4

Multi-Electrode Gas Filled Counting Tubes And Their Circuits

4 Kc/s double pulse tubes are made by a number of manufacturers, each manufacturer having published different practical circuits for their use. The principle of operation and basic circuit requirements of this type of tube are discussed in Section 4·2, but the practical circuits for these tubes recommended by the various manufacturers are discussed in the section of the chapter covering the tubes of the manufacturer concerned. The principle of operation of other types of polycathode tubes is discussed together with practical circuits for their use in the section which covers the tubes of the particular manufacturer.

4.1 INTRODUCTION

One of the disadvantages of trigger tube counting circuits is that ten of the tubes are required in each decade. Great efforts have, therefore, been made to design cold cathode tubes one of which can replace ten trigger tubes in counting circuits; the resulting polycathode tubes are one of the most commonly used devices in medium speed counting equipment. Most of them can count at frequencies up to four thousand pulses per second, some up to twenty thousand, whilst two types can count at up to one million pulses per second.

Most polycathode tubes require a greater H.T. supply voltage than trigger tube counting circuits, but they usually pass a smaller current than trigger tubes. In common with most other cold cathode tubes, the polycathode counting tubes have a very long life when they are correctly used. The number of components required per decade is usually less when a polycathode tube is being used than when trigger tubes are employed, but a more complicated input circuit may be necessary.

4.1.1 Construction

In practice, simple polycathode gas filled tubes for decade counting usually consist of twenty, thirty or forty cathodes placed around a single common anode. Groups of the cathodes are joined together internally so that the number of external connections is reasonably small. A discharge takes place between the anode and one of the cathodes when the tube is in operation and a 'negative' glow is formed. The position of the glow can be observed through the dome of the glass envelope and provides a visual indication of the state of the count. Most of the tubes are fitted into an escutcheon on which the digits are marked, but a few of the tubes do not require an escutcheon.

The tubes have the same basic properties as the simple cold cathode gas filled tubes described in Chapter 3. The striking voltage is normally much greater than the maintaining voltage. If a discharge is taking place to one of the cathodes, it can be transferred to an adjacent cathode by the application of a negative going pulse to the latter. The coupling between the two cathodes takes place automatically by means of the ions provided by the discharge at the first cathode. Cathodes adjacent to the discharge are much more strongly primed than any of the other cathodes.

The coupling components which are used in trigger tube circuits are not required when polycathode tubes are used. No priming electrodes are required, since a discharge is always taking place to one of the cathodes when the tube is in operation. After the transfer has taken place, the discharge to the cathode which was initially glowing is normally extinguished automatically by the fall of anode voltage. In some of the earlier polycathode tubes, however, an additional positive going pulse had to be applied to the cathode which was to be extinguished at the same time that the negative going pulse was applied to the cathode to which the glow was about to be transferred[1].

4.1.2. Types of Tubes

If a tube contains only ten cathodes around a common anode, the glow can be made to move from cathode to cathode by suitable successive negative going pulses applied to each succeeding cathode in turn. This is the principle of the indicator tube to which pulses are fed from a counting circuit. Such a simple tube with only ten cathodes cannot actually perform the counting operation itself, since a circuit is said to be able to count only if it changes its state when successive input pulses are fed into the circuit along the same wire. Indicator tubes (as opposed to counting tubes) require pulses to be fed successively to each of the cathodes along different wires; they are described in Chapter 10.

In counting tubes at least one additional cathode (known as a transfer or guide cathode) is placed between each two adjacent main cathodes. The discharge does not remain at any transfer cathode for more than a very short time. The main cathode at which the glow rests corresponds to a certain digit which can be read from the escutcheon which surrounds the domed end of most of the tubes. If only one transfer cathode is employed between each two main cathodes, all of the transfer cathodes are normally connected together. Negative going pulses to be counted are applied to all of the transfer cathodes, but the discharge can move only to a transfer cathode which is adjacent to the main cathode which is initially glowing, since no other transfer cathode is appreciably primed by the ions from the discharge. At the end of the pulse the discharge is made to travel from the transfer cathode to the next main cathode, usually by means of a positive bias which is applied to the transfer cathodes.

4.1.3 Asymmetrical Tubes

If only ten transfer electrodes are employed and they are all connected together, the electrode geometry must be asymmetrical so that the discharge can travel around the tube only in the desired direction. For example, the main cathodes may be so shaped that the discharge can pass only to the transfer electrode which is one step in a clockwise direction from the main cathode which is initially glowing. The discharge may be prevented from returning to the previous main cathode at the end of the pulse by the effect of a parallel capacitor and resistor from each main cathode to earth. Whilst the discharge remains at a main cathode the capacitor charges and subsequently holds this cathode at a positive potential whilst the discharge is at the succeeding transfer cathode. This technique employing directional main cathodes is used in the S.T.C. G10/241E 'Nomotron' counting tube.

In other types of counting tubes both the main and transfer cathodes are directional. The counting speed is then not limited to such an extent by the effect of the cathode circuit time constant, since the latter does not control the direction of rotation of the discharge. The Elesta EZ10B tube employs this principle. Tubes which use directional asymmetrical electrode structures cannot be used for reverse counting (subtraction).

4.1.4 Symmetrical Tubes

In many other types of tube two transfer electrodes are employed between each two of the main cathodes. The tubes themselves are symmetrical in each direction and the direction of the rotation of the discharge is determined by the timing of the applied input pulses. All of the transfer cathodes which are on the clockwise side of the main cathodes adjacent to them are joined together and are known as the first guides (see Fig. 4.1). Similarly all of the transfer electrodes which are on the anticlockwise side of the adjacent main cathodes are joined together and are known as the second guides.

In operation a negative going pulse is applied to the first transfer electrodes to cause the discharge to move one step and a fraction of a second later another pulse is applied to the second guide electrodes so that the discharge moves another step. Finally, the discharge moves to the next main cathode at the end of the second guide pulse. Such tubes are known as double pulse tubes, since two successive pulses are required for each counting operation. Three distinct stepping operations take place each time a count is registered. Examples of those tubes operating on this particular principle are the Mullard Z504S, the Ericsson GC10B and the Sylvania 6476.

Another type of symmetrical tube has ten main cathodes and thirty transfer cathodes surrounding a common anode. The Ericsson GC10D is a tube of this type and is known as a single pulse Dekatron, since only one pulse is fed to the circuit to operate this tube.

4.1.5 Counter and Selector Tubes

The 'zero' main cathode of almost all tubes is brought out to a separate base pin so that an output pulse can be taken from it for triggering the next decade. In many counting tubes which are intended for use in simple straightforward counting circuits, the other nine main cathodes are brought out to a single common base pin. Such tubes are known as counter tubes.

Some tubes, such as the Mullard Z504S and the Ericsson GS10C/S, have each main cathode connected to a separate base pin so that an output pulse can be obtained from the circuit after any desired number of counts. This pulse may be used to initiate some external action. Such tubes are known as selector tubes and must be used when electrical readout from any cathode is required. They can perform any function which can be carried out by counter tubes.

Counter tubes can sometimes be manufactured rather more cheaply than the equivalent type of selector tube. In addition, the user of counter tubes has fewer soldered connections to make than the user of selector tubes.

Some tubes are also manufactured in which some but not all of the main cathodes are connected to separate base pins; they are useful in bidirectional counting circuits. A typical example is the Ericsson GC10/4B.

4.1.6 Scale of Twelve

Cold cathode tubes are available with ten main cathodes for decade counting and also with twelve main cathodes for counting on a scale of twelve. Other types of counting tubes, such as E1T tubes and Trochotrons, are not manufactured for scale of twelve operation, presumably because of a lack of demand.

Scale of twelve tubes are useful when pence are to be counted, since one output pulse is provided for each twelve pence counted. Tubes with twelve main cathodes are also useful dividing the number of input pulses by three, four, six or twelve (for example, in conjunction with a decade tube for converting one pulse per second into one pulse per minute).

4.1.7 The Operation of Numerical Indicator Tubes

The Ericsson GCA10G counter and GSA10G selector tubes can be used to drive numerical indicator tubes directly, ten additional anodes being provided in each tube for this purpose. Other cold cathode decade tubes require ten amplifier stages per decade if readout by means of a numerical indicator tube is required.

4.1.8 Maximum Counting Speed

The maximum counting speeds quoted in this Chapter are those stated by the manufacturers of the tube concerned. In some cases operation at considerably greater speeds can be obtained if a stabilised power supply and close tolerance components are used and if the input pulses are accurately controlled in amplitude and duration. Some manufacturers seem to be rather more conservative in their maximum frequency ratings than others. Generally, however, it is not wise to attempt to appreciably exceed the maximum counting speed quoted by the manufacturers of the tube if a reliable counting circuit is required.

Some indication of the safety margin which is available for any tube when it is operating at a certain speed may be obtained by varying the anode resistor (and hence the anode current) of the tube when it is operating at that speed in order to ascertain the anode current range for satisfactory operation. The actual readings of the anode current should be taken whilst the discharge is stationary in the tube. The anode current should not be allowed to exceed the maximum value for the tube concerned, although input pulse frequencies greater than the maximum recommended for the tube being used may be tried. The anode current range over which satisfactory operation is obtained normally becomes smaller as the operating frequency is increased in the region of the maximum published frequency for the tube. A stabilised H.T. supply is, therefore, normally desirable if the maximum possible operating frequency is required at the expense of circuit simplicity. Tests for reliability of counting using various input pulse amplitudes and/or durations are also very helpful in assessing whether or not a particular tube will operate satisfactorily at a certain counting speed.

Most double pulse tubes have a maximum counting speed of about 4,000 pulses per second, but other types can operate at up to 10,000, 50,000 or 100,000 pulses per second. The single pulse GC10D and the S.T.C. Nomotron can operate at up to 20,000 pulses per second whilst the Elesta EZ10B and ECT100 can count up to one million pulses per second.

The maximum counting speed may be reduced at high temperatures (above about 60° C) owing to the increased pressure of the gas. Substances which can poison the electrode surfaces may also be given off from the glass envelope if the ambient temperature increases, but these substances will not settle on the cathodes if the discharge is circulated. The maximum speed of operation may also be reduced at temperatures below −15 °C.

4.1.9 Life

The life of most types of polycathode gas filled tube is normally many tens of thousands of hours (tens of years). If, however, the discharge is allowed to remain at one cathode and is never circulated, minute amounts of material may be sputtered from the electrodes and be deposited on the adjacent cathodes. The discharge characteristics are different for sputtered nickel and pure nickel[2] and after the discharge has rested at one cathode for a very long time, longer input pulses may be needed for the operation of the tube. The tube may then be considered to be at the end of its useful life, although longer pulses may be used to drive it at low speeds. The sputtered material from the cathodes may also darken the inside surface of the glass envelope.

Longer life can be obtained from some tubes if the discharge is circulated around the tube at least once per week. Alternatively in a multidecade scaler which is to be used at low speeds, the positions of the tubes may be interchanged about once per month so that none of the tubes are used in the slowest decade for more than a month at a time. These precautions are, of course, required only when the discharge is likely to remain at one cathode for a very long time.

Longer life may be obtained from some types of tube if a value of the anode current near to the minimum recommended value is used. This may, however, reduce transfer sensitivity and hence the maximum operating speed somewhat.

No current should be allowed to pass through a cold cathode tube in the reverse direction, since this will probably result in damage to the surfaces of the cathodes.

4.1.10 Design for Optimum Anode Current

The current flowing through the tube should be within the limits specified by the manufacturer. A current greater than the specified maximum value leads to excessive sputtering of material from the cathodes and to short life, whilst a current below the specified minimum value will result in reduced transfer sensitivity and hence to unreliable counting or reduced operating speed. High speed tubes generally require a greater anode current than the simple 4 kc/s double pulse tubes.

The potential across a cold cathode tube is almost independent of the current flowing through the tube provided that it is being operated in the 'normal' region of the characteristic. The current which flows through the tube can be calculated by applying Ohm's Law to the circuit:

$$V_b - V_m = I_a (R_a + R_k) \tag{1}$$

where

V_b is the H.T. supply voltage
V_m is the tube maintaining voltage
I_a is the tube anode current
R_a is the anode resistance
R_k is the cathode resistance

A minimum value for the H.T. supply voltage is quoted by the tube manufacturers. If a smaller supply voltage than this is used, the tube may not strike when the voltage is first applied. Since the tubes are not primed, there may be a delay of up to about a minute before they strike if a value of H.T. supply voltage near to the minimum recommended value is employed.

There is normally no upper limit to the H.T. supply voltage which can be used provided that the cathode current is kept within the rating of the tube by a suitable choice of resistor values. In most cases the H.T. supply need not be stabilised.

When the value of R_a has been chosen, the maximum value of the supply voltage may be calculated from the above equation by substituting for I_a the maximum permissible value of the tube current and for R_k the smallest value of resistor which is to be used in any of the cathode circuits of the tube. (The maximum current flows in that cathode circuit which has the smallest value of cathode resistor.)

Similarly the minimum value of the supply voltage may be calculated by using the same equation and substituting in it the minimum permitted value of the tube current and the largest value of cathode resistor which is to be used in any cathode circuit.

In the case of the GS10C/S, for example, let us assume that 100 kΩ resistors are used in alternate cathode circuits and that the anode resistor is 680 kΩ [2]. The maximum current will flow when the discharge rests at one of the cathodes which is directly earthed. The maximum permitted current for the GS10C/S tube is 550 μA and the maintaining voltage is about 192 V. The maximum supply voltage is, therefore, given by:

$$V_{b\,\max} = (0.00055 \times 680{,}000) + 192 = 566 \text{ V}$$

The minimum recommended anode current is 250 μA. The anode current will have its smallest value when the discharge is resting at one of the cathodes connected to a 100 kΩ resistor. The minimum supply voltage is therefore given by:

$$V_{b\,\min} = 0.00025(680{,}000 + 100{,}000) + 192 = 387 \text{ V}$$

This value is slightly below the minimum recommended value for reliable striking (400 V). The mean of the maximum and minimum values of H.T. supply voltage, that is 475 V, may be used as the H.T. supply voltage design value.

It might appear that this mean value could vary by ±90 V or have a 64 V R.M.S. ripple. If variations of this magnitude did occur, however, the change in current flowing through the cathode resistors would cause a variation of about ±10 V on the nominal output voltage of 30. This might well cause unsatisfactory operation of the circuits into which the output voltage is fed.

The circuits of some of the tubes are fairly critical and it is therefore usually advisable to employ a circuit which has been designed and thoroughly tested by the manufacturers of the tube concerned as the basis of any design for a piece of counting equipment.

4.2 4 kc/s DOUBLE PULSE TUBES

Some of the most commonly used cold cathode counter tubes function on the double pulse principle [2–5]. The electrode structure of a double pulse selector tube is shown in Fig. 4.1. The anode is a circular metal disc placed near to the domed end of the tube (Plates 6 and 7). Thirty identical rods of small diameter are placed symmetrically around the anode; they are the main cathodes and the transfer cathodes. There are two transfer electrodes between each two main cathodes. All of the first guides are joined together and all of the second guides are joined together. In a counter tube (as opposed to a selector tube) the main cathodes K_1 to K_9 are also brought out to one common external connection.

The basic circuit for the normal operation of the tube is shown in Fig. 4.2. The tube may be represented as shown, the circular structure being illustrated as a linear one for convenience. The square brackets near each set of transfer electrodes indicate that

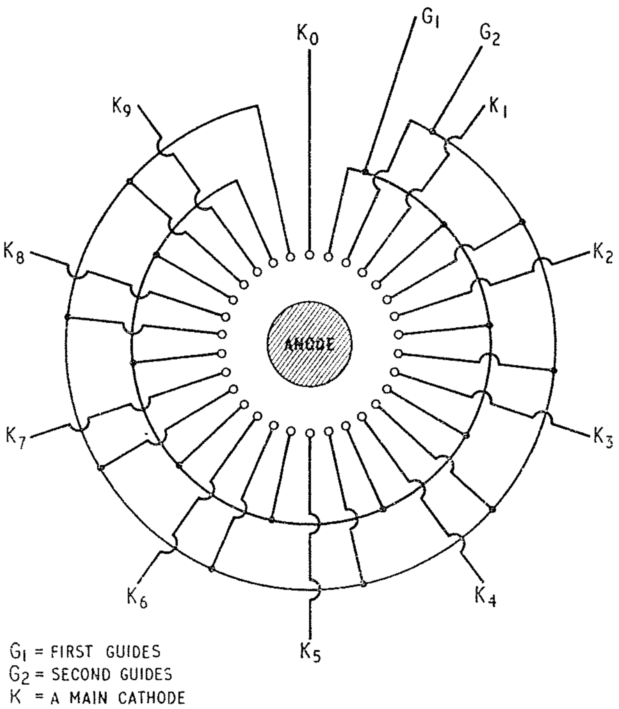
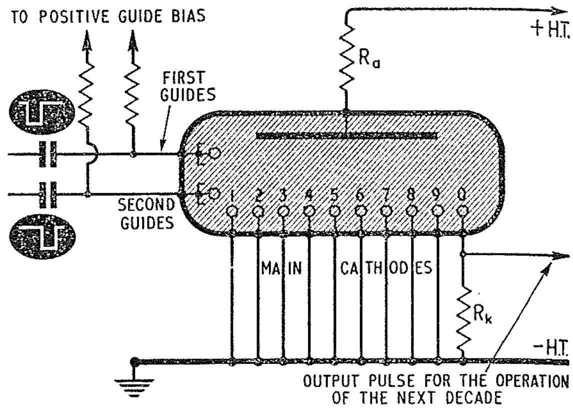


Fig. 4.1 The electrode structure of a double pulse selector tube

Fig. 4.2 The basic circuit for the operation of a double pulse tube



there are more than one first guide and more than one second guide in the tube.

The main cathodes are normally at earth potential whilst both sets of guide cathodes have a quiescent positive potential which is determined by the source of bias voltage. When an H.T. supply of over 400 V is connected to the circuit, one of the main cathodes will strike preferentially to any guide cathode, since the guide bias renders the anode to main cathode potential greater than the potential between the anode and any guide. As soon as ignition has taken place at any one main cathode, the potential between the anode and that main cathode will drop from the striking voltage to the maintaining voltage owing to the fall of potential across the anode resistor, R_a. The anode potential is then below the striking voltage to any other cathode and, therefore, the discharge will occur at only one main cathode.

4.2.1 Double Pulse Counting

The counting operation is performed in three stages. A negative going pulse is first applied to all of the first guide electrodes so that they fall in potential to a value which is appreciably below earth potential. In a typical double pulse tube with a maintaining voltage of 190 V, the priming effect of the ions from the discharge at the main cathode reduces the striking voltage at the two adjacent guide electrodes to approximately 200 V, whilst the striking voltage at the cathode three positions away is reduced to about 250 V[2]. If the glowing cathode is earthed, the potential difference between the anode and the first guide will be 200 V when the first guide potential has fallen to −10 V. The first guide which is adjacent to the main cathode, therefore, commences to strike when it is at this potential. No other first guide is sufficiently primed for striking to occur.

As the guide potential falls further, the current to the guide increases so that the operating point moves to the flat portion of the anode voltage/anode current characteristic where the voltage between the anode and the first guides is almost constant and independent of the current flowing. The anode potential falls with the potential of the first guides so that the potential difference between these electrodes is constant and equal to the maintaining voltage for the tube concerned. This fall of anode voltage results in the voltage between the anode and the main cathode falling below the maintaining voltage of this gap and the discharge to the main cathode is, therefore, extinguished.

The transfer characteristic of the tube for any two adjacent cathodes is of the form shown in Fig. 4.3. It can be seen that as the current passing to the cathode which is about to glow increases, the current passing to the cathode which was initially glowing decreases and the total anode current remains more or less constant.

It should be noted that the guide electrode, which is one position in an anticlockwise direction from the discharge at the main cathode, is a second guide. The discharge shows no tendency to move in an anticlockwise direction to this electrode, since the second guide electrodes are still receiving a positive bias.

The discharge has thus moved one step in a clockwise direction to the first guide and now primes the

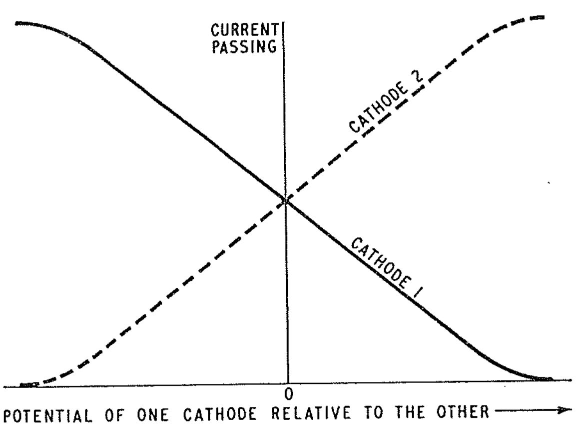


Fig. 4.3 The transfer characteristic for two similar cathodes in a cold cathode tube

succeeding second guide. If the pulse now ceased, however, the discharge would return to its original position at the main cathode owing to the positive guide bias.

When the discharge has been fully transferred to the first guide electrode, a negative going pulse is applied to the second guide electrodes so that their potential is reduced to a value which is appreciably below that of the main cathodes and which is approximately equal to that of the first guides which are still receiving a pulse. The pulse to the first guides terminates soon after the application of the second guide pulse and the first guide potential rises towards the bias voltage. The anode potential also rises so that the anode to first guide voltage is kept constant at the maintaining voltage of the tube. Soon the anode to second guide primed striking potential of about 200 V is reached. The second guide which is primed then strikes and the anode voltage falls until the anode to second guide potential is equal to the maintaining voltage of the tube. The anode to first guide potential is now below the maintaining voltage for this gap and the discharge at the first guide is extinguished. The discharge has now moved two positions clockwise.

Finally, when the second guide pulse terminates, the anode voltage again rises, since the anode to second guide potential tends to remain constant at the maintaining voltage. When the potential of the second guides reaches about 10 V above earth whilst returning to the quiescent bias potential, the discharge will move one further step in a clockwise direction to the next (primed) main cathode. There is obviously no tendency for the discharge to move in an anticlockwise direction to the first guide, since this electrode is at a positive potential with respect to the main cathode and the anode to first guide striking potential is, therefore, not reached. One of the purposes of the guide bias is to cause transference of the discharge to the main cathode at the end of the second guide pulse. The three successive stepping operations have now been completed and one count has been registered.

The guides are used to determine the direction in which the discharge rotates in the tube. If the second guides receive a negative going pulse and subsequently the first guides receive a similar negative going pulse just before the termination of the second guide pulse, the discharge will move in an anticlockwise or reverse direction. Circuits for addition or subtraction can, therefore, be constructed using double pulse tubes.

When the anode current flows to the zero cathode, K_0, the voltage produced across the cathode resistor (see Fig. 4.2) can be used to trigger the next decade. The output pulse is not suitable for feeding directly to the counting tube of the next decade, but must be fed into a coupling circuit which amplifies it, changes its polarity and converts it into the required double pulse.

4.2.2 Cathode Resistor and Guide Bias Values

If the cathode resistor is small in value compared with the anode resistor, an increase in the value of the cathode resistor will not appreciably affect the magnitude of the current passing through the tube. The output voltage available at the cathode will therefore be proportional to the value of the cathode resistor if the latter is small.

As the cathode voltage increases with increasing values of cathode resistor, however, it will approach the bias potential of the two sets of guides. Further increases in the value of the cathode resistor then merely cause more of the anode current to flow to the adjacent guides and less to the main cathode (see Fig. 4.3). Any increase in the output voltage as the value of the cathode resistor increases is then negligible[2].

Another effect occurs if the guides receive a large positive bias (say +100 V) in an attempt to prevent the above effect from limiting the output voltage. The maintaining voltage of the tube is virtually constant and as the cathode at which the discharge is occurring becomes more positive, the potential of the anode will increase by the same amount as that of the cathode. The non-glowing cathodes remain at earth potential, however, and therefore the potential between them and the anode has increased. The discharge may, therefore, spread somewhat to the adjacent cathode gaps and these may break down at an anode—cathode potential difference of about 250 V which corresponds to a cathode potential of less than +60 V. The glow is especially likely to jump back to the previous main cathode, however, if that cathode has not completely deionised.

The optimum value of the guide bias is normally a compromise between a high value which would result in limited tube life and a low value which would limit the output pulse amplitude. A guide bias of about +40 V is about the maximum which is recommended for 4 kc/s tubes; if this value of bias is used, an output pulse of about 35 V across a 150 kΩ resistor can then be obtained. Under carefully controlled conditions output pulses of 65 V across 200 kΩ cathode resistors have been obtained with a guide bias of +65 V[2], but these operating conditions are not recommended for general use.

4.2.3 Negative Cathode Bias

An increased output pulse amplitude can be obtained by returning the cathode load resistors to a source of negative voltage. For instance, if they are returned to a −20 V line, a 50 V output signal can be obtained if the cathodes rise to +30 V when passing a current. The anode potential will then rise to only +220 V (for a tube with a maintaining voltage of +190 V), so that there is no danger of an adjacent cathode striking. The bias potential of the output cathode may also be employed to bias the succeeding valve in the coupling stage to cut off, the cathode of the coupling valve being earthed.

When a negative bias is applied to the output cathode(s), the minimum amplitude of the pulses applied to the first guides must be increased by an amount equal to the negative bias. This ensures that the guides fall in potential by an amount which is sufficient to cause reliable transfer of the discharge from the negatively biased cathodes to the first guides.

It is not wise to return the output cathode load resistor to a bias voltage which is more negative than −20 V, or the discharge may transfer correctly from the output cathode to the first and second guides and then suddenly jump back to it, as it will still be primed somewhat and is at a greater negative potential than the succeeding main cathode. Most of the circuits published by the Ericsson Company for their tubes have the output cathodes returned via the cathode resistor to a −20 V line. The Mullard/Philips circuits employ a −12 V line for the same purpose.

The potential of any cathode which is used to generate an output pulse should not be allowed to rise to within ten volts of the positive guide bias potential or the glow discharge may fail to transfer from it to the succeeding first guide owing to the possibility of current sharing between the main cathode and the preceding second guide electrode.

The maximum recommended value of the cathode resistor in any main cathode circuit is given by the equation[4]:

$$R_{k\ \max} = \frac{(V_g + V_k - 10)R_a}{(V_b - V_m - V_g + 10)} \qquad (2)$$

the output voltage for any value of R_k is given by:

$$V_{\text{out}} = \frac{(V_b - V_m + V_k)R_k}{(R_a + R_k)} \qquad (3)$$

where V_g is the positive guide bias and V_k is the output cathode negative bias. The other symbols are as defined earlier for equation (1) in Section 4.1.10.

If the values of $V_g = +40$ V and $V_k = -12$ V (as recommended in Mullard/Philips circuits) are used, the maximum value of R_k is found to be 140 kΩ. The preferred value of 120 kΩ is, therefore, recommended and output pulses of 30 V are obtained[4].

4.2.4 Output Pulse Shape

When the discharge is transferred to the main cathode, the current does not increase very suddenly, but depends on the instantaneous value of the potential difference between the main cathode and the guide from which the discharge is transferred (see Fig. 4.3). The rate of rise of the leading edge of the output pulse is approximately equal to the rate of decay of the trailing edge of the second guide pulse. The transfer from the second guide to the main cathode may not take place at the same potential difference at various positions in the tube and there can be jitter in the time at which the leading edge occurs. The trailing edge of the output signal is produced by the leading edge of the first guide pulse which is usually quite sharp; the trailing edge of the output signal is, therefore, more suitable for use when the pulse is to be employed as a form of time marker[2].

The duration of the output pulse is approximately equal to the time during which neither set of guides is receiving a pulse.

4.2.5 Input Pulse Requirements

It is essential that the pulses applied successively to the two sets of guides should be of a suitable amplitude and duration and that they should be correctly timed with respect to each other. Transfer can be effected by a number of types of waveform, but for maximum speed of operation the optimum waveforms are rectangular pulses which have a slight overlap in time as shown in Fig. 4.4.

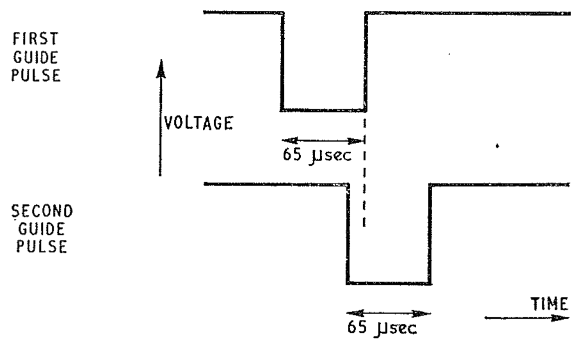


Fig. 4.4 Ideal rectangular negative going pulses for feeding to the first and second guides

It is not usually practical to construct input circuits which convert a single input pulse into two almost perfectly shaped rectangular overlapping pulses for the guides, although a suitable circuit for this purpose has been described[3]. In actual practice pulses similar to those shown in Fig. 4.5 are usually used. Although the second guide pulse is very different in shape from the ideal pulses of Fig. 4.4,

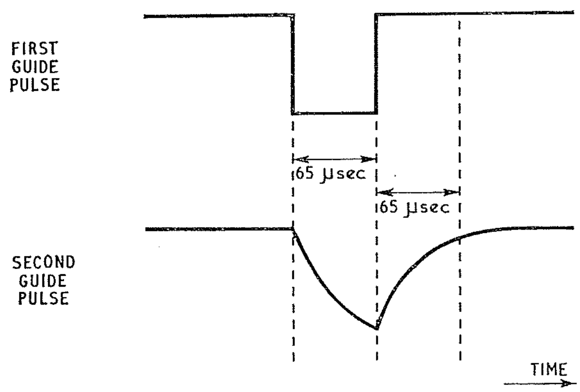


Fig. 4.5 Practical waveforms for 4 kc/s double pulse tubes. The second guides pulses are obtained by integrating the pulses applied to the first guides

the only disadvantage in the use of pulses of the shape shown in Fig. 4.5 is that the maximum operating speed of the tube is slightly reduced. The pulse for the second guides is normally obtained by integrating the first guide pulse by means of a simple resistance-capacitance circuit.

If the pulse to the second guides is applied too soon after the pulse to the first guides, the discharge will not have been fully transferred to the first guides and the preceding second guide will still be primed to some extent. The discharge will be pulled forward to the first and second guides at the same time as it is being pulled backwards to the preceding second guide with the probable result that no transfer at all will take place.

If the first pulse terminates appreciably before the beginning of the second pulse, the glow will transfer to the first guide, but during the interval between the two guide pulses it will return to the main cathode from which it came. When the second guide pulse is applied, it will move one further step in an anticlockwise direction to the second guide preceeding the main cathode at which the discharge initially rested. Finally at the end of the second guide pulse the discharge will return to the initial position at the main cathode.

New tubes may count correctly if a small gap is present between the two guide pulses, but a minimum overlap of one or two microseconds is essential if the tube characteristics have been affected by long stand-by periods[2].

4.2.6 Pulse Duration

The pulse applied to the first guides must be of sufficient duration for three successive processes to take place. First of all, the discharge must be established at the first guides and the anode to main cathode glow must be extinguished. Secondly, the priming of the succeeding second guide electrode must take place and, finally, the second guide preceding the main cathode which was initially glowing must have time to become deionised. These processes take a total time of about 65 μsec, but a nominal first guide pulse width of about 75 μsec is recommended so that an adequate allowance can be made for tolerances, etc.[4].

Similarly the pulse applied to the second guide electrodes must be of a sufficient duration for three similar processes to occur. The discharge must be formed at the second guide electrodes and extinguished at the first guides. Secondly, the succeeding main cathode must be primed. In addition the main cathode which was previously glowing must be deionised, but this last process can occur during the total time in which the pulses are applied to the first and second guide electrodes. The required pulse duration to the second guides is about the same as that to the first guides and a minimum of about 75 μsec is recommended[4].

If the guide bias is 40 V ±10%, it is recommended that the glow discharge should remain at each main cathode for at least 100 μsec[4].

4.2.7 Maximum Counting Speed

The total time occupied by the three separate steps is $75+75+100 = 250$ μsec. The maximum speed of operation is, therefore, about 4,000 pulses per second.

4.2.8 Pulse Amplitude

The use of guide pulses of fairly large amplitude generally results in the most reliable counting. The upper limit of the pulse amplitude is set by the breakdown of the main cathode to guide gap which occurs at a potential of about 140 V. The guide to main cathode voltage should always be appreciably less than this figure or the adjacent main cathode may act as an additional anode, in which case the surface of the electrode would be ruined. In addition, if the guide pulses are too large in amplitude, it is possible for an unprimed guide to strike.

The minimum pulse amplitude which must be applied to the guide electrodes to accomplish the transfer is a function of the pulse duration. It is also dependent on the guide bias; the greater the positive guide bias, the greater the negative pulse voltage required to overcome this bias and to cause the transfer to occur.

If the minimum permissible pulse duration of 65 μsec is employed, the potential difference required between a primed cathode and anode for transfer is about 231 V for Mullard/Philips tubes. The amplitude of the pulse which must be applied to the primed guide cathode is $(231-V_m)$ where V_m is the maintaining voltage. This pulse amplitude is equal to approximately 35 V[4]. If the pulse length is increased to 100 μsec or more, the required anode to cathode potential is reduced to 214 V so that the negative guide pulses need have an amplitude of only about 18 V[4]. A further increase of pulse length will not reduce the required pulse amplitude

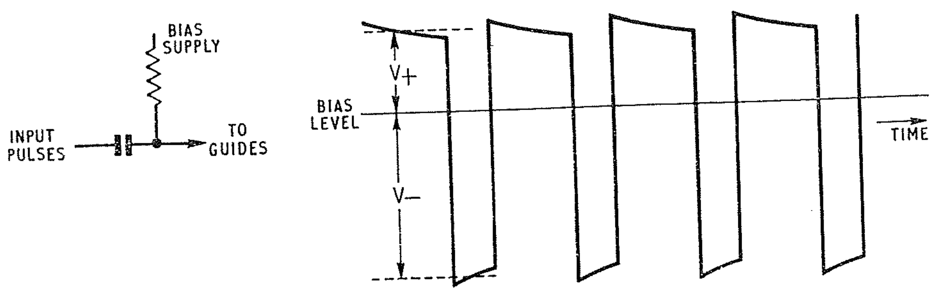


Fig. 4.6 Instantaneous guide potential plotted against time

any further. These figures apply to the least favourable tubes at the start of life.

An optimum anode to guide voltage during the pulse of $V_m+80\pm20$ V is recommended for Mullard/Philips 4 kc/s double pulse tubes. This is equivalent to applying a negative pulse to the first guide equal in amplitude to $V_g+80\pm20$ V where V_g is the positive guide bias voltage. It is also recommended that the second guides should receive a pulse of about the same amplitude. A positive guide bias of $+40$ V $\pm10\%$ is recommended[4].

If high speeds are not required, 4 kc/s double pulse tubes may be operated with a guide bias of $+8$ V. Pulses of -15 V in amplitude will then drive the tube. Under these conditions the maximum counting speed is about 700 pulses per second and the output signal amplitude is about 1 V[2].

The leading edge of the guide pulses should have a rise time exceeding 1 μsec or otherwise a discharge may occur between two of the leads which connect the electrodes to the tube base.

4.2.9 Guide Bias Circuit

When the pulses are fed to the guides through a capacitor, the effective value of the guide bias is different from the applied bias voltage. When a train of rectangular pulses is passed through a capacitor to the guides (Fig. 4.6), the potential at the guide is such that the area of the waveform above the horizontal line representing the applied bias is equal to the area below this line. If the pulse applied to one set of guides is 60 μsec in duration with interpulse spacings of 190 μsec and the total voltage swing $(V_+ + V_-)$ is 80 V, it can easily be shown that V_+ will be 19.2 V. V_+ is effectively added to the steady bias applied to the guides. If the repetition rate is halved, the interval between the pulses becomes 440 μsec and V_+ falls to 10 V. Thus if either the pulse amplitude or the mark to space ratio can vary and the tube is to be operated at fairly high speeds, it is essential to use clamping diodes to ensure that the guide bias is kept constant[2].

The internal resistance of the bias supply for the guides (R in Fig. 4.7) also requires some consideration. Immediately after a pulse is applied to the guides, the coupling capacitor, C, begins to charge from V_g through the resistor R and also from the current passing through the tube; this charging current also passes through the internal resistance

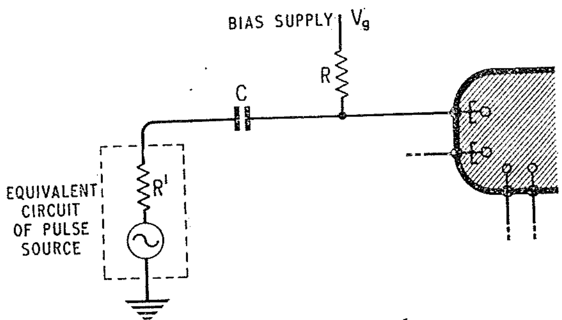


Fig. 4.7 Bias supply impedance

R' of the source of the guide pulses. The potential of the guide rises and if C is small it may rise so much that the discharge moves from the guide whilst the pulse is still being applied to it. R and C should, therefore, be large during the time that the pulse is applied so that C does not charge appreciably from V_g.

At the end of the guide pulse, however, it is desirable that R and C should be small so that C can be discharged through R and R' in series before the next pulse arrives.

In practice one satisfactory arrangement consists in the use of a fairly large value for C and a diode for R[2]. The diode presents a large impedance during the pulse, but its resistance is very low as C discharges by sending a current through it in the forward direction. The use of a potentiometer to supply the guide bias for a number of double pulse tubes is only permissible when the potential divider resistance values are so low that the guide currents of all stages together cause a bias change of only a few volts. Adequate decoupling should be provided.

4.2.10 Basic Guide Integrator Circuit

Normally two suitable separate input pulses are not available for the operation of a double pulse tube and therefore the pulse required for the second guides must be obtained from that applied to the first guides. In practice the second guide pulse is almost always obtained by passing the first guide pulse through a simple integrating circuit (see Fig. 4.8). The pulse is delayed by the desired amount, but its amplitude may be reduced somewhat by the integrating circuit. The circuit design is fairly critical, since a compromise between the desired second guide pulse amplitude, width and delay must be made. Numerous pulse shapes are possible, but satisfactory results will normally be obtained if a voltage at least equal to the minimum recommended transfer voltage is maintained for at least the minimum recommended transfer time with a suitable overlap. The form of the integrated second guide pulse is shown in Fig. 4.5.

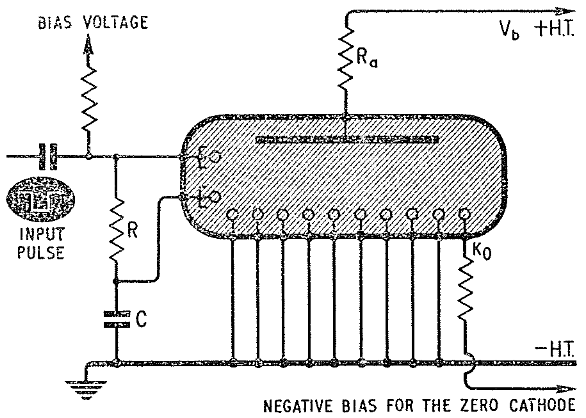


Fig. 4.8 The basic RC integrator circuit for obtaining the two guide pulses from a single input pulse

When the negative going input pulse of about 120 V in amplitude is applied to the input of the circuit of Fig. 4.8, the first guide potential falls and the capacitor C begins to charge from the negative pulse. The time constant for this charging is determined by the values of R and C; by a suitable choice of these components the potential of the second guides can be made to reach the transfer potential after any desired time.

At the end of the input pulse the first guide potential rises immediately to the guide bias voltage, but the capacitor C takes time to discharge through the resistor R and the bias supply resistors. The second guide potential thus rises exponentially to the guide bias level as shown in Fig. 4.5 and the transfer is then complete.

4.2.11 Anode Capacity

If the tube anode to cathode capacity is excessive, the anode potential may be prevented from rising rapidly as the guide potential rises at the end of the second guide pulse. The anode to second guide potential may then fall below the maintaining voltage of the tube so that the glow is extinguished. The anode voltage will rise and ignition may occur at any of the ten main cathodes. This difficulty is most likely to occur when the trailing edge of the second guide pulse is steep; for this reason the slope of the trailing edge should not exceed 100 V/μsec[2]. Stray anode circuit capacitance should also be minimised by soldering the anode resistor directly to the tag of the tube base. The problems associated with the anode circuit capacity become much more acute when high speed cold cathode tubes are used.

4.2.12 Reset

When a discharge is present at any place in a 4 kc/s double pulse tube, the striking voltage of any anode to cathode gap does not exceed about 300 V. The ischarge may, therefore, be reset to zero (or, in the ase of a selector tube, to any desired digit) by ausing the above potential difference to be present or a short time across the gap to which it is desired o transfer the discharge. There are two basic nethods by which this may be accomplished[2].

If the glowing cathode is earthed, the anode otential will be about +190 V with respect to arth. If any other cathode receives a pulse which educes its potential to at least 110 V below earth otential, this cathode will strike. The anode voltage vill fall to +80 V so that the potential across the ube is equal to the maintaining voltage. The cathode which was initially glowing will therefore be xtinguished.

Alternatively the cathode to which it is desired o transfer the discharge may be left at earth potential and all of the other cathodes may be pulsed to at least 110 V above earth potential. The anode potential will commence to rise towards +300 V, but as soon as the discharge strikes at the desired anode–cathode gap, the anode potential will fall again to +190 V. This is only +80 V higher than the potential of all the other cathodes and the discharge to the cathode which was initially glowing will, therefore, be extinguished.

Practical circuits for double pulse tubes have been designed by a number of manufacturers; typical examples are included in Sections 4.3–4.5.

4.3 MULLARD/PHILIPS COLD CATHODE DECADE TUBES AND THEIR CIRCUITS

Double Pulse 4 kc/s Counter: Z303C (CV2271).
Double Pulse 4 kc/s Selectors: Z502S (CV2325) and Z504S.
Double Pulse 50 kc/s Selector: Z505S.
Tube requiring no coupling amplifier between stages: Z302C.

4.3.1 4 kc/s Double Pulse Tubes

The same circuits may be used for all three of the electrically similar 4 kc/s double pulse tubes. The Z303C is a counter tube with an international octal base. The Z502S has a B12E base with a bottom cap which projects through the centre of the base, whilst the smaller Z504S has a B13B base.

4.3.2 The 4 kc/s Mullard Input Circuit[4]

The recommended Mullard input circuit for double pulse 4 kc/s tubes is shown in Fig. 4.9. The E88CC double triode is used in a cathode coupled monostable circuit which generates the required rectangular pulse of 75 μsec duration when it is suitably triggered. The first guide pulse is passed to the integrating circuit $R_{12}C_5$ and the resulting pulse is fed to the second guides. The circuit will operate a double pulse tube over the range 0 to 4 kc/s with a supply voltage tolerance of ±10%. In this type of circuit the amplitude and width of the guide pulses are independent of the normal variation in the valve characteristics during life.

The triode *V*2a is normally conducting whilst *V*2b is normally cut off by the bias developed across R_4 by the current flowing to *V*2a. The grid potential of *V*2a and hence the cathode potential of both triodes is determined by the values of the potential divider R_1, R_2 and R_3 which are chosen to provide a nominal cathode voltage of 78 V for the triodes. This cathode voltage determines the anode current which will flow when *V*2b is switched to the conducting state.

When a suitable negative going pulse is fed into the circuit of Fig. 4.9, *V*2a is cut off and this results in the bias to *V*2b being reduced. This triode, therefore, conducts. The capacitor C_3 maintains the potential at the grid of *V*2b at nearly its quiescent level, since this capacitor discharges relatively slowly through R_7.

The anode current of *V*2b is determined by R_4 whilst the anode load (which is effectively R_6 and R_{12} in parallel) determines the amplitude of the first guide pulse (120 V). The capacitor C_2 discharges through R_3 and R_6 and *V*2a will return to its original conducting state after a time determined by C_2R_3 (R_6 is small compared with R_3). The values shown in Fig. 4.9 have been chosen so that the circuit returns to its original state after 75 μsec.

When *V*2b returns to its quiescent condition, a positive pulse occurs at its anode. This pulse is prevented from reaching the guide electrodes of the

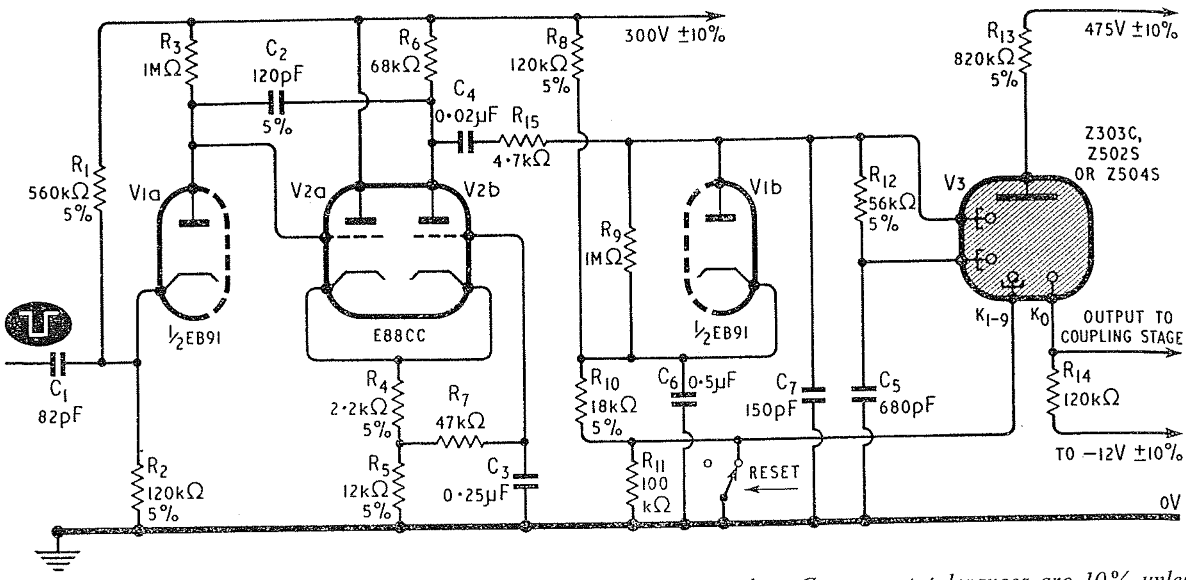


Fig. 4.9 An input circuit for the Mullard Z303C, Z502S or Z504S tubes. Component tolerances are 10% unless otherwise stated

counter tube by the diode $V1$b. Thus the guides do not rise above the bias potential.

The diode $V1$a prevents the positive going trailing edges of the input pulses from causing $V2$ to return prematurely to its quiescent condition.

Input Pulses

The negative going leading edges of the input pulses should have slopes of not less than 10^8 V/sec and their amplitude should not be less than 30 V for satisfactory operation of the input circuit of Fig. 4.9.

The time constant of $R_{12}C_5$ which determines the form of the second guide pulses is 38 μsec. The second guide pulse width varies from 80 to 90 μsec as the supply voltage varies from +10% to −10% of its nominal value. Both guide pulse amplitudes can vary by about 10 V in either direction from the nominal value of 120 V as the supply voltage varies within the permitted tolerances.

4.3.3 Mullard Valve Coupling Circuit for 4 kc/s Tubes

The amplitude of the output pulse from the zero cathode of $V3$ in the circuit of Fig. 4.9 is about 42 V; the maximum positive potential reached by this cathode is, therefore, 30 V. The output pulse is positive going and its duration can vary from 100 μsec upwards depending on the length of time for which the discharge rests at the zero cathode of the counter tube. If this pulse is to be used to drive a succeeding decade, it must be fed into a coupling circuit which will convert it into a negative going rectangular pulse of about 120V in amplitude and 75 μsec in duration.

A practical coupling circuit for coupling two decade counter tubes is shown in Fig. 4.10. Only one half of an E88CC double triode ($V2$) is used in the coupling stage; in a multidecade counter the other half of the E88CC tube may be used in a succeeding coupling stage.

When no discharge is present at the zero cathode of the preceeding counter tube, $V1$, the grid of the triode $V2$ is maintained at −12 V and the valve is cut off. When the discharge in $V1$ rests at the zero cathode, the grid potential of $V2$ rises and the valve conducts. The anode potential of $V2$ thus falls from that of the H.T. positive supply to about +100 V; this negative anode pulse is used to provide the pulses for the succeeding counter tube, $V3$. The potential divider R_6-R_7 taps off the required 120 V pulse for the first guides. The second guide pulse is obtained by integration of the pulse at the anode of $V2$.

$V2$ conducts for the whole of the time during which the discharge rests on the zero cathode of $V1$. This is 100 μsec upwards. The maximum frequency at which the first coupling circuit must be able to operate is, of course, 400 c/s which is one tenth of the maximum input frequency.

At high counting speeds (approaching 400 'carries' per second) the anode of $V2$ returns to the H.T. positive potential when the valve is cut off at the end of the pulse. The first guide electrodes

The potential divider R_3, R_4, R_5 and C_2 shown in Fig. 4.10 which is used to provide the bias and reset voltages may be used as a common supply for up to five further coupling stages.

Resetting to Zero[4]

The main cathodes and guides are normally returned to the H.T. negative line in Figs. 4.9 and 4.10 by the reset switch. If this switch is opened, the potential of all cathodes other than the zero cathode

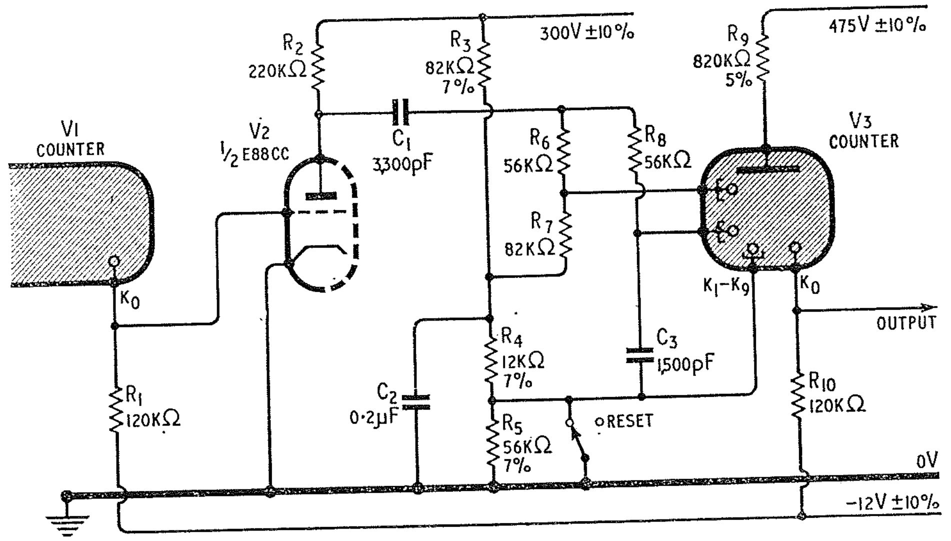


Fig. 4.10 A valve coupling stage for the Mullard Z303C, Z503S or Z504S tubes. Component tolerances are 10% unless otherwise stated

return to the positive bias potential and the discharge in $V3$ is transferred first to the second guides and then to the next main cathode.

At low counting speeds the transfer must be completed before the trailing edges of the pulses arrive from $V1$. The discharge transfers to the first guides by the same mechanism as at high speeds, but the transfer to the second guide and to the next main cathode depends on the rate of flow of charge to C_3. The transfer is always completed within 1 msec. The second guide pulse has a smaller effective amplitude (about 50 V) than the first guide pulse at low operating frequencies, but its duration is about 200 μsec which is long enough to ensure reliable counting. At the end of the pulse from $V1$ the guides may rise to a potential above the guide bias voltage for up to about 1.5 msec.

rises to +120 V and the anode rises towards +310 V. The striking potential of the anode to zero main cathode gap is therefore exceeded. When this gap strikes, the anode potential falls and discharges in any other positions are extinguished.

A relay or a manually operated switch may be used for the resetting switch; it must remain open for at least 5 msec. It is also possible to reset the tubes by the application of a negative going pulse with an amplitude of between 120 and 140 V to the zero cathodes of the counter tubes, but precautions must be taken to ensure that the stages which are reset do not pass pulses to the succeeding decades.

It should be noted that the circuit of Fig. 4.10 cannot be driven from the output of a counter tube which does not have its output cathode resistor

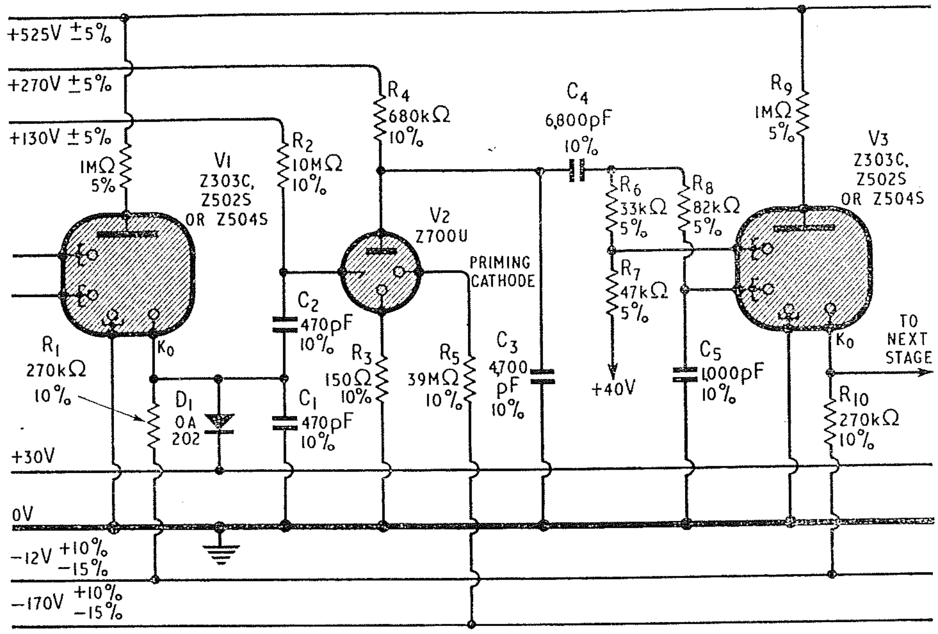


Fig. 4.11 A 40 c/s trigger tube coupling circuit

returned to a negative supply line of about −12 V. If the cathode resistor is returned directly to earth, the output pulse will probably be too small to operate the coupling circuit[4].

Preferred Tube

The Mullard/Philips special quality valve type E88CC has been specified for the circuits of Figs. 4.9 and 4.10, since the tube has a closely controlled tail characteristic which ensures that either triode is fully cut off when it is biased to −12 V. The E88CC also has the advantage that it is designed for long life where conditions of prolonged cut off may be encountered.

It is possible to use the ECC81 (CV455 or 12AT7) instead of the E88CC, but some current may be passed by a proportion of ECC81 tubes when biased to −12 V. The coupling circuit will then generate a smaller output signal which can result in faulty operation.

4.3.4 Trigger Tube Coupling Circuits[6, 7]

Trigger tube circuits have been designed which will couple two decade counting tubes, only one Z700U trigger tube being required in each coupling circuit for pulse shaping and amplification. The Z700U has been chosen because of its small size, low cost, low power consumption and short deionisation time which permits operation at frequencies up to 400 c/s. The tube feeding the coupling circuit can thus be used to count at up to its maximum speed of 4 kc/s.

Two coupling circuits will be described; one is suitable for operation at up to 400 c/s whilst the other is a slower but simpler circuit for operation at up to 40 c/s.

4.3.5 40 c/s Coupling Circuit[6, 7]

The circuit for use at frequencies up to 40 c/s is shown in Fig. 4.11. The output pulse from *V*1 is fed via C_2 to *V*2 which is ignited. The trigger of *V*2 also receives a positive bias from R_2. The *V*2 circuit is self extinguishing owing to the presence of R_4 and C_3. The negative anode pulse from *V*2 is used to operate the succeeding counter tube.

The maximum voltage which should be present at the zero cathode of *V*1 is 30 V. If a simple cathode resistor were to be used to return the output cathode to the −12 V line, the output volt-would depend on the exact values of the com-ents and of the supply voltage. This difficulty revented in the circuit of Fig. 4.11 by the use large K_0 cathode resistor—which alone would vide a pulse exceeding a peak value of 30 V ve earth—and by the use of a clamping diode n the K_0 electrode to the +30 V line as shown. soon as the output voltage tends to exceed 30 V ve earth, the diode conducts and prevents any ther rise in the output potential. The tolerance the amplitude of the output voltage is thus de-mined by the tolerance in the potential of the V line rather than by the wider variations in the unter tube current.

No Z700U tube will ignite at a trigger voltage wer than +137 V, whilst all Z700U trigger tubes ould ignite at trigger voltages of +153 V. A bias 130 V ±5% applied to the trigger electrode of 2 can be shown to ensure reliable operation with e component and supply voltage tolerances ecified(6–7).

The time constant of the components C_2R_2 must nsure self extinction and allow full recovery in e time of 25 msec between pulses at the maximum perating frequency of 40 pulses per second.

The capacitor C_1 is necessary to prevent spurious nition of $V2$ at the end of the pulse from $V1$. he manner in which these spurious pulses can rise in the absence of C_1 can be explained as ollows. When $V2$ is extinguished by the action of R_4C_3, the anode potential falls to about +60 V n 20 μsec and drags the trigger voltage with it. A negative going pulse of about 110 V can thus appear at the trigger electrode. This pulse is coupled to the output cathode of $V1$ which falls from about +30 to about −60 V. After $V2$ has been extinguished the current passing to the zero main cathode of $V1$ raises the potential of this cathode to +30 V—which is a 90 V step. This causes the trigger of $V2$ to rise from +60 to +150 V, which is enough to cause some Z700U tubes to strike.

When C_1 is incorporated in the circuit, it forms a potential divider in conjunction with C_2. If these two capacitors are equal in value, only half of the negative going pulse is fed from the trigger electrode back to the zero cathode and the resulting positive going pulse is much reduced in amplitude.

R_6 and R_7 should be large so that a large portion of the output energy from the anode of $V2$ is not wasted in the charging of C_4. On the other hand the total resistance of R_6, R_7 and R_8 should not be greater than 200 kΩ or the effective guide bias may rise due to the flow of guide current in these resistors. This could reduce tube life.

4.3.6 400 c/s Coupling Circuit (6–7)

The time constant for the rise of the anode voltage of $V2$ of Fig. 4.11 must be greater than 150 μsec for satisfactory self extinction of the circuit, but this time constant is too short to allow a satisfactory period of rest of the discharge at the first guides. If the time constants are increased to allow the discharge to remain for a suitable time at each of the guides, the maximum operating frequency is limited to 40 c/s.

The slightly more complicated circuit shown in Fig. 4.12 can, however, be used at frequencies up to 400 c/s; it is basically the same circuit as that of Fig. 4.11. The time constant of the trigger tube input circuit has been reduced to 560 μsec (C_2R_2), whilst C_1 of Fig. 4.12 has the smaller value of 100 pF so that the output voltage rise time is a small fraction of the $V2$ input time constant. Although the voltage available for igniting the trigger tube is slightly less than in the 40 c/s circuit, it is still sufficient, however, for satisfactory operation.

The d.c. restoring diode D_3 is added to return the effective guide bias to +40 V at the higher operating speeds. Its cathode is taken to +33 V to compensate for the forward voltage drop in the diode at the higher counting speeds. The addition of D_3 overcomes the objection to the use of larger values of the guide resistors R_6 and R_7 which have been increased in value to minimise the loss in pulse amplitude by the charging of C_4.

The $V2$ anode recovery time has been reduced by the return of R_3 to the 525 V line and the use of D_2 to clamp the anode voltage at the original H.T. level of +270 V as used to supply the trigger tube of Fig. 4.11. C_5 has been reduced to preserve the desired guide pulse amplitude whilst reducing the recovery time.

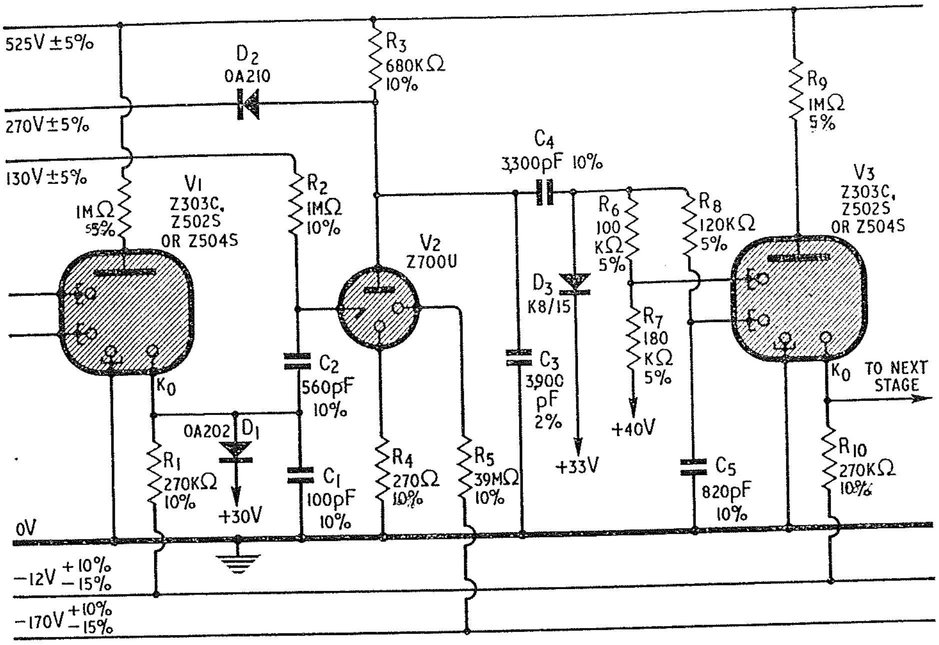


Fig. 4.12 A 400 c/s trigger tube coupling circuit

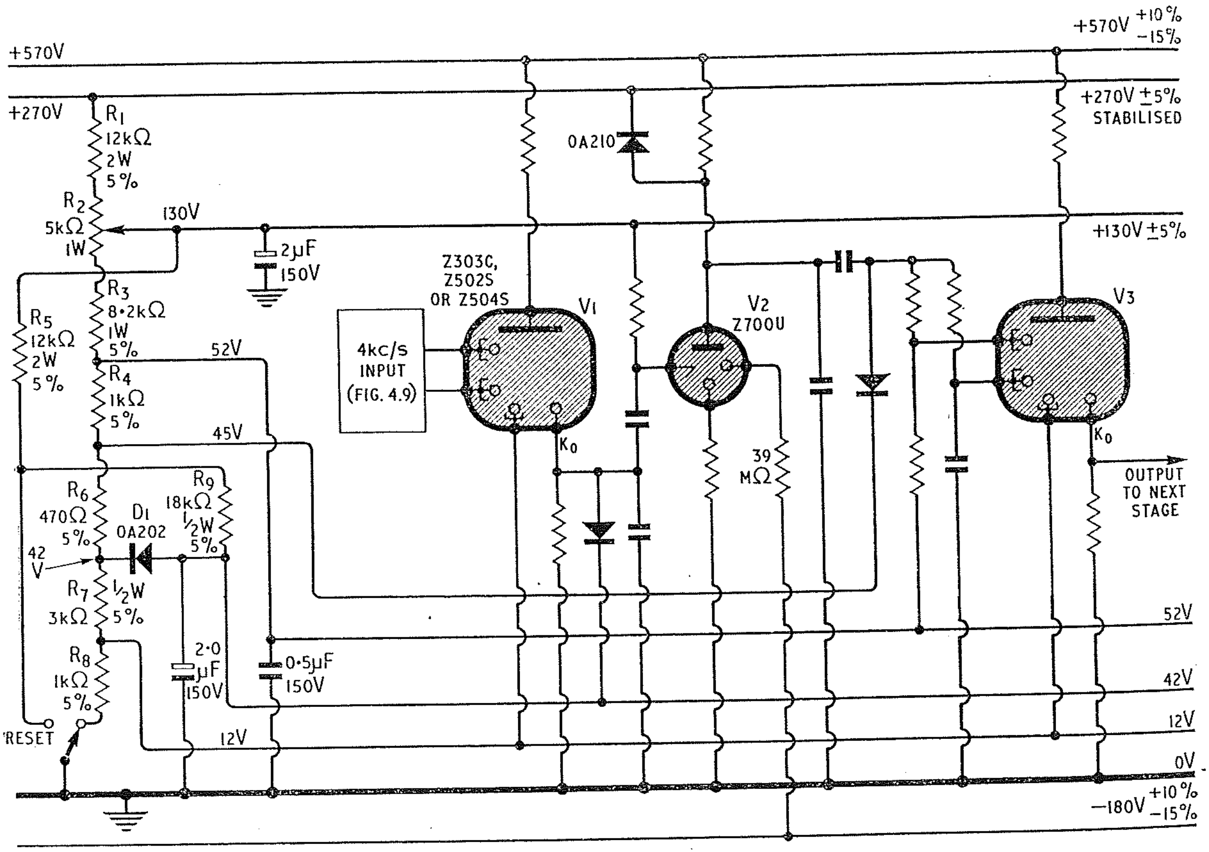


Fig. 4.13 A modified potential divider circuit for use with the power supply of Fig. 4.14. The values not marke are as in Fig. 4.12

Input Circuit

The input pulse to the 400 c/s circuit may be obtained from a counter tube which is fed from the 4 kc/s input circuit of Fig. 4.9. If the complete scaler in which the circuits are to be used will not be required to count at speeds above 400 c/s, a trigger tube circuit similar to the type shown in Fig. 4.12 may be used to operate the first counter tube.

In both the 40 c/s and 400 c/s trigger tube coupling circuits, the priming resistor of the Z700U tube is returned to a negative supply of −170 V so that the priming discharge is not extinguished when the anode circuit of the tube ignites and the anode voltage falls to about +60 V.

4.3.7 A Power Supply for Trigger Tube Coupling Circuits [6-8]

The power supply requirements of the trigger tube coupling circuits can be somewhat simplified if the circuit of Fig. 4.12 is rearranged as shown in Fig. 4.13 and similar modifications are made to the slower circuit of Fig. 4.11.

In order to avoid the necessity for a −12 V supply line for the zero cathodes of the counter tubes, these cathodes are returned to earth and the other counter tube main cathodes are returned to a +12 V tapping on the potential divider chain. The output cathode reference potential then becomes (32+12) = 42 V and the required guide bias level (40+12) = 52 V. The potential divider network shown in Fig. 4.13 is fed from the +270 V stabilised supply.

Reset

When the reset switch of Fig. 4.13 is operated, the potential of all of the main cathodes except the zero cathode increases to about +125 V and the discharge therefore moves to the zero cathode.

In order to prevent the output cathode diodes from being damaged by excessive peak inverse voltages, these diodes are effectively disconnected from the potential divider by the diode D_1 during the resetting operation. D_1 is returned to earth through R_9 and is thus reversed biased during the resetting operation. When the reset switch returns to its normal position, the capacitors connected from the +130, +52 and +42 V supply lines to earth prevent any excessive transient voltage rise in these line potentials.

4.3.8 The Power Supply Unit

Three power supply lines are required to operate the circuit of Fig. 4.13.

They are: (a) An unstabilised supply of +570 V
(b) A stabilised supply of +270 V
(c) An unstabilised supply of −180 V

All of these may conveniently be obtained from the circuit of Fig. 4.14 which employs a Z806W trigger tube for stabilising purposes. This tube has a very stable ignition voltage and this determines the degree of stabilisation obtained. The electrode shown connected to the junction of R_7 and R_8 in Fig. 4.14 is a screening anode, whilst the electrode connected to R_9 is the priming anode. The Z806W has a B9A base.

The 425 V R.M.S. supply from the transformer undergoes full wave rectification by the four diodes (D_1 to D_4) and C_1 is charged via D_5 and R_1. The resistor R_1 is included so as to reduce the rate of rise of the counter tube anode supply voltage and to prevent spurious breakdowns within the counter tubes immediately after the circuit is switched on.

When the potential of the anode of the Z806W tube rises to a predetermined value (270 V), the portion of this voltage tapped off by R_5 causes the tube to ignite. The voltage at the junction of R_2 and R_3 falls when the tube ignites and D_6 thus receives a reverse bias so that all of the current passes through the tube. At the end of the half cycle of the mains supply the trigger tube will be extinguished.

During the next half cycle the anode voltage of the tube rises until D_6 conducts and any charge which has passed from C_3 into the load is replaced so that the potential difference across this capacitor again rises to 270 V. The trigger tube then ignites and the diode D_6 is reversed biased so that no more current can flow through it until the next half cycle.

The diode D_5 prevents the capacitor C_1 from maintaining the potential of the tube anode at the maintaining voltage during the time when the

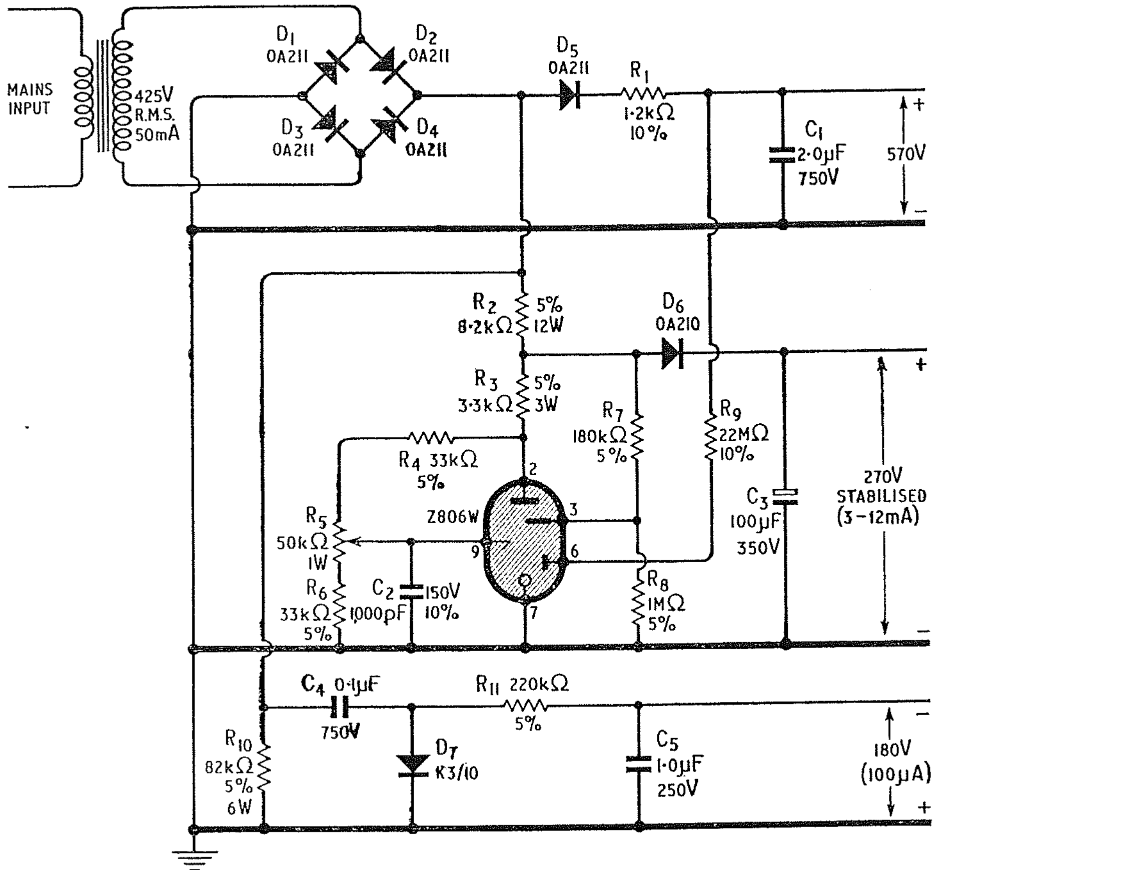


Fig. 4.14 The power supply for the scaler of Fig. 4.13

instantaneous voltage from the mains transformer is small.

The negative supply for the priming cathodes of the Z700U coupling tubes is obtained from the output of the bridge rectifier. The resistors R_{11} and R_{10} act as a potential divider and ensure that the charge on the capacitors cannot be fed back so as to hold the anode voltage of the Z806W at a value which would prevent the tube from being extinguished.

The circuit of Fig. 4.14 should not be operated without any load connected to the stabilised +270V supply or the current passing through the Z806W tube will be excessive. The tube current increases as the load decreases.

The variation in the stabilised output voltage of the circuit when loaded by a six stage scaler is less than 0.6%. The variable resistors R_2 of Fig. 4.13 and R_5 of Fig. 4.14 may be used for setting the 130 V and the 270 V lines to their nominal values. If a stabilised voltage other than +270 V is used to supply the circuit of Fig. 4.13, it is only necessary to modify the value of R_1.

The trigger tube coupling circuits which have just been described are very suitable for use in small or portable equipment owing to the small size of the tubes used, the low power dissipation and the absence of heaters. Each decade can be conveniently constructed as a module which may be plugged into the complete unit.

4.3.9 Transistor Coupling Circuit [9]

The circuit of Fig. 4.15(a) shows how transistors may be used to couple counting tubes. The output pulse from a counting tube is passed to an OC75 transistor current amplifier which feeds a pulse to a pair of ACY17 transistors employed in a cascode circuit. They drive the first guides of the succeeding counting tube, the second guide pulses being obtained by means of a modified integrator circuit. The cascode pair are used instead of a single transistor owing to the difficulty of obtaining a transistor with a sufficiently high voltage rating at low cost.

If the discharge in *V*1 is not at the ninth cathode, *T*1 is bottomed. *T*2 and *T*3 are also normally bottomed so that the first guides are at a potential which is only slightly smaller than the +45 V supply. When the discharge reaches the ninth cathode of *V*1, *T*1 is cut off and its collector potential falls. The flow of current through the emitter-base junction of *T*2 effectively clamps the base potential of this transistor to +45 V and no pulse is applied to *V*2.

When the discharge in *V*1 leaves the ninth cathode, *T*1 is bottomed again and a positive going edge of about 9.4 V in amplitude is applied to the base of *T*2. The cascode pair are thus cut off and a negative pulse is applied from the collector of *T*3 to the first guide. *T*2 and *T*3 remain cut off until the coupling capacitor has discharged to a point at which the base potential of *T*2 falls to the emitter potential. The duration of the pulse applied to the first guides is determined by the negative supply voltages and the time constant of the circuit which couples *T*1 to *T*2.

The second guide circuit has been designed so that the discharge remains at the second guides for at least 160 μsec. This is achieved by means of a diode and a 10 MΩ resistor through which current flows to complete the charging of the integrating capacitor.

A diode is used in the base circuit of *T*3 (and *T*6) to clamp the base voltage of these transistors to −9.4 V. When the cascode pair are suddenly cut off, the base current in each transistor is reversed. A considerable reverse current can flow until the stored holes are neutralised. If the diode were omitted, the base potential of *T*3 would fall to such an extent that the collector–base voltage rating of *T*2 would be exceeded.

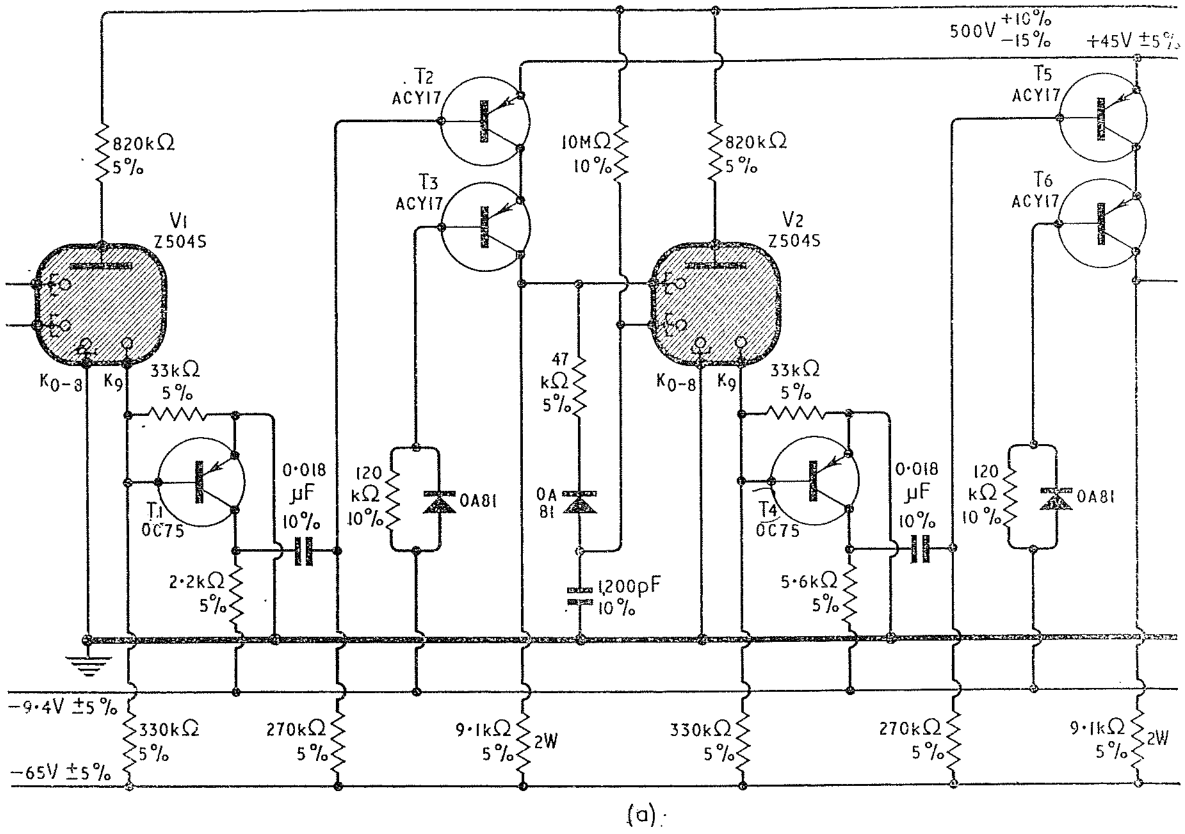
The value of the OC75 collector resistor must be small enough to allow the coupling capacitor to fully discharge during the time the glow rests at the ninth cathode. In the case of *V*1 this may be as short as 100 μsec if this tube is operating at 4 kc/s. A collector resistor of 2.2 kΩ is suitable. In any subsequent slower stages the resistor value may be increased to reduce the current consumption; a 5.6 kΩ resistor is recommended for any coupling stage after the first.

The circuit of Fig. 4.15(a) requires positive power supply voltages of 500 V at 0.5 mA per stage and 45 V at 12 mA per stage. A negative supply voltage of −65 V at 12 mA per stage is also required. The −9.4 V supply may be obtained from the −65 V line by the use of an OAZ207 zener diode; the current required from the 9.4 V line is 5 mA for the first coupling stage and 2 mA for each succeeding stage.

This type of circuit in which the coupling pulse is obtained from the ninth cathode of the counting tube has some advantages over trigger tube and hard valve coupling circuits in which the pulse is taken from the zero cathode when it is to be used for batching or timing operations. The delay per stage as a scaler based on the circuit of Fig. 4.15(a) moves from 09999 to 10000 is only about 2 μsec and this minimises errors in coincidence gating circuits.

It is probable that a complete transistor coupled stage (including the Z504S tube holder) can be made in module form with a volume less than 1 in^3.

The valve input circuit of Fig. 4.9 may be used for driving the first counting tube of Fig. 4.15(a), but it is usually more convenient to employ the transistor blocking oscillator driving circuit of Fig. 4.15(b).[9] Input pulses greater than 6 V in amplitude and not less than 2 μsec in duration can be used to drive the ACY17 transistor, *T*1, of the blocking oscillator circuit. A fairly large number of turns are employed on the secondary windings of the transformer so that the output pulses have an amplitude great enough to drive the decade tube, *V*1. The leading edge of the pulse from L_4 is used to drive the first guides, but the trailing edge cannot pass through the OA202 diode. The second guides are driven by the trailing edge of the blocking oscillator pulse; this is taken from L_5 so that it is of the correct polarity to drive the guides.



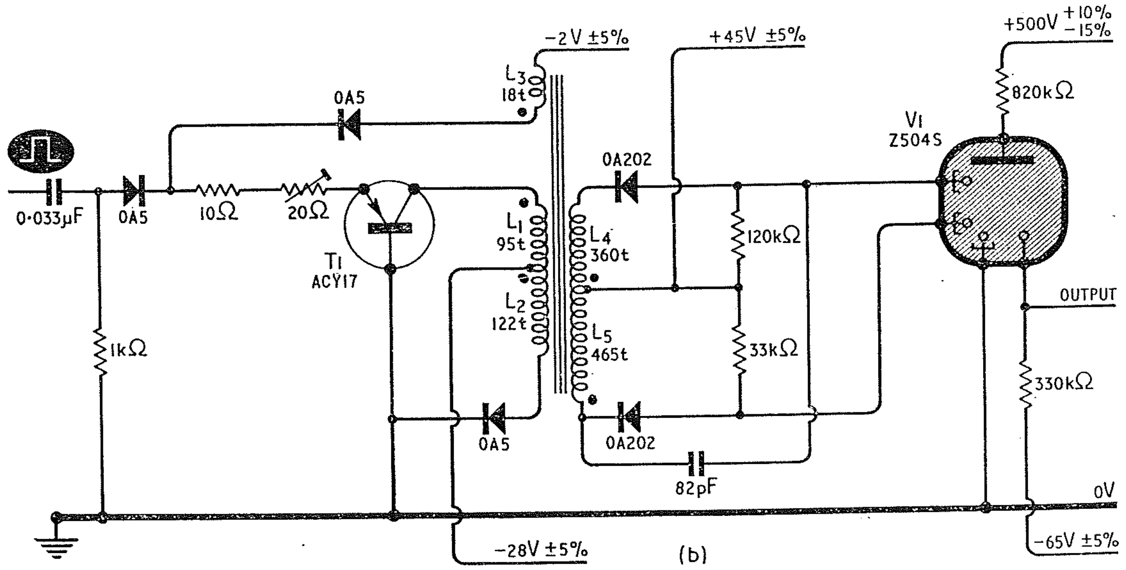
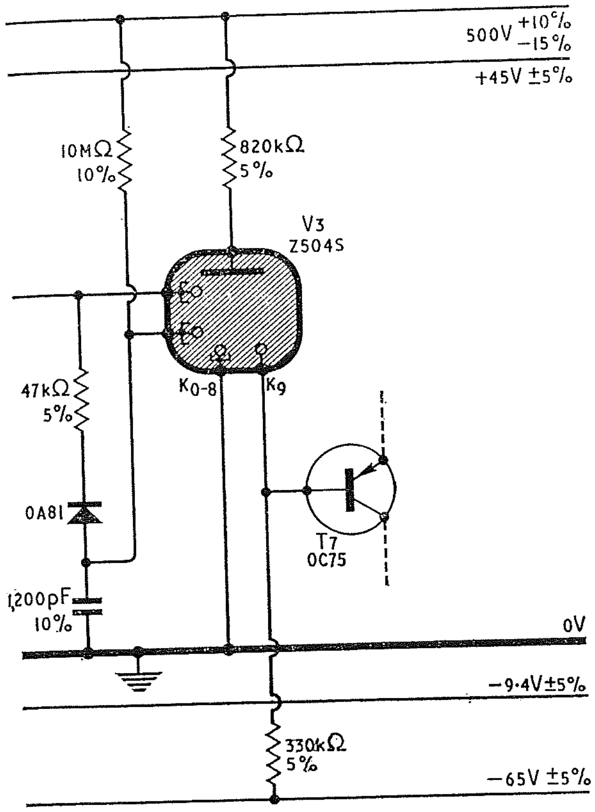


Fig. 4.15(a) Transistor coupling stages; (b) a blocking oscillator circuit for driving the Z504S, etc.



TRANSFORMER DETAILS

Core: – Mullard FX2240
Bobbin type DT2179
Tag plate DT2227
Clamping nut DT2155 (6B.S.)

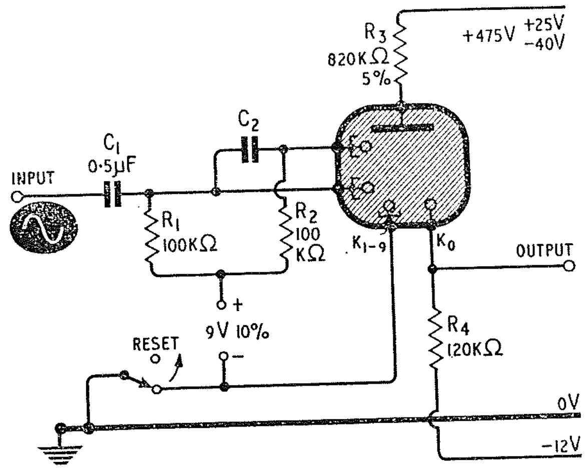
Winding order	*No. of turns*
L_1	95
L_2	122
L_3	18
L_4	360
L_5	465

4.3.10 Sine Wave Drive for 4 kc/s Tubes(4)

When a double pulse tube is to be used to count the peaks of a sine wave, the simplified input circuit of Fig. 4.16 can be used. The input sine wave is applied to the second guides if clockwise rotation of the glow is required and if the negative peaks of the wave are to be counted. The sine wave which is applied to the second guides is also changed in phase by C_2 and R_2 and the resulting sine wave is applied to the first guides. The wave applied to the first guides leads that applied to the second guides in phase if clockwise rotation is desired.

The input voltage to the circuit of Fig. 4.16 should be between 40 and 70 V R.M.S. and the frequency must not exceed the maximum operating frequency of the tube (4 kc/s). The value of the capacitor C_2 required depends on the input sine wave frequency and is shown in the table beneath Fig. 4.16.

The positive guide bias required is only 8 to 10 V, since the positive half cycles of the input waveform provide the additional bias required.



Input frequency (c/s)	50	100	200	500
C_2 (μF)	0.1	0.05	0.02	0.01

Input frequency (c/s)	1000	2000	4000
C_2 (μF)	0.005	0.002	0.00068

Fig. 4.16 A sine wave drive circuit for the Mullard 4 kc/s double pulse tubes. Component tolerances are 10% unless otherwise stated

It should be noted that if a multidecade counter is required for sine waves, the output pulses from the circuit of Fig. 4.16 are not steep enough to operate the coupling circuit of Fig. 4.10 if the frequency of the sine wave input is below about 300 c/s. The circuit can be modified for low input frequencies[4].

The circuit of Fig. 4.16 is very similar to the Ericsson circuit of Fig. 4.22. Neither of these circuits can count every peak from the moment the sine wave input is applied, since a short time is necessary for the correct phase relationship to be established at the first guides. It is obvious that no first guide peak will precede the first peak applied to the second guides, since each peak actually reaches the second guides before its effect reaches the first guides.

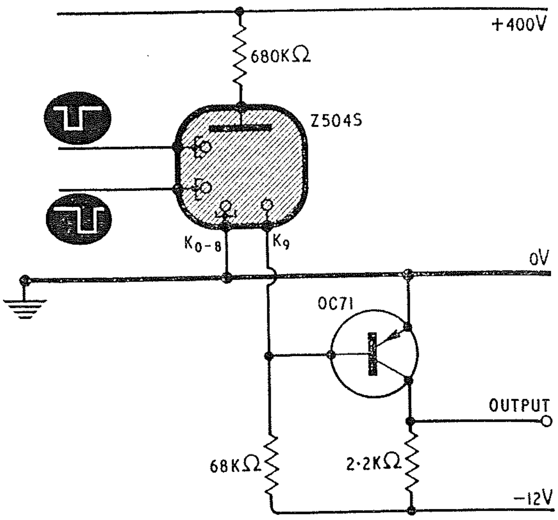


Fig. 4.17 Operation of the Z504S at 10 kc/s

4.3.11 The Operation of the Z504S Above 5 kc/s[10]

The maximum operating frequency of the Z504S tube is limited by the fact that an output pulse must be obtained from the tube for the operation of the coupling circuit of the next decade. It has been found that if all cathodes of Z504S tubes are connected directly to earth, all of the tubes will operate at frequencies up to 18 kc/s and most tubes of this type will operate at over 25 kc/s.

In the circuit of Fig. 4.17 an OC71 transistor is connected as a grounded emitter amplifier to convert the current pulse from the output cathode into a voltage pulse. The transistor is normally held in the bottomed condition by a current of approximately 180 μA which flows through the emitter-base circuit and through the 68 kΩ resistor. When the discharge in the Z504S passes to the output cathode, the 350 μA cathode current supplies the 180 μA taken by the 68 kΩ resistor and also supplies an additional current of about 170 μA to the transistor base. The direction of the current passing in the transistor base lead is therefore reversed and the transistor is cut off. The collector potential changes from nearly zero volts to −12 V.

A negative output pulse of −12 V can thus be obtained without the output cathode of the Z504S changing by more than 0.3 V from the earth potential. The transistor may be connected to the ninth cathode of the tube. The 12 V negative going output pulse can be differentiated so that, when the discharge leaves the ninth cathode for the zero cathode, a positive going pulse is obtained which can be used to drive a hard valve coupling stage.

Measurements have been made on several Z504S tubes operating in this type of circuit and it has been found that operation at 10 kc/s could be achieved without any sacrifice in reliability[10]. The negative going input pulses to the tube under these conditions should have an amplitude of 100 V and a duration of 33 μsec.

4.3.12 The Z505S Tube

The Mullard Z505S tube is a double pulse selector tube which can operate at frequencies up to 50 kc/s, since the duration of the guide pulses may be 6 μsec as opposed to the 75 μsec pulses required by the 4 kc/s tubes. Various circuits are available[11].

The tube may be used with 15 kΩ cathode resistors returned to earth, in which case 12 V output pulses are available. Cathode resistors should be used only in those cathode circuits from which outputs are required; the remaining main cathodes should be returned to earth. Alternatively the Z505S may be used with the one output cathode returned to a −12 V supply via a 32 kΩ resistor; output pulses of about 24 V are then obtained.

The Z505S tube may be fed from similar circuits to those used for the 4 and 5 kc/s double pulse tubes, but the time constants of the driving circuit must be altered if advantage is to be taken of the greater maximum operating speed of the Z505S. The multivibrator pulse shaping circuit should have a time constant which will give an output pulse for driving the Z505S of not less than 6 μsec duration. The time constant of the integrating circuit should also be reduced. The values of anode resistor, supply voltage, etc. required for the Z505S tube are first counted in the normal way, but the counting process must be stopped whilst the digits are displayed by the indicator tubes.

4.3.13 The Z302C Tube

The Z302C tube is interesting because it can be used in circuits which require no amplifying device of any kind between successive counting tubes. Circuits employing this tube have an upper frequency limit of about 1 kc/s. Both positive and negative

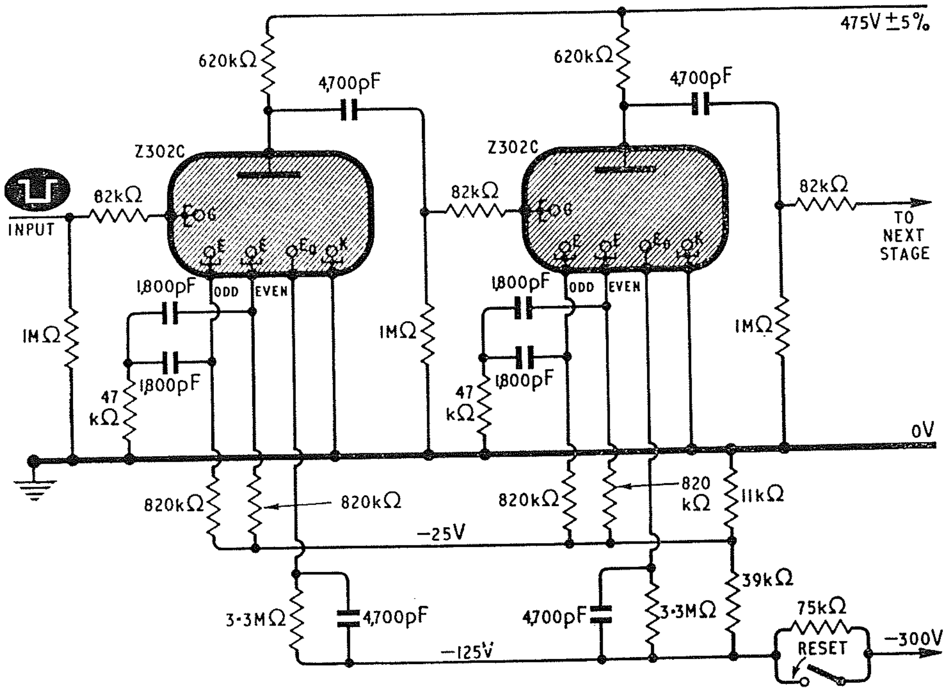


Fig. 4.18 A two decade circuit for the Z302C counter tube

shown in the table of Mullard tube data. It should be noted that a guide bias of +50 V is recommended.

A decade counting circuit using the Z505S has been developed in which 'In-line' numerical readout is provided by Z520M digital indicator tubes(11). The maximum counting speed is limited to about 40 kc/s by the transistor coupling circuits employed; these coupling circuits are also used to drive the digital indicator tubes. The operation of this type of circuit occurs in two phases. The input pulses are supply voltages of fairly high value are required, although the current taken is small.

The Z302C has thirty equally spaced cathodes arranged in a circle around a common anode, two transfer electrodes being placed between each two main cathodes. The first guides are all connected together and are given the symbol G. The second guides are connected in two groups. All of the second guides which precede an odd numbered main cathode are joined together and are given the symbol E_{odd}, since the second guides in this type of tube are also known as extinguishing electrodes. The second guide which precedes the zero main cathode has a separate external connection, E_0, but the remaining second guides which precede the even numbered main cathodes are connected to a common base pin, E_{even}. The main cathodes are joined to a common base pin, K.

The type of circuit which can be used with the tube is shown in Fig. 4.18.[12] An input pulse of about 80 V in amplitude and about 300 μsec in duration is applied to all of the first guides. This causes the discharge to be transferred to a first guide. The guide current flows through a 1 MΩ resistor to earth and the potential of the first guides therefore rises. When the input pulse terminates, the discharge is transferred to the second guide, since the latter is returned to a source of negative potential of about −25 V through an 820 kΩ resistor.

Whilst the discharge rests at the second guide, the 1,800 pF capacitor connected to the second guide charges and after a short time the second guide becomes sufficiently positive to cause the discharge to be transferred to the next main cathode. Any tendency the discharge may have to return to the first guide is opposed by the positive potential which the latter would acquire as soon as the first guide current commenced to flow through the 1 MΩ first guide resistor.

Table 4.1 BASIC DATA AND BASE CONNECTIONS FOR MULLARD/PHILIPS COLD CATHODE COUNTER AND SELECTOR TUBES

	Z302C	*Z303C*	*Z502S*	*Z504S (ZM1070)*	*Z505S (ZM1060)*
Maximum counting speed (kc/s)	1	4	4	5	50
Recommended anode current (mA)	0.4	0.34	0.34	0.34	0.80
Recommended H.T. supply (V)	475	475	475	475	525
Recommended anode load (Ω)	680K	820K	820K	820K	330K
Recommended guide bias (V)	—	+40	+40	+40	+50
Recommended pulse amplitude (V)	80	100	100	100	120
Recommended pulse duration (μsec)	350	75	75	75	6
Maintaining voltage (nominal)	190	191	191	195	260
Minimum H.T. supply voltage	400	350	400	375	400
Anode current Max. (mA)	0.55	0.55	0.55	0.525	1.00
Anode current Min. (mA)	—	0.25	0.25	0.25	0.60
Base	I.O.	I.O.	B12E	B13B	B13B
Escutcheon required (Mullard)	101065	101065	101064	101065	101065
Max. diameter (mm)	29.5	29.5	33	30	30
Max. seated height (mm)	87.5	87.5	70.5	36	36
Type of tube	10 way counter	10 way counter	10 way selector	10 way selector	10 way selector
Base Connections					
Pin 1	I.C.	K	K_0	K_5	K_5
Pin 2	E_{odd}	N.C.	K_9	K_4	K_4
Pin 3	E_{even}	G_1	K_8	K_3	K_3
Pin 4	G	A	K_7	G_2	G_2
Pin 5	K	G_2	K_6	K_2	K_2
Pin 6	E_0	N.C.	K_5	K_1	K_1
Pin 7	I.C.	K_0	K_4	K_0	K_0
Pin 8	A	N.C.	K_3	G_1	G_1
Pin 9	—	—	K_2	K_9	K_9
Pin 10	—	—	K_1	K_8	K_8
Pin 11	—	—	G_2	A	A
Pin 12	—	—	G_1	K_7	K_7
Pin 13	—	—	—	K_6	K_6
Base Cap	—	—	A	—	—

(The Z2302C tube is now obsolete)

When the discharge is resting at a main cathode, a small current will flow to the preceeding second guide, since this is connected to the −25 V line. The flow of this small priming or probe current through the 820 kΩ second guide resistor ensures that the second guides are maintained at a positive potential which prevents the back transfer of the glow from the main cathode to the preceding second guide. Alternate second guides are joined together so that, although the second guide preceding the main cathode at which the discharge is resting is at a positive potential with respect to the −25 V line, the succeeding second guide (which is taking virtually no current, as it is not strongly primed) is at the potential of the −25 V line; this, therefore, enables the discharge to move from the first to the second guide at the end of the input pulse.

The zero second guide, E_0, is returned to a negative supply of about −125 V via a 3.3 MΩ resistor in parallel with a capacitor. When the discharge first reaches E_0, the potential of this cathode is maintained at about −125 V whilst the 4,700 pF capacitor is charging. A larger current, therefore, flows to the zero second guide than flows when the discharge rests at any other cathode. As the capacitor in the cathode circuit of the zero second guide charges, however, the guide becomes more positive owing to the flow of current through the 3.3 MΩ resistor. The discharge, therefore, moves to the zero main cathode.

The large current which flows to the zero second guide for a short time produces a relatively large voltage pulse across the anode resistor and this pulse can be used to operate the succeeding decade directly through a resistance-capacitance coupling, as it is of a suitable amplitude and of the correct polarity.

The reset switch can be used to apply momentarily a negative potential of about 300 V to the zero cathode of the counter tubes. The discharge can thus be transferred to the zero cathodes of all of the tubes in the scaler.

Although the Z302C is no longer in current production, the above details have been included since it is felt that the principle of operation of this tube is of interest.

4.4. ERICSSON TUBES AND THEIR CIRCUITS

Double Pulse Decade Tubes:

- *4 kc/s Counter tubes: GC10B; GC10B/S (CV2271).*
- *4 kc/s Counter specially processed for long life: GC10B/L (CV6044).*
- *4 kc/s Computing tube with intermediate outputs: GC10/4B (CV1739).*
- *4 kc/s Computing tube specially processed for long life: GC10/4B/L. (CV6100).*
- *4 kc/s Selector tube: GS10C/S (CV2325).*
- *5 kc/s Selector tube: GS10H (with routing guides; the smallest and cheapest dekatron.)*
- *10 kc/s Selector tubes: GS10D and GS10E.*
- *1 kc/s Low voltage dekatron: GS10J.*
- *10 kc/s Tubes with auxiliary anodes for direct operation of digitrons*
  - *Counter: GCA10G*
  - *Selector: GSA10G.*

Double Pulse 12 way Tubes:

- *4 kc/s 12 way Computing tube with intermediate outputs: GC12/4B.*
- *4 kc/s 12 way Selector tube: GS12D.*

Single Pulse 20 kc/s Decade tube: GC10D (CV5143).

Tubes for Maintenance Only:

- *1 kc/s GC10/2P (miniature)*
- *4 kc/s GS12C (soldered contacts on phenolic tube)*
- *10 kc/s GS10G (with routing guides)*
- *10 kc/s GS10K (decade selector with three sets of guides for high voltage or high current output).*

(Ericsson tubes are now being manufactured by Hivac Ltd.)

Ericsson gas filled polycathode counter and selector tubes are known by the registered trade mark of Dekatron. The basic data for these tubes is shown in Table 4.4. All of the current types, except for the single pulse GC10D, operate on the double pulse principle discussed in Section 4.2, but there are a large number of different types from which the circuit designer can choose.

4.4.1 Circuits for Double Pulse Tubes

The same basic type of circuit can be used with any of the simple 4 kc/s double pulse Dekatrons, but the optimum values of some of the components depend on the particular type of tube chosen; these values are shown on the circuit diagrams. The circuits of Figs. 4.19 to 4.23 inclusive can be used with any of the following tubes: GC10B, GC10B/S, GC10B/L, GC10/4B, GC10/4B/L, GC12/4B, GS10C/S, GS10H and GS12D.

4.4.2 Dekatron Coupling Circuits[13]

The circuit of Fig. 4.19 shows how a GTE175M trigger tube, *V*2, can be used for coupling two 4kc/s douple pulse Dekatrons. When the discharge in the first counting tube, *V*1, moves to the zero cathode, the resulting positive going pulse from this cathode is applied to the trigger electrode of *V*2 via the capacitor C_1. This pulse, when added to the bias applied to the trigger electrode, causes the trigger tube to ignite. The flow of anode current in the trigger tube causes the anode potential of the tube to fall, and this fall is fed to the first guides of the succeeding counter tube, *V*3, via a capacitor. The second guide pulse is obtained from a tapping on the anode load resistor of the trigger tube.

The number of 'carries' per second is limited to a maximum of about 500 by the characteristics of the trigger tube, but even if the preceding Dekatron, *V*1, is operating at its maximum speed of 4 kc/s, the trigger tube will not be required to handle, more than 400 pulses per second. Although Fig. 4.19 requires no heater wiring, a −100 V supply is required for the priming cathodes of the GTE175M tube.

A similar circuit using a hard valve for coupling two Dekatrons is shown in Fig. 4.20. The valve is used to amplify and invert the phase of the positive going signal from the cathode of the first Dekatron. The resulting negative going pulse is fed to the first guides of *V*3 and, through an integrating circuit, to the second guides.

If a selector tube is used with a resistor in each of the main cathode leads, the current passing through the tube will be less than in a counter tube of similar construction in which nine of the main cathodes are directly earthed. In order to overcome this change of anode current, it is recommended that, when a 4 kc/s selector tube is used with a 150 kΩ resistor in each cathode circuit, the anode resistor should be reduced from the value of 820 kΩ recommended for 4 kc/s counters to 680 kΩ so that the total (anode+cathode) resistance remains almost unchanged. Thus the anode current is kept

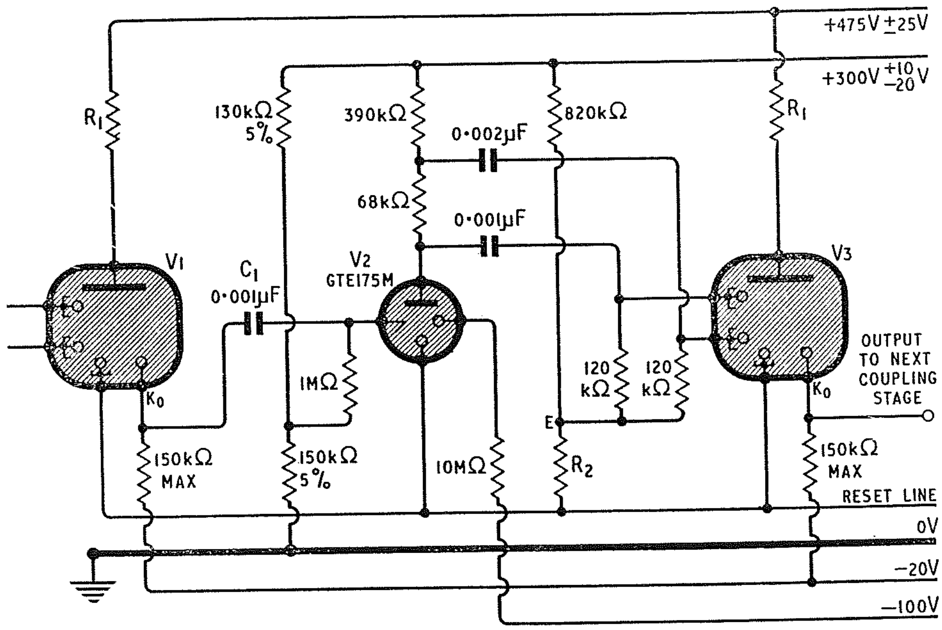


Fig. 4.19 A trigger tube coupling circuit for 4 kc/s Dekatrons

V_1, V_3	*Counters*	*Selectors*
R_1	820 kΩ	680 kΩ
R_2	39 kΩ	47 kΩ

at its optimum value if the recommended H.T. supply potential of 475±25 V is employed.

The maximum positive potential of the output cathode of a counter tube is about +18 V, but owing to the smaller value of the anode resistor used in selector tube circuits, the potential of the output

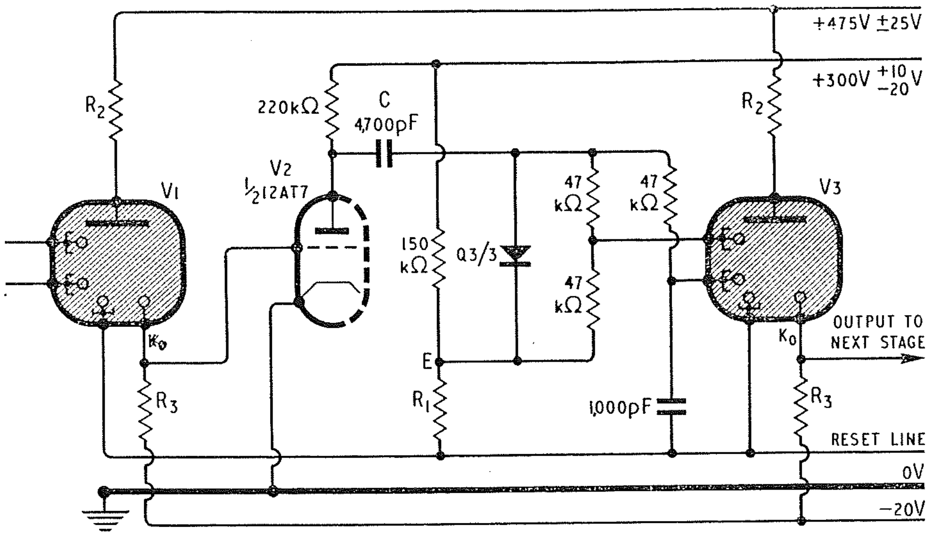


Fig. 4.20 A valve coupling circuit for 4 kc/s Dekatrons

V_1, V_3	*Counters*	*GS10C*	*GS12D*
R_1	10 kΩ	22 kΩ	22 kΩ
R_2	820 kΩ	680 kΩ	910 kΩ
R_3	150 kΩ	150 kΩ	270 kΩ
E	+18 V	+36 V	+36 V

cathode of a selector tube may reach +36 V. The positive guide bias should not be less than the maximum potential reached by any main cathode (except for sine wave inputs) and, therefore, a larger bias is recommended for selector tubes than for counter tubes. Suitable values for the potential divider resistors from which the guide bias may be obtained are shown in Figs. 4.19 to 4.21 and also in Fig. 4.23. The guide bias is the potential at the point marked 'E' in these circuits.

In the case of the trigger tube coupling circuit of Fig. 4.19, the capacitor C_1 should be increased to 0.01 μF if the input to *V*1 is a sine wave; otherwise the pulses from *V*1 might not be steep enough to pass through C_1 to the trigger tube *V*2.

4.4.3 Input Circuit for 4 kc/s Dekatrons[13]

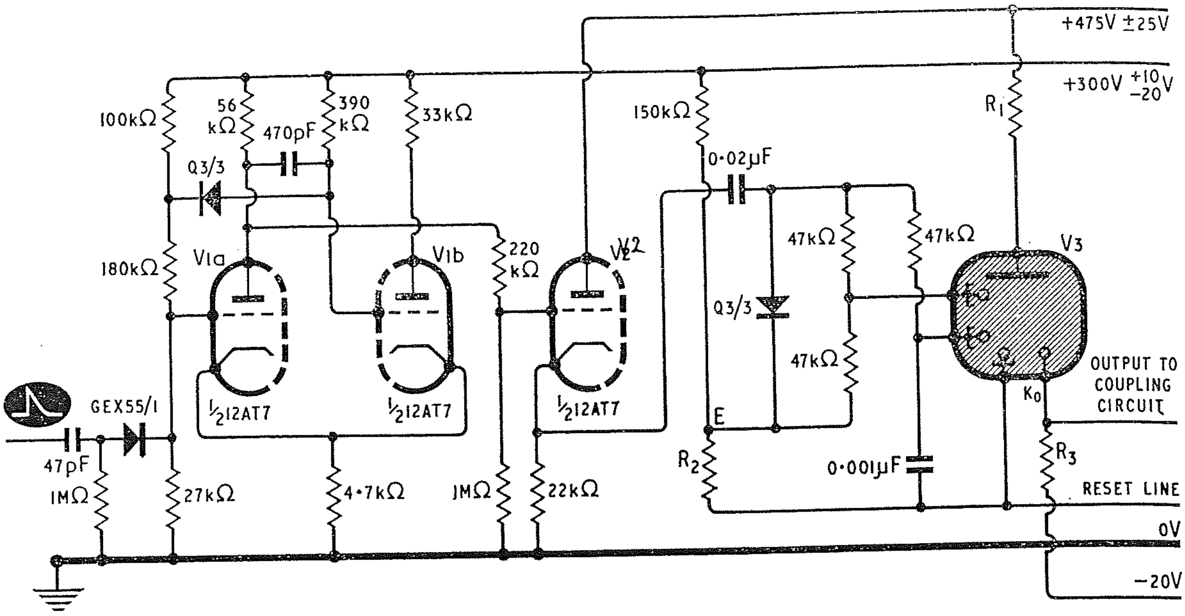
A suitable circuit for providing the twin pulses of the correct shape for the first counter tube of Fig. 4.19 or 4.20 is shown in Fig. 4.21. A short positive pulse of an amplitude not less than 20 V may be used to trigger the monostable multivibrator *V*1.

In the quiescent condition *V*1b conducts owing to the fact that its grid is connected to the positive H.T. line via a 390 kΩ resistor. *V*1a is normally cut off by the voltage present across the common cathode resistor resulting from the flow of anode current in *V*1b. The input pulse causes *V*1a to conduct and the resultant negative pulse at the anode of this valve is fed to the cathode follower, *V*2. The output at the cathode of *V*2 is, of course, in phase with the grid potential of this valve and is fed to the first guides of the Dekatron, *V*3. The same pulse is fed through an integrating circuit to the second guides.

The Q3/3 diode in the guide circuits of Figs. 4.20, 4.21 and 4.23 prevents the guides from becoming more positive than the guide bias supply point, E. The GEX55/1 diode in Fig. 4.21 prevents the negative going trailing edge of the input pulse from reaching the grid of *V*1a where it might cause the multivibrator to return prematurely to its quiescent state.

Sine Wave Input[13]

If the input consists of sine waves, the circuit shown in Fig. 4.22 may be used to count the peaks. The circuit is very similar to the Mullard circuit of Fig. 4.16 and suffers from the same disadvantage that the correct phase relationship of the pulses at the



V_3	*Counters*	*Selectors*
R_1	820 kΩ	680 kΩ
R_2	10 kΩ	22 kΩ
R_3	150 kΩ (max.)	150 kΩ (max.)
E	+18 V	+36 V

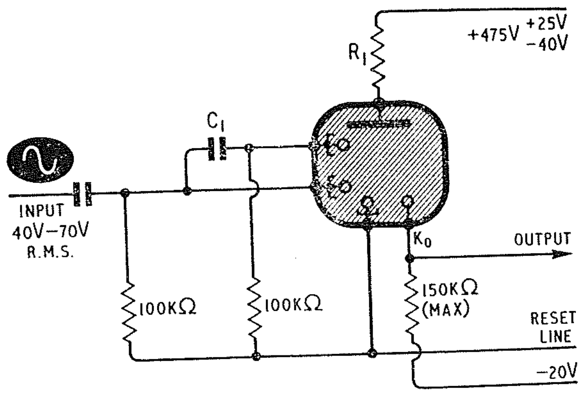
Fig. 4.21 An input circuit for 4 kc/s Dekatrons

two guides is not established until a few cycles have elapsed. If it is necessary to count every sine wave peak from the moment that the signal is applied to the circuit, the circuit of Fig. 4.23 may be used. The 12AU7 acts as a Schmitt trigger circuit. Each negative peak of the input sine wave causes *V*1a to be cut off and *V*1b to conduct. The negative pulses at the anode of *V*1b are fed to the first guides of *V*2.

Reset

The reset lines shown in the circuits in this section should be connected to earth through a resistor which is shorted out by a switch or a relay except during the actual moment when the resetting operation is carried out. The output cathodes of the Dekatrons and the cathodes of the valves in the input and the coupling circuits are returned to separate H.T. negative lines.

If the switch or relay which connects the reset line to earth is opened, the current from the counting tubes flows through the resistor to earth and



Input frequency	4 kc/s	2 kc/s	1 kc/s	500 c/s
C_1	680 pF	0·002 µF	0·005 µF	0·01 µF

Input frequency	200 c/s	100 c/s	50 c/s
C_1	0·02 µF	0·05 µF	0·1 µF

	Counters	*Selectors*
R_1	820 kΩ	680 kΩ

Fig. 4.22 A circuit for feeding 4 kc/s Dekatrons from a sine wave input

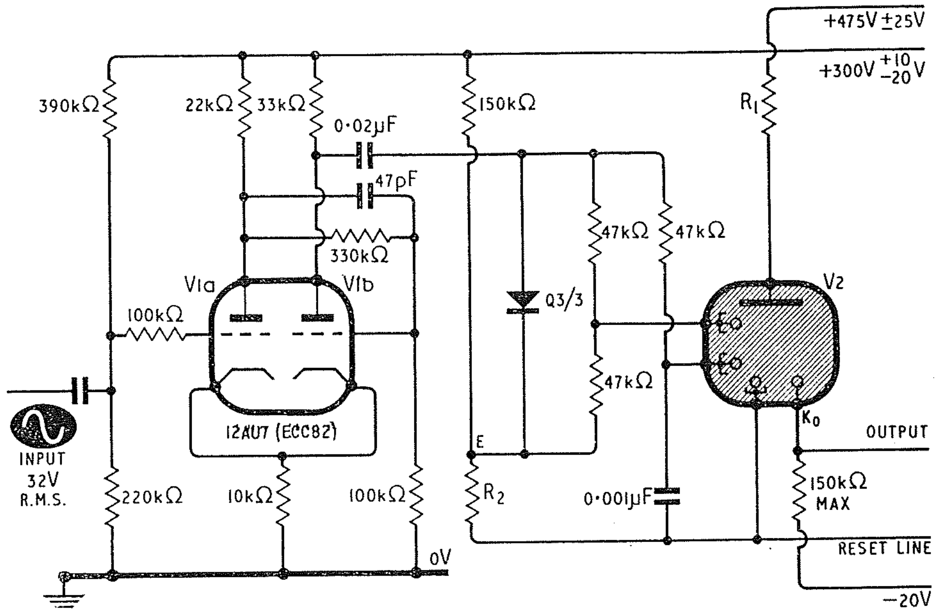


Fig. 4.23 A Schmitt trigger circuit for shaping sine wave input signals

	Counters	*Selectors*
R_1	820 kΩ	680 kΩ
R_2	10 kΩ	22 kΩ
E	+18 V	+36 V

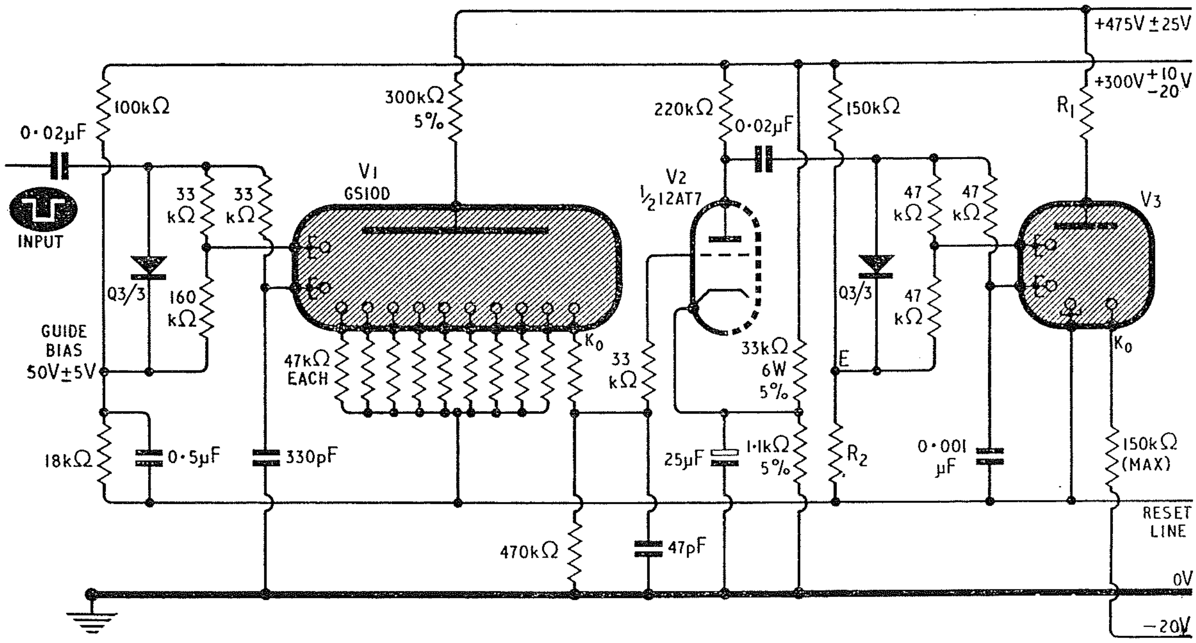


Fig. 4.24 A circuit for coupling the GS10D to a 4 kc/s Dekatron

	Counters	*Selectors*
R_1	820 kΩ	680 kΩ
R_2	10 kΩ	22 kΩ
E	+18 V	+36 V

the potential of all of the main cathodes except the zero cathode of each Dekatron is raised so that the discharge in each tube moves to the zero cathode.

The value of the reset resistor should be chosen so that the potential of the reset line increases by about 100 V during the resetting operation. The value of this resistor should be varied according to the number of decades used.

4.4.4 The GS10D Tube (13)

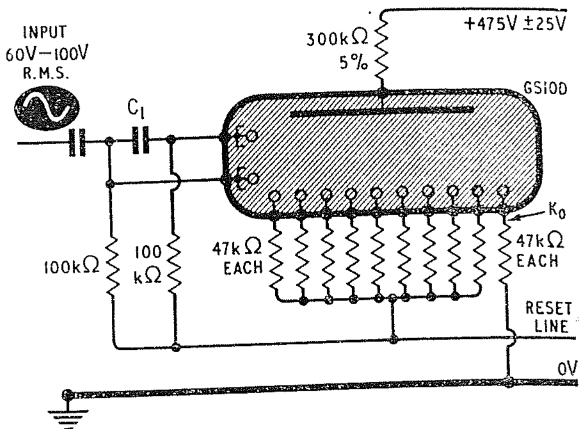
The GS10D double pulse selector tube can be used to count impulses at frequencies up to 10 kc/s, but it can count sine wave peaks at up to 20 kc/s. The operating principle of the GS10D circuits is the same as that of the 4 kc/s double pulse tubes, but the input pulses can be shorter in duration. A typical circuit for the GS10D is shown in Fig. 4.24 in which it is coupled to the succeeding 4 kc/s tube by a valve amplifier. The grid and cathode of the valve are also used as a limiting diode for the GS10D output cathode voltage.

The GS10D has a higher anode current and requires a rather higher guide bias than the 4 kc/s tubes. It can be seen from Fig. 4.24 that the integrating circuit time constant in the GS10D second guide circuit is much less than in the second guide circuit of the succeeding 4 kc/s tube, *V*3.

The impulses to the circuit of Fig. 4.24 should have an amplitude of 145±15 V and a duration of 33 μsec (±20%). The slope of the leading edge of the negative going input pulse should not exceed 150 V/μsec. The circuit may be fed from a circuit identical to the input section of Fig. 4.21, but the capacitor connecting the grid of *V*1b in Fig. 4.21 to the anode of *V*1a should be reduced from 470 pF to about 150 pF so that the desired pulse length of about 33 μsec is obtained.

If the maximum possible speed of operation is to be obtained from the GS10D, it is essential to reduce the effect of stray capacitance from the anode to ground to a minimum. The anode resistor should be wired not more than 1/4 in. (5 mm) from the anode tag of the tube holder.

The characteristics of the GS10E are rather similar to those of the GS10D and both tubes can be used in similar circuits. The maximum operating



Input frequency	20 kc/s	15 kc/s	10 kc/s	5 kc/s	2 kc/s
C_1	270 pF	330 pF	470 pF	680 pF	0.002 μF

Input frequency	1 kc/s	500 c/s	200 c/s	100 c/s	50 c/s
C_1	0.005 μF	0.01 μF	0.02 μF	0.05 μF	0.1 μF

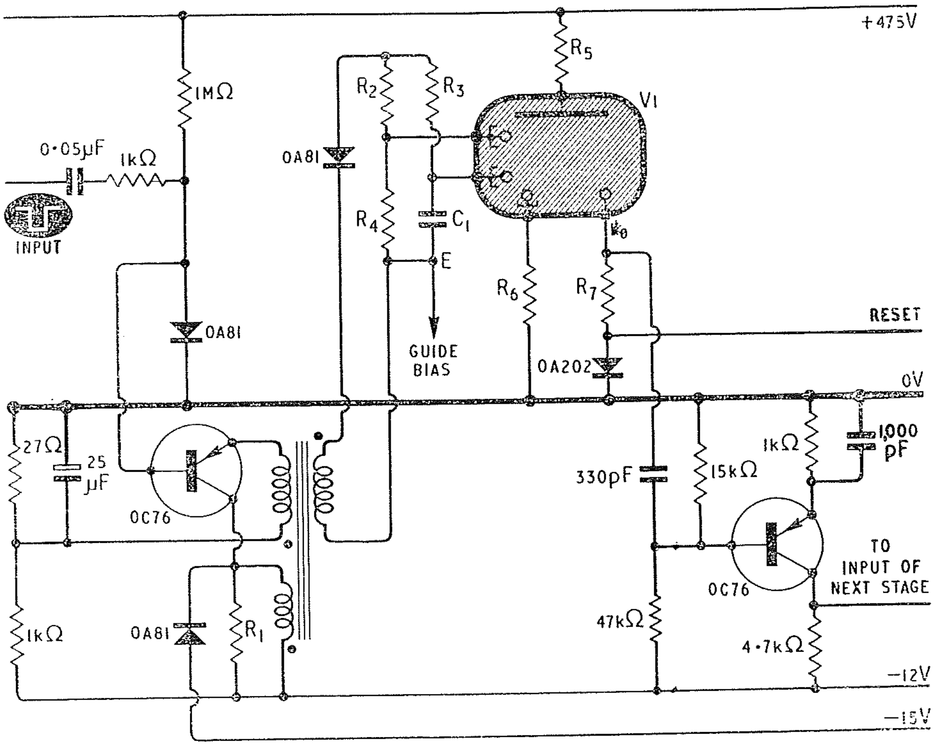
Fig. 4.25 A sine wave input circuit for the GS10D

speed quoted for the GS10E is 10 kc/s both in the case of rectangular input pulses and in the case of sine wave input.

The GS10D may be used in the circuit of Fig. 4.25 to count the peaks of sine waves at frequencies up to 20 kc/s. The value of C_1 should be varied as shown in Fig. 4.25 for different operating frequencies. When the input is first applied, the correct phase relationship of the guide voltages will not be established for a short time and a few of the first peaks of the input wave will not be counted.

4.4.5 Transistor Drive circuits

The circuit of Fig. 4.26 shows how a transistor may be employed to drive a Dekatron(13). The input pulses should have an ampitude of between 5 and 12 V and should be negative going; their duration should not be less than 10 μsec. The transistor is employed in a blocking oscillator circuit so that a single transistor can be used and so that a voltage large enough to drive the Dekatron can be taken from the secondary winding of the blocking oscillator transformer. A cheap low voltage transistor can be used, since the voltage applied to it is relatively small.



Transformer details for **4** *kc/s. Dekatrons*

5/16 in stack of 0·008 in mu-metal laminations RCL191, type 421. Collector winding 100 turns, emitter winding 20 turns, output winding 906 turns

Transformer details for **10** *kc/s Dekatrons*

1/4 in stack of 0·004 in mu-metal lamination RCL191, type 450. Collector winding 45 turns, emitter winding 7 turns, output winding 515 turns.

Type of tube	V_1	R_1	R_2	R_3	R_4	R_5	R_6, R_7	C_1	*Guide Bias*
4 kc/s Dekatrons	GC10B,	4·7 kΩ	47 kΩ	47 kΩ	47 kΩ	820 kΩ	150 kΩ max	1000 pF	+18 V
	GS10C	4·7 kΩ	47 kΩ	47 kΩ	47 kΩ	680 kΩ	150 kΩ max	1000 pF	+36 V
	GS12D	4·7 kΩ	47 kΩ	47 kΩ	47 kΩ	680 kΩ	270 kΩ max	1000 pF	+36 V
10 kc/s Dekatrons	GS10D	Omit	33 kΩ	160 kΩ	160 kΩ	300 kΩ	47 kΩ max	330 pF	+50 V
	GS10E	Omit	33 kΩ	33 kΩ	16 kΩ	240 kΩ	39 kΩ max	330 pF	+50 pF

Fig. 4.26 A transistor drive and coupling circuit for Dekatrons

The circuit will provide an output pulse which is capable of driving a similar succeeding decade directly.

The type of transformer, the guide bias and the values of some of the components should be chosen according to the type of Dekatron which is to be used. Full details are given in Fig. 4.26. Other transistor drive circuits have been published. [14, 15]

4.4.6. The Computing Tubes [13,16]

The decade computing tube GC10/4B is of exactly the same construction as the GC10B counting tube except that four of its main cathodes are brought out to separate base pins whereas in the GC10B only one of the main cathodes has a separate base pin. The GC10/4B/L is a long life version of the GC10/4B, whilst the GC12/4B has twelve main cathodes, four of which are brought out to separate base pins.

The computing tubes can be used in multidecade circuits for addition or subtraction where the direction sensing circuits require at least one output pulse between the digits zero and nine. The four output cathodes which are connected to separate base pins are designated *A*, *B*, *C* and *D*. The remaining main cathodes are connected to a common base pin. The spacing of the output cathodes is so arranged that, by choosing the appropriate one of them to be the zero cathode, an output pulse can be obtained from the tube at any desired intermediate count. The method of connection is shown in Tables 4.2 and 4.3. For example, in the case of the GC12/4B, if the cathode *B* is acting as the zero cathode and the discharge is travelling in a clockwise direction, outputs will be obtained at the 6th, 8th and 11th input pulses from the cathodes *C*, *D* and *A* respectively.

Table 4.2. THE NUMBER OF PULSES TO BE APPLIED TO A GC10/4B TUBE IN ORDER TO OBTAIN AN OUTPUT PULSE FROM CATHODE *A*, *B*, *C* OR *D* WHEN THE CATHODE INDICATED IS THE ZERO CATHODE AND THE DIRECTION OF ROTATION IS AS SHOWN.

		A	*B*	*C*	*D*
A Zero	Clockwise	0	1	4	6
	Anticlockwise	0	9	6	4
B Zero	Clockwise	9	0	3	5
	Anticlockwise	1	0	7	5
C Zero	Clockwise	6	7	0	2
	Anticlockwise	4	3	0	8
D Zero	Clockwise	4	5	8	0
	Anticlockwise	6	5	2	0

Table 4.3. THE NUMBER OF PULSES TO BE APPLIED TO A GC12/4B IN ORDER TO OBTAIN AN OUTPUT PULSE FROM CATHODE *A*, *B*, *C* OR *D* WHEN THE CATHODE INDICATED IS THE ZERO CATHODE AND THE DIRECTION OF ROTATION IS AS SHOWN.

		A	*B*	*C*	*D*
A Zero	Clockwise	0	1	7	9
	Anticlockwise	0	11	5	3
B Zero	Clockwise	11	0	6	8
	Anticlockwise	1	0	6	4
C Zero	Clockwise	5	6	0	2
	Anticlockwise	7	6	0	10
D Zero	Clockwise	3	4	10	0
	Anticlockwise	9	8	2	0

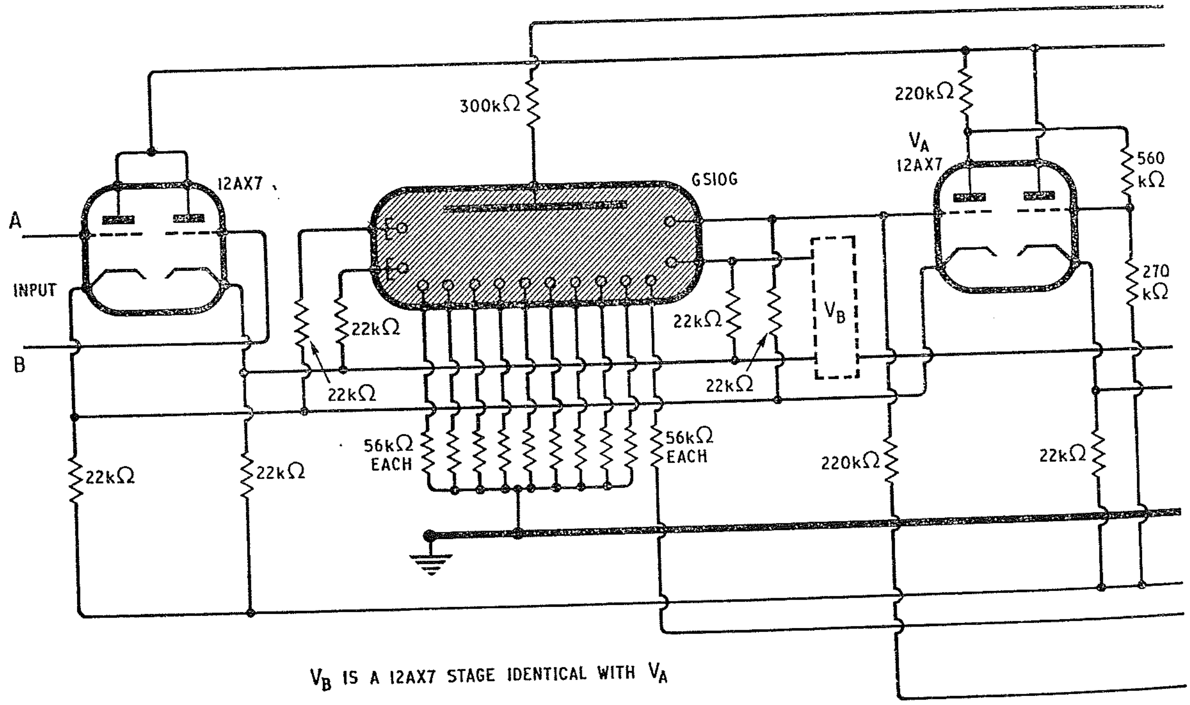


Fig. 4.27 A multi-decade

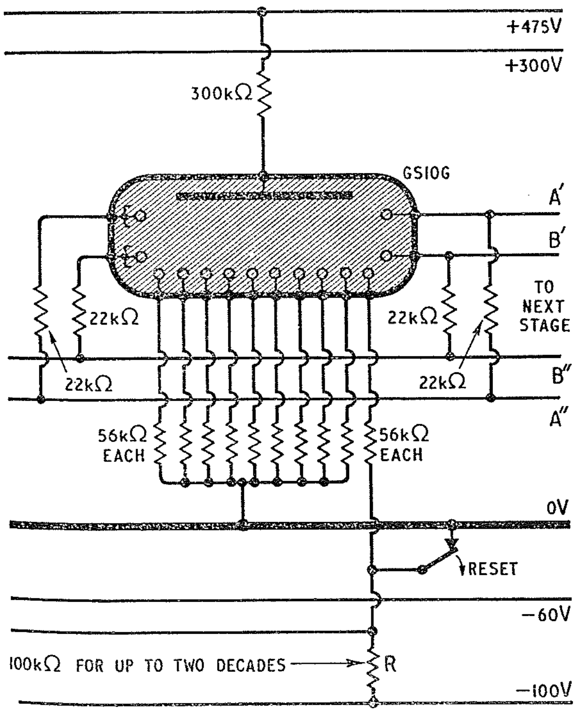
4.4.7 The GS10J

The GS10J is a low voltage Dekatron which has a striking voltage of 150 V. The recommended H.T. supply voltage is 200 V, but the maximum operating frequency is 1 kc/s. The pulses fed to the guides should be of about 24 V in amplitude and 300 μsec in duration with a 10 μsec overlap.

The GS10J may be used in circuits similar to those designed for 4 kc/s tubes, but the time constant of the integrating circuit feeding the second guides should be increased by a factor of about four and the input pulses must be about four times as long as those recommended for 4 kc/s tubes. The anode resistor should be 330 kΩ and the maximum output voltage which can be obtained from the tube is about 3 V across 3.3 kΩ cathode resistors.

4.4.8 Tubes with Routing Guides for Bidirectiona Counting[13, 17]

In the GS10J, GS10H, GS10G, GCA10G and GSA10G tubes the first guide electrode following the ninth main cathode and the second guide electrode preceding the zero cathode are each brought out to separate base pins. These electrodes are known as routing guides and enable the tubes to be used in multidecade bidirectional counting circuits. The conventional symbol for Dekatrons with access to routing guides is as shown in the circuit of Fig. 4.27, the routing guides being the two electrodes on the right hand side of the tube symbol.



reversible counting circuit

If a scaler is adding pulses, a 'carry' pulse must be fed to the succeeding decade when the discharge arrives at the zero cathode. Similarly, if the input pulses are being subtracted from the total count, a negative carry pulse must be passed to the next decade when the discharge arrives at the ninth cathode. If the same circuit is to be used for both forward and reverse counting, it is not sufficient merely to insert resistors in the zero and ninth cathode circuits in order to obtain the carry pulses. The carry pulses must also be gated according to the direction of counting.

In the bidirectional counting circuit of Fig. 4.27, the first guide pulses are applied to nine of the first guide electrodes and also, via a resistor, to the first routing guide. Similarly, the second routing guide is connected via resistors to the other second guides. When the discharge rests momentarily at either of the routing guides, a potential difference will be present across the routing guide series resistor.

If the discharge is moving forwards, it will first rest momentarily at the first routing guide. The voltage across this guide resistor will be amplified by the double triode stage V_A and a pulse will be fed to the first guides of the succeeding Dekatron. A fraction of a second later the discharge in the first Dekatron will rest momentarily at the second routing guide and the voltage across the guide resistor will be amplified by V_B so that a pulse is fed to the second guides of the next decade. Since the second Dekatron receives a pulse at its first guides before the pulse arrives at its second guides, the discharge will move one position in a clockwise direction.

If the first Dekatron had been counting in reverse, however, the discharge would have rested at its second routing guide before coming to its first routing guide. The resulting pulses would have been amplified by V_B and V_A respectively and passed

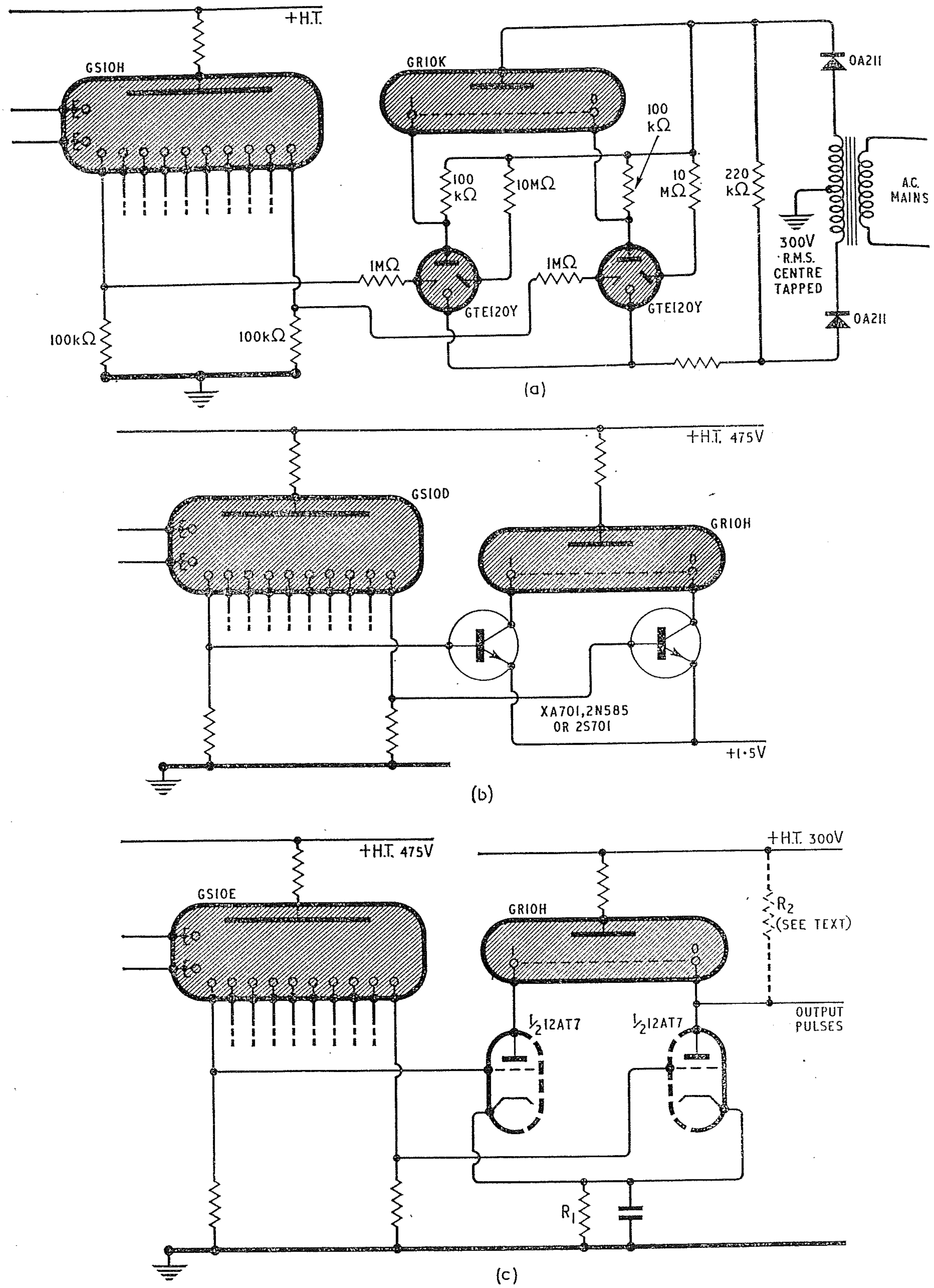


Fig. 4.28 Digitron readout from Dekatron circuits using (a) trigger tube, (b) transistor and (c) valve coupling

to the second Dekatron; the second guide electrodes of this Dekatron would, therefore, have received a pulse before the first guide electrodes and the tube would count in reverse (or subtract).

It can be seen that the grid and cathode of the first stage of each coupling amplifier are connected directly across the corresponding routing guide resistor. The second stages of the coupling amplifiers are cathode followers which provide a drive of low impedance for the succeeding Dekatron and also provide a means by which a suitable guide bias may be obtained. The coupling amplifiers V_A and V_B are d.c. coupled throughout.

A negative going pulse of about 100 V in amplitude and 30 μsec in duration fed into the '*A*' input followed by a similar and slightly overlapping pulse to the '*B*' input will cause the count to increase by one unit, whereas two similar pulses fed first into the '*B*' input and then into the '*A*' input respectively will reduce the total count by one unit. The switching of the second decade takes place simultaneously with the switching of the first decade and the whole process is, therefore, very rapid.

The resistor *R* in the resetting circuit of Fig. 4.27 may be 100 kΩ for up to two decades, but its value should be reduced in proportion to the number of decades if more than two are employed.

4.4.9 Digital Indication from Dekatron Circuits

Dekatron tubes are self indicating devices, but the state of the count is shown merely as the position of a point of light. If readout in the form of actual digits is required, it is necessary to use the Dekatron to control the operation of a numerical indicator tube (see Chapter 10). Ericsson Numerical Indicator Tubes are known as 'Digitrons'.

Two main requirements must be satisfied for the operation of Digitrons[18]. The current passing through the Digitron must be great enough for the whole of the cathode to be covered by the glow. The second requirement is that all of the Digitron cathodes which are not glowing at any given time must be at a positive potential or pre-bias of about 40 V which will prevent any discharge from taking place to them.

Circuits such as those shown in Fig. 4.28 have been developed which enable Digitron readout to be obtained from standard type Dekatrons [18–21], but since the normal Dekatron does not pass enough current to operate a Digitron, some form of amplifying device must be used in this type of circuit.

The circuit of Fig. 4.28(a) was developed in order to provide a simple means of adding digital readout to an existing Dekatron scaler without altering the existing circuitry. GTE120Y miniature wire ended trigger tubes are used as amplifying devices. This type of tube has a sufficiently stable trigger characteristic to enable the circuit to operate from an input differential of 12 V developed across the cathode resistors of a Dekatron selector tube[20].

The power supply to the Digitron and trigger tubes is half wave rectified unsmoothed a.c. The tubes will, therefore, be extinguished once per cycle of the mains frequency. When one of the trigger tubes has ignited, the fall in potential across the resistor in the trigger tube cathode circuit ensures that no other tube can ignite. The peak negative voltage applied to the trigger tube cathodes is well in excess of the trigger to cathode striking potential of 120 V and, therefore, one trigger tube will always strike. The discharge then spreads to the anode and this prevents other tubes from striking by the mechanism discussed.

The time taken for the tube to strike decreases rapidly as the trigger to cathode voltage increases above the required minimum. An over-voltage of one volt applied to a tube is sufficient to enslur that this tube will strike first, but in order to allow for the spread of trigger tube striking voltages from tube to tube, it is necessary to apply about 12 V from the cathode of the Dekatron at which the discharge is resting.

The anode current of the trigger tube which has been ignited causes a potential drop across the htigger tube anode resistor and this is applied to the corresponding cathode of the Digitron which, therefore, glows.

An alternative circuit employing ten transistors per decade is shown in Fig. 4.28(b)[20, 21]. The transistors must be used in the grounded emitter configuration, since they are required to give a current gain. The output voltage from the Dekatron is positive going and this voltage must be used to render the transistors conducting. NPN transistors are therefore required. When a transistor conducts, a current flows from the Digitron cathode to the transistor collector and the Digitron cathode glows.

The non-glowing Digitron cathodes will have a potential which is dependent on the leakage current of the transistors used. The current flowing from these cathodes must not exceed about 100 μA per cathode or spurious glows may occur which make readout more difficult. The non-glowing cathodes will be about 40 V positive with respect to the glowing cathode when this current is passing and, therefore, fairly high voltage transistors should be used. These tend to be fairly expensive and hence the trigger tube circuit may be preferred. The GR10G is the only current type of Digitron tube which is not suitable for operation from commercially available transistors, since the degree of ionisation coupling in this tube necessitates much higher values of pre-bias voltage[22].

A third alternative is the circuit of Fig. 4.28(c) in which five double triodes per decade are used as amplifiers[20]. The flow of the anode current of one triode through the common cathode resistor, R_1, biases all of the other nine triodes to cut off. If a positive voltage is fed from a cathode of the Dekatron to the grid of the corresponding triode, the latter will conduct and the triode which was previously conducting will be cut off. The Digitron cathode supplying the current to the conducting triode will glow. The value of the resistor R_1 determines the Digitron current.

Negative going pulses may be obtained from a Digitron cathode (e.g. for the purpose of operating the succeeding decade), but in this case an extra resistor, R_2 in Fig. 4.28(c), should be included so that the leading edge of the pulse is not affected by the ionisation time of the Digitron.

Although the valve circuit requires no modifications to the Dekatron circuits, it has the disadvantage of being rather bulky.

4.4.10 Dekatrons for Digitron Operation

Two Dekatrons have been developed which contain ten additional electrodes in the form of an inner ring between the main anode and the cathode-guide ring of electrodes. These additional electrodes are known as auxiliary anodes and can be seen in the photograph of the GCA10G and GSA10G. Each auxiliary anode is situated radially between a main cathode and the main anode. Dekatrons containing these additional electrodes may be used without any coupling amplifier for the direct operation of Digitron tubes and thus enable the extra cost and complexity of the ten amplifiers per decade shown in the circuits of Fig. 4.28 to be eliminated.

The only difference between the GCA10G and the GSA10G is that the former is a counter tube whilst the latter is a selector tube with a separate connection to each of the ten main cathodes. In both tubes the routing guides are brought out to separate external connections so that they can be used for bidirectional counting. Each of the ten auxiliary anodes is also connected to a separate base pin.

The total current passing to a glowing main cathode is shared between the main anode and the auxiliary anode which is nearest to the glowing cathode. The recommended main anode operating current is 0.62 mA and the auxiliary anode current 2.0 mA. The Digitron cathodes are connected directly to the auxiliary anodes, but a bias supply network also feeds the auxiliary anodes.

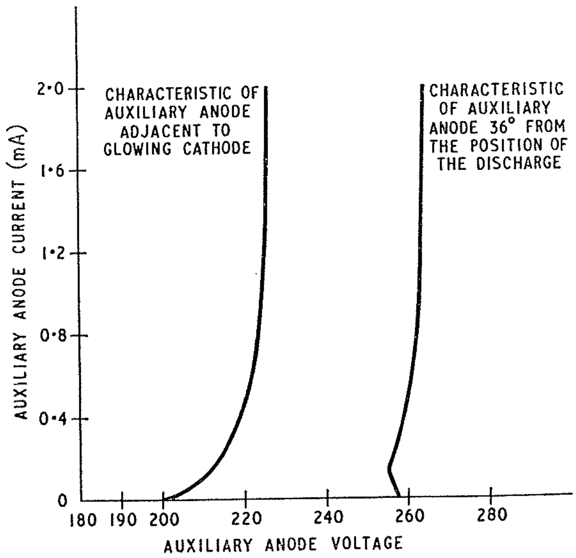


Fig. 4.29 Auxiliary anode characteristics

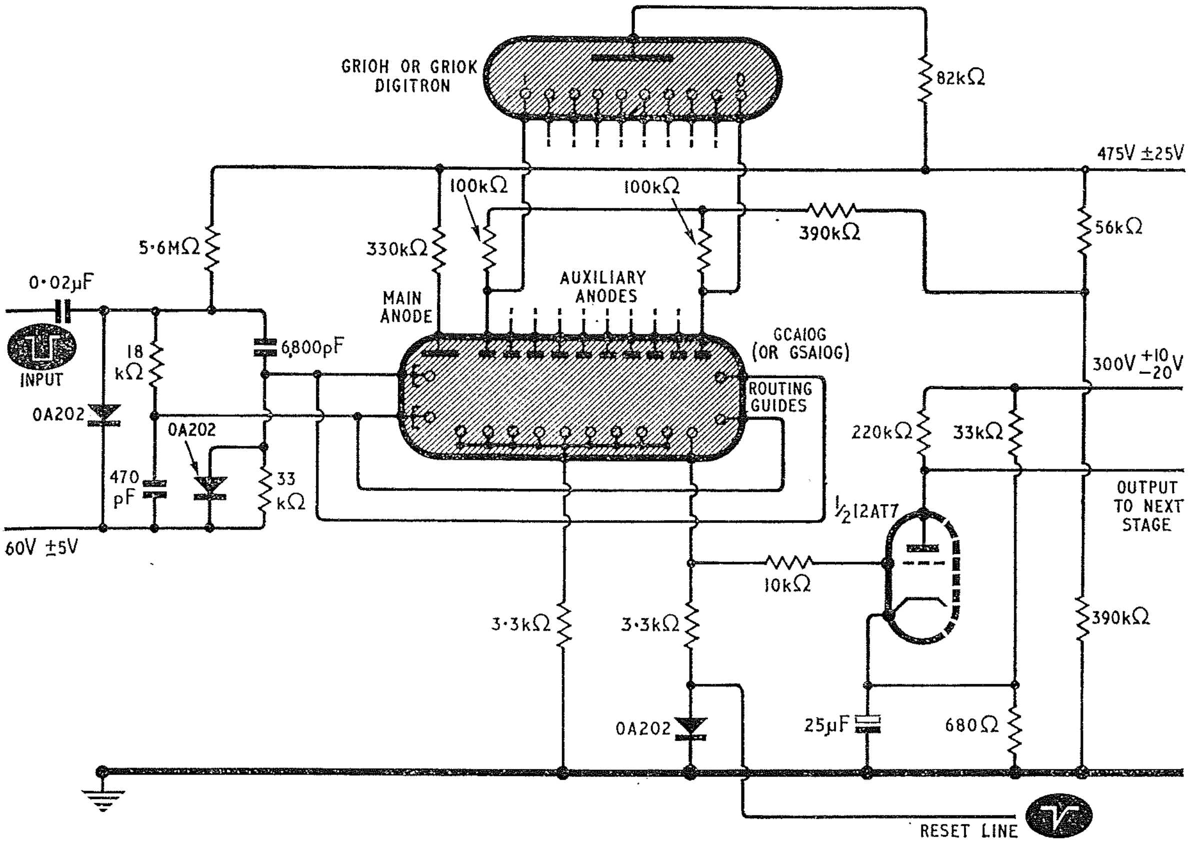


Fig. 4.30 The direct operation of a Digitron from a GCA10G tube

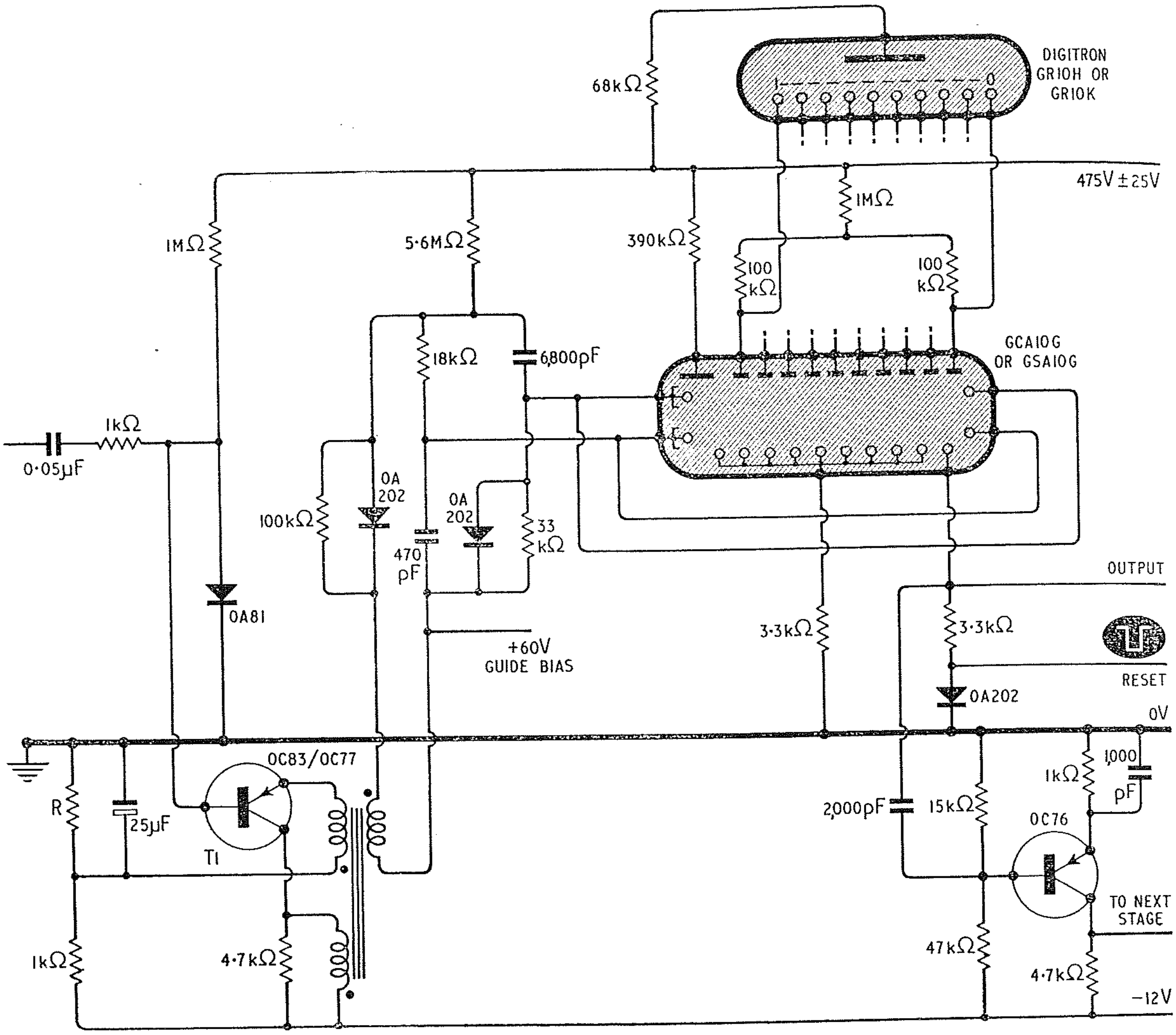
The extent to which the auxiliary anodes are primed depends on their distance from the glowing main cathode. It can be seen from the auxiliary anode characteristics of Fig. 4.29 that the auxiliary anode radially in line with the glowing cathode will conduct at an applied potential of about 40 V less than is required to cause one of the other adjacent auxiliary anodes to conduct. The characteristic is very steep, so the output impedance of the auxiliary anode circuit is very low. The normal operating point is about 225 V at 2 mA.

The fact that a potential of about 40 V can exist between the conducting auxiliary anode and an adjacent auxiliary anode before any appreciable conduction takes place to the latter enables the required pre-bias for the Digitron to be obtained.

A typical circuit for the operation of a Digitron from a GCA10G or a GSA10G is shown in Fig. 4.30[18]. A 100 kΩ resistor is connected to each auxiliary anode and the junction of the upper ends of these resistors is returned to a source of +430 V via a 390 kΩ resistor. These values are chosen so that the potential across the 100 kΩ resistor connected to the conducting auxiliary anode will be about equal to the required pre-bias for the Digitron of 40 V. This, therefore, ensures that a negligible current flows to the non-glowing cathodes of the Digitron.

The current passing to the auxiliary anode may be varied by changing the value of the Digitron anode resistor, whilst the Dekatron main anode current can be varied by changing the value of its main anode resistor. The two currents are more or less independent of each other.

The GCA10G can provide a pulse of about +10 V from its output cathode, whereas the GSA10G can provide a pulse of this value from



TRANSFORMER DETAILS

516 in stack of 0·008 in mu-metal laminations RCL 191, type 421	
collector winding	120 turns
emitter winding	50 turns
output winding	1500 turns

Max. freq.	T_1	R	*Input Pulses* V_{min}	*Input Pulses* t_{min}
2 kc/s	0C77	27 Ω	5	10 μ sec
5 kc/s	0C83	12 Ω	10	20 μ sec

Fig. 4.31 Transistor drive and coupling circuits for the GCA10G or GSA10G

any of its main cathodes. In addition either tube can supply a negative going pulse of about 40 V amplitude from any of the auxiliary anodes.

The input pulses to the circuit of Fig. 4.30 should have an amplitude of between 140 and 160 V and should be between 90 and 110 μsec in length. The circuit of Fig. 4.30 is designed for forward counting only and the first routing guide is connected to the other first guides. Similarly, the second routing guide is connected to the other second guides.

Owing to the relatively high cathode current of the Dekatrons which employ auxiliary anodes, the input circuit techniques which are used are somewhat different from those employed with other types of Dekatron. It is important to note that the Digitron is an integral part of the system and its associated circuitry cannot be modified without affecting the Dekatron drive conditions.

The circuit of Fig. 4.31 shows how transistors may be used in the input and coupling circuits of the auxiliary anode tubes[13, 23]. The maximum counting speed is 5 kc/s if an OC83 transistor is employed for *T*1. The input pulses are used to operate this transistor which is connected in a blocking oscillator circuit. The output winding of the blocking oscillator transformer has a large number of turns in order that the voltage developed shall be great enough to operate the Dekatron. An OC76 transistor is used in the coupling circuit to invert the phase of the positive going output pulses from the zero cathode so that pulses which are suitable for the operation of the blocking oscillator of a succeeding stage are obtained. The capacitance coupling from the output cathode of the Dekatron to the base of the OC76 coupling transistor controls the duration of the pulses which are fed to the succeeding Dekatron. The reset pulses should be of 100 V amplitude and 50 μsec duration.

The circuit of Fig. 4.32 shows how a GCA10G or a GSA10G tube may be used for forward counting when Digitron readout is not required[13]. The input and coupling circuits may be similar to those of Fig. 4.30 or 4.31.

4.4.11 Reversible Counting with Digital Readout[18]

The circuit of Fig. 4.33 illustrates the use of GCA10G or GSA10G tubes in reversible counting

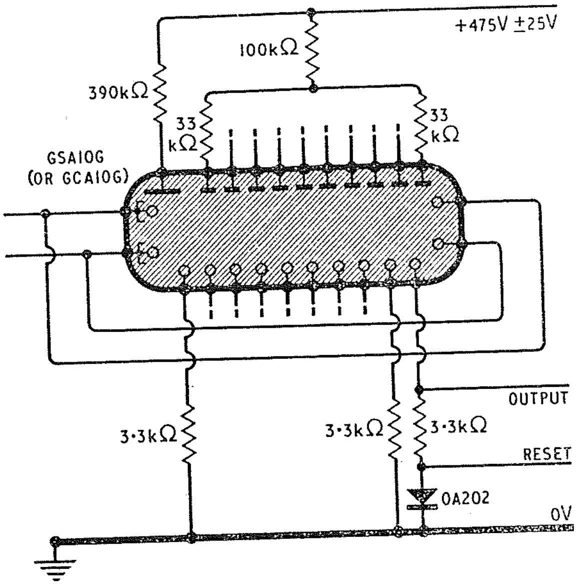


Fig. 4.32 A circuit for the GSA10G (or GCA10G) without Digitron readout

circuits which provide digital indication. The principle of operation of this circuit is the same as that of Fig. 4.27, but Digitron readout has been added. The input pulses should be of 100 V in amplitude and 60 μsec in duration with an overlap of at least 15 μsec. If the first pulse is applied to the '*A*' input and the second pulse to the '*B*' input, the count will increase, but if the first pulse is applied to the '*B*' input and the second pulse to the '*A*' input, subtraction will take place.

4.4.12 Circuits for Division

If a 10-way Dekatron is used in the circuits which have been discussed, it will divide the number of incoming pulses by 10 and similarly a 12-way Dekatron can be used to divide by 12. If the 0 and 5 main cathodes of a 10-way Dekatron are connected together and the junction is returned to earth via a load resistor, the circuit can be used to divide by five, since two output pulses will be obtained across the load for each complete revolution of the discharge in the tube.

If the even cathodes of a decade selector tube are connected to a load resistor and the odd cathodes are connected to earth directly, the system can be

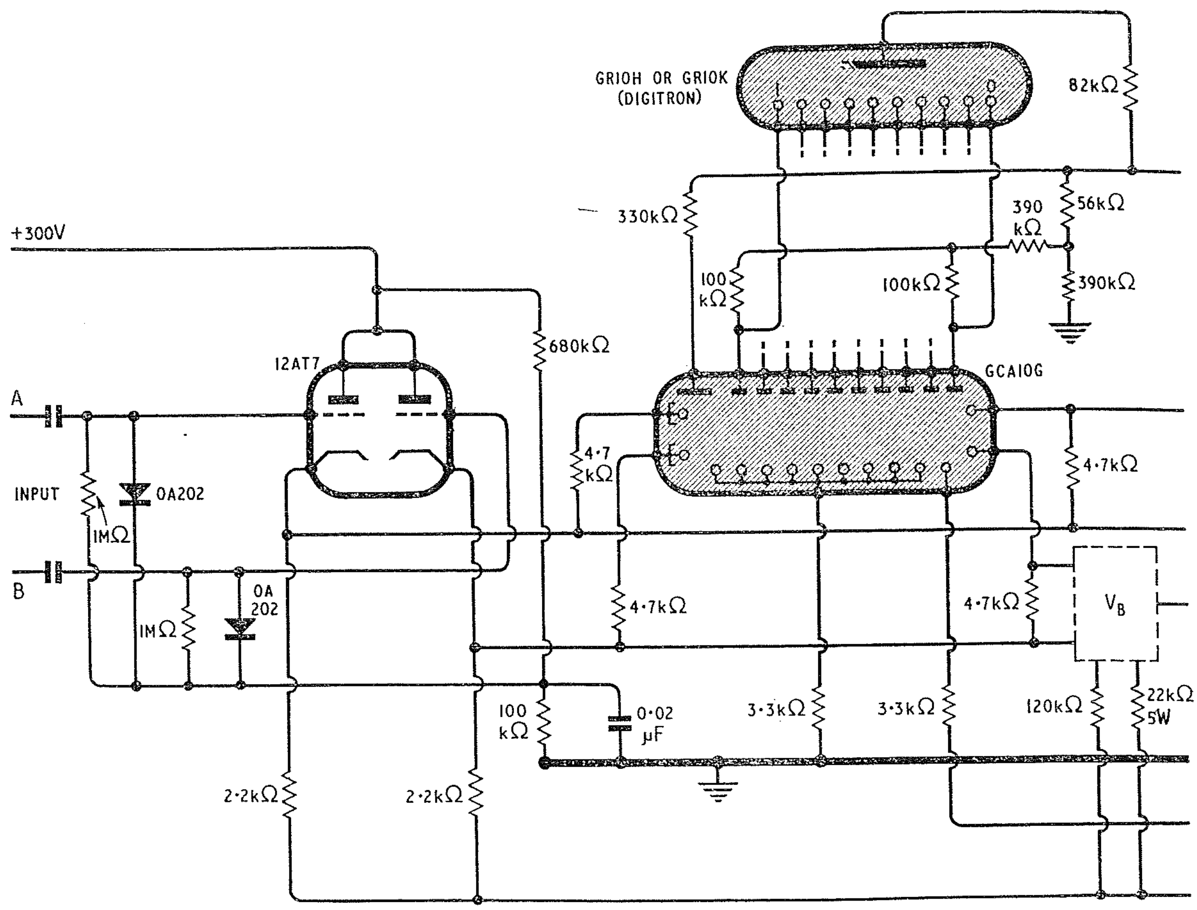


Fig. 4.33 A bidirectional

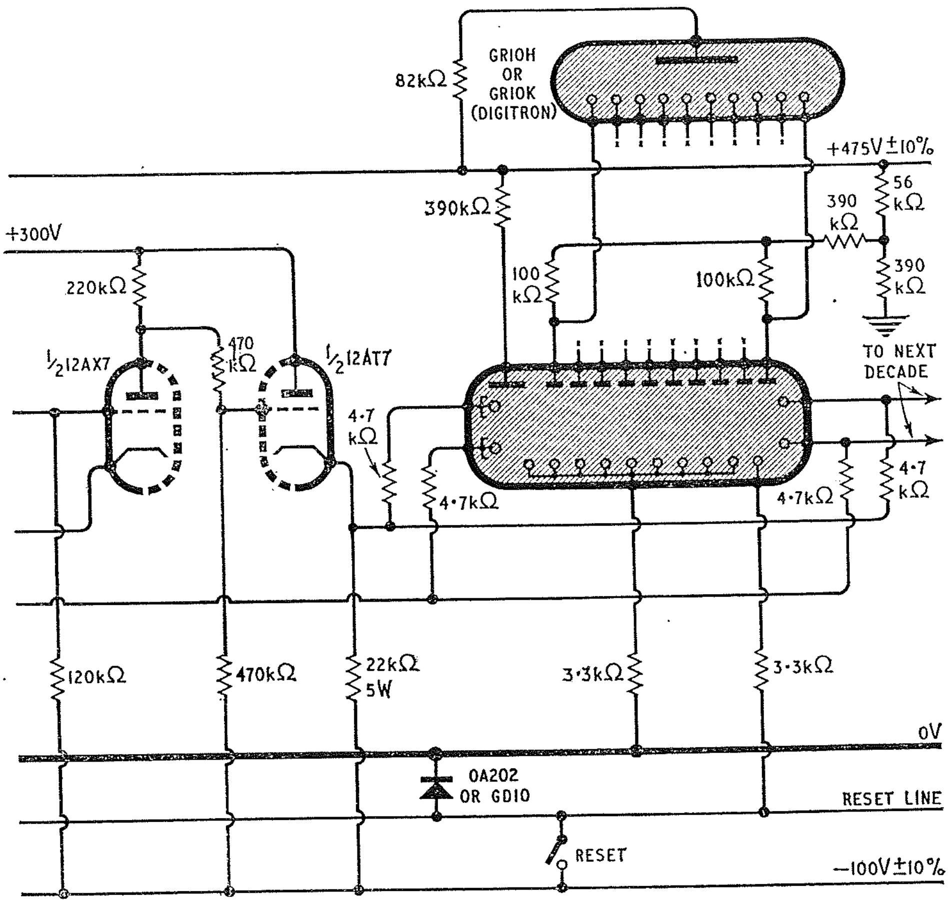
used to divide by two. The 12-way selector tube type GS12D is especially versatile in this type of application, since it can be used to divide by 2, 3, 4, 6 or 12. The output pulses are equally spaced.

4.4.13 The GC10D Single Pulse Dekatron[13, 24]

The GC10D single pulse Dekatron requires only one input pulse to cause it to count. In addition it has the advantage that it can operate at frequencies up to 20 kc/s. The structure of the GC10D tube is similar to that of the double pulse Dekatron shown in Fig. 4.1, except that forty identical cathodes surround the common anode instead of the thirty cathodes used in double pulse tubes. Ten of the cathodes are main cathodes, whilst the remaining thirty are transfer or guide cathodes. There are three guide cathodes between each two main cathodes.

All of the guide cathodes which are on the clockwise side of the adjacent main cathode are joined together and are known as the first guides (G_1 in Fig. 4.34). The electrodes on the clockwise side of each of the first guides are also joined together and are known as the second guides (G_2). Nine of the third guides are joined together (G_3), but the third guide preceding the output cathode is brought out to a separate base pin and is shown on the right hand side of the GC10D circuit symbol in Fig. 4.34. It is known as the output third guide.

The basic type of circuit in which the GC10D can be used for counting random pulses is shown in Fig. 4.34. The first and second guides are joined together via a resistor and a capacitor in parallel and are returned to a source of positive bias via a



counter with Digitron readout

resistor R_1 and a diode D_1. The third guides are returned to earth via a parallel resistor and capacitor. The small capacitors in the guide circuits limit the rate of change of guide potential to a suitable maximum value.

The negative input pulses are applied directly to the second guides and also via the parallel resistor and capacitor to the first guides. When the pulse is applied, the discharge moves one position in a clockwise direction from the glowing main cathode to the adjacent first guide which has been strongly primed. The anode voltage falls so that the first guide to anode potential is equal to the maintaining voltage of the tube and the discharge to the main cathode is then extinguished.

The capacitor in the first guide circuit charges from the current passing to the guide and the first guide potential increases. The discharge, therefore, transfers to the second guide which is still at its maximum negative potential. Transfer will occur when the potential across the capacitor in the first guide circuit is equal to the difference between the primed striking voltage and the maintaining voltage of the tube.

During the remainder of the input pulse the discharge rests at the second guide, but when the pulse ceases the anode potential rises so that the anode to second guide voltage is kept at the maintaining voltage of the tube. The third guide which is strongly primed then strikes, but soon the capacitor in the third guide circuit becomes charged from the third guide current to a potential which is great enough to cause the discharge to transfer to the succeeding earthed main cathode.

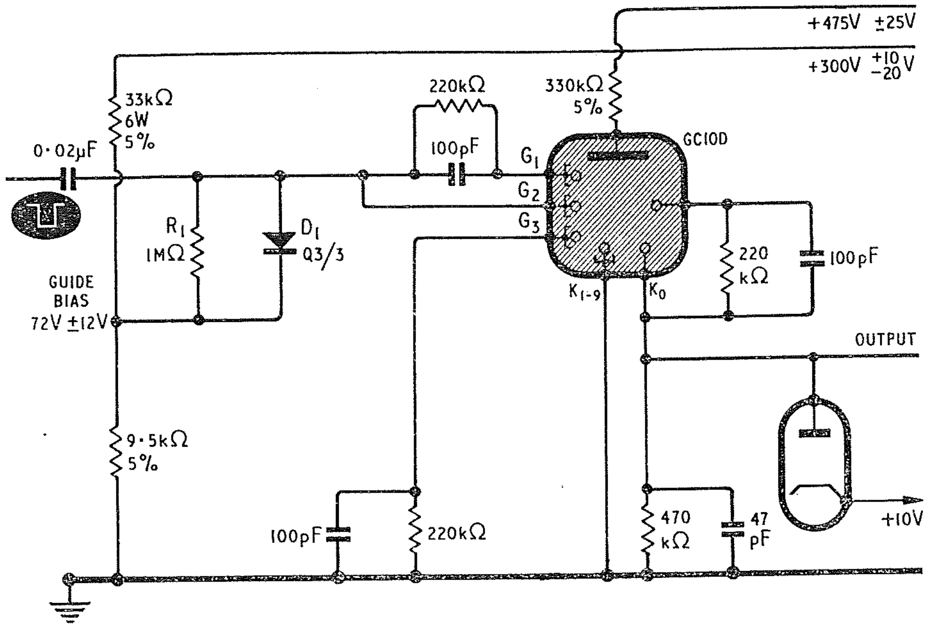


Fig. 4.34 The basic circuit for the single pulse GC10D tube

Although each count requires four separate steps (as compared with the three steps of the double pulse Dekatrons), the time the discharge remains at the first and third guides is extremely short owing to the automatic transfer mechanism as the capacitors in the guide circuits charge. The length of time for which the discharge rests at the second guide electrode is determined by the length of the input pulse. Thus the four stepping operations which take place in a single pulse Dekatron can be arranged to occur in a shorter time than the three steps of the double pulse tube.

The diode D_1 presents a large impedance to the input pulses and serves to prevent the first and second guide electrodes from becoming appreciably more positive than the guide bias supply point. If the diode were omitted, the ions from the adjacent conducting main cathode would produce a small current in R_1 which would result in an additional positive bias being formed at the guides.

The third guide preceding the output cathode is connected to the latter by a resistor and capacitor in parallel. When the output cathode is conducting and is at a positive potential (owing to the flow of current through the cathode resistor), the potential of the third guide is raised to the potential of the output cathode. The discharge is thus prevented from returning from the output cathode to the preceding third guide when the output cathode potential becomes positive with respect to earth.

The output cathode should not be allowed to rise to a potential above +10 V or the discharge may transfer spontaneously from this cathode to another

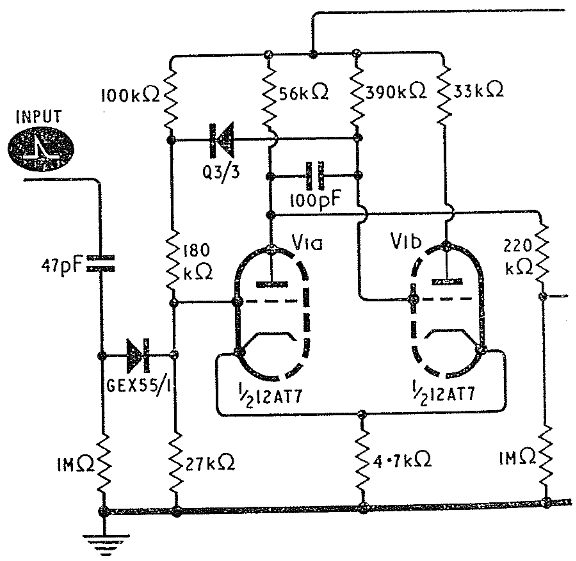


Fig. 4.35 An input circuit for the GC10D with

electrode. A clamping diode is, therefore, used from the output to a 10 V supply as shown in Fig. 4.34.

The amplitude of the input pulses to the second guides of the tube should be between 133 and 195 V and their duration should not be less than 25 μsec.

A suitable input circuit for the GC10D is shown in Fig. 4.35. The pulse shaper, consisting of *V*1a, *V*1b and *V*2a, is similar to the input circuit of Fig. 4.21, but the capacitor connecting the anode of *V*1a to the grid of *V*1b has been reduced to 100 pF so that pulses of about 25 μsec duration are fed into the GC10D tube instead of the 80 μsec pulses which are required for the operation of the 4 kc/s double pulse tubes.

A pulse coupling amplifier, *V*2b, is included in the circuit of Fig. 4.35. The grid and cathode of this valve also serve as the diode shown in Fig. 4.34. The output from the circuit may be fed into the capacitor marked *C* in Fig. 4.20 so that *V*3 of Fig. 4.20 serves as the next decade, *V*1 and *V*2 being omitted.

If a −20 V supply is available, the point marked 'A' of Fig. 4.35 may be taken to it instead of to earth, in which case the cathode of *V*2b should be taken directly to earth. The potential divider in the cathode circuit of *V*2b is then eliminated.

It is important that the stray capacitance from he anod e of the GC10D to earth should be kept to a minimum; the anode resistor should not be more than $^1/_4$ in from tag 4 of the tube base.

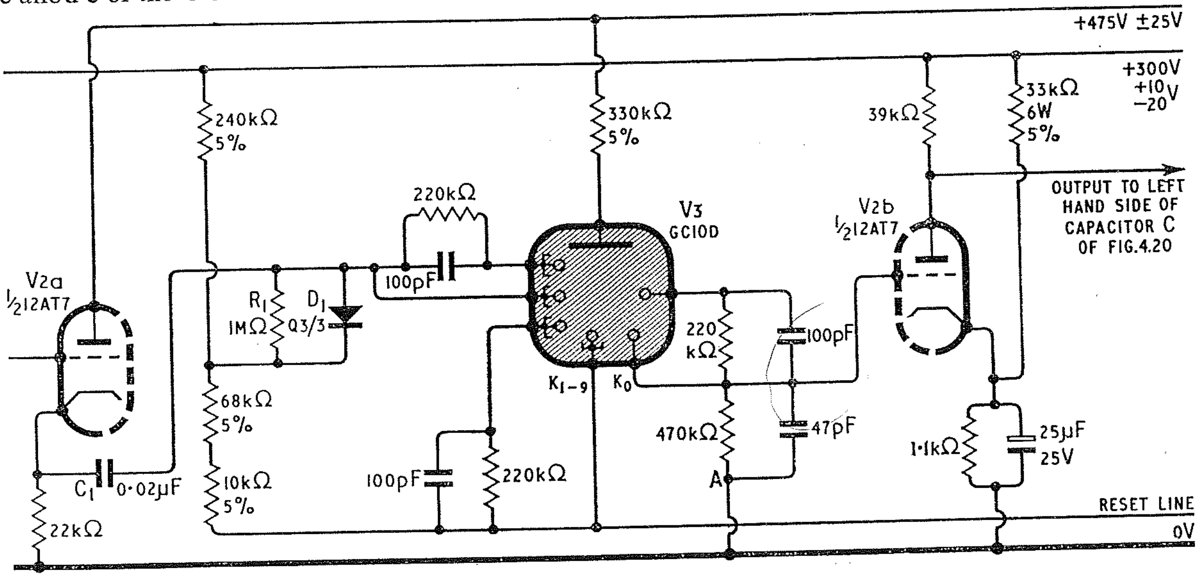
GC10D Sine Wave Circuit[13]

The GC10D may be used in the circuit of Fig. 4.36 to count the peaks of sine waves. The amplitude of the input waveform should be between 65 and 100 V R.M.S. The circuit may be used to feed a second decade by connecting the output to the capacitor *C* of Fig. 4.20, *V*1 and *V*2 of Fig. 4.20 being omitted.

4.4.14 Coupling Dekatrons to Magnetic Counters

Dekatrons may be used to divide the frequency of an input signal so that the output pulse frequency is not too great to be counted by an electro-magnetic counter. The output pulses from the Dekatron cannot be fed directly into the magnetic counter, since the output power which a Dekatron can supply is much too small to operate a magnetic counter directly and the pulse duration will not, in general, be suitable.

A typical circuit for coupling a 4 kc/s Dekatron to a magnetic counter is shown in Fig. 4.37[25]. The double triode *V*2 forms a monostable multivibrator circuit which is used to amplify and shape



a coupling circuit for driving a 4 kc/s tube

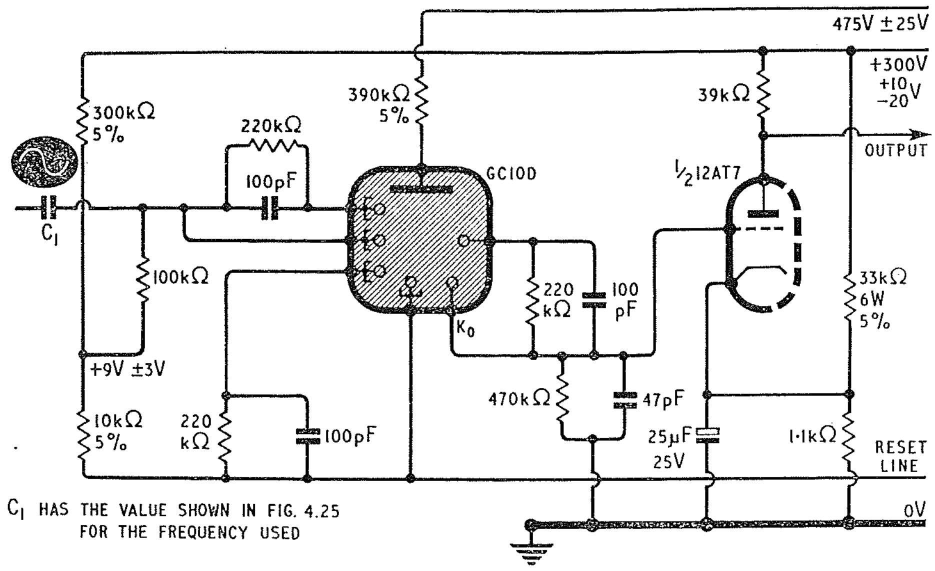


Fig. 4.36 A sine wave input circuit for the GC10D

the pulses from the Dekatron, *V*1. *V*2a is normally conducting because its grid is connected to the +350 V line via the counter coil, whilst *V*2b is normally cut off by the bias produced by the flow of the *V*2a current through the common cathode resistor. In the quiescent state no appreciable current, therefore, flows through the magnetic counter in the *V*2b anode circuit.

If a negative going pulse is applied to the grid of *V*2a, this triode is cut off and *V*2b conducts, thus operating the magnetic counter. After a preset time the circuit returns to its initial state and is then ready to receive another pulse. Although the output pulses from the Dekatron are positive going, the positive leading edges are shorted to earth by the OA85 diode. The negative trailing edges are

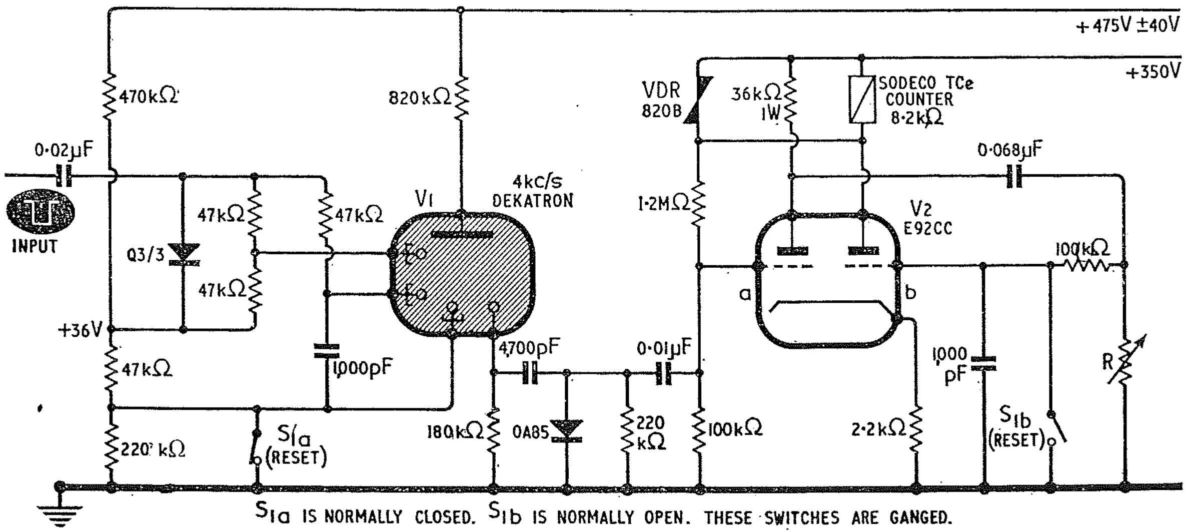


Fig. 4.37 The use of a 4 kc/s Dekatron for feeding a magnetic counter

Table 4.4 BASIC DATA FOR ERICSSON DEKATRON TUBES

Current Types	Max. Counting Rate (kc/s)	Nominal Maintaining Voltage (volts)	Min. V_b (volts)	Max. i_a (μA)	Min. i_a (μA)	Recommended Operating Conditions: i_a (μA)	V_b (volts)	Anode Load (ohms)	Max. cathode Load (ohms)	Guide Bias (volts)	Pulse Drive (volts)	Pulse Duration (μsec)	Reset Pulse (volts)	Dimensions: Max. Diameter (mm)	Max. Seated Height (mm)
GC10B, GC10B/S, GC10/4B, GC12/4B	4	191	350	550	250	310 ±20%	475	820k	150k	+18	−145 ± 15	80	−120	29.5	88.5
GC10B/L	4	190	350	550	250	310 ±20%	400	470k	100k	+35	−145 ± 15	80		29.5	87.5
GS10C/S	4	192	400	550	250	325 ±20%	475	680k	150k	+36	−145 ± 15	80	−120	33.1	70.5
GS10D	10 or 20	208	440	900	700	800	475	300k 5%	47k	+50 ±5	−145 ± 15	33 ±20%	−140	33.1	70.5
GS10E	10		440	900	700	800	475	240k 5%			−130	25	−120	33.1	70.5
GS10J	1		150			350	200	330k	3.3k	+12	− 24	300			
GS10H	5	187	380	370	250	340	475	{820k 910k}	82k 0	+35 +15	{−145 ±15}	75	−120	30	36
GCA10G, GSA10G	10	240	440	900	500	620	475 ±25	390k	3.3k	+60±5	−150±10	30	−100	29.5	54.2
GS12D	4	191	400	350	190	270 ±20%	475	910k	270k	+36	−145 ± 15	80	−120	33.1	70.5
GC10D	20	215	420	1200	700	800	475	330k		+72 ±12	−144+50 − 12	25	−140	29.5	88.5
Maintenance Types															
GS10G	10	210	400	900	700	725	475	300k 5%	68k		−100	30	−140	29.5	54.2
GS10K	10	210	480	2000	1500		500	{120k 160k}	{27k 62k}	+85	−150	65		29.5	54.2
GC10/2P	1	190	320	500	315	350 ±10%	475	820k	150k	+18	−145 ± 15	350	−120	19	47.5
GS12C	4	192	350	550	250	325 ±20%	475	680k	150k	+36	−145	80	−120	29.5	96

Ericsson tubes should now be obtained from Hivac Ltd.

Table 4.5 ERICSSON TUBE ESCUTCHEONS,

Current Types:	*Escutcheon (Ericsson)*	*Base*	*BASE*								
			1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
GC10B, GC10B/S GC10B/L	N78211 (bakelite) or N79368 (brass)	I.O.	K_{1-9}	–	G_1	a	G_2	–	K_0	–	
GC10/4B, GC10/4B/L	(AsGC10B)	I.O.	K_{1-9}	K_D	G_1	a	G_2	K_A	K_B	K_C	
GC12/4B	N79369 (brass)	I.O.	K_{1-11}	K_C	G_1	a	G_2	K_A	K_B	K_D	
GS10C/S, GS10D GS10E	N80977 (brass)	Duodecal + base cap	K_0	K_9	K_8	K_7	K_6	K_5	K_4	K_3	K_2
GS10H, GS10J	(As GC10B)	B17A	K_6	K_5	I.C.	K_4	K_3	I.C.	K_2	a	K_1
GS12D	N84538 (brass)	Duodecal +base cap +2 flying leads	K_0	K_{11}	K_{10}	K_9	K_8	K_7	K_6	K_5	K_4
GCA10G	(As GC10B)	B27A	K_{1-9}	K_0	RG_2	RG_1	A_1	A_0	A_9	A_8	A_7
GSA10G	(As GC10B)	B27A	K_1	K_0	RG_1	RG_2	K_9	A_8	K_8	K_7	I.C.
GC10D	(As GC10B)	I.O.	K_{1-9}	G_3	G_1	a	–	K_0	G_3 out	G_2	
Maintenance Types: GS10G	(As GC10B)	B26A or B27A	K_6	K_5	K_4	G_2	K_3	I.C.	K_2	I. C.	K_1
GS10K	—	B27A	K_5	I.C.	K_4	G_1	K_3	I.C.	K_2	G_2	K_1
GP10/2P	N84338 (brass)	B7G	I.C.	G_1	K_{1-8}	G_2	K_0	K_9	a		
GS12C	N79369 (brass)	16 tags for soldering	a (Red)	–	K_0	K_{11}	K_{10}	K_9	K_8	K_7	G_2

CONNECTIONS

10	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*19*	*20*	*21*	*22*	*23*	*24*	*25*	*26*	*27*	*28*
K_1	G_2	G_1	Base Cap = Anode.														
K_0	RG_2	RG_1	K_9	K_8	G_2	K_7	G_1										
K_3	K_2	K_1	Base Cap = anode				Yellow lead = G_1				Green lead = G_2						
A_6	A_5	A_4	A_3	A_2	I.C.	G_2	G_1	–	–	–	–	–	–	–	–	–	*a*
K_6	K_5	I.C.	K_4	K_3	G_2	G_1	K_2	A_1	A_0	A_9	A_7	A_6	A_5	A_4	A_3	A_2	*a*
K_0	RG_2	RG_1	K_9	I.C.	K_8	K_7	G_1	–	–	*a*	–	–	*a*	–	–	*a*	–
K_0	G_3	K_9	I.C.	K_8	I.C	K_7	K_6	–	–	–	–	–	–	–	–	–	*a*
K_6	K_5	K_4	G_1	K_3	K_2	K_1											

G_1 = 1st Guides
G_2 = 2nd Guides
G_3 = 3rd Guides

G_3 out = Output 3rd guide (GC10D)
RG_1 = 1st Routing guide

RG_2 = 2nd Routing guide
a = Main anode
A_5 = Auxiliary anode 5
K_A = Main cathode A

thus passed to the E92CC multivibrator which is triggered. The input circuit to the Dekatron may be of the type shown in Fig. 4.21 or, for sine wave inputs, as in Fig. 4.22.

Ideally, the value of the resistance R should be such that the current pulse to the magnetic counter is of about the same duration as the time between pulses when the circuit is operating at its maximum speed. For example, if the Dekatron is counting at 250 pulses per second, the magnetic counter will be operating at 25 pulses per second and the value of

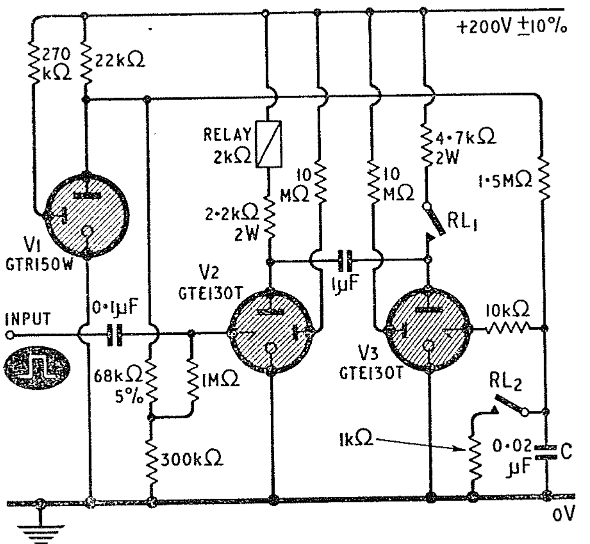


Fig. 4.38 A trigger tube circuit for operating a magnetic counter from a Dekatron

R should be about 120 k Ω. The voltage dependen resistor, VDR 820B, is used to short circuit the voltage peaks formed when the current ceases to flow in the relay.

During the operation of the reset switch, S_{1a}, a spurious pulse might be registered by the magnetic counter, but this can be prevented by earthing the grid of $V2$b by means of S_{1b} during the resetting of the Dekatron. The switches however may be replaced by relays if, it is so desired. S_{1b} must open after S_{1a} has closed at the end of the resetting operation.

A trigger tube circuit for operating a relay or electromagnetic counter is shown in Fig. 4.38[13]. It is very suitable for driving a relay from the output of a decade tube. The maximum operating speed is about 15 pulses per second.

When an input pulse is received, the combined effect of the pulse and the trigger bias cause $V2$ to strike and the relay in the anode circuit of this tube closes. The relay contacts RL_1 close and RL_2 open. The capacitor C charges through the 1.5 MΩ resistor and after a short time $V3$ ignites. The negative pulse at the anode of this tube is coupled to the anode of $V2$ which is thus extinguished. The relay contacts RL_1 open so that $V3$ is extinguished and in addition the contacts RL_2 close so that the capacitor C loses virtually all of its charge through the 1 kΩ resistor. If RL_2 shorted C directly to earth, excessive sparking would occur at the contacts.

The circuit requires input pulses of about 25 V in amplitude and 100 μsec in duration. The relay or electro-magnetic counter should be rated at about 50 V, 25 mA. The GTR150W provides a stabilised supply of about 150 V for biasing the trigger electrodes of the tubes. The value of the capacitor C determines the duration of the energising pulses fed to the relay; with the values shown the duration of these pulses is about 50 msec.

4.4.15 Power Supplies for Ericsson Dekatrons[13]

Wherever possible the circuits designed by the Ericsson Company for their Dekatrons operate with power supply potentials of 475 $\pm$25 V, 300

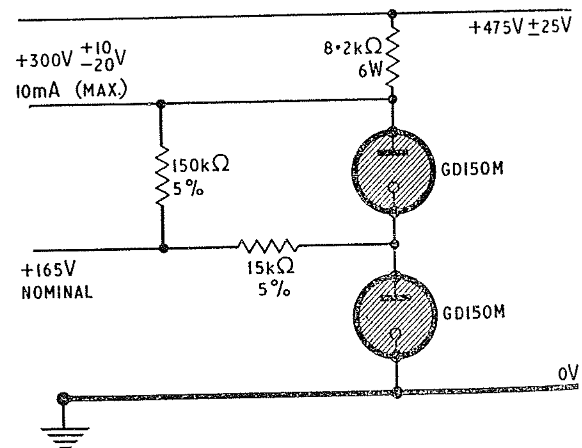


Fig. 4.39 A stabilised 300 volt power supply for Dekatron circuits

± 10 V, -20 V and -100 V. The $+300$ V supply may be obtained from the stabilised circuit of Fig. 4.39 which employs two Ericsson GD150M tubes and can supply up to 10 mA. The -20 V supply for the Dekatron output cathodes can be obtained from a potential divider across the -100 V power supply; care should be taken to ensure that the impedance of the -20 V line is not greater than 4 kΩ.

4.5 RAYTHEON AND SYLVANIA DOUBLE PULSE DECADE TUBES AND THEIR CIRCUITS

4 and 5 kc/s tubes:

Selector tubes: Sylvania, Raytheon — *6476, 6476A*
Raytheon — *7978*
'Computer' tube with access to 4 cathodes:
Sylvania, Raytheon — *6802*
Miniature tube with access to 3 cathodes:
Sylvania — *6879*

100 kc/s tubes:

Selector tubes: Sylvania, Raytheon — *6910*
Raytheon — *8262*
'Computer' tube with access to 4 cathodes:
Sylvania, Raytheon — *6909*
'Computer' tube with access to 3 cathodes:
Sylvania — *7155*

Raytheon and Sylvania tubes which have the same type number are equivalents, but sometimes the Raytheon Company put the letters CK in front of the type number; for example, the CK6476 is equivalent to the 6476. British equivalents to some of these tubes are given in the appendix.

4.5.1 4 and 5 kc/s tubes

The 4 and 5 kc/s American tubes may be used in the 4 kc/s circuits given in Sections 4.3 and 4.4. In addition, some rather interesting circuits have been published by the American manufacturers.

In the circuit of Fig. 4.40[26], the whole of the triode anode current is obtained from the guide electrodes of the counting tube. The triode, *V*1, conducts only during the time the grid is receiving a positive going pulse, the duration of which is limited by the differentiating circuit in the input.

The circuit of Fig. 4.41[26] may be used to divide the incoming pulse frequency by a factor of eight. The input circuit is somewhat similar to that of Fig. 4.40. *V*2 is normally cut off by the applied

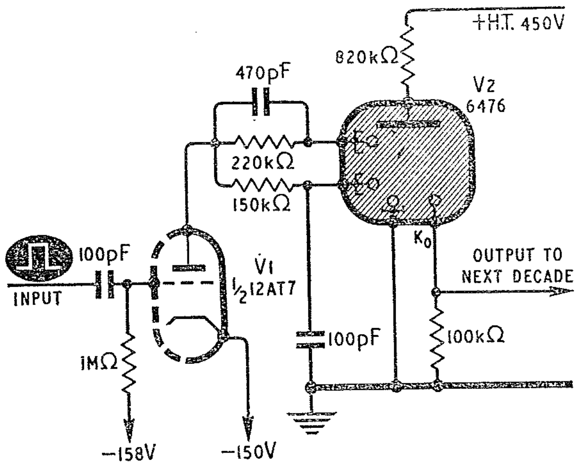


Fig. 4.40 A circuit for driving the 6476 tube

grid bias, but conducts when the discharge in *V*3 first reaches K_8; the discharge is thus returned to the zero position, the ninth position being omitted. The resetting action is quite fast and no counts are missed provided that the pulses are spaced by at least 250 μsec.

The circuit can be preset to divide by any desired number up to ten if an output from the appropriate cathode is used to operate the resetting valve, *V*2. All of the subsequent cathodes will be missed. Division by 2 or 5 may be accomplished by the method suggested in the previous section of this chapter, the resetting circuit being unnecessary.

4.5.2 100 kc/s Tubes

100 kc/s double pulse tubes function in exactly the same way as 4 kc/s double pulse tubes, but they can operate from rectangular guide pulses of 4 μsec in duration which have a minimum overlap of 2 μsec. The guide pulse amplitude should be between 120 and 140 V, which is very similar to that required for the 4 kc/s tubes. In actual practice, rectangular guide pulses are somewhat difficult to obtain and the tubes are normally operated from somewhat rounded pulses.

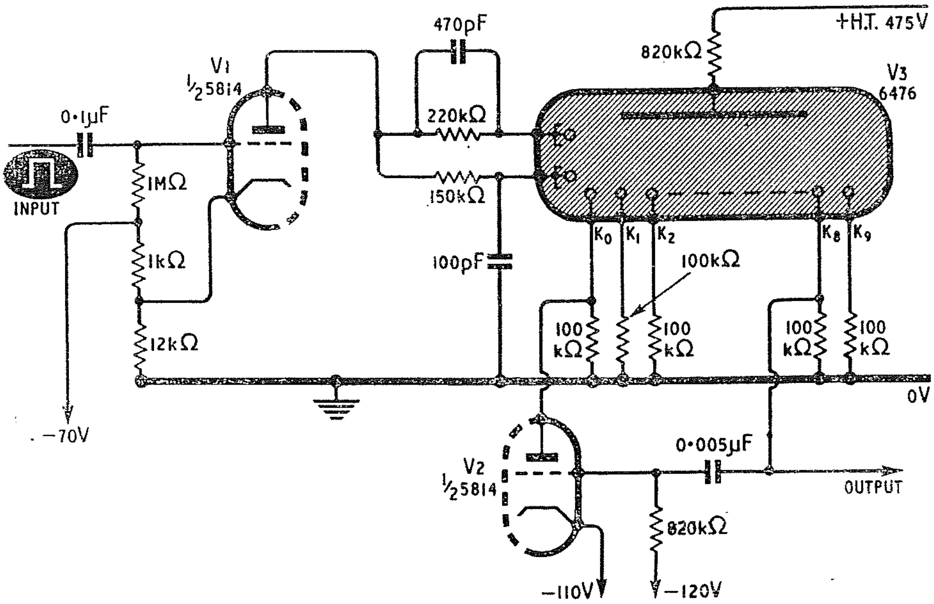


Fig. 4.41 A scale of eight frequency divider

Whenever double pulse tubes are used at high speeds, the anode resistor of the counting tube should be soldered directly to the tube base in order to keep stray anode to earth capacitance to a minimum. When 100 kc/s tubes are used at frequencies above 50 kc/s, a potentiometer should be included in the anode circuit so that the average anode current taken by the tube can be adjusted by at least 100 μA above and below the specified value in order to obtain the optimum anode current for the tube concerned. The potentiometer cannot be soldered directly to the anode tag of the tube, since this would increase the anode to earth capacitance. A fixed resistor should be included between the anode and the potentiometer.

A circuit which will drive a 6910 tube at frequencies up to 50 kc/s is shown in Fig. 4.42[26]. A positive going pulse applied at the input through the differentiating circuit causes anode and screen grid currents to flow in the 5654 tube, *V*1, for a short time. Initially the capacitor in the screen grid circuit maintains the screen grid voltage well

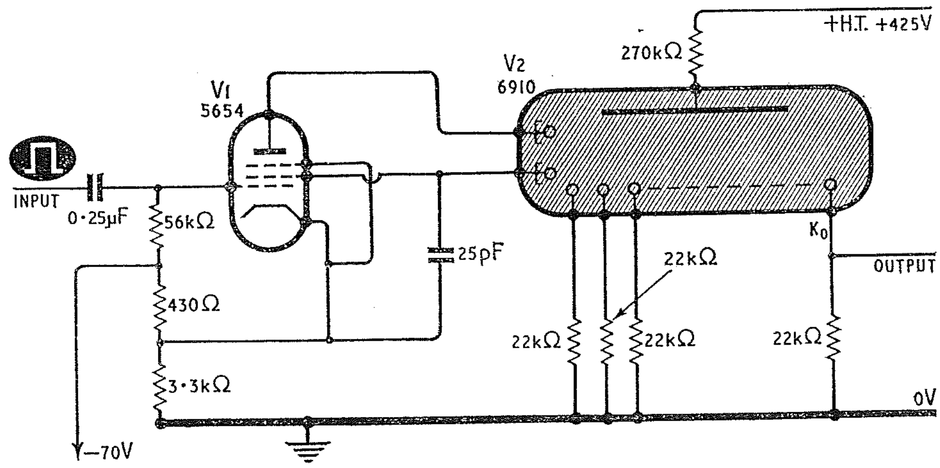


Fig. 4.42 A 50 kc/s counting stage

Table 4.6 BASIC DATA AND CONNECTIONS FOR THE AMERICAN DOUBLE PULSE TUBES

	6476	*6802*	*6879*	*7978*	*6910*	*6909*	*7155*	*8262*
Max. frequency (kc/s)	4	4	5	5	100	100	100	100
Anode current (μ A) max.	600	600	600	600	800	800	800	800
min.	300	300	300	300	600	600	600	600
Min. anode supply voltage	350	350	350	350	400	400	400	400
Min. transfer voltage	35	35	35	35	35	35	35	35
Min. guide bias (V)	+35	+35	+35	+35	+45	+45	+45	+45
Min. rectangular pulse amplitude (V)	−75	−75	−75	−75	−85	−85	−85	−85
Min. rectangular pulse duration (μsec)	60	60	60	60	4	4	4	4
Min. reset pulse amplitude (V)	−120	−120	−120	−120	−120	−120	−120	−120
Min. reset pulse duration (μsec)	50	50	50	50	4	4	4	4
Max. cathode resistor (kΩ)	150	150	150	150	50	50	50	50
Base	Modified duodecal	I.O.	B7G	13 pin	Modified duodecal	I.O.	B7G	13 pin
Bulb Type	*T*11	*T*9	*T*5½	*T*9	*T*11	*T*9	*T*5½	*T*9
Connections								
Pin 1	K_0	K_{1-7}	K_8	a	K_0	K_{1-7}	K_8	a
Pin 2	K_9	K_5	G_1	K_5	K_9	K_5	G_1	K_5
Pin 3	K_8	G_1	K_{1-7}	K_4	K_8	G_1	K_{1-7}	K_4
Pin 4	K_7	a	G_2	G_2	K_7	a	G_2	G_2
Pin 5	K_6	G_2	K_0	K_3	K_6	G_2	K_0	K_3
Pin 6	K_5	K_9	K_9	K_2	K_5	K_9	K_9	K_2
Pin 7	K_4	K_0	a	K_1	K_4	K_0	a	K_1
Pin 8	K_3	K_8	—	K_0	K_3	K_8	—	K_0
Pin 9	K_2	—	—	K_9	K_2	—	—	K_9
Pin 10	K_1	—	—	G_1	K_1	—	—	G_1
Pin 11	G_2	—	—	K_8	G_2	—	—	K_8
Pin 12	G_1	—	—	K_7	G_1	—	—	K_7
Pin 13	—	—	—	K_6	—	—	—	K_6
Base Cap	a	—	—	—	a	—	—	—

The 6476A tube is similar to the 6476, but the voltage between two electrodes other than the anode has a maximum value of 200 volts instead of the maximum rating of 140 volts for the 6476.

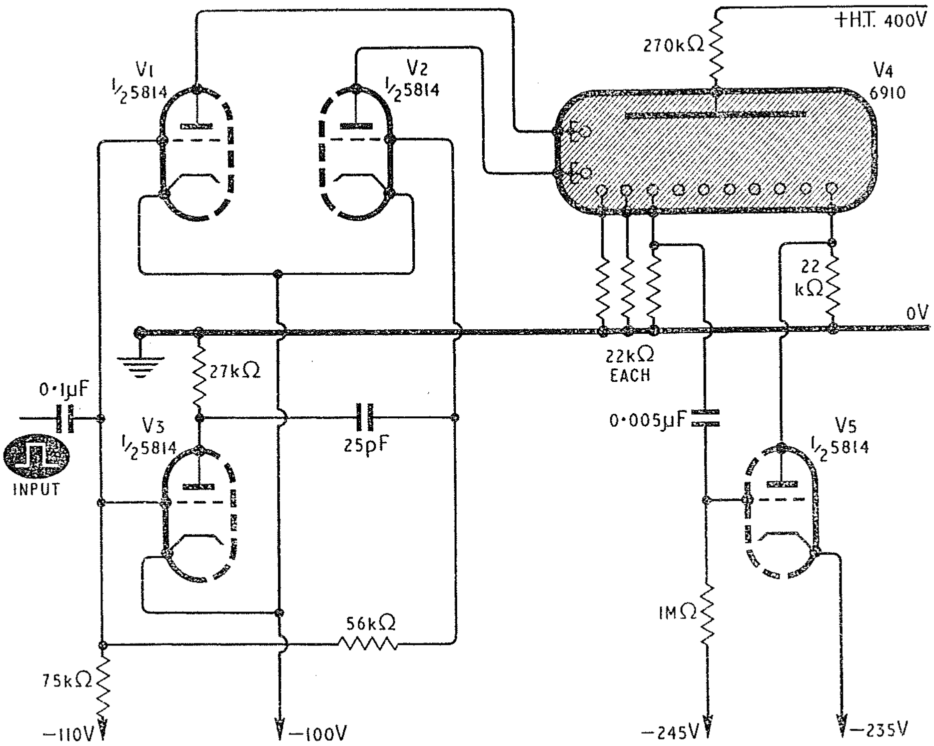


Fig. 4.43 A high speed frequency divider

above the cathode potential and the current taken by the anode results in the anode to cathode potential falling to a small value. The discharge transfers to the first guides at this point, but the low anode voltage causes the screen current to increase and the capacitor in the screen grid circuit is discharged. As the control grid potential of $V1$ falls, the anode voltage rises and the discharge moves to the second guide. When the screen capacitor recharges, the positive potential of the screen grid causes the glow to move to the succeeding main cathode.

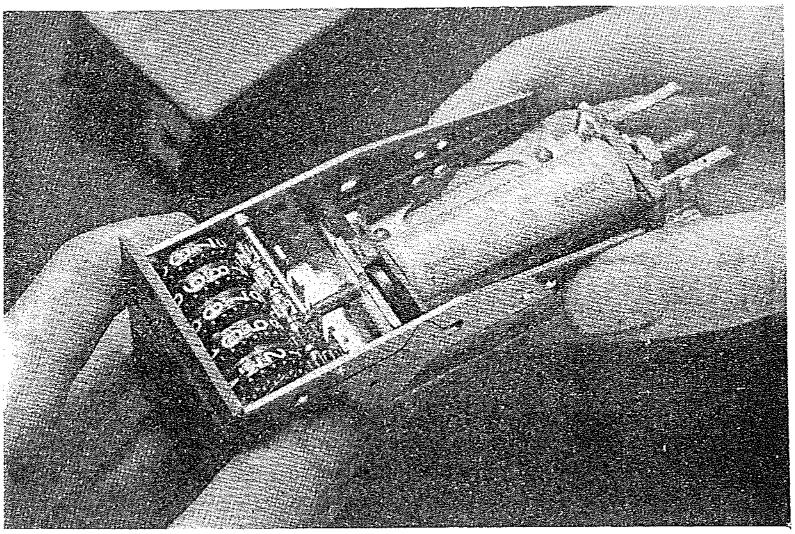
The circuit of Fig. 4.43 may be used to divide the input pulse frequency by any number up to ten[26]. The input frequency may have any value up to about 70 kc/s, but above this value the operation of the circuit is not very reliable unless the optimum component values and voltages are very carefully chosen. The circuit is similar to the slower circuit of Fig. 4.41, since a pulse taken from any cathode may be used to reset the discharge to the zero cathode.

The input pulses to this circuit should be positive going and have an amplitude of 10 V and a duration of 4 μsec. They are amplified by $V1$ and fed to the first guides. They are also amplified by $V3$ and differentiated by the anode circuit of this valve. The resultant waveform is mixed with a fraction of the original input signal and, after amplification by $V2$, the combined pulse is used to drive the second guides of the counting tube, $V4$.

4.6 THE CERBERUS DZ10 TUBE AND ITS CIRCUITS

The 3 kc/s Cerberus DZ10 decade selector tube differs from the tubes described in Sections 4.2–4.5, since it employs only one transfer or guide electrode between each two main cathodes. The guide electrodes and the main cathodes are so shaped that counting can occur in the forward or clockwise direction only. All of the main cathodes are connected to separate base pins. The tube is essentially a low voltage type, but it requires more current than the types which have been discussed previously. Further details of the DZ10 are given in the table.

Plate 1. Sodeco TCe5E counter.
(Courtesy: Sodeco)



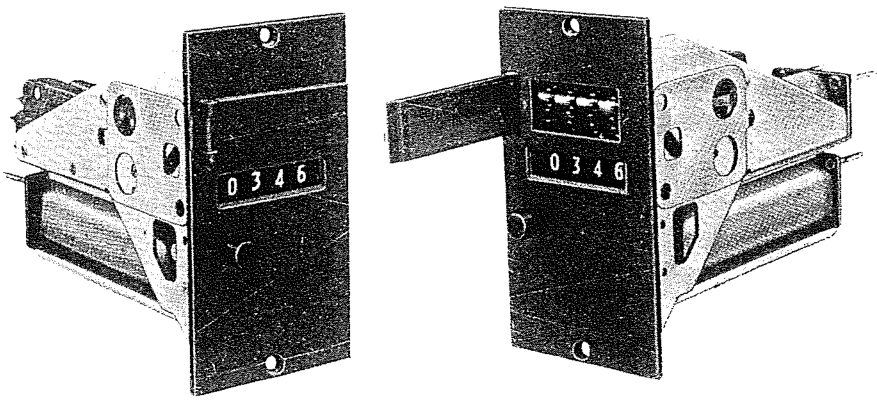


Plate 2. Sodeco TCeF4PE predetermined counters.
(Courtesy: Sodeco)

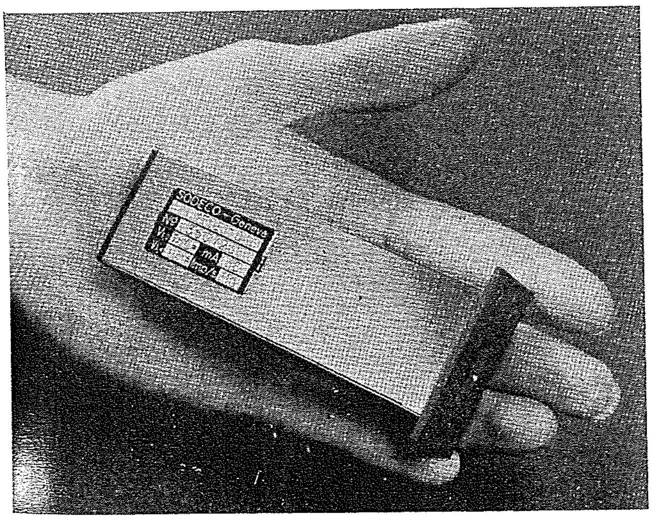
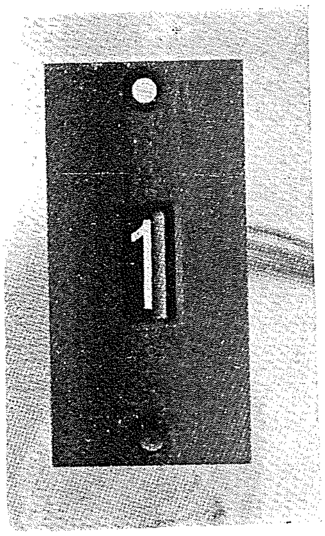


Plate 3. A Sodeco single digit counter.
(Courtesy: Sodeco)



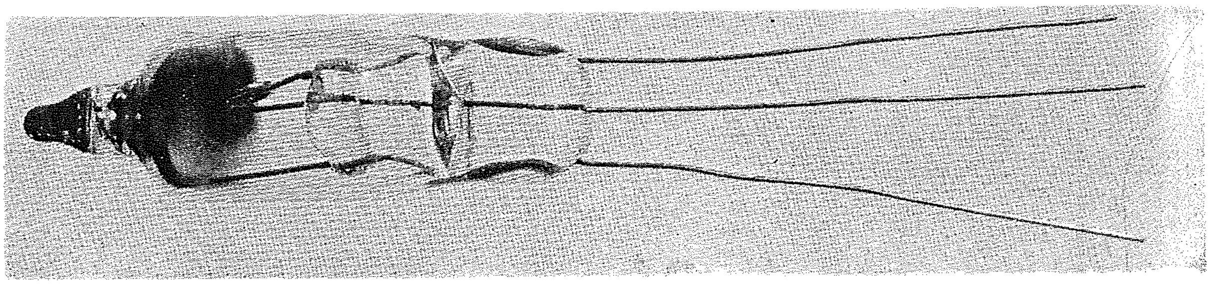


Plate 4. A miniature trigger tube Type GTR120W. (Courtesy: Ericsson)

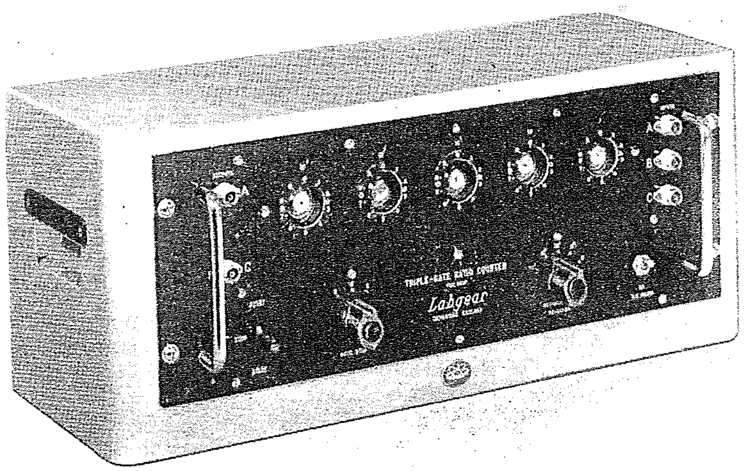
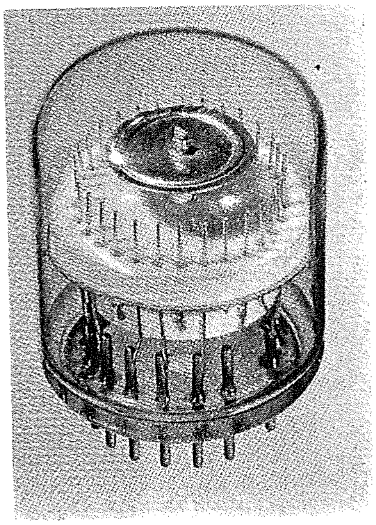


Plate 5. A typical scaler employing polycathode decade tubes. (Courtesy: Labgear)

Plate 6. The GC10B decade tube. (Courtesy: Ericsson)

Plate 7. The GS10H miniature decade tube. (Courtesy: Ericsson)



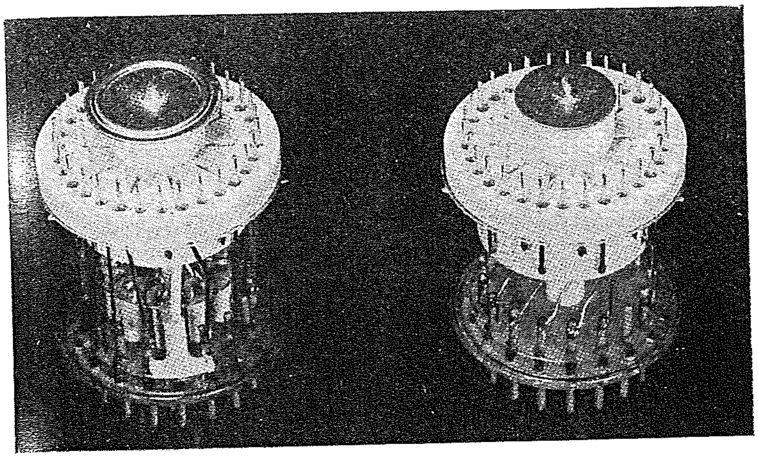


Plate 8. The electrode structure of the GSA10G (left) and the GCA10G (right) showing the auxiliary anodes. (Courtesy: Ericsson)

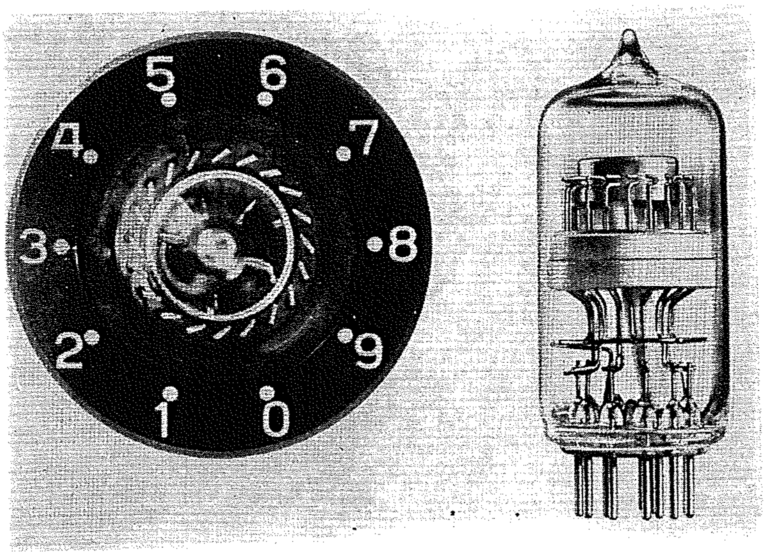


Plate 9. The EZ10B tube (Courtesy: Elesta)

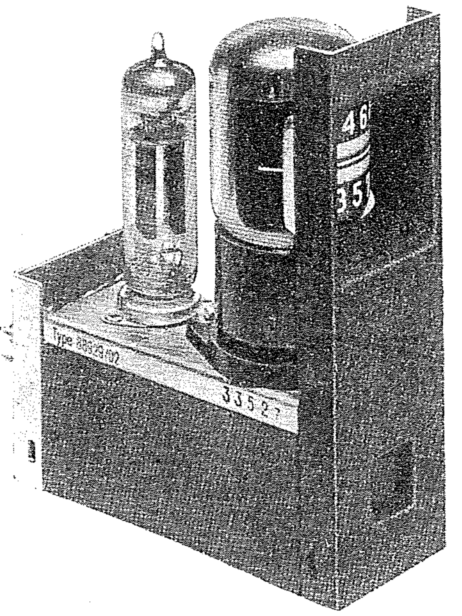


Plate 10. A 30 kc/s E1T decade module. (Courtesy: Mullard)

Plate 11. An Ericsson VS10G trochotron. (Courtesy: Ericsson)

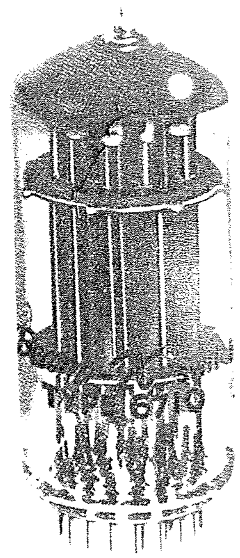


Plate 12. A Beam X tube (Courtesy: Burroughs)

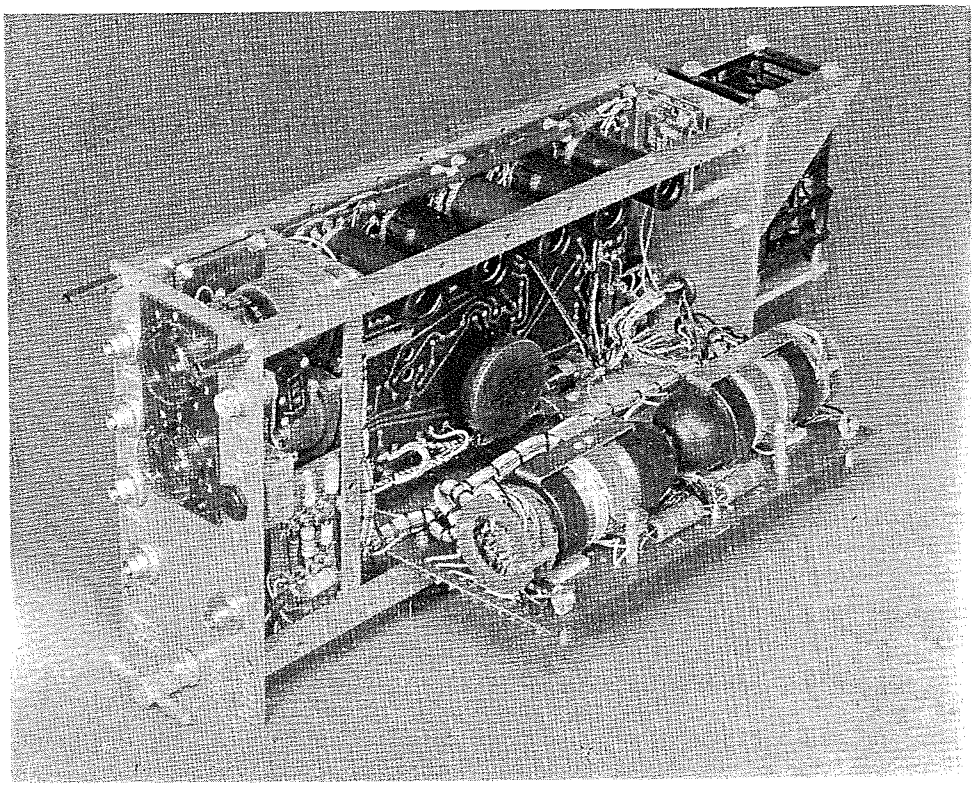


Plate 13. A two decade trochotron pre-scaler with GR10A readout—Bendix-Ericsson 2028A unit. (Courtesy: Bendix-Ericsson)

The five transfer cathodes which follow the main cathodes numbered zero to four inclusive are connected together and are brought out to the pin designated B_1 in the table of connections. The other five transfer cathodes are brought out to the connection marked B_2. The two sets of transfer electrodes, B_1 and B_2, are connected together in almost all circuits. The transfer electrodes receive a positive bias of about 30 V. The discharge, therefore, rests fed to the grid of an EL83 pentode which amplifies the pulse and inverts its phase so that it is suitable for feeding into the succeeding stage.

Stages which will not be required to operate at frequencies above 1 kc/s do not require resistors and capacitors in their cathode circuits, although a resistor is, of course, required for those cathodes from which output pulses are to be taken. No cathode capacitors need, therefore, be used in any

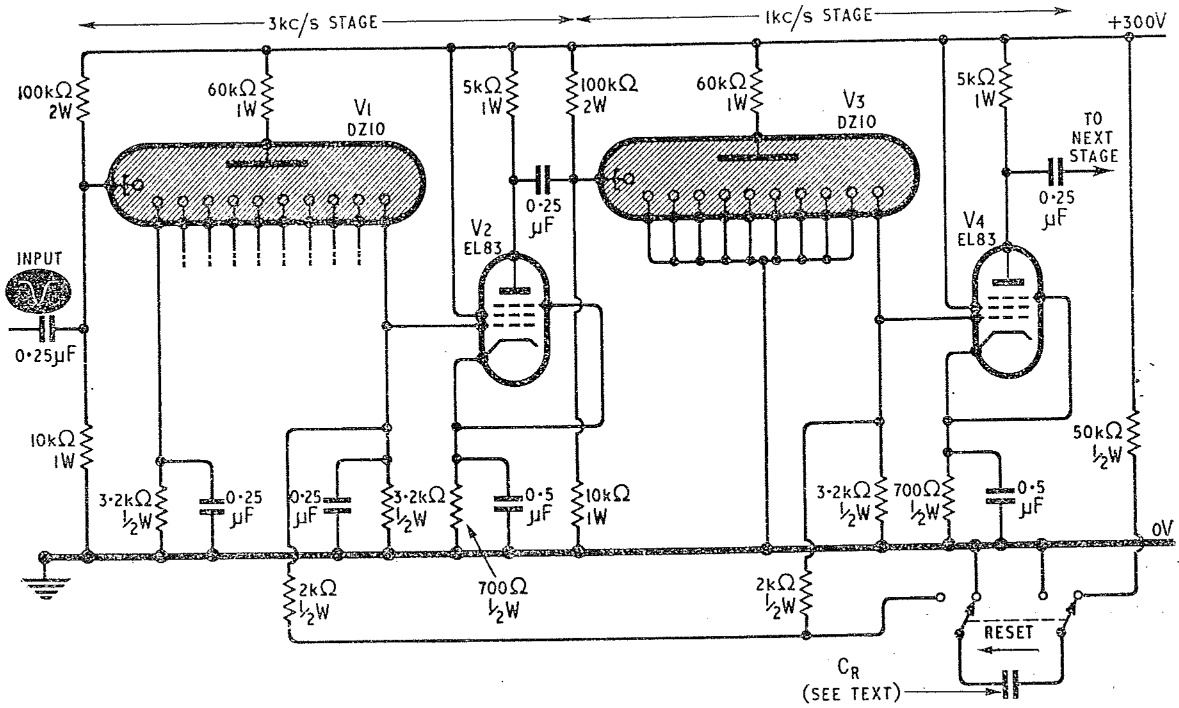


Fig. 4.44 A 3 kc/s counter using the Cerberus DZ10 tube

preferentially at the main cathodes except when the transfer cathodes are receiving a negative pulse. Each negative pulse applied to the transfer cathodes causes the discharge to move from a main cathode to the succeeding transfer cathode. At the end of the pulse the discharge moves to the next main cathode owing to the bias at the transfer cathodes.

A typical simple counting circuit is shown in Fig. 4.44. The input stage employs a resistor and a capacitor in parallel from each main cathode to earth; these components are necessary if the maximum counting speed of 3 kc/s is to be attained. The positive going pulse from the first decade is stage after the first, since the maximum speed at which they will be required to count is one tenth of the maximum speed of the first decade, that is 300 c/s.

The internal resistance of the source of pulses feeding the circuit of Fig. 4.44 should be less than 4 kΩ or alternatively the amplitude of the input pulses should be greater than the values shown in the table. If positive going pulses of at least 150 µsec in duration are available, an EL83 circuit similar to the coupling circuits in Fig. 4.44 may be used as the input circuit; otherwise a circuit should be used which will lengthen the pulses to this figure.

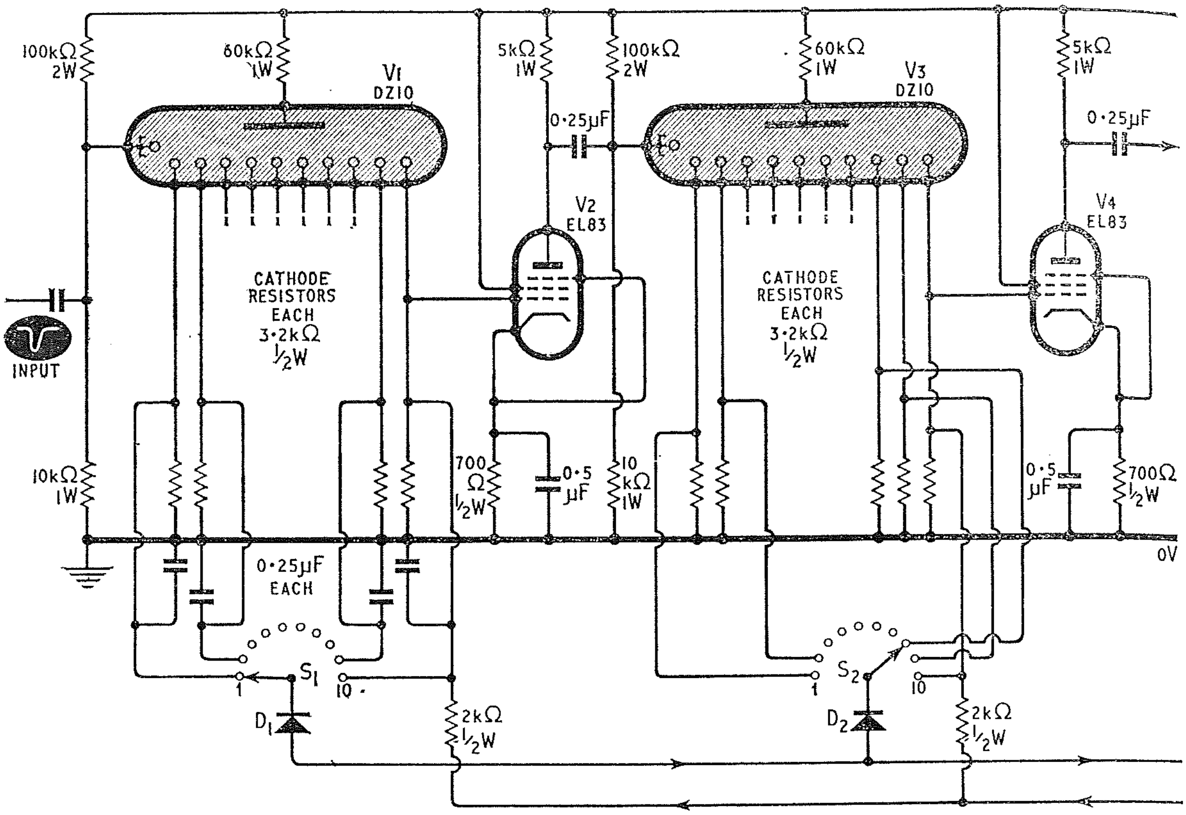


Fig. 4.45 A preset circuit using

Reset

During the counting operation the capacitor C_R becomes charged to the full H.T. voltage. When the reset switch is pressed, this capacitor provides a negative pulse which is fed to the zero cathode of each tube. All of the tubes are thus set to zero by the same process as for the double pulse tubes.

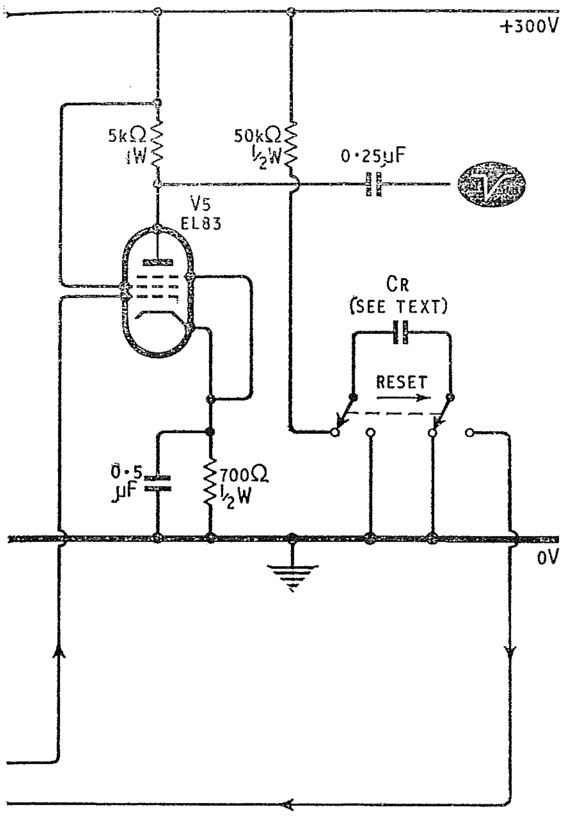
The value of C_R should be 2 µF for resetting one decade and should be increased in proportion to the number of decades employed.

Preset Counter

DZ10 tubes may be used in the circuit of Fig. 4.45 for preset counting[27]. The basic circuit is similar to that of Fig. 4.44, but cathode resistors are required in each of the cathode circuits of each decade.

The diodes D_1 and D_2 act as a simple coincidence circuit or AND gate. If the discharges rest at the first cathode of $V1$ and at the first cathode of $V3$, these cathodes will become positive with respect to earth. If S_1 and S_2 are in the positions shown, D_1 will be reverse biased by the cathode potential of $V1$, whilst D_2 will tend to be forward biased by the same potential, since D_2 is connected by S_2 to the eighth cathode of $V3$ and this is at earth potential. D_1 therefore, acts as a high impedance and D_2 as a low impedance. These two diodes form a potential divider together with the eighth cathode resistor of $V3$. The junction of the two diodes remains at about earth potential owing to the ratio of their impedances.

If, however, the discharge in $V1$ rests at the first cathode and the discharge in $V2$ rests at the eighth cathode (and S_1 and S_2 are in the positions shown), both of these cathodes will be at a positive potential with respect to earth. The junction of the two diodes will reach this potential in spite of the fact that the cathode potentials tend to reverse bias both of the diodes, since negligible current is taken from the



junction of the diodes by the grid of $V5$. When the discharge rests at the main cathodes of each of the counter tubes which have been selected by S_1 and S_2, the junction of the diodes becomes positive and this pulse is fed to $V5$ where it is amplified and phase inverted.

If S_1 and S_2 are in the position shown, the potential at the anode of $V5$ becomes lower when (and only when) the number of counts indicated is 81. At any other state of the count, no appreciable positive potential is present at the junction of the two diodes. Further decades similar to the second decade may be added to the circuit with all of the diodes returned to the grid of $V5$. An output pulse will then be obtained from $V5$ only when the discharge in each of the decades rests at the cathodes selected by the switches.

The output pulses from the anode of $V5$ can be used for operating any mechanism when the count has reached the value preset by the switches and can also be used to reset the counting circuit to zero automatically. The reset circuit can, of course, be arranged so that the counter is reset to any desired number of counts instead of to zero.

the DZ10 tube

Table 4.7 BASIC DATA AND CONNECTIONS FOR THE DZ10 TUBE

Max. counting speed (kc/s)	3
Striking voltage	160–200
Maintaining voltage	110–115
Anode current (mA)	2–8
Anode supply voltage	220–400
Max. output voltage	35
Min. reset or preset voltage	80
Transfer voltage between two adjacent cathodes	25–80
Min. length of input pulse (µsec)	150
Max. slope of leading edge of input pulse (V/sec)	10^6
Typical Operating Conditions	
Anode supply voltage	300
Anode current (mA)	4
Anode resistor (kΩ)	47
Cathode resistor (kΩ)	3.3
Cathode capacitor (for 3 kc/s stages) (µF)	0.25
Output voltage	13
Input pulse amplitude	50
Transfer electrode bias	+30

Base
14 pin Diheptal

Connections

Pin	1	2	3	4
Electrode	K_1	B_1	K_0	K_9
Pin	5	6	7	8
Electrode	a	K_8	K_7	K_6
Pin	9	10	11	12
Electrode	B_2	K_5	K_4	a
Pin	13	14		
Electrode	K_3	K_2		

Dimensions
seated height 90 mm (max.) — Diameter 56 mm (max.)

(The DZ10 tube is now recommended for maintenance purposes only).

4.7 THE G10/241E 'NOMOTRON' TUBE AND ITS CIRCUITS

The 20 kc/s G10/241E decade selector tube, also known by the name of 'Nomotron', is manufactured by the Special Valve Division of Standard Telephones & Cables Ltd.[28]. The Nomotron tube contains ten main cathodes equally spaced in a circle, one transfer cathode being placed between each two main cathodes. The electrode structure of the main cathodes has been made asymmetrical so that the discharge is able to move only in the forward direction from a main cathode to the succeeding transfer electrode. The asymmetry of the transfer electrodes ensures maximum priming in the forward direction. Each main cathode is connected to a separate base pin, but all of the transfer electrodes are joined to one common base pin. The Nomotron requires a higher current than the double pulse tubes, but a lower supply voltage is permissible. The current passed by the tube is sufficient to operate a relay directly.

The structure of the tube is shown in Fig. 4.46. The anode consists of a cylindrical cup placed around the cathodes. A shield is also used to limit the glow to the desired part of the tube; it confines the discharge to the front surface of the main cathodes and transfer electrodes. The glow is observed through one of ten small holes in the anode. The asymmetrical shape of the cathodes can be clearly seen in Fig. 4.46.

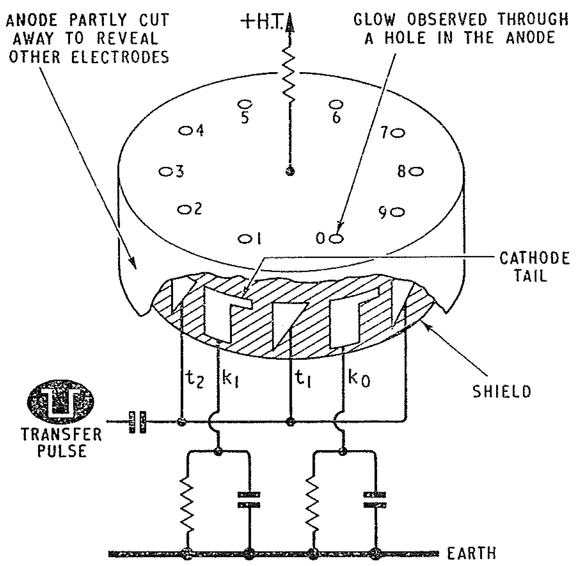


Fig. 4.46 The structure of the S.T.C. G10/241E Nomotron decade tube

In operation the shield receives a positive bias of between 75 and 110 V, whilst the transfer electrodes receive a bias of about +90 V (see table of tube data). The tube is not sensistive to light and may be used in bright light or darkness without its characteristics being affected.

If the glow is resting at K_0 when a suitable pulse is applied to the transfer electrodes, the discharge will spread to the most strongly primed transfer electrode, that is to t_1. As the potential of t_1 falls with the applied pulse, the anode voltage of the tube will fall also so that the voltage between these electrodes remains constant at the maintaining voltage of the tube. The fall of anode voltage results in the discharge at K_0 being extinguished.

At the end of the input pulse the transfer electrodes return to their normal bias potential. The cathode which was previously glowing (K_0) will still be at a positive potential with respect to earth owing to the charge held by the cathode capacitor. The discharge, therefore, moves to the most strongly primed electrode which is not positively biased, that is to K_1. The discharge moves to the 'tail' of K_1 initially, but quickly moves to the main part of the cathode, since a high current concentration at the small tail area would result in a greater maintaining voltage than normal. The next transfer cathode is then primed by the discharge.

4.7.1 Cathode Circuit Time Constants

The decay of the voltage across the cathode capacitor after the discharge has left the corresponding main cathode occurs exponentially with a time constant C_kR_k, the cathode capacitor C_k discharging through the cathode resistor, R_k. When the discharge comes to rest at a main cathode, the corresponding cathode capacitor commences to charge. The a.c. resistance of the tube and of the power supply are negligible compared with R_k and the anode resistor, R_a. If steady voltages are ignored and only voltage changes are considered, the anode resistor and the cathode resistor may, therefore, be considered to be in parallel with the cathode capacitor which thus charges with a time constant of

$$\frac{R_a R_k}{R_a + R_k} C_k.$$

The minimum value of the cathode capacitor is determined by the requirement that the cathode potential shall remain above 33 V until the end of the input pulse to the transfer electrodes so as to ensure that the discharge does not return to the main cathode which was previously glowing. The maximum value of the cathode capacitor is determined by the requirement that the voltage across it shall have decayed to less than five volts before the discharge arrives at that cathode again; otherwise the discharge may not transfer to that cathode easily.

5 V during the period in which the discharge rests at the other cathodes. Subject to this condition, the main cathodes K_1, K_3, K_5 and K_7 may be connected together and returned to earth through a single common resistance–capacitance circuit. By connecting alternate main cathodes together in this way some economy may be effected. Any cathode from which an output pulse is required, normally K_9, must obviously have its own parallel resistance–capacitance circuit to earth.

4.7.2 5 Kc/s Circuit

The basic circuit for operating a Nomotron tube at frequencies up to 5 kc/s is shown in Fig. 4.47[28]. The positive bias potentials for the transfer electro-

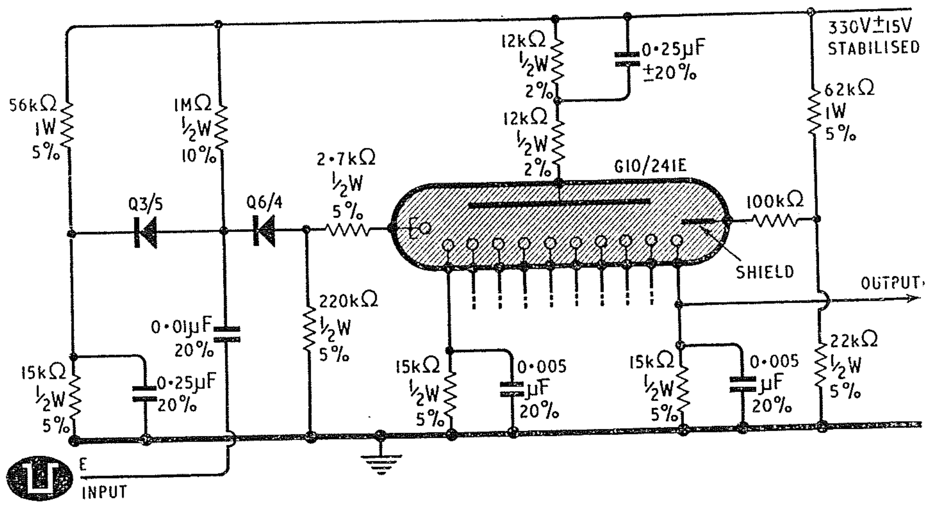


Fig. 4.47 The circuit recommended for the operation of the G10/241E up to 5 kc/s

The value of the cathode capacitor used should be the maximum permitted for the speed required (see table of data), but should not normally exceed 0.1 μF. If it is necessary that the value of the cathode capacitor should be greater than this, the capacitor in the anode circuit should be omitted so that extended current surges are avoided.

In simple straightforward counting circuits it is unnecessary to employ more than three parallel resistance–capacitance cathode circuits provided that the charge on each capacitor decays to less than

des and for the shield are obtained from the potential dividers shown. The input pulses are fed to the transfer electrodes via the Sen Ter Cel 'Unistor' type Q6/4 which isolates the input circuit from the transfer electrode during the quiescent period and permits a condition of bias equilibrium across the transfer leak resistor.

During the time that the pulse is applied, the Q6/4 is, of course, in its conducting state. The unistor type Q3/5 is used to provide d.c. restoration of the applied pulses.

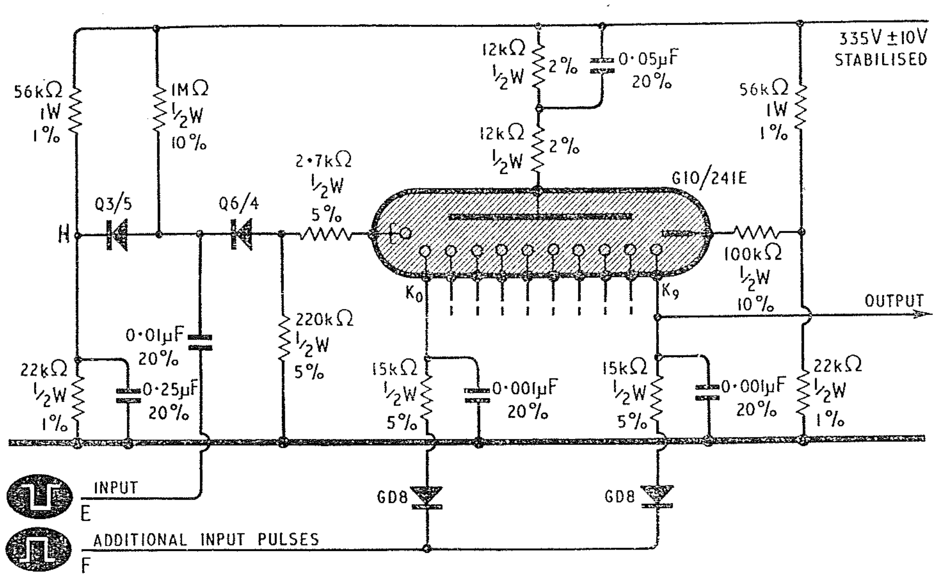


Fig. 4.48 A Nomotron 20 kc/s circuit

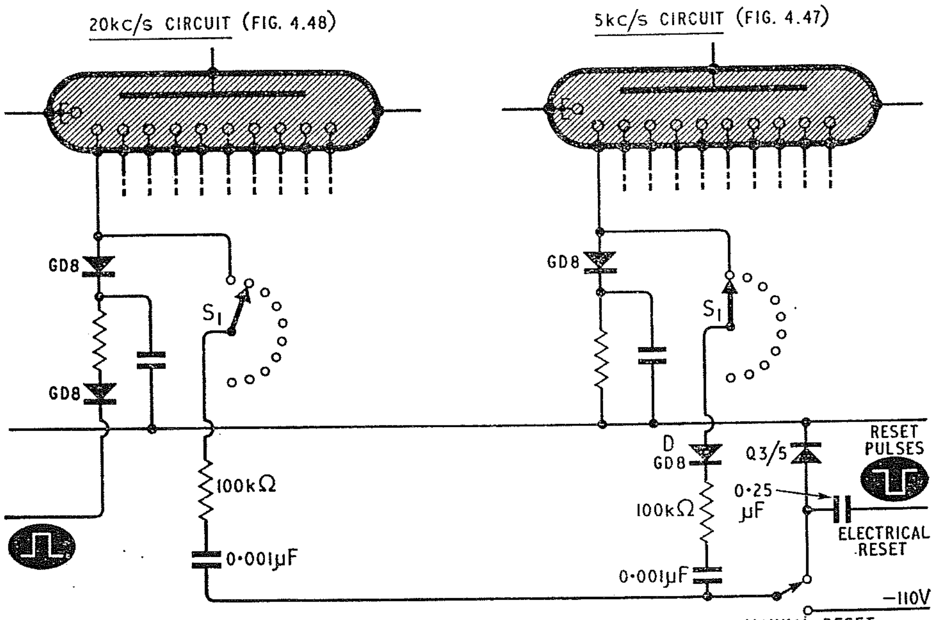


Fig. 4.49 Two methods of resetting Nomotron circuits

4.7.3 Input Pulse Requirements

The input pulse should be of sufficient amplitude to reduce the anode to earth potential to less than 60 V and its duration should be great enough to ensure that the discharge can spread across the surface of the transfer electrode during the time that the pulse lasts. Whilst it is desirable that the pulse should be fairly long, its duration must be related to the cathode circuit time constants so as to ensure that there is a potential of at least 33 V at the previously conducting main cathode when the input pulse terminates.

The effective duration of the pulse is from the time the anode potential commences to fall to the time at which the anode to earth potential rises to 180 V. When this potential is reached the anode current will commence to flow to the next main cathode.

The minimum input pulse duration is determined by the rate at which the discharge spreads over the surface of the transfer electrode. If the internal impedance of the source of the transfer pulses is kept small, the minimum pulse duration is approximately 4 μsec. Generally 120 V ($\pm$15 V) rectangular negative going pulses of 16$\pm$4 μsec in duration are recommended.

Fig. 4.47, with the Nomotron inserted, presents an impedance of about 13 kΩ to the pulse source; the latter should be matched to this impedance.

4.7.4 20 Kc/s Circuit

Whilst satisfactory results may be achieved with the Nomotron circuit of Fig. 4.47 at frequencies above 5 kc/s, it is necessary to make the time constant of the cathode components so short that the duration of the transfer pulse must be reduced to a point at which reliability may be impaired.

This difficulty may be overcome by the use of the circuit of Fig. 4.48 in which the Nomotron can operate at frequencies up to 20 kc/s[28]. Although cathode circuits of short time constant are employed, the discharge of the cathode capacitors is prevented until the end of the input pulse by means of an additional positive going input pulse applied to the cathodes as shown in the circuit. The two input pulses occur simultaneously and are of the same duration; they may be generated by the circuit of Fig. 4.50 or alternatively a pulse transformer or a paraphase amplifier may be employed.

The transfer electrodes of Fig. 4.48 should be fed with rectangular negative going pulses of 120$\pm$15 V in amplitude and of 10$\pm$2 μsec in duration. The auxiliary positive going pulses fed to the cathode circuit should be of 50$\pm$5 V in amplitude and of 10$\pm$2 μsec in duration; they should be obtained from a circuit of internal impedance not exceeding 5 kΩ to earth.

The shield electrode may be connected via a 100 kΩ resistor to point H instead of as shown in the circuit of Fig. 4.48, thus eliminating the potential divider resistors in the shield circuit.

Prolonged conduction at one cathode of a Nomotron should, where possible, be avoided. If this type of operation is unavoidable, a value of cathode current close to the minimum should be chosen and it is preferable that the discharge in the tube should be circulated from time to time at any frequency between 50 and 5,000 c/s.

Reset

The recommended circuit for the resetting of Nomotron tubes is shown in Fig. 4.49[28]. The resetting operation can be made to take place either manually or automatically by means of a suitable pulse. The cathode circuit of the Nomotron on the left-hand side of Fig. 4.49 is arranged for operation at up to 20 kc/s, whilst that on the right-hand side is for use at up to 5 kc/s. A selector switch is shown in the cathode circuit of each tube; it enables the discharge to be reset to any desired cathode — a facility which is useful when articles are being batched. In simple counting circuits where the tubes are always reset to zero, the selector switch may be omitted. If a positive pulse is used to delay the discharging of the cathode capacitor in the first Nomotron stage for 20 kc/s operation, an isolating diode (marked D in Fig. 4.49) is required in each subsequent stage.

If the reset switch is pressed to the manual position, a negative pulse passes from the -110 V line to the selected cathode circuits. If electrical reset is required, a negative pulse of -150 ± 20 V in amplitude and about 30 μsec in duration should be applied to the reset pulse input.

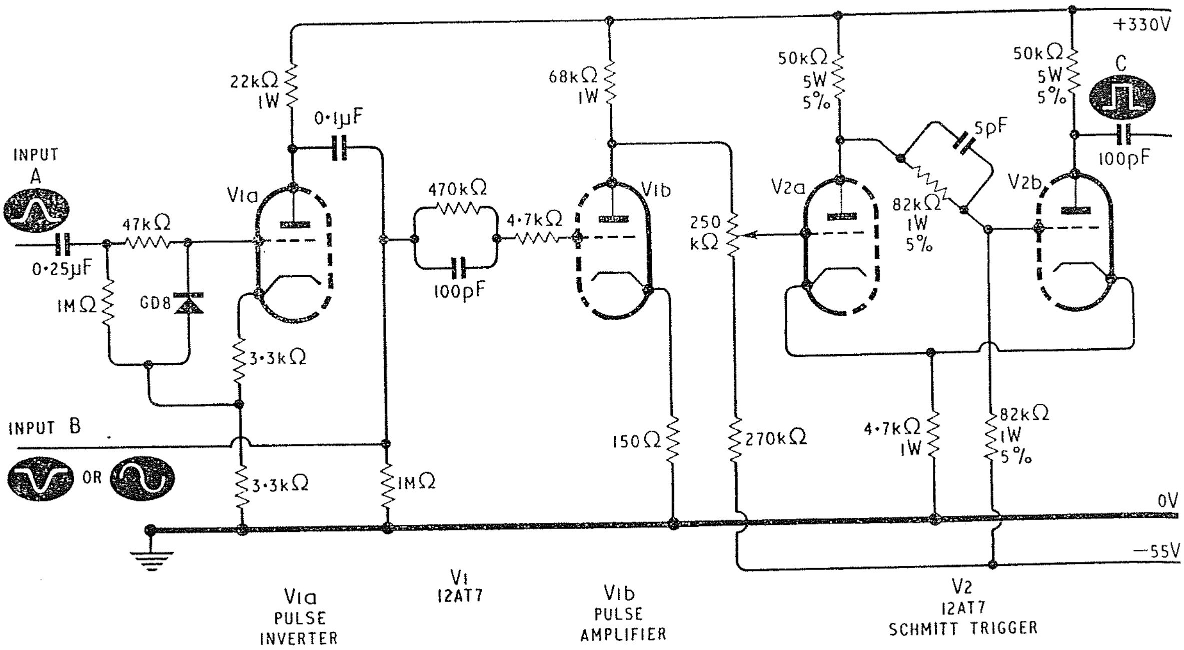


Fig. 4.50 An input circuit for feeding

4.7.5 Input Circuit [28]

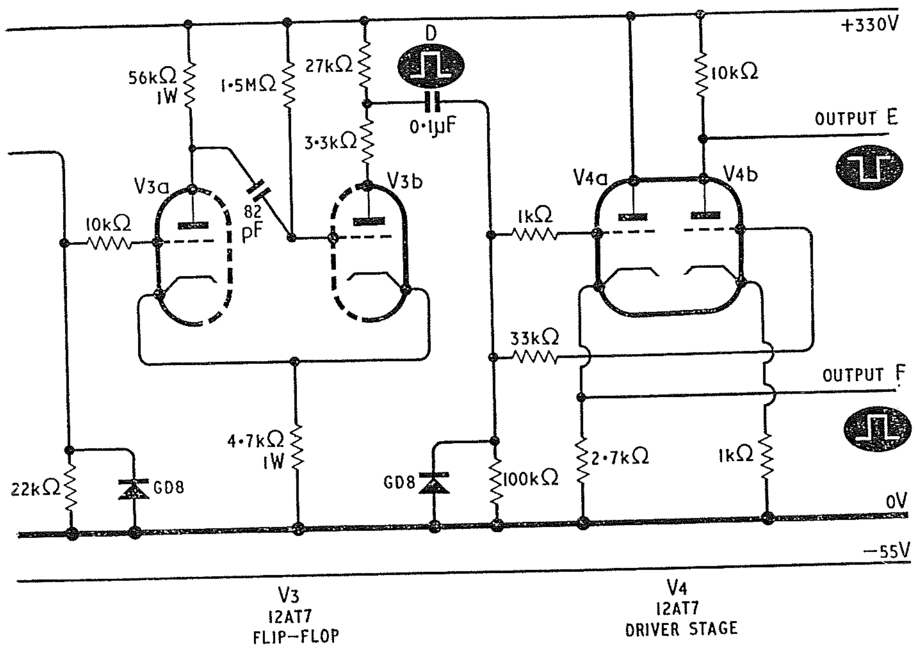
The pulses which are required for the operation of the circuits of Figs. 4.47 and 4.48 may be obtained from the circuit of Fig. 4.50. Four 12AT7 double triode valves are used in this input circuit. If the pulses to be counted are positive going, they should be applied to the input terminal *A*; they are inverted in phase by *V*1a and the resulting negative going pulses are fed into the pulse amplifier *V*1b. If sine waves or negative going pulses are to be counted, the input may be fed directly into *V*1b by using the input *B*. *V*1b is a d.c. coupled amplifier which permits input waveforms of low amplitude (down to 5 V peak) and low rates of rise to be used.

The output from *V*1b is fed into the Schmitt trigger circuit *V*2a and *V*2b which converts the pulse into a rectangular waveform of short rise time. The voltages at the grid of *V*2a should be set so that the trigger circuit operates from the input signals but not from stray signals such as mains hum. The 'speeding up' capacitor shunting the resistor between the anode of *V*2a and the grid of *V*2b must be very small if the input waveform is not to distort the sharp corners of the output waveform from *V*2b (shown at *C*).

The positive going output pulses from the Schmitt trigger circuit are fed via a differentiating network into *V*3a. *V*3 is a flip-flop circuit which adjusts the duration of the pulses to approximately 16 μsec. The output pulse amplitude from *V*3b at point *D* is about 75 V. If the input which is to be counted consists of discrete positive going pulses with a rate of rise of the leading edge exceeding 40 V/μsec, the circuits of *V*1 and *V*2 can be omitted and the input can be fed directly into the differentiating capacitor and resistor in the grid circuit of *V*3a.

The positive going pulses from the point marked *D* in Fig. 4.50 are fed into the grids of the driver stage, *V*4a and *V*4b. *V*4b provides the negative going pulses at output *E* for feeding to the transfer electrodes of the Nomotrons in Figs. 4.47 and 4.48. *V*4a is a cathode follower which provides the positive going pulses at output *F* which are required for the operation of the 20 kc/s circuit of Fig. 4.48; it also provides the positive pulses required to drive hard valve coupling stages.

If it is required to gate the input, a suitable valve such as the short suppressor base pentode type 6F33 or the heptode type 7032 may be used in the



the circuit of Figs. 4.44 and 4.45

circuit. If the input pulses are positive going, it is often convenient to replace *V*1a by the gating valve. Alternatively the gating valve may be inserted between the flip-flop (*V*3) and the driver stage (*V*4). If the tube type 7032 is used, care should be taken that the anode and screen voltage rating are not exceeded. Precautions should also be taken to ensure that gating does not occur during the time in which a transfer pulse is applied to the input.

4.7.6 Hard Valve Coupling Circuit

The hard valve coupling circuit recommended for use with Nomotron tubes is shown in Fig. 4.51[28]. A negative going pulse for the operation of the succeeding Nomotron is produced at the anode of the coupling valve if and only if all of the gating diodes in the input circuit of the coupling tube receive simultaneous input pulses. One gating diode is connected to the positive pulse line (*F* in Fig.

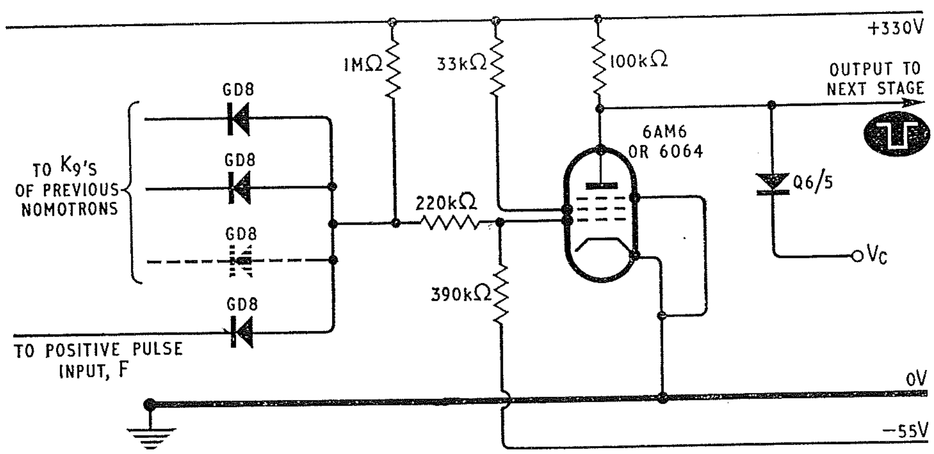


Fig. 4.51 A hard valve circuit for coupling Nomotrons

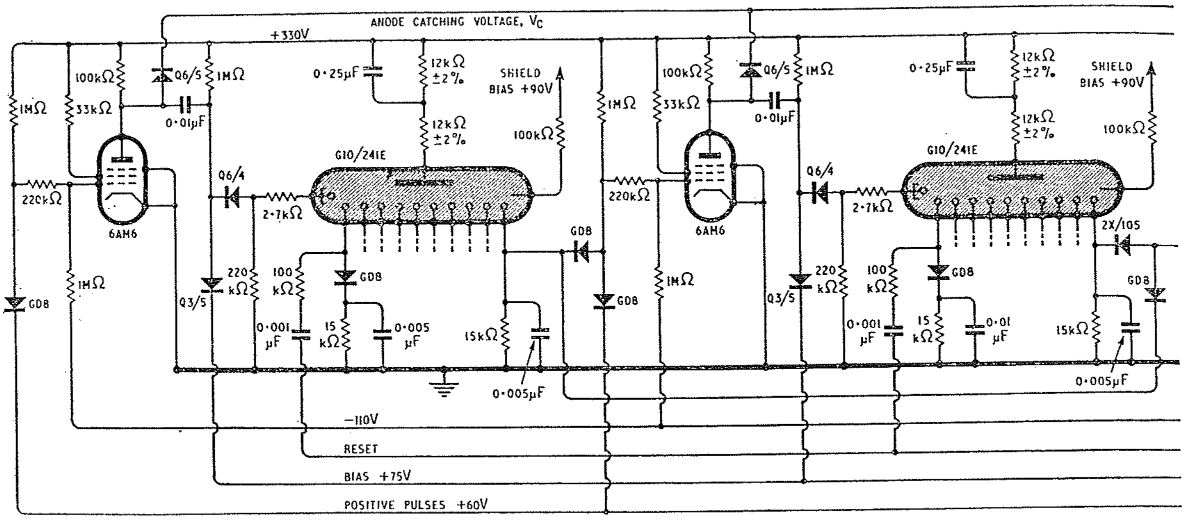


Fig. 4.52 A three decade Nomotron

4.50), whilst each of the remaining diodes are connected to the ninth cathode of one of the preceding Nomotrons.

Positive potentials will be fed to all of the diodes simultaneously only when an input pulse is received at a time when the discharge in each of the preceding Nomotrons is at the ninth cathode. The minimum value of cathode capacitance should be used in the ninth cathode circuits of the Nomotrons in order to avoid double gating. The catching potential, V_c, of the anode circuit should be adjusted so that the output pulse from the coupling circuit has an amplitude of 120 V.

A typical three decade counting circuit employing hard valve coupling is shown in Fig. 4.52[28]. The impedance of the anode catching voltage supply must be small compared with all of the valve anode resistors connected in parallel. If several decades are to be used, a cathode follower is more economical on power than a potential divider for supplying the required adjustable catching potential. A 6CH6 cathode follower is used in Fig. 4.52.

4.7.7 Trigger Tube Coupling Circuit

The use of the trigger tube circuit of Fig. 4.53 enbles a number of Nomotrons to be coupled without the necessity for heater supplies[28]. This circuit requires input voltages of closer tolerances than the hard valve coupling circuit. Negative input pulses of 160 V in amplitude which occur simultaneously with the input pulses to the first Nomotron must be fed into the circuit.

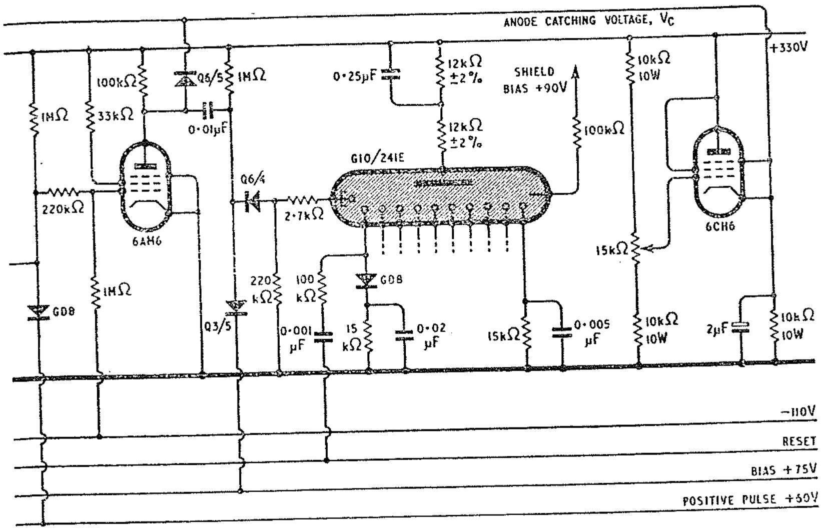
The catching potential, V_c, must be adjusted so that the trigger tube anode voltage does not exceed 165 V in the quiescent condition; this is 10 V less than the maintaining voltage, so the tube will be extinguished between successive pulses. The negative input pulses which are applied to the cathode must not be much less than 155 V in amplitude or the output pulses will be too small. On the other hand the input pulses must not exceed 165 V or they may cause spurious triggering.

The output pulse amplitude from the trigger tube coupling circuit is equal to the input pulse amplitude at the cathode plus the catching potential minus the maintaining voltage of the tube.

A three decade circuit using trigger tubes as the coupling amplifiers is shown in Fig. 4.54. The anode catching potential may be obtained from a 6CH6 cathode follower stage as in the hard valve circuit of Fig. 4.52.

4.7.8 Sine Wave Drive

It is not generally recommended that Nomotron tubes should be operated directly from sine waves, since large values of cathode capacitance are requir-



scaler using valve coupling

ed owing to the comparatively long time for which the discharge rests at the transfer cathodes. For a given value of cathode capacitance and supply voltage, the frequency range over which satisfactory operation can be obtained is very limited. Good results can, however, be obtained from sine wave inputs if the input peaks are shaped by a circuit such as that shown in Fig. 4.50.

A simple circuit for the direct operation of a Nomotron tube from 50 or 60 c/s a.c. mains is shown

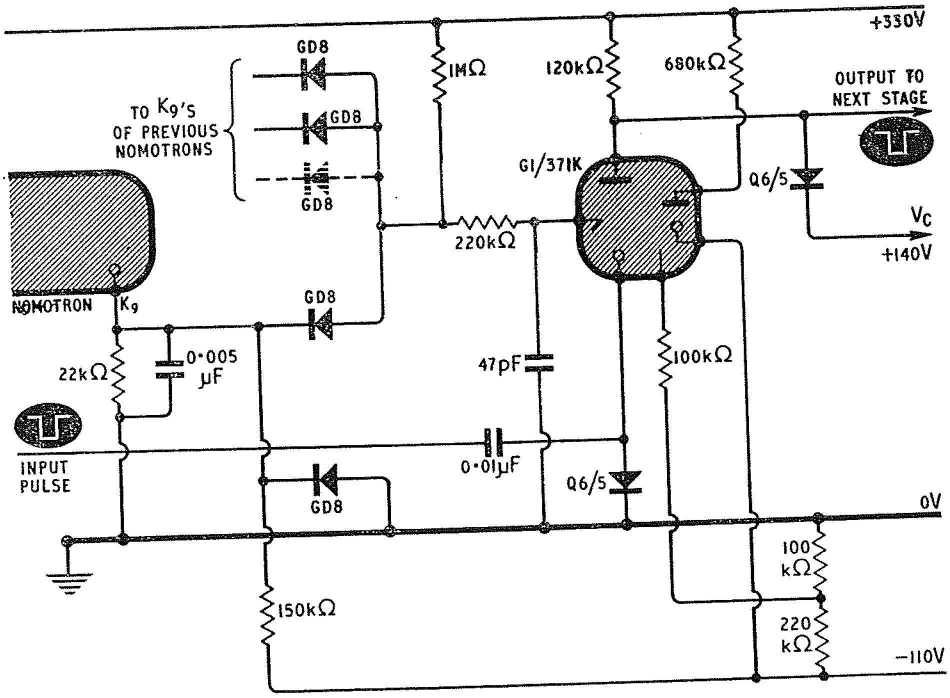


Fig. 4.53 A trigger tube circuit for coupling Nomotrons

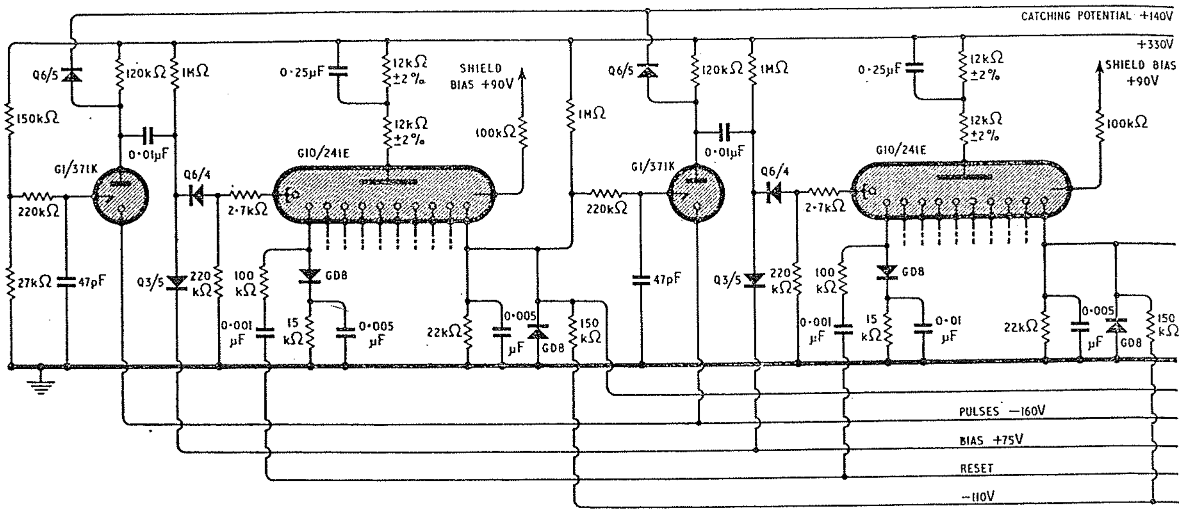
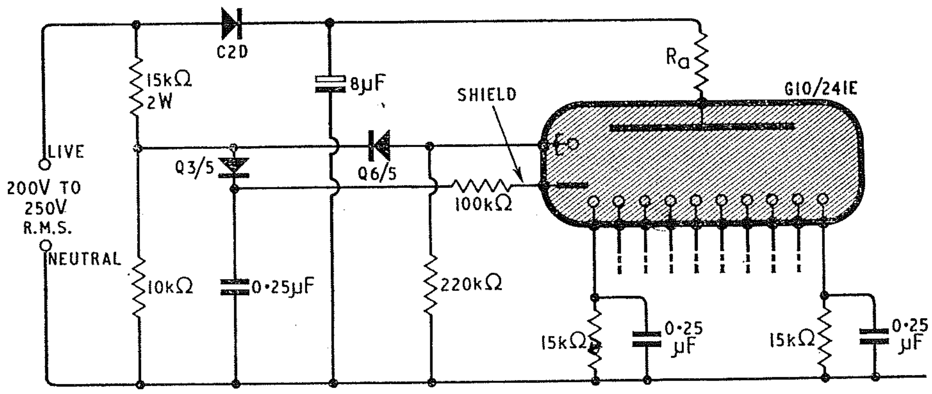


Fig. 4.54 A three decade Nomotron scaler using trigger tube coupling. (Right) connections

in Fig. 4.55. It is very useful in count-down circuits which give an output at a sub-multiple of the mains frequency. The capacitor which normally shunts one of the anode load resistors is omitted in order to avoid an excessive flow of current through the tube. The potential divider which supplies the guide bias may be modified so as to include reactive elements which shift the phase of the cathode waveforms relative to the mains sine wave. If it is desired to isolate the circuit from the mains, the potential divider can be replaced by a transformer with 100 V R.M.S. output; an anode supply voltage of 315 V will then be required.

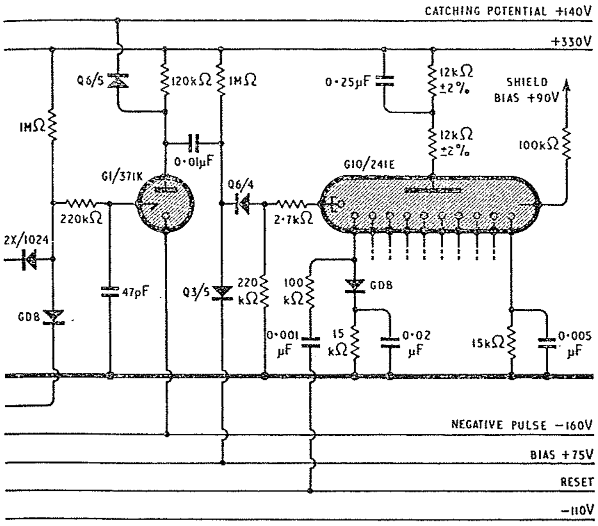
4.7.9 The Operation of Relays from Nomotrons

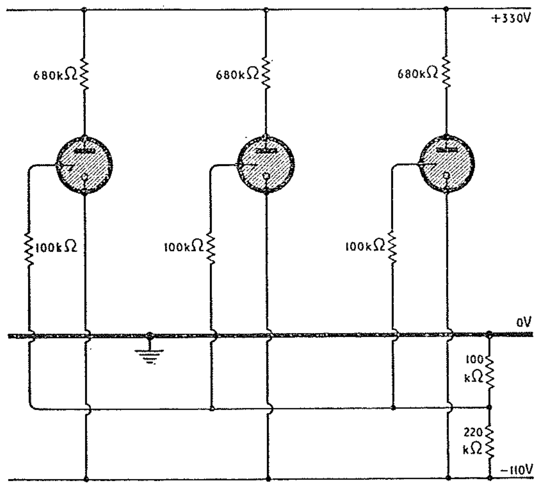
The comparatively high cathode current passed by Nomotron tubes (2.4 to 5 mA) enables them to be used to operate a relay directly without any intermediate amplifier. Whilst it is desirable that relays which have a coil resistance approaching 15 kΩ should be used, satisfactory operation can be obtained with the S.T.C. midget relay type 4192AA which has two change over contacts or with the S.T.C. relay type 4600 which is limited to one change over contact. A suitable circuit is shown in Fig. 4.56[28].



Mains voltage	R_a
200–230	24 kΩ
220–255	27 kΩ

Fig. 4.55 A Nomotron circuit for counting the waveform of 50 or 60 c/s A.C. mains





to priming gaps and shield electrodes of the trigger tubes—see also Fig. 4. 53

Table 4.8 BASIC DATA FOR THE S.T.C. NOMOTRON, G10/241E (CV2223).

Striking voltage	280 V	*Connections*
Maintaining voltage	180 V	

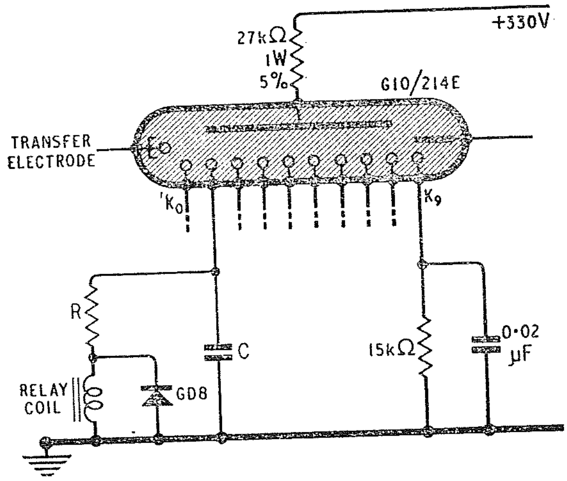
Pin	1	2	3	4	5	6
Electrode	Shield	K_0	K_9	K_8	K_7	K_6
Pin	**7**	**8**	**9**	**10**	**11**	**12**
Electrode	K_5	K_4	K_3	K_2	K_1	Transfer cathodes

Ratings:	
Minimum H.T. supply voltage	310 V
Maximum anode voltage relative to any non-conducting cathode	250 V
Quiescent cathode current	2.4 – 5 mA
Shield bias	75 – 110 V

Base cap = anode
A numbered escutcheon plate around the tube may be used to facilitate readout.

Typical Operating Conditions:	Maximum Frequency		
	1 kc/s	*5 kc/s*	*20 kc/s*
Stabilised H.T. voltage	315–345 V	315–345 V	325–345 V
Transfer electrode bias	75 V	75 V	90 V
Nominal shield bias	90 V	90 V	90 V
Anode load (2% tolerance)	24 kΩ	24 kΩ	24 kΩ
Anode load capacitor (20%)	0.25 μF	0.25 μF	0.05 μF
Cathode load (5%)	15 kΩ	15 kΩ	15 kΩ
Cathode capacitor (20%)	0.02 μF	0.005 μF	0.001 μF
Input pulse duration	15–100 μsec	12–20 μsec	8–12 μsec
Input amplitude	105–135 V	105–135 V	105–135 V
Output pulse	40 V	40 V	40 V
Cathode current	3.7 mA	3.7 mA	3.7 mA

Dimensions Seated height 50.8 mm (max.) Diameter at base: 43.7 mm (max.)
Base B12E (McMurdo type X12E)



Relay type	Relay Coil resistance	Recommended Values C	R
S.T.C. Midget 4193 AA	6·8 kΩ	0·1 µF	8·2 kΩ
S.T.C. type 4600 Post Office type 3000	6·5 kΩ	0·5 µF	2·2 kΩ

Fig. 4.56 The operation of a magnetic relay from a Nomotron

The inductance of the relay coil reduces the effective time constant of the cathode circuit and a larger capacitor should be employed to compensate for this. A diode should be connected across the relay to prevent oscillations from occurring when the discharge leaves the cathode to which the relay circuit is connected. If such oscillations occurred, the cathode would swing to a negative potential and spurious back stepping of the glow could occur.

The relay could, of course, be used to operate an electro-magnetic counter in order to increase the number of digits which can be displayed without increasing the number of Nomotrons.

4.8 THE ELESTA EZ10B AND ECT100 TUBES AND THEIR CIRCUITS

4.8.1 The EZ10B

The Elesta EZ10B tube is a miniature gas filled decade selector tube which can be used for counting at frequencies up to 1 Mc/s[29–31]. A total of 20 cathodes are employed around the cylindrical anode, one transfer cathode being placed between each two main cathodes. All of the cathodes are placed in the tube at an oblique angle (as shown in the photographs) in order that the discharge shall be able to rotate in the forward direction only. When the discharge is resting at a certain main cathode, the succeeding transfer cathode is strongly primed owing to the fact that the oblique angle at which the cathodes are placed results in a small part of the succeeding cathode being in the edge of the discharge region. An appreciable current, known as the probe current, flows to the cathode succeeding the cathode at which the discharge is resting. This assists very rapid transfer of the discharge. The cathode preceding the discharge is not strongly primed.

The gas with which the tube is filled is hydrogen; this has low ionisation and deionisation times and its use, therefore, enables high counting speeds to be attained. The discharge, which gives the visual indication of the count, is blue in colour as opposed to the orange coloured discharge which occurs in most other cold cathode counting tubes. A special type of cathode must be used for tubes filled with hydrogen in order to avoid instability.

All of the main cathodes in the EZ10B are connected to separate base pins, but the transfer cathodes are connected in two groups to two base pins. This is merely for convenience in manufacture and the two groups are normally joined together externally when the tube is being used.

When a negative pulse is applied to the transfer cathodes, the discharge will move to the most strongly primed transfer cathode, that is, to the one succeeding the main cathode at which the discharge was resting previously. At the end of the pulse the transfer cathodes become positive with respect to the main cathodes (owing to the positive bias applied to them) and the discharge will be automatically transferred to the next main cathode.

4.8.2 The EZ10B and the EZ10A

The EZ10B tube has been evolved from the EZ10A tube[31–34] which is now a maintenance type. The structure of the two tubes is very similar, but they are filled with different gases. The EZ10B can count at frequencies up to about 1 Mc/s whereas the EZ10A is limited to about 300 kc/s. It is most important that the correct circuits should be used for each type of tube. The EZ10A will have a very short operating life if it is used in the circuits which have been designed for the EZ10B (despite the fact that its initial performance will be quite satisfactory). If the EZ10B is used in circuits designed for the EZ10A, faulty counting is likely to occur. The anode current range for satisfactory operation is not the same for the two tubes. The circuits to be described are for use with the current production tube, the EZ10B.

Anode Supply Voltage

In the circuits to be described an anode supply voltage of +580 V is recommended. This is about twice the maintaining voltage of the tube. A fairly high voltage is required to ensure that the anode current remains within the specified working range for all normal mains supply variations. A stabilised supply as low as +450 V may be employed provided that the anode resistor is decreased in value so as to keep the anode current within the specified operating range. The current should be adjusted to 1.5 mA when the discharge is stationary at one cathode.

The anode resistor should be mounted as closely as possible to the tube socket so that stray capacitance is kept as small as possible. If a variable anode resistor is employed so that adjustment can be made for optimum anode current, an additional fixed resistor of at least half the total anode resistance should be mounted close to the tube socket.

Input Pulses

Although the shape and amplitude of the input pulses to the EZ10B are not critical, it is advisable to use the optimum wave forms so that satisfactory operation over a fairly large range of anode current (and hence of anode voltage) is possible. Counting errors due to the changing of the tube characteristics during life are then prevented.

The pulses should be preferably approximately rectangular in shape, since if the input voltage changes slowly, double transfers may occur. The rate of rise of the leading edge of the input pulse should not exceed 10^9 V/sec, but if input pulses of a comparatively long duration are used, it is advisable to increase the rise and fall times of the input pulses to about 10% of the total pulse length up to a maximum of 1 msec. Rise or fall times exceeding 1 msec may cause double transfers.

A capacitor of about 10–100 pF, may be connected between the transfer cathodes and earth in order to reduce the rate of change of input pulse voltage.

The pulse amplitude should be about 100 to 120 V for counting speeds up to 100 kc/s with a pulse length of not less than 5 μsec and a transfer cathode bias of about +55 V. Both the pulse amplitude and the transfer cathode bias should be increased with increasing counting speed above 100 kc/s. For counting at up to 500 kc/s the pulses may have an amplitude of 200 V and a duration of 1 μsec and the transfer bias may be about +80 V. An input pulse amplitude of 220 V and a duration of 0.5 μsec are recommended for counting speeds of up to 1 Mc/s with a transfer cathode bias of +120 V. The pulse amplitude should be adjusted for optimum performance when the tube is used at frequencies approaching 1 Mc/s.

Cathode Circuits

Capacitors should be placed in parallel with the cathode resistors in circuits which are intended for use at very high speeds. A cathode will then remain at a positive potential for a short time after it has ceased to conduct. This reduces the possibility of a transfer of the discharge in the reverse direction. In addition, the capacitors in parallel with the cathode resistors absorb any spurious pulses which may be coupled into the cathode circuits from the steep edges of the drive pulses by stray capacitance.

Output Pulses

The main output pulse has an amplitude of approximately 7 V, but it is preceded by a smaller positive going rectangular pulse of about 2 V in amplitude. The smaller pulse is caused by the flow of the 'probe' current through the resistor in the main cathode circuit during the time the discharge rests momentarily at the preceding transfer cathode.

The duration of the 2 V output pulse is equal to the duration of the input transfer pulse.

Two methods may be used to prevent the preliminary 2 V step from causing double triggering of the succeeding stage. The simplest method involves

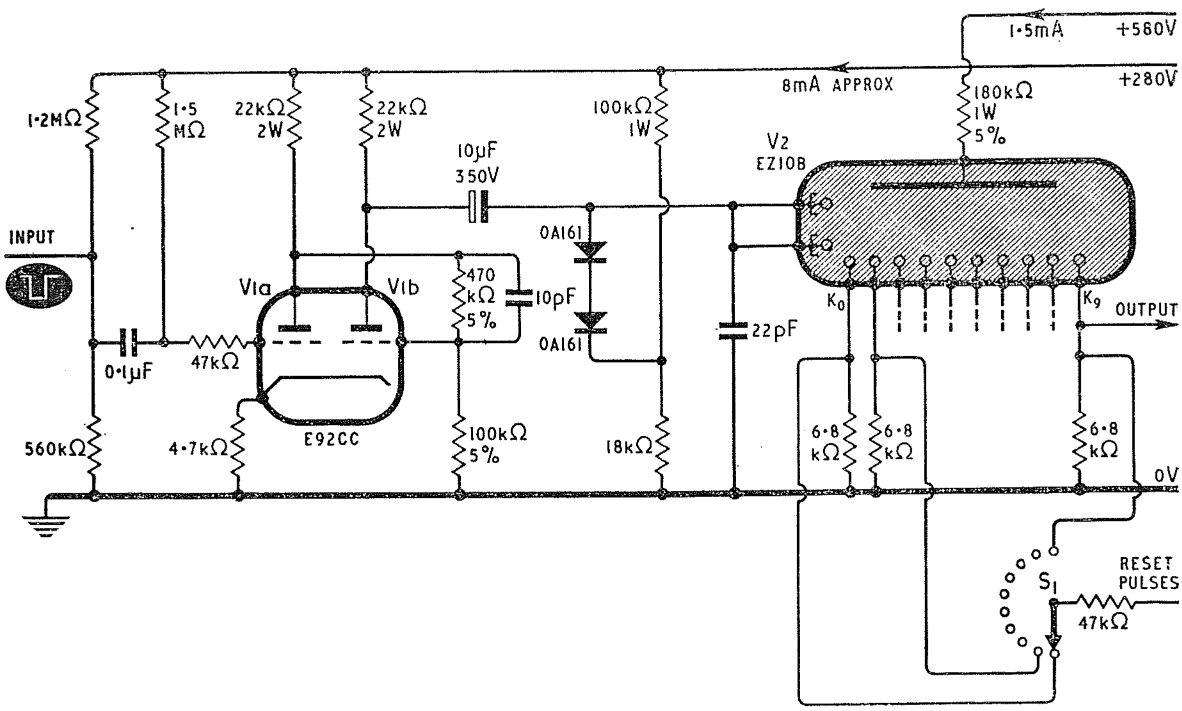


Fig. 4.57 A 100 kc/s circuit for the EZ10B tube

the differentiation of the output pulse by means of a coupling capacitor; the negative peaks thus produced at the end of the cathode pulses may be used to trigger the following driver stage of the next decade. The output pulse must be taken from the ninth cathode of the EZ10B. This method is used in the circuits to be described and has the advantage that the output pulse is little delayed.

The second method involves the use of a series diode connected to a suitable bias supply. The diode passes only those pulses which exceed 2 V in amplitude. When this method is employed, the positive going output pulses must be taken from the zero cathode of the EZ10B; they may be used to control PNP transistors which are used as the pulse amplifiers.

Tolerances

The tolerances of the resistors and capacitors in the EZ10B circuits to be discussed are ±10% unless otherwise stated. The capacitors may be rated at 400 V d.c. working and the resistors may be $^1/_2$ W size unless otherwise indicated. The supply voltages may vary from −10% to +15% of the stated value except in the case of the high speed circuits requiring stabilised supplies.

100 kc/s Input Circuit[29]

The input circuit of Fig. 4.57 can be used for counting at up to 100 kc/s. The left-hand triode of the E92CC, *V*1a, is normally conducting, since its grid is connected to the positive H.T. line via two resistors. A suitable negative pulse applied to the input cuts off *V*1b and causes *V*1b to become fully conducting. The resulting negative going rectangular pulse at the anode of *V*1b is fed to the transfer electrodes of the EZ10B.

The 0.1 μF capacitor and the 1.5 MΩ resistor in the input circuit impose a lower limit on the rate of rise of the input waveform. The input pulse must reach an amplitude of 30 V within 0.05 sec if it is to be counted. The pulse duration is limited to 0.1 sec. If sine waves of amplitude 40 V R.M.S. are applied at the input, the minimum frequency of operation is approximately 1 c/s.

The 10 μF electrolytic capacitor which couples the anode of *V*1b to the EZ10B should have a low leakage current. The large value is necessary in order that the longest pulses shall be transmitted without too much distortion. In this way an undesirable slow voltage rise at the transfer cathodes at the end of the pulse is avoided. Smaller input and drive pulse coupling capacitors may be used if the input consists of short pulses or of pulses with steep fronts.

A potential divider is used to provide the bias voltage for the transfer electrodes. The OA161 diodes are used to clamp the transfer electrode potential to the bias voltage. The 22 pF capacitor from the transfer electrodes to earth prevents these electrodes from changing in potential very rapidly.

The tube may be reset to any desired digit by selecting the appropriate cathode by means of the selector switch and applying a resetting pulse. If the 47 kΩ resistor in the reset line is replaced by a diode, output pulses may be taken from any desired cathode. If the tube is to be used for simple counting, the reset line may be connected via the 47 kΩ resistor to the zero cathode, the switch S_1 being omitted.

If a photoelectric pick-up is to be used, a Siemens photodiode type TP 50 may be connected across the input. A counting speed of 10 kc/s can then be attained if the light is of sufficient intensity and if not more than three feet of a low capacity cable is used to connect the diode.

500 kc/s Input Circuit[29]

An input circuit which is very similar to that described previously can be used for counting at frequencies up to 500 kc/s provided that a stabilised power supply is employed. This type of circuit is shown in Fig. 4.58. The left hand triode of the E182CC is normally conducting, but if a suitable negative pulse is applied to the grid of *V*1a, the other triode, *V*1b conducts and a negative rectangular pulse is thus produced at the anode of *V*1b. This pulse is fed to the EZ10B transfer electrodes by means of the coupling capacitor. The inductance of approximately 3.7 mH in the anode circuit of *V*1b is used to compensate for the circuit capacities and ensures that pulses fed to the counting tube have a constant amplitude up to the maximum frequency at which the circuit is designed to operate. The two diodes in the grid circuit of *V*1a prevent this tube from taking excessive positive grid current.

A −140 V supply is required. This may be obtained from a 120 V a.c. supply from a transformer as shown in the circuit. Any suitable diode may be used for *D*. The resistor *R* should be chosen so that the negative supply voltage is −140 V.

At high counting speeds the input pulses should have a fairly large amplitude. The steep fronts of these pulses are coupled to some extent through the tube and wiring capacities to the output cathodes and mask the wanted signal. In order to suppress these spurious pulses, pulses of opposite polarity to those fed to the transfer electrodes are taken from the anode of *V*1a and fed through an *RC* network (39 kΩ, 2 pF) to the output cathode. The spurious pulses are thus cancelled out and the output pulses may be used to operate the succeeding decade. It may be necessary to find the optimum values of the *RC* network by experiment for the particular circuit layout used.

The two diodes in the circuit of the output cathode prevent negative pulses from being fed along the output line to the next decade. Small capacitors are placed in parallel with the cathode resistors for the reasons discussed previously.

The satisfactory operation of the circuit is not very dependent on the shape of the input pulses. The amplitude of the pulses fed to the circuit should be between −30 and −100 V and their duration must be not less than 0.5 μsec. The circuit layout and wiring must, of course, conform to the standards normally used for microsecond pulse circuits.

1 Mc/s Input Circuit[29]

The design and operation of EZ10B circuits which are intended for use at the maximum operating

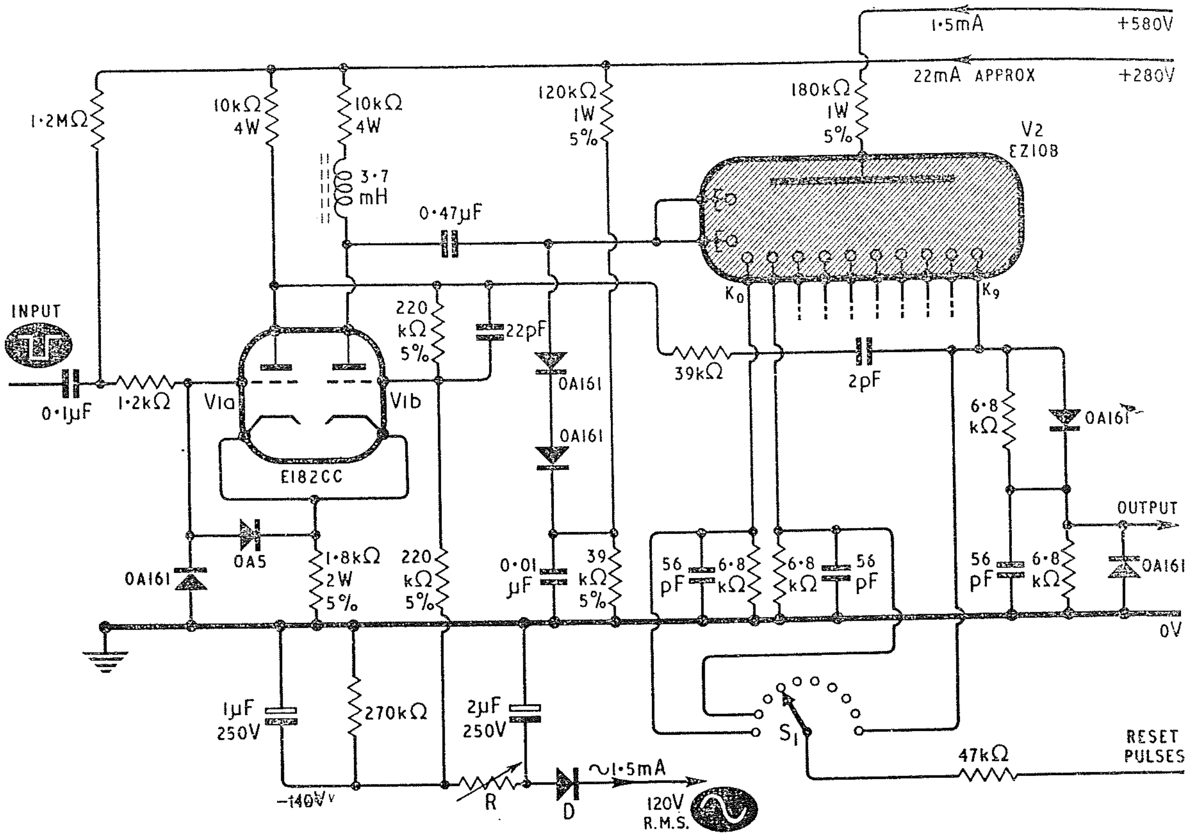


Fig. 4.58 A 500 kc/s circuit for the EZ10B tube

frequency of the tube are somewhat more critical than in circuits used for lower speed operation. The recommended circuit is shown in Fig. 4.59. A stabilised power supply is required for reliability. The input pulses to this circuit should be approximately rectangular in shape and should have an amplitude of not less than −20 V. The input pulse duration should be between 0.5 μsec and 25 msec. Such pulses may be obtained from a suitable monostable circuit such as a Schmitt trigger circuit.

The input pulses are fed to the grid of *V*1a, the OA161 diode in the input circuit preventing the grid of this triode from becoming positive when the trailing edge of the input pulse is fed to the circuit. For short pulses the anode load of *V*1a is effectively 2.2 kΩ. Pulses are fed from the anode to the grid of *V*1b which has a bias of −16 V. The negative going pulses from the anode of *V*1b are fed to the transfer electrodes of the counting tube. The diodes in the transfer electrode circuit are used to clamp the pulses to the desired bias voltage and to limit their amplitude to the optimum value. Pulses are also fed from the anode of *V*1a to the output cathode of the EZ10B for the same purpose as in the circuit of Fig. 4.58; the coupling resistor and capacitor should be adjusted for the particular circuit layout being used.

The anode current should be adjusted so that the value used is in the centre of the range over which the tube operates satisfactorily. The input pulse amplitude should also be adjusted for satisfactory operation over the largest possible anode current range. These adjustments must be repeated each time the EZ10B tube is replaced.

Coupling Circuits[29]

Coupling circuits which can be used at up to 1 kc/s or at up to 10 kc/s are shown in Fig. 4.60. The circuit of Fig. 4.57 may be used as the preceding circuit and will, of course, operate at ten times the

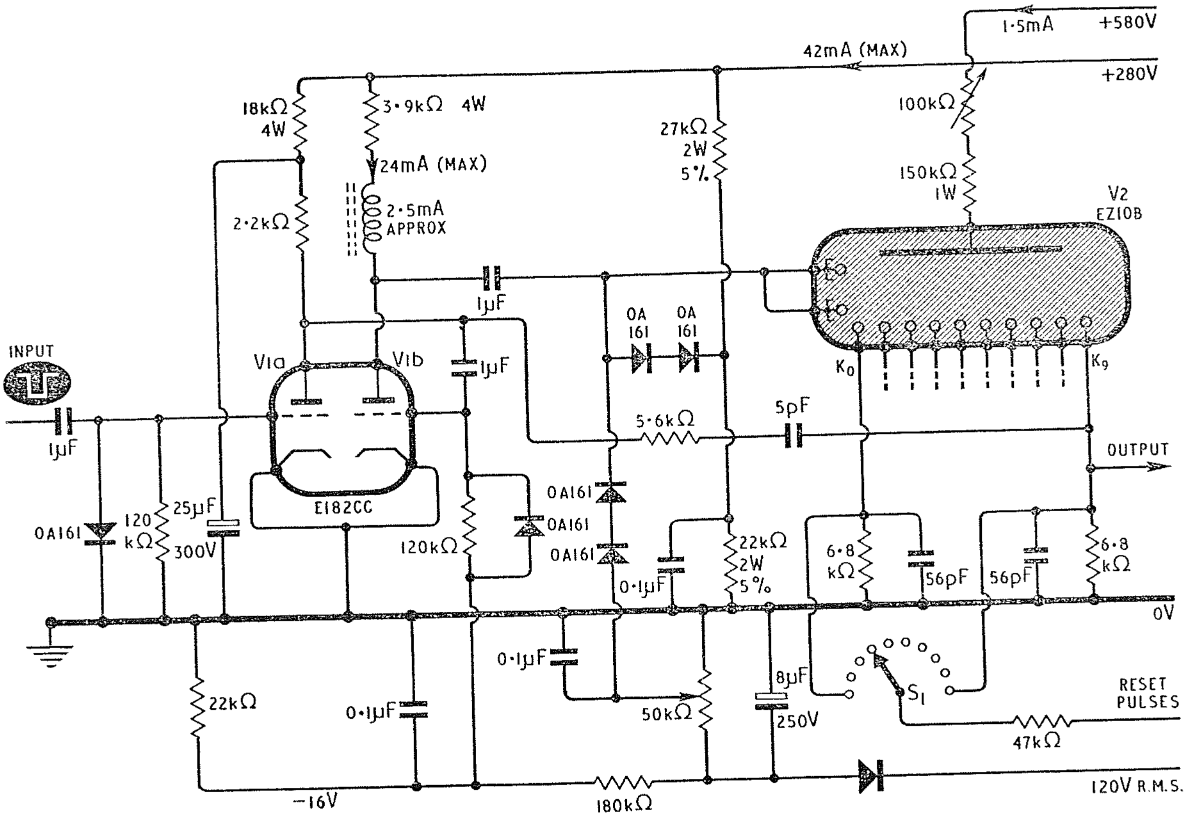
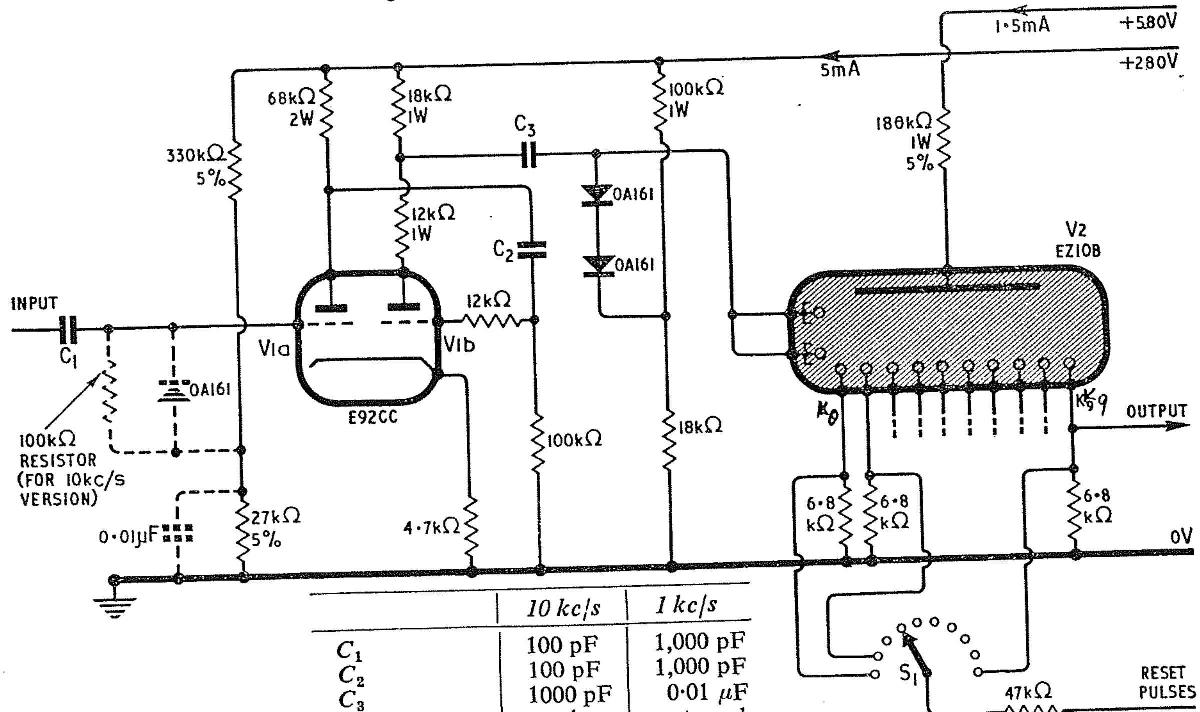


Fig. 4.59 A 1 Mc/s input circuit for the EZ10B



	10 kc/s	1 kc/s
C_1	100 pF	1,000 pF
C_2	100 pF	1,000 pF
C_3	1000 pF	0·01 μF
Dotted components	used	not used

Fig. 4.60 EZ10B circuits for coupling frequencies of up to 1 kc/s or up to 10 kc/s

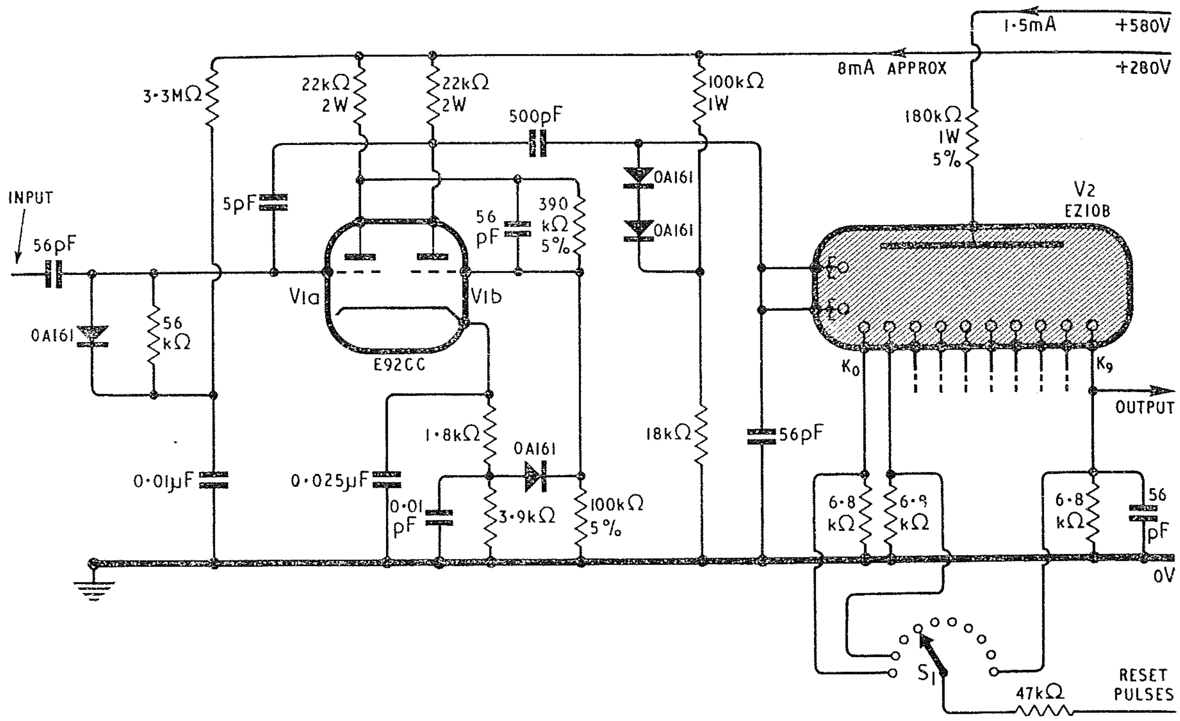


Fig. 4.61 A 100 kc/s coupling stage for the EZ10B

rate at which the coupling circuit operates. Any number of identical coupling circuits may be cascaded.

The 1 kc/s version of the circuit of Fig. 4.60 requires three components fewer than the 10 kc/s version. In addition it is less critical in design and operation and is therefore to be preferred for use at operating speeds of less than 1 kc/s.

The capacitor C_1 and the input resistor serve to differentiate the output pulses from the ninth cathode of the previous counting tube. The extra components shown dotted decrease the charging time of C_1 for high frequency operation.

*V*1 is a cathode coupled multivibrator, *V*1a normally being in the conducting state. The negative pulses formed by differentiation of the input pulses cause *V*1a to be cut off and the resulting pulse from *V*1b is used to operate the counting tube. The duration of the pulse fed to the EZ10B is determined by C_2 and the associated resistors.

100 kc/s Coupling Circuit[29]

The circuit of Fig. 4.61 can be used at frequencies of up to 100 kc/s and is therefore suitable for use after the high speed circuits of Figs. 4.58 and 4.59. It contains a monostable multivibrator in which *V*1a is normally conducting. The circuit has a very high sensitivity and can be triggered reliably with negative input pulses of 2 V peak amplitude.

The input pulses are differentiated in the input of the circuit of Fig. 4.61. In order to obtain the desired sensitivity of 2 V, the grid of the second triode is connected through a diode to a bias voltage produced by the flow of current through a part of the cathode resistor of the tube. Thus the negative peaks of the grid potential of *V*1b are limited to the optimum value.

The duration of the pulses fed to the EZ10B is determined mainly by the value of the 5 pF capacitor which is connected from the anode of *V*1b to the grid of *V*1a.

Relay Output Circuit, Reset Circuit and Power Supply Unit[29]

If a relay or electro-magnetic counter is to be used in the output stage of a scaler employing EZ10B tubes, its coil can be fed from the E92CC multivibrator circuit shown in Fig. 4.62. The capacitor

C_1 may be adjusted in value from about 0.01 to 0.5 μF in order to obtain pulses of optimum duration for the operation of the particular relay or counter employed. The negative going input pulses should have an amplitude, however, of not less than 4 V.

The reset or predetermining pulses are obtained by the discharging of the 0.25 μF capacitor which is in the reset line. This capacitor is normally connected to the +580 V line via the 1 MΩ resistor. When the manual reset button is pressed, one side of the capacitor is connected to earth via the 100 Ω resistor and a negative pulse is applied to the reset line. The resistors and capacitors in the reset circuit damp any oscillations due to contact bounce. An additional contact must be employed on the manual reset switch if a relay or electro-magnetic counter is used in the output stage. This contact isolates the relay and the anode of *V*1b of Fig. 4.62 from the H.T. supply during the resetting operation so that the pulse produced when the final EZ10B tube is reset does not operate the relay or magnetic counter. In general, proper resetting is possible only if the reset pulses are of longer duration than the longest drive pulses employed.

Variable resistors may be employed in the power supply unit (as shown in Fig. 4.62) so that the anode supply potentials may be adjusted to the optimum values. If mains voltage variations greater than −15% or +10% of the nominal value are likely to occur, the use of a magnetic voltage stabilising circuit is recommended.

The relay circuit of Fig. 4.62 is very convenient when a predetermined number of objects are to be

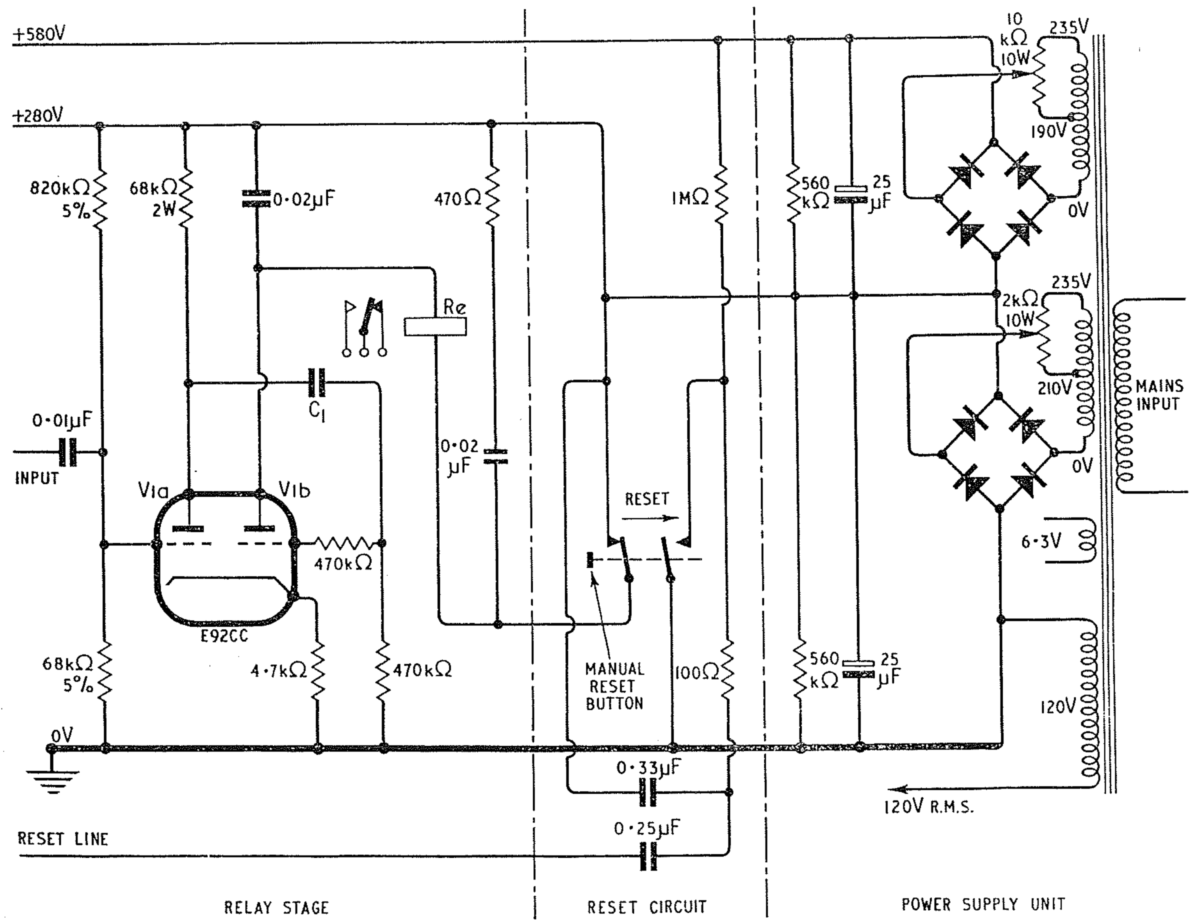


Fig. 4.62 A power supply, reset circuit and relay output stage for use with EZ10B circuits

placed in each batch. The EZ10B tubes should be preset so that the counter indicates the difference between the maximum capacity of the scaler and the number of objects to be placed in each batch. The output pulse produced by the multivibrator or relay may be used to preset the counter and also to operate the mechanism which moves the container for the next batch of objects into the correct position.

Transistor Circuits for the EZ10B

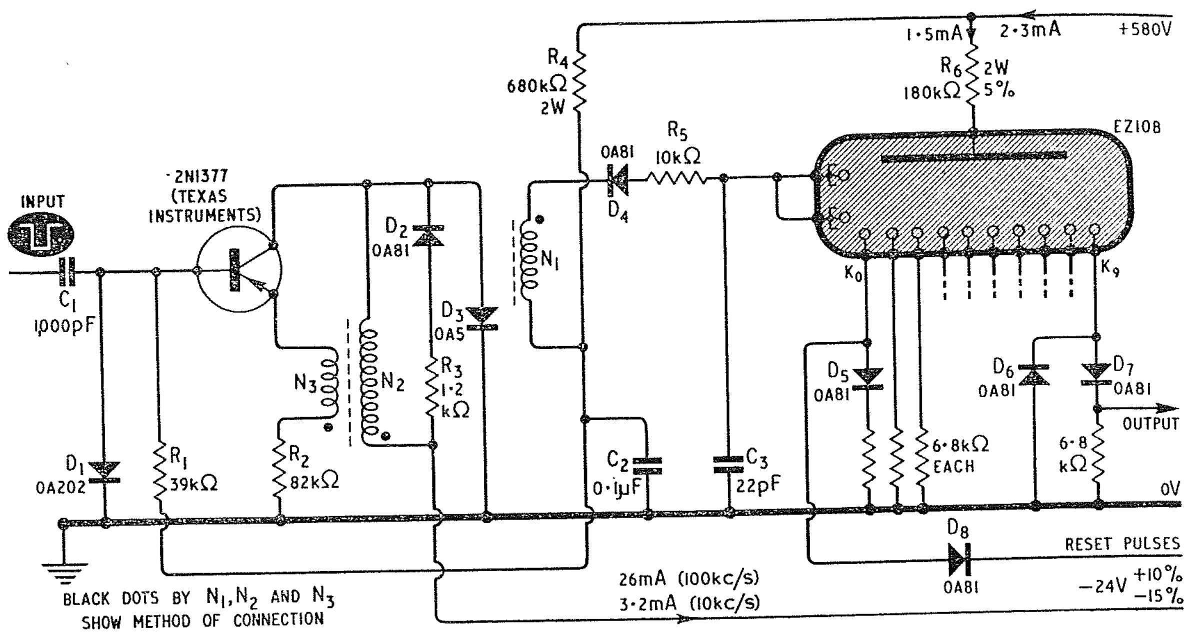
The EZ10B tube requires input pulses exceeding 100 V in amplitude for reliable operation. It has been found that the most economical way of producing such pulses is by the use of low priced transistors in blocking oscillator circuits. One transistor is required to drive each EZ10B tube. The quiescent power consumption is very small.

The transistor circuits discussed in this section operate satisfactorily in the temperature range 0 °C to 45 °C.

100 kc/s Transistor Input Circuit[30]

A 100 kc/s counting stage employing a transistor blocking oscillator circuit to feed an EZ10B is shown in Fig. 4.63. This circuit is normally used as the input stage of an EZ10B transistor scaler. The input pulses used to operate the circuit should have an amplitude of −10 V and a minimum duration of 3 μsec. The rise time of the negative going leading edge of the input pulse should be less than 1 μsec.

The three windings of the blocking oscillator transformer, N_1, N_2 and N_3 are wound on a common Philips S14/8 pot core. D_1 and D_3 protect the transistor base and collector respectively against any

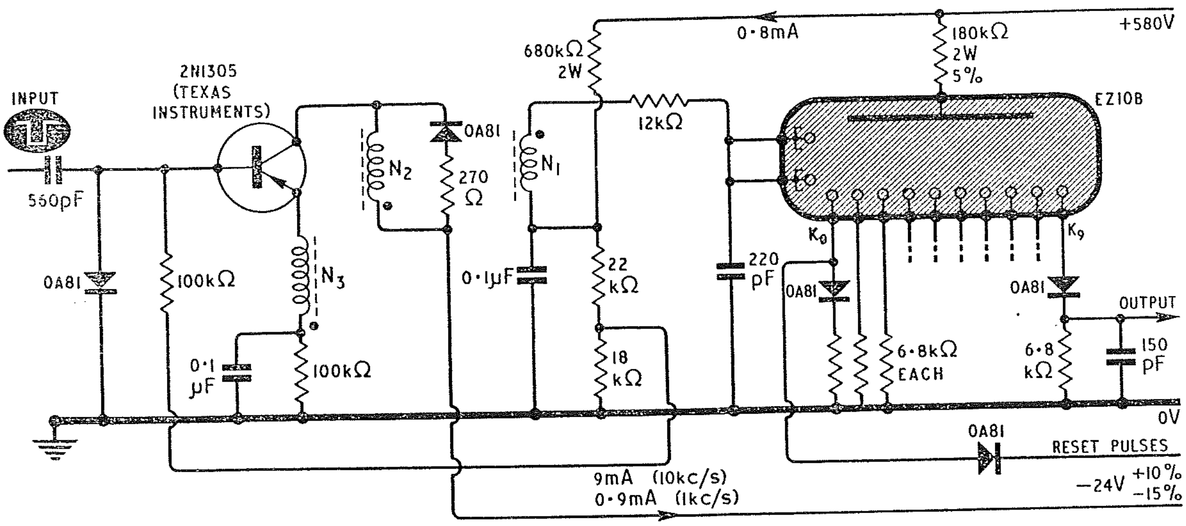


TRANSFORMER DETAILS

Philips pot core S14/8. Material 3B2. No air gap or adjustment screw

N_1	400 turns	0·065 mm enam. wire
N_2	60 turns	0·1 mm enam. wire
N_3	15 turns	0·1 mm enam. wire

Fig. 4.63 A transistor drive circuit for the operation of the EZ10B at up to 100 kc/s



TRANSFORMER DETAILS

Philips pot core S18/12. Material 3B2. Air gap 0·16 mm
No adjustment screw

N_1	1200 turns	0·064 mm enam. wire
N_2	200 turns	0·1 mm enam. wire
N_3	70 turns	0·1 mm enam. wire

Fig. 4.64 A transistor drive circuit for the operation of the EZ10B at up to 10 kc/s

excessive peak voltages, whilst D_2 and R_3 (assisted by D_4) clamp the free oscillations of the transformer at the end of each pulse. R_5 and C_3 are used to give the pulse the desired shape. The output from the ninth cathode of the EZ10B may be used to feed a succeeding 10 kc/s stage.

The resetting pulses are applied through D_8 to the zero cathode. All of the zero cathodes are connected together by the reset line and diodes (such as D_8) provide the necessary decoupling. D_5 presents a high impedance to the reset pulses and prevents a large portion of these pulses from being shorted to earth.

10 kc/s Transistor Input Circuit[30]

The circuit shown in Fig. 4.64 may be employed in scalers operating at input frequencies not exceeding 10 kc/s and in decades following the 100 kc/s circuit of Fig. 4.63. The 10 kc/s stage closely resembles the 100 kc/s stage, but the problem of damping the transformer oscillations is reduced because of the smaller mark to space ratio. The sensitivity of the circuit of Fig. 4.64 has been increased by placing a capacitor in parallel with the resistor in the emitter circuit so that the stage can be operated from the output pulses furnished by the preceding decades.

Windings N_1, N_2 and N_3 are all on a common core.

Pulse Shaping Circuit[30]

The circuits of Figs. 4.63 and 4.64 require input signals with steep sides. The input circuit of Fig. 4.65 may be used to convert the incoming pulses

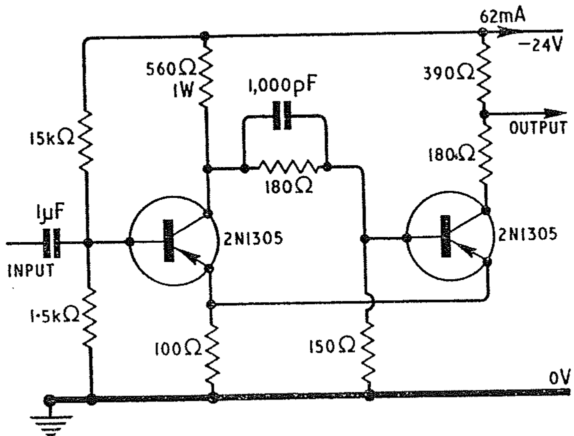


Fig. 4.65 A pulse shaping circuits for feeding the circuits of Figs. 4.60 and 4.61

which are to be counted into pulses of a suitable shape for operating the counting stages. This pulse shaping circuit is basically a Schmitt trigger circuit which converts input signals of 5 to 15 V in amplitude and of arbitrary waveform into the 14 V rectangular pulses required for the operation of either of the counting circuits discussed previously.

The capacitor in the input of the pulse shaping circuit limits the lowest operating frequency for reliable counting of sine waves to about 5 to 10 c/s. At lower frequencies the capacitor may be omitted.

Relay or Magnetic Counter Operation[30]

The circuit of Fig. 4.66 shows how a transistor amplifier may be used to convert the output pulses from an EZ10B tube into pulses which are suitable for the operation of a relay or an electro-magnetic counter.

When the discharge leaves the ninth cathode of the EZ10B, the resulting negative pulse is used to trigger a transistor monostable multivibrator which shapes the pulse. The resulting pulse is fed into an OC26 power transistor which operates the relay or magnetic counter. The coil of the relay or counter should be designed to operate from 24 V at a maximum current of 0.5 A. The Sodeco magnetic counter type TCeZ6E which has a 24 V 350 Ω coil is suitable for use in this circuit.

Transistor Circuits Providing a Digital Display[30]

The circuit of Fig. 4.67 shows how a digital display may be obtained from an EZ10B circuit by means of relatively cheap germanium PNP transistors. The cathode resistors have been divided into two sections so that a suitable output can be obtained for feeding into the bases of the transistors. Normally the emitters of the transistors are positive with respect to their bases; the transistors are therefore in their low resistance state and their collectors are almost at zero potential. When a certain cathode in the EZ10B strikes, however, a positive voltage is fed to the base of the corresponding transistor and this results in the transistor being cut off. The collector, therefore, becomes negative and this negative pulse causes the corresponding digit of the indicator tube to glow.

Table 4.9 THE BASIC DATA AND CONNECTIONS FOR THE ELESTA EZ10B TUBE

	Min.	*Normal*	*Max.*
Striking voltage	300	380	450
Maintaining voltage	280	300	330
Supply voltage	500	580	—
Anode current (mA)	1.2	1.5	1.9
Anode resistor (Ω)	—	180 k	—
Slope of pulse sides (V/sec)	—	—	10^9
Input pulse duration and spacing (sec)	5×10^{-7}	—	—
Input pulse amplitude (V)	SEE TEXT		
Resetting pulse amplitude (V)	—	120	—
Cathode resistor (Ω)	0	6.8 k	6.8 k
Peak output amplitude (V)	—	7	—

Dimensions
Seated height 48 mm max. Diameter 21 mm max.

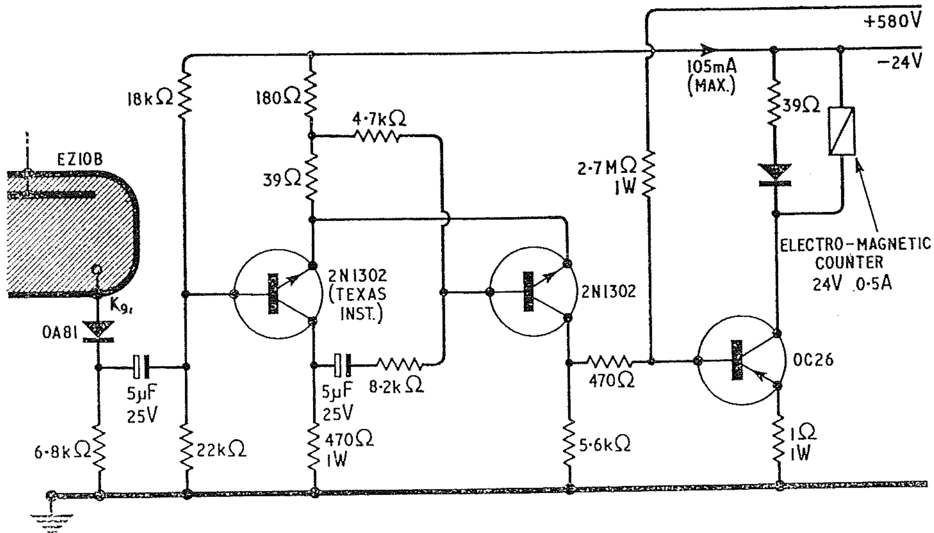
Escutcheon
Elesta type ZB33 with circular polarised filter to improve constrast.

Base
13 pin miniature fitting into 15 pin Elesta socket ZB13.

Connections

1	2	3	4	5	6	7	8	9	10	11 and13	15
K_0	K_9	K_8	K_7	K_6	K_5	K_4	K_3	K_2	K_1	transfer electrodes	A

When the wires have been soldered to the tube socket, the pins of the socket should remain completely movable to prevent strains at the glass base which could cause small cracks around the base pins.



4.66 A transistor circuit for coupling the EZ10B to an electro-magnetic counter

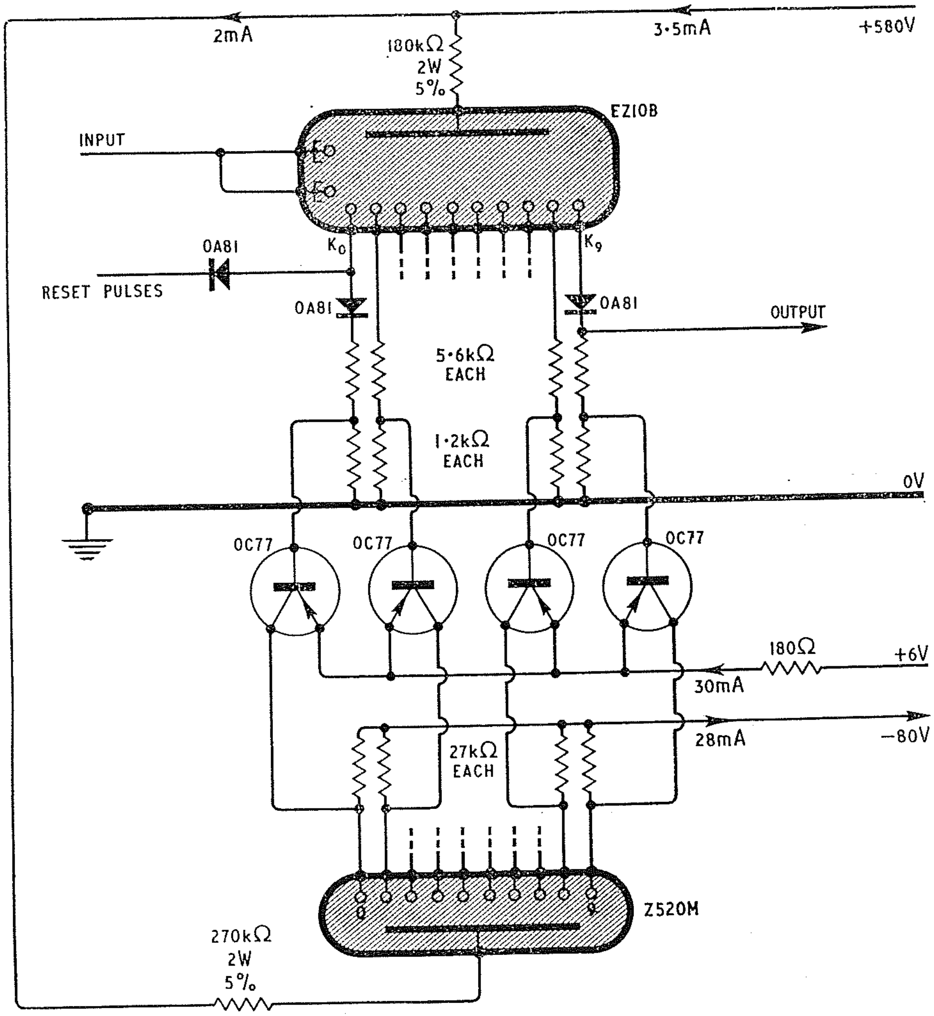


Fig. 4.67 Digital display from an EZ10B tube using PNP transistors

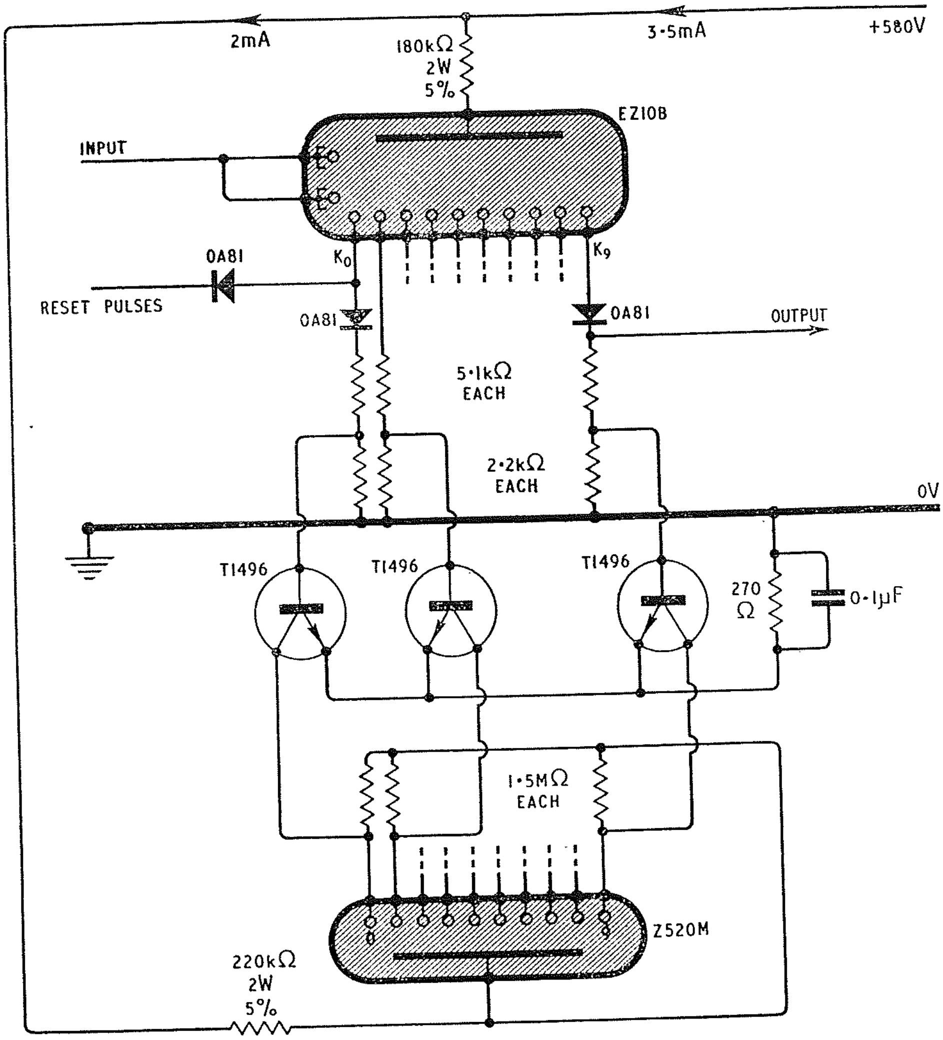


Fig. 4.68 Digital display from an EZ10B tube using NPN transistors

The disadvantage of this type of circuit is that nine of the ten transistors are conducting at any one time and, therefore, the current consumption is fairly high.

The circuit of Fig. 4.68 employs NPN Texas Instrument transistors type TI496 (or an equivalent type). The use of NPN transistors enables the positive voltage from the circuit of the EZ10B glowing cathode to be used to switch the corresponding transistor to the conducting state. Thus only one of the ten transistors is conducting at any instant and the power consumption is considerably smaller than when the circuit of Fig. 4.67 is used.

4.8.3 The ECT100 Reversible Selector Tube

The Elesta ECT100 tube[35] operates on principles which are rather different from those of the other tubes which have been discussed in this chapter. The electrode assembly and the basic circuit for the ECT100 tube is shown in Fig. 4.69. Four star shaped electrodes are stacked inside a cylindrical anode, *A*, so that they are separated from each other by a very small distance. Two of the electrodes are main cathodes and two are guide cathodes. Each of the four electrodes has five limbs or spokes, each of which points to the anode. The limbs are in the same plane as the remainder of the particular electrode ring to which they are attached. An output electrode, S, is placed at the end of each main cathode limb. The fifteen electrodes of the system are placed in a miniature glass envelope which is filled with hydrogen.

One of the cathode rings will be referred to as K_1 and the other as K_2. The first limb of the K_1 ring will be called K_{11} and the second limb of this ring K_{12}, etc. Similarly the fourth limb of K_2 will be designated K_{24}. A similar nomenclature will be used

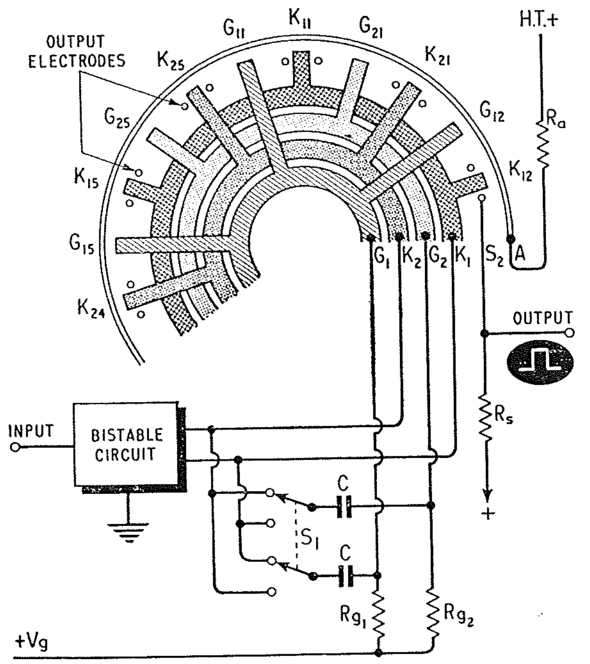


Fig. 4.69 The structure of the ECT100 tube and the basic circuit in which it is used

for the two guides (G_1 and G_2) and for the guide limbs.

The cathode rings are fed from the two outputs of a bistable circuit as shown in Fig. 4.69. The outputs of the bistable circuit are also differentiated and applied to the guides. The switch S_1 reverses the direction of counting; when G_1 is connected via a capacitor to K_1, the tube counts in a forward or clockwise direction.

When the tube first strikes, a discharge occurs between the anode and one of the limbs of the cathode ring which is at the lower potential. Let us assume that an initial discharge takes place at K_{11}. The potential drop across the tube anode resistor ensures that the tube cannot strike at any other limb of the same cathode ring. The other electrodes (K_2, G_1, G_2 and the ten output electrodes) are all at a positive potential with respect to K_1 and no discharge can occur between the anode and any one of them.

An input pulse will change the state of the bistable circuit and the potential of K_1 rises as that of K_2 falls. In addition the guide electrodes receive pulses of opposite phase. If the switch S_1 is in the position shown in Fig. 4.69, the potential of G_2 falls and the discharge moves to G_{21}, since this is the most strongly primed limb of G_2. The positive going pulse applied to G_{11} prevents any possibility of the discharge moving in the wrong direction. As the amplitude of the differentiated pulse applied to G_2 decays, K_2 becomes the most negative of the electrodes. The discharge therefore moves to the limb of K_2 which is most strongly primed, namely K_{21}. A second input pulse will return the multivibrator to its initial state and the discharge will move to G_{12} and then to K_{12}.

If the position of the switch S_1 is changed and an input pulse is applied when the discharge is resting at K_{11}, G_1 will receive a negative going pulse. The discharge therefore moves in an anticlockwise direction from K_{11} to G_{11} and then to K_{25}. Thus the tube is counting in reverse.

In order to obtain the maximum possible reliability, the output waveforms from the multivibrator should be symmetrical with respect to each other. The guide bias should be equal to half the mean amplitude of the multivibrator output. The quiescent guide potential is slightly above the guide bias supply voltage, since a small 'probe' current always flows through the guide resistors when the discharge is resting at a main cathode. The rise time of the multivibrator output pulses should be short so that the peak voltage of the differentiated drive pulses equals the cathode drive pulse amplitude. Stray electrode capacitance must, of course, be kept low if a high counting speed is required. The time constant of the differentiating components must be short compared with the time taken for one count to be registered.

Readout and Reset

The tube provides the normal visual readout (which is blue in colour) and in addition electrical readout can be obtained by the use of the output electrodes.

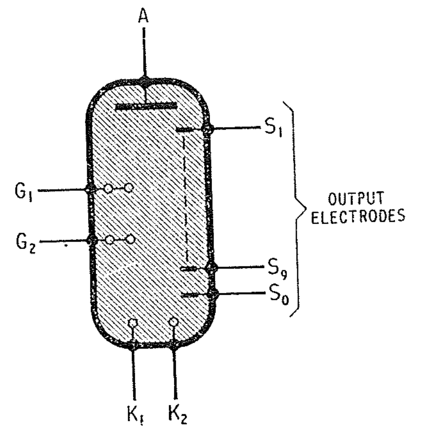


Fig. 4.70 The symbol for the ECT100 tube

Each main cathode has a small output electrode associated with it and the latter acts as a probe in the discharge. A positive going output pulse is obtained whose amplitude is a function of the output electrode load resistance. The output electrodes receive a positive bias to prevent them from initiating a discharge.

If outputs are not required from all of the output electrodes, a number of these electrodes may be connected together and returned to the output electrode bias supply via a common load resistor of maximum value 1 MΩ. At frequencies not exceeding 100 kc/s any number of the output electrodes may be connected in parallel.

If a large negative going pulse is applied to an output electrode, the discharge is transferred to this electrode for the duration of the pulse and the voltage drop across the tube anode resistor causes the discharge at any other point in the tube to be extinguished. At the end of the resetting pulse the main cathode limb which is adjacent to the conducting output electrode takes over the discharge, since it is strongly primed. The bistable circuit must be reset at the same time as the ECT100 tube.

The symbol for the ECT100 tube is shown in Fig. 4.70; for simplicity only three of the ten output electrodes are included in the symbol.

100 kc/s ECT100 Stage

A transistor driven ECT100 decade stage[35] is shown in Fig. 4.71. The two transistors are employed in a non-saturating bistable circuit in order to render the circuit less dependent on the current gain of the transistors. The input pulses should be negative

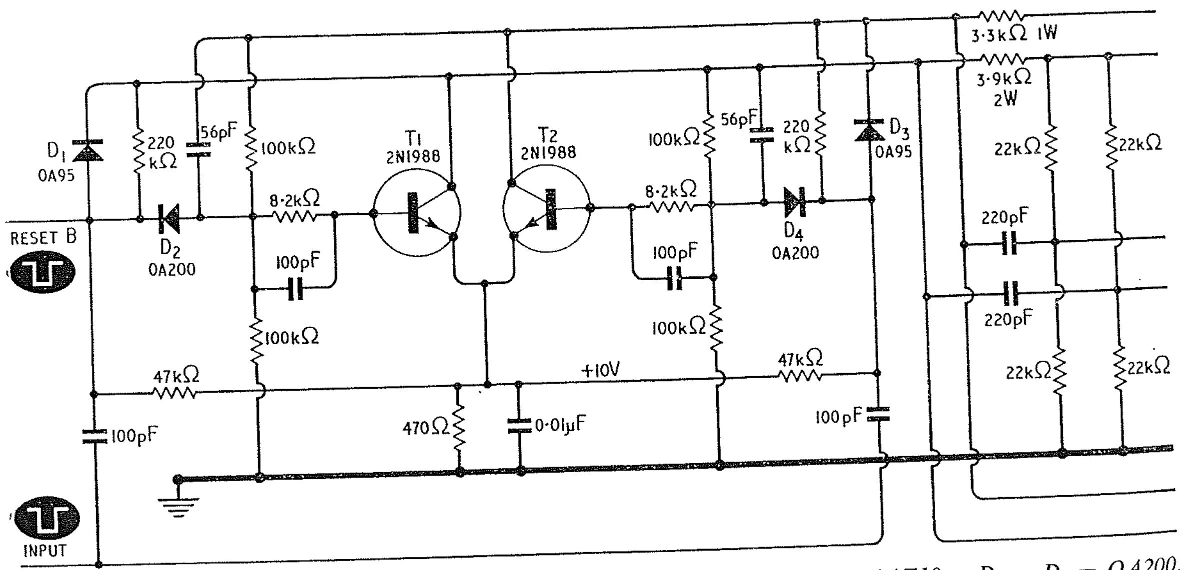


Fig. 4.71 A 100 kc/s circuit for the ECT100 tube. $D_1 = D_3 = OA95$ *or AAZ10;* $D_2 = D_4 = OA200$, *BFY13 may be used instead of the*

going, of between 10 and 25 V peak amplitude and of a duration which is not less than 0.1 μsec. The negative going leading edge which triggers the bistable circuit should have a rise time not exceeding 4 μsec. These pulses may be obtained from an identical preceeding counter decade or from the pulse shaping circuit of Fig. 4.72. The method of feeding the ECT100 from the bistable circuit is similar to that of Fig. 4.69, except that no direction reversing switch is shown.

The ten output electrodes are returned via 100 kΩ resistors to a potential of +60 V on the potential dividing chain. For simplicity, only three output electrodes and three of their load resistors are shown in the circuit of Fig. 4.71. When the discharge moves to position nine (K_{25}), the positive going pulse at the ninth output electrode (S_9) renders D_5 conducting. The collector waveform is fed back through D_5 to S_9 when the discharge leaves position nine; this results in the output pulse to the next decade having the required sharp negative going edge and enables the delay between successive stages to be reduced to less than 0.4 μsec.

Power supply voltage changes of +10% to −15% will not affect the operation of the circuit of Fig. 4.71. If unstabilised voltage supplies are employed,

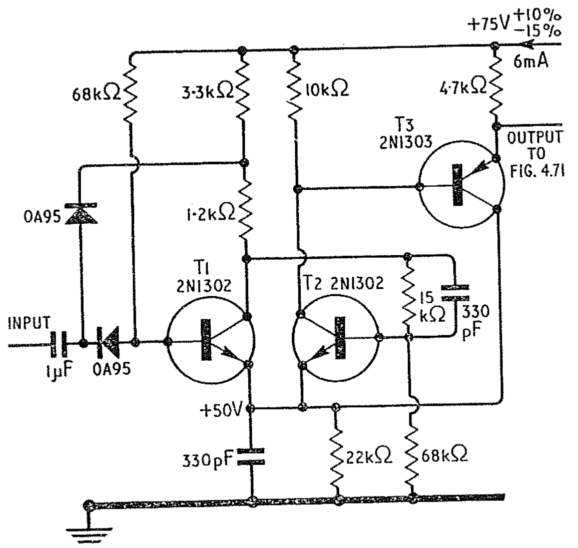


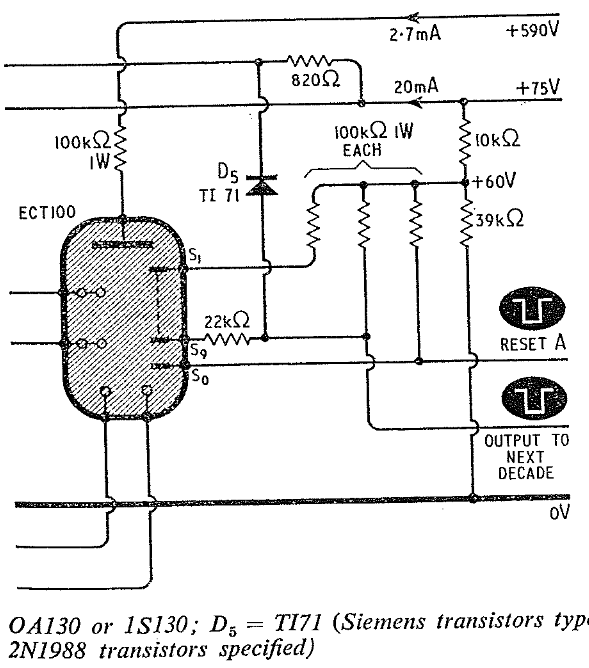
Fig. 4.72 An input pulse shaping unit

the effects of any mains voltage variations on the tube bias and drive circuits tend to cancel each other. If stabilisation is necessary, all of the voltage supplies should therefore be stabilised.

The input pulse shaping circuit of Fig. 4.72 is designed to provide the pulses with a sharp negative going edge which are required for the operation of the circuit of Fig. 4.71. The circuit shown in Fig. 4.72 consists of a Schmitt trigger circuit followed by an emitter follower circuit. It can be operated by input pulses of any shape which have a peak amplitude of not less than 18 V. The output pulses from the circuit of Fig. 4.72 have an amplitude of 13 V and a rise time of 0.2 μsec when no load is applied to the output.

If a negative going pulse of 220 V in amplitude and not less than 10 μsec in duration is applied at the 'Reset *A*' terminal of Fig. 4.71 and at the same instant a negative going pulse of at least 10 V in amplitude is applied to the 'Reset *B*' terminal, the circuit will be reset to zero. The pulse applied to the 'Reset *A*' terminal resets the tube and that which is applied to the 'Reset *B*' terminal resets the bistable circuit.

The circuit of Fig. 4.73 can be used for providing the pulses required for resetting any number of stages up to ten. When the resetting switch is closed, the capacitor *C* discharges and a negative pulse of about 220 V in amplitude is fed through the diodes



OA130 or 1S130; D_5 = TI71 (Siemens transistors type 2N1988 transistors specified)

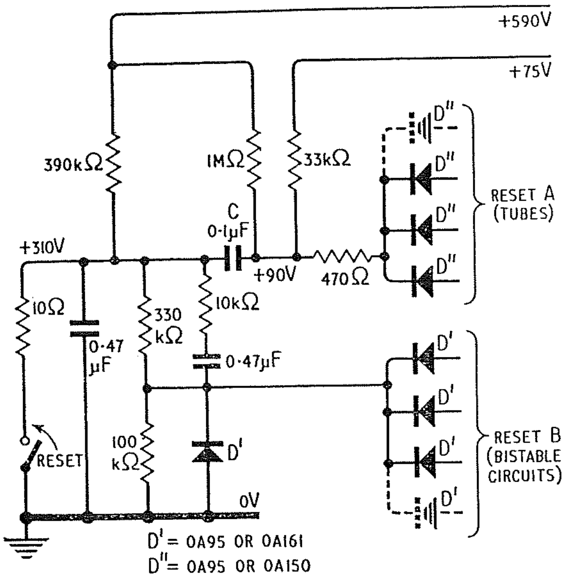


Fig. 4.73 A resetting circuit for the ECT100

D″ to reset the ECT100 tubes. The outputs from the circuit of Fig. 4.73 which are connected to the bistable circuits (Reset *B*) are normally at a potential of +72 V, but when the resetting switch is closed, this potential falls to zero. The circuit is capable of carrying out ten resetting operations per second. The supply voltage tolerances are −15% to +10% of the specified nominal value.

1 Mc/s ECT100 Decade

A 1 Mc/s circuit for the ECT100 is shown in Fig. 4.74[36]. The output pulses from this circuit may be used to directly drive the 100 kc/s circuit of Fig. 4.71. The reset pulses required for the 1 Mc/s decade are similar to those required for the 100 kc/s decades. Four ES11 voltage stabiliser tubes are used in the anode circuit of the 1 Mc/s decade. The 25 kΩ resistor in the anode circuit of the ECT100 tube in Fig. 4.74 should be adjusted until the potential difference across the 33 kΩ anode resistor is 52 V.

The absolute maximum speed at which the ECT100 can count is about 2 Mc/s.

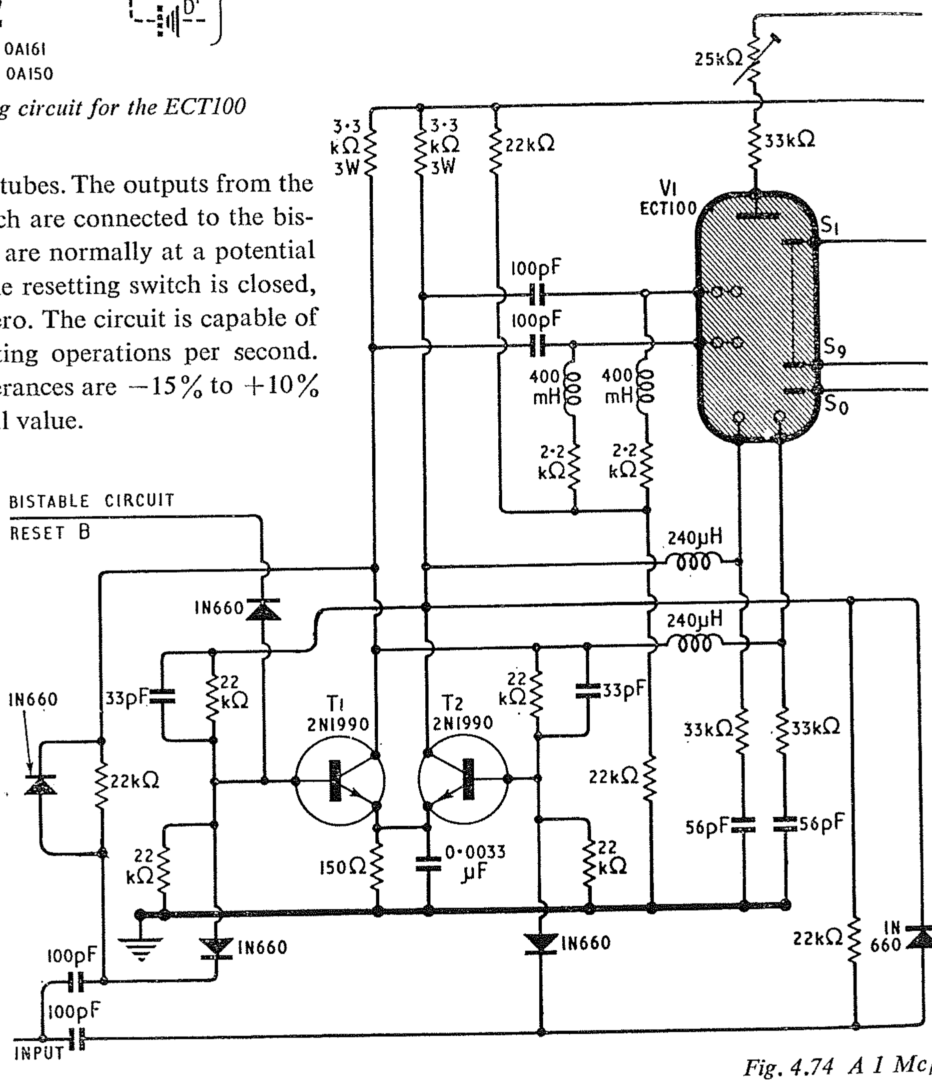
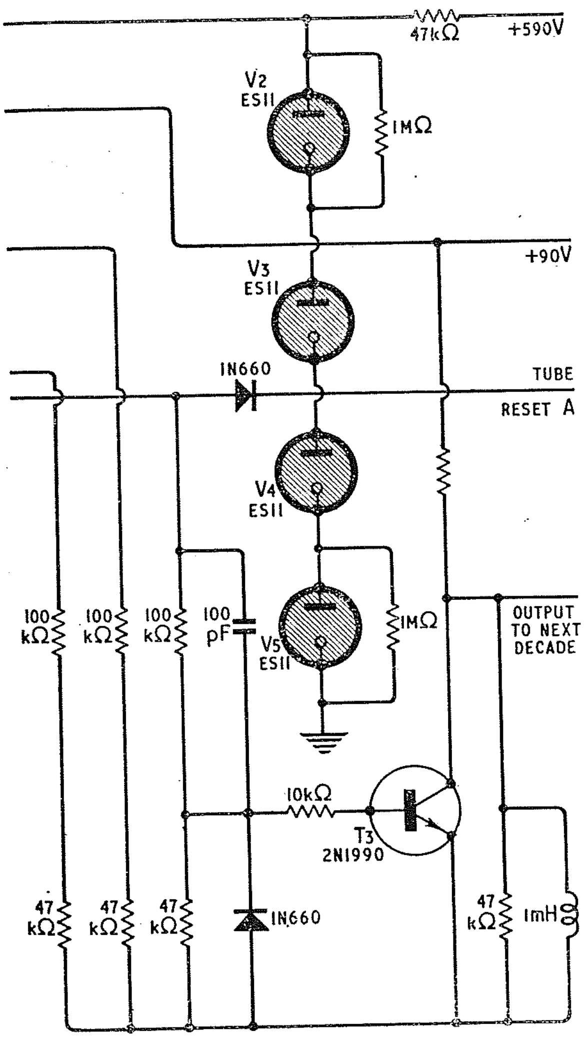


Fig. 4.74 A 1 Mc/s

Table 4.10 BASIC DATA AND BASE CONNECTIONS FOR THE ECT100 TUBE

Anode to cathode breakdown voltage	320–375
Maintaining voltage	295–320
Temperature range	−100 to +100 °C
Max. magnetic field (gauss)	200 (any direction).
Mounting position	Any
Minimum life (h)	25,000
Dimensions Seated height 38 mm (max.)	Diameter 21 mm (max.)
Escutcheon Elesta type ZB23 with circular polarised filter	
Base Elesta special type socket ZB25	

Base	*Connections*
1	S_0
2	S_9
3	S_8
4	S_7
5	S_6
6	S_5
7	S_4
8	S_3
9	S_2
10	S_1
11	A
12	K_2
13	G_2
14	K_1
15	G_1



circuit for the ECT100

4.9 MULTIPLE ANODE COUNTING TUBES

The characteristics of the multiple cathode tubes described in the preceding sections cf this chapter tend to change if the discharge rests for a long time at any one cathode. The sputtering which occurs at the cathodes results in a non-uniformity of the cathode surfaces and a reduction in reliability. New types of tube are being developed in England(37) and Japan(38) in which the reliability is improved by the use of a single cathode surrounded by a number of anodes. If the cathode is a wire completely surrounded by the glow, no variation of the tube characteristics due to changes in the cathode surface are likely to occur during the life of the tube. Some multiple anode tubes employ a circular cathode resembling the anode of a normal double pulse tube; in this case only a part of the cathode surface is covered by the glow at any one time.

Multiple anode tubes have the additional advantage that they can drive numerical indicator tubes directly without any intermediate amplifying device. Each anode of the counting tube is connected to the appropriate cathode of the indicator tube.

4.9.1 Inverse Tubes

One type of multiple anode tube consists of a single cathode surrounded by thirty anodes. The structure is very similar to that of the conventional double pulse tube, but the polarity of the applied potential

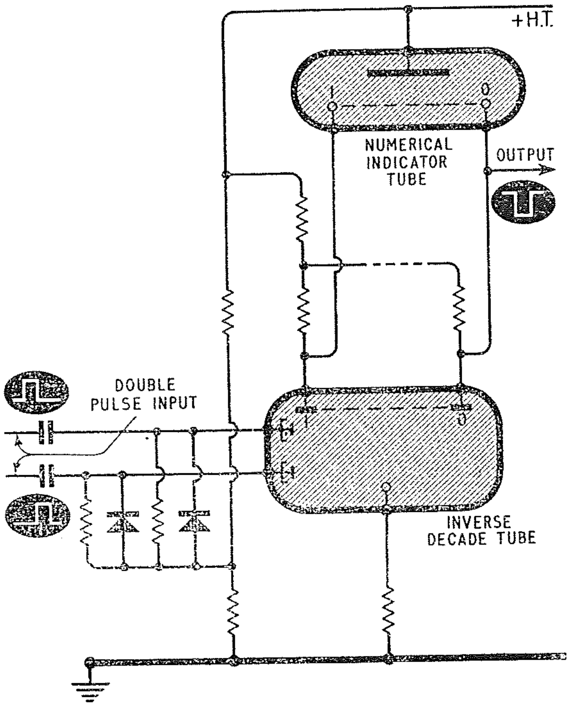


Fig. 4.75 The basic circuit for the operation of an inverse tube

is reversed. Such tubes are often referred to as inverse tubes, although the Japanese tubes are known as 'Polyatrons'. The operation is very similar to that of normal double pulse tubes. Ten of the anodes are main anodes, whilst the other twenty are used as first and second guide electrodes. The tube registers a count when a suitable positive going pulse is applied to the first guides followed by a positive going pulse to the second guides.The amplitude of the guide pulses is smaller than for the conventional double pulse tubes, about 40–50 V[37].

The basic circuit for the operation of an inverse decade tube is shown in Fig. 4.75. The load resistor may be placed in the indicator tube anode circuit or in the counting tube cathode circuit. The method of applying pulses to the guides is the same as that used with normal double pulse tubes, but the pulses must be positive going.

4.9.2 Magnetically Biased Tubes[37]

Another type of multiple anode tube employs twenty anodes, one guide anode being placed between each two main anodes. In this type of tube the direction of rotation of the glow is determined by the polarity of an applied magnetic field. If the guide electrodes are left unnconnected, a value of the magnetic field strength can be found at which the discharge will rotate continuously. A suitable negative potential applied to a guide will cause the rotation to cease. In this type of tube the guides may, therefore, be referred to as locking electrodes.

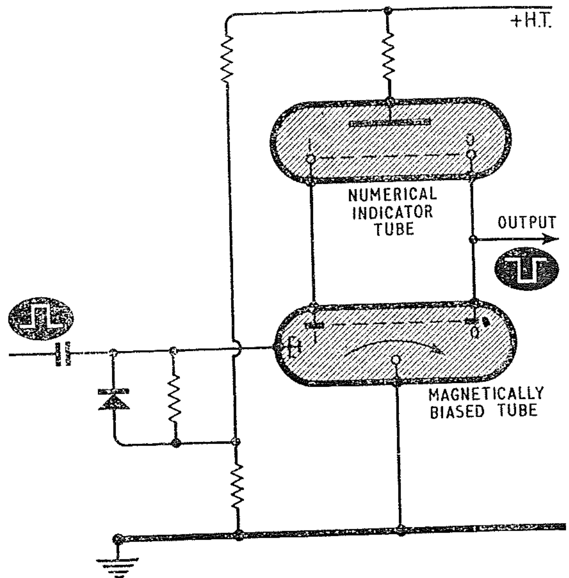


Fig. 4.76 The basic circuit for a magnetically biased decade tube

It is possible to operate tubes of this type by applying a pulse to all of the guides simultaneously so that the discharge commences to rotate, but the duration of the pulse must be controlled if only one count per pulse is to be registered. Pulses of 20 V in amplitude are sufficient. They may have any shape, since once the discharge has commenced to rotate, the stepping process is independent of the locking electrode potential. Alternatively alternate locking electrodes may be connected together and the two groups (each of five electrodes) thus formed may be driven from the two outputs of a bistable circuit; this effectively prevents the tube from stepping more than one position if the input pulses are long.

The speed of operation of the present experimental magnetically biased tubes is limited to a few hundred cycles per second, but the characteristics are very stable. An external magnet is employed, but the field uniformity and alignment are not critical. The basic circuit for the operation of a numerical indicator tube from a magnetically biased decade tube is shown in Fig. 4.76.

It seems certain that more will be heard of multiple anode gas filled decade tubes in the future, since they seem likely to satisfy the increasing demand for a very high degree of reliability coupled, of course, with an economical form of digital readout.

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