth pulse passing on to $A$.

Ignition of $k_1$ has the following effects:

(1) Tube $l_1$ is extinguished, and therefore $G_a$ will be closed, level $N_1$ becoming low.

(2) Gate $G_{b1}$ will be opened as the level $N_k$ rises.

During the clock pulse succeeding the one which ignited tube $i$, tube $j_1$ will be ignited, and so again a pulse will appear across $R_1$. This pulse will pass through $G_{b1}$ on to output $B$ and also to tube $m$, which tube will be ignited, due to the fixed bias $N_v$.

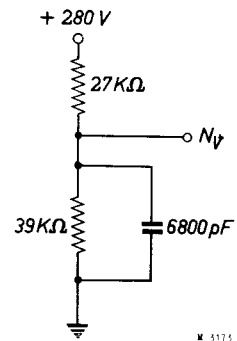

Fig.38b.

The pulse will also ignite $l_1$ again, bringing the multivibrator back into its original state. The next clock pulse will leave the upper circuit (also back in its original state) and the multivibrator untouched, but will ignite tube $n$, which tube was extinguished by the pulse appearing across $R_2$ when $m$ was ignited. The pulse appearing across $R_2$ when tube $n$ is ignited again, will cause tube o to be ignited, as the level $N_m$ is then high.

Ignition of o will cause $p$ to be extinguished at the same time. The following clock pulse will once more ignite tube $p$ (o will then be extinguished again), and the pulse appearing across $R_1$ will pass through gate $G_c$, the level $N_o$ being high at that moment.

Now the cycle is completed and the circuit is back in its original state.

*II. The case n = 1*

In this case tube $i$ is ignited by the pulse appearing on input line 1. This would mean that tube $k_1$ would not be ignited during the further cycle, as level $N_h$ would never become high. To overcome this difficulty, tube $k_2$ is provided, which will also be ignited by the input pulse on line $l$, the latter pulse being fed to the starter of this tube too.

Ignition of $k_2$ has the same effect as ignition of $k_1$, and so the circuit will behave as described above for that part of the cycle after tube $i$ was ignited.

*III. The case n = o*

In this case the incoming pulse is fed to the gate $G_{b2}$, which gate is always open (due to the fixed level $N_v$), and so a pulse will immediately appear at output $B$, as required. Passing through $G_{b2}$, this pulse also arrives at the starter of tube $m$, causing this tube to be ignited ($N_v$ is always high). From now on, the circuit functions as described for case I.

SOME REMARKS

(a) It will be clear that when the pulse-width of the clock pulses is excessive, two tubes (or even more) could be ignited in succession during one clock pulse. To prevent this, the in-

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dividual cathode impedances are given an adequately large time constant, namely 100 kΩ, 0.022 μF (2.2 msec), leaving enough reserve in the particular case.

(b) Generally it will be possible to use a sine wave to synchronise the output pulses. In that case, too, it is necessary to make the time constant of the individual cathode impedances sufficiently long. To avoid excessive starter current, a diode (semi-conductor type) may be used to form half sine-waves, clipping the negative-going parts.

(c) For resetting the circuit to its original state by hand (after switching on, for instance), tubes $j_2 - l_2 - n_2 - p_2$ (not shown) are provided. To the starters of these tubes a level $N_r$ is fed, which is raised from its steady-state value of approximately 120 V to the power supply voltage the moment the reset knob is pushed. At the same time the anode voltage of all other tubes is interrupted, preventing any faulty triggering, and extinguishing the burning tubes. Ignition of $j_2 - l_2 - n_2$ and $p_2$ has the same effect on the circuits as ignition of the tubes $j_1 - l_1 - n$ and $p$.

## GRINDING MACHINE CONTROL UNIT

We shall now describe a control unit which may be used with all kinds of production machines, to control the size of workpieces produced. The actual process under consideration is a grinding operation.

### DESCRIPTION

In the unit described (see Fig.39), every finished workpiece passes under a special test-head, with three separate output leads: $A$, $B$ and $C$. Output $A$ delivers a pulse when the workpiece measured is too large, output $B$ when the workpiece is too small, and output $C$ delivers an output pulse every time a workpiece passes the test-head.
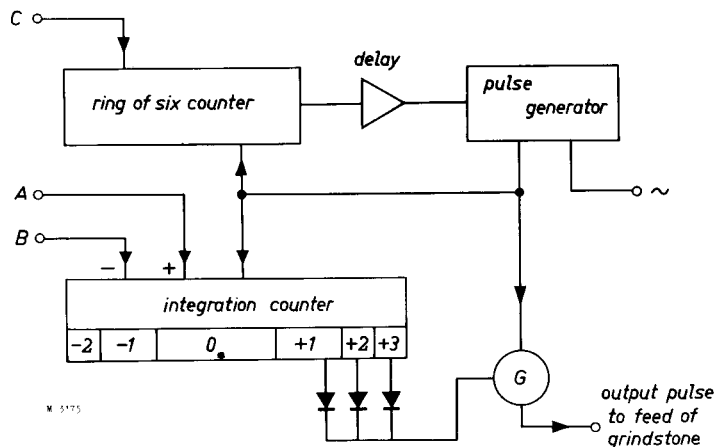


Fig.39. Block diagram of grinding machine control unit.

Pulses $A$ and $B$ are fed to a counter which counts in the forward direction when an $A$-pulse comes in, and counts in the reverse direction when a $B$-pulse arrives. This counter is called an integration counter (I.C.). Pulses $C$ are fed to a ring-of-six counter. At the start of the process both counters are in their zero position.

Let it be assumed that the third workpiece is too large, whereas the other ones are within the preset limits. In that case the counting will proceed as follows. When the first workpiece is measured, only a C pulse is delivered, which causes the ring counter to move to the "1" position. When the second workpiece is measured, the ring counter will move to position "2", the other counter still remaining in its zero position. When the third workpiece is measured, the ring counter will move to position "3", but at the same time the integration counter will go to its "+1" position (+ indicating that the workpiece is too large). This will open the gate G, to which, however, no pulse is delivered.

The 4th and 5th workpieces will bring the ring counter to the position "5". As soon as this position is reached, a (positive) d.c. level will be fed from the ring counter to the pulse generator (P.G.) via a delay. As soon as the d.c. level in the pulse generator has reached a certain value, it will deliver an output pulse which is fed:

(a) to the gate,
(b) to the ring counter,
(c) to the integration counter.


This will have the following results:

(a) As the gate is open (the integration counter still being in its +1 position) the pulse fed to the gate will be passed on to the grindstone feed.

(b) The pulse fed to the ring counter will bring this counter back to its zero position (being at the same time the sixth pulse delivered to it).

(c) The pulse fed to the integration counter will also bring this counter back to its zero position. From the above description it follows that the unit is brought back to its original state after five workpieces have been measured. (It should be noted that it is possible to use any other number than five, if desired.)

The gate will be open in any of the positions +1, +2 or +3 of the integration counter. The positions +4 and +5 are not provided since they are not needed.

The positions -3, -4 and -5 are also omitted. That these positions can be omitted may be explained as follows:

The groups consist (in this particular case) of only five workpieces. As soon as the integration counter has reached the position +3, it is certain to come to rest at a positive position.

As the gate will be open in any positive position of the I.C., it is not necessary to include the positions +4 and +5, as both would in any case be positive and indistinguishable from the other positive positions. Roughly the same holds for the positions -3, -4 and -5. When the I.C. is in the position -2, and a further negative pulse were to arrive, there would be no need to have the I.C. stepped to a -3 position, as even with two positive pulses to follow after the third negative pulse the I.C. would never reach a "+" position, and only a "+" position can open the gate.
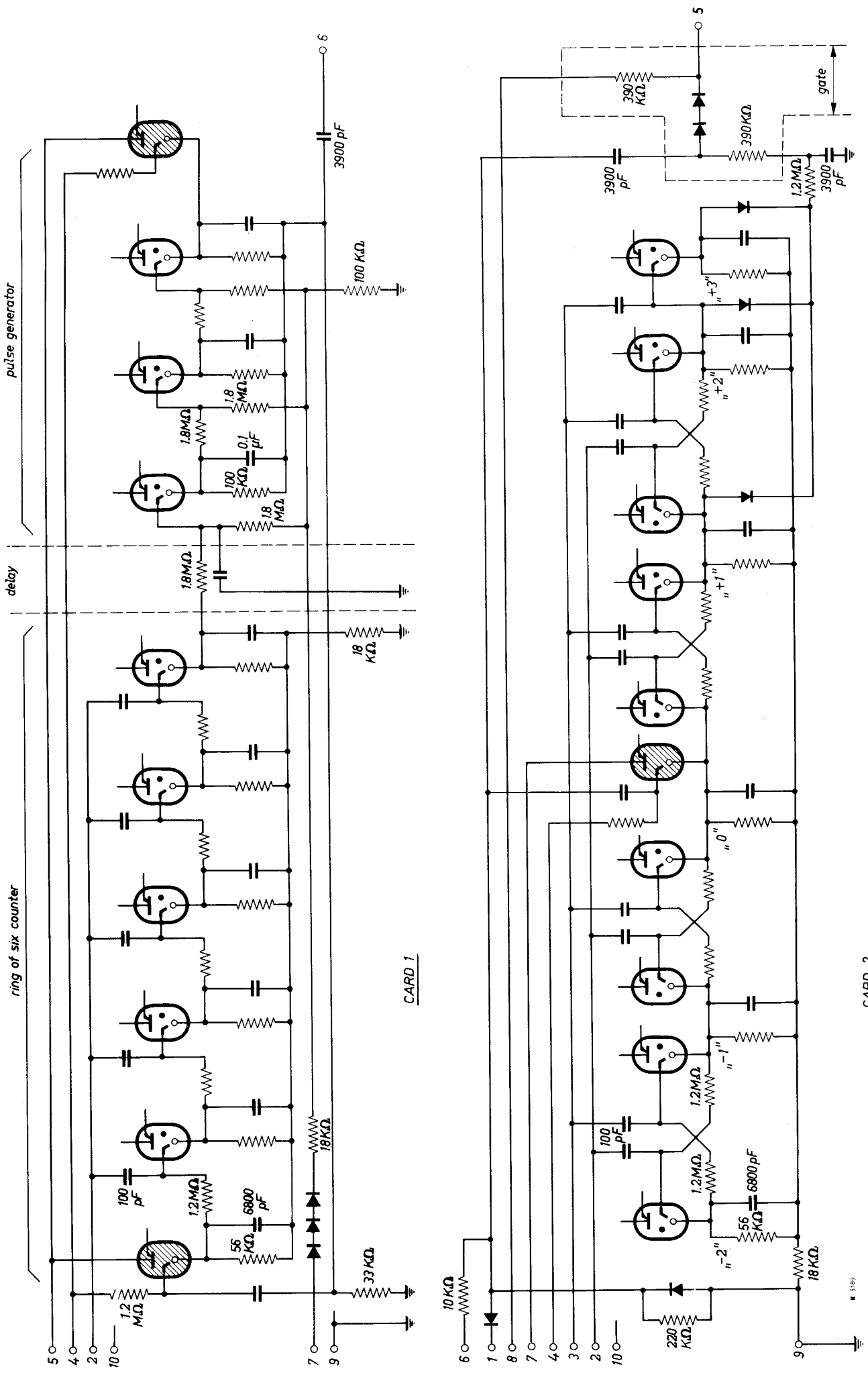
pulse generator

delay

ring of six counter

CARD 1

gate

CARD 2

Fig. 40. Circuit diagram of grinding machine control unit.

TECHNICAL DETAILS

*A. General*

Fig.40 shows the circuit diagram of the unit. This unit has been built on two cards, imitating printed wiring. Instead of the printed wiring, however, tinned copper wire has been used. The numbers indicated refer to the contact numbers of the respective cards.

In the circuit diagram the anodes of most of the tubes as well as their anode leads have been omitted in order to simplify the diagram. These anodes are connected to contact *10*, to which is fed a voltage of 280 V, which is interrupted during "hand reset". This hand reset may be used to start the unit after switching on, or in the event of a failure in the grinding machine, in the test-head or in the mains supply. To contact *4* of both cards is fed a d.c. level which, during hand-reset, is raised to such a value as to assure the ignition of the hatched tubes. As the amplitude of the reset-pulse is rather high, the peaks of these pulses could possibly pass through the gate, causing errors in the grindstone feed.

To prevent this, a clipper circuit is used, formed by two germanium diodes and resistors of 10 and 220 k$\Omega$ respectively. A constant voltage of a suitable value is fed to this clipper via contact *1*. A constant voltage level is also applied via contact *8* to the gate, to match the gate to the voltages on the cathodes of the "+" tubes in the I.C. To simplify the diagram some component values have been omitted.

*B. The delay circuit*

After tube *5* of the R.C. has been ignited, some time should elapse before the 0 tube is ignited. As 0 of the ring counter is ignited by a pulse from the P.G., there should be some delay between the ignition of tube *5* and the pulse from the P.G. This is obtained by means of a resistor (1.8 M$\Omega$) and a capacitor of suitable value in the starter circuit of tube *1* in the P.G.

*C. Pulse generator*

To the starters of the tubes in this P.G. a series of half sine-waves is fed, obtained by means of three germanium diodes OA 85. This voltage is not sufficient to ignite the tubes. However, when tube *5* of the ring-of-six counter has been ignited, the cathode voltage of this tube will rise to approx. 155 V. This voltage is fed to the first tube of the P.G. via the delay circuit mentioned above.

This extra direct voltage causes the tube to be ignited during one of the positive half cycles. After the first tube has been ignited the cathode voltage of this tube is raised, and so the second tube will be ignited during the following positive half cycle. In the same way the third tube will be ignited during the next half cycle. To prevent successive ignition of two or of all three tubes, the individual cathode impedances are given an adequately large time constant. During this process three pulses will appear on the common cathode impedance of 33 k$\Omega$ of this P.G. These pulses are used to bring both the ring-of-six counter and the I.C. back to their zero position. The pulses are also fed to the gate, and a pulse will pass on to the feed of the gri tone when one of the

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"+" tubes is on. Only one pulse will pass, as the I.C. is back in its zero position after the first pulse has been applied.

It will be clear that the pulse-generating process must be finished before the next C pulse arrives. This requirement is easily fulfilled, as the maximum pulse repetition frequency of the C pulses is only 1 c/s.

## D. Power supply

In circuits with cold-cathode tubes the loading of the power supply is practically constant, which makes for simple power supplies.

The reason for the load being constant lies in the fact that the igniting of one tube practically always means the extinguishing of another. A diagram of a possible circuit is given in Fig.41. Of course any other power supply may be used, provided the output voltage does not change more than allowed in the specific case.
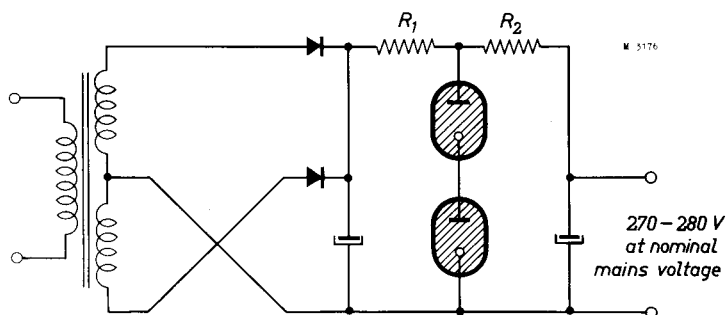
Fig.41. Power supply of grinding machine control unit.

The circuit suggested has the following advantages:

(a) It is very simple and does not contain high-vacuum tubes.

(b) It allows independent setting of the current through the stabiliser tubes and of the voltage across the second capacitor for any given load.

(c) A capacitor is connected across the load to prevent oscillations.

(d) The burning voltage of the stabiliser tubes is not critical, provided it is high enough.

## E. General Remarks

In the example given, the workpieces are divided into groups of five. As far as the control unit is concerned, any other number may be chosen. However, several points have to be taken into account when choosing this number; these are:

(1) the number of workpieces made;
(2) the number made per minute;
(3) the tolerances in the given case;
(4) the rate of wear of the tool(s) used;
(5) the price per workpiece;
(6) the accuracy of the measurement;
(7) the difference between control-limits and tolerances;
(8) the number of workpieces between (cutting) tool and test-head;
(9) the unit feed of the cutting tool.

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## TOUCH CONTROL WITH TWO TUBES Z 70 U

The electronic microswitch discussed below is equipped with two cold-cathode trigger tubes and contains a relay. The first tube is triggered by a simple finger touch; depending on the positions of the relay contacts, the second tube is either ignited or extinguished by the pulse produced by the first tube. The relay, which is energised by the anode current of the second tube, switches the load on or off.
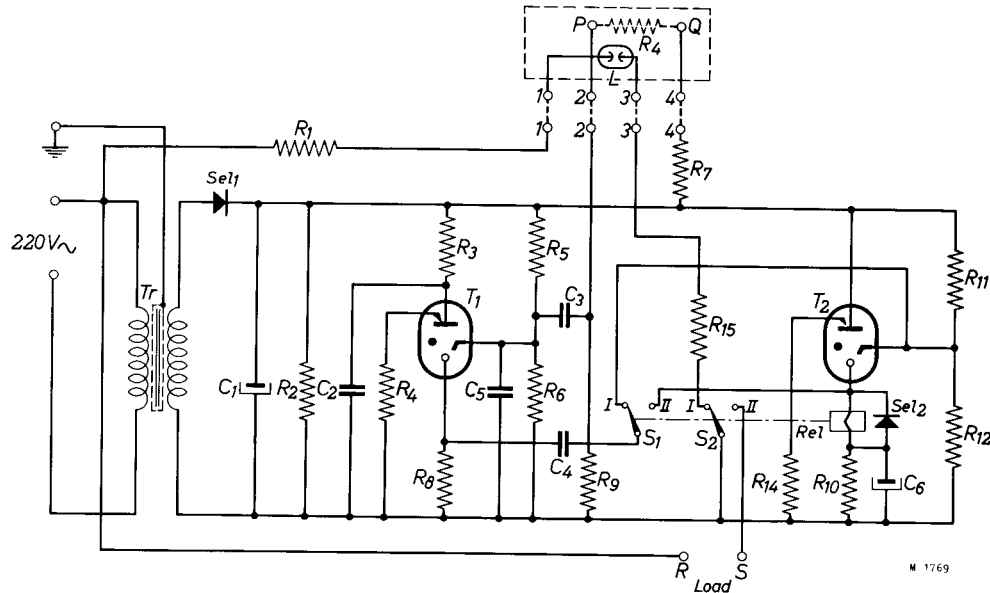


Fig.42. Touch control with two trigger tubes Z 70 U.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| $R_1$ | = | 470 k$\Omega$, ½ W | $R_{10}$ | = | 47 k$\Omega$, ½ W | $C_1$ | = | 8 $\mu$F |
| $R_2$ | = | 330 k$\Omega$, ½ W | $R_{11}$ | = | 6.8 M$\Omega$, ½ W | $C_2$ | = | 0.033 $\mu$F |
| $R_3$ | = | 10 M$\Omega$, ½ W | $R_{12}$ | = | 3.3 MW, ½ W | $C_3$ | = | 0.01 $\mu$F |
| $R_4$ | = | 0-10 M$\Omega$, ½ W | $R_{13}$ | = | 18 M$\Omega$, ½ W | $C_4$ | = | 0.01 $\mu$F |
| $R_5$ | = | 10 M$\Omega$, ½ W | $R_{14}$ | = | 18 M$\Omega$, ½ W | $C_5$ | = | 220 pF |
| $R_6$ | = | 6.8 M$\Omega$, ½ W | $R_{15}$ | = | 150 k$\Omega$, ½ W | $C_6$ | = | 8 $\mu$F |
| $R_7$ | = | 1 M$\Omega$, ½ W | Sel | = | BS 250 Y 10 | $T_1, T_2$ | = | Z 70 U |
| $R_8$ | = | 150 k$\Omega$, ½ W | Tr | = | 220/220 V | L | = | Z 8 |
| $R_9$ | = | 10 M$\Omega$, ½ W | | | | Rel | = | SZS 1301/200/o |

The operation of the circuit will be explained by reference to Fig.42. The 220 V alternating mains voltage is rectified by a selenium rectifier $Sel_1$. The rectifier circuit supplying a voltage of approx. 280 V is slightly loaded by the resistor $R_2$. In this way the voltage difference between the operating and the no-load condition is reduced, which renders the working of the circuit less dependent on mains voltage fluctuations. The anode voltage of $T_1$ is taken from the capacitor $C_2$, which remains charged via $R_3$.

Points $P$ and $Q$ form the contacts between which a conductor $R_4$ with an ohmic resistance of 0 to 10 M$\Omega$, for example a finger touch, can be applied.

The voltage divider formed by $R_5$ and $R_6$ ensures that the potential of the starter of $T_1$ is just below the voltage at which starter breakdown occurs. As soon as the external resistance $R_4$ is present, an additional voltage pulse is applied to the starter of $T_1$ so that the latter is ignited. Since $R_9$ has a value of 10 M$\Omega$, starter

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breakdown will occur even when $R_4$ has a very high value; the starter current is slightly increased by the presence of the capacitor $C_5$. In view of the possibility of the live points $P$ and $Q$ being touched, the very high resistors $R_9$ and $R_7$ are connected in series with these points to limit the current to a safe value.

When the capacitor $C_2$ is discharged through $T_1$, a voltage pulse is produced across its cathode resistor $R_8$. This pulse is fed to the starter of the second trigger tube $T_2$ via $C_4$. The starter of this tube is biased by the voltage divider $R_{11}$, $R_{12}$, so that its potential is slightly below the minimum required ignition voltage, but as soon as $T_1$ supplies the additional voltage pulse, starter breakdown occurs. The relay contacts are then changed from position I to position II, so that a following pulse, produced by $T_1$, is applied to the cathode instead of to the starter of $T_2$.

The excitation current of the sensitive d.c. relay $Rel$ slightly exceeds the holding current. The capacitor $C_6$ ensures a sufficiently large excitation current. Moreover, the values of $R_{10}$ and $C_6$ have been so chosen that the voltage across $R_{10}$ counteracts the negative voltage excursions of the oscillations occurring across the relay coil. The necessity of this precaution is manifest when $T_2$ is extinguished by a following pulse produced by $T_1$. (It should be noted that $R_3$ and $C_2$ are so chosen that $T_1$ is self-extinguishing, this tube thus being ready to cope with a following pulse immediately after the previous pulse has been applied.) The pulse of $T_1$ is now applied to the cathode impedance of $T_2$ via $S_1$, which occupies position II, thus extinguishing the tube. This gives rise to oscillation in the cathode potential as a result of the self-inductance of the relay coil, and these might cause $T_2$ to re-ignite immediately after the tube has been extinguished. Another measure taken to reduce the effect of the self-inductance of the relay coil is to shunt it by the selenium rectifier $Sel_2$.

When $T_2$ is extinguished the relay is de-energised, and $S_1$ and $S_2$ return to position I, so that the load is disconnected and the original condition restored.

When the relay is energised the total supply current is approximately 3.5 mA; with de-energised relay the current is approximately 0.9 mA, which is mainly due to the presence of $R_2$. The tubes $T_1$ and $T_2$ are pre-ionised by incorporation of the resistors $R_{13}$ and $R_{14}$ of 18 M$\Omega$ each, which ensure a continuous discharge between the anode and the priming cathode.

The circuit works reliably notwithstanding mains voltage fluctuations ranging from +10% to -20%. The dependence on mains voltage fluctuations is reduced by the above-mentioned load resistor $R_2$. A neon pilot lamp $L$ is incorporated in the finger touch switch so that the switch can easily be traced in darkness. This lamp goes out automatically when the load is switched on.

# TIMING CIRCUIT FOR SPOT AND SEAM WELDING

This timing circuit, with which 1 to 50 cycles "on" as well as "off" periods of mains frequency may be arranged, can be employed for controlling an ignitron switch of the standard system, working with normal thyratrons for welding. Only cold-cathode tubes are used.

## BLOCK DIAGRAM I

The units counter A is used for counting the units contained in the desired number of welding periods as well as in the number of cooling periods. After that, the tens counter B counts the remaining tens contained in the welding and cooling time. These numbers are pre-selected with the switches $S_{s1}$ to $S_{s4}$. Whether a welding time or a cooling time is pre-selected is decided by part D, which consists of two parts. At the end of a period one of these is operated by a pulse from the flip-flop circuit C, which also con-
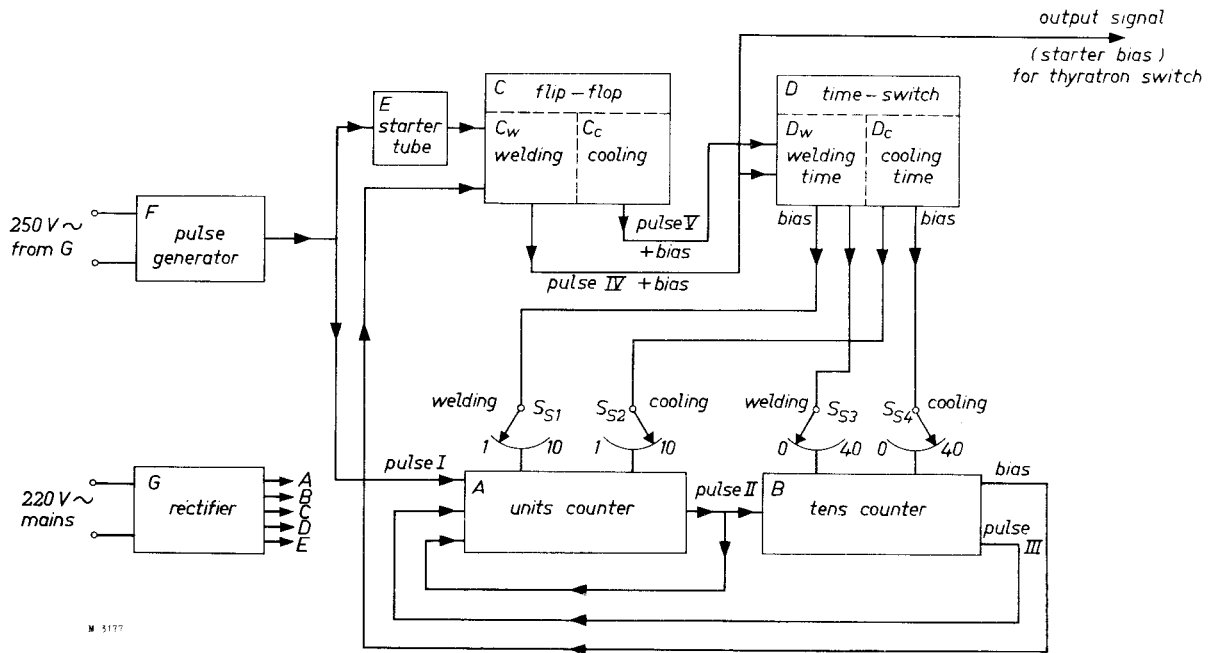


Fig.43. Block diagram I.

sists of two parts: $C_w$ and $C_c$. The welding part $C_w$ gives a pulse IV to the welding part of D and starter bias to its cooling part; or the cooling part $C_c$ gives a pulse V to the cooling part of D and starter bias to its welding part. The position of C changes at the end of a welding or cooling period because of the output pulse III from part B at the end of the tens counting. Part $C_w$ also provides the starter bias necessary for the pulse generating circuit, which supplies the control-grid pulses for the welding thyratrons. From part D come the biasing voltages for those trigger tubes in parts A and B that correspond to the position of the pre-selector switches $S_{s1}$ to $S_{s4}$. The first pulse, that starts the welding cycle, is supplied by starter tube E to part C. The pulse generator F produces trigger pulses continuously for the units counter A and also for the starter part E. All parts receive their supply voltages from the rectifier G.

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The counting proceeds in the normal way with the tubes Z 70 U. Pre-selector switches $S_{s1}$ and $S_{s2}$ are set for the unit numbers of the welding and cooling periods, so that the corresponding tubes receive starter bias. The last tube of the units counter is $T_{15}$.
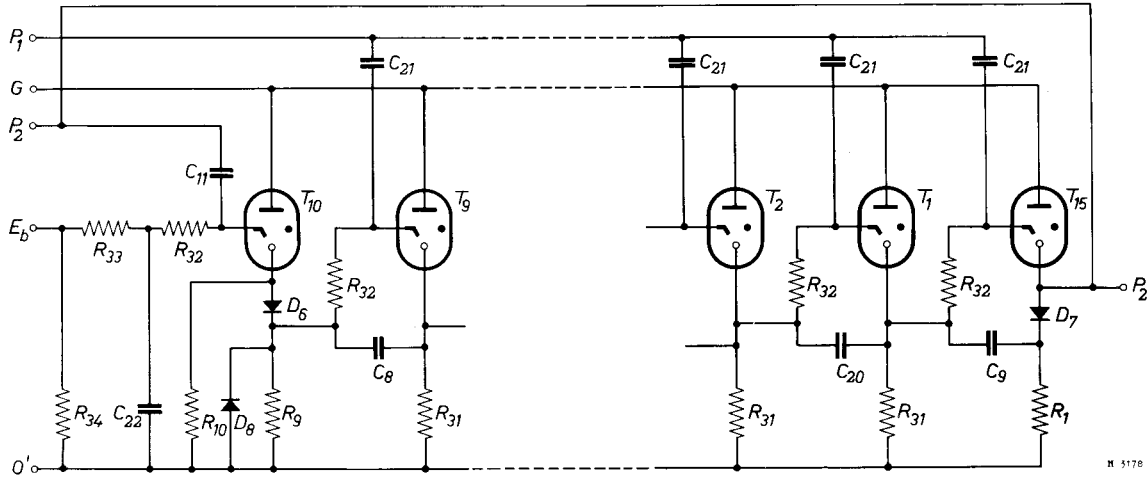


Fig.44. Units counter. (Part A)

| | | | | | |
|---|---|---|---|---|---|
| $R_1$ | = | 1 M$\Omega$ | $R_{34}$ = | 1 M$\Omega$ | $C_{21}$ = 1000 pF |
| $R_9$ | = | 82 k$\Omega$ | $C_8$ = | 3300 pF | $C_{22}$ = 3300 pF |
| $R_{10}$ | = | 10 M$\Omega$ | $C_9$ = | 2500 pF | $D_6 = D_7 = D_8$ germ. diode OA 85 |
| $R_{31}$ | = | 8.2 M$\Omega$ | $C_{11}$ = | 330 pF | (2 in series) |
| $R_{32}$ | = | 1.2 M$\Omega$ | $C_{20}$ = | 3300 pF | $T_1 - T_{10}, T_{15}$ = Z 70 U |
| $R_{33}$ | = | 1 M$\Omega$ | | | |

As soon as $T_{15}$ is ignited, the bias of point $P_2$ is raised and gives a pulse II on line $P_2$. If more than 9 pulses have to be counted, tube $T_{10}$ is ignited by the tens counter. $T_{15}$ is extinguished because its cathode lead is loaded with the capacitors $C_1$ to $C_5$ (Fig.45) and the series resistor $R_1$ is very large.

TENS COUNTER (PART B)
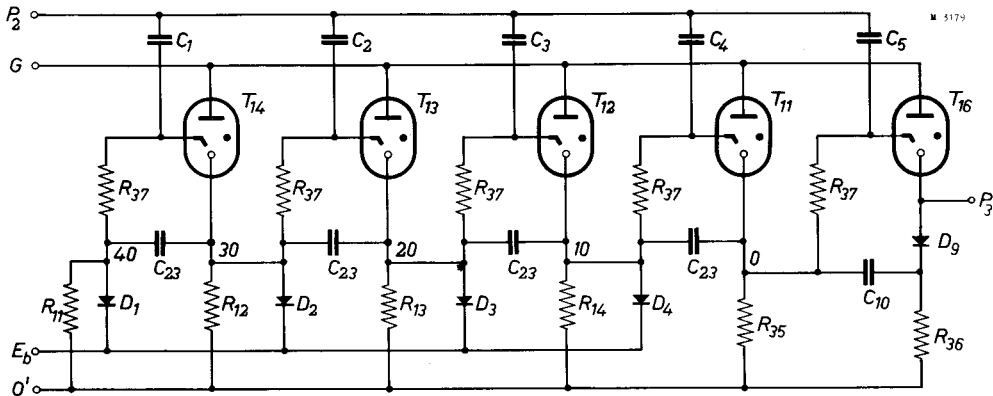


Fig.45. Tens counter. (Part B)

| | | | | | |
|---|---|---|---|---|---|
| $R_{11}-R_{14}$ | = | 82 k$\Omega$ | $C_1-C_5$ = 1000 pF | $D_1-D_4, D_9$ | = germ. diode OA 85 |
| $R_{35}$ | = | 82 k$\Omega$ | $C_{10}$ = 2500 pF | | (2 in series) |
| $R_{36}$ | = | 1 M$\Omega$ | $C_{23}$ = 3300 pF | $T_{10}-T_{14}, T_{16}$ | = Z 70 U |
| $R_{37}$ | = | 1.2 M$\Omega$ | | | |

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This part works quite analogously to the units counter. On the pulse line $P_2$ arrive the pulses from point $P_2$ in Fig.44. The points 0, 10, 20, 30 and 40 receive starter bias corresponding to the position of the pre-selector switches $S_{s3}$ and $S_{s4}$. The last tube $T_{16}$ delivers a pulse to the flip-flop circuit of part C (Fig.46). As soon as the voltage on points 40, 30, 20 or 10 is raised, the voltage on line $E_b$ is raised too via the germanium diodes $D_1$ - $D_4$ and this provides starter bias for tube $T_{10}$ in Fig.44. This tube is then ignited by a pulse coming via $P_2$ from $T_{15}$. The units counter is then able to work again and counts 10 periods in this case.

SWITCHING FOR WELDING - COOLING (PART C)
CIRCUIT FOR DETERMINING THE WELDING AND COOLING TIME (PART D)

The right-hand part of Fig.46 shows the flip-flop circuit, of which tube $T_{17}$ upon ignition supplies starter bias via line $P_5$ to tubes $T_{19}$ and $T_{20}$ in the timing part (Fig.47) and delivers a starter pulse via line $P_6$ to tubes $T_{21}$ and $T_{22}$ in the same part. The reverse happens upon the ignition of tube $T_{18}$; this supplies bias to the starters of $T_{21}$ and $T_{22}$ and a starter pulse to $T_{19}$ and $T_{20}$.
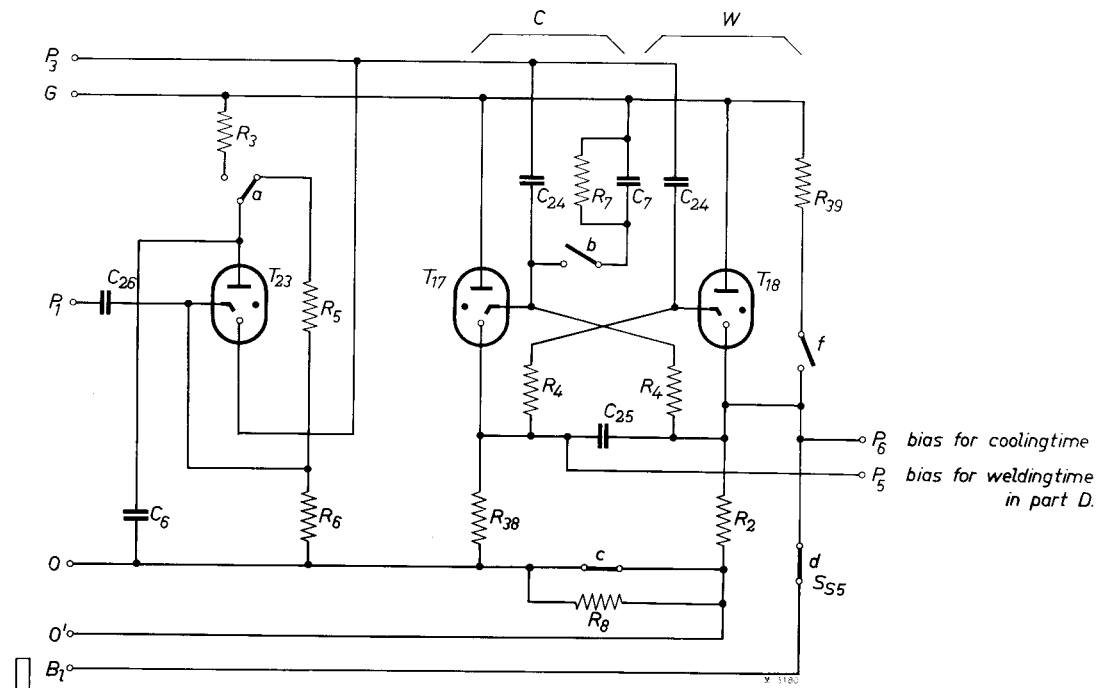


Fig.46. Starter tube and flip-flop circuit. (Welding-cooling time.) (Parts E and C)

| | | | | | | |
|---|---|---|---|---|---|---|
| $R_2$ | = | 82 k$\Omega$ | $R_7$ | = | 10 M$\Omega$ | $C_6$ = 0.01 $\mu$F |
| $R_3$ | = | 82 k$\Omega$ | $R_8$ | = | 1 M$\Omega$ | $C_7$ = 3300 pF |
| $R_4$ | = | 1.2 M$\Omega$ | $R_{38}$ | = | 82 k$\Omega$ | $C_{24}$ = 330 pF |
| $R_5$ | = | 10 M$\Omega$ | $R_{39}$ | = | 82 k$\Omega$ | $C_{25}$ = 0.02 $\mu$F |
| $R_6$ | = | 10 M$\Omega$ | | | | $C_{26}$ = 330 pF |

Each pulse on line $P_3$ in Fig.46 and coming from the coupling tube $T_{16}$ of the tens counter (Fig.45) extinguishes one of the two tubes $T_{17}$ or $T_{18}$ and ignites the other, so that either $T_{19}$ and $T_{20}$ or $T_{21}$ and $T_{22}$ conduct the current.
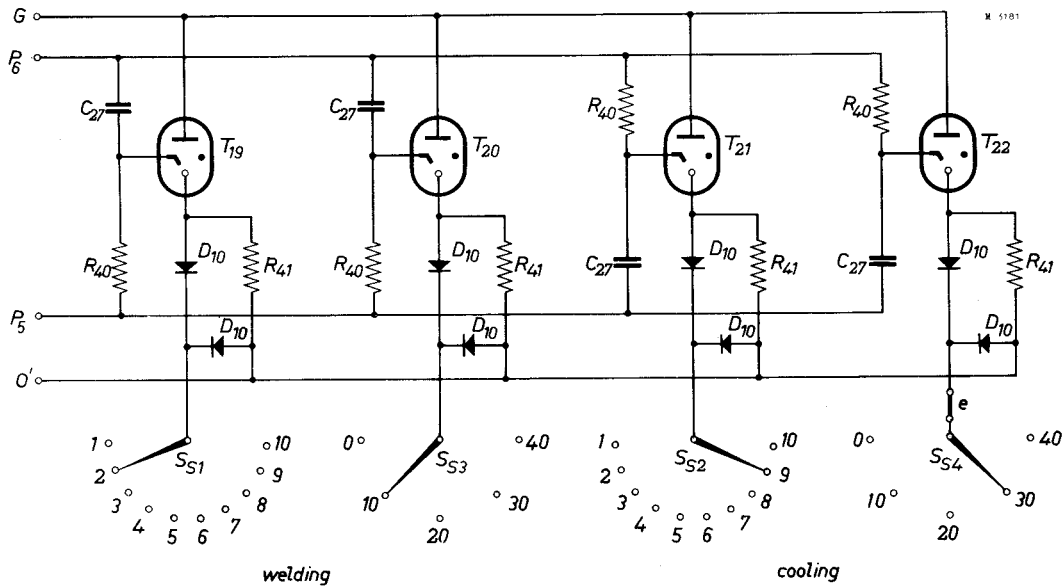
Fig.47. Circuit set-up for welding and cooling time. (Part D)

$R_{40}$ = 10 M$\Omega$          $D_{10}$ = germ. diode OA 85
$R_{41}$ = 10 M$\Omega$                    (2 in series)
$C_{27}$ = 470 pF          $S_{s1}$ to $S_{s4}$ switches.

In this way, via the tube pairs $T_{19}$-$T_{20}$ or $T_{21}$-$T_{22}$ and the switches $S_{s1}$ to $S_{s4}$, bias is given to a tube of the units counter and a tube of the tens counter, whereby the number of periods of welding or cooling may be set. Moreover, if tube $T_{18}$ is conducting, the voltage on its cathode resistor $R_2$ is brought on to line $B_1$ via the switch $S_{s5}$. This line is connected to the pulse pair circuit (part $H$, Fig.53), which operates the control grids of the welding thyratrons.

THE STARTING CIRCUIT (PART $E$)

The starting circuit is so designed that at the instant the starter button is depressed the welding period is begun. The starter tube $T_{23}$, in Fig.46 left, operates with the right part of the flip-flop, which, as explained, switches from welding to cooling and vice versa.

The starter button, which consists of four switches working at the same time (in Fig.46 all are in the rest position) is operated in two movements. It is a resilient push-button combination. What happens when it is depressed and released is described in the table on page 51.

DECOUPLING BY GERMANIUM DIODES

60   1. In Fig.44 (units counter) there are two germanium diodes $D_6$ (only one shown) between the cathode of tube $T_{10}$ and its cathode resistor $R_9$. A situation is possible in which a voltage coming from the ignited tube $T_{19}$ (or $T_{21}$) in Fig.47 appears on $R_9$. When $T_9$ is ignited the voltage on $R_9$ is raised to about twice that value, which can give rise to a high (negative) starter-cathode voltage if the starter electrode of $T_{10}$ is not biased (this means that no tens are to be counted). Thus $T_{10}$ is ignited in an abnormal way and disturbs the counting. The

| Switch | Depressed | Released |
|---|---|---|
| a | $C_6$ is charged | I   During time $(C_6 - R_5/R_6)$ starter bias appears until the next synchronous pulse on line $P_1$ ignites tube $T_{23}$.<br><br>II  A pulse then arrives on line $P_3$, and $T_{18}$, already biased, is ignited (see switch $b$).<br><br>III  When $T_{18}$ is ignited the flip-flop changes ($T_{17}$ extinguishes).<br><br>IV  A pulse arrives on line $P_6$ (see Fig. 47) which ignites $T_{19} + T_{20}$.<br><br>V  Starter bias comes on $T_{21} + T_{22}$. |
| b | I   A strong pulse ignites tube $T_{17}$ via $C_7$.<br><br>II  Starter bias comes on $P_5$ and $T_{18}$ (Fig.46). | $C_7$ can discharge over $R_{17}$. |
| c | Prevents pulse $P_3$ from igniting any other tube than $T_{23}$ and $T_{17}$ during starting, because the supply line from the rectifier $G$ is disconnected (see Fig. 48). Even if during counting of the welding periods a set button is pushed by mistake, the counter stops by the opening of $c$. | Switch $c$ closes a little earlier than switch $a$ and so makes it possible for a sufficient voltage to appear over $R_2$. |
| d | Prevents a signal from appearing on line $B_1$ upon the ignition of $T_{17}$. | Makes it possible to apply bias on line $B_1$ as long as $T_{18}$ is burning. |

reverse resistance of the diodes in combination with $R_{10} = 10 \ \text{M}\Omega$ forms a voltage divider, which reduces the said starter overvoltage to an acceptable value.

2. Faulty triggering of $T_{10}$ can also be caused by the discharging of the coupling capacitor $C_8$. At the moment that $T_9$ extinguishes, $C_8$ discharges over $R_9$ and gives rise to a voltage across it that makes the starter of $T_{10}$ positive with regard to the cathode. This voltage, added to the starter voltage of $T_{10}$, which may already be present, can ignite the tube at a wrong moment.

In this case a pulse would also arrive via $C_{11}$ on line $P_2$ and this could ignite one of the tubes of the tens counter. Here again, two series-connected diodes $D_8$ parallel to $R_9$ prevent undesired effects.

The same decouplings are necessary in the cathode leads of tubes $T_{19}$ to $T_{22}$ inclusive in Fig.47.

3. The coupling tubes $T_{15}$ (of the units counter) and $T_{16}$ (of the tens counter) must pass on a voltage pulse via $P_2$ or $P_3$ respectively, since upon ignition of these tubes a direct voltage appears on their cathode resistors. A voltage pulse can also appear on the respective cathode resistors as soon as the preceding tube $T_1$ or $T_{11}$ is ignited. In series with the coupling capacitors $C_9$ and $C_{10}$ a pulse arrives in that case on the lines $P_2$ and $P_3$, and this can cause faulty triggering. This effect is prevented by the germanium diodes $D_7$ and $D_9$ in the cathode leads of $T_{15}$ and $T_{16}$, as indicated in Figures 44 and 45.

4. The germanium diodes $D_1$ to $D_4$ in the tens counter (Fig.45) allow the voltages appearing across the resistors $R_{11}$ to $R_{14}$ to be transferred to the line $E_b$. Every time one of these resistors conducts current, the diodes not belonging to that resistor prevent the potential on the other resistors from rising.


EXPLANATION OF THE PRE-SELECTOR SWITCHES

*I.* *The desired number of welding periods and cooling periods* is selected by simultaneously depressing two buttons for the units and again two buttons for the tens. The buttons are mechanically so connected, that when one button is pushed-in, any second button, already "in" jumps "out". At the same time the direct voltage for all circuits is interrupted by pushing one button (only the "primers" of the 22 Z 70 U tubes are still fed; the primer of the 23rd. tube, $T_{23}$ is fed separately).
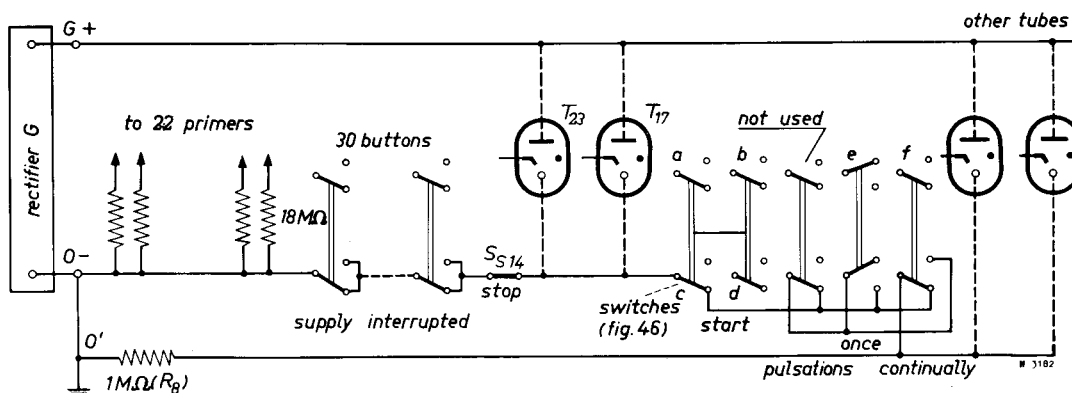


Fig.48. Explanation of pre-selector switches.

*II.* *Choice between a single or a repeated welding cycle*
The choice between pulsation welding, a single-period welding cycle or continuous welding periods without cooling time is made possible by three extra switches. The buttons for pulsation welding and a single-period welding cycle are not resilient, but are mechanically so connected that only one of them can remain pushed in.

The button for continuous welding is resilient, i.e. it makes contact as long as it is kept depressed.

*III. The starter* button is also resilient.

*IV.* When the resilient "stop" button is depressed the direct voltage is interrupted and the timing switch stops immediately.

*Remark:*

The function of resistor $R_8$ (1 M$\Omega$) is to ensure that, when the starter button is depressed, the cathode potentials of all tubes Z 70 U (with the exception of $T_{17}$ and $T_{23}$) do not become too high as long as switch $c$ is opened (compare the text belonging to part $E$).

## THE PULSE GENERATOR (PART $F$)

To ignite the tubes in the units counter and the starter tube, voltage pulses for the respective starters are required on pulse line $P_1$ in Fig.44 and Fig.46. In contrast to the other "$P$" pulses mentioned, this $P_1$ pulse is generated outside the rest of the timing circuit by a special generator. During the positive half
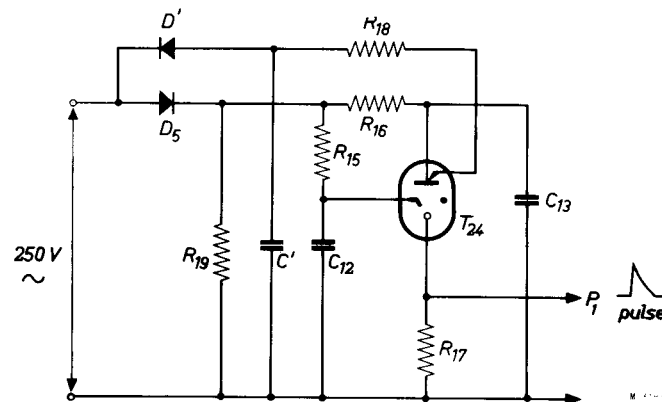


Fig.49. 50 c/s pulse generator. (Part F.)

| | | | |
|---|---|---|---|
| $R_{15}$ = | 10 M$\Omega$ | $C_{12}$ = | 220 pF |
| $R_{16}$ = | 100 k$\Omega$ | $C_{13}$ = | 0.01 $\mu$F |
| $R_{17}$ = | 10 k$\Omega$ | $C'$ = | 0.01 $\mu$F |
| $R_{18}$ = | 2x18 M$\Omega$ in series | $D_5$ = | SR250Y85 |
| $R_{19}$ = | 68 k$\Omega$ | $D'$ = | BS250Y10 |

periods of the 250 V supply with mains frequency the capacitors $C_{12}$ and $C_{13}$ in Fig.49 are charged according to the $RC$ times $R_{15}$-$C_{12}$ and $R_{16}$-$C_{13}$ respectively. As soon as the voltage on $C_{12}$ has reached the starter breakdown voltage of tube $T_{24}$, this tube starts to conduct and $C_{13}$ is discharged in series with $R_{17}$. The tube then stops conducting. The voltage pulse on $R_{17}$ is supplied to line $P_1$. To maintain the priming current the diode $D'$, capacitor $C'$ and resistor $R_{18}$ are necessary. Resistor $R_{19}$ makes it possible for $C_{12}$ and $C_{13}$ to discharge in the rest situation.

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## THE RECTIFIER (PART $G$)

The most suitable direct voltage (between points $G$ and $O$, and $G$ and $O'$ in Fig.44 to 48) for operating the trigger tubes Z 70 U is in this case about 235 V. This voltage is to be stabilised for

mains fluctuations from 180 to 240 V. Two stabilising tubes $T_{25}$ (type OA 2) and $T_{26}$ (type OB 2) in series keep the voltage between points A and B constant at about 260 V. Between points C and D,
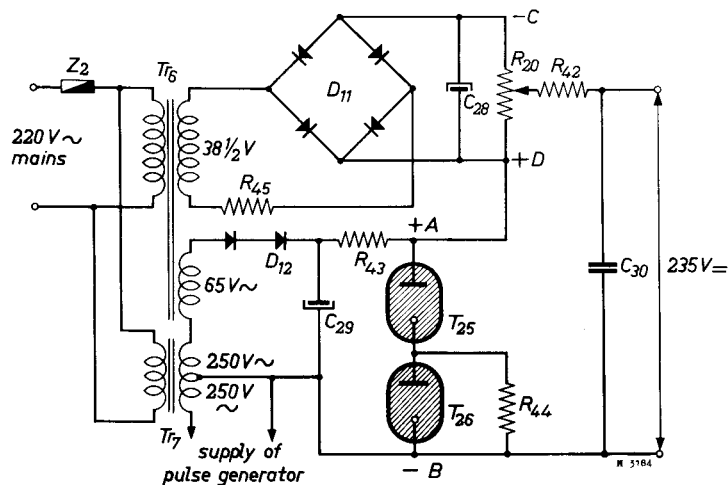


Fig.50.Stabilised 235 V rectifier. (Part G)

| | | | |
|---|---|---|---|
| $R_{20}$ = | 1 kΩ. 3 W | $D_{11}$ = | selenium cells SR250B90 |
| $R_{42}$ = | 100 Ω. 1 W | $D_{12}$ = | 2×SR250Y85 |
| $R_{43}$ = | 5 kΩ. 5 W | | selenium cells in series |
| $R_{44}$ = | 1 MΩ. 1 W | $T_{25}$ = | tube OA 2 |
| $R_{45}$ = | 33 Ω. 1 W | $T_{26}$ = | tube OB 2 |
| $C_{28}$ = | 100 μF. electrolytic cond. | $Tr_6$ = | transformer 3H58728 |
| $C_{29}$ = | 50 μF. electrolytic cond. | $Tr_7$ = | transformer R314135 |
| $C_{30}$ = | 1 μF. electrolytic cond. | $Z_2$ = | fuse 2 A |

then, 25 V is connected in opposite polarity. This voltage, which is not stabilised, is used to compensate for changes in the operating voltage of the stabiliser tubes caused by mains fluctuations. The result is therefore a reasonably constant direct voltage of approx. 235 V.

BLOCK DIAGRAM II

The part for counting a number of welding and cooling cycles having been described in the preceding paragraphs, the remaining part, containing thyratrons and ignitrons in inverse connection, is described below (Fig.51).
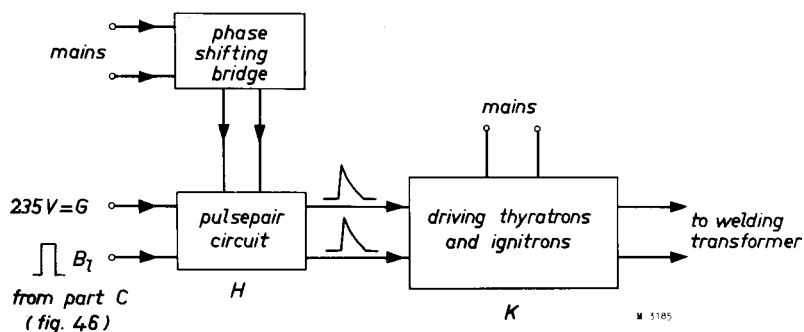


Fig.51. Block diagram II.

Part $H$, the pulse forming circuit, which generates the grid pulses for two thyratrons in part $K$, is fed by 110 V from the phase shifting bridge $J$ and by the block voltage (line $B_1$) from the periods counter (see part C, Fig.46) and the 235 V direct voltage

(line $G$): Part $H$ gives a double positive voltage pulse 50 times per second (mains frequency) but only as long as the rectangular voltage on line $B_1$ is present. The phase of these two pulses in relation to the mains voltage may be regulated with bridge $J$.

Part $K$ is the real "switch", which applies the mains voltage (380 V) to the load (i.e. the welding transformer) during the selected number of periods.

## THE PHASE-SHIFTING BRIDGE (PART $J$)

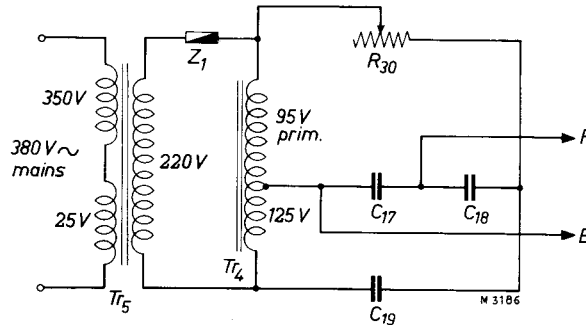Fig.52 shows this bridge of which the principle is well-known.

Fig.52. Phase-shifting bridge. (Part J.)

| | | | | |
|---|---|---|---|---|
| $R_{30}$ = | 8 k$\Omega$, 40 W | $Z_1$ = fuse 2 A | $Tr_5$ = | transf. 3H576 11.3 |
| $C_{17}$ = | 1/2 $\mu$F | $Tr_4$ = transf. A 314135.3 | | prim. 350 + 25 V |
| $C_{18}$ = | 1 $\mu$F | prim. 95 + 125 V | | sec. 220 V |
| $C_{19}$ = | 1 $\mu$F | sec. not used | | |

The tapping of the secondary winding of transformer $Tr_4$ is slightly off-centre, which reduces the variation in the voltage of the diagonal between the points $E$ and $F$. The phase of the mains connection must be decided upon; a phase shift between $40°$ and $140°$ of the welding sine waves is possible.

## THE PULSE PAIR CIRCUIT (PART $H$)

The two thyratrons and ignitrons, which, in inverse connection, switch the welding transformer on the a.c. mains, must always give an even combination of positive and negative half sine waves to avoid a d.c. component in the windings. Therefore in each period of the mains frequency a pulse pair is supplied to the thyratrons. Fig.53 illustrates how these pulse pairs are generated. Trigger tube $T_{27}$ receives bias on its starter as long as a rectangular voltage is present on line $B_1$ (voltage from flip-flop circuit, Fig.46). $Tr_2$ is a peak voltage transformer connected to the 110 V diagonal voltage of the phase shifting bridge, part $J$ (Fig.52). At the next positive peak $T_{27}$ is ignited and a voltage appears on the cathode resistor $R_{21}$. This voltage biases the starter of tube $T_{28}$, which half a period later also receives a peak voltage from $Tr_2$ and in its turn is ignited, while at the same time $T_{27}$ is extinguished. In this way a cycle is completed, i.e. a pulse pair is given to transformer $Tr_3$, the primary of which is fed by the voltages on the two cathode resistors $R_{21}$-$R_{22}$. If the rectangular voltage $B_1$, however, is wider than 1 period, then, depending on that width, two or more pulse pairs will be generated.

For each primary voltage pulse $Tr_3$ supplies two identical secondary driving pulses to the thyratron grids. One of these driving pulses is useful for each of the thyratrons, viz. the one that falls in the positive half of the anode a.c. voltage.
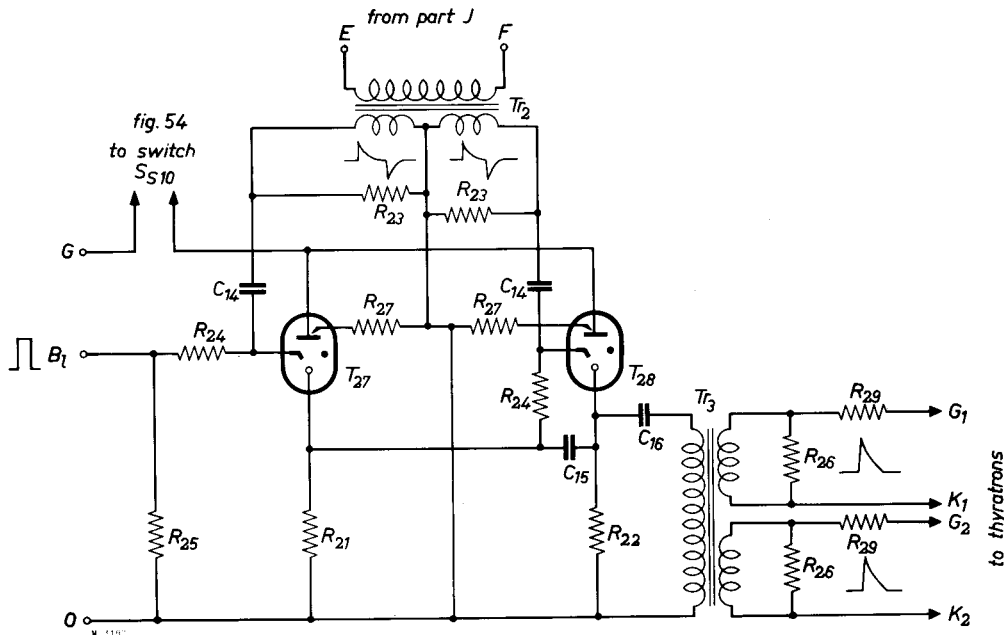


Fig.53. Pulse pair circuit. (Part H)

| | | | | |
|---|---|---|---|---|
| $R_{21}$ | = | 47 k$\Omega$ | | |
| $R_{22}$ | = | 47 k$\Omega$ | | |
| $R_{23}$ | = | 330 k$\Omega$ | | |
| $R_{24}$ | = | 2.2 M$\Omega$ | | |
| $R_{25}$ | = | 1 M$\Omega$ | | |
| $R_{26}$ | = | 33 k$\Omega$ | | |
| $R_{27}$ | = | 18 M$\Omega$ | | |

$R_{29}$ = 10 k$\Omega$

$C_{14}$ = 350 pF

$C_{15}$ = 0.047 $\mu$F

$C_{16}$ = 0.022 $\mu$F

$Tr_2$ = peaktransf. 84590

$Tr_3$ = coil T198254 - prim. 1 winding
             sec. 2x2 windings in series

THE WELDING SWITCH PROPER (PART K)

The primary winding of the welding transformer $Tr_{10}$ must be connected either via two inverse-parallel connected thyratrons (type PL 6755, welding capacity about 300 kVA) or via two ignitrons in inverse-parallel connection (type PL 5551 (A) welding capacity about 600 kVA) during the selected number of periods of the mains voltage (380 V).

In the closed position of the double-pole switch $S_{s13}$ the ignitors of the ignitrons cannot be controlled, but the thyratrons can conduct the main current. The pulses delivered by transformer $Tr_3$ make the control grids, having a negative bias from the rectifier $R_n$, positive. In the opened position of $S_{s13}$ the ignitrons are ignited according to the anode ignition method with the aid of the two thyratrons.

$S_{s7}$ is a precontact on main switch $S_{s6}$, which first of all brings a negative bias on the control grids of the thyratrons and thereby prevents premature ignition caused by switching operations. The auxiliary apparatus consists of a delay circuit, which prevents the arrival of control pulses on the grids of the thyratrons as long as the cathodes are not warm enough (relay $S_{s10}$). Furthermore

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the klixon temperature switch $S_{s9}$, which is mounted on the cooling envelope of ignitron $T_{31}$, controls the cooling water supply (water economising circuit with solenoid valve).
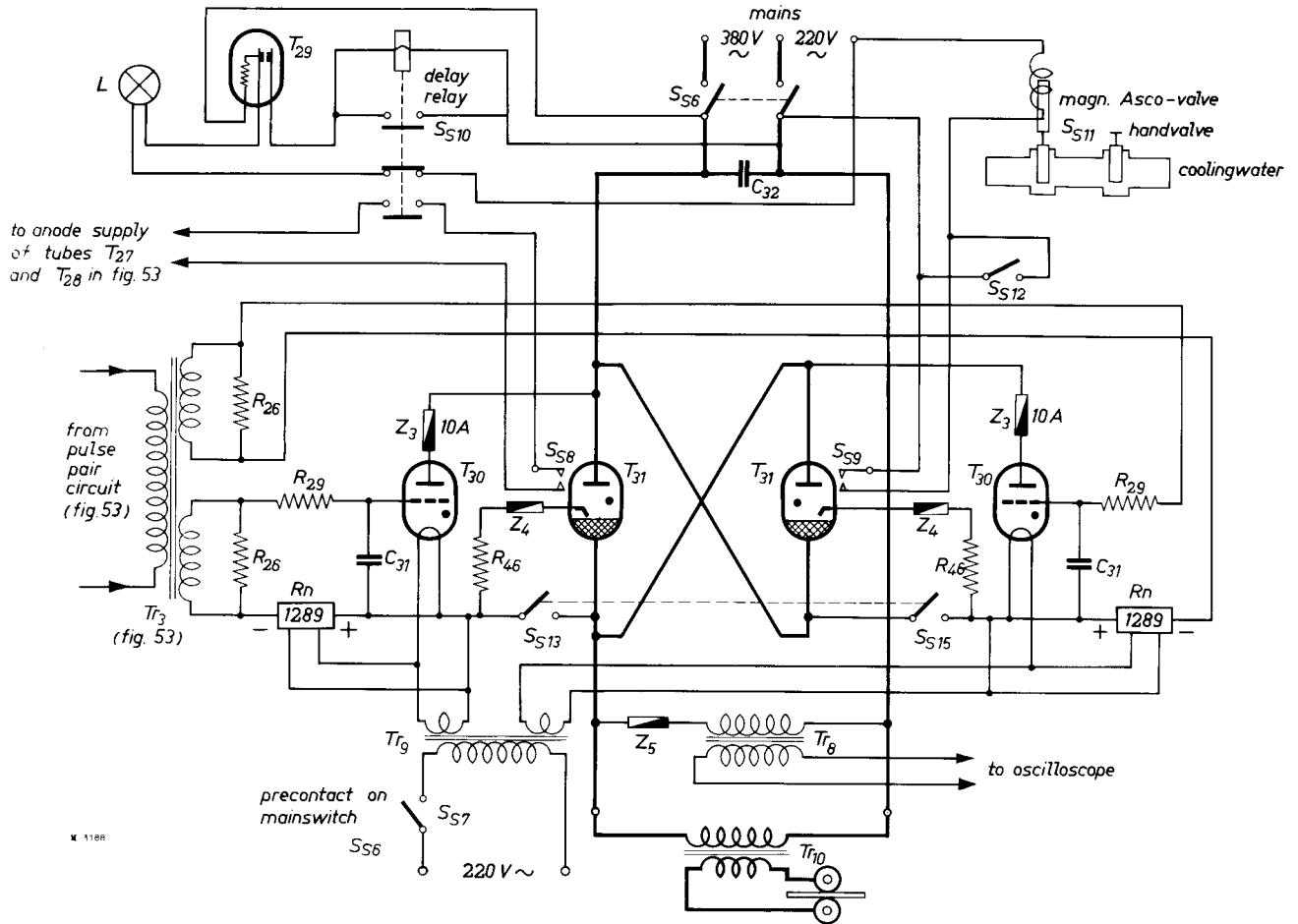


Fig.54. Driving thyratrons and ignitrons. (Part K.)

| | | | |
|---|---|---|---|
| $R_{26}$ | = | 33 k$\Omega$ | |
| $R_{29}$ | = | 10 k$\Omega$ | |
| $R_{46}$ | = | 4 $\Omega$, 100 W | |
| $C_{31}$ | = | 100 pF | |
| $C_{32}$ | = | 0.047 $\mu$F | |
| $Tr_8$ | = | transf. 380/25-50 V, T171013 | |
| $Tr_9$ | = | transf. 220/2x2.5 V, 2K00956 | |
| $Tr_{10}$ | = | welding transformer | |
| $T_{29}$ | = | bi-metal relay tube 4152 | |
| $T_{30}$ | = | thyratron PL 6755 | |
| $T_{31}$ | = | ignitron PL5551A | |
| $L$ | = | 220 V/25 W signal lamp | |

| | | |
|---|---|---|
| $S_{s6}$ | = | main switch. 3 phase, 60 A. 0857007 |
| $S_{s7}$ | = | micro switch, precontact on $S_{s6}$. 0852360 |
| $S_{s8}$ | = | klixon switch, 55306 |
| $S_{s9}$ | = | klixon switch, 55305 |
| $S_{s10}$ | = | relay 0870007 |
| $S_{s11}$ | = | Asco switch. 8210A2 |
| $S_{s12}$ | = | switch, V357716 |
| $S_{s13}$ | = | switch, V357716 |
| $Z_3$ | = | fuse 10 A |
| $Z_4$ | = | fuse 2 A |
| $Z_5$ | = | fuse 2 A |
| $R_n$ | = | rectifier type 1289 (neg. grid voltage) |

If, when starting ($S_{s9}$ open, solenoid valve closed) it is not certain whether the ignitron envelope is filled with water, the switch $S_{s12}$ must temporarily be put in by hand until cooling water is seen flowing out of the water outlet tube. The third precaution pertains to the temperature safety switch $S_{s8}$, which disconnects the supply to the pulse-pair circuit (Fig.53) as soon as, owing to insufficient water supply, the ignitron temperature rises too high and so switching over to the thyratrons becomes impossible.
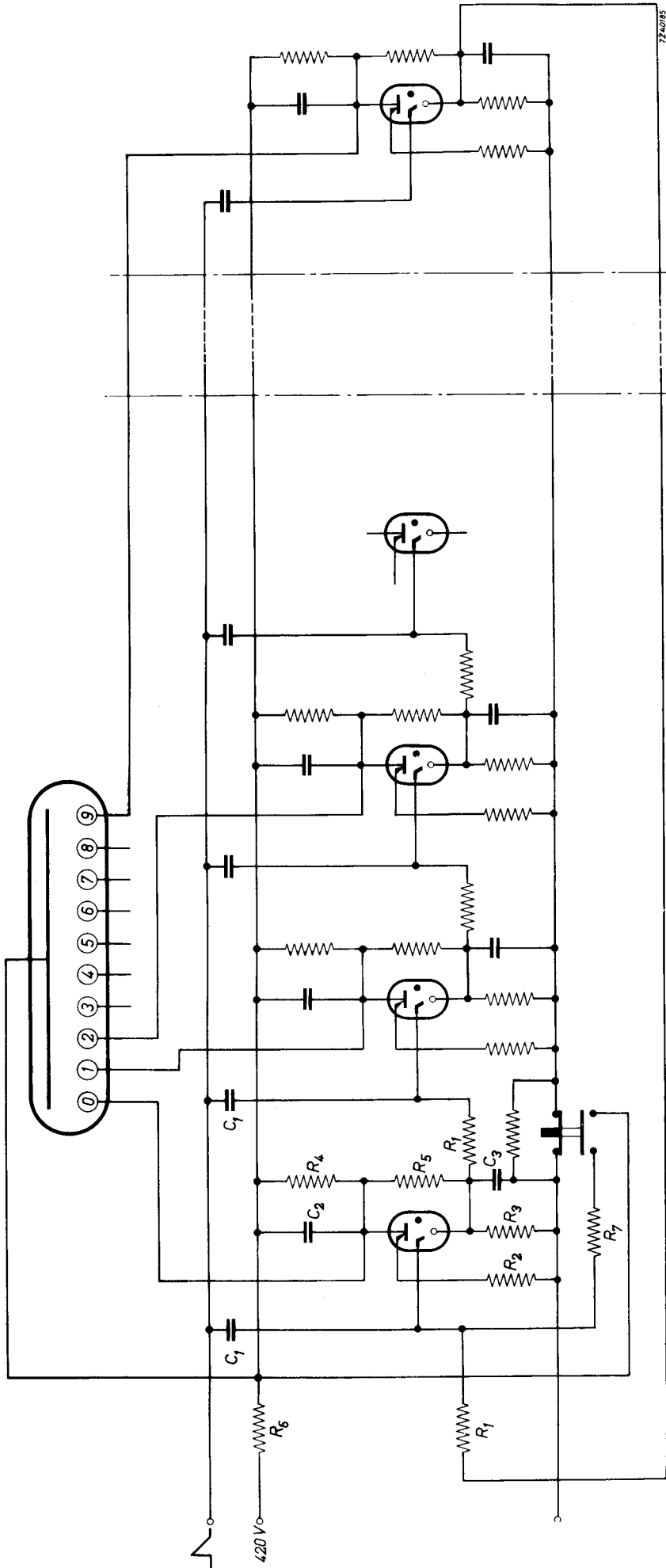
Fig. 55. Ring counter with trigger tubes Z70U and with Z510M tubes for read-out.

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CONCLUDING REMARKS

1. When the respective buttons are depressed for changing the welding or cooling time, the welding is stopped immediately and has to be started again. The same happens when the stop button is pushed.

2. The periods can only be counted when one of three buttons marked "pulsation 1x", "pulsations" or "continuous" is depressed.

3. A positive welding current pulse is always followed by a negative one and so no saturation of the core of the welding transformer is to be feared, unless switch $S_{s8}$ (or $S_{s10}$) from Fig.54 opens.

4. Mains voltage fluctuations from 180 to 240 V have no influence on the counting.

5. All resistors used in the counter circuits are of the ½ W type and have values with +10 or -10% tolerance; the capacitor tolerances should be +10 or -10%.

## RING COUNTER EQUIPPED WITH TRIGGER TUBES Z70U AND WITH Z510M TUBES FOR READ-OUT

In advanced counters the ten-spot read-out is going to be discarded in favour of the figure read-out, for which purpose the Z510M tube with ten figure-shaped cathodes is employed. This tube, being no counting tube itself, may be coupled to digital counters equipped with e.g. Z70U and Z70W tubes. Conventional counters, however, cannot be directly coupled to the Z510M, because the digit to be ignited requires a negative voltage, whereas a positive voltage is present at the cathode of the ignited tube to bias the next one.

Fig.55 gives a circuit of a forward ring counter with the Z70U in which the voltage drop across the additional anode resistor $R_4$ is used to ignite the corresponding digit in the Z510M. A similar method may be employed for forward and backward ring-counters equipped with the Z70W.

Another method of coupling is with the ORP 60 photoresistors connected in series with each digit cathode of the Z510M, and mounted close to the base of the Z70U tubes in the ring counter. If the Z70U is ignited, the resistance of the ORP 60 is so far reduced that the corresponding digit in the Z510M figure tube ignites. It will be clear that the methods mentioned are only two of the several circuits that are possible for coupling the Z510M numerical indicator tube with e.g. transistors, decade selector tubes, etc.