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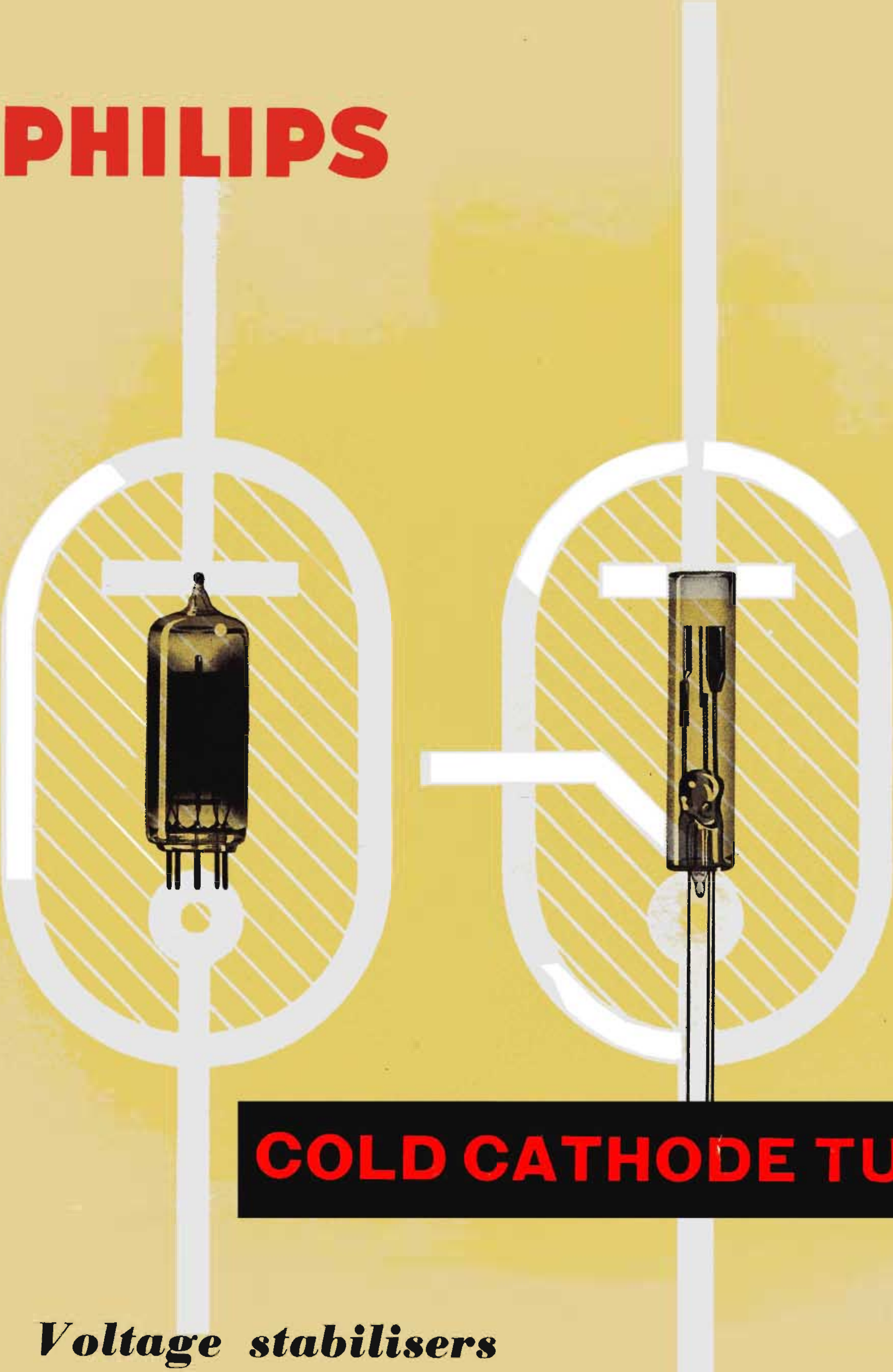


COLD CATHODE TUBES

Voltage stabilisers
Trigger tubes

PHILIPS ELECTRON TUBE DIVISION

PREFACE

Among the methods of obtaining electron emission, thermionic emission is the best known. Practically all electron tubes used in equipment for communication and entertainment are based upon this principle. Cold emission by ion bombardment is not employed to the same extent, but there are several tubes using this principle which have found wide-spread application in some special branches of electronic and electrical engineering. This publication deals with the following classes of cold-cathode tubes:

1. *Voltage stabilising tubes, i.e. gas-filled diodes having a voltage-current characteristic which renders them particularly suitable for voltage stabilisation. Special attention is paid to the voltage reference tube 85 A 2, which delivers an extremely constant reference voltage.*
2. *Trigger tubes. These types of tube bear some resemblance to thyratrons. They are also provided with a grid or auxiliary electrode, called the "starter", by means of which the main discharge between anode and cathode can be initiated. For this purpose only a small energy pulse is required on the grid, and this makes the tubes specially suitable for a large number of applications such as remote control, timers, etc.*

Complete technical data of the above-mentioned classes of tubes are given, whilst their application is illustrated either by design calculations or circuits. Upon request assistance will always be gladly given to designers for the solution of any questions relating to the use of these tubes.

CONTENTS

VOLTAGE STABILISING TUBES

INTRODUCTION

Voltage stabilising tubes are used in a very wide range of apparatus where a direct voltage must be kept constant.The voltage to be stabilised may vary as a result of fluctuations in the mains voltage from which the direct voltage is obtained by rectification, or as the result of changes in the load current. Such fluctuations in voltage may be very undesirable,as indicated in the following practical examples.

a) In standard signal generators and transmitters the oscillator frequency varies with the supply voltages at the electrodes of the oscillator tube A considerable improvement in frequency stability can be obtained by stabilising the H.T. supply voltage.

b) In apparatus where a direct voltage is measured by comparing it with a reference voltage, the latter voltage must be independent of mains fluctuations; this can be ensured by using a voltage stabilising tube.

c) In power supply units employing electronic stabilisation, a constant voltage reference is also required, and this again can be obtained by a voltage stabilising tube.

d) In A.F.Class B or Class AB amplifiers with a pentode output stage the screen-grid current of the output tubes increases with the drive, and normally results in a decrease of screen-grid voltage, which reduces the available output. This can be avoided by stabilising the screen-grid voltage by means of voltage stabilising tubes.

For these and many other applications a range of voltage stabilisers is available, data of which will be found on pages 22 to 33 .These tubes cover operating voltages from 85 V to 150 V, so that a suitable tube may be selected for the majority of applications. Higher operating voltages can be obtained by connecting two or more tubes in series.

The principle of operation may be explained briefly as follows. A voltage stabilising tube is a two-electrode cold cathode tube, filled with a rare gas at a pressure between 0.5 mm and 40 mm of mercury. Its operation is based on the fact that if a voltage exceeding a critical value (the ignition voltage) is applied to the tube a glow discharge occurs, caused by ionization of the gas. This discharge is visible at the cathode and is separated from it by a dark layer, called the Crookes dark space. Once the glow discharge is established, the voltage across the tube is almost independent of the current through it, and it is upon this fact that the use of the tube as a voltage stabiliser is based. If the tube is operated under conditions at which the current is smaller or greater than current values in the glow discharge region, stabilisation will be less satisfactory.

IGNITION VOLTAGE AND OPERATING VOLTAGE

A minimum voltage (the ignition voltage) is required at the electrodes of the tube to initiate the discharge. The average tube will ignite at a voltage somewhat lower than the maximum value indicated in the data, so that this value should be regarded as the upper limit for a given type of tube.

When considering the ignition of cold-cathode tubes, a very important requirement is that the anode-cathode gap always breaks down when a given voltage charge is applied to one or both of the electrodes.

There are two physical phenomena which introduce a time lag between the application of a sufficient voltage on the anode to produce breakdown in a gas-discharge system and the stable establishment of the discharge. These are called the *statistical delay time* and the *formative delay time*.

The *statistical delay time* depends on the presence of an electron or ion in the gap between the electrodes at a particular instant. The ion can be accelerated towards either electrode and produces sufficient ionization in the gas to cause breakdown between the electrodes. Ions are normally present in any gas atmosphere because of ionization by cosmic radiation, but the number of ions present per unit of volume in a gas-gap can be greatly increased by irradiation of the gas by X-rays or ultra-violet light or by photo-electric effects at the electrodes due to either of these agents or to visible light. The statistical delay time can therefore be eliminated by suitable "priming".

The *formative delay time* depends upon the time that the ion or electron which initiates the discharge takes to produce sufficient ionization to cause breakdown and produce a self-sustaining discharge. This depends upon parameters governed by the pressure and nature of the gas and the geometrical dimensions which are normally constant for a given gas-gap, but it is also governed by the voltage applied between the electrodes. The formative delay time cannot therefore be eliminated, but is reduced by increasing the voltage applied between the electrodes to initiate the breakdown, above the value that will just cause breakdown if it were applied for a very long time.

The formative delay time necessitates the application of pulse voltages with amplitudes greater than the normal d.c. break-down voltage of a gas-gap in circuits where pulse techniques are used to initiate the discharge. The difference in voltage between the pulse amplitude required to produce breakdown and the d.c.breakdown voltage is called the "overvoltage". In general the overvoltage required to produce breakdown depends on:

(1) the history of the cathode (i.e. whether it has been conducting or left idle);
(2) the pulse duration;
(3) the light falling on the electrodes: photo-electric effect;
(4) the presence of an internal priming source.

The photo-electric effect can be promoted by mounting a small incandescent lamp in the neighbourhood of the tube so that the light impinges on the electrodes. The indicated breakdown values mentioned in this documentation are consequently only valid if some ambient illumination is present. In complete darkness the ignition voltage can assume a higher value and there may be a considerable ignition delay.

The internal priming can be produced by several means, as will be explained below.

One way of obtaining an internal priming source consists in providing the tube with a so-called auxiliary electrode, the "primer". This very small electrode should be connected to the supply voltage via a very high resistance, so that a minimum current of only a few microamps will flow continuously from this primer to another electrode, thus ensuring that there is a constant stream of electrons.

Another method of internal priming is to introduce a radio-active substance into the tube, so that ionization is produced by radioactivity. The advantage of this method is that no electrical power is consumed to produce the priming.

As soon as ignition occurs, the voltage across the tube drops to a value termed the operating voltage. This voltage is lower than the ignition voltage, provided the current through the tube is within the specified range. The data also specify voltage limits representing the spread of the operating voltage and the recommended quiescent current for different specimens of the same type of tube. In the voltage reference tube type 85A2 these limits are narrow, and particularly the variation in operating voltage during life is very small.

It may be mentioned that a small difference between ignition voltage and operating voltage is advantageous in practical applications, since the requirements must always be fulfilled that a sufficiently high voltage is available for obtaining ignition. A conveniently high value of the operating voltage and low value of ignition voltage are obtained by suitable choice of the electrode configuration, the type of cathode material used, and the mixture and pressure of the gas.

PERMISSIBLE CURRENT RANGE

The current range over which the tube operates satisfactorily is determined by the cathode area. At low currents only part of the cathode is covered by the glow discharge, the area increasing or decreasing with the current through the tube. Until the cathode is entirely covered by the glow discharge, the current density is constant and the operating voltage increases only slightly. A typical characteristic of a voltage stabilising tube is reproduced in fig. 1 (see curve a).

If the current is increased above $I_{norm\ max}$, the voltage across the tube will increase more rapidly, and the current density at the cathode also assumes a higher value. Consequently the tube will operate in a region of higher internal resistance. This is the region of so-called anomalous glow discharge. The 85A2, which has been made according to the so-called sputtering technique to obtain highest cleanness inside the tube, is intentionally operated in this region at the cost of higher internal resistance. A higher constancy of operating voltage during life is thus obtained, and erratic effects, such as jumps and hysteresis, which are apt to occur when the operating current is suddenly changed, are reduced. By choosing a lower gas pressure, the slope in the anomalous region has been decreased considerably (see curve *b* of fig.1). Below I_{min} the voltage-current characteristic becomes very steep, and this region is unsuitable for stabilisation.

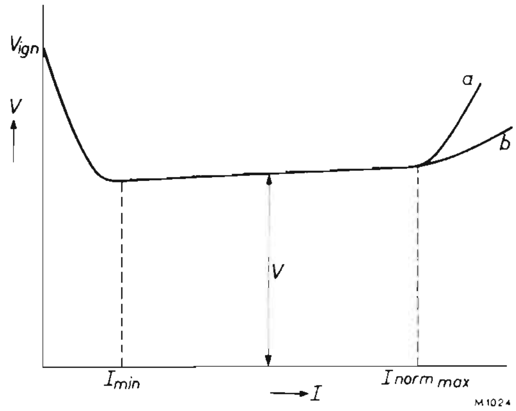


Fig.1. Voltage versus current characteristic of a stabilising tube.

In equipment using indirectly heated amplifier or oscillator tubes with a directly heated rectifying tube for the H.T. supply voltage stabilising tubes are often used to stabilise the supply voltage of one or more of the indirectly heated tubes. Since, however, the cathodes of the indirectly heated tubes require a heating-up time after the apparatus is switched on, whereas the directly heated rectifier provides high tension immediately, the maximum direct operating current of the stabiliser might be temporarily exceeded. To avoid damage to the stabiliser, this so-called starting current must not exceed 2.5 times the rated maximum direct operating current averaged over a starting period not exceeding 10 seconds. The instantaneous value of the starting current of a stabiliser with a rated maximum direct operating current of, for example, 30 mA must therefore not exceed 75 mA. In order to prevent permanent changes in the tube characteristics, it is advisable to keep the starting current as low as possible.

REGULATION

When the current through the tube is varied within the permissible current range, the operating voltage will be substantially constant, provided the tube operates in the region of normal glow discharge. The operating voltage will be less constant when the tube works in the region of the anomalous discharge, which occurs only with sputtering-technique tubes. At low currents the operating voltage will have the lowest value, whilst with increasing current the voltage across the tube will also increase. The difference between the operating voltage obtained at the maximum current and that obtained at the minimum current is termed the regulation voltage. The regulation of the tube for small current variations is usually expressed in the a.c. resistance, which, as with radio tubes, can also be termed the internal resistance.

PURITY OF THE CATHODE

In practice the physical properties of the cathode surface will not be uniform over the whole of its area, and this may result in appreciable variations in operating voltage when the current is varied. A very slight amount of contamination of the cathode surface may have a large influence upon the operating voltage, and special measures have to be taken in manufacture to ensure purity of the cathode material.

With the voltage reference tube type 85A2 special care has been taken in manufacture to obtain very constant discharge characteristics. Special homogeneous metal is used as cathode material, and this has resulted in a very small spread in operating voltage and a small variation of this voltage during life. This type of tube is therefore not only suitable for use as a voltage stabiliser with very constant operating voltage, but it will also prove most useful for replacing conventional voltage reference sources. It will be clear that in operation, the electrode originally prepared as cathode must always be used as the cathode; to avoid risk of the tube being reversed, the cathode and anode contacts are therefore indicated in the base diagram of all voltage stabilising tubes. A momentary or permanent reversal of the polarity will seriously affect the characteristics of the tube.

LIMITING RESISTOR

As with all other gas-discharge tubes, a current limiting device must be used in series with the tube to prevent the current from becoming excessive, should a voltage greater than V_{ion} (see fig.1), derived from a source having negligible internal resistance, be applied to the tube. Such conditions would normally lead to destruction of the tube and, since a stabilising tube is used at direct voltage, a limiting resistor must be connected in series with it. In some cases, of course, the internal resistance of the source may be sufficiently high to render the use of an external current limiting resistor unnecessary.

APPLICATIONS

DESIGN CALCULATIONS FOR STABILISATION

A basic circuit for voltage stabilisation is given in fig.2. In this diagram V_b is the supply voltage, V the voltage across the tube, I the current in the tube, I_L the current in the load and R_L the load resistance. R_1 is the limiting resistor which may partly or wholly consist of the internal resistance of the supply.

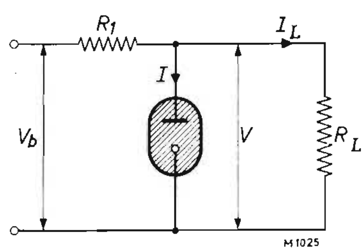


Fig.2. Basic circuit for voltage stabilisation.

It may be seen from fig.2 that the voltage across the load cannot be chosen at will, since it is determined by the operating voltage of the tube, which is, according to the type used, 85 V to 150 V. With a load requiring a lower voltage it is, of course, possible to utilise a series resistance, so that the operating voltage of the stabiliser is reached. For high voltages, tubes can be connected in series.

Since a considerable number of interdependent parameters is involved, there is no simple straight-forward method of calculation. In a practical case, therefore, the type of tube most likely to satisfy the requirements is selected, and it is then determined by calculation whether the tube operates within its rating limits under the working conditions. If ratings are exceeded, the next larger type must be tried or if, compared with the permissible regulating range of the tube, the actual current variation is small, then the calculation can be repeated for a smaller tube.

The supply voltage influences the operating conditions and it is often possible to keep the current variation in the tube within the permissible limits or to improve the performance with regard to stabilisation by choosing a higher supply voltage. In practical circuits, however, the supply voltage is often pre-determined, so that this method cannot always be applied.

For any type of tube there are three conditions that must be satisfied to ensure reliable and safe operation.

1) The current in the tube during operation must not drop below the permissible limit I_{min}.
2) The maximum permissible tube current I_{max} must not be exceeded.
3) Ignition must be ensured under the most unfavourable conditions.

In a practical circuit the direct voltage is often obtained from a directly heated rectifier, the other tubes in the circuit being indirectly heated. When the apparatus is switched on, the rectified voltage will initially be greater than that occurring when all tubes draw current. If, however, the apparatus is switched off and, after a very short time, switched on again, then the cathodes of the indirectly heated tubes have not sufficient time to cool down and the rectified voltage will not exceed the value occurring during normal operation. To ensure ignition at all times, it is therefore necessary to base the calculation of the stabilising circuit on the normal rectified voltage.

The current in the tube may be expressed as:

$$I = \frac{V_b - V}{R_1} - I_L .$$

The tube current must remain larger than the given I_{min} at the lowest possible conditions, i.e. at the lowest value of the supply voltage, at the highest operating voltage occurring with any tube of the given type, and at the highest load current.

Reckoning with a supply voltage variation of ΔV_b and a load current variation of ΔI_L the following condition is found:

$$\frac{V_b - \Delta V_b - V_{max}}{R_1} - (I_L + \Delta I_L) > I_{min},$$

$$\frac{V_b - \Delta V_b - V_{max}}{R_1} > I_{min} + I_L + \Delta I_L ,$$

and

$$R_1 < \frac{V_b - \Delta V_b - V_{max}}{I_{min} + I_L + \Delta I_L} .$$

Assuming that the tolerance in R_L is $p\%$, the nominal value of R_1 should be:

$$R_1 < \frac{V_b - \Delta V_b - V_{max}}{I_{min} + I_L + \Delta I_L} \cdot \frac{1}{1 + p}. \qquad (1)$$

In this formula

$V_b - \Delta V_b$ denotes the lowest possible value of the supply voltage,

V_{max} denotes the highest operating voltage occurring with any tube of the given type,

I_{min} denotes the given minimum permissible tube current,

$I_L + \Delta I_L$ denotes the highest value of the load current, and

p denotes the spread in the value of the limiting resistor.

Considering that the tube current must remain beyond the given I_{max} at the highest possible conditions, i.e. at the highest value of the supply voltage, at the lowest operating voltage occurring with any tube of the given type, and at the lowest load current, a second condition is found, namely,

$$\frac{V_b + \Delta V_b - V_{min}}{R_1} - (I_L - \Delta I_L) < I_{max},$$

$$\frac{V_b + \Delta V_b - V_{min}}{R_1} < I_{max} + I_L - \Delta I_L,$$

and

$$R_1 > \frac{V_b + \Delta V_b - V_{min}}{I_{max} + I_L - \Delta I_L},$$

With a tolerance of $p\%$ for R_L:

$$R_1 > \frac{V_b + \Delta V_b - V_{min}}{I_{max} + I_L - \Delta I_L} \cdot \frac{1}{1 - p} \qquad (2)$$

In this formula

$V_b + \Delta V_b$ denotes the highest possible value of the supply voltage,

V_{min} denotes the lowest operating voltage occurring with any tube of the given type,

I_{max} denotes the given maximum permissible tube current,

$I_L - \Delta I_L$ denotes the lowest value of the load current, and

$p\%$ denotes the spread in the value of the limiting resistor.

To ensure ignition, the following relationship must be satisfied:

$$V_b \cdot \frac{R_L}{R_1 + R_L} > V_{ign}.$$

$$V_b R_L > V_{ign} R_1 + V_{ign} R_L,$$

$$R_L \cdot (V_b - V_{ign}) > R_1 V_{ign},$$

$$R_1 < R_L \cdot \frac{V_b - V_{ign}}{V_{ign}} \ ,$$

$$R_1 < R_L \cdot \left\{ \frac{V_b}{V_{ing}} - 1 \right\}$$

or, assuming the most unfavourable conditions:

$$R_1 < R_L \cdot \left\{ \frac{V_b - \Delta V_b}{V_{ign}} - 1 \right\} \cdot \frac{1}{1 + p} \ . \qquad (3)$$

With the formulae given above, it has been assumed that the operating voltage does not vary during regulation; this assumption is permissible for practical calculations since the variation in operating voltage during regulation is only small. When the voltage variation during regulation is, moreover, neglected in calculating the limiting resistor, allowance is made for an additional safety margin. It should also be pointed out that V_{min} and V_{max} indicate the spread of operating voltage occurring amongst the tubes of a given type. With a stabilising tube type 90C1, for example, it is possible that one specimen has an operating voltage close to the lower limit of 86 V, but if this tube is replaced by another of the same type, the operating voltage may be increased to a value near the upper limit of 94 V.

The conditions under which the tube may be required to operate can be divided into three classes:

a) R_L is constant, V_b fluctuates;
b) V_b is constant, R_L fluctuates;
c) both V_b and R_L fluctuate.

The method of calculating the stabilising circuit will now be illustrated by examples corresponding to each of these cases:

a) R_L is constant, V_b fluctuates

The case is considered where the voltage across a load of 25 kΩ must be stabilised at a nominal value of 85 V, i.e. the load current must be 85/25 = 3.4 mA. The supply voltage is 250 V, fluctuating 10%, thus between 225 and 275 V. For the limiting resistor R_L a resistor with a tolerance of 5% must be used. With the stabilising tube 85A2 the current limits are 1 mA and 10 mA respectively, whilst the operating voltage lies between the limits 83 and 87 V.

Basing the calculation on I_L = 87/25 = 3.48 mA, condition (1) gives:

$$R_1 < \frac{225 - 87}{1 + 3.48} \cdot \frac{1}{1.05} = 29.4 \text{ k}\Omega,$$

whereas with I_L = 83/25 = 3.32 mA, condition (2) gives:

$$R_1 > \frac{275 - 83}{10 + 3.32} \cdot \frac{1}{0.95} = 15.2 \text{ k}\Omega.$$

It has been assumed that the load consists of a linear resistance, making it possible to substitute values of I_L corresponding to V_{max} and V_{min} respectively. In cases where the voltage-current relation of the load is not linear it will be necessary to measure the actual load current at V_{max} and V_{min} and also at V_{ign}.

Condition (3) is satisfied when:

$$R_1 < 25 \cdot \left\{ \frac{225}{125} - 1 \right\} \cdot \frac{1}{1.05} = 19 \text{ k}\Omega.$$

In this case a resistor R_1 of 19 kΩ must be used with a maximum tolerance of 5%. With minimum supply voltage and nominal limiting resistance the current in the average tube then is

$$\frac{225 - 85}{19} - 3.4 = 4 \text{ mA},$$

and with maximum supply voltage 6.6 mA. It is an advantage in the design of a stabilising circuit if the spread in operating voltage is small, such as that of the 85A2. With a large spread in operating voltage it is often necessary either to employ a tube having a larger current range or to use a limiting resistor with very small tolerance, which is, of course, an expensive solution. In this respect the stabilising tube 85A2 offers important advantages.

b) V_b is constant, R_L fluctuates

Since the voltage across the tube is almost constant during regulation, the total variation in load current must be taken up by the tube. It is therefore immediately seen that the current range of the tube must be greater than the total variation in load current.

Let it be assumed that it is desired to stabilise the voltage at a load which is traversed by a current from 10 mA to 30 mA at 90 V. The supply voltage is 500 V. The total variation in load current is 20 mA, so that the 90C1 might be suitable. The conditions for a limiting resistor with a tolerance of 10% then becomes:

(1) $$R_1 < \frac{500 - 94}{1 + \frac{94}{90} \cdot 30} \cdot \frac{1}{1.1} = 11.4 \text{ k}\Omega,$$

(2) $$R_1 > \frac{500 - 86}{40 + \frac{86}{90} \cdot 10} \cdot \frac{1}{0.9} = 9.3 \text{ k}\Omega,$$

(3) $$R_1 < 3 \left\{ \frac{500}{125} - 1 \right\} \cdot \frac{1}{1.1} = 8.2 \text{ k}\Omega.$$

To satisfy condition (3) it is necessary to take the smallest load resistance occurring during operation into account. With this load resistance, ignition is most difficult to obtain.

Conditions (2) and (3) are conflicting, but this may be improved by employing a limiting resistor with smaller tolerance. If a resistor with 2% tolerance is used the conditions become:

(1) $$R_1 < \frac{500 - 94}{1 + \frac{90}{94} \cdot 30} \cdot \frac{1}{1.02} = 12.3 \text{ k}\Omega,$$

(2) $$R_1 > \frac{500 - 86}{40 + \frac{86}{90} \cdot 10} \cdot \frac{1}{0.98} = 8.53 \text{ k}\Omega,$$

(3) $$R_1 < 3 \cdot \left\{\frac{500}{125} - 1\right\} \cdot \frac{1}{1.02} = 8.82 \text{ k}\Omega .$$

It is thus seen that a resistor with a nominal value between 8.53 and 8.82 kΩ, say 8.6 kΩ, and 2% tolerance may be used. The variation in tube current will be about 20 mA, and this may result in a variation of voltage across the load of 7 V, as the average voltage regulation of the tube is 14 V for a current range of 40 mA.

If, instead of a stabilising tube, a simple series dropping resistor is used this must have a value of (500 - 90)/20 = 20.5 kΩ at the nominal current. If the load resistor then varies between 90/10 = 9 kΩ and 90/30 = 3 kΩ, the voltage across the load will vary between 9 x 500/29.5 = 153 V and 3 x 500/23.5 = 63.4 V, giving a total variation of 153 - 63.4 = 89.6 V. When using a stabilising tube type 90C1, the constancy of the voltage across the load is therefore improved by a factor 89.6/7 = 12.8.

c) V_b and R_L fluctuate

A fluctuating supply voltage and a fluctuating load represent conditions most frequently occurring in practice. By way of example, a stabilising circuit will be calculated for the following data:

V_b = 250 V ± 10%,
I_L = 10 mA ± 4 mA,
V_L = 150 V.

The total variation in load current is 8 mA at 110 V, so that the calculation must be carried out with tube type OB2. With this type and a limiting resistor having a tolerance of 10%, the three conditions become:

(1) $$R_1 < \frac{225 - 111}{5 + 14.1} \cdot \frac{1}{1.1} = 5.42 \text{ k}\Omega,$$

(2) $$R_1 > \frac{275 - 106}{30 + 5.84} \cdot \frac{1}{0.9} = 5.25 \text{ k}\Omega,$$

$$(3) \qquad R_1 < 7.85 \cdot \left(\frac{225}{133} - 1\right) \cdot \frac{1}{1.1} = 4.94\ \text{k}\Omega.$$

Conditions (2) and (3) are conflicting, but as the difference between the required values is not so large, a limiting resistor with a smaller tolerance, for instance 5%, might fulfil the requirements with this tolerance. The conditions become:

$$(1) \qquad R_1 < \frac{225 - 110}{5 + 14.1} \cdot \frac{1}{1.05} = 5.7\ \text{k}\Omega,$$

$$(2) \qquad R_1 > \frac{275 - 106}{30 + 5.84} \cdot \frac{1}{0.95} = 5.0\ \text{k}\Omega,$$

$$(3) \qquad R_1 < 7.85 \cdot \left(\frac{225}{133} - 1\right) \cdot \frac{1}{1.05} = 5.15\ \text{k}\Omega.$$

A limiting resistor having a nominal value of 5.1 kΩ and a tolerance of 5% can be used in this case to obtain a reliable stabilisation under the required conditions.

STABILISERS IN PARALLEL

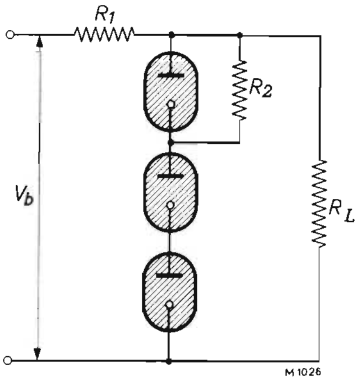
If the stabilisation obtained with a given tube proves to be insufficient, it can be improved only by choosing a tube having a smaller regulation voltage for the given current variation. This will normally involve the use of a larger type of tube. It would appear at first sight that a similar improvement could be obtained by connecting tubes in parallel, but as shown below, this is not an attractive solution.

When two tubes are connected in parallel it is very important that the current be equally divided, as otherwise one of the tubes may be overloaded. Since, however, the operating voltage of two tubes of the same type may differ quite considerably, the current of one tube will normally be greater than that of the other when both tubes operate at the same voltage. This can be remedied only by connecting a resistance in series with the tube taking the larger current, but this partly cancels the advantages of a low regulation voltage.

It should, moreover, be borne in mind that in an arrangement with a resistance in series with one of the tubes, ignition of both tubes is not ensured. It would therefore be necessary to include a resistance in series with each tube, but this results in a considerable deterioration of the stabilisation. The conclusion is, therefore, that no advantage is gained by using voltage stabilisers in parallel.

STABILISERS CONNECTED IN SERIES

There is a limited choice of the value of the stabilised voltage because available tubes have operating voltages of either about 100 V or about 150 V. Other voltages can be obtained by connecting two or more of these tubes in series, thus giving voltages of 200, 250, 300 V etc. The total regulation voltage of the combination then equals the sum of the individual regulation voltages.



For ignition of the series of tubes the voltage required may be less than the sum of the individual starting voltages.

Fig.3. Stabilising tubes connected in series to obtain a high stabilised voltage.

If, as shown in fig.3, one of the tubes is shunted by a resistor R_2 having a value between 0.2 and 0.5 MΩ, the two unshunted tubes will ignite immediately the supply voltage is applied. Once these are ignited, the voltage across each tube drops to the operating voltage, and the remaining voltage then ignites the tube shunted by R_2.

BY-PASSING ALTERNATING CURRENTS

Hitherto only relatively slow fluctuations in supply voltage and load current have been assumed, but it frequently occurs that an alternating current of relatively high frequency is superimposed on the direct current.

This is particularly the case when the tube stabilises the anode voltage of an oscillator, in the anode supply line of which no smoothing circuit is incorporated. Due to the internal resistance of the voltage stabiliser, an alternating voltage may give rise to undesired coupling effects. In order to avoid couplings via the supply unit, the stabilising tube must usually be shunted by a capacitor the value of which depends upon the permissible impedance. Circuits incorporating a voltage stabiliser shunted by a capacitor may introduce the risk of relaxation oscillations. As a general rule the capacitance across the stabilising tube should be kept as small as permissible with regard to the required bypassing action.

Moreover, the internal resistance of the stabilising tube increases with increasing frequency, due to inertia occurring in the ionisation process. As a consequence the waveform of the alternating voltages across the stabiliser may be distorted. In extreme cases, when sudden changes in tube current occur, the output waveform can be improved by adding two series combinations of a resistor and a capacitor in parallel with the stabilising tube as shown in fig.4. Both combinations have differing time constants, the one with the smaller time constant eliminating the short pips which still remain when shunting with a series combination having a long time constant. This network using the values indicated in fig.4 reduces the transients occurring as a result of inertia in the ionization process to ± 1 V for maximum output voltage changes. The final variation in output voltage is, of course, determined by the internal resistance of the tube.

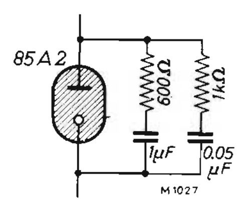


Fig.4. Stabilising tubes shunted with two series combinations to improve the output wave-form.

[1]) For additional information see The Impedance of Voltage Stabiliser and Reference Tubes, Electr. Appl. Bull. 15, p. 175, 1954 (No.12).

VOLTAGE DIVISION WITH VDR

If the stabilised voltage across the tube is too high and a lower output voltage at the load is required, a series dropping resistor R_S may be used as shown in fig.5. The disadvantage of this circuit, however, is the large variation in output voltage with variation in load. A considerable improvement may be obtained by using a VDR (R_d) for series dropping, see fig.6.

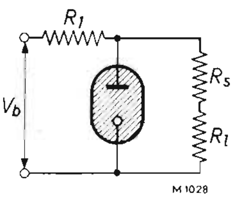


Fig.5. Series circuit with a dropping resistor for voltage division.

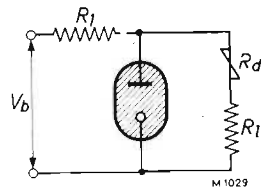


Fig.6. Series circuit with a dropping resistor for voltage division.

For these VDR (Voltage Dependent Resistors) the general formula $V = C.I^{\beta}$ is applicable. In this formula the β -value depends on the composition of the material of the VDR, the C-value depending furthermore on the shape and the dimensions. Values of β and C for currently available VDR are approx. 0.2 and 100 to 1000. A complete description of these resistors is given in Matronics No.2.

Neglecting variations of the stabilised voltage V across the tube, the voltage across the load becomes: $V_L = V - CI_L^{\beta}$. If the load current varies by a small amount ΔI_L the output voltage variation may by expressed by:

$$\Delta V_L = \Delta I_L \cdot \frac{\beta \cdot V_d}{I_L}.$$

In this formula it is assumed that the current variation through the VDR is so small that its characteristic may be considered as being straight in this region. The expression $\beta \cdot V_d / I_L$ is therefore the differential resistance of the VDR at the voltage V_d, which may be derived by differentiating the general formula and eliminating C. With a VDR for series dropping, therefore, the variation in output voltage for a given variation in load current will be β times smaller than in the case of a normal series dropping resistor.

To determine the voltage drop across a VDR in a series circuit with a given load it is convenient to use the graph of fig.7. In this figure the linear characteristic is given for a β -value of 0.19 with C as parameter. A load line may be drawn which intersects a given VDR curve in a point which, when projected on the ordinate, directly gives the voltage across the VDR.

By way of example a series dropping circuit will be calculated for the following data:

Supply voltage 190 V,
Stabiliser type 90C1,
Required voltage across load 35 V,
R_1 = 2200 Ω ± 10%,
Load resistance R_L = 2500 Ω.

The voltage drop across the VDR should be 90 - 35 = 55 V; this voltage drop corresponds to the horizontal line drawn in the graph of fig.7. Now the load line a-b is drawn for R_L = 2500 Ω, which intersects the horizontal line in point c. As will be seen, this point almost coincides with the intersection of the load line and the VDR characteristic for a C-value of 120. A VDR with a β-value of 0.19 and a C-value of 120 is therefore chosen, the load voltage

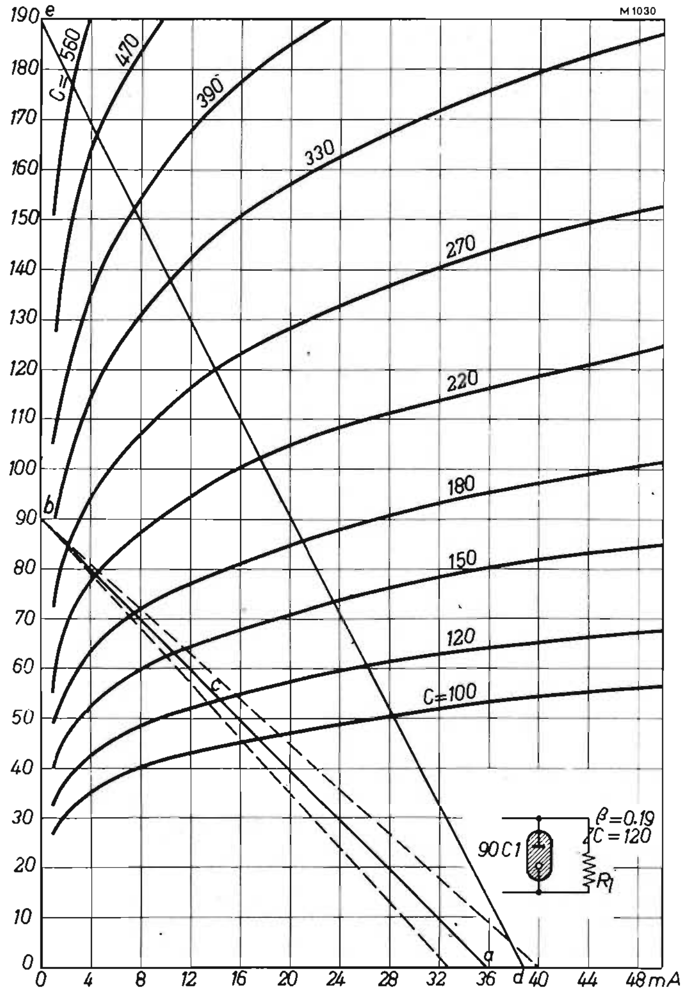


Fig.7. Voltage-current characteristic of a Voltage Dependent Resistors for β = 0.19, with the C-value as parameter.

then becoming 90 - 54 = 36 V. If the load variation is 10% the extreme values are 2250 Ω and 2750 Ω. Neglecting the voltage variation across the stabilising tube, the broken lines in fig. 7 correspond to these loads. Projecting the points of intersection with the VDR characteristic on the ordinate gives the voltage drops of 54.5 and 53 V across the VDR. The load voltages then amount to 90 - 54.5 = 35.5 V and 90 - 53 = 37 V, giving a total relative variation of :

$$\frac{37 - 35.5}{36} \times 100 = 4\%.$$

A normal series dropping resistor would have a value of :

$$R_s = \frac{54}{36} \times 2500 = 3750\ \Omega.$$

The load voltages with varying load now are:

$$\frac{2250}{2250 + 3750} \times 90 = 33.8 \text{ V},$$

and

$$\frac{2750}{2750 + 3750} \times 90 = 38 \text{ V}.$$

The total relative variation is then :

$$\frac{38 - 33.8}{36} \times 100 = 12\%.$$

The improvement with a VDR is, therefore, certainly worthwhile.

Since the resistance value of a VDR decreases with increasing voltage it is necessary to check whether ignition of a stabilising tube in a circuit with a VDR instead of a normal dropping resistor is still ensured. Calculations can quickly be made if in the graph of the VDR a resistance line for $R_1 + \Delta R_1 + R_L$ at the supply voltage is drawn. Ignition is ensured if the sum of the voltage drops across the VDR and that across R_L exceeds the ignition voltage V_{ign}. In the graph of fig. 7 the resistance line *d-c* corresponds to: $R_1 + \Delta R_1 + R_L = (2200 + 220 + 2500)\ \Omega$ at $V_b = 190$ V. The voltage drop across the VDR is 60.5 V. The voltage drop across the tube is:

$$60.5 + \frac{2500}{2500 + 2420} \times 129.5 = 126.5 \text{ V}.$$

The maximum ignition voltage of the 90C1 is 125 V, so this tube will ignite.

APPLICATION OF THE VOLTAGE REFERENCE TUBE 85A2

a) VOLTAGE REFERENCE FOR MEASURING PURPOSES

The previous paragraphs have only dealt with normal voltage stabilisation. For making accurate electrical measurements, however, it is often necessary to have available an extremely constant reference voltage, particularly if it is desired to measure relatively small voltage variations. If a voltage stabilising tube is to be used as the source for the reference voltage, a fairly high standard of stability is obviously required. Not all types of stabilising tubes are suitable for this application, but in one type already mentioned, viz. the 85A2, the operating voltage during life is extremely constant, and the difference in operating voltage between tubes of the same type is also very small. The operating voltage of the 85A2 varies less than 0.5% during the life of the tube.

In order to achieve this constant operating voltage characteristic, special precautions have been taken in manufacture to ensure that the nature of the cathode surface and the composition of the gas content do not change during life. If, for instance, the cathode were made from anything but a single pure metal, the composition of the cathode surface might change under the influence of the discharge. Again, even small traces of impurities in the gas of the tube may affect the cathode, as these impurities might be absorbed by its surface. The glass envelope of the tube could also be a source of contamination.

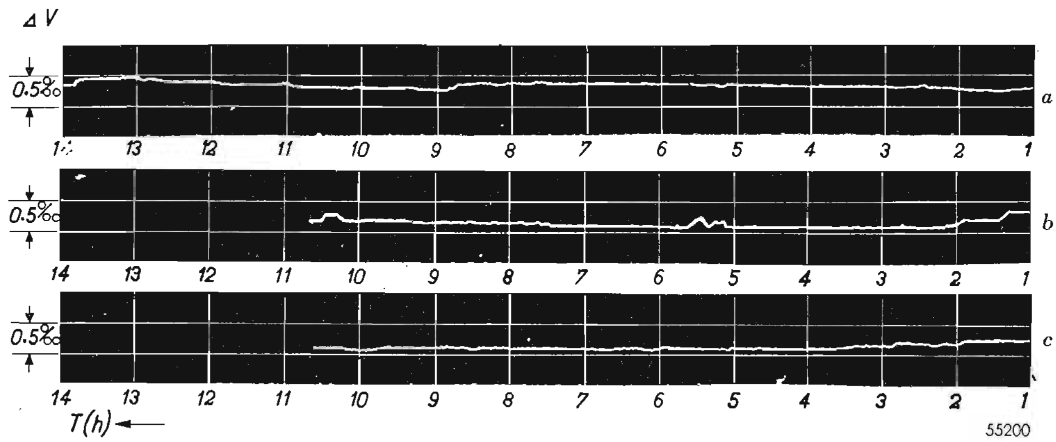


Fig.8. Measured fluctuations of the operating voltage of a voltage reference tube as a function of time (registered from right to left). The horizontal axis has been divided in hours, and the subdivisions of the vertical axis correspond to fluctuations of 0.5°/oo.

Discharge properties of remarkable constancy are achieved in the stabilising tube 85A2. In the graphs reproduced in fig.8, the fluctuations of the operating voltage of such a tube, taken at random from stock and measured by a very sensitive recording instrument, are plotted as a function of time. The voltage is seen to be extremely constant indeed, and during time intervals of approximately 14 hours (see fig.8*a*) and 10 hours (see fig.8*b* and 8*c*) the variations do not exceed a few hundredths of one per cent. During these measurements the current was rigorously kept constant.

To take full advantage of the constancy of the operating voltage, the current through the tube must be stabilised. Although the internal resistance of the 85A2 is low, its maximum value being 450 Ω between 1 and 10 mA, current variations would give rise to inadmissibly high voltage variations. Since the operating voltage is approximately 85 V, the variations of the operating voltage must be less than 42.5 mV if the voltage is to be kept constant within 0.05%. Assuming the internal resistance of the 85A2 to amount to 450 Ω, this means that the current variations may not exceed 0.1 mA.

Apart from the variation of current, temperature changes may also influence the operating voltage. This effect is, however, exceedingly small, as the temperature coefficient of the operating voltage is max. -4 mV/°C. Normal fluctuations of the ambient temperature will thus result in voltage variations of a few hundredths of one per cent only. If, however, the tube is located inside an instrument, temperature may rise to, say, 40 to 50 °C, resulting in a voltage variation of about 100 to 150 mV. It normally takes a considerable time for the temperature in an apparatus to reach its final value, and voltage drift will occur during this period. For an exceedingly high constancy of the operating voltage it is therefore advisable to mount the stabilising tube in such a way that it will not be heated by other tubes, resistors, etc. Similar precautions would in fact be even more essential if a battery were used as a voltage reference.

Fig.9 shows a simple circuit for stabilising the current flowing through an 85A2. The nominal value of the supply is 275 V, and a very constant voltage between 0 and 85 V can be taken from the sliding contact of the potentiometer R_3. It has been assumed that this voltage only serves as a reference level and that no current is taken from the output terminal.

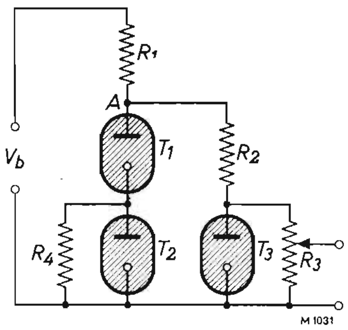


Fig.9. Stabilisation of the current flowing through the voltage reference tube T_3 by means of two other tubes 85A2 (T_1 and T_2). In this circuit R_1 = 12.5 kΩ, R_2 = 36 kΩ, R_3 = 0.1 MΩ, R_4 = 1 MΩ, and V_b = 275 V.

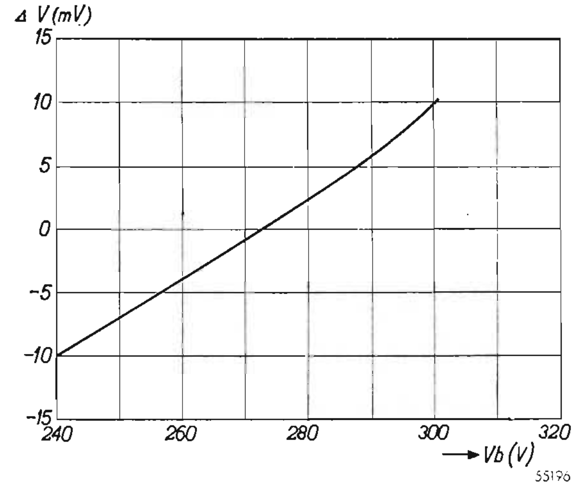


Fig.10. Variation ΔV of the voltage across R_3 (see fig.9) as a function of the supply voltage V_b.

Various measurements carried out with the circuit of fig.9 have shown that the variation in operating voltage of T_3 is less than 40 mV (= 0.05%) at supply variations from -10 to +10%. The result of these measurements is shown in fig.10.

This curve is the average of a number of measurements with six different tubes types 85A2 used as voltage reference tube (T_3). When the supply voltage was varied from 240 to 300 V the greatest difference obtained was 38 mV with one tube, and the smallest difference was only 4 mV.

b) VOLTAGE REFERENCE FOR STABILISED D.C.POWER SUPPLIES

Power supply units with stabilisation by means of electronic tubes are used extensively in all cases where a very constant and adjustable output voltage is required, for example during measurements, in life tests, etc. The fundamental diagram of such a unit is given in fig.11. The operation of these circuits has been described in several text books and articles so that it is not necessary to give

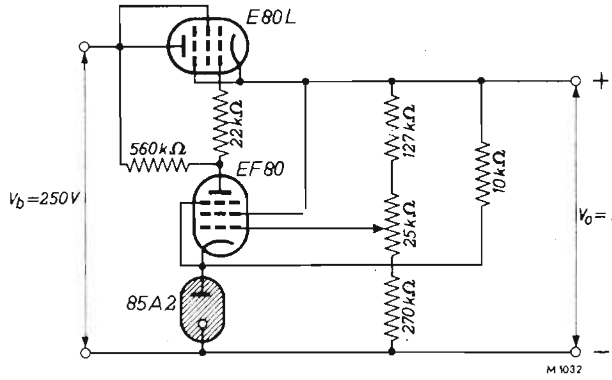


Fig.11. Fundamental diagram of stabilised d.c. power supply.

a full description here. For our purpose the most important feature is that the output voltage of the unit is compared with a constant voltage, any variation in output voltage being amplified and fed back to the series tube E 80 L, so that the original variation is reduced. The output is made adjustable by applying different proportions of it to the control grid of the amplifier tube (EF 80). A very high reduction factor from the supply voltage variation can be obtained in such units.

As a source of reference voltage, stabilising tubes have been used, but the stability in operating voltage of these tubes is often insufficient for this purpose. Voltage reference tubes, such as the 85A2, are much more suitable for this purpose. Apart from their low incremental resistance, their low minimum current above which "step" effect does not occur and their low temperature coefficient, these tubes have, by their design, a very good short-term stability of the operating voltage of better than 0.1% during max. 100 hours after the first 300 hours of operation, and a long-term stability of better than 0.2% after the first 300 hours of operation. It is thus seen that when a tube of this type is used in a stabilised power supply unit, a very constant output voltage with respect to time can be obtained.

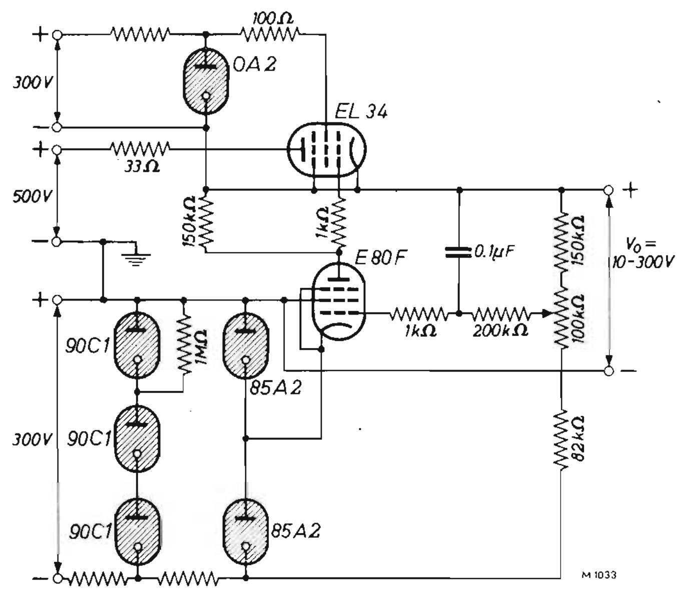


Fig.12. Diagram of a stabilised d.c. power supply, adjustable from 10 to 350 V.

A disadvantage of the unit according to fig. 11 is that the cathode of the amplifier tube is held positive, by which the minimum stabilised output voltage is limited. The fundamental circuit diagram of a stabilised power supply unit of which the output voltage can be regulated from 10 to 350 V is given in fig. 12, the cathode voltage of the amplifier tube (E 80 F) now being negative with respect to the negative output terminal. The supply voltage for the reference tubes must now be obtained from a separate unit, the output voltage of which is subject to mains voltage fluctuations. These fluctuations would influence the output voltage of the stabilising unit, and this is prevented by the additional chain of stabilising tubes with 90C1. Mains voltage fluctuations have, therefore, very little influence on the reference voltage.

[1]) For the description of a d.c. supply unit with very high stability, see Electr. Appl. Bull. 14, p. 61, 1953 (No.5).

e) VOLTAGE REFERENCE FOR STABILISED A.C.POWER SUPPLIES

Fig.13 shows the simplified diagram of an automatic voltage regulator, delivering a stabilised alternating voltage. Its operation may be explained in brief as follows.

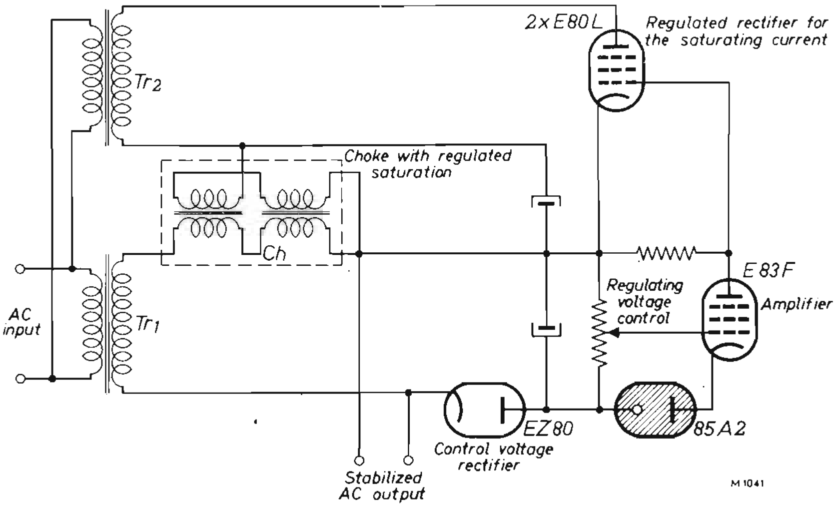


Fig.13. Simplified diagram of a stabilised a.c. power supply.

The transformer Tr_1 feeds the load through a choke *Ch*, which is presaturated. The automatically controlled direct premagnetisation current is obtained in the following way:
The alternating output voltage is rectified by an EZ 80, so that the direct voltage, appearing across the electrolytic capacitor, is substantially proportional to the output voltage. Variations of this direct voltage are amplified by the tube E 83 F, the cathode of which has a fixed potential of 85 volts, supplied by the voltage reference tube 85A2. The E 83 F governs the control-grid voltages of both E 80 L tubes, used as rectifiers for the saturation current of the choke.

Assuming that at a given instant the mains voltage increases, the voltage rectified by the EZ 80 will also slightly increase and the negative grid bias will decrease with respect to the reference voltage of the cathode of the E 83 F.

As a result, the anode current of the E 83 F will increase, so that its anode potential is reduced. Consequently the grid bias of both E 80 L tubes becomes more negative; their anode current and the premagnetisation of the choke are thus reduced. The inductance of the choke will increase, thereby counteracting the increase of the mains voltage.

Fig.14 presents the complete circuit diagram of the apparatus. The mains transformer Tr_1 has three tappings, supplying 125, 145 and 160 volts, respectively. The 125 volts tapping is used for loads up to 50 watts. In this position the output voltage of the stabiliser is maintained at 110 V ± 1% at mains voltage fluctuations between 192 and 228 volts. The second tapping (at 145 volts) is intended for loads between 50 and 100 watts, supplying an output of 110 V ±1% at mains voltage fluctuations between 182 and 236 volts.

Finally, the 160 volts tapping of the secondary coil is intended for loads between 100 and 200 watts, stabilising the output at 110 V ±1% at mains voltages ranging from 172 V to 240 V. The stabilisation may be further improved for loads not exceeding 100 watts

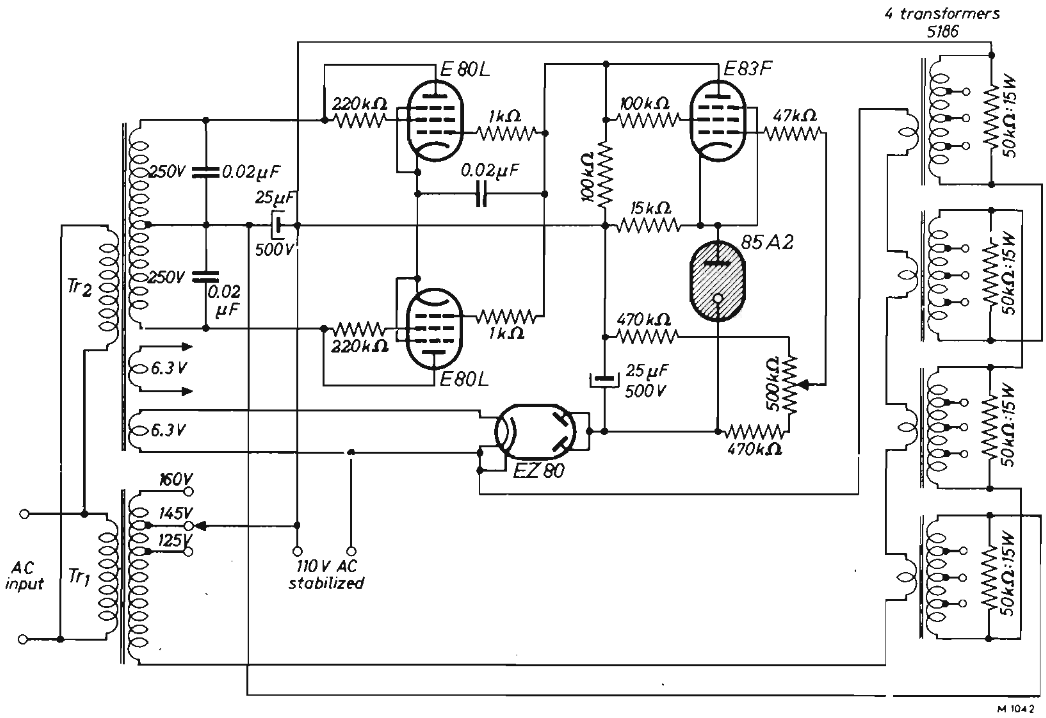


Fig.14. Diagram of a stabilised a.c. power supply.

by feeding the transformer Tr_2 from the stabilised voltage, thus providing a constant voltage for the filaments and for the saturation current rectifiers.

The choke Ch consists of the secondary windings of four output transformers type 5186, connected in series. The complete secondary windings (7 Ω connections) must be used. The direct saturation current of 0 to 50 mA passes through the primary winding of these transformers, which are also connected in series, but with two windings inverted to neutralise the alternating voltage induced in these windings. The resistors R_{12} - R_{15} are connected across these windings to prevent instability and to ensure that the waveform of the stabilised voltage remains more or less sinusoidal.

A 15kΩ resistor maintains the current through the 85A2 practically constant, independent of cathode current variations of the E 83 F. Damping resistors are included into the control-grid and screen-grid circuits of the tubes to prevent the occurrence of high frequency oscillations. The capacitors C_4 in the control-grid circuits of the E 80 L tubes suppress low frequency variations of the output voltage.

DATA OF VOLTAGE STABILISING TUBES

VOLTAGE REFERENCE TUBE 85 A 2

The fact that the spread in operating voltage of stabilising tubes and its variation during life are comparatively large, is not a drawback for normal stabilising applications, but such tubes cannot be used as voltage reference tubes.

The 85A2, however, is not only suitable for use as a stabiliser but also as a voltage reference tube. Special processes in manufacture were necessary to attain the required constancy of operating voltage, which must be preserved during the whole life of the tube. Among the measures taken are the use of a very homogeneous metal cathode and a special manufacturing process which prevents contamination of this cathode during life.

Fig. 15. Voltage reference tube 85A2.

With a nominal operating voltage of 85V at a recommended quiescent current of 5.5 mA the spread of the voltage from tube to tube for the 85A2 is - 2 V. The drift in operating voltage after 1300 hours is less than 0.1% per 1000 hours; after the first 300 hours of operating the maximum short-term (100 hours) drift is also 0.1%.

The 85A2 is built in a 7-pin miniature envelope and is therefore particularly suitable for those applications where economy of space is of primary importance. The maximum permissible current of the 85A2 is 10 mA.

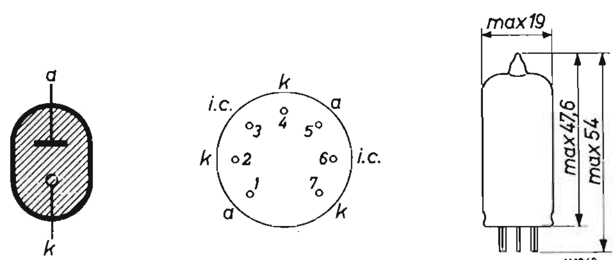


Fig. 16. Dimensions and electrode connections of the 85A2.

Tube socket : 7-pin miniature, type 5909/36.

Mounting position: Some ambient illumination should be present to facilitate ignition. In all other respects the tube may be mounted in any position.

CHARACTERISTICS

Operating voltage of average tube at 5.5 mA........		85 V
Spread of operating voltage at 5.5 mA from tube to tube..............................		83 - 87 V
Ignition voltage { at an illumination of 50-500 lux....	max.	125 V
Ignition voltage { in complete darkness................	max.	160 V
Recommended quiescent current......................		5.5 mA
Current regulating range..........................		1-10 mA
Regulation (1- 10 mA).............................	max.	4 V
Maximum voltage jumps from 1 to 4 mA...............		100 mV
Maximum voltage jumps from 4 to 10 mA..............		50 mV
Drift in operating voltage during the first 300 hours of life at 5.5 mA................		0.3 %
Drift in operating voltage during the subsequent 1000 hours at 5.5 mA.................	max.	0.2 %
Short-term drift in operating voltage (100 hours max.) after the first 300 hours of operation at 5.5 mA.........................	max.	0.1 %
Temperature coefficient of operating voltage over a temperature range from 15 to 90°C........		-2.7 mV/°C
Ambient temperature................................		-55 to +90 °C

NOTES

1) Equilibrium conditions are normally reached within 3 minutes.

2) The tube should be operated only with the cathode negative and the anode positive. A momentary or permanent reversal of the polarity will seriously affect the characteristics of the tube.

3) The greatest constancy of the operating voltage is obtained if the tube is operated at one given value of the current.

4) The supply voltage necessary to ensure starting throughout the life at an illumination of 50-500 lux is minimum 125 V.

5) The noise of the tube over a frequency band of 30 - 10000 c/s is of the order of 60 μV (R_{eq} = 22 MΩ), and is evenly distributed over the frequency range.

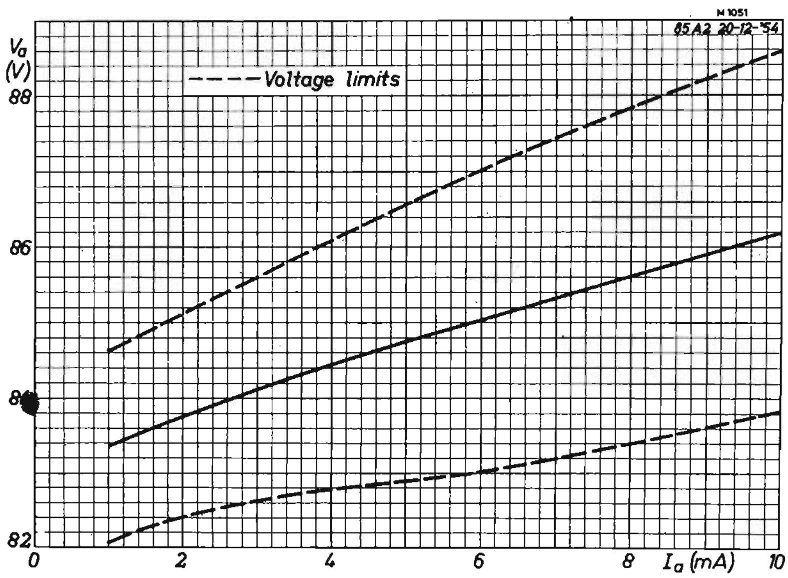


Fig.17. Voltage-current characteristic of the 85A2.

VOLTAGE STABILISING TUBE 90 C 1

The 90C1 is a voltage stabiliser with a large current regulating range, namely from 1 to 40 mA, and a very small value of the minimum current for stabilisation. The operating voltage at the recommended quiescent current of 20 mA lies between 86 and 94 V.

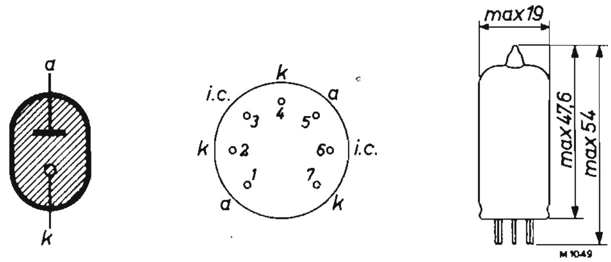


Fig.18. Dimensions and electrode connections of the 90C1.

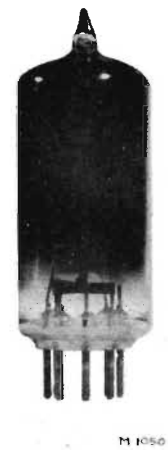


Fig.19. Voltage stabilising tube 90C1.

<u>Tube socket</u>: 7 pin miniature, type 5909/36.

<u>Mounting position</u>: Some ambient illumination should be present to facilitate ignition. In all other respects the tube may be mounted in any position.

CHARACTERISTICS

Operating voltage of average tube at 20 mA........		90 V
Spread of operating voltage at 20 mA from tube to tube............................		86 - 94 V
Ignition voltage { at an illumination of 50-500 lux...	max.	125 V
Ignition voltage { in complete darkness	max.	160 V
Current regulating range.........................		1 - 40 mA
Regulation (1-40 mA)......................	max.	14 V
Variation of operating voltage during 1000 hours at 20 mA....................................		±1 %
Ambient temperature...............................		-55 to +90°C
Starting current (averaging time max.10 sec)......	max.	100 mA

NOTES

1) Equilibrium conditions are normally reached within 3 minutes.

2) The tube should be operated only with the cathode negative and the anode positive.

3) The supply voltage necessary to ensure starting throughout tube life at an illumination of 50-500 lux is minimum 125 V.

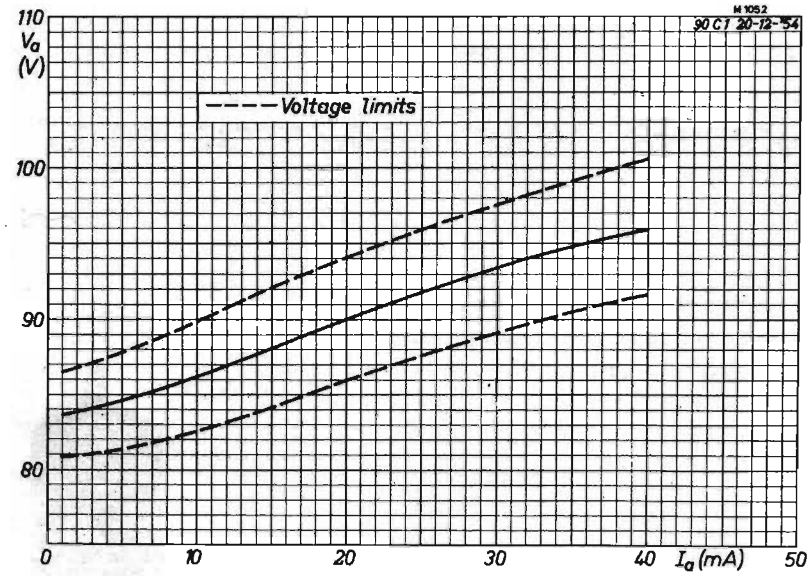


Fig. 20. Voltage-current characteristic of the 90C1.

VOLTAGE STABILISING TUBE 100 E 1

The 100E1 is a voltage stabiliser with a large current regulating range (50-200 mA); the operating voltage of the average tube is 100 V. Within this current regulating range the variation in operating voltage of the average tube is less than 4 V.

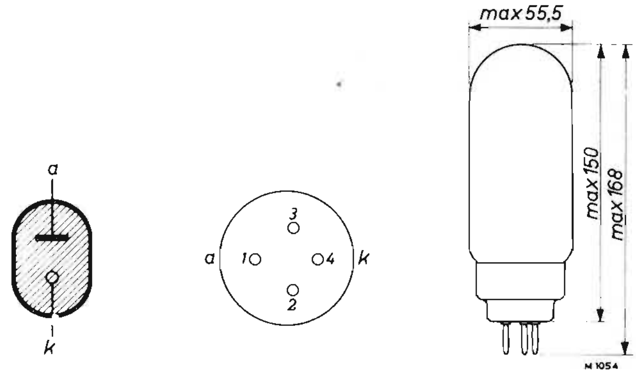


Fig.21. Dimensions and electrode connections of the 100E1.

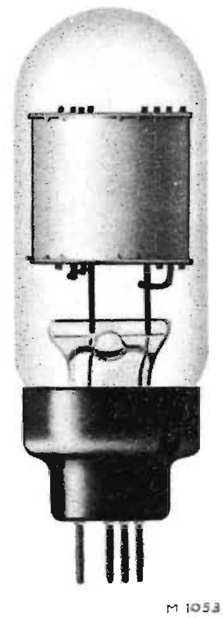


Fig.22. Voltage stabilising tube 100E1.

Tube socket: Type A, No. 40404.

Mounting position: Some ambient illumination should be present to facilitate ignition. In all other respects the tube may be mounted in any position.

CHARACTERISTICS

Operating voltage of average tube at 125 mA........		100 V
Ignition voltage ....max.		125 V *)
Current regulating range..............................	50 -	200 mA
Regulation (50-200 mA)................................		4 V

*) In the presence of some ambient illumination. In complete darkness there may be considerable delay in the ignition of the tube.

NOTES

1) The tube should be operated only with the cathode negative and the anode positive.
2) The tube should not be subjected to severe shocks or continuous vibration.

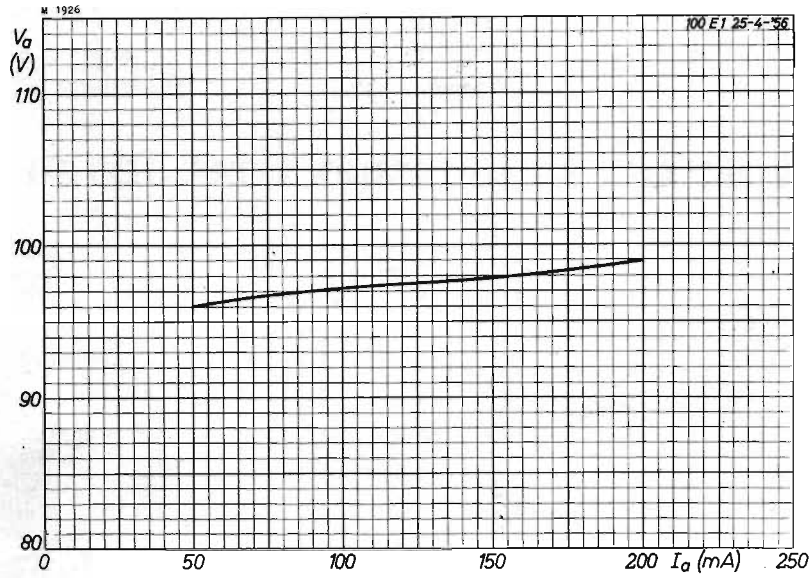


Fig. 23. Voltage-current characteristic of the 100E1.

VOLTAGE STABILISING TUBE OB 2

The OB2 is a voltage stabiliser with a current regulating range of 5 to 30 mA: the operating voltage of the average tube is 108 V. Within this current regulating range the variation in operating voltage of the average tube is less than 3.5 V.

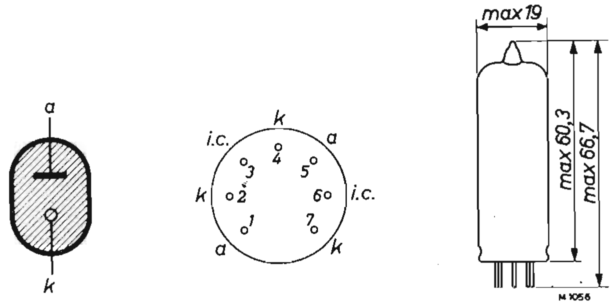


Fig.24. Dimensions and electrode connections of the OB2.

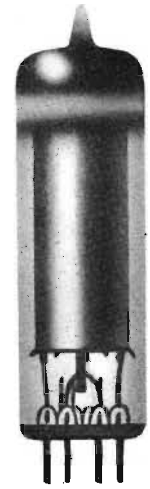


Fig.24. Voltage stabilising tube OB2.

<u>Tube socket</u>: 7-pin miniature, type 5909/36.

<u>Mounting position</u>: Some ambient illumination should be present to facilitate ignition. In all other respects the tube may be mounted in any position.

CHARACTERISTICS

Operating voltage of average tube at 17.5 mA..........		108 V
Spread of operating voltage at 17.5 mA from tube to tube..................................		106 - 111 V
Ignition voltage { at an illumination of 50-500 lux	max.	127 V
Ignition voltage { in complete darkness	max.	210 V
Current regulating range..........................		5 - 30 mA
Regulation (5 - 30 mA)..........................		3.5 V
Variation of operating voltage during 1000 hours at 17.5 mA.................................		± 2 %
Ambient temperature............................		-55 to ±90°C
Starting current(averaging time max.10 sec.)....	max.	75 mA
Shunt capacitor..............................	max.	0.1 μF

NOTES

1) The tube should be operated only with the cathode negative and the anode positive.

2) The tube should not be subjected to severe shocks or continuous vibration.

3) The supply voltage necessary to ensure starting throughout tube life at an illumination of 50-500 lux is minimum 133 V.

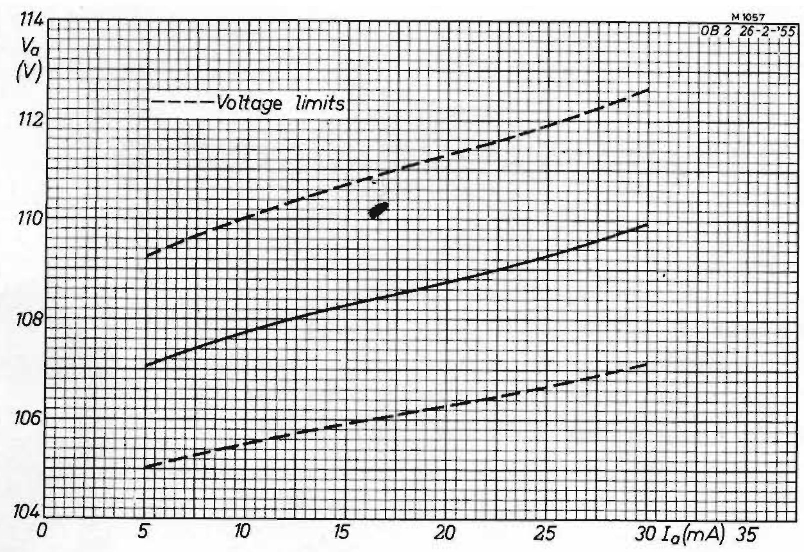


Fig.26.Voltage-current characteristic of the OB2.

VOLTAGE STABILISING TUBE OA 2

The OA2 is a voltage stabiliser with a current regulating range of 5 to 30 mA; the operating voltage of the average tube is 150 V. Within this current regulating range the variation in operating voltage of the average tube is less than 6 V.

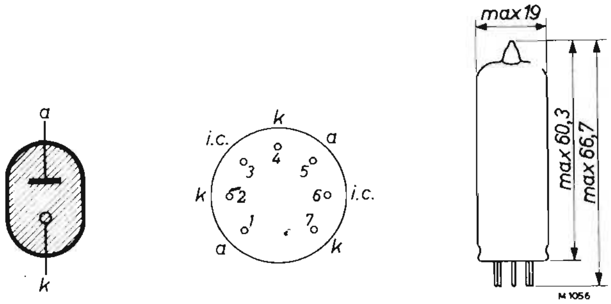


Fig.27. Dimensions and electrode connections of the OA2.

Fig.28. Voltage stabilising tube OA2.

Tube socket: 7-pin miniature, type 5909/36.

Mounting position: Some ambient illumination should be present to facilitate ignition. In all other respects the tube may be mounted in any position.

CHARACTERISTICS

Operating voltage of average tube at 17.5 mA....		150 V
Spread of operating voltage at 17.5 mA from tube to tube...........................		144 - 164 V
Ignition voltage { at an illumination of 50-500 lux	max.	180 V
{ in complete darkness	max.	225 V
Current regulating range......................		5 - 30 mA
Regulation (5 - 50 mA)........................		6 V
Variation of operating voltage during 1000 hours at 17.5 mA................		± 2 %
Ambient temperature..........................		-55 to +90 °C
Starting current (averaging time max.10 sec)....	max.	75 mA
Shunt capacitor	max.	0.1 μF

NOTES

1) The tube should be operated only with the cathode negative and the anode positive.

2) The tube should not be subjected to severe shocks or continuous vibration.

3) The supply voltage necessary to ensure starting throughout tube life at an illumination of 50-500 lux is minimum 185 V.

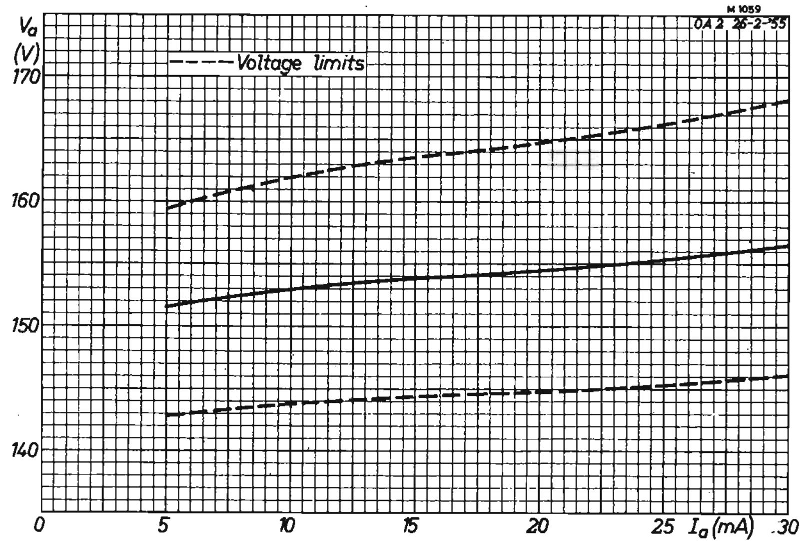


Fig.29. Voltage-current characteristic of the OA2.

VOLTAGE STABILISING TUBE 150 B 2

The 150B2 is a voltage stabiliser with a current regulating range of 5 to 15 mA; the operating voltage of the average tube is 150 V. Within this current regulating range the variation in operating voltage of the average tube is less than 5 V.

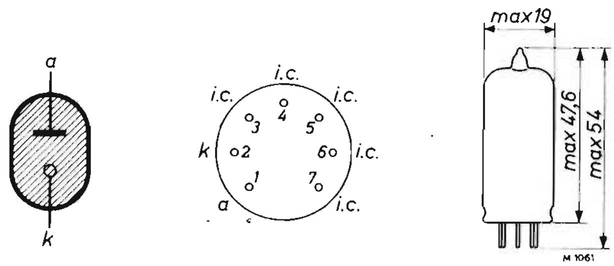


Fig.30. Dimensions and electrode connections of the 150B2.

Fig.31. Voltage stabilising tube 150B2.

Tube socket: 7-pin miniature, type 5909/36.

Mounting position: Some ambient illumination should be present to facilitate ignition. In all other respects the tube may be mounted in any position.

CHARACTERISTICS

Operating voltage of average tube at 10 mA......			150 V
Spread of operating voltage at 10 mA from tube to tube............................			146 - 154 V
Ignition voltage	at an illumination of 50-500 lux	max.	180 V
	in complete darkness.............	max.	225 V
Current regulating range.......................			5 - 15 mA
Regulation (5 - 15 mA)			5 V
Variation of operating voltage during 1000 hours			± 1 %
Temperature coefficient of operating voltage....			10 mV/°C
Ambient temperature............................			-55 to +90°C
Starting current (averaging time max.40 sec)		max.	40 mA

NOTES

1) Equilibrium conditions are reached within 3 minutes.

2) The tube should be operated only with the cathode negative and the anode positive.

3) The tube should not be subjected to severe shocks or continuous vibration.

4) The supply voltage, necessary to ensure starting throughout tube life at an illumination of 50-500 lux is minimum 180 V.

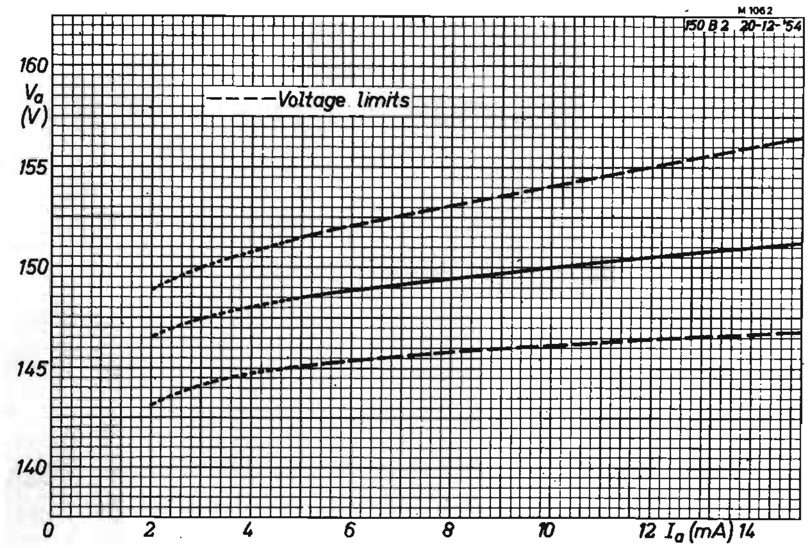


Fig.32.Voltage-current characteristic of the 150B2.

TRIGGER TUBES

INTRODUCTION

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 corresponding to the distance between anode and cathode, but high enough to maintain the main discharge once a discharge has been initiated between starter and cathode.

The trigger triode is, like most other gas discharge tubes, essentially an "on-off" device, that is to say 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 welding timers, relay and counting circuits, power switching apparatus etc. For these applications the trigger triode 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) During stand-by periods the tube is entirely inoperative so that a long life may be expected.
5) The amplitude of the starting pulse required for firing the tube is practically independent of the anode voltage.

PRINCIPLE OF OPERATION

Since the trigger triode has three electrodes, there are various ways in which the discharge may be arranged. 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. The tube thus has rectifying characteristics, and it is indeed possible to use it as a rectifier. 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 much larger than in the reverse direction.

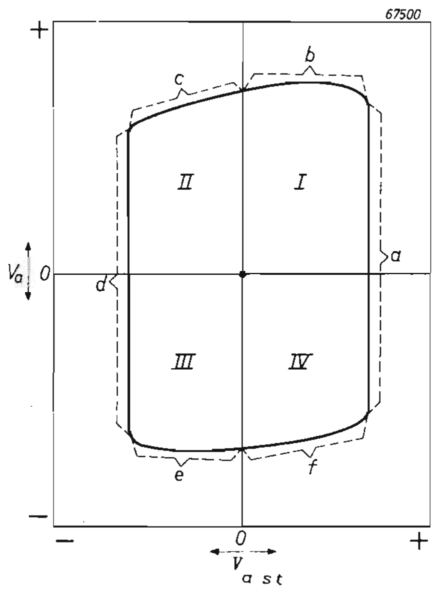


Fig.33. Typical breakdown characteristic of a trigger tube.

It is possible to represent the breakdown characteristics between the various electrodes graphically. Such a graph is reproduced in fig.33. For all combinations of anode starter voltages within the closed loop there is no discharge, provided the border line has not 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.

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 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.

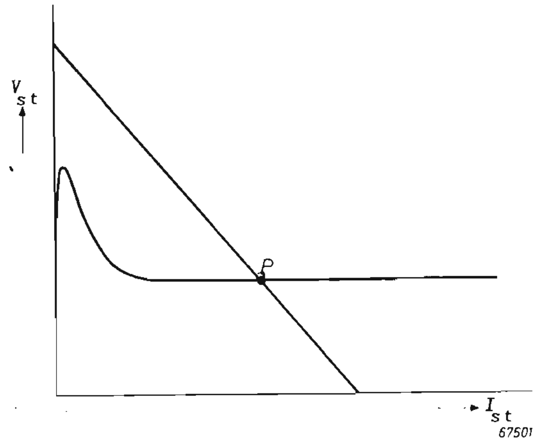
As already mentioned, the tube has rectifying characteristics, and it is therefore intended to operate in quadrant *I* of the loop represented in fig.33. This quadrant refers to positive anode and starter voltages.

The discharge characteristic between each of the two electrodes and the cathode has the typical form of any gas discharge. For the space between starter and cathode this is represented in fig.34. As with the stabiliser tubes, distinction must be made between the "covered cathode" tubes (Z300T, 5823 and Z50T) and the tubes manufactured according to the new "molybdenum sputtering technique" (Z70U and Z804U).

In the first category of tubes the ignition voltage, which corresponds to the peak of the curve of fig.34, 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, namely 140 - 160 V and 120 V respectively, and the molybdenum sputtering technique offers the advantage of ensuring very stable and uniform operating characteristics and facilitating mass production, which results in lower prices.

In series with the starter of all types a limiting resistor must be used; this is indicated by the straight load line which intersects the discharge characteristics of fig.34 in point *P*.

The discharge characteristic for the space between anode and cathode is represented in fig.35. Different characteristics are shown here, each referring to one specific current between starter and cathode. Curve *a* refers to zero starter current. In this case a high voltage is required to initiate the discharge between anode and cathode.



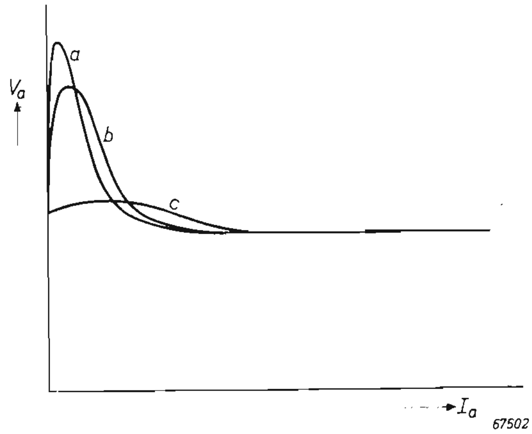


Fig.34. Typical discharge characteristic for the space between starter and cathode. A limiting resistor, indicated by the straight load line, must be employed in series with the starter.

Fig.35. Typical discharge characteristic for the space between anode and cathode. Curve *a* refers to zero starter current, curves *b* and *c* to cases where current flows between starter 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.

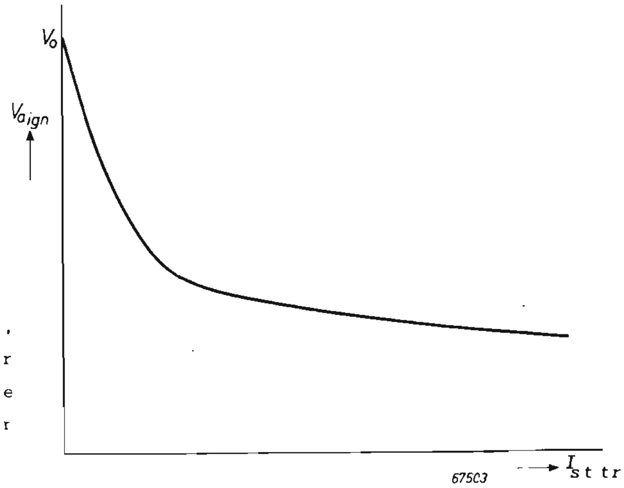


Fig.36. Transition characteristic, i.e. breakdown characteristic for the space between anode and cathode as a function of the transfer current.

It is possible to plot the transition characteristic, which represents the ignition voltage between anode and cathode against the starter current required for obtaining transition from starter-cathode discharge to anode-cathode discharge, i.e. the so-called transfer current. This is done in fig.36. Under normal operating conditions at zero starter current the amplitude of the anode voltage is kept below V_o. 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. This pulse should have a duration in excess of about 20 μsec to cover the ionization time. It is possible to use a sequence of H.F. pulses each having a duration much shorter than 20 μsec.

In the case of a direct voltage on the anode only one pulse is required for starting the main discharge. For extinguishing the tube it is then necessary to reduce the anode voltage below the operation voltage. With a pure alternating voltage on the anode the tube conducts during part of the positive half cycles only, so that it is necessary to apply repetitive pulses to the starter in synchronism with the alternating anode voltage. In any case it must be ensured that ignition in one of the quadrants *II*, *III* or *IV* in fig.33 is prevented, when tubes with a starter *anode* (such as the 5823) are used, whereas ignition in quadrant *II* is prescribed when a tube with a starter *cathode* (Z 804 U, see p. 60) is used.

For example, when the ignition voltage for the starter lies between 70 and 90 V, as is the case for the covered-cathode types, this means that to ensure ignition of an individual tube having an ignition voltage of 90 V and to allow for tolerances in the circuit, a pulse of about 100 V would be required. For this reason a positive bias of 50 to 65 V is normally applied to the starter, so that in the case of 60 V bias the required pulse amplitude is of the order of 40 V.

It should be pointed out that with alternating anode voltage and a positive d.c. bias on the starter, there is a risk of breakdown between anode and starter during the negative half cycles of anode voltage (see section *f* of the breakdown characteristic in fig.33). Since the ignition voltages corresponding to section e of this figure are higher, it is advisable in this case to use alternating bias in phase with the alternating anode voltage. Ignition can then be brought about by providing positive pulses during the positive half cycles of starter voltage, or by adding a positive direct voltage.

The life of a cold-cathode tube is a function of the time integral of the cathode current. If possible, therefore, circuits with these tubes should be so designed that the stand-by periods are long compared with the periods during which anode current flows, and that the anode current has a low value.

APPLICATIONS OF TRIGGER TUBES

Since trigger tubes require no heating power, and do not therefore deteriorate during stand-by periods, the application of these tubes has special advantages in equipment where long life and low power consumption are of prime importance. These tubes are therefore used in welding timers, counter circuits, photo-electric control circuits and in circuits for remote control. Practical applications are given below.

CIRCUIT FOR REMOTE CONTROL WITH THE Z300T

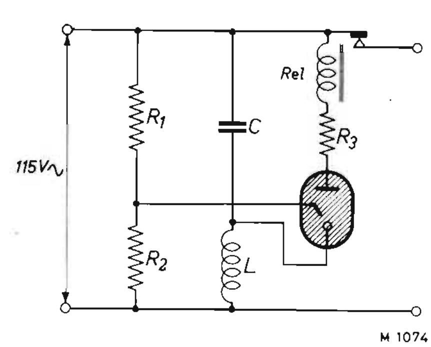


Fig.37. Circuit for remote control with the trigger triode Z 300 T.

Fig.37 shows a simple circuit for remote control that is used for switching on boilers etc., during the night when the load on the power station is small. In this circuit the tube is directly connected to a 115 V d.c. mains, a relay being incorporated in the anode circuit for performing the switching operation. During stand-by period the trigger tube does not conduct, and an alternating bias is applied to the starter via the potentiometer consisting of R_1 and R_2. It may be advisable to make R_2 variable for adjusting the apparatus to maximum sensitivity consistent with an adequate marging of safety against uncontrolled ignition.

Ignition of the tube is obtained by sending sequences of H.F. pulses along the power lines during the positive half cycles of anode voltage. These H.F. pulses with a frequency of the order of 200 kc/s may be obtained by means of an oscillator at the power station. According to the H.F. characteristics of the power lines and the distance to be covered, the oscillator should have an output of about 1 W. The pulsatory character of the H.F. signal is obtained by feeding the anode of the oscillator with a.c. The signal is applied to the cathode of the tube via a high-Q circuit tuned to the frequency of the oscillator at the power station.

High quality of this circuit is desirable, since this reduces the signal power required. Moreover, it is possible to employ selective control by having several oscillators tuned to differe t frequencies at the power station. With high-Q circuits a larger quantity of control groups can then be accommodated in a given frequency band.

A SINGLE CYCLE TIMER FOR SMALL SPOT-WELDERS USING THE Z300T

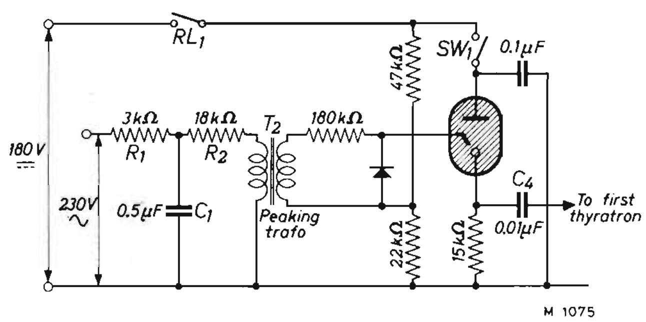


Fig.38. A single cycle timer for small spot-welders with the Z 300 T.

When the operator depresses his foot pedal switch SW_1 (fig.38) is closed, connecting the anode voltage to the trigger tube, but nothing happens because relay contact RL_1 is still open (the relay RL itself is not shown in the diagram of fig.38).

After the preheating period of the thyratrons (about 7 min.), the relay RL in a special delay circuit (also not shown) closes contact RL_1 and completes the anode circuit of the Z300T, which now is ready to act. Anode-to-cathode breakdown takes place when a timing pulse (each positive half cycle of the mains voltage) from peaking transformer T_2 appears on the starter. The cathode potential rises suddenly, and this pulse fires (via C_4) the first of two inverse parallel connected thyratrons in series with the welding transformer.

When the first thyratron is extinguished at the end of the positive half cycle, it triggers the second thyratron, which conducts during the negative half cycle. The phase shift circuit R_1-C_1 causes the timing pulse to lag 30 to 40° with respect to the mains, so that the trigger pulse does not arrive at the first thyratrons until the anode potential is positive. Breakdown of the Z300T during the negative half cycle is prevented by eliminating the negative timing pulses. This is done by connecting a rectifier between the starter of the Z300T and the junction of the resistors for the starter bias. The Z300T remains conducting until the foot pedal is lifted, so that the thyratrons are not re-ignited after having conducted during half a cycle each. For repeating the cycle of operations the foot pedal must be depressed again.

THREE BASIC CIRCUITS FOR THE 5823

1. TYPICAL A.C. OPERATED RELAY CIRCUIT (fig.39)

The prefiring voltage supplied by the voltage divider is just below that required for tube conduction. A positive triggering voltage V_t applied to the starter develops a voltage across the 10 MΩ resistor, which, when added to the prefiring voltage, causes the tube to strike.

Resistors R_1 and R_2 are current-limiting resistors for the anode and the starter. C = 2 to 8 μF, may be used for preventing relay chatter.

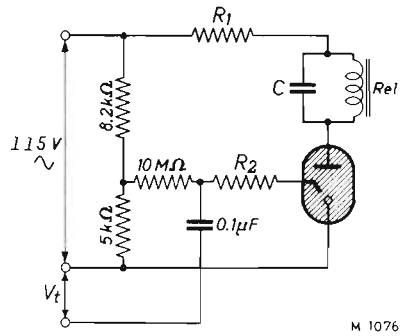


Fig.39. Typical a.c.operated relay circuit with the 5823.

2. TYPICAL D.C. OPERATED RELAY LOCKING CIRCUIT (fig.40)

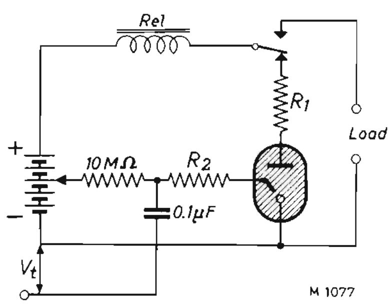


Fig.40. Typical d.c. operated self-locking relay circuit with the 5823.

The prefiring voltage is provided by the battery supply. A positive triggering voltage applied to the starter develops a voltage across the 10 MΩ resistor, which, when added to the prefiring voltage, causes the tube to fire. The anode current energizes the relay, which switches the supply voltage on to the load. The load current must be sufficient to keep the relay energized.

Resistors R_1 and R_2 are current-limiting resistors for the anode and the starter.

3. TYPICAL D.C. OPERATED SELF-RESETTING RELAY CIRCUIT (fig.41)

The prefiring voltage is provided by the battery supply. A positive triggering voltage V_t applied to the starter develops a voltage across the 10 MΩ resistor, which, when added to the prefiring voltage, causes the tube to fire. The capacitor of 1 μF, which has been charged by the supply voltage through the 1 MΩ resistor, will discharge through the tube and energize the relay winding until the voltage of the anode is insufficient to maintain tube conduction. The relay resets itself when the capacitor recharges.

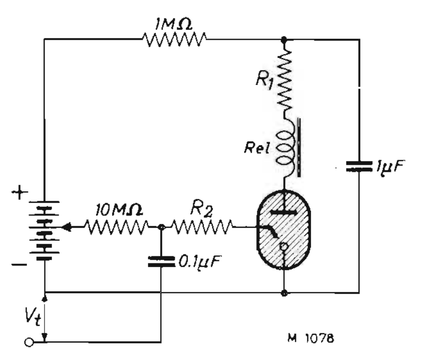


Fig.41. Typical d.c.operated self-resetting relay circuit with the 5823.

Resistors R_1 and R_2 are current-limiting resistors for the anode and starter.

SIGNALLING SYSTEM FOR FOUR SUBSCRIBERS ON ONE CABLE PAIR BY MEANS OF THE 5823

In some sparsely populated countries a system with one cable pair to signalise each one of a group of four subscribers separately, is very economical. For such a system only one cold cathode tube is needed per subscriber. Fig.42 shows the wiring diagram.

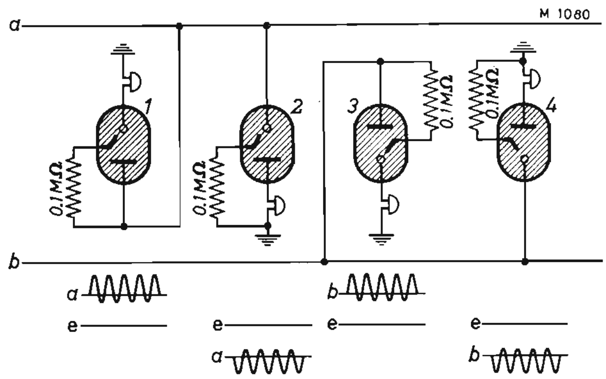


Fig.42. Signalling system for four subscribers on one cable pair with the 5823.

The signal which fires the tube is indicated below each tube. To fire tube *1*, a combination of a positive prefiring voltage and an alternating trigger voltage is needed between line *a* and earth. For tube *2* the combination of a negative voltage and an alternating voltage must be applied between line *a* and earth. For tubes *3* and *4* similar signals are applied between line *b* and earth. Since the earth functions as the third line, care must be taken to ensure good earthing.

CIRCUIT FOR PHOTO-ELECTRIC COUNTING AND CONTROL BY MEANS OF THE 5823

Fig.43 shows a very simple circuit for photo-electric control which is fed by an alternating voltage of 115 V, and is not affected by mains voltage fluctuations of ± 15%.

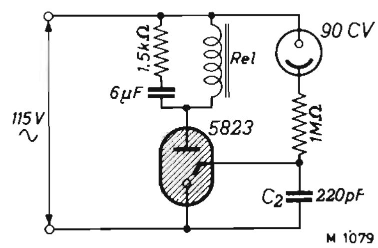


Fig.43. Circuit for photo-electric counting and control with the 5823.

The operation is based on the rectifying effect of the phototube when it is illuminated. During the positive half cycle of the alternating mains voltage the capacitor C_2 is charged by the current flowing through the phototube. This current, and hence also the charge of the capacitor, depends on the amount of light falling on the photocathode.

At sufficient illumination, a glow discharge will be initiated between the starter and cathode, and the discharge current of C_2 via the starter and cathode initiates in turn the main discharge between anode and cathode. The relay in the anode circuit is thus energized 50 times per second; to prevent chatter, the relay is bridged by a large capacitor. To avoid overloading of the tube, its resistance must exceed 2000 Ω.

When no light falls on the photocathode, no trigger pulses will occur at the starter of the 5823 and there will be no ignition between the anode and cathode at the peak value of the mains voltage (165 V). The relay is thus released. The so-called "twilight switch" operation may be mentioned as the most obvious application: with darkness the light is switched on, and in the morning, when daylight begins to energize the phototube, the light is switched off again. The sequence of events in this circuit is reversed by interchanging the phototube and the capacitor C_2. The relay is then operated when no light falls on the photocathode.

The applications of this circuit are manifold. Provided the necessary precautions are taken, such as the use of an infra-red filter and artificial cooling by means of water or air, etc., this circuit is extremely suited for flame control. With the aid of a thermocouple and a reflecting galvanometer a very sensitive temperature control device is obtained. With a counting relay instead of the normal relay, a perfect counting circuit for industrial applications is obtained.

A UNIVERSAL ELECTRONIC SWITCH WITH THE 5823 FOR INDUSTRIAL PURPOSES

Fig.44 shows the diagram of a more elaborate circuit for photoelectric counting and control. It has the following improvements with respect to the circuit of fig.43.

(*a*) The double switch S_1 offers the possibility of changing-over from a "light" circuit (in which case the relay is operated by light impinging on the photocathode) to a "dark" circuit (in which case the relay is operated by darkness).

(*b*) By incorporating the capacitor C_3 a certain leading phase shift (α in fig.45) is introduced between the trigger voltage and the anode voltage of the 5823, thus ensuring that the duration of the current pulse flowing through the relay (β in fig.45) is a maximum.

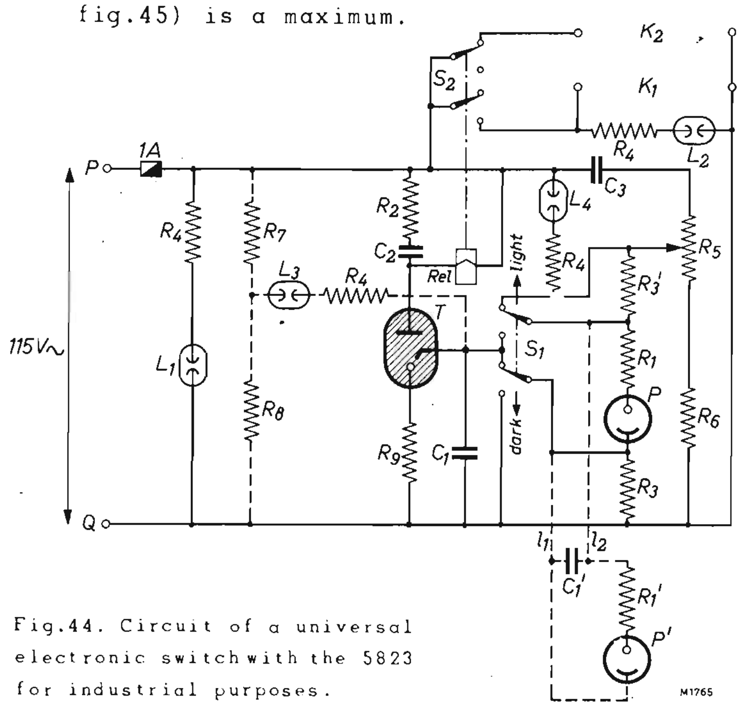


Fig.44. Circuit of a universal electronic switch with the 5823 for industrial purposes.

PARTS LIST

R_1	=	1 MΩ, ½ W
R_1'	=	10 MΩ, ½ W
R_2	=	1 kΩ, ½ W
R_3	=	10 MΩ, ½ W
R_3'	=	10 MΩ, ½ W
R_4	=	200 kΩ, ½ W
R_5	=	500 kΩ, ½ W
R_6	=	1 MΩ, ½ W
R_7	=	100 kΩ, ½ W
R_8	=	220 kΩ, ½ W
R_9	=	1 kΩ, ½ W
C_1	=	120 pF
C_1'	=	120 pF
C_2	=	6 μF
C_3	=	0.022 μF
T	=	5823
P, P'	=	90CV
L_1 - L_4	=	Z8

(c) A more reliable action is obtained by using a 15 000 Ω relay instead of the 2000 Ω relay used in the simple circuit of fig.43.

(d) The resistor R_9 of 1 kΩ has been incorporated in the cathode circuit of the 5823 to limit the peak starter current and to provide the required voltage difference between the switching-on and -off voltages.

(e) The sensitivity of the apparatus is adjustable by varying the phototube voltage, by means of the potentiometer R_5.

(f) The resistor R_3 of 10 MΩ has the function of a leak resistor for the capacitor C_1, thus rendering the discharge time of C_1 more constant in the "light" circuit. In the "dark" circuit R_3' forms a potential divider with C_1.

In the "light" circuit, i.e. when the switch S_1 occupies the position indicated in fig.44, the operation is based on the rectifying effect of the phototube when it is illuminated. The capacitor C_1 is then gradually charged by the current flowing through the phototube until the trigger breakdown voltage has been reached.

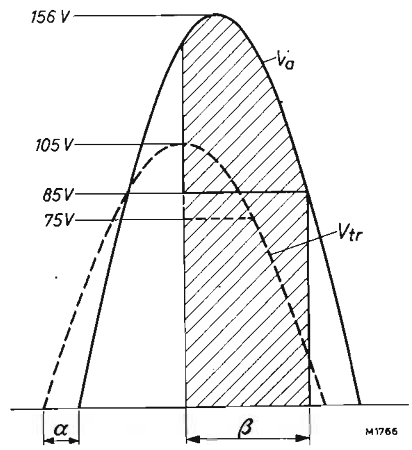


Fig.45. Anode and starter voltage of the 5823. α = leading phase angle, β = anode current angle.

The operation of the "dark" circuit is based on a different function of the phototube, which then forms a variable leak resistor for the capacitor C_1. When the phototube is illuminated the discharge current through the phototube is so large that the remaining voltage across C_1 is too low to trigger the 5823. The difference between the two circuits therefore amounts to the 10 MΩ resistor and the phototube (with the protecting resistor R_1) being interchanged.

The neon pilot lamps L_1 and L_2 have the following functions. The lamp L_1 indicates when the mains voltage is switched on, whereas L_2 shows whether the relay is energized. In the latter case the mains voltage appears at the plug sockets K_1, whereas in the non-energized condition the mains voltage appears at the sockets K_2.

The circuit drawn in dashed lines provides for the case that the phototube is mounted at some distance from the electronic switch, the apparatus being used for example as a flame control. In this case provision must be made that a warning is given when a short circuit occurs in the long cable towards the phototube. For the "light" circuit (flame control) this is achieved by means of the neon pilot lamp L_4 and in the "dark" circuit (twilight switch) by means of the neon pilot lamp L_3. If the capacitance C_1' of the cable is fairly large in the "dark" circuits this can be compensated by reducing the capacitance C_1 accordingly.

ELECTRONIC FENCE CONTROLLER WITH THE 5823

Up to recently, electric fencing of grazing-land was performed by a controller containing three tubes, namely a rectifying tube, an oscillator tube and a thyratron. Furthermore, a heavy mains transformer, two electrolytic smoothing capacitors and an oscillator coil were indispensable parts of this apparatus.

In the controller described below (fig.46) only one cold-cathode tube and a relay are required instead of all above-mentioned components. A further feature of this controller is that it consumes no power during stand-by periods owing to the cold cathode of the 5823. These stand-by periods cover almost 99.9% of the total time, as the controller only gives a voltage pulse on the fence wire when the latter is touched.

Therefore, a battery can be used as supply source, ensuring in this way an easily portable unit, which is very important for economical cattle-grazing, since the fencing has to be shifted often from one plot to another, when the cattle are moved on to fresh grazing ground. Two batteries of 67.5 V will last at least one season, depending on the insulating of the fence with respect to earth.

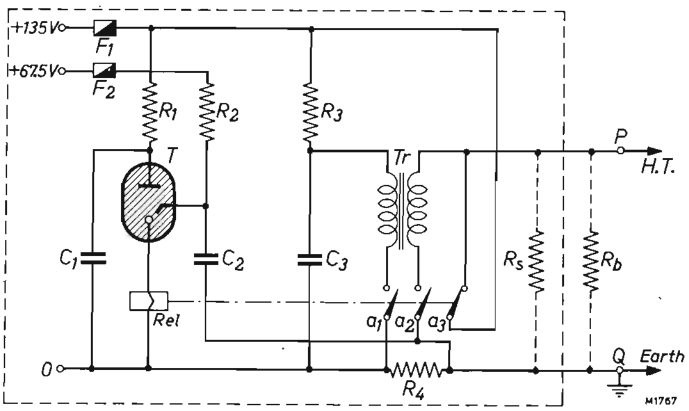


Fig.46. Single-pulse fence controller with the 5823.

PARTS LIST

R_1	=	220 kΩ, ½ W
R_2	=	10 MΩ, ½ W
R_3	=	100 kΩ, ½ W
R_4	=	680 kΩ, ½ W
R_s	=	leakage resistance between the fence and earth
C_1	=	4 μF
C_2	=	0.1 μF
C_3	=	8 μF
T	=	trigger tube 5823
Tr	=	output transformer S8 441 42.1
Rel	=	relay SZS1301/200/a

The operation of the circuit may be explained as follows. As soon as the fence wire is touched (point P) a body resistance R_b will be present between P and Q. At this moment battery current starts to flow via R_4 and this resistance. The voltage across R_4 increases the voltage that is already present across C_2, as a result of which the tube is triggered.

Capacitor C_1 now discharges over the ionised tube, and this current flows through the relay coil. The relay closes the contacts A_1 and A_2 and breaks contact A_3. Subsequently, capacitor C_3 discharges over the primary coil of the transformer Tr, a high-tension pulse of 2800 V thus being generated between P and Q.

After a period of 3 msec the tube extinguishes and the relay is de-energised, thus breaking contacts A_1 and A_2 and closing contact A_3. This enables capacitors C_1, C_2 and C_3 to be recharged via R_1, R_2 and R_3 respectively, so that the initial condition is re-established.

A drawback of this circuit is that the capacitors C_1, C_2 and C_3 cannot be recharged as long as the body resistance is present between P and Q. Cattle touching the fencing wire will therefore feel only one single shock when they keep in touch with the fence.

In respect of the safety regulations, this apparatus answers all the requirements imposed by the KEMA, a government-authorised institute. The regulations in other countries, if any, are of the same purport, though they may differ slightly in some cases. It is remarked that this type of circuit may be used for many other applications, for example for all kinds of alarm and warning systems.

IMPROVED ELECTRONIC FENCE CONTROLLER WITH THE 5823

If it is desired that the fence controller continues to produce H.T. pulses during the time that the wire is touched, the circuit shown in fig. **47** may be used.

This circuit operates as follows. When the fence wire is touched (point *P*) and the body resistance R_b forms contact between points *P* and *Q*, current starts to flow from the positive battery terminal (point *A*) through R_2, R_3, junction *D*, switch S_1, R_b, R_1 and relay *Rel* to point *B*. The voltage drop across the large resistance R_1 causes trigger breakdown; the capacitor C_4 delivers the necessary current.

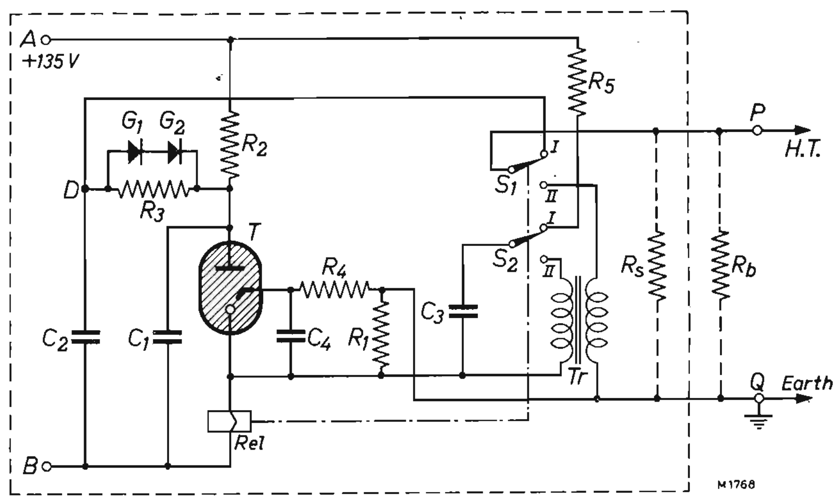


Fig.47. Multi-pulse fence controller with the 5823.

PARTS LIST

R_1 = 10 MΩ, ½ W	C_1 = 4 μF	*Tr* = output transformer S8 441 42.1
R_2 = 100 kΩ, ½ W	C_2 = 2 μF	*Rel* = relay SZS1301/200/a
R_3 = 1 MΩ, ½ W	C_3 = 8 μF	*T* = trigger tube 5823
R_4 = 1 MΩ, ½ W	C_4 = 820 pF	G_1, G_2 = germanium diode OA 85
R_5 = 100 K, ½ W		
R_s = leakage resistance between the fence and earth		

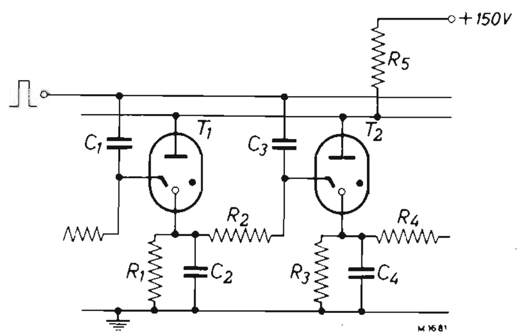
The capacitors C_1 and C_2 now discharge over the ionised tube and the relay coil (C_2 can be rapidly discharged via the rectifying diodes G_1, G_2). The relay is thus energized so that its contacts S_1 and S_2 are switched from the test position *I* to the working position *II*, thus allowing the capacitor C_3 to discharge over the primary coil of the transformer *Tr*. An H.T. pulse of 2800 V is then induced in the secondary coil.

As the 5823 circuit is self-quenching, the tube subsequently extinguishes, and the relay contacts S_1 and S_2 return to their rest position *I*. After the tube has extinguished, the capacitors C_1 and C_2 are recharged via R_2 and R_3, so that the potential of point *D* gradually rises again. After a short time (about 1 second) has elapsed, the 5823 will again be triggered, provided the body resistance R_b is still present between points *P* and *Q*, and the cycle is repeated. It is thus seen that an H.T. pulse is produced once a second, as long as the fence wire is touched.

Care should be taken to ensure a good insulation with respect to earth (resistance R_s > approx. 6 MΩ), for both the pulse frequency and the battery life are affected by inadequate insulation [1]).

RING COUNTER WITH EIGHT TUBES Z 50 T

Fig.48 shows two stages of a ring counter, equipped with the trigger tubes Z 50 T, and having a maximum counting rate of approx. 1000 pulses per second. The anodes of the tubes are interconnected and, moreover, connected to a positive voltage with respect to the cathode via a common resistor. The cathode of T_1 is connected to the starter of T_2 via a resistor. The pulses to be counted are fed simultaneously to the starters of all tubes via a common lead.



PARTS LIST

R_1 = R_3 =	12 kΩ ± 2%, ½ W:	5332C/12K
R_2 = R_4 =	0.47 MΩ ±10%, ½W:	AR1001A/470K
R_5 =	10 kΩ ± 5%, ½ W:	AR1001B/10K
C_1 = C_3 =	470 pF ±10%:	AC3003A/470E
C_2 = C_4 =	33.000 pF ±10%:	5325A/33K

Fig.48. Two stages of a ring counter equipped with the tubes Z 50 T.

To explain the operation of the circuit it will be assumed that tube T_1 is conducting. A direct voltage is then present across the cathode resistor R_1, which forms a positive bias for the starter of tube T_2. The anode voltage of T_2 has such a value that T_2 cannot ignite at this bias.

A positive-going pulse, which is insufficient to ignite tubes without a positive starter bias, is now applied to all starters; as a result, only tube T_2 ignites, and current starts to flow through this tube. Since the cathode resistor of T_1 is by-passed by a large capacitor, the cathode voltage of T_1 will temporarily remain almost constant, so that, due to the voltage drop across the common anode resistor, the anode voltage of T_1 will drop below the burning voltage and this tube will therefore be extinguished.

The cathode current of T_2 produces a voltage drop across its cathode resistor, so that the tube following T_2 attains a positive starter bias When the next positive pulse is applied to the common pulse lead, the following tube will therefore ignite, whereas T_2 is extinguished.

By means of the glow discharge of the tubes it can be seen which lamp is burning.

When ten of the stages shown in fig.48 are connected in cascade, and the output of the tenth is connected to the input of the first, a decade-counter (ring counter) is obtained.

---

1) If R_s < 6 MΩ, R_1 should be reduced to avoid continuous pulsing.

PARTS LIST

R_1=	0.47 MΩ ±10%,	½ W:	AR1001A/470K
R_2=	0.33 MΩ ± 2%,	½ W:	5332C/330K
R_3=	10 kΩ ±10%,	½ W:	AR1001A/10K
R_4=	0.56 MΩ ± 2%,	½ W:	5332C/560K
R_5=	68 kΩ ± 2%,	½ W:	5332C/68K
C_1=	470 pF ±10%,		AC3003A/470E
C_2=	1000 pF ±10%,		5308A/IK
C_3=	0.1 µF ±10%,		5325A/100K

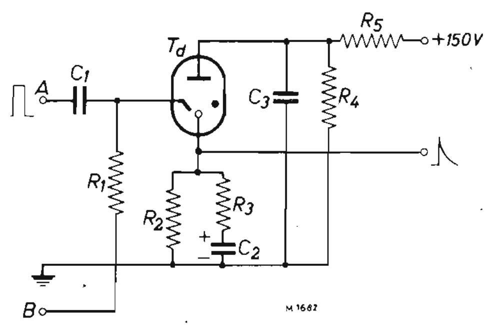


Fig.49. Interstage pulse shaper for the coupling between two decades.

Passing the pulses from one decade to the next requires a special self-quenching circuit, since no suitable positive pulse is available from the ninth stage. Such a self-quenching circuit (pulse shaper and pulse amplifier) is shown in fig.49.

Terminal A is connected to the common pulse lead, whereas terminal B is connected to the cathode of tube No.9, so that the starter of T_d obtains a positive bias via R_1 if tube No.9 is conducting. When, due to a positive-going pulse at the starter, the tube is ignited, the tube current is determined by the intersection point P_1 of the tube characteristic with the load-line of R_3 (fig.50), as initially C_2 forms a short circuit [1]. After the ignition C_2 immediately starts to be charged with the polarity indicated in fig.49. As a result, the voltage across the series connection of the tube and R_3 decreases (V_{b2}), so that the load line or R_3 is shifted vertically, and the intersection point is thus shifted to the left (P_2). Capacitor C_2 continues to be charged until P has arrived at the point of contact P_3. The voltage across the tube then becomes too low to maintain the glow discharge, so that the tube is extinguished. Since the stable point Q, determined by the load line of R_2, is situated at the left of P_3, this condition is never reached.

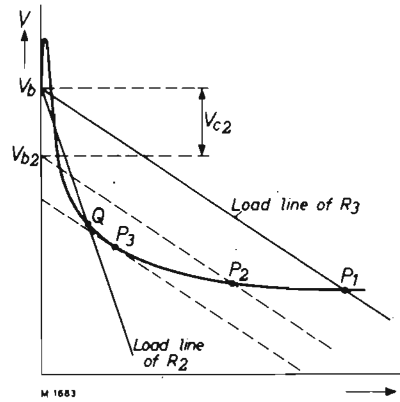


Fig.50. Diagram showing the operation of the circuit of fig. 51.

After the tube has been extinguished, C_2 will be discharged via R_2 and R_3 until the initial condition is re-established.

EXPERIMENTAL DECADE COUNTER
WITH EIGHT TUBES Z 70 U

Fig.51 shows the circuit diagram of an experimental bi-quinary decade counter equipped with eight 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.

[1]) R_2 is much larger than R_3 so that its influence may be neglected.

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: one of the tubes of the scale-of-five and one of the tubes of the scale-of-two circuit.

As shown in fig.51, the tubes T_1 and T_5 have a common non-bypassed cathode resistor (R_7). This has the same effect as the common anode resistor of the circuit of fig.48. T_6 and T_7 also have a common cathode resistor (R_8), and their starters are coupled to the cathode of T_5 via two resistors R_5. The incoming pulses are applied simultaneously to the starters of T_1 to T_7. The operation of the circuit is as follows (see fig.52).

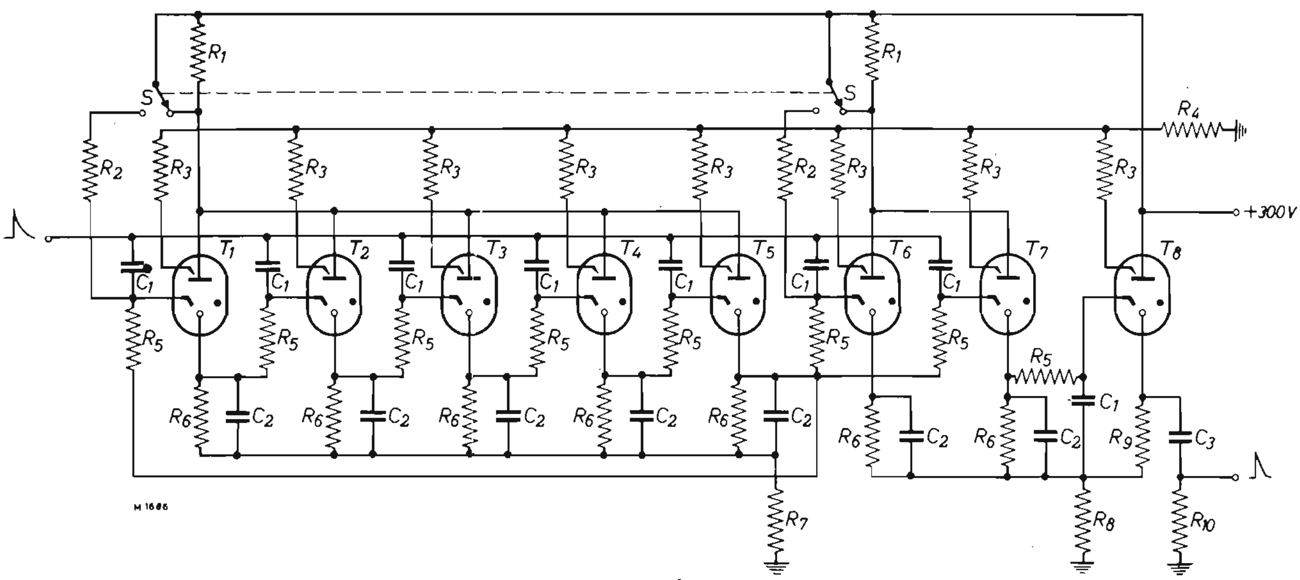


Fig.51. Circuit diagram of a bi-quinary decade counter with 8 tubes Z 70 U.

PARTS LIST

R_1 =	12 kΩ ±10%, ½ W:	AR1001A/12K	R_8 =	33 kΩ ±10%, ½ W:	AR1001A/33K
R_2 =	560 kΩ ±10%, ½ W:	AR1001A/560K	R_9 =	680 kΩ ±10%, ½ W:	AR1001A/680K
R_3 =	10 MΩ ±10%, ½ W:	AR1001A/10M	R_{10} =	27 kΩ ±10%, ½ W	AR1001A/27K
R_4 =	1.2 MΩ ±10%, ½ W:	AR1001A/1M2	C_1 =	100 pF ±10%,	AC3003A/100E
R_5 =	1.2 MΩ ±10%, ½ W:	AR1001A/1M2	C_2 =	4700 pF ±10%,	5325A/4K7
R_6 =	56 kΩ ±10%, ½ W:	AR1001A/56K	C_3 =	2200 pF ±10%,	5325A/2K2
R_7 =	27 kΩ ± 5%, ½ W:	AR1001B/27K			

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 due to the voltage drop across R_7. Tube T_6 remains ignited because its anode voltage is not changed.

After four pulses have been applied, T_5 and T_6 are ignited; T_6 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.

M 1687

Number of pulses	Tube number	1	2	3	4	5	6	7	8
0		×	○	○	⊙	○	×	○	○
1		○	×	○	○	○	×	○	○
2		○	○	×	○	○	×	○	○
3		○	○	○	×	○	×	○	○
4		○	○	○	○	×	×	○	○
5		×	○	○	○	○	○	×	○
6		○	×	○	○	○	○	×	○
7		○	○	×	○	○	○	×	○
8		○	○	○	×	○	○	×	○
9		○	○	○	○	×	○	×	○
10		×	○	○	○	○	×	○	×

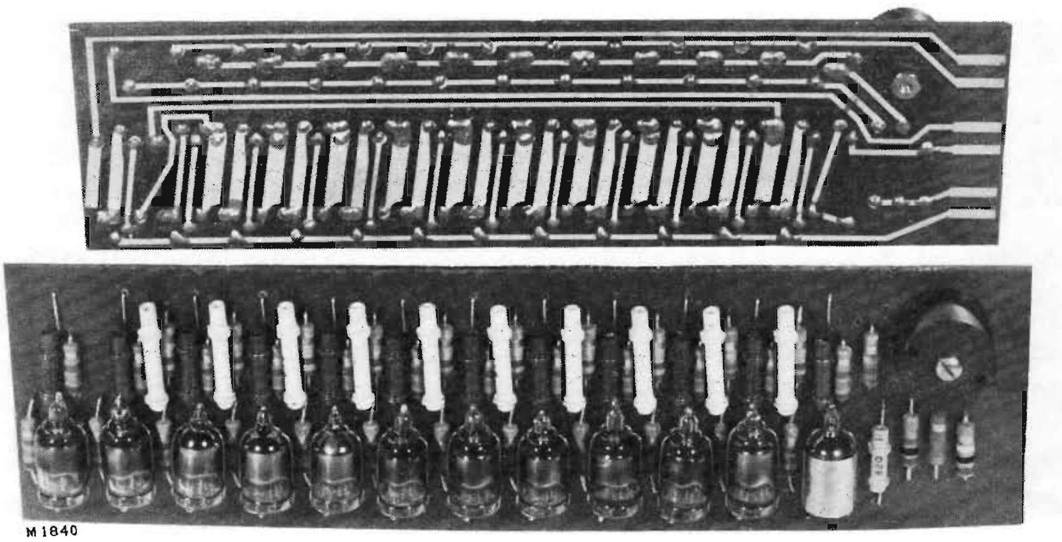
× Tube ignited ○ Tube extinguished

Fig.52. Diagram showing the operation of the circuit of fig.51.

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 sudden voltage drop across R_8 is fed to the starter of T_8 via C_1. This additional voltage at the starter of T_8 causes the latter to ignite. A pulse is then produced across R_{10}, which is 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 setting the switch S in the left-hand position, thus applying a high positive voltage to the starters of T_1 and T_6, which causes these tubes to become ignited.

If a rectangular input pulse is applied, it should have an amplitude of approx. 80 V at a duration of 15 to 30 μsec.



M 1840

Fig.53. Experimental set-up of a decade counter. (A mirror was used to show the image of the printed wiring at the rear.)

The maximum counting speed that can be obtained with this counter is about 3 kc/s. The counting speed is not limited by the deonization time (being 200 μsec) as might be expected, but by the time constants τ_1 and τ_2 and τ_3 [1]) in the circuit. This has been proved by some recent laboratory experiments, at which counting speeds of even 10 kc/s have been reached. Further investigations are proceeding to develop circuits which allow for counting speeds of 5 to 6 kc/s for practical use. In this respect a circuit may be mentioned in which a coil (0.2 to 0.3 H) is used, in series with a resistor of 8200 Ω instead of the resistor R_7. For this coil a ferroxcube pot-core was used (type no. 18/12), which is small-size type.

The photograph of fig.53 shows an experimental decade counter with the additional coil in printed circuit execution.

[1]) $\tau_1 = R_1C_1$; $\tau_2 = (R_1 // R_2)C_1$; $\tau_3 = R_3C_3$.

TOUCH CONTROL WITH TWO TUBES Z 70 U

The electronic microswitch discussed below is equipped with two cold-cathode trigger tubes and comprises 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 quenched by the pulse produced by the first tube. The relay, which is energized by the anode current of the second tube, switches the load on or off.

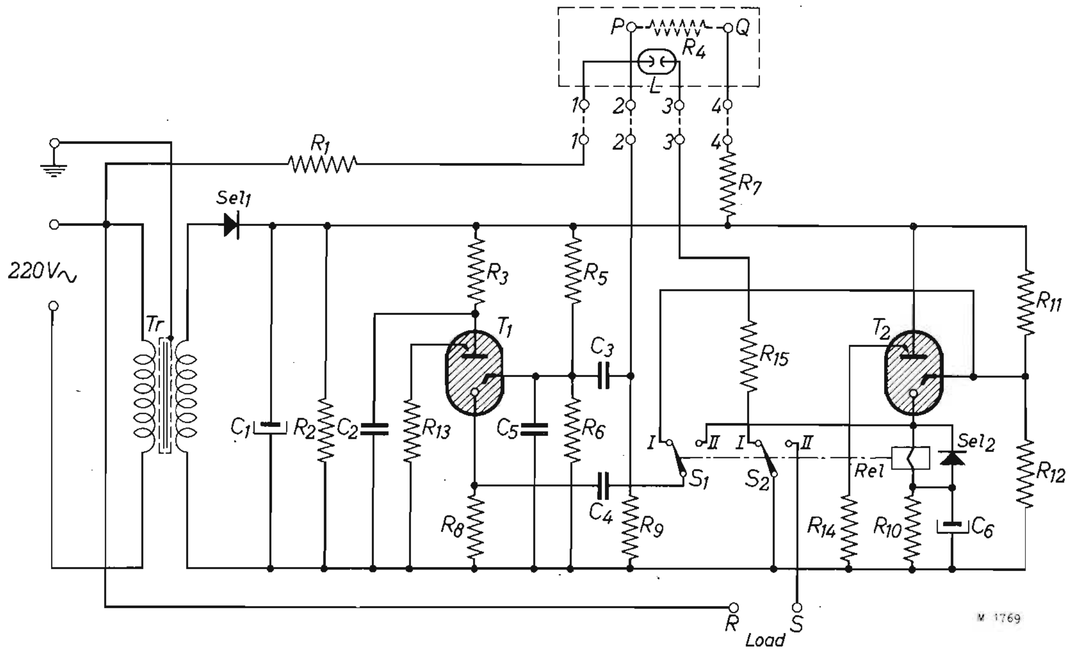


Fig.54. Touch control with two trigger tubes Z 70 U

PARTS LIST

R_1	= 470 kΩ, ½ W	R_9	= 10 MΩ, ½ W	C_1	= 8 μF
R_2	= 330 kΩ, ½ W	R_{10}	= 47 kΩ, ½ W	C_2	= 0.033 μF
R_3	= 10 MΩ, ½ W	R_{11}	= 6.8 MΩ, ½ W	C_3	= 0.01 μF
R_4	= 0-10 MΩ, ½ W	R_{12}	= 3.3 MΩ, ½ W	C_4	= 0.01 μF
R_5	= 10 MΩ, ½ W	R_{13}	= 20 MΩ, ½ W	C_5	= 220 pF
R_6	= 6.8 MΩ, ½ W	R_{14}	= 20 MΩ, ½ W	C_6	= 8 μF
R_7	= 1 MΩ, ½ W	R_{15}	= 150 kΩ, ½ W	T_1, T_2	= Z 70 U
R_8	= 150 kΩ, ½ W	*Sel*	= BS 250 Y 10	*L*	= Z 8
		Tr	= 220/220 V	*Rel*	= SZS 1301/200/a

The operation of the circuit will be explained by reference to fig.54. The 220 V a.c. 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 MΩ, 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 trigger 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 MΩ, starter 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 alive points P and Q being touched, the very high resistances 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_{12}, R_{13}, 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 the excitation current to be sufficiently large. The values of R_{11} and C_6 have, moreover, been so chosen that the voltage across R_{11} 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 selfinductance of the relay coil is to shunt it by the selenium rectifier Sel_2.

When T_2 is extinguished the relay is de-energized, 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 energized the total supply current is approximately 3.5 mA; with de-energized 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_{14} and R_{15} of 20 MΩ each, which ensure a continuous discharge between the anode and the auxiliary cathode.

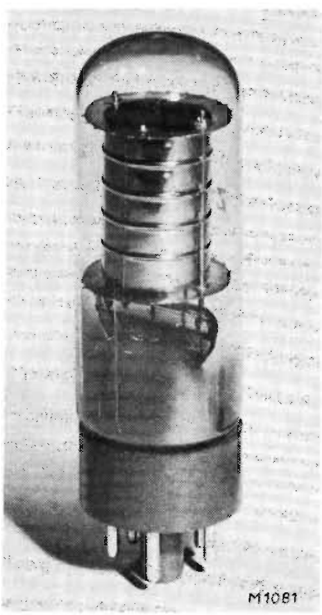
Reliable operation of the circuit will be obtained notwithstanding mains voltage fluctuations ranging from +10% to -20%. The dependence on mains voltage fluctuations is reduced by the abovementioned load resistor R_2 and the neon pilot lamp L incorporated in the finger touch switch. When the touch control is used, for example, for lighting purposes the pilot lamp will be alight when the relay is de-energized and the light is switched off, so that the switch can easily be traced in darkness.

DATA OF TRIGGER TUBES

TRIGGER TUBE Z 300 T / PL1267

TYPICAL CHARACTERISTICS

Typical anode breakdown voltage............	$V_{a\,ign}$	=	255 V
Anode voltage, below which breakdown will not occur in any tube.............	$V_{a\,ign}$	= min.	225 V
Anode voltage, above which breakdown will occur in all tubes................	$V_{a\,ign}$	= max.	310 V
Typical starter to cathode breakdown voltage...............................	$V_{st\,ign}$	=	85 V
Starter to cathode voltage, below which breakdown will not occur in any tube....	$V_{st\,ign}$	= min.	70 V
Starter to cathode voltage, above which breakdown will occur in all tubes.......	$V_{st\,ign}$	= max.	90 V
Anode burning voltage (I_a = 25 mA)............	V_a	=	70 V
Starter voltage drop......................	V_{st}	=	60 V
Starter transfer current at V_a = 140 V.....	$I_{st\,tr}$	= max.	100 μA



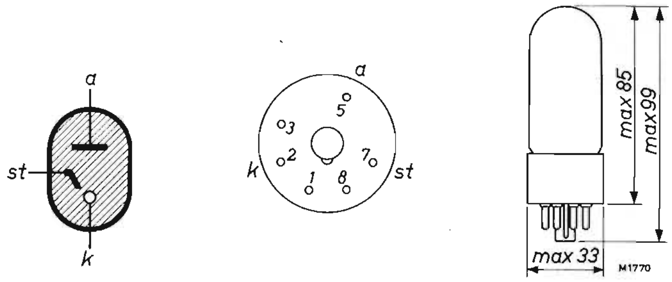


Fig.55. Dimensions and electrode connections of the Z 300 T.

Fig.56. Trigger tube Z 300 T.

TUBE HOLDER: eight pin Octal type 5903/12 or 5903/13.

MOUNTING POSITION: any

LIMITING VALUES (*absolute limits*)

Average continuous cathode current (T_{av} = max. 15 sec.)..................	I_k	= max.	25 mA
Forward peak cathode current..............	I_{kp}	= max.	100 mA

REMARK The data are valid for quadrant *I* of the breakdown characteristic (V_a and V_{st} positive) for the operation in which the tube is recommended. The tube must be exposed to some light. Full sunlight or complete darkness should be avoided.

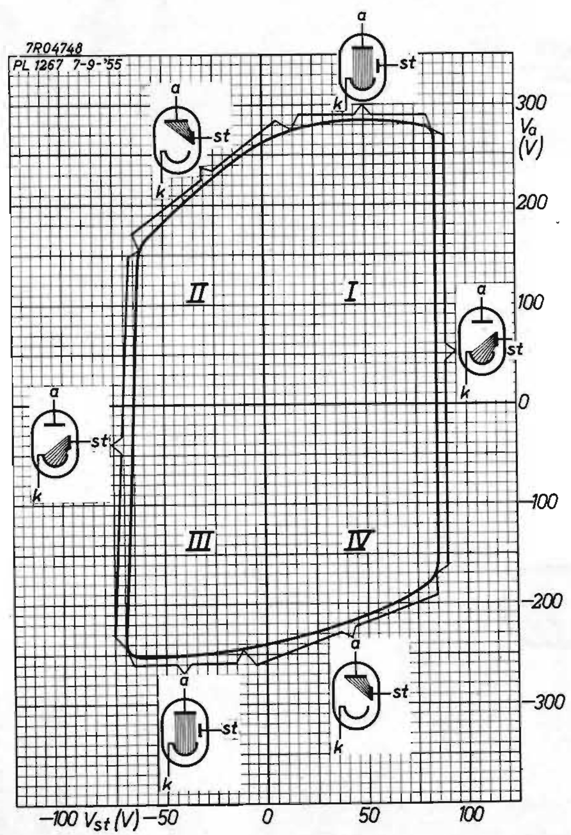


Fig.57. Breakdown characteristic of the trigger tube Z 300 T. The different sections of the loop refer to a discharge between the electrodes as indicated schematically.

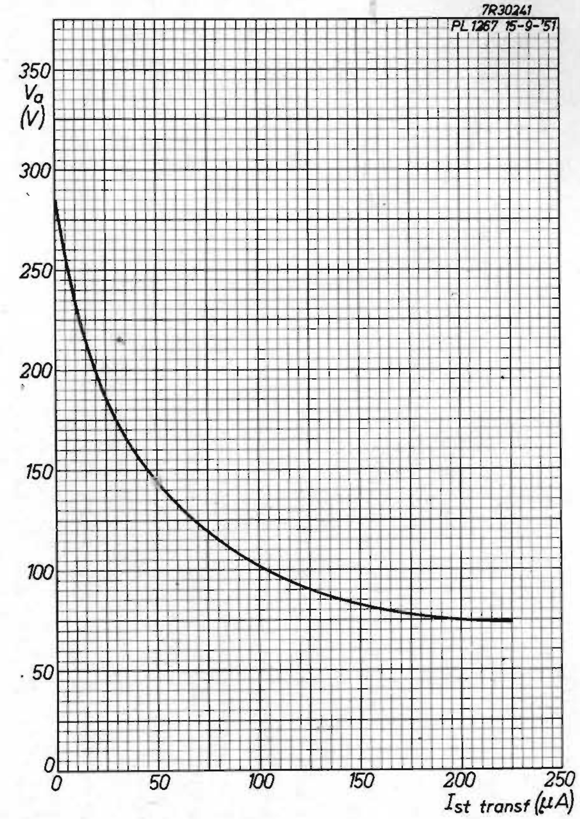
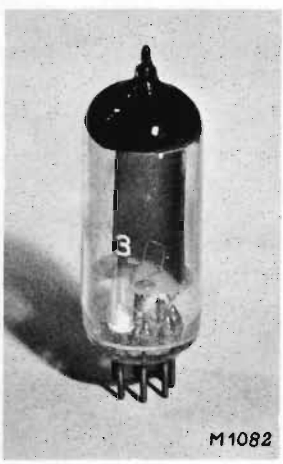


Fig.58. Transition characteristic i.e. breakdown characteristic for the space between anode and cathode of the Z 300 T as a function of the starter current.

TRIGGER TUBE 5823/Z 900 T

TYPICAL CHARACTERISTICS

Typical anode breakdown voltage..........	V_{aign}	=	290 V
Anode voltage, below which breakdown will not occur in any tube...........	V_{aign}	=	min. 200 V
Typical starter to cathode breakdown voltage	V_{stign}	=	80 V
Starter to cathode voltage, below which breakdown will not occur in any tube..	V_{stign}	=	min. 73 V
Starter to cathode voltage, above which breakdown will occur in all tube......	V_{stign}	=	max. 105 V
Anode burning voltage (I_a = 25 mA)..........	V_a	=	nom. 62 V max. 85 V
Starter burning voltage (I_a = 25 mA)........	V_{st}	=	61 V
Starter transfer current at V_a = 140 V........................	I_{sttr}	=	nom. 50 μA max. 400 μA
Starter transfer current at V_a = 175 V........................	I_{sttr}	=	max. 160 μA
Ionisation time........................	T_{ion}	=	20 μsec [1])
Deionisation time......................	T_{dion}	=	500 μsec



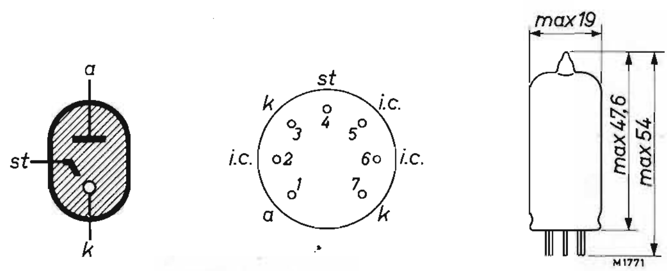


Fig.59. Dimensions and electrode connections of the 5823.

Fig.60. Trigger tube 5823.

TUBE HOLDER: 7-pin miniature type 5909/36

MOUNTING POSITION: any

LIMITING VALUES (absolute limits)

Average continuous cathode current (T_{av} = max. 15 sec.)..................	I_k	=	max. 25 mA [2])
Forward peak cathode current............	I_{kp}	=	max. 100 mA
Forward peak starter current............	I_{stp}	=	max. 100 mA
Ambient temperature.....................	t_{amb}	=	min. -60 °C max. +75 °C

For footnotes see next page.

OPERATING CHARACTERISTICS for use as a relay tube with 50 c/s a.c. supply:

Anode supply voltage................	V_{ba}	= 117 V_{eff}
Peak value of starter bias voltage..	$V_{b\,stp}$	= max. 70 V
Peak value of starter pulse voltage.	$V_{b\,imp\,p}$	= max. 35 V
Total starter voltage (sum of in phase starter bias voltage and starter pulse voltage)...........	$V_{st\,t}$	= min. 105 V

For use as a rectifier with an a.c. supply of 50 c/s (starter connected to anode by means of $R_{a\,st}$ = 50 kΩ) the inverse peak anode voltage may not exceed 200 V, thus $V_{a\,inv\,p}$ = max. 200 V.

LIFE EXPECTANCY

In intermittent relay service the life performance of the 5823 will prove to be excellent. The average life expectancy depends on the frequency of "on" cycles, on the total duration of the "on" periods, and on the peak value of the cathode current. If the trigger tube 5823 is fed by a 50 c/s alternating voltage and triggered every cycle, its life will be determined mainly by the number of starts that it can withstand and by the peak value of the cathode current. The average number of starts the tube may be expected to withstand under these conditions is about 45 000 000. For d.c. operation the life expectancy depends on the same factors, but as the frequency of the starts is reduced, the importance of the "on" periods increases. By keeping the cathode current as low as possible, the tube life may be considerably increased, both at a.c. and at d.c. operation.

REMARK The data are valid for quadrant *I* of the breakdown characteristic (V_a and V_{st} positive) for the operation in which the tube is recommended. The tube must be exposed to some light. Full sunlight or complete darkness should be avoided.

[1]) Tube exposed to some light. Full sunlight or complete darkness should be avoided.

[2]) Recommended value of I_k : > 8 mA.

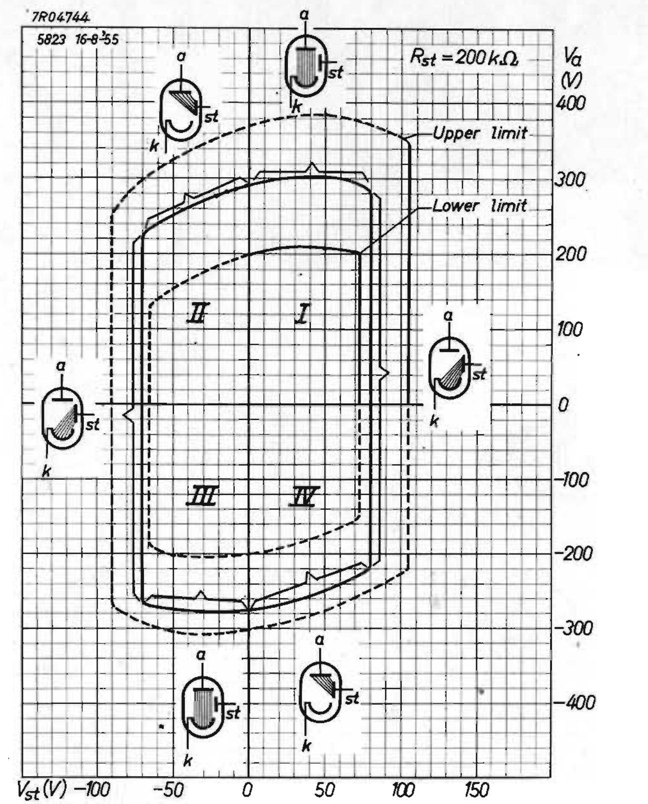


Fig.61. Breakdown characteristic of the trigger tube 5823. The different sections of the loop refer to a discharge between the electrodes as indicated schematically.

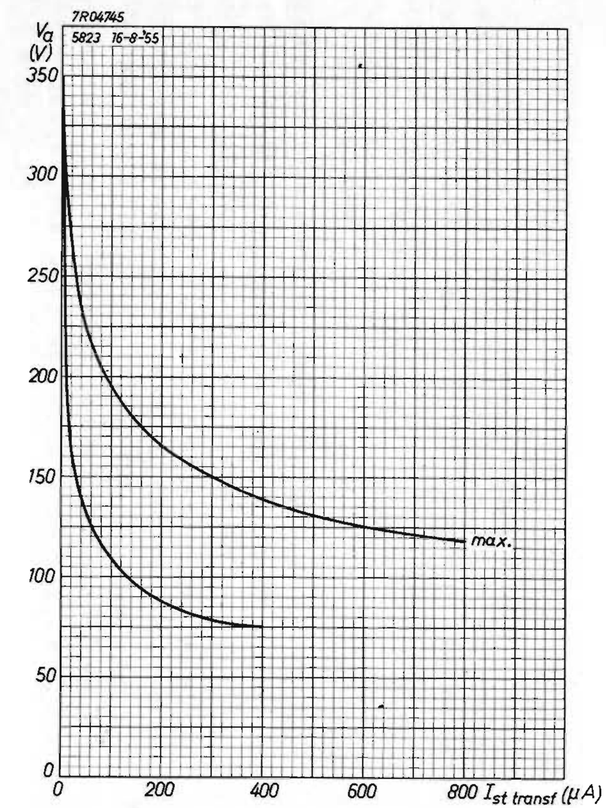


Fig.62. Transition characteristic i.e. breakdown characteristic for the space between anode and cathode of the 5823 as a function of the starter current.

TRIGGER TUBE Z 50 T

The Z50T is a cold-cathode trigger tube for use as a switching tube for the "on-off" control of lowcurrent electrical circuits. Visual control of the tube is possible by the presence or absence of a bluish glow. The current supplied by the Z50T is sufficient for operating a small relay, the large difference between the anode voltage before and that after breakdown of the anode cathode gap being of advantage.

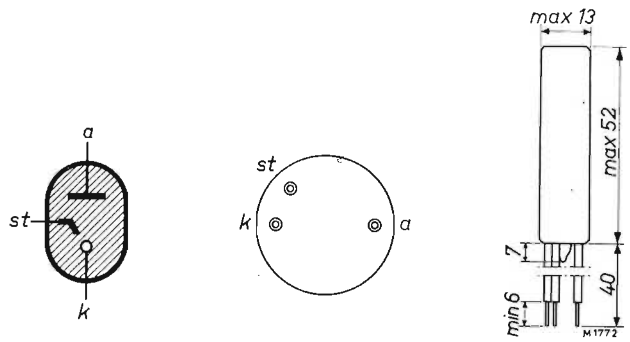


Fig. 63. Dimensions and electrode connections of the Z 50 T.

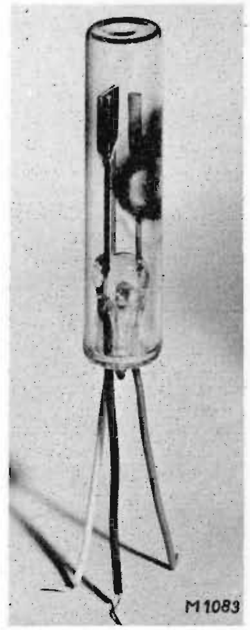


Fig. 64. Trigger tube Z 50 T.

A feature of the Z50T is its space saving dimensions, which make the tube very suitable for application in telecommunications and in industry. Important are further the small tolerances of the ignition and burning voltages which are valid during life, provided the tube ratings are not exceeded.

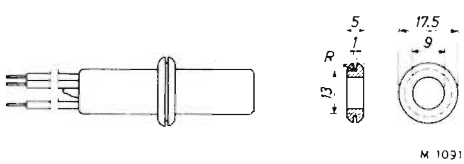


Fig. 65. Dimensions of rubber supporting ring.

The Z50T is supplied with a rubber supporting ring (fig. 65), which facilitates the mounting in front plates, etc. and prevents the tube from being subject to shock and vibration. The connecting leads of the tube can be soldered directly in the wiring.

TYPICAL CHARACTERISTICS

Anode voltage below which breakdown will not occur in any tube..................	V_{aign}	=	min.	175 V
Typical starter to cathode breakdown voltage...............................	V_{stign}	=		71 V [1])
Starter to cathode voltage, below which breakdown will not occur in any tube..	V_{stign}	=	min.	66 V [1])
Starter to cathode voltage, above which breakdown will occur in all tubes.....	V_{stign}	=	max.	90 V [1]) [2])
Anode burning voltage (I_a = 2 to 6 mA)......	V_a	=	min. nom. max.	54 V 61 V 67 V
Starter transfer current at V_a = 130 V...	I_{sttr}	=	nom. max.	50 μA 100 μA
Ionisation time.........................	T_{ion}	=		50 μsec [3])
De-ionisation time.....................	T_{dion}	=		200 μsec

For footnote see next page.

LIMITING VALUES (absolute limits)

Average continuous cathode current	I_k	= min.	2 mA [2]
		max.	6 mA [4]
Forward cathode current	I_{kp}	= max.	24 mA [4]
Ambient temperature	t_{amb}	= min.	-40 °C
		max.	+60 °C

LIFE EXPECTANCY AND MOUNTING

The life expectancy is 6000 hours current life at 6 mA d.c.

The tube should be so mounted that ambient light can impinge on the cathode. Tubes must be protected against shock and vibration; therefore it is recommended to use the rubber supporting ring type 40645 (see fig. 65). This ring should be mounted in a chassis aperture of 15 mm diameter (chassis plate 1 mm).

[1]) At anode voltage of 130 V and a capacitor between starter and cathode of 56000 pF tube exposed to some light; full sunlight or complete darkness should be avoided.

[2]) When anode current pulses with a short duration and an average current of less than 2 mA are applied (e.g. in oscillators, counting circuits), $V_{st\,ign}$ may increase to 95 V.

[3]) Tube exposed to at least 60 lux.

[4]) When used at a continuous current of a mA ($a > 6$), the tube life will be shortened by a factor of about $(6/a)^3$ to $(6/a)^4$.

SUBMINIATURE TRIGGER TUBE Z 70 U

The Z 70 U is a subminiature trigger tube with very small dimensions (bulb diameter 10 mm; height max. 25 mm). The Z 70 U has four electrodes; the extra electrode, the "primer", is a sharp pin that is very close to the anode. During operation a continuous glow discharge is maintained between the anode and the primer, so that some ions are always present in the tube. The main discharge can therefore be initiated without any delay, so that the tube can be used in complete darkness.

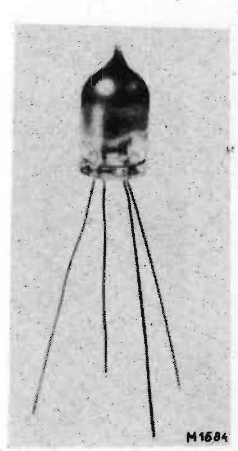


Fig. 66. Photograph of the Z70U (actual size).

Similar to the Z 50 T, the Z 70 U has connecting leads, which, together with its small dimensions, offer the possibility of mounting the tube in printed wiring.

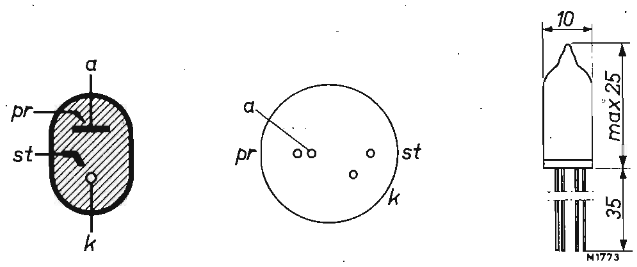


Fig. 67. Electrode arrangement, electrode connections and maximum dimensions in mm.

TYPICAL CHARACTERISTICS (Advance Data)

Anode voltage below which breakdown will not occur in any tube (cold)	V_{aign}	= min.	330 V
(warm I_a = 3 mA)	V_{aign}	= min.	310 V
Starter to cathode breakdown voltage	V_{stign}	=	145 ±6 V
Anode burning voltage (I_a = 3 mA)	V_a	=	118 ±3 V
Starter transfer current at V_a = 250 V	I_{sttr}	=	20 μA
Minimum resistance in primer circuit	R_{pr}	= min.	10 MΩ
Primer to anode voltage below which breakdown will not occur in any tube	V_{prign}	= min.	210 V
Typical primer current	I_{pr}	=	3 μA

LIMITING VALUES

Average continuous cathode current (T_{av} = max. 1 sec.)	I_k	= max.	3 mA
Forward peak cathode current	I_{kp}	= max.	12 mA
Maximum primer current	I_{pr}	= max.	5 μA

NOTES: The tube can be mounted in a metal clamp connected to the chassis.
During operation manual touching should be avoided.
The tube gives a bright glow when ignited.

NOVAL TRIGGER TUBE Z 804 U

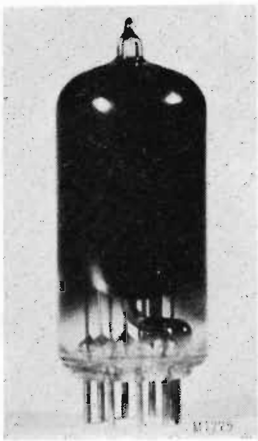


Fig.68. The Z 804 U.

The Z 804 U is a noval trigger tube with high reverse breakdown voltages. Due to this construction a 220 V a.c. mains supply has been made possible.

In this way inexpensive circuits can be obtained since in many cases no supply transformer will be required.

An important difference with the other trigger tubes mentioned in this bulletin is that the tube has been developed for use with a negative d.c. trigger voltage, which obviates breakdown between anode and trigger when the negative half cycle of the supply voltage is on the anode.

The tube can also be used with an a.c. trigger voltage at audio frequencies, as in this case the tube maintains its rectifying properties between anode and cathode due to the great difference in forward and inverse breakdown voltage at 50 μA starter current.

When an a.c. voltage of the same frequency as the anode voltage is applied to the trigger, care has to be taken that approximately 180° phase difference exists between both voltages.

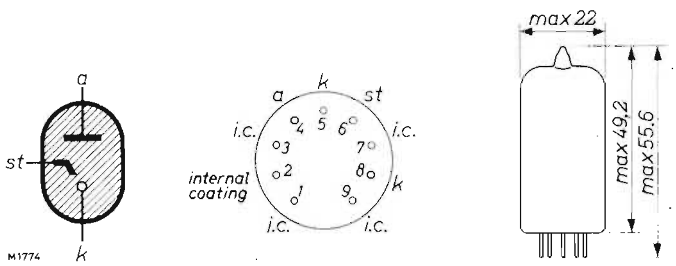


Fig.69. Electrode arrangement, electrode connections and maximum dimensions in mm.

TYPICAL CHARACTERISTICS (Advance Data)

TUBE HOLDER: Noval type 5908/46

Anode supply voltage	V_{ba}	=	200 - 250 V [1]
Anode voltage below which breakdown will not occur in any tube with starter at cathode potential	V_{aign}	= min.	400 V
Anode voltage above which breakdown will occur in all tubes at 50 μA transfer current	V_{aign}	= max.	160 V
Inv. anode voltage below which (abs. value) breakdown will not occur in any tube	V_{aign}	= min.	-400 V
Typical starter to cathode breakdown voltage at V_a = 160 - 400 V	V_{stign}	= appr.	-125 V
Starter to cathode breakdown voltage tolerance at V_a = 250 V			± 6 V
Anode burning voltage (I_a = 15 mA)	V_a	=	108 - 115 V
Continuous current range	I_a	=	5-25 mA [2] 5-40 mA [3]

REMARKS The tube is suitable for operation under any condition of light or darkness. The wall contact (pin 2) must always be connected to the cathode (pin 5 or 8) via a 2 MΩ resistor.

[1]) Alternating voltage. [2]) Rectified alternating current. [3]) Direct current.

Printed in Holland

20/241/D/E-1-'57