Some tubes (such as the GR10H) may be operated from an unrectified alternating supply. An additional electrode, called the a.c. anode, is placed so that the glow from it cannot be seen from the viewing position. The main anode is connected to the additional anode through a high resistance to facilitate the striking of the tube.

Numerical indicator tubes cannot be operated from either an unsmoothed rectified or an unrectified supply unless isolating buffer amplifying stages are employed between the counting circuit and the indicator tube, since counting circuits cannot be operated from unsmoothed supplies.

A number of methods have been published by which the amount of light evolved from an indicator tube can be reduced for operation in subdued light(4). These circuits employ valve or transistor astable circuits so that the voltage supply is applied to the indicator tube for a fraction of the operating time. In conditions of high ambient lighting it is recommended that a red filter or a polaroid filter be placed in front of the tube to reduce reflections from the glass envelope and hence to increase the contrast of the display(4).

10.3 THE Z550M INDICATOR TUBE(7, 8)

The Mullard/Philips Z550M is a unique tube which has been developed to satisfy the need for a decade indicator tube which can be operated directly from the low voltage electrical readout provided by transistor scalers. It requires an input signal of about 5 V at a current of about 50 μA. The form of the display is different from that of other indicator tubes. Ten figures are cut in the anode in the shape of the digits to be indicated; they are arranged in a circle, each digit being 3 mm in height. A gas discharge takes place behind one of the digits so that red light from the discharge shines through the cut away portion of the anode in the form of the digit to be indicated. The display can be quite bright, since the control circuit does not supply power to the main discharge.

The tube employs common anodes and common cathodes with ten separate trigger electrodes. The cathodes are in the form of a ring of molybdenum as shown in Fig. 10.4(a). The shaded parts of the ring are coated with a material of high work function so that they do not emit electrons under ionic bombardment. The ring thus acts as ten separate cathodes. Two other rings are mounted 3 mm above and below the cathode ring and are connected together to act as the anodes. The digits are cut out of the upper anode ring. A wire trigger passes through the lower anode ring into the hole in the cathode ring as shown in Fig. 10.4(b). A trigger electrode can be used to initiate the discharge at the

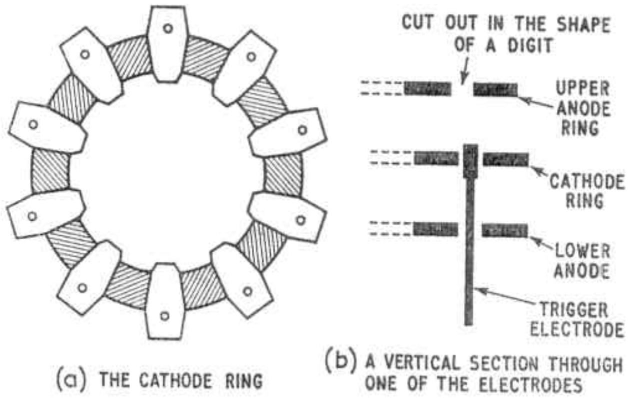

Fig. 10.4 The electrodes structure of the Z550M tube

desired position in the tube between the main anode and one section of the cathode. The tube is filled with neon containing a small percentage of argon, the total pressure being about 10 cm of mercury. Some material is sputtered from the cathode during manufacture so that the cathode surface is purified and the sputtered film which is deposited on the walls of the tube assists in the removal of contaminating gases.

The basic circuit in which this type of indicator tube can be used is shown in Fig. 10.5; for simplicity only two trigger circuits are shown. The power supply should be half wave or full wave rectified, but must not be smoothed. The trigger electrodes have a potential which is not very different from that of the common anodes provided that no discharge is taking place. A discharge between a trigger and the cathode can be initiated by a lower applied potential than is required to initiate a discharge between the anode and cathode. As the unsmoothed power supply voltage rises during a

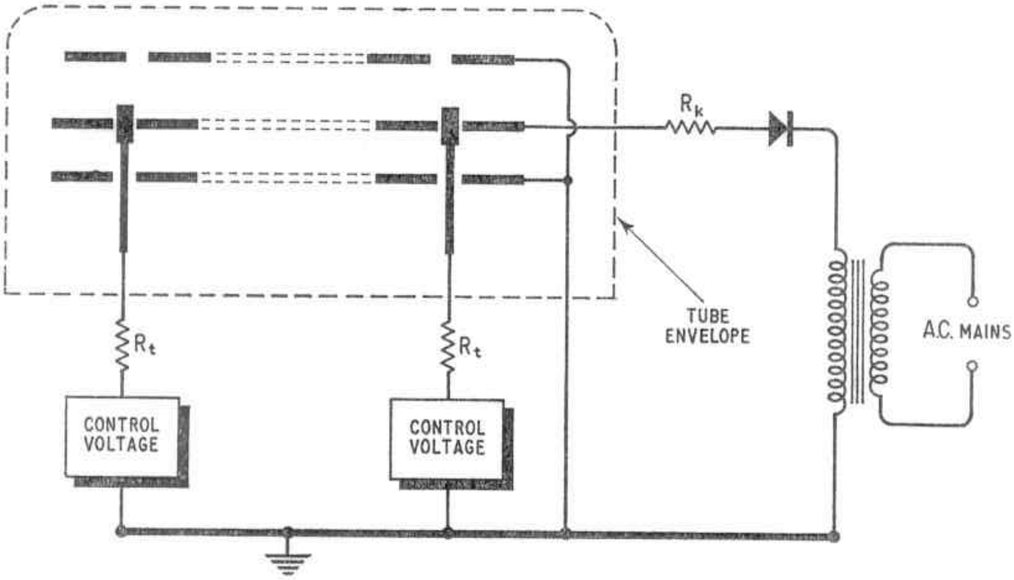

Fig. 10.5 The basic Z550M circuit

half cycle of the mains supply, a discharge will occur between the cathode and one of the trigger electrodes. If the current passing across this gap is large enough, the ions formed in this discharge will initiate a discharge between the main anode and cathode at the point at which the triggering discharge took place. The potential difference between the anode and the cathode then falls to the maintaining voltage for the tube and none of the other gaps can therefore reach their breakdown potential. The discharge ceases when the power supply voltage falls at the end of the half cycle. The process is repeated during a succeeding half cycle. Once a discharge has commenced at any point, a discharge cannot take place at any other point during the same half cycle of the power supply.

The position at which the triggering discharge occurs is controlled by the application of a small positive potential from the counting circuit to the desired trigger electrode so that the potential of this electrode is slightly higher than that of the other trigger electrodes. Its potential therefore rises to a value which is large enough to initiate a discharge before any of the other trigger gaps have reached their breakdown potential. At the next half cycle of the mains supply, the same trigger will initiate the discharge unless the counting circuit has switched the small additional potential to another trigger.

If the trigger voltage required for the initiation of an auxiliary discharge could be made exactly the same at all points in the tube, the tube could be operated by a very small control voltage. In practice, the trigger potentials required for ignition may vary by not more than 5 V and therefore the positive control voltage applied to the selected trigger electrode should not be less than this value. The differences between the ignition potentials of the various trigger to cathode gaps are minimised by the careful purification of the cathode surfaces. In addition the gas mixture is carefully chosen so that the trigger to cathode ignition potential is not strongly dependent on the electrode spacing.

The power supply frequency to the tube is quite important. It should not be so low that there is a noticable flicker. On the other hand it should not be so high that there is not enough time for a gap to deionise between cycles of the power frequency or the glow will remain at one cathode indefinitely. The control voltage, which must be applied to the selected trigger electrode, increases at power input frequencies above 500 c/s and in excess of 3 kc/s it is not possible to alter the position of the discharge.

There is some statistical delay in the ignition of a trigger to cathode gap, since each discharge must be started by the presence of an electron in a suitable position. If there is a large statistical delay in the firing of one trigger to cathode gap, another gap

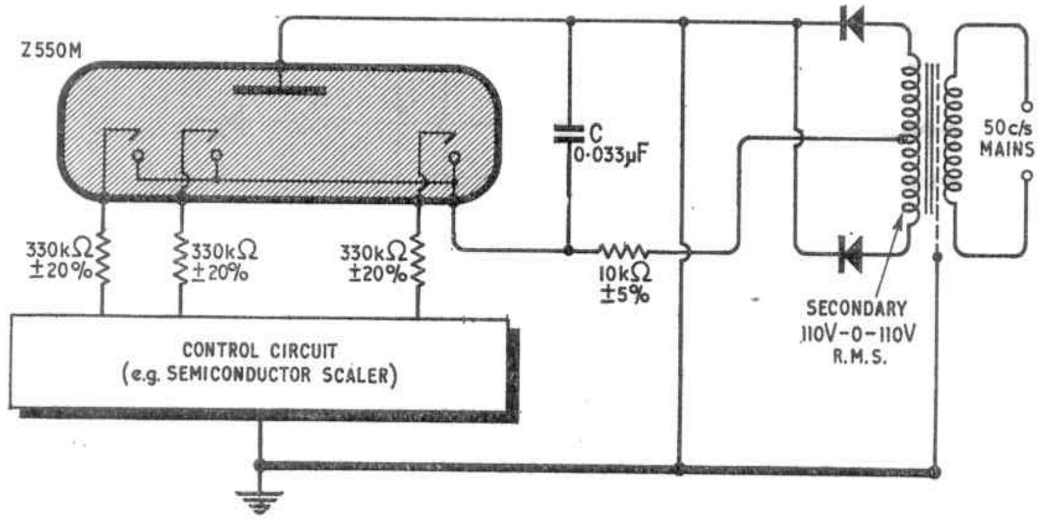

Fig. 10.6 A practical circuit for the Z550M.

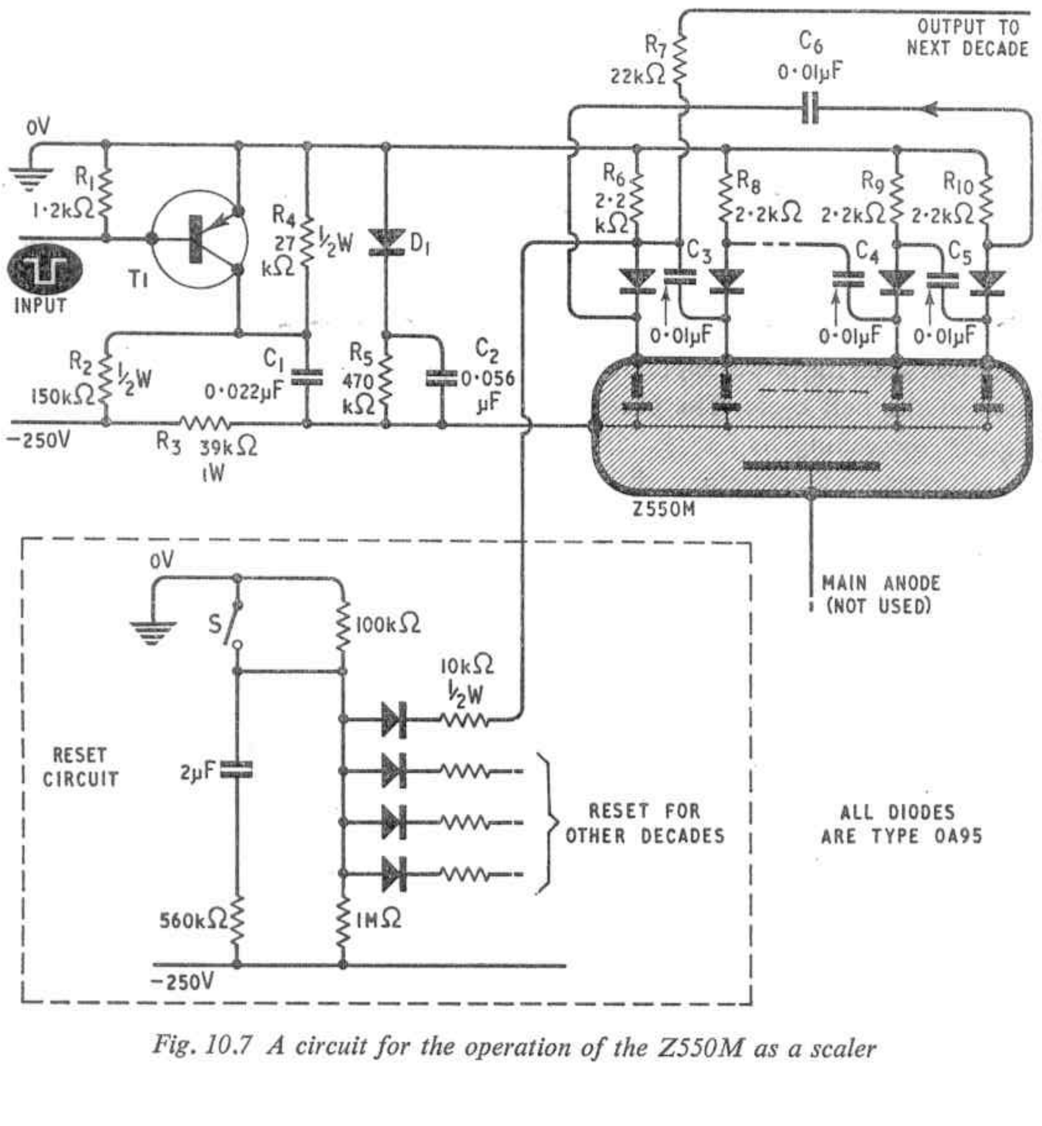

Fig. 10.7 A circuit for the operation of the Z550M as a scaler

may ignite during the delay time. This effect is minimised by the addition of a trace of radio-active gas to the tube; this gas provides electrons which can initiate the discharge. Nevertheless the power input frequency should not be too low or the gas will become almost completely deionised during the non-conducting period and this may cause a greater statistical delay in the striking of the tube.

A practical circuit for the operation of the Z550M indicator tube from a decade scaler is shown in Fig. 10.6. The scaler may employ PNPN devices in a ring circuit to provide decade electrical readout which can drive the indicator tube. If a cascaded transistor binary circuit is employed in the scaler with feedback to convert the scale of 16 to a scale of 10, some means must be provided to convert the binary readout into decade readout to drive the indicator tube. Full wave rectification is normally preferred to half wave circuits. The capacitor, C, is used to prevent any voltage spikes from affecting the operation of the tube. The cathode current should be about 3 mA and the control circuit resistance in the trigger circuits should be between 100 and 470 kΩ. A power supply of between 90 and 130 V R.M.S. (nominally 110 V) at 40 to 100 c/s is suitable. The maximum potential between any trigger and the anode should be limited to 30 V and that between the anode and the other nine triggers not being used should be limited to ± 5 V.

10.3.1 The Operation of the Z550M as a Scaler

The Z550M was primarily developed for use as an indicator tube, but it can itself be used as a counting tube for frequencies up to 1 kc/s, only one driving transistor per decade being required. The tube may be used as an indicator in high speed transistor decades and as a counter in the succeeding slower but much more economical decades; a uniform type of readout is thus obtained from all decades.

A ring circuit in which the Z550M tube is used as a scaler is shown in Fig. 10.7[9]. In this circuit the trigger electrodes are used as anodes, the normal common main anode of the tube being left unconnected. The trigger electrodes should be regarded as the anodes of ten neon diodes which have a common cathode. Although an alternating power supply is used with the tube when it is an indicator, a smoothed power supply must be employed to operate it when it is used as a scaler.

A negative going input pulse of 0.5 V in amplitude and 0.2 msec in duration applied to the base of the transistor $T1$ causes it to saturate. The amplified positive going pulse at its collector is fed via C_1 to the common cathodes of the tube. The collector of $T1$ is connected to the tapping of the voltage divider R_2-R_4 in order to reduce the collector to emitter voltage applied to $T1$ to a value within the ratings of this transistor. If the input pulse has a steep trailing edge, $T1$ is cut off so rapidly that a sudden large negative change in the common cathode voltage will occur and this could result in faulty counting. This difficulty can, however, be avoided by the use of D_1, C_2 and R_5. Any sudden negative going pulse in the common cathode line merely charges C_2 via D_1. The values of C_2 and R_5 are chosen so as to ensure reliable operation of the circuit even if square wave input pulses are used. In addition, C_2 protects $T1$ against excessive transient voltages.

The tube counts on the same principle as the neon diode circuits of Chapter 3. When a positive going pulse from $T1$ is applied to the common cathodes, the trigger electrode which was passing current will be extinguished. A positive pulse of about 9 V in amplitude will occur in this trigger circuit and is capacitively coupled to the succeeding trigger electrode. This latter electrode will therefore conduct when the cathodes resume their normal potential at the end of the input pulse. The coupling in the reverse direction is not appreciable, since the coupling capacitor concerned is discharged via the two trigger resistors and a forward biased diode.

When the zero trigger gap strikes, a negative going pulse is produced at the output which is suitable for the operation of a succeeding identical decade. It is not essential to employ components corresponding to D_1, C_2 and R_5 in any decade after the first, since pulses derived from a preceding decade have a suitable shape for the operation of a Z550M tube. When S is closed momentarily, a positive going resetting pulse is fed to the zero trigger electrode of all decades. The amplitude of this pulse is great enough to cause a current to flow in the zero trigger and cathode circuit which will increase the common cathode voltage to a value at which a discharge at any other trigger electrode will be extinguished. The diodes in the reset circuit prevent undesired coupling between the various decades.

The Z550M tube can also be used for reverse counting in the type of circuit shown in Fig. 10.8[9]; the input circuit should be similar to that of Fig. 10.7. For forward counting the line marked '*F*'

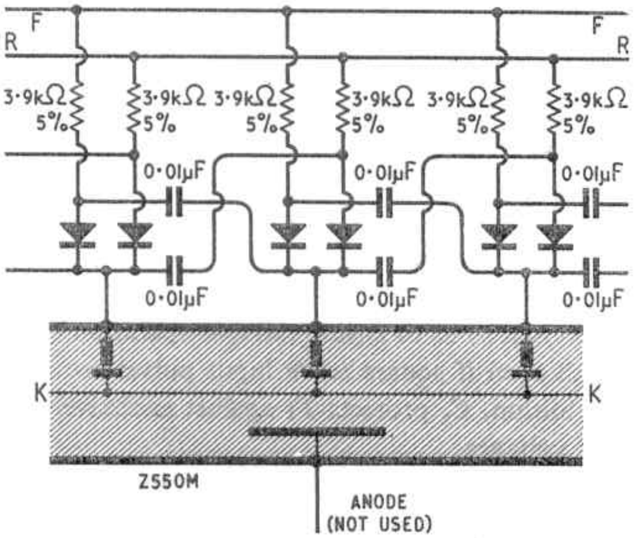

Fig. 10.8 The Z550M used in a reversible counting circuit

should be at least 15 V positive with respect to the line marked '*R*', but for reverse counting the polarities of these lines should be reversed. In either case the input pulses should be positive going and are applied to the common cathode line, *K*. If the line '*F*' is more positive than the line '*R*', the conducting trigger electrode will take its current from the '*F*' line and the diode connecting that trigger with the '*R*' line will be reverse biased. The additional components therefore have little effect on the counting which proceeds in the forward direction as in the circuit of Fig. 10.7. If, however, the '*R*' line is positive with respect to the '*F*' line, the trigger electrode current will be taken from the '*R*' line and counting will occur in the reverse direction.

In the reversible counting circuit of Fig. 10.8 the trigger electrodes are loaded by an extra capacitor and resistor; the pulses coupled from a preceding stage are therefore attenuated somewhat. For this reason the resistance values chosen should be rather higher than those used in the circuit of Fig. 10.7 and should be of close tolerance. The common cathode resistor (not shown in Fig. 10.8) should have a value of 47 kΩ, $\pm 2\%$ (compare with R_3 of Fig. 10.7). The value of the voltage supply to this cathode resistor should be -210 V $\pm 2\%$ with respect to the line '*F*' for forward counting or with respect to line '*R*' for reverse counting.

10.4 ELECTROLUMINESCENT READOUT

Electroluminescence occurs when a suitable phosphor is excited by a changing electric field so that it emits light. A thin layer of the phosphor in a suitable dielectric (e.g. polystyrene) is placed between two conducting films (one of which is transparent) and the three layers are attached to a suitable base such as a sheet of glass or metal for mechanical support.

When an alternating potential is applied between, the two conducting layers of the 'photo-capacitor's the phosphor emits light which passes through the transparent conducting film. The brightness and colour of the emitted light depend on the composition and thickness of the phosphor, the amplitudo and frequency of the applied voltage and the temperature[10]. Such electroluminescent panels can be used for lighting purposes. The maximum amount of light which can be obtained from a given area of the phosphor is limited by the dielectric breakdown which occurs at high applied potentials.

The frequency of the applied voltage is important, since its affects the colour and the amount of light. The frequency of the emitted light is twice the frequency of the applied potential, but at higher frequencies the light output does not fall to zero between half cycles of the applied voltage. An increase in the frequency of the power input increases the number of times per second the charge of the capacitor is reversed. Hence an increase of power frequency increases the light output, but if the frequency is raised above about 1 kc/s the life of the phosphors being produced at present is reduced[11].

In order to display digits, the back electrode of an electroluminescent panel may consist of ten strips