Commentary

IN 1904 Rutherford wrote that " there is reason to believe that an enormous store of latent energy is resident in the atoms of radioactive elements—energy which is derived from the internal energy of the atoms . . . If it were possible to control at will the rate of disintegration of radio-active elements an enormous amount of energy could be obtained ".

He was later to see his predictions verified, but in 1904 he could not have foreseen the subsequent developments of atomic energy which have derived from the work in the intervening fifty years.

If Rutherford would have been horrified by the events of 1945 when the atom bomb was first used as a military weapon, he would, we think, have read with much satis-faction that section dealing with the peaceful uses of atomic energy in the first annual report of the United Kingdom Atomic Energy Authority which has just been published.

The main emphasis of the peaceful uses of atomic energy is on the generation of electrical energy by the nuclear reactor and it is this development which was one of the principal reasons for the formation in July of last year of the United Kingdom Atomic Energy Authority under Sir Edwin Plowden.

The report is understandably vague with regard to those aspects of atomic energy which relate to military require-ments, but on what is referred to as " the civil field " the report is both frank and factual.

After presenting the background history of atomic energy since the war, the report gives a most satisfactory picture of the Authority's activities since its formation, but the most disturbing feature is the alarming shortage of man-power of the right kind which, the report frankly states, is setting a limit to the Authority's progress.

As the report says, " Her Majesty's Government have never hesitated to furnish money needed for buildings, plant and equipment for the atomic energy programme; material shortages have never been insuperable; but the difficulty of recruiting and retaining sufficient skilled scientists, engineers and craftsmen has become acute throughout the ten years of the project and shows no signs of becoming easier ".

The Authority has done what it can in the way of advertising its needs and by maintaining personal contact with universities, schools and technical colleges, but the results have been disappointing and the Authority has come to the conclusion that " there is a serious national shortage of most types of scientists and engineers and of many technical and craft grades, and that the Authority has not the same freedom of movement as industry in the matter of salaries ".

The cold fact is that the growth of technological developments of all kinds has proceeded at such a pace in the post-war years that it is outstripping our manpower resources and we are suffering from an inflationary spiral where more and more advances are chasing a dwindling supply of skilled manpower. We are, in fact, trying to do too much in too short a time, yet if we are to survive as an economic power we simply cannot call a halt to research and development.

The complaint by the Authority that it cannot compete with industry as regards salaries is probably based on fact, but the granting of higher salaries provides no perma-nent solution. It only takes away a man from industry who more than likely is already contributing to industry's share of the atomic energy programme.

The announcement by the chemical, electrical and mechanical fields of industry of the formation of its plans to overcome the shortage is a step—but only a step. " Viewing with growing disquiet the shortage of scientists, mathematicians and technologists ", the companies con-cerned have decided to assist the teaching of pure and applied mathematics in secondary schools and have set up an industrial trust of £1 500 000 to provide capital grants towards the building expansion, modernization and equip-ping of science buildings in independent and direct grant schools in Britain.

It does not, however, do anything to relieve the lack of science teachers in such schools, which lack is frequently put forward as one of the reasons why there is, in fact, so little interest in the scientific subjects at school.

The shortage is a long-term one and the solution can only be obtained it seems by going right back to the schools and " catching them young ".

With the educational system as it now stands, there is no lack of opportunity for the child of adequate intel-ligence and no occasion to be " born to blush unseen and waste one's sweetness on the desert air ".

The main problem is whether, with a decreasing popula-tion, we have a rising generation in sufficient numbers and capable of receiving adequate training to meet our future needs. If we have not, our future is very bleak.

16mm Tele-Recording for Sequential Television Systems

By V. B. Hulme*, M.A.

A system of tele-recording using continuous film motion through a shutterless gate is described. The camera motor speed is controlled by means of negative feedback components of phase, velocity and acceleration. A d.c. generator and pulse generator driven by the motor together with a phase-discriminator provide these components in the form of voltages.

A RECENT paper by Wood[1] on telerecording fundamentals gives an admirable presentation of the special features of continuous movement recording. The system described here which was developed for a sequential television system provides an interesting example of a continuous recording system in the 16mm field. Although the sequential nature of the television system puts this recorder outside the field of current broadcast television, interlacing is not a fundamental feature of television. It is rather interesting to note Wood's statement that the most economical means of recording a waveform on film is "to lay a variable density track across the film in closely spaced parallel lines" which exactly describes the method of picture recording described in the present article.

Continuous Movement Recording

Continuous film motion is employed mainly to avoid the loss of information which the pull-down period of the normal cine camera involves. Although an ultra-rapid pull-down period equal to, or less than, the frame blanking period is possible, the mechanical difficulties appear to be greater than those of a continuous recorder.

In order to clarify certain unconventional features of the design, the operation of the recording system will be described with reference to Figs. 1, 2, and 3.

The composite video signal is fed into a display unit to control the brightness of a fluorescent spot on the face of a c.r.t. (Fig. 1), the spot being caused to scan a line, as in normal television practice, in synchronism with line synchronizing pulses, but without the frame scan component. The image of the line is focused on a film in the camera by a lens, and the film is moved past the point of exposure continuously at a velocity $v = dF$ where d is the distance between sprocket holes and F is the frame recurrence frequency, since 16mm film has one sprocket hole per frame.

In the frame-scanning diagram (Fig. 2), the movement of the line image relative to the film is indicated by the straight line OC. This can be seen to be equivalent to the sum of waveforms A and B, where A represents the movement of the image due to the frame scan of a normal television raster and B, an intermittent film motion; the film being moved only during the frame-blanking period. The symbol η is used to denote the percentage of total frame-period available for picture information (i.e. unblanked).

The areas on the film exposed to active scanning are shown on the right, successive frames numbered 1, 2, 3, being exposed during the corresponding time intervals. The areas are scanned horizontally by the c.r.t. line scan

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and vertically by relative movement of film and line image.

With an intermittent system, the film motion must be synchronized with the frame-blanking for obvious reasons. With the continuous system, synchronism is desirable to fix the relation between image and sprocket holes on the film and to facilitate projection on a standard projector
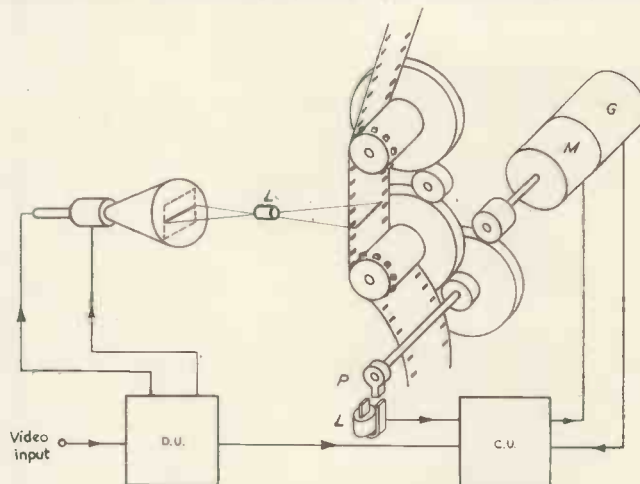

Fig. 1. Block diagram of recording system (simplified)

with intermittent film motion. Synchronism is effected by means of a pulse generator P (Fig. 1) producing pulses related in phase to the sprocket tooth of the sprocket driving the film. The pulses are fed to a motor control unit, together with pulses derived from the frame synchronizing signals from the display unit, and an output proportional to the phase difference is used to correct the speed and phase of the motor M.

There are two important disadvantages of the simple continuous recording system outlined above which may be effectively disposed of by combining the continuous film movement with a proportion of frame scan on the c.r.t. display. One disadvantage is the risk of burning the phosphor by concentration of the electron beam on a single line and the other is the difficulty of recording titles. Some form of titling is essential for identification of the recording in subsequent operations, e.g. editing. In Fig. 3, the line OE is the sum of a straight line representing a film velocity dF and an opposing frame scan waveform A. It is seen that the area of the film exposed to active scanning is reduced in the frame direction, the effective frame scan being $(1-S)\,d$, where S is the proportion of normal frame scan employed to form the raster. By reducing the line scan, the geometrical distortion of the aspect ratio is removed at the cost of a reduction in the size of the picture.

It is shown below that considerable reduction in energy per unit area on the tube face and hence increase in c.r.t. life is achieved by introducing a small amount of frame scan, say 5 per cent.

To record titles with a continuous film movement, a spot of constant brightness can be made to scan a transparent screen placed in front of the tube and carrying the titles in opaque or semi-opaque lettering.
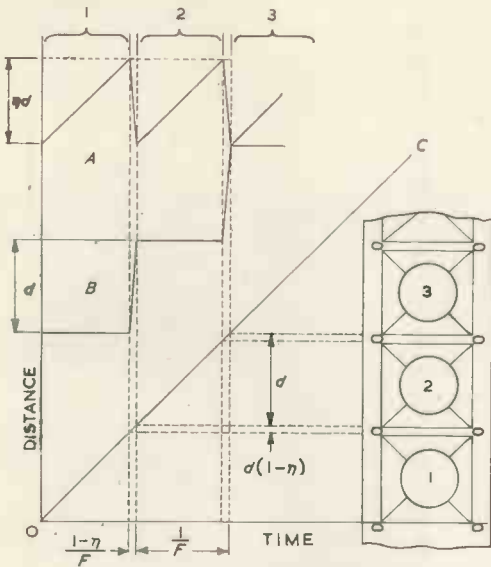

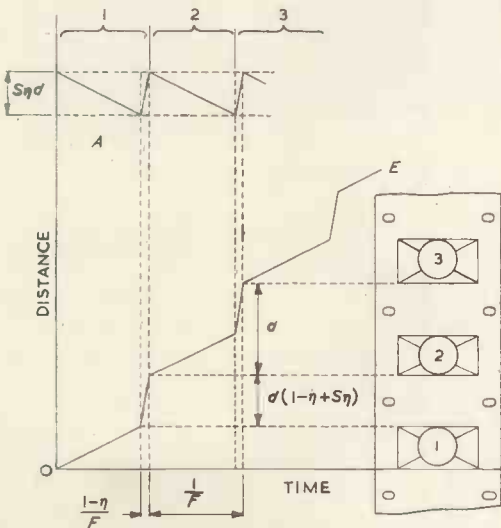Fig. 2. Frame scanning diagram

Fig. 3. Modified scanning diagram

For this purpose, all geometrical distortion will be avoided if the aspect ratio of the exposed area on the film matches that of the scanned area on the tube. It can be seen that this condition is satisfied if $S = 1 - S = \frac{1}{2}$, i.e. half normal frame scan is employed. Since the tube scan opposes the effective scan, the writing must be inverted. This is done by writing normally and turning the writing towards the tube face. It is interesting to observe that, with an opposing frame scan of amplitude $2d$ and frequency $F/2$, alternative frames of an interlaced picture

could theoretically be recorded and exactly superimposed with a continuous film motion[2]. In practice, however, registration of the alternate frame is difficult.

It is necessary to compromise when choosing the proportion of frame scan S to be employed when recording. With S too small, the c.r.t. screen life can be reduced and, with S too large, the area of the picture is too greatly reduced with resultant loss of resolution. In fact, with 16mm film, very little reduction in the used area of the film can be tolerated as, in general, the emulsion is the limiting factor in the definition obtainable from the system. An exception to this might be made in the case of some film stocks having high resolving power, but these are insensitive and require a correspondingly brighter display.

For a given tube-brightness setting, the average brightness of the picture (light flux per unit area) will vary in inverse proportion with the frame scan but, assuming that lines are not overlapping, the maximum intensity at the centre of a line remains unchanged. As the lines begin to overlap, further reduction of the frame scan increases the maximum intensity in approximately inverse proportion until the scan S approaches the width of one line. The intensity then becomes that of a single line multiplied by the number of lines in a frame, since these are all superimposed when the frame scan is reduced to zero. While this reduction of scan results in high concentration of energy which may burn the tube, the total light-flux emitted per second is no greater and the film exposure remains the same as if full frame scan were employed with the film stationary. It is not, therefore, permissible to avoid tube damage by reducing the brightness as under exposure would result.
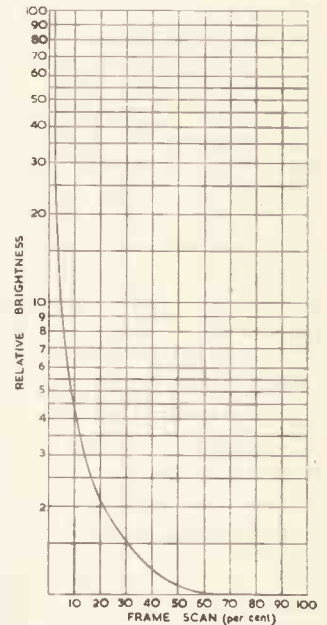

Fig. 4. Tube brightness against frame scan

The relation between average tube brightness and frame scan amplitude is illustrated by the curve of Fig. 4, which has been calculated on the basis that the lines begin to overlap at 50 per cent of normal frame scan. It can be seen that at 5 per cent of normal scan, the brightness is only ten times that occurring in a normal display, although the useful film area lost is only 2·5 per cent. This was found to be a satisfactory compromise.

A most important factor governing the choice of a c.r.t. for continuous recording is the decay characteristic of the afterglow. The effect of an excessive decay time is to destroy definition of the recorded image in the direction of the film movement, i.e. vertically. The common white television phosphor containing a mixture of yellow and blue sulphide is obviously useless for continuous recording. A blue silicate phosphor was chosen in preference to the zinc oxide, as used for flying spot scanning in telecine apparatus, as some afterglow results in greater efficiency and is not objectionable provided it falls below recording

level within one line period. The CaTiSiO$_4$ phosphor used has proved completely satisfactory; no afterglow affects being recorded with normal brightness levels, The requirement is, of course, much more critical with a flying spot scanner, when afterglow effects must be restricted to one horizontal picture element, usually with the aid of electrical compensation.

Apart from afterglow, other important tube qualities are brightness and resistance to screen burning. Although a projection-type tube might be preferable on the first score, a direct-view aluminized type was chosen, partly for greater life and reliability, and partly for convenience and availability of standard accessories. The cathode-ray tube, a type TA10, modified for a maximum anode voltage of 10kV and with a blue silicate phosphor screen, was found to have an adequate light output. A flat tube face is not essential in the absence of appreciable frame scan.

Physical Layout

The recorder rack assembly shown in the photograph, Fig. 5, is a complete two-channel recording unit. The two outer bays each contain, from top to bottom, a display unit, a mirror viewing unit, camera, camera-motor power unit and display e.h.t. unit. The central bay contains the two camera-motor control units, four stabilized h.t. units for the display and control units and a locker whose doors open downward to form a small writing table.

For convenience in rack mounting, the tube axis and camera optical axis are vertical, the tube being mounted face downwards to minimize risk of damage and to prevent accumulation of dust. In order to preserve maximum shadow detail and to exclude external light, a tunnel extends from the tube face to the camera lens. A hinged mirror fitted to the wall of the tunnel nearest the front panel allows a visual examination of the display to be made but the image cannot be recorded while it is being visually examined.

The Display Unit

The display unit has several features worth mentioning for their bearing on the continuous method of recording. Since negligible frame scan is used during recording, no attempt has been made to provide optical means for monitoring the picture on the recording tube, but some attention has been given to the problems of simplifying the operator's task. A three position switch allows titling, recording and setting-up operations by controlling the amount of frame scan and operating interlock circuits; the latter are designed to prevent incorrect operation of the camera, with particular reference to the titling facility.

Titling is carried out, as previously mentioned, by applying 50 per cent frame scan in a direction to oppose the scanning effect of the continuously moving film, and the tube is used somewhat as a flying spot scanner to reproduce titles and other identification marks, which may be written with a chinagraph pencil on a perspex screen placed immediately in front of the tube. For this purpose a slot is provided in the cast aluminium tube support and in the front panel, into which the perspex screen can be inserted Thus when the titling facility is required, half the normal frame scan is applied, a suitable d.c. bias is substituted for the video input to the tube, and microswitches in the camera motor circuit permit operation of the camera only when the titling screen is in position. The synchronizing input is also switched for direct synchronism of the frame scan by the camera, so that external signals are not

required for this operation, and a warning indicator lamp is lit on the front panel.

For normal recording, the necessary small amount of frame scan required to prevent the burning of the tube screen is provided and the microswitches are set to prevent operation until the titling screen is removed from the slot. For setting up purposes, full frame scan is provided and the camera motor power is disconnected.

The brightness and contrast controls are calibrated, since both these adjustments are critical for correct exposure of the film and, hence, for correct tone reproduction. Fortunately, a sensitive and accurate monitor for the tube brightness is readily available in the form of a beam current
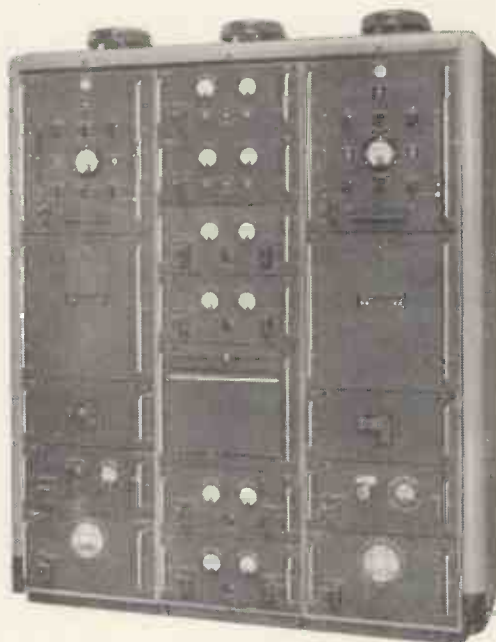

Fig. 5. Recorder rack assembly

meter since the relation between brightness and beam current is almost completely linear.

To ensure that the brightness control remains independent of the contrast and to stabilize the black level, a black level clamp circuit is provided. Fig. 6 shows a simplified circuit diagram in which V_2 and V_{3a} are video amplifiers and V_{3b} a cathode-follower which provides a low output impedance for rapid charging of the d.c. blocking capacitor C_1. The diodes V_4, V_5 form a clamp circuit which connects the c.r.t. grid virtually to earth when the diodes conduct; this occurs on the application of a negative pulse to the grid of the switching valve V_6. The negative pulse is derived from a pulse generator (not shown) which is triggered by pulses differentiated from the back edge of the line synchronizing pulses, so that the diodes conduct during the "back porch" interval of the line period, corresponding to black level in the video waveform, and maintain the charge on C_1 so that the tube grid potential is always zero during this interval. The contrast control is set to zero for adjustment of the brightness control VR_1 to give, say, $0.5\mu A$ beam current. The contrast is then set normally without the necessity for further adjustment to brightness; it is maintained at the black level by the clamp circuit.

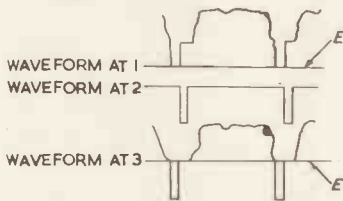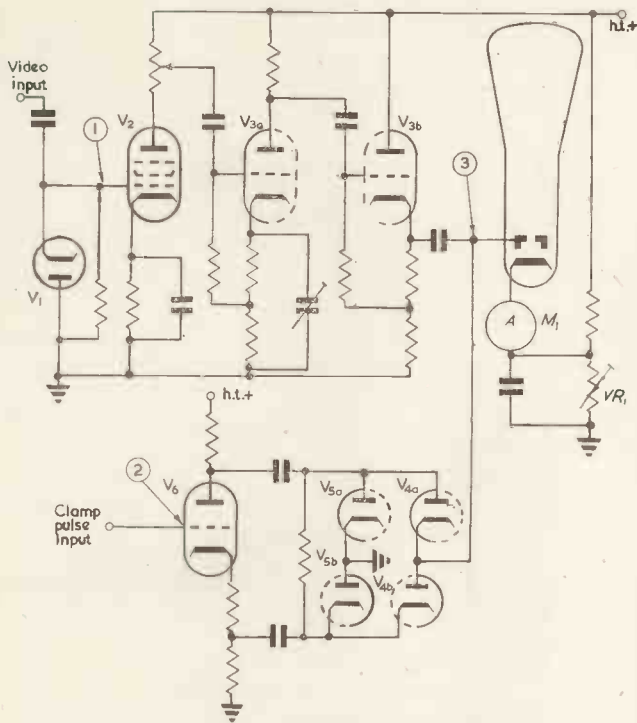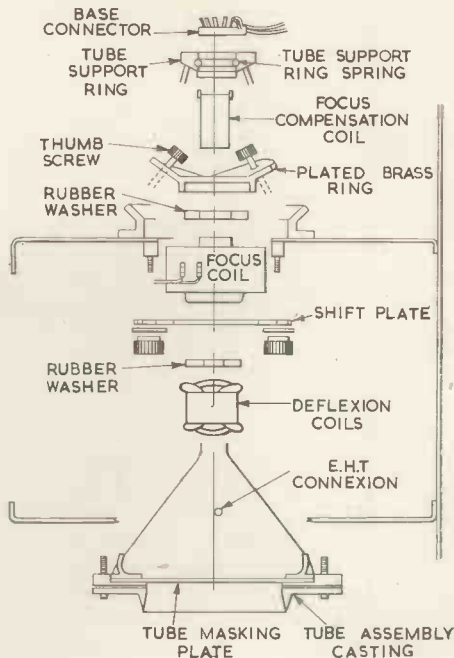For monitoring the peak value of the brightness, a switch

Fig. 6. Video amplifier and black level clamp

Fig. 7. Exploded assembly of c.r.t. components in camera display

is provided which converts the meter M_1 to a peak volt-meter to measure the voltage developed across a load resistor in the cathode circuit of the c.r.t.

The tube is an E.M.I. TA10 tetrode, modified in that it has a blue silicate phosphor screen which is backed with an aluminized coating. An e.h.t. potential of 9kV is used, giving a screen brightness of 6 foot-lamberts at $100\mu A$ beam current. Current for the focusing electromagnet is supplied by a tetrode valve which is fed with waveforms of line and frame frequency; these waveforms are parabolic to compensate for deflexion defocusing. A small sub-sidiary focus coil having low self capacitance is used in series with the main coil for the line focus compensation. An exploded view of the c.r.t. components is given in Fig. 7.

THE CAMERA

A general view of the camera unit is given in the photo-graph, Fig. 8; Fig. 9 shows a close-up of the camera light box and the path followed by the film from the feed maga-zine through the light box to the take-up magazine.

Before giving a detailed description of the camera mechanism, it may be as well to consider the design prob-lem posed by the simultaneous requirement of continuous movement recording and compatibility with intermittent projection on a standard projector; this is rather more diffi-cult that that of sound-on-film recording. In sound record-ing, comparatively large phase errors are tolerable pro-vided the rate of phase change is restricted, consequently large compliances may be employed to depress the cut-off frequency of the low-pass mechanical filter controlling the film speed. In picture recording, phase errors result in faulty framing when projected, and phase modulation greater than 0.1 per cent at frequencies as low as 1 or 2c/s shows up as a concertina effect on the vertical dimen-sions of the picture which is more objectionable than the random errors normally present in intermittent projection. Assuming a perfect projector, such errors may amount to ±0.16 per cent due to manufacturing tolerances on the film sprocket holes alone.

The basic elements of a typical sound recorder filter system[3] are shown in Fig. 10 together with a simple elec-trical analogy. The sprockets drive the film and maintain a constant loop length in the filter system, and are repre-sented by the generator E; the jockey arms and spring con-trol the tension in the loop and provide the compliance L in the filter system. The inertia drum is driven by the film and is rigidly coupled to a flywheel; this provides the inertia represented by C while the damping is provided by the dashpot which is represented by R. The velocity of the film at the drum is represented by E_o and the system exhibits the characteristics of a simple low-pass filter.

This basic scheme has been used, with suitable amend-ments, in the camera light box and the completed filter is shown in Fig. 9. In order to limit phase errors, the length of film between the sprockets has been reduced to the minimum necessary for adequate filtering of sprocket flutter. The spring-loaded jockey arms supply most of the compliance and provide the tension necessary for a fric-tion drive on the inertia drum, which is coupled by a common shaft to a flywheel in the gear box. The film is exposed on this drum. The tension in the film loop on either side of the drum is controlled by ratchets which secure one end of the coiled springs on the jockey arms. The parameters of the mechanical filter are not critical, and it was found that incidental friction provided adequate damping. The flywheel dimensions were calculated to pro-
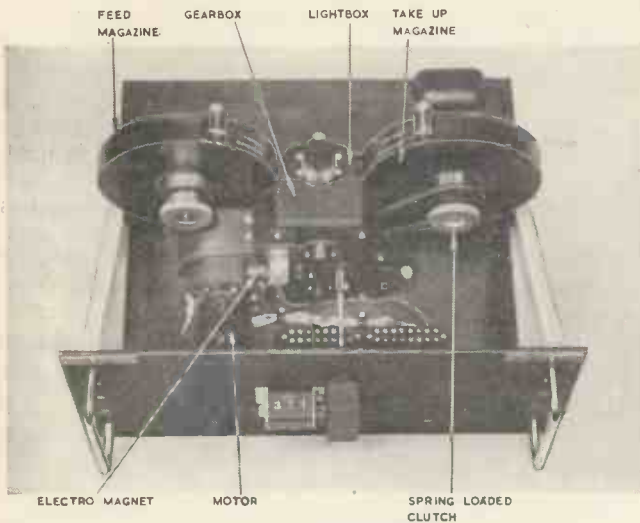
Fig. 8. Camera unit

Labels: FEED MAGAZINE, GEARBOX, LIGHTBOX, TAKE UP MAGAZINE, ELECTRO MAGNET, MOTOR, SPRING LOADED CLUTCH

vide the maximum inertia compatible with acceleration to full speed in two or three seconds.

Fig. 9 shows the interior of the light box and magazines, and the path of the film is illustrated. The film leaves the feed magazine via a labyrinth light trap of three idling rollers and passes round the hold-back sprocket, the inertia drum and take-up sprocket; to facilitate threading the film, the pad rollers and jockey arms can be held in a retracted position by means of ball catches. The sprockets are to SMPTE standards and have teeth on one end only, thus single or double perforated film can be used. The sprocket for the feed magazine is designed as a hold-back sprocket and that for the take-up magazine as a drive sprocket; this technique is necessary to achieve perfect engagement between the teeth and the film holes and minimum flutter.

The motor, which is mounted on the outside of the gear box is a d.c. motor generator (Velodyne 88X), providing a maximum torque of 2·1oz. in. The speed, which is controlled by a field winding rated at 25mA d.c. maximum, may be critically adjusted over the range 20 to 9 000rev/min by using the generator output voltage, which is proportional to speed, in a negative feed-back loop whose
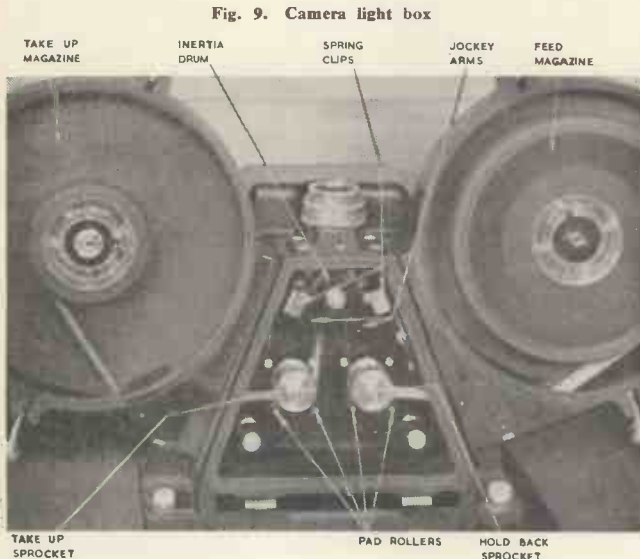
Fig. 9. Camera light box

Labels: TAKE UP MAGAZINE, INERTIA DRUM, SPRING CLIPS, JOCKEY ARMS, FEED MAGAZINE, TAKE UP SPROCKET, PAD ROLLERS, HOLD BACK SPROCKET

amplifier feeds the field windings. The precise phase of the film drive with relation to the scan on the c.r.t. is controlled by means of a mild steel arm rotating on an intershaft geared to the sprocket shaft with an 8:1 ratio, since the sprockets have eight teeth. The arm passes close to a gap in a electromagnet every time a sprocket tooth passes through a certain phase and thus produces a pulse which is fed to a phase discriminator in the motor control unit. The phase is maintained constant with reference to that of the television frame pulse. The details of this operation are given in the next section.

CAMERA MOTOR CONTROL

The camera drive and control gear is designed to achieve economy of weight, space and power consumption and the velodyne motor is most appropriate for this purpose; the control unit, in fact, weighs 30lb, is $8\frac{3}{4}$in deep and consumes less than 100W.
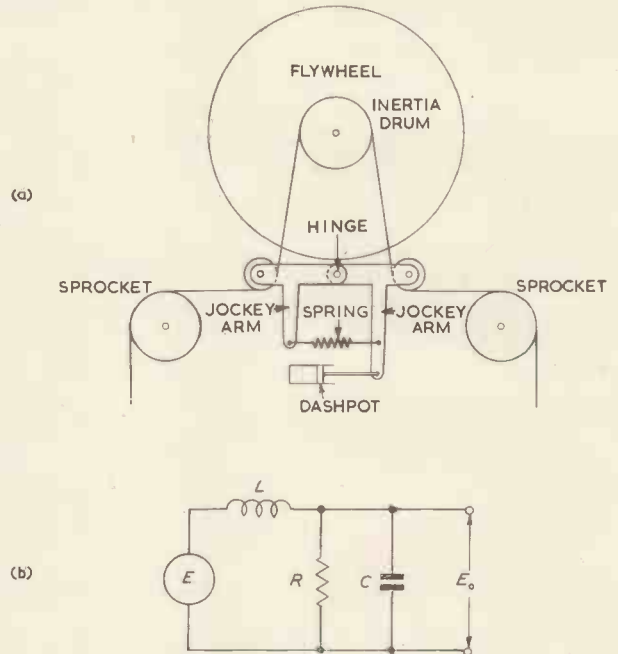

Fig. 10(a). Mechanical filter. (b) Electrical analogy

The basic circuit of the control unit is shown in Fig. 11. The velodyne 88X, consists of a d.c. motor M and a d.c. generator G, coupled together on a common shaft[4]. The power required to drive the motor is supplied to its armature winding from a 24V d.c. supply via the lamp LP_1; S_1 is the motor on-off switch. The motor field windings, which are used to control the speed of the motor, take a maximum current of the order of 20mA and are connected between the anodes of the cathode-coupled control valves V_4, V_5. Since the motor is required to rotate in one direction only, the anode loads R_1, R_2 are adjusted for an initial field current of 9 to 10mA when the motor is at rest and the grids of V_4, V_5 are at ground potential, the potential of V_5 grid being limited by the diode V_8.

The generator, whose field current is supplied from the h.t. line, produces a d.c. voltage proportional to the generator field current and the shaft speed. As the motor accelerates, the voltage generated increases and, when it exceeds the "delay" voltage set by VR_1, it is applied to the control valve V_8 so as to reduce the motor field current. A negative feedback loop is thus formed, and the motor speed is
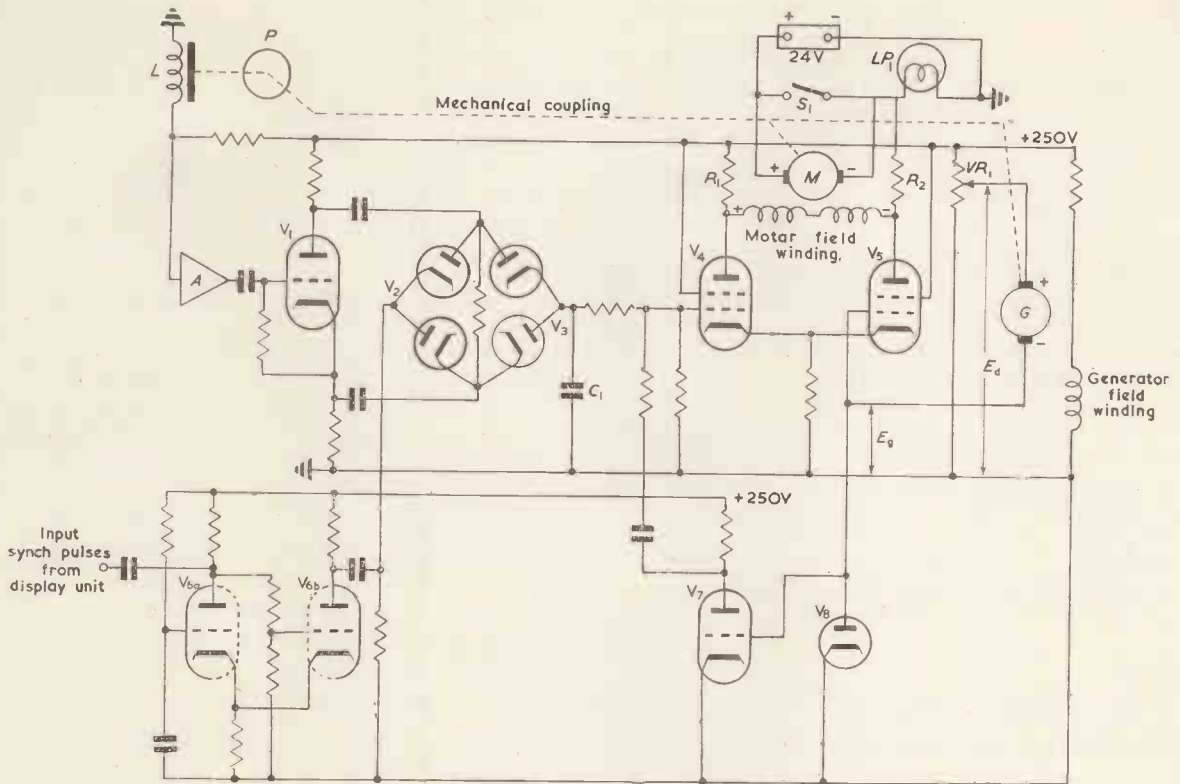
Fig. 11. Simplified camera motor control circuits

stabilized to give a generator output voltage which exceeds the "delay" voltage by a fraction of the grid base of V_s as defined by the conditions required for equilibrium.

The required grid voltage is:

$$E_g = \frac{E_d}{1 + Af}$$

where E_d is the delay voltage, A is the function relating motor speed to E_g and f is a constant relating generator output to speed. Substituting the speed v for $A.E_g$, and v/A for E_g, in the above equation:

$$v = E_d \frac{A}{1 + Af}$$

and, if $Af \gg 1$,

$$v = E_d/f$$

i.e. the motor speed is controlled solely by the delay voltage setting

The motor generator shaft is geared to the mild steel arm which rotates past the air-gap in the flux path of coil L (the electromagnet of Fig. 8). The d.c. flux is modulated by the variation in the reluctance of the magnetic circuit when the arm passes the gap, so producing a voltage pulse across the coil which is fed via the amplifier A and phase splitter V_1 to close the four-diode switch V_2, V_3. The switch also receives a symmetrical square wave from V_{6b} which is triggered by the frame synchronizing pulse from the display unit and, when the switch is closed by the pulse from L, C_1 is charged to the instantaneous value of the potential at the output of V_{6b}. When the recurrence of the switching pulse is equal to, or an integral submultiple of, the frame frequency, the potential at C_1 will depend only on the relative phases of the pulse and the waveform.

The circuit thus forms a phase discriminator, the output of which is fed to the control valves V_4 and V_5.

The combination of motor, pulse generator, phase discriminator and control valve, forms a phase-sensitive feedback loop. When the pulse coincides with the negative-going transition of the square-wave, the feedback is negative and the circuit is stable. External forces tending to displace the phase of the motor produce a voltage at C_1, proportional to the phase error, which counteracts this tendency. When the motor is correctly phased, there is no potential across C_1.

When the pulse coincides with the positive going transition, the feedback is positive and the motor phase is unstable. It may move in either direction, and a discriminator output is then obtained which brings the phase into synchronism with the negative-going transition, and hence with the frame synchronizing pulses.

The inertia of the motor produces a time lag in the transient response which will result in hunting if the loop gain is sufficient. As the loop gain is necessarily high for good phase sensitivity, it is necessary to damp the transient response by adding, to the phase control voltage, a voltage proportional to acceleration. This voltage is derived by differentiation of the velocity voltage from the generator G, after amplification by V_7, and is phased to oppose rapid changes of motor speed. This forms another negative feedback loop which opposes changes in motor speed and is desirable on this account alone in a continuous film drive, quite apart from its effect on the phase lock. The phase discriminator does not operate continuously, but samples the phase at frame synchronizing intervals; the velocity of the motor between phase sampling points is controlled

mainly by the inertia of the motor and by acceleration feedback.

The phase control circuit does not operate until the motor reaches the correct speed, and to avoid spurious outputs from the phase discriminator while starting, the switching pulse is gated by cathode bias of the first valve in the pulse amplifier A. The bias is applied by a cathode-follower which is d.c. coupled to the positive voltage from VR_1 via the generator armature winding G. When the motor reaches the correct speed, the negative output from the generator cuts off the cathode-follower and removes the bias from the pulse amplifier valve. The pulse amplifier includes shaping and limiting circuits, so that the pulse fed to the phase-splitter valve V_1 is of constant amplitude and duration, regardless of motor speed.

The voltage output from the discriminator is proportional to the phase error, and is monitored by a valve voltmeter for the convenience of the operator; full scale deflexion representing a phase error of 0·8msec. The voltage output of the generator is also monitored to indicate the motor speed.

An advantage of this form of camera drive is its versatility. The camera may be adjusted to operate at any speed up to 18in per second, with or without synchronism.

Performance

The time required for the camera to reach full speed from a stationary condition and to become synchronized is between two and three seconds. Should the television signal fail, the motor coasts at normal speed, since the discriminator output is zero when synchronized with zero phase error or in the absence of signal. The normal speed is maintained without synchronization by the d.c. negative velocity feedback, while the a.c. acceleration feedback prevents changes in speed due to random friction, until the synchronizing signal is restored. The camera then returns to phase synchronizm in a fraction of a second. The system has proved exceedingly stable; over periods of several months it has been unnecessary to adjust the synchronizing controls.

The resolution of the recording system is limited by that of the film itself. The photographic aspect is conventional, except when using comparatively slow, high-definition film stock. In the latter case, it is necessary to record at low contrast, with the black level set to one-third peak brightness, and peak white set to normal peak brightness. The negative is then developed to a high gamma (2·5 to 2.·7), using a positive bath. In this way, a normal range of density is obtained on a negative which must otherwise be under-exposed, and a tolerable reproduction of tone values is obtained.

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Crystal Palace Television Station

The Television Advisory Committee has informed the Postmaster-General that the best technical solution of the problem of siting television stations in the London area is a single tower to carry the aerials for all the television services of the BBC and ITA. The BBC has accordingly agreed to make provision for the ITA's requirements on the tower now in course of erection by the BBC at its new television station at Crystal Palace. The BBC's offer has been welcomed by the General Post Office, which is responsible for approving the sites of all BBC and ITA stations, and by the ITA itself. The ITA is at present negotiating with the L.C.C. to acquire land near the base of the tower for the erection of a building to house a new television station which will replace the temporary station now in service at Croydon.

The new arrangements will involve halving the size of the BBC's Band I aerial. The top 250ft of the tower will have to be redesigned and this will delay its completion by 18 months. It will not therefore be possible for the new tower to be brought into service early next year as had been planned. However, in order that the new high-power transmitter which is being installed at Crystal Palace may be brought into service as soon as possible, the BBC will erect a temporary mast and aerial, 250ft high. This temporary mast and aerial system will be capable of a radiated power of 60kW which the BBC had hoped to be able to radiate initially from Crystal Palace.

The Corporation has decided to make this arrangement in order to achieve co-siting of the BBC and ITA stations in London, which has been recommended by the Television Advisory Committee as a means of giving the best reception to viewers of both services. When the new tower and aerial system in its new form come into service about May 1957, the BBC will be able to raise the power of its transmission to 125kW. Later on a further increase to nearly 500kW, the maximum permitted by international regulations, is planned.

The ITA hopes to begin transmitting from the new tower at the Crystal Palace during 1957.

The BBC have awarded further contracts to Marconi's Wireless Telegraph Co. Ltd. for work on the Crystal Palace television station.

These call for the erection of a 250ft mast, together with an aerial and feeder system, and for the design, construction, and installation of a special catwalk.

This latter is rendered necessary because, for technical reasons, the mast has had to be built in the middle of a disused reservoir; the catwalk will carry the feeders across to the base of the mast.

Due to the unusual nature of the siting, the work involved represented a radical departure from routine. First, the water had to be drained and a number of carp transferred to a pond in the Crystal Palace grounds. This done, mud to a depth of several feet was removed from an area to enable the mast foundations to be laid.

Although a rumour—subsequently disproved—of the presence of an unexploded German bomb caused a certain delay in progress, the foundations have gone in, and work on the mast is virtually complete.

For the purpose, use is being made of the Marconi mast which formerly carried the temporary aerial at Northern Ireland's television station. This aerial was recently replaced by a permanent structure, and consequently became redundant. It was dismantled by Marconi's in under three weeks.

The re-erection of the mast at Crystal Palace is being carried out for the BBC and Marconi's by British Insulated Callender's Construction Co. Ltd. It will be in use there until the permanent 640ft tower is completed.

The two pairs of Marconi vision and sound transmitters for the Crystal Palace station are already on site, and in an advanced stage of installation.

The Electron Gun of the Cathode-ray Tube
Tetrode or Triode?

By J. A. Darbyshire*, M.Sc., Ph.D., F.Inst.P., A.M.I.E.E.

An attempt is made to assess the relative merits of the tetrode and triode types of electron guns as used for cathode-ray tubes. The discussion covers matters relating to spot size, beam angle, cathode loading, and other relevant features.

It will be seen that, for certain applications, the triode gun has some characteristics which are more desirable than those of the tetrode. In most of the normal television applications of cathode-ray tubes, however, the tetrode type of gun would be preferred.

IT is intended here to review some of the main features of the tetrode gun and to compare them with those of the triode gun. In this way it is possible to emphasize the fundamental differences in the behaviour of these two guns and to indicate the advantages which the tetrode can claim when it is compared with the triode.

The Triode Gun

The triode gun is shown diagrammatically in Fig. 1.

Electrons leave the cathode O and pass through a crossover region at C shortly after passing through L_1.

This crossover point C is then focused on the luminescent screen by means of L_3 to form a spot S.

The manner in which the crossover is formed at the

Fig. 1. The triode gun

point C is very complicated and is not thoroughly understood at the present time. The following description is in accordance with the principles of geometrical optics and electron optics. The electrons leaving the cathode pass into a lens which can be regarded as represented by a surface convex towards the cathode and of very high refractive index. In such a case all electrons from the cathode pass through what is effectively a single point which is situated at the effective centre of curvature of the refracting surface and is also the focal point of the lens for parallel light. This image point is called the crossover and it is usually much smaller in diameter than the effective diameter of the cathode, because it is closer to the effective position of this first lens L_1 than the cathode itself. The crossover diameter is usually found to be approximately one-tenth of that of the emitting surface of the cathode.

The above explanation as to the formation of the crossover is usually quite sufficient to form the basis of any discussion on the design of cathode-ray tubes. It is certainly quite sufficient for all the discussions in this article. It is desirable, however, to indicate briefly a further elaboration of the theory of the formation of the crossover which is often believed to be a more correct description of what actually takes place in this complicated immersion system.

The crossover point formed in the manner just indicated

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is probably developed so that it appears just inside another refracting surface which is itself divergent[1]. This means that the rays which leave this second divergent lens appear to come from a virtual image of the crossover which is situated some distance behind the cathode itself.

This means that the focusing lens receives its rays from a virtual image of the crossover situated a good deal further away than the position at which the original crossover would have been formed if it had not been for the presence of the divergent component in the complete immersion lens.

The Tetrode Gun

The tetrode gun is shown diagrammatically in Fig. 2. Electrons leave the cathode O and pass through a cross-

Fig. 2. The tetrode gun

over region at C. The lens L_2 is of considerably less power than the lens L_3 of the triode. This lens L_2 collects the beam after passing through the crossover and serves to make the beam emerging from the crossover less divergent than in the case of the triode. The beam is converged by the final lens L_3 which serves to form an image of the crossover on the luminescent screen. This explanation of the optical system of the tetrode is based on the simple theory of the formation of a real crossover just in front of lens L_1 and which itself forms a real object for the remainder of the optical system which involves L_2 and L_3.

The more complicated theory of the formation of the crossover as outlined in the case of the triode could also be used in giving a full description of the mode of operation of the tetrode type of gun.

The fundamental feature of the tetrode type of gun is that it has a smaller beam width than the triode in the region of the scan coils. This comes about because the beam diverging from the crossover is focused to some extent by the $L_1 L_2$ lens and therefore the beam is fairly narrow when it passes through the final lens L_3. This final lens is nearly always a magnetic lens in the case of both triode and tetrode type of gun in cases where the cathode-ray tube has been designed for television purposes.

If it is desired to obtain a narrow beam in the triode it is necessary to move the lens L_3 to a position quite close to the modulator. It is not possible to construct

a magnetic lens of sufficient power and whose action could be sufficiently sharply localized in this region so as to simulate the performance of the normal tetrode gun. It is evident that it is better to arrange for an electrostatic lens to be put in position close to the crossover in such a manner that the lens gives rise to a considerable degree of convergence of the rays from the crossover and directs them towards the main focusing lens L_3.

Magnification

The overall magnification is given by:
$$M = \theta_\text{c}/\theta_\text{s}$$

Where θ_c is the semi-angle of divergence from the crossover and θ_s is the semi-angle of convergence on to the spot on the screen.

This expression for M holds good, no matter whether the result has been obtained by means of one or by means of more than one lens.

The formula $M = (\theta_\text{c}/\theta_\text{s})$ does not take into account the difference in refractive index in the image and object spaces.

If n_c represents the refractive index near to the crossover and n_s represents the refractive index at the screen, the formula for M becomes:
$$M = (\theta_\text{c}/\theta_\text{s}) \cdot (n_\text{c}/n_\text{s}) \quad \dots\dots\dots\dots (1)$$

This leads directly to the usual form of expression
$$\text{Spot size} = \text{crossover} \times M \times \sqrt{(V_\text{c}'/V_\text{s}')}$$

where V_c' is the potential at the crossover and V_s' is the potential at the screen.

The system of lenses in the tetrode means that it is possible to start off with a certain value of θ_c and finish up with a smaller value of θ_s than in the case of the triode. The ratio $\theta_\text{c}/\theta_\text{s}$ is always greater in the case of the tetrode than the triode, and the magnification of the spot in the tetrode is always greater than in the case of the triode. Thus the smaller beam width is obtained at the direct expense of a larger spot size which is one of the disadvantages of the tetrode type of gun.

Advantages of the Tetrode

In the first place let us consider some of the main features of the triode type of gun. The electrons leave the cathode and pass through a crossover and then diverge at an appreciable angle from the crossover. In the case of the triode this angle is rather large, and therefore the beam is likely to be fairly wide in the region of the focusing coil and also fairly wide in the region of the deflecting coils.

In order to keep the beam width as small as possible there is a tendency to design the triode in such a manner that the cut-off is high (long grid base) and this means, in turn, that the peak cathode loading (mA/cm²) will also be high. If the diameter of the grid aperture is kept constant at d_m then the peak cathode loading varies with cut-off V_c in accordance with the following relationship.
$$I_\text{c} = k_1 V_\text{c}^{6/7} \quad \dots\dots\dots\dots\dots\dots (2)$$

therefore we can say that the peak cathode loading is virtually proportional to the cut-off.

It is also desirable to keep the diameter of the grid aperture very small because the beam angle 2α is related to d_m by the following expression[2]:
$$\sin \alpha = \frac{0 \cdot 27 V_\text{d}\, d_\text{m}}{a^{3/4}\, V_\text{c}} \quad \dots\dots\dots\dots (3)$$

In this equation a represents the anode-grid distance and V_d the drive.

This can also be written as:
$$\sin \alpha = \frac{0 \cdot 27\, d_\text{m}}{a^{3/4}\, V_\text{c}^{3/7}} \cdot (I_\text{b}^2/9)^{1/7} \quad \dots\dots\dots (4)$$

where I_b is the beam current.

The cathode loading will again be increased as d_m is reduced. It can be taken that anything that reduces the semi-angle α will also increase the cathode loading. If the beam angle is reduced by designing the tube so that it has a long cut-off then the modulation characteristic will be somewhat "degenerate" (i.e. poor slope). On the other hand, if the beam angle is reduced by designing the tube so that the grid aperture (d_m) is very small then the associated grid-cathode distance c will also have to be very small and this means that the assembly is difficult to construct. The final grid to cathode distance which appears after the tube has settled down in operation is likely to be slightly different to that which was given to the electron gun while it was on the assembly bench.

The cathode coating usually shrinks and its thickness is reduced by approximately 20 per cent during activation and the cathode tube would probably expand during heating. Also, the surface of the modulator might move slightly towards or away from the cathode.

These effects would be troublesome if attempts were to be made to design cathode-ray electron gun assemblies which have a very small value of c.

Modulator Cut-Off

According to the formula given by Moss[3] the cut-off for the triode type of gun is given by the formula (final anode voltage V_2 assumed to be constant).
$$V_\text{c} = K_2 d_\text{m}^3/bca \quad \dots\dots\dots\dots\dots (5)$$

where the symbols have the significance as already defined and b represents the thickness of the modulator material. If the final anode voltage V_2 is variable then the cut-off varies linearly with the final anode voltage V_2.

That is:
$$V_\text{c} = K_3 V_2 \quad \dots\dots\dots\dots\dots\dots (6)$$

In the case of the tetrode, however, we have another electrode, known as the first anode, situated between the modulator and A_2 and the field from A_2 makes only a very small contribution to the resultant field at the surface of the cathode. The potential gradient at the surface of the cathode is therefore determined almost entirely by the composite effect of the modulator and the first anode. The cut-off V_c of the tetrode tube is therefore determined by the potential on A_1 and almost independent of the potential on A_2. This is one of the most important advantages of the tetrode tube as compared with the triode because it means that one design of electron gun can be operated satisfactorily over a fairly wide range of values of final anode potential V_2. The cut-off voltage can be kept reasonably constant at any required value merely by suitable adjustment of the potential of the first anode. In practice there are limitations to this universal feature of the tetrode and it is not possible to design a tetrode which is equally efficient when it is operating at values of V_2 which differ very widely from that for which it was originally designed.

Spot Size

The triode type of gun always gives a smaller fluorescent spot when viewed in the head-on direction and this is due

to the following factors:

(1) The grid diameter is usually small, this leads to a small size of crossover as explained later on.

(2) The magnification ratio is less than that of the tetrode. The reason for this is that the tetrode has been designed so that it can accept a beam of a certain angle of divergence from the crossover and will then deliver a beam which has a smaller angle of convergence to the spot on the screen than would have been delivered under similar circumstances by a triode type of gun. The smaller magnification ratio of the triode leads directly, of course, to a smaller final spot on the fluorescent screen.

(3) The ratio of drive to cut-off (that is V_d/V_c) is usually less for the triode than in the case of the tetrode. The fraction V_d/V_c determines the area of the emitting surface of the cathode which is called into action and if this is small the crossover size will tend to be small. The size of the crossover will be small because of the smaller degree of spherical aberration and also, more directly, because the crossover size depends to some extent on the ratio V_d/V_c.

(4) The semi-angle of convergence θ_s into the spot on the screen is greater in the case of the triode and this also leads to a smaller spot in accordance with the Langmuir relationship[4],

$$\sigma_s = \sigma_c[(V_s'e/kT) + 1] \sin^2\theta_s \quad \ldots\ldots\ldots \quad (7)$$

where σ_s = maximum current density at the screen

σ_c = maximum current density at the crossover

V_s' = final voltage at the screen

k = Boltzmann's constant

θ_s = semi-angle of convergence into the spot at the screen

T = cathode temperature in °K

This formula is quite independent of space charge considerations. It is merely the electron optical expression of normal relationships in ordinary geometrical optics and it is the consequence of the application of the following formula taken from ordinary light optics,

$$y_o/y_i = n_iu/n_ov \quad \ldots\ldots\ldots\ldots \quad (8)$$
$$B_o/B_i = (n_o/n_i)^2 \quad \ldots\ldots\ldots\ldots\ldots \quad (9)$$

where y_o = size of object

y_i = size of image

n_o = refractive index in object space

n_i = refractive index in image space

u = distance of object from lens

v = distance of image from lens

and

B_o = brightness of object

B_i = brightness of image.

The Langmuir relationship is really another form of expression of the magnification principle as outlined by formula (1).

The requirements that θ_s should be small are often suggested as a desirable feature in connexion with any kind of electron gun and would appear, at first sight, to be in confliction with the Langmuir relationship. In a sense there is a confliction of condition because θ_s is required to be small only because of spherical aberration in the focusing lens and difficulties in providing a deflecting field which will handle a beam of large diameter in the scan coils.

Summary

For the reasons given above it will be evident that the triode always gives a smaller spot size, and therefore better resolution, at the centre of the screen than the tetrode, but the greater width of the beam in the triode tends to give rise to deflexion defocusing trouble much more readily than in the case of the tetrode.

The size of the crossover varies inversely as the potential at the point in space where the crossover has been formed. It has been suggested that the potential at the crossover is greater in the case of the tetrode than in the case of the triode. There does not appear to be any evidence to indicate that the potential at the crossover is statistically any different in the tetrode as compared with the triode. The spot size of the triode is smaller than that of the tetrode because the magnification ratio is less than that of the tetrode.

If one considers the range of normal values of peak beam current as used in direct viewing television tubes, the greater beam width of the triode does not give rise to a confusion of spot size in the central region of the screen especially when a solenoid type of focusing lens is used, because in nearly every case, the solenoid is capable of dealing with the greater beam width of the triode just as easily as that of the smaller beam width of the tetrode.

If, however, the focusing is carried out by means of a permanent magnet type of lens, the beam angle is of considerably greater importance because permanent magnet lenses cannot deal with wide electron beams as well as the solenoid type of lens.

In one particular experiment it was found that the solenoid could hold focus on both triode and tetrode tubes as the drive was increased from cut-off point at 60V until the total drive was 50V in each case. Thus each tube had a cut-off value of 60V and could be driven within 10V of zero bias before the spot size became too confused for television reception (at a degree of resolution of 2·5Mc/s).

When permanent magnet focusing was used instead of the solenoid the results were very much different. In this case, the tetrode could still be given a drive of 50V whereas the triode could only be driven to the extent of 30V before the spot (as viewed in the head-on direction) became too confused to be capable of giving a television picture at the reasonable degree of resolution of 2·5Mc/s. It should be emphasized that the tests just described are concerned only with spherical aberration of solenoid and permanent magnet focusing systems on tetrode and triode tubes in the undeflected head on direction only. Defocusing due to deflexion will be considered in the next paragraph.

Deflexion Defocusing

If the degree of focus of the spot deteriorates as the spot is deflected towards the edge of the screen, the spot is said to be suffering from deflexion defocusing.

The principal causes of deflexion defocusing are:—

(1) Non-uniform transverse field in the region of the scan coils. If the electron beam was very narrow this would give rise to distortion of the pattern (pin cushion effect or barrel distortion) but not deflexion defocusing. If the beam has appreciable width then this non-uniform field can cause different sections of the beam to be deflected to different degrees and so give rise to deflexion defocusing.

(2) Axial component of field in the scan coils.

This can contribute to deflexion defocusing of the beam to a certain extent, but this is not likely to be of any great importance with well designed scan coils.

(3) Interaction between the scanning field and the focusing field.

In certain cases the field from the scan coils can penetrate into the region of the focusing solenoid (or permanent magnet) and give rise to a variation of focus of the beam. This error in focusing condition will be a maximum when the field from the scan coils is a maximum and therefore the beam will appear to be suffering from deflexion defocusing.

(4) Beam too wide in region of the scan coils.

This is by far the most frequent cause of deflexion defocusing. The smaller angle of the beam from the tetrode makes deflexion defocusing much easier to avoid. The beam width might be due to poor design of the gun or wrong position of the focusing coil or low emission.

(5) Spherical aberration.

This is not in itself a cause of deflexion defocusing, but if the spot is confused owing to spherical aberration as viewed at the centre of the screen it will tend to become still more confused when deflected. In this way a badly focused spot owing to spherical aberration will appear to be giving rise also to deflexion defocusing.

(6) Scattering on electrode system.

This type of deflexion defocusing occurs only on electrostatically focused guns. It comes about when a beam of large dimensions is passing too close to some portion of the electrode system and is being scattered in an undesirable manner. If this takes place it is very probable that secondary electrons might also be emitted which would give rise to a diffuse tail to the spot. This effect will reveal itself as a function of the deflecting field because the beam in the head-on direction is probably just missing the obstruction but impinges on it during the period of maximum deflecting field intensity. This takes place because the field from the deflecting coils is capable of penetrating into certain portions of the electrode assembly.

The essential advantage of the tetrode is that the narrower beam makes deflexion defocusing easier to avoid. To some extent the apparently greater superiority of the tetrode with regard to deflexion defocusing is an optical delusion. The triode gives a finer spot in the central region of the screen and a rather more diffuse spot at the outer edges of the raster, as compared with the tetrode. This gives rise to the impression that the triode is much worse from the point of view of deflexion defocusing than it really is when considered on purely technical grounds. It is quite safe to say that the tetrode has earned a reputation for comparative freedom from deflexion defocusing to a large extent because it gives rise to a considerably larger spot at the centre of the screen in any case. Therefore the contrast between the spot size when deflected as compared with that at the centre is not as marked as in the case of the triode.

All the above remarks must be taken to apply to the average typical designs of commercial types of triode and tetrode tubes. It could be said that it is possible to reduce the grid aperture of the tetrode and so reduce the crossover size and therefore improve the focal spot as seen in the undeflected direction. This would increase the cathode loading and thus remove one of the main advantages of the tetrode type of gun.

Crossover Size

In earlier papers[5] on cathode-ray tube design it has been said that the size of the crossover is very largely dependent on the following factors:—

(1) The size of the crossover is inversely proportional to the square root of V_o' where V_o' is the potential at the crossover.

(2) The size of the crossover varies directly as $a^{3/2}$ where a is the anode-modulator distance.

(3) The size of the crossover is directly proportional to $\sqrt{E_0}$ where E_0 is the energy of emission of the electrons from the cathode in volts.

Several other factors might have an influence on the size of the crossover. The more important of these secondary factors are:—

(4) Spherical aberration in the crossover-forming lens.

(5) Space charge effects near the cathode.

(6) Diameter of the grid aperture.

(7) Modulator potential.

It is possible that space charge could modify the $A_1 A_2$ lens and therefore have some effect upon the size of the crossover. It is difficult to obtain any direct evidence as to what extent this takes place, but it would appear that any material disturbance of the field set up by the crossover-forming lens because of the electron space charge is negligible in the case of electron beams of the intensity used in a normal cathode-ray tube.

It is sometimes said that the superior performance of the tetrode is due to the fact that the high field gradient at the crossover reduces the space charge and therefore the crossover is more sharply defined. There does not appear to be any evidence to support such a claim because the spot size is always greater in the case of the tetrode as compared with the triode. The increase of spot size does not imply that the crossover size is greater in the case of the tetrode, because the greater spot size comes about by virtue of the fact that the magnification ratio is greater in the tetrode. The spot size appears to be increased by the amount that would have been expected if the crossover size were to have remained substantially the same in each case. It appears therefore, that for all normal purposes the crossover size in the case of the tetrode and the triode can be considered to be the same.

Crossover Size as a Function of Modulator Drive

It is usually said that the size of the crossover is independent of the drive if space charge and aberrations are neglected.

The formula which determines the position of any point on the crossover (in a radial direction) corresponding to any point of emission from the cathode is given by[5]:

$$y_o = y_0 \sqrt{\left(\frac{E_0}{E_0 + V_c'} \right)} \cdot \frac{\sin \theta_0}{\sin \theta_0} \dots \dots (10)$$

y_o = the point on the crossover.

y_0 = the corresponding point on the cathode.

E_0 = energy of emission of the electrons from the cathode in volts.

V_c' = potential at the crossover in volts.

θ_c = semi-angle of convergence to the point on the crossover.

θ_o = angle of emission of electrons of energy E_o to the normal to the cathode surface.

Now as the drive V_d is increased y_o will increase and it can be shown[6] that formula (10) leads to:

$$y_c = K_4 / \sqrt{V_2} \cdot (I_b / i_{cm})^{\frac{1}{2}} \quad \ldots \ldots \ldots (11)$$

where K_4 is a constant

I_b total beam current

i_{cm} mean cathode loading

V_2 final anode potential.

The formula (11) can be derived from (10) provided that the variation of θ_o with drive is given full consideration.

If, to a first approximation it were to be assumed that θ_c remains small as the drive is increased, then it would be found that y_c is independent of drive and this would lead to the erroneous conclusion that the crossover size remains constant as the drive is increased.

CROSSOVER SIZE AS A FUNCTION OF ANODE POTENTIAL

Equation (10) indicates that y_c varies as $K_5 / \sqrt{V_2}$, where V_2 is the final anode potential and K_5 is a constant. This follows directly from equation (10) if it is assumed that the potential at the crossover V_o' is proportional to the final anode potential V_2 and it is almost certain that such a relationship should exist.

This formula also indicates that the limit of the crossover radius for electrons of any one energy value E_o is formed by taking $\theta_o = 90$ and this gives the expression:

$$y_c = y_o \sqrt{\left(\frac{E_o}{E_o + V_o'}\right) \cdot \frac{1}{\sin \theta_c}} \quad \ldots \ldots \ldots (12)$$

as representing the extreme radius of the crossover for electrons of energy of emission corresponding to E_o. This indicates that y_o is proportional to $\sqrt{E_o}$ and if E_o were zero, the crossover would be represented by a single point on the axis of beam.

CROSSOVER SIZE AS A FUNCTION OF THE GRID DIAMETER

Consideration of the expression (10) for y_c leads to the conclusion that the cross over diameter will increase if the diameter of the grid aperture d_m is increased. This means that if we take two tubes which have the same cut-off and if we drive them to the same extent then we shall find the crossover size is greater in the case of the tube with the large value of grid aperture d_m.

MOVEMENT OF CROSSOVER

As the drive increases the position of the crossover moves away from the cathode towards the final anode. The actual size of the crossover is usually considered to be approximately one-tenth of the diameter of the actual emitting surface of the cathode. The crossover may be situated anywhere between the modulator and the first anode, but it is customary to assume that the crossover can be considered to be situated midway between the modulator and the first anode.

Variation of Focusing Power with Final Anode Voltage

It is often said that one of the advantages of the tetrode is the fact that the spot does not go out of focus so readily when the final anode potential is changed by a small amount from its normal value. Actual measurements indicate that the power of the focusing lens varies with the final anode voltage in the same way and to the same extent in the case of the tetrode, as in the case of the triode.

Nevertheless, in spite of the academic observations as indicated above, it is certainly true in practice that the final anode voltage can be varied to a greater extent in the case of the tetrode before the spot appears to be off focus to a certain degree. This comes about because the beam is converging more slowly in the tetrode and therefore the depth of focus is appreciably greater than in the triode.

If the final anode voltage V_2 is increased while V_1 is kept constant it might be expected that the power of the $A_1 A_2$ lens would have been increased and therefore the necessary increase in power of the final focusing lens would be less than in the case of the triode. Measurements indicate that there is no appreciable difference in this respect in the case of the particular tetrode tubes which were examined and therefore the $A_1 A_2$ lens does not increase in power very much as the V_2 voltage is varied (over a range of about 2kV from its normal operating value).

In certain cases it has been observed that the power of the final focusing lens has to be increased to an even greater value in the case of the tetrode than in the case of the triode for a given change in V_2. This implies that the power of the $A_1 A_2$ lens has actually decreased as V_2 was increased. This is possible if the $A_1 A_2$ lens consists of a very short disk-shaped diaphragm on the A_1 side of the combination. In such cases the tetrode is even more liable to pass out of focus as the V_2 voltage is varied than the triode.

However, because these various factors compensate one another to a considerable extent the final result is that the tetrode and triode show the same variation of final lens focusing power as V_2 is varied, but the tetrode appears to hold focus better than the triode because the beam is more nearly a line beam than the triode, and therefore the depth of focus is considerably greater than that of the triode.

Power of the Final Focusing Lens

The actual power required in the final focusing lens is, of course, always slightly less for the tetrode than for the triode because of the slight prefocusing action of the $A_1 A_2$ lens.

Cathode Loading

According to Moss[38] peak cathode loading is given by:

$$i_{cp} = \frac{0 \cdot 0145 \, V_d{}^{3/2}}{d_m{}^2} \quad \ldots \ldots \ldots \ldots (13)$$

and the radius of the portion of the cathode which is emitting at a time when the drive is represented by V_d is given by:

$$r_o = (V_d / V_o) \cdot (d_m / 2) \quad \ldots \ldots \ldots (14)$$

These formulæ hold good for both triode and tetrode.

Now the formula for the beam angle is:

$$\sin \alpha = \frac{0 \cdot 27 \, V_d d_m}{a^{3/4} V_c}$$

(where α is the semi-angle of the beam from crossover) and we have seen that the essential feature of the tetrode is that α can be larger than when a triode type of gun is used.

This means that d_m can be larger than in the case of the triode, also the ratio of V_d / V_c can be greater.

Now let us consider the case where d_m is constant but V_c is variable.

The beam current is represented by $I_b = (3V_d{}^{7/2} / V_c{}^2)$

and therefore if I_b is constant we have the relation $V_d^{7/2} = K_4 V_c^2$, where K_4 is a constant.

This means that (for constant beam current I_b) the drive V_d will be proportional to $V_c^{4/7}$, that means:

$$V_d = K_5 V_c^{4/7} \text{ for constant } I_b \dots \dots (15)$$

Now the mean cathode loading is given by:

$$i_{cm} = \frac{12 V_d^{3/2}}{\pi d_m^2} \dots \dots \dots \dots (16)$$

and therefore if d_m is kept constant and I_b is constant, but V_c is varied:

$$i_{cm} = K_6 V_c^{6/7} \dots \dots \dots \dots (17)$$

Therefore the mean loading (at constant I_b and constant d_m) is nearly proportional to the cut-off V_c.

Now V_c can be smaller for the tetrode than for the triode because the larger beam angle which then appears in the case of the tetrode is immediately reduced by the action of the $A_1 A_2$ converging lens. Thus one of the fundamental advantages of the tetrode is that the mean cathode loading can be lower than that of the triode because the tube can be designed so that it has a lower value of cut-off. In addition, the tetrode can be designed so that it has a larger modulator aperture (because the corresponding larger beam angle from the crossover can be dealt with by the action of the $A_1 A_2$ lens), and this leads again directly to a lower value of peak and mean cathode loading.

When I_b and d_m are kept constant and V_c is varied, it has been shown that the mean cathode loading is approximately directly proportional to the first power of V_c which is a very simple relationship and this applies equally to the tetrode or triode type of gun. Therefore, the long values of cut-off which we tend to adopt on the triode type of gun leads very directly to high values of cathode loading and should be avoided if possible.

The usual figures for the peak cathode loading which are attained in the design for cathode-ray tubes which have oxide coated cathodes are between 250 and 500mA/cm². If Lemmens cathodes or sintered nickel cathodes can be developed for this purpose it is considered possible that cathode-ray tubes could be designed so that much higher values of cathode loading would be possible[7]. This would mean that for a given beam current the size of the spot as observed on the fluorescent screen could be reduced considerably as indicated by the Langmuir relationship. Also, the Langmuir relationship indicates that a great improvement could be brought about if the cathode could be designed in such a manner that it could deliver this greater emission at a lower temperature.

Modulation Characteristics

Various formula have been given for the beam current of a cathode-ray tube as a function of the various relevant parameters. Thus Allard[7] gives:

$$I_b = 3 V_d^3 / V_c^{3/2} \dots \dots \dots \dots (18)$$

whereas Moss[3] gives:

$$I_b = 3 V_d^{7/2} / V_c^2 \dots \dots \dots \dots (19)$$

These expressions do not differ in practice to any great extent and they apply to both tetrode and triode type of gun assemblies. It has been said that one advantage of the tetrode over the triode is that is has a steeper modulation characteristic than the triode.

If we have a tetrode tube and a triode tube with the same value of cut-off V_c then the modulation characteristic would be substantially the same for each tube.

In order to obtain a small beam angle in the case of the triode it is usual to design a tube which has a long cut-off (approximately 60V) and this fact gives rise to a modulation characteristic which is less steep than the tetrode. The corresponding tetrode type of tube could be designed so that the cut-off is no greater than 35V in order to obtain appreciably the same width of electron beam in the region of the scan coils.

The above formulæ for the modulation characteristic would imply, in each case, that I_b is dependent only on V_d and V_c. In practice it is found that when the distance between the modulator and cathode is small the modulation characteristic tends to have a steeper slope than would be given by these formulæ (18) or (19).

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Automobile Association Mobile Office

Illustrated is the latest addition to the Automobile Association fleet. It is a super mobile office designed and constructed by British Films Ltd, of Balham, London, on a Carrimore articulated semi trailer with a Seddon Tractor Unit as the prime mover.

The body is divided into four main sections, the wireless control room, in which Pye Telecommunications equipment is installed, is situated in the forward section and separated from the office and reception area by a partition with sliding glass panels through which operation may be seen while no inconvenience to members is caused when messages are sent or received.

G.P.O. lines may be connected to the office which is wired for two phones, one at the counter and the other for members' use in an acoustically treated booth.

The upper rear section is fitted out as a living compartment for a crew of two.

The space beneath the soundproof floor of the living compartment houses the generator and provides a capacious stowage compartment.

A feature of the unit is a hydraulic telescopic mast, which is built into the rear of the body and to which the aerial is attached. The mast is electrically operated and can be extended to a height of 60 feet in approximately four minutes by simply pressing a button. Jacks are fitted to the trailer to stabilize the body when the mast is extended.
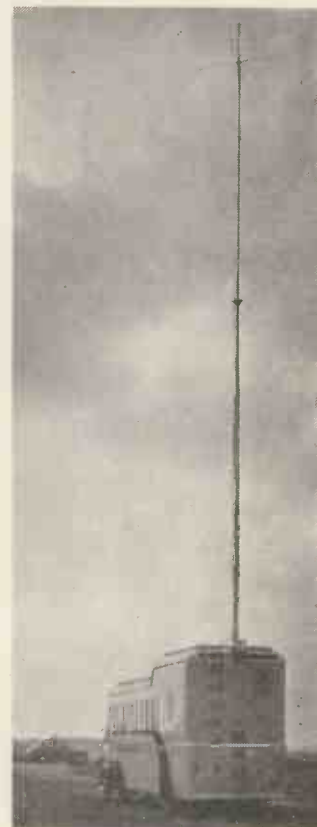
Some High Impedance Current Generating Circuits

By J. H. McGuire*, B.Sc., A.M.I.E.E., A.Inst.P.

A basic high impedance current generating circuit is described together with practical designs developed from it.

IT is often necessary, as in the stabilization of electro-magnetic lens systems and in the use of analogue computers, to apply to a network a current which is independent of the network impedance. One way of doing this is to apply to the load, through a very high resistance, a voltage waveform having the same time characteristic as the required current waveform. This is obviously in-efficient and is often very inconvenient as it necessitates the generation of an e.m.f. many times the potential difference developed across the load.

This note describes the basic and practical designs of a circuit which will generate current waveforms with a reason-able efficiency.
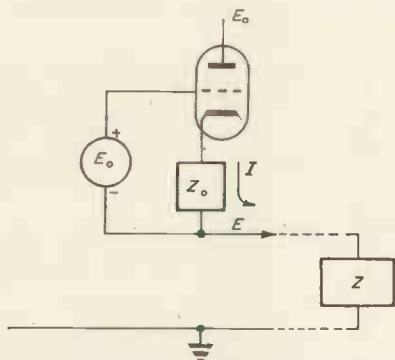
Fig. 1. A simple potentiometric current generating circuit

Two Simple Current Generating Circuits

Fig. 1 illustrates the simple high impedance current generating circuit which forms the basis of the various circuits described in this note. Its performance is analysed in Appendix 1, where it is shown that the arrangement of Fig. 2 is an equivalent circuit. If Z_0 is resistive the circuit waveform will be substantially that of the applied voltage waveform, though it may be noted that this may be modi-fied somewhat if Z_0 is complex.

In cases where the output capacitance of the circuit must be low and the source E_0 is capable of supplying the output current I, the alternative circuit illustrated in Fig. 3 may be used. The generator E_0 will almost certainly constitute the largest stray capacitance to earth in either arrangement. In Fig. 1 this stray capacitance will be connected directly across the output and can only be charged through the impedance Z_0. In the circuit of Fig. 3, however, the stray capacitance of the generator E_0 will be shunted by the output impedance of the cathode-follower.

The performance of the circuit is substantially that of Fig. 1 and Appendix 1 is applicable provided that the factor μE_0 be replaced by $(\mu + 1)E_0$ wherever it appears.

Where greater stability of current is required, improved circuits may be developed from those of Figs. 1 and 3 by arranging for the potential drop across the valve to be maintained constant.

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Pentode Current Generating Circuits

The circuits of Figs. 4(a) and 4(b) illustrate the use, as a current generator, of a pentode, the screen grid of which is maintained at a constant potential with respect to the cathode. The output current, in both circuits, will be independent of the output voltage to the extent that the
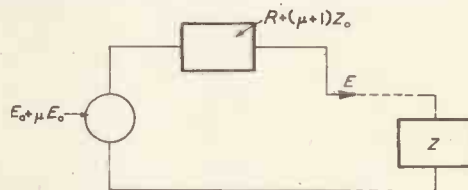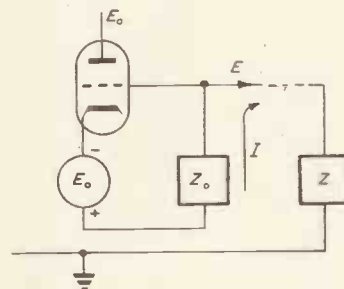

Fig. 2. Equivalent circuit of Fig. 1

Fig. 3. An alternative current generating circuit

valve behaves as an ideal pentode, i.e. to the extent that anode current is independent of anode voltage.

This type of circuit is of most practical value in generat-ing a constant current and in this case E_0 is constant, Z_0 being a pure resistance. One floating supply may then serve for both E_0 and V_B if a circuit of the type shown in Fig. 4(a) is to be used. Such an arrangement is illustrated in Fig. 4(c).

Two and Three Valve Current Generating Circuits

Fig. 5 illustrates a circuit which is substantially of the same design as that of Fig. 1, but which has a series valve in the h.t. line, so that the potential difference across the cathode-follower is maintained nearly constant. Since there is no current drain from the voltage source E_B a battery may be used as illustrated in the diagram.

It is shown in Appendix 2 that the arrangement of Fig. 6 is an equivalent circuit and that, in most practical cases, the variation of output current with output voltage is μ times less than with the circuit of Fig. 1, μ being the amplification factor of either valve.

If the output capacitance of the circuit must be low and the source E_0 is capable of supplying the output current I, the alternative arrangement of E_0 and Z_0, described previously, may again be used. The performance will be sub-stantially unaltered.

With either arrangement it might also be convenient to

connect the lower end of the potential source E_B to the lower end of Z_0 and not to the valve cathode.

Where it is undesirable to include any batteries in the circuit a stability approaching the order of the above may be obtained by incorporating a third valve and neon stabilizer tubes. Such a circuit, operating on the same principle as the circuit of Fig. 5, is illustrated in Fig. 7. A similar circuit based on the alternative arrangement of E_0 and Z_0 would be cumbersome as it would require a negative supply line in addition to the positive h.t. supply.
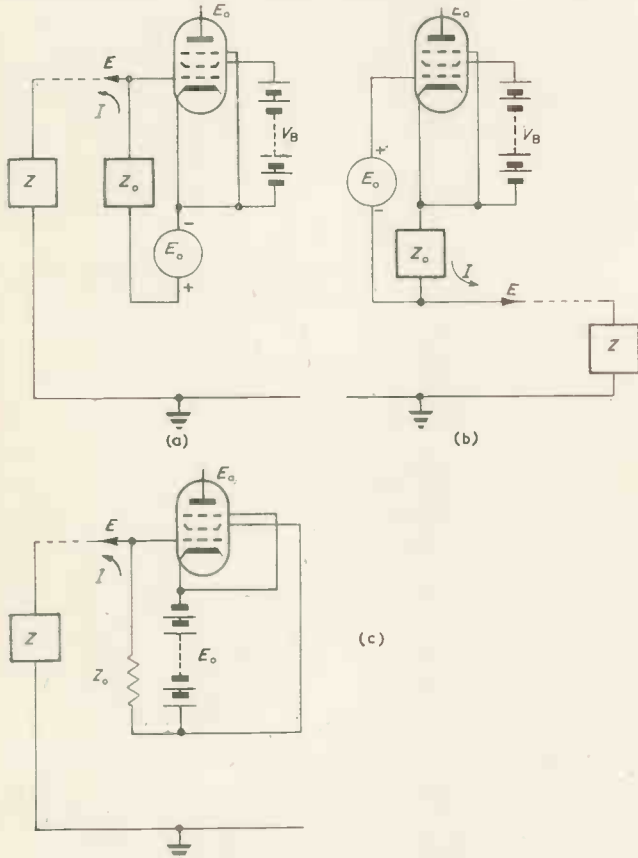
Fig. 4. Pentode current generating circuits

Currents of Opposite Polarity

If currents of the opposite polarity are required, the load Z in the circuits of Figs. 1 to 5 may be placed in series with the h.t. supply. With this arrangement the positive side of the h.t. supply would be earthed, and thus the lower end of the generator E_0 would be at a fixed potential with reference to earth. The capacitance of the generator E_0 would therefore become unimportant and it would be pointless to use a modified arrangement of the circuit of Fig. 3.

The circuit of Fig. 5 would be simplified if the lower end of the potential source E_B were connected to the lower end of Z_0. The potential could then be derived from a potential divider across the h.t. line and in these circumstances the circuit of Fig. 7 would be redundant.

Conclusions

Several current generating circuits have been described and it is shown that in a practical example the output current waveform will be constant, with variations in output voltage, to within $4\frac{1}{2}$ per cent for the simple circuit and $\frac{1}{4}$ per cent for the more complex circuits. Equivalent

circuits are given and it is shown that, if a valve with an amplification factor of 20 is used, the simple circuit operating from supplies not exceeding 500V will give the same performance (within limits) as a circuit including a high impedance generator of e.m.f. 4·5kV. In the case of the more complex circuit, operating from supplies not exceeding 700V the e.m.f. of the equivalent high impedance
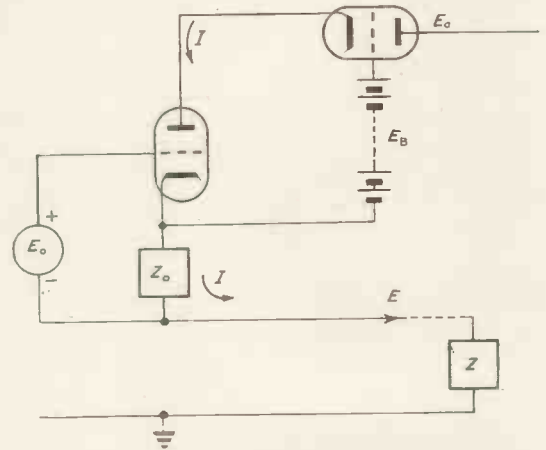
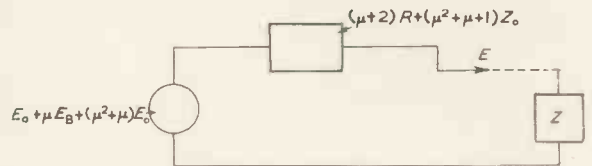Fig. 5. An Improved Current Generator

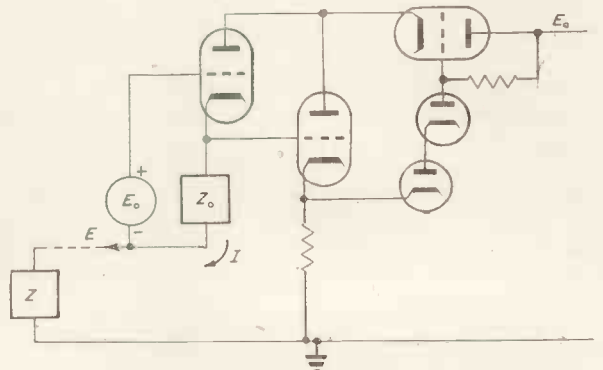
Fig. 6. Equivalent circuit of Fig. 5

Fig. 7. A neon tube stabilized current generating circuit

generator would be of the order of 88kV, again assuming that valves with an amplification factor of 20 are used.

The circuits of Figs. 4(c) and 3 have been used successfully to give constant and impulsive currents respectively in an electric analogue of heat conduction.

APPENDIX 1

A Simple Current Generator

If, in the circuit of Fig. 1, the valve is considered to be ideal and stray capacitances are neglected, then the current flowing through the load Z is given by:

$$I = \frac{E_a + \mu E_o}{R + (\mu + 1)Z_o + Z} \quad \cdots \cdots \cdots \quad (1)$$

where μ and R are the amplification factor and equivalent d.c. resistance of the valve respectively.

Thus, provided the potential drop E across the load Z does not rise to such a level that the potential difference across the valve tends to zero, the circuit will behave as if it were the generator of an e.m.f. $(E_a + \mu E_o)$ with an internal impedance $R + (\mu + 1)Z_o$ (see Fig. 2).

The fractional variation of I with Z will be small provided Z is small compared with $R + (\mu + 1)Z_o$ and in these circumstances is given by:

$$\frac{dI/dZ}{I} \simeq \frac{-1}{R + (\mu + 1)Z_o} \quad \cdots \cdots \cdots \quad (2)$$

In many applications of the circuit the load Z will be complex and it may not be practicable to evaluate equation (2). The performance of such circuits is best described in terms of the potential drop E across the load Z rather than in terms of Z. It follows from the equivalent circuit of Fig. 2 that provided E is small compared with $E_a + \mu E_o$, the fractional variation of I with E is:

$$\frac{dt/dE}{I} \simeq \frac{-1}{E_a + \mu E_o} \quad \cdots \cdots \cdots \quad (3)$$

Thus if a valve with a μ of 20 is used in a circuit with an h.t. of 500V and E_o has a constant value of 200V, then a typical value of the maximum excursion of E will be 200V. On substituting these values in equation (3) it will be seen that the fractional difference between the current when the potential difference across the load varies between 0 and 200V is:

$$(\delta I/I)_{max} \simeq 4\tfrac{1}{2} \text{ per cent}$$

In the equivalent circuit of Fig. 2 the same potential difference E would be developed across the load if the generator developed an e.m.f. of 4·5kV and had an internal impedance of $R + (\mu + 1)Z_o$.

APPENDIX 2

An Improved Current Generator

If in the circuit of Fig. 5, the valves are considered to be ideal and stray capacitances are neglected, then the current flowing through the load Z is given by:

$$I = \frac{E_a + \mu E_B + \mu(\mu + 1)E_o}{(\mu + 2)R + (\mu^2 + \mu + 1)Z_o + Z} \quad \cdots \cdots \quad (4)$$

where μ and R are the amplification factor and equivalent d.c. resistance of the valves respectively.

Thus, provided the potential drop E across the load Z does not rise to such a level that the potential difference across the valve tends to zero, the circuit will behave as if it were the generator of an e.m.f. $[E_a + \mu E_B + \mu(\mu + 1)E_o]$ with an internal impedance $[(\mu + 2)R + (\mu^2 + \mu + 1)Z_o]$ see Fig. 6.

The variation of I with Z will be small provided Z is small compared with $[(\mu + 2)R + (\mu^2 + \mu + 1)Z_o]$ and in these circumstances is given by:

$$\frac{dI/dZ}{I} \simeq \frac{-1}{(\mu + 2)R + (\mu^2 + \mu + 1)Z_o} \quad \cdots \quad (5)$$

As with the previous circuit, many applications will involve complex loads and in these cases the performance is best described in terms of E, as follows:

$$\frac{dI/dE}{I} \simeq \frac{-1}{E_a + \mu E_B + \mu(\mu + 1)E_o} \quad \cdots \cdots \quad (6)$$

The order of variation likely to be encountered in practice may be found by substituting appropriate values in equation (6). Thus, if $\mu = 20$, $E_a = 700$V and $E_B = E_o = 200$V then for a change in E of 200V $(dI/I)_{max} = 0·23$ per cent.

In the equivalent circuit of Fig. 6 the same potential difference would be developed across the load if the generator developed an e.m.f. of 88·7kV and had an internal impedance of $(\mu + 2)R + (\mu^2 + \mu + 1)Z_o$.

New Equipment for Testing Television Valves

The M.O. Valve Co Ltd has developed a new table specially for conditioning and testing Osram N339 and U329 valves. Both types are used in domestic television receivers, the N339 as a line output-valve and the U329 as a booster diode with exceptionally high heater-cathode insulation. The new table subjects them to the same high peak voltages and currents as they encounter in service, and ensures a uniform high standard of performance.

Each table incorporates twelve test positions which will accommodate either type of valve. The valves are inserted and a Perspex window is drawn down over them. The peak voltages developed on the valves can then be increased from zero to maximum either manually or automatically to a preset sequence. Each valve is monitored by pressing the button located immediately below it, the peak output voltage being indicated on a meter let into the front of the table.

The test circuit for each valve is very similar to the line time-base circuit used in television receivers. The line transformer is loaded with a dummy coil to simulate the effect of the deflexion coils. All twelve test positions are driven by a negative 10kc/s pulse at the grid of the N339 from a common driver unit, the output of which is kept at a constant amplitude.

The peak voltage developed on the anode of the N339 is dependent on the rate of change of current through the valve at cut-off. The current flowing through the valve is controlled by a variable screen grid supply which, therefore, controls the peak voltage output.

The automatic conditioning is achieved by providing a stepped input voltage to the screen grid power supply from a thyratron operated timer unit. The number of switched steps available is 24 and the duration of each step is variable over a considerable range by adjustment of the thyratron circuit. The maximum screen grid voltage may be preset by a control on the front of the desk.

After the conditioning process is completed the equipment may be set up for testing the valves. The valves are switched on cold and the peak voltages are allowed to build up quickly to the maximum rating. This is the treatment the valves receive in a television receiver and the conditioning process ensures that no flashing will take place during testing and use.

Reliable Power Pack Design

By A. F. Standing*

A method is described which reduces the design of capacitor input power packs to simple calculations aided by graphs. Full details of the voltages and currents both a.c. and d.c. throughout the power pack can be readily calculated, enabling correct components and ratings to be chosen.

IN many applications of electronic equipment reliability is of the utmost importance, and a great deal of work is going on to increase reliability, including the study of design methods that enable components to work within their ratings at all times.

The following method reduces the design of capacitor input power packs to simple calculations aided by graphs. Full details of the voltages and currents both a.c. and d.c. throughout the power pack can be readily calculated, enabling correct components and ratings to be chosen.

A rectifier has five main ratings (a) peak inverse voltage, (b) mean anode current, (c) peak anode current, (d) surge anode current, (e) heater cathode voltage. For any given load or mean anode current, a minimum applied voltage is required before the rated peak anode current is reached. If this minimum voltage is below the value set by the rated peak inverse voltage, the design is limited by the rated peak anode current; if, however, this minimum voltage is above the peak inverse voltage, then the design is limited by the rated peak inverse voltage. A list of valves and their limiting ratings under full load conditions is given in Table 1. As the load current and/or the applied voltage is reduced, the maximum peak anode current is reduced and the valve works well within its ratings. Two methods of design are given to cover the two cases, peak current limited and peak inverse limited, and the calculation of their regulation curves.

TABLE 1

VALVE	I_L' (mA)	I_v'' (mA)	P.I.V. (kv)	LIMITING RATING
CV140 (6AL5)	9	54	0.414	I''_v
CV493 (6X4)	68	207	1.238	I''_v
CV378	225	1.125	1.125	P.I.V.
5Z4G	126	374	1.260	I''_v
5U4G	203	608	1.400	I''_v
CV261	4.5	36	11.25	I''_v

Theory

(a) DESIGN LIMITED BY PEAK ANODE CURRENT

If the power pack is in a stable condition, i.e. the load and d.c. voltage remain constant, the charge lost in feeding the load is replaced during the rectifier conduction time.

Since charge is the product of current and time:

$$I_L t_c = I_v' t$$

where I_L = load current

I_v' = mean rectifier anode current during conduction period

t = rectifier conduction time

t_o = load discharge time.

Assuming charge and discharge to be linear, (these assump-

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tions are discussed later) the voltage waveforms are as shown in Fig. 1.

The ratio of peak valve current I_v'' to mean valve current I_v' is equal to the ratio A of maximum height to mean height of the shaded area (see appendix). This ratio does
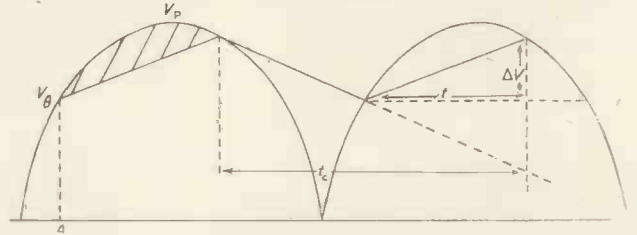

Fig. 1. Assumed ripple waveform for a full wave rectifier, superimposed on to the input voltage
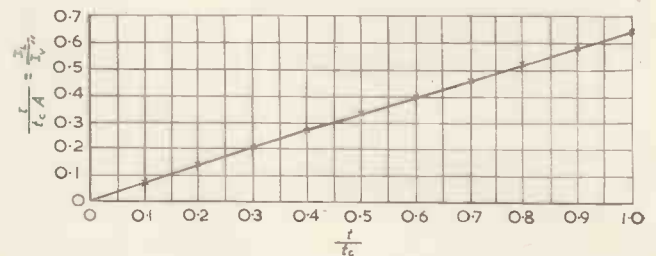

Fig. 2. Curve for calculating t/t_c in the peak anode current limited case

not change significantly with ΔV when ΔV is less than 20 per cent of V_p. When ΔV is greater than 20 per cent the accuracy falls off.

Now $A = I_v''/I_v'$ and $t/t_o = I_L/I_v'$

$$t/At_c = I_L/I_v'' \dots \dots \dots \dots (1)$$

The ratio of conduction time to discharge time does not depend on the value of capacitor used, but on the ratio of load current to peak anode current during the conduction period.

Using equation (1) and the graph of t/At_c against t/t_o, Fig. 2 (see appendix), the value of t/t_c can be obtained.

The ripple voltage ΔV depends on the discharge time $t_o - t$, less the load current I_L and the capacitor C.

$$\Delta V = \frac{I_L (t_o - t)}{C} \dots \dots \dots \dots (2)$$

Assuming the mean value of the ripple voltage to be $\Delta V/2$ the direct voltage across the capacitor is:

$$V_{dc} = V_\theta + \Delta V/2 \dots \dots \dots \dots (3)$$

For calculation of V_θ see Fig. 1 and appendix.

From appendix:

$$V_\theta = V_p \sin \theta \dots \dots \dots \dots (4)$$

where:

$$\theta = \cos^{-1}\left[\frac{\Delta V}{2V_p \sin ft\pi}\right] - ft\pi$$

This means that, to a first approximation, the output voltage does not depend on the value of capacitor used.

The maximum voltage V_a'' across the rectifier and series resistance is proportional to the maximum height of the shaded area, Fig. 1, and is given by (see appendix):

$$V_a'' = V_p \left[\sin \alpha - \sin \theta - \frac{(\alpha - \theta) \Delta V}{(\pi t/t_c) V_p} \right] \dots \dots (5)$$

where $\cos \alpha = \dfrac{\Delta V}{(\pi t/t_c) V_p}$

To limit the peak anode current to the required value, the total resistance R_T in the charging circuit must equal the ratio of maximum voltage V_a'' to peak valve current I_v'':

$$R_T = V_a'' / I_v'' \dots \dots \dots (6)$$

The resistance R_T is made up of four parts, transformer leakage inductance being neglected: (a) rectifier at I_v'', (b) resistance of transformer secondary, (c) primary transformer resistance reflected into the secondary, (d) external series resistance R_s. Curves of rectifiers resistance with load current are given in Fig. 3. The value of the series resistance R_s is given by:

$$R_s = R_T - R_{v_0} - R \dots \dots \dots (7)$$
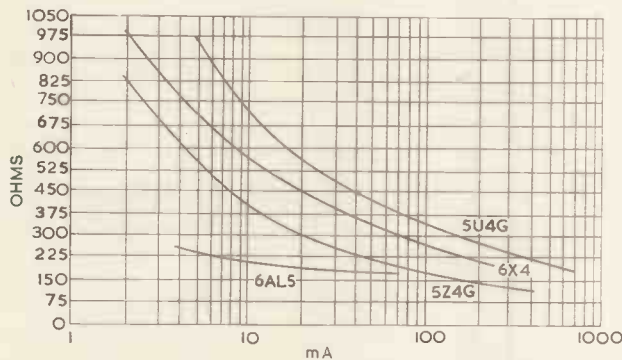
Fig. 3. Relationship between resistance and current for a number of rectifiers

where R_s = external series resistance

R_T = total required resistance

R_v = rectifier resistance at I_v''

R = total transformer resistance.

The dissipation of R_s is given by the mean valve current during the conduction time the value of R_s, and the charge and discharge ratio:

$$W_R = t/t_c (I_v')^2 R_s$$

but:

$$A = I_v'' / I_v'$$
$$W_R = (t/t_c) R_s (I_v'')^2 / (A)^2 \dots \dots \dots (8)$$

From the above equations, a full load design can be produced provided the limiting rating is the peak anode current.

(b) Design Limited by Peak Inverse Voltage

When the design is limited by the rated peak inverse voltage, it means the required R_T from the previous method is less than the rectifier resistance at that peak anode current. It is therefore necessary to design the power pack from the known applied voltage, R_T and load current.

Now from equations (1) and (6):

$$t/t_c = A (I_L / I_v'')$$

and:

$$R_T = V_a'' / I_v''$$

The ratio A of peak anode current to mean anode current is the same as the ratio of peak anode voltage to mean anode voltage (during conduction time).

Thus:

$$A = V_a'' / V_a'$$

Combining equations:

$$t/t_c = I_L R_T / V_a'$$

Dividing through by V_p:

$$V_a' / V_p = (I_L R_T / V_p) \cdot 1/(t/t_c) \dots \dots \dots (9)$$

Using equation (9) and the graph of t/t_c, Fig. 4 (see appendix), successive approximations will give the value of t/t_c to the accuracy required for any given value of applied voltage, load current and R_T. Having found the value of t/t_c, calculation will give V_{dc} and ΔV for the load used.

The design method for P.I.V. limited valves can be used to calculate the output voltage and ripple at any load (see discussion of assumptions), thus enabling the regulation of the power pack to be calculated irrespective of the original design method used. The regulation of change of output voltage with load of the power pack is not linear, requiring at least three points to define the regulation curve. Two points are available: (a) no load where the output voltage equals V_p, (b) full load calculated from the graphs and
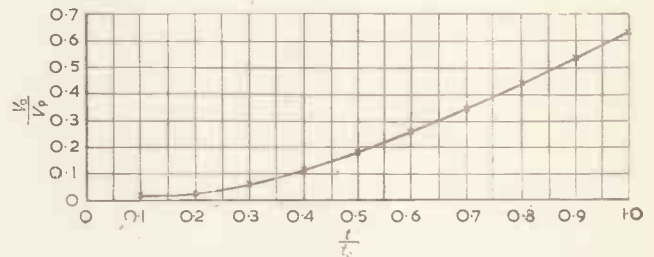
Fig. 4. Curve for calculating t/t_c in the peak anode voltage limited case

equations. It is therefore necessary to calculate the output voltages at loads other than full and no load. Normally calculations for half load will provide enough information to enable the regulation curve to be constructed.

The two methods can be applied to half and full wave circuits by using the appropriate values of t_c, $1/f$ and $1/2f$ respectively, where f is the supply frequency.

Voltage doublers of conventional type can be calculated on the basis of two half-wave rectifiers whose outputs add. Ripple frequency will be twice the supply frequency and the amplitude ΔV_T will be the sum of the two ripple voltages, one of which is 150° out of phase with the other giving a final ripple amplitude equal to the half-wave case.

Discussion of Assumptions

The theory is based on the following three assumptions:

(a) linear fall of voltage during discharge;

(b) linear rise of voltage during charge;

(c) A remains constant for all values of ΔV.

The error introduced by assuming linear discharge is very small, and can be neglected in comparison with the errors introduced by the other assumptions.

Since A is not constant for all values of ΔV (from geometry) the curve of t/At_c against I_L'/I_v'' is one of a

533

family of curves. The curve given represents this relationship with reasonable accuracy up to 20 per cent ripple, i.e. $\Delta V = 0.2 \, V_p$.

The limiting assumption is that of linear charge, this will predict in the ideal rectifier case (zero forward resistance $\infty \, I_v''$) an infinite charging current. In fact the charging current in this case is governed by the rate of rise of the applied voltage and is given by:

$$I = C \, dv/dt$$

In practice reasonably accurate results are obtained for values of I_v''/I_L not exceeding 6.0.

Examples of Method

To illustrate the methods, a full wave 50c/s power pack using a CV493 (6X4) is designed.

The power pack is fed from a 250V input, 350-0-350V output, 50c/s transformer, and uses a CV493 full-wave rectifier feeding a 4μF capacitor (Fig. 5).

TRANSFORMER

Primary resistance $= 13.7\Omega$

Half secondary resistance $= 125\Omega$, i.e., 0-350V

Reflected primary resistance $= 26.8\Omega$

Impedance ratio $= 1.96$
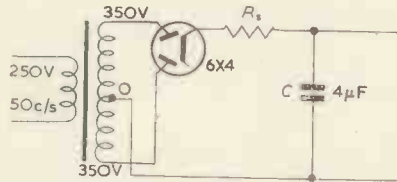
Fig. 5. Rectifier circuit for the example given.

VALVE CV493

From Table 1, this valve is limited by the peak anode current rating; use equation (1) and graph Fig. 2.

Diode resistance at 207mA is 200Ω.

Valve ratings:

$$I_L = 68\text{mA} \qquad I_v'' = 207\text{mA} \qquad I_L/I_v'' = 0.328$$
$$A = 0.5/0.328 = 1.52$$

From graph Fig. 2 $t/t_c = 0.5$

Supply frequency 50c/s, $t_c = (1/2f) = 10 \times 10^{-3}$sec

$$t = 5 \times 10^{-3}\text{sec} \qquad (t_c - t) = 5 \times 10^{-3}\text{sec}$$

Calculate ripple amplitude from equation (2):

$$\Delta V = \frac{68 \times 10^{-3}(5 \times 10^{-3})}{4 \times 10^{-6}} = 85\text{V peak-to-peak}$$

$$V_p = \sqrt{2} V_{rms} = \sqrt{2} \times 350 = 494\text{V}$$

Percentage ripple $= (85/494) \times 100 = 17.2$ per cent of V_p

Since the ripple is less than 20 per cent the value of capacitor used is large enough.

From equations (3) and (4), calculate V_{dc}.

$$ft\pi = 50 \times 5 \times 10^{-3} \times \pi = 0.786 \text{ radians} = 45° \, 02'$$
sine $ft\pi = 0.7075$

$$\theta = \cos^{-1}\left[\frac{85}{2 \times 494 \times 0.7075}\right] - 45° \, 02'$$

$$\theta = 83° \, 02' - 45° \, 02' = 38°$$

$$V_\theta = V_p \sin\theta = 494 \times 0.6157 = 304.5\text{V}$$

$$V_{dc} = 304.5 + (85/2) = 347\text{V}$$

From equation (5) calculate V_a''

$$V_a'' = V_p\left[\sin\alpha - \sin\theta - \frac{(\alpha - \theta)\Delta V}{\pi t/t_c \, V_p}\right]$$

$$\cos\alpha = \frac{85}{494\pi \times 0.5} = 0.1093$$

$$\cos\alpha = 0.1093 \qquad \alpha = 83° \, 43' = 1.4611 \text{ radians}$$

$$\sin\alpha = 0.9940 \qquad \theta = 38° \qquad = 0.6632 \quad ,,$$

$$\sin\theta = 0.6157 \qquad \alpha - \theta \qquad = 0.7979 \quad ,,$$

$$V_a'' = 494 \, [0.9940 - 0.6157 - 0.1093 \times 0.7979]$$

$$V_a'' = 144\text{V}$$

From equations (6), (7), (8), calculate R_s and its wattage

$$R_T = (V_a''/I_v'') = (144/0.207) = 696\Omega$$

$$R_s = 696 - 200 - 26.8 - 125 \simeq 352\Omega$$

$$W_{Rs} = 0.5 \times 352 \times (0.207^2/1.52^2) = 3.28\text{W}$$

The calculation of half-load voltages will illustrate the second method.

Calculate the value of t/t_c for half-load from the graph, Fig. 4, and equation (9). Start with the assumption that t/t_c is the same as in the full-load case. Successive approximations will lie each side of the correct value; in practice three or four attempts should produce an adequate answer for t/t_c.

Half-load 34mA

$$V_a'/V_p = \frac{34 \times 10^{-3} \times 696}{494} \cdot (1/(t/t_c)) = 0.0479 \, (1/(t/t_c))$$

Assume $t/t_c = 0.5$ as for full load.

HIGH t/t_c BY GRAPH	LOW V_a'/V_p BY EQN.	LOW t/t_c BY GRAPH	HIGH V_a'/V_p BY EQN.
0.5	0.096	0.367	0.13
0.43	0.111	0.397	0.121
0.415	0.116	0.405	0.118
0.41	0.117	0.41	0.117

Thus $t/t_c = 0.41$

$$t_c = 10\text{msec} \qquad t = 4.1\text{msec} \qquad (t_c - t) = 5.9\text{msec}$$

From equation (2):

$$\Delta V = \frac{34 \times 10^{-3} \times 5.9 \times 10^{-3}}{4 \times 10^{-6}} = 50.2\text{V peak-to-peak.}$$

From equations (3) and (4) calculate V_{dc}

$$ft\pi = 50 \times 4.1 \times 10^{-3} \times \pi = 0.6442 \text{ radians } 36° \, 55'$$
$$\sin ft\pi = 0.6006$$

$$\theta = \cos^{-1}\left[\frac{50.2}{2 \times 494 \times 0.6006}\right] - 36° \, 55'$$

$$\theta = 85° \, 9' - 36° \, 55' = 48° \, 14'$$

$$V_\theta = 494 \times 0.7459 = 369\text{V}$$

$$V_{dc} = 369 + 25 = 394\text{V}$$

The regulation curves calculated and measured are given in Table 2.

TABLE 2

	NO LOAD		HALF LOAD		FULL LOAD	
	CAL	MEA	CAL	MEA	CAL	MEA
I_v''	—	—	—	—	207	197mA
ΔV	—	—	50.2	48V	85	83V
V_{dc}	494	494	394V	397V	347V	343 V

The measurement of output voltage and current presents no difficulty with a normal meter. Ripple voltage and peak

anode current can be measured by means of an oscilloscope. In the peak anode current case, connexion of the oscilloscope across R_s will give the required answer, the only precaution needed being the removal of the power pack earth.

To calculate the worst case of anode current surge which occurs when the anode voltage is applied and the heaters are operating, divide the peak applied voltage by the total resistance.

$I_s'' = (V_p/R_T) = (494/696) = 710$mA within the rating. Filter design for the above example would follow well-known methods.
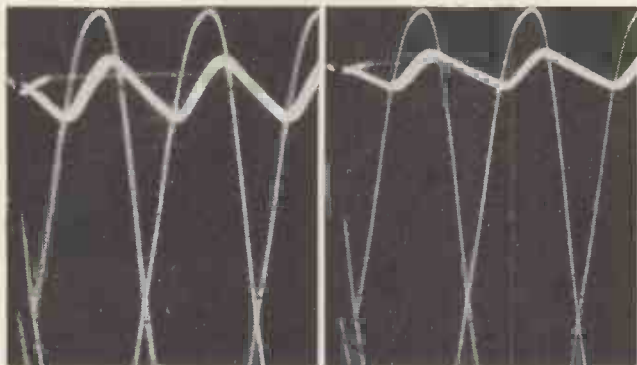
Fig. 6. Double exposure oscilloscope photographs of ripple voltages superimposed on to input voltages, and showing the assumption of linear charge to be reasonable for the example given
Left—full load   Right—half load

Double exposure oscilloscope photographs (Fig. 6) of the ripple voltage superimposed on the transformer secondary voltage show the assumption of linear charge to be reasonable in the example given.

In the case of peak inverse voltage limited valves, or under conditions where the peak anode current is limited by the external resistance, the rectifier resistance is unknown. A reasonable assumption of rectifier resistance can be made from Fig. 3 or the specification and corrected if necessary on a second attempt.

Acknowledgments

Acknowledgment is made to the Chief Scientist, Ministry of Supply, for permission to publish this article. Crown copyright is reserved.

APPENDIX

(See Fig. 7)

α is the angle at which V_a is a maximum

V_a' = mean height of shaded area

$$V_a''/V_a' = (I_v''/I_v') \text{ and } t/(1/2f)) = \frac{\pi - \gamma - \theta}{\pi}$$

$V_a' =$

$$\frac{V_p \int_\theta^{(\pi-\gamma)} \sin \theta \, d\theta - V_p(\pi - \gamma - \theta)\sin \theta - \left(V_p/2\right)(\pi - \gamma - \theta)\dfrac{\Delta V}{V_p}}{\pi - \gamma - \theta}$$

$$V_a' = V_p \left[\frac{\cos \theta - \cos(\pi - \gamma)}{(\pi - \gamma - \theta)} - \sin \theta - (\Delta V/2V_p)\right]$$

$$V_a'' = V_p \left[\sin \alpha - \sin \theta - \frac{(\alpha - \theta)}{\pi - \gamma - \theta} \cdot (\Delta V/V_p)\right]$$

To find the maximum value of V_v differentiate and equate to zero.

$$dV_a/d\alpha = V_p \left[\cos \alpha - \frac{\Delta V}{V_p (\pi - \gamma - \theta)}\right]$$
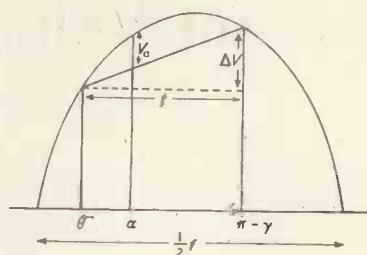
Fig. 7.

$$\therefore \cos \alpha = \frac{\Delta V}{V_p (\pi t/(1/2f))}$$

Now:

$$A = (V_a''/V_a') = \frac{\sin \alpha - \sin \theta - \dfrac{(\alpha - \theta)}{(\pi - \gamma - \theta)}(\Delta V/V_p)}{\dfrac{\cos \theta - \cos(\pi - \gamma)}{\pi - \gamma - \theta} - \sin \theta - (\Delta V/2V_p)}$$

Plot graphs of t/t_c against t/At_c

$t_c = 1/2f$ and $1/f$ for full and half wave respectively.

CALCULATION OF V_θ

$\sin(\pi - \gamma) - \sin \theta = (\Delta V/V_p)$

and $(\pi - \gamma) = (t/(1/2f))\pi + \theta$

$\sin(2ft\pi + \theta) - \sin \theta = (\Delta V/V_p)$

$2 \cos(ft\pi + \theta) \sin ft\pi = (\Delta V/V_p)$

$\cos(ft\pi + \theta) = \dfrac{\Delta V}{2V_p \sin ft\pi}$

$\theta = \cos^{-1} \left[\dfrac{\Delta V}{2V_p \sin ft\pi}\right] - ft\pi$

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Ferroxcube Beads for Decoupling Circuits

The inductance and h.f. resistance of a straight wire can be increased appreciably by threading it through a small bead of "Ferroxcube". This fact is made use of in a variety of h.f. decoupling applications, including simple "grid stoppers" to prevent parasitic oscillation, and decoupling circuits in heater leads.

The use of Ferroxcube beads for decoupling heater wiring is particularly attractive in that there is no increase in resistance at d.c. or supply frequencies, though the h.f. resistance may be increased by an appreciable amount by the addition of a single 3mm bead. This large resistive component also reduces the risk of the decoupling elements themselves causing parasitic oscillation, since any tuned circuit formed by them will be heavily damped.

Two types of Ferroxcube bead are available from the Component Division of Mullard Limited—type FX1666 which is suitable for applications involving relatively low radio frequencies, and type FX1667 for high frequency circuits. Both types take the form of short tubes (length, 3mm, inside diameter, 1·2mm, outside diameter, 3·5mm). The beads are put into circuit simply by slipping them over the relevant leads. They can be held in place if necessary by pieces of sleeving. More than one bead can be used to obtain increased inductance and loss resistance.

A Constant Voltage Amplifier and Oscillator

By G. N. Patchett*, Ph.D., A.M.I.E.E., M.Brit.I.R.E., M.I.R.E.

The apparatus will operate as an amplifier or as an oscillator with a constant voltage output. The output voltage remains within 0·1 per cent for large changes of input voltage, from no load to full load and for large changes of supply voltage. The apparatus may be used for instrument calibration or for any purpose where a constant voltage supply is required

THE apparatus to be described† was designed to give a voltage, or current output, which would be constant to a high degree of accuracy and be almost independent of reasonable supply voltage changes and load conditions. The apparatus may be operated in one of two ways:— (a) As an amplifier, being fed with a voltage of the frequency corresponding to that required on the output. In this case the output voltage is practically independent of the input voltage fed to the amplifier, within large limits
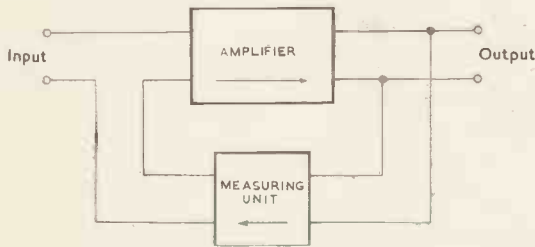
Fig. 1. Basic principle of amplifier

and also independent of large changes of power supply voltage and load changes from no load to full load.

(b) As an oscillator, the frequency of the voltage output being determined by the constants of the circuit. In this case the magnitude and frequency of the output are constant within close limits and nearly independent of supply voltage changes and load changes from no load to full load.

The principle of the device is shown in Fig. 1, where the apparatus is shown as an amplifier and connected so as to maintain a constant output voltage. The output of the amplifier is connected to the measuring unit which gives no output when the voltage is correct but, a relatively large output if the output voltage of the amplifier departs from its predetermined value. The output from the measuring unit is connected in series with the amplifier input so that the actual input to the first valve is the sum, or difference, of the amplifier input and the output of the measuring unit. Instead of actually being connected in series with the input it may be connected in other ways so that the output of the measuring unit adds, or subtracts, from the input to the amplifier. The sense of the output of the measuring unit is such that, if the output falls, the output voltage of the measuring unit adds to the input so increasing the actual input to the first stage and, hence, the output of the amplifier, so tending to restore the output voltage to normal. Under these conditions the feedback is, of course, positive, tending to increase the overall gain of the amplifier. If the output voltage of the amplifier increases above normal the phase of the output of the measuring unit is reversed so that it opposes the input, so decreasing the output and tending to restore it to its correct value. In

this case the feedback is negative and, therefore, decreases the effective amplification of the amplifier.

Although it is possible to use any suitable measuring unit in this circuit the main point of the apparatus is the use of a thermistor bridge which has the advantage of
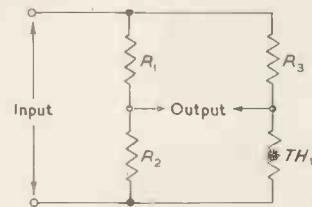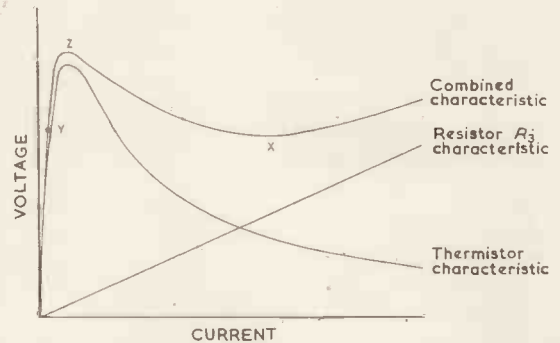

Fig. 2. Thermistor bridge measuring unit

Fig. 3. Current-voltage characteristics of thermistor and thermistor bridge

producing a large output voltage for a small change of input voltage[1,2,3]. The bridge is composed of three linear resistors R_1, R_2 and R_3 and one directly heated thermistor TH_1, as shown in Fig. 2. The current-voltage characteristic of the thermistor is shown in Fig. 3, from which it will be seen that, over a large portion of the characteristic, the slope resistance is negative. On the same figure is shown the characteristic of R_3 (a straight line) and also the combined characteristic of the thermistor and resistor R_3 in series. This combined characteristic is, of course, the voltage current characteristic of the right-hand side of the bridge, the left-hand side being a linear characteristic. It will be seen that, at point x, the characteristic is horizontal over a small region and, therefore, the current in the circuit may change, and hence the output of the bridge will change, without a change of input voltage. The ratio of change of output voltage to change of input voltage, is called the figure of merit and with this bridge, operating with small changes, it approaches infinity. The figure of merit is difficult to measure in practice but a value of about 50 may be obtained. This is a great improvement over bridges using other types of non-linear element where the figure of merit is usually less than unity.

If the input to the amplifier is reduced below a certain value the feedback is then positive. If the circuit is designed correctly the amplifier may then be made to operate as an oscillator having the same output characteristic, but with a frequency determined by the amplifier circuits.

It is obvious that a large number of different amplifier and oscillator circuits may be designed around this principle, but only one will be described in this article. The amplifier to be described was designed to operate at 1 000c/s and give a constant voltage output of approxi-

transformer secondary. As the bridge is temperature sensitive, a temperature compensating circuit is added, consisting of resistor R_4 and thermistor TH_2. Thermistor TH_2 is a large type thermistor where the self heating is small. On a rise of ambient temperature the resistance of TH_2 decreases, so decreasing the voltage fed to the bridge. This is arranged to correspond with the decrease in the balance voltage of the bridge, so that the whole circuit remains in balance for a fixed primary voltage applied to transformer T_3, over a reasonable temperature range. To compensate for some quadrature output from the bridge due to the
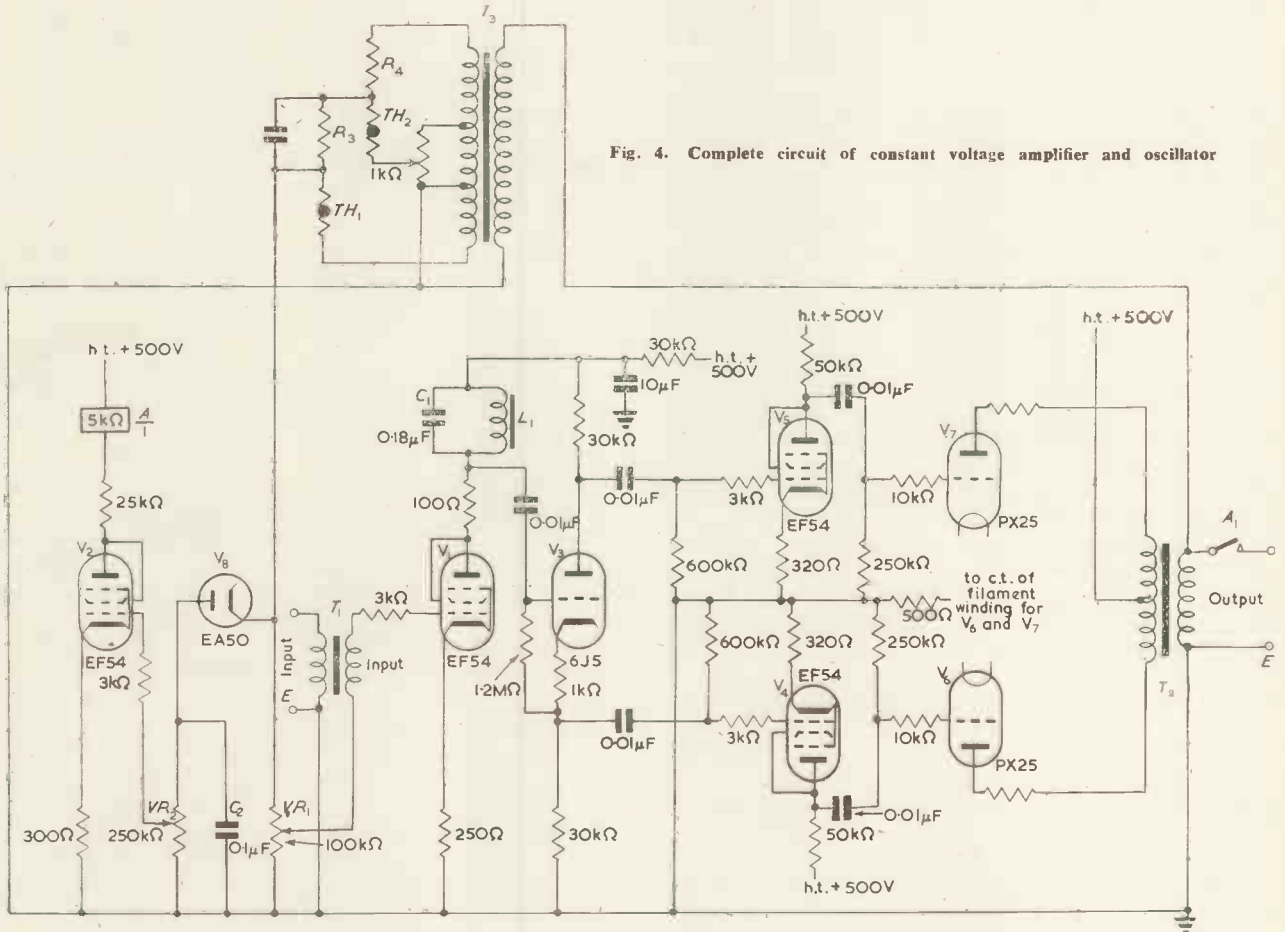
Fig. 4. Complete circuit of constant voltage amplifier and oscillator

mately 230V, with a maximum power of 10.W. The circuit of the complete amplifier, excluding power supply, is shown in Fig. 4. The amplifier itself consists of the first stage V_1 fed from the input transformer T_1. The anode load of this stage consists of a tuned circuit L_1C_1 tuned, in this particular case, to 1 000c/s. This stage is followed by a phase-splitter valve V_3 which feeds the two amplifier valves V_4 and V_5 in push-pull. These two valves feed, in turn, the two output valves V_6 and V_7, which feed the output terminals through the output transformer T_2. This amplifier is fairly conventional and may be replaced by any suitable amplifier circuit.

The output of the amplifier is fed to the measuring unit bridge through transformer T_3, to give a suitable voltage for the bridge. The bridge is similar to that previously described[1,2,3], two arms of the bridge being formed by R_3 and the thermistor TH_1. Instead of using resistors for the other two arms they are replaced by a suitable tap on the

thermal inertia of the thermistor and due to the stray capacitances, a suitable capacitor is placed across R_3 and adjusted until the quadrature output is zero. The output from the bridge is fed to the potentiometer VR_1 which can be adjusted to give the correct amount of feedback. The output from VR_1 is then fed, in series with the secondary of the input transformer T_1, to the input valve V_1.

It is necessary to use a tuned circuit in the anode of valve V_1, or some other means of making the amplifier frequency selective, for two reasons:—

(a) The feedback loop contains two transformers and it is difficult to maintain the circuit stable when the negative feedback is large i.e. when the input voltage is large.

(b) When the feedback becomes positive, as it must when the input voltage decreases below a certain value, rather violent oscillation takes place when the positive feedback exceeds a certain value, unless the circuit is reasonably frequency selective in which case the oscillations are of

a steady value, giving the same output as in the case of the operation as an amplifier.

This feature could probably be omitted if the range of input voltage was restricted so that the circuit never became an oscillator and the negative feedback never became excessive.

On first switching on the amplifier the thermistor is cold and will operate at a point such as y, if the voltage remains constant (see Fig. 3). When the bridge operates at this point the phase of the bridge output is such as to increase the output of the amplifier and, under no load conditions, the voltage will rise until point z is reached when the bridge operating point will move rapidly to the stable point x. To prevent this rise in output voltage being applied to the output terminals a relay A is incorporated. The output from the bridge is rectified by the valve V_8 and smoothed by C_2 so as to give a negative voltage proportional to the bridge output. A portion of this voltage (being controlled by the potentiometer VR_2) is fed to valve V_2, in the anode circuit of which is the coil of the relay A. When first switching on, the output from the bridge is large and valve V_2 is biased to cut-off and the relay is not energized. The output terminals are, therefore, disconnected from the output transformer by contact A_1. When the bridge has warmed up and reached its correct operating point x, the output is small and there is not sufficient voltage to maintain V_2 cut off. Accordingly relay A is energized and the transformer T_2 is connected to the output terminals. Thus, no overvoltage is applied to the output terminals and the starting is simple and reliable.

Having described the circuit and principle of operation, the performance of this particular amplifier will be considered. The figures have been obtained by measuring the output voltage with a thermocouple meter on which a change of 0·1 per cent could be detected. The resistance of the meter circuit was 73kΩ and the no load readings included the loading of this meter circuit.

Output Voltage—Input Voltage as an Amplifier

The nominal input voltage is 0·4V at 1kc/s. The change of output for a change of input of $+10$dB to -20dB was found to be less than 0·1 per cent. With an input of $+20$dB the output rises by about 0·4 per cent and, if the input is increased to about 12·5V, the output rises still further but operates relay A and disconnects the output terminals from the output transformer, so protecting any apparatus fed from the amplifier.

When the input is reduced below -20dB the amplifier becomes an oscillator but the output voltage still remains with 0·1 per cent of the output at 0dB.

In other words, the output remains within 0·1 per cent and the apparatus operates as an amplifier over an input voltage range of 30dB, a change of 32 times on voltage. The variations of voltage are therefore reduced by a factor of 32/0·001 or 32 000.

Output Voltage—Load

When the equipment is operated as an amplifier with an input between $+10$dB and -20dB and also as an oscillator, the output is constant within 0·1 per cent from no load to the full output of 10W.

Output Voltage—Supply Voltage

Oscillator on No Load

The nominal supply voltage is 230V but this may be changed from 130V to 250V without the output voltage changing more than 0·1 per cent. When the input voltage is increased to 260V the output was found to rise by 0·1 per cent.

As an Oscillator on Full Load

The output voltage now changes by less than 0·1 per cent when the supply voltage is changed from 170V to 260V. The range of voltage is now less due to the drop in h.t. voltage and filament voltage which prevent the amplifier giving an output of 10W.

As an Amplifier with an Input of 0·4V

No Load

The output is within 0·1 per cent for supply voltage variations from 120V to 260V.

Full Load

The range of variation is reduced, but the output is still constant to 0·1 per cent for an input variation from 170V to 260V.

Distortion

This is the same as an amplifier or an oscillator and is largely determined by the output stage.

No Load

Less than 1 per cent, being about 0·25 per cent second harmonic and 0·65 per cent third harmonic.

Full Load

Less than 3 per cent, being about 0·5 per cent second harmonic and 2·5 per cent third harmonic.

Due to the fact that the amplifier is frequency selective the output waveform may be much better than the input and a fairly good sine wave is produced when the input is fed from a square wave source.

Change of Frequency as an Oscillator

No Load

The output frequency changes by about 1c/s when the supply voltage is changed from 140V to 250V.

Full Load

In this case a change of about 1c/s takes place when the supply voltage is changed from 180 to 250V. The effect of changing the load from no load to full load is to change the frequency by 2 to 3c/s.

Effect of Change of Input Frequency as an Amplifier

The amplifier was designed to operate with an input frequency of 1kc/s and, if the frequency departs from this, the performance is not as good. If the input voltage is between 0 and $+10$dB the amplifier will work with the same performance as quoted, from about 900 to 1 100c/s. When the input is reduced below 0dB the amplifier tends to operate as an oscillator when the input frequency departs appreciably from 1kc/s.

These figures show that the performance is quite remarkable since the output voltage is within 0·1 per cent for any input voltage from zero to 4V, from no load to full load and for any supply voltage from 180 to 250V, or even greater on light loads.

Although the amplifier was designed for a fixed frequency of 1kc/s there is no reason why this frequency cannot be changed to any other frequency over a large range, by alteration of the tuned circuit of valve V_1. There

is also no reason why the frequency should not be made variable and, in place of the tuned circuit, an RC network could be used to give the amplifier suitable frequency selective properties. At low frequencies the output from the thermistor bridge contains some third harmonic and it would probably be necessary to include a parallel-T filter in the output of the measuring unit, tuned to this frequency (see ref. 1 and 2).

The apparatus was designed for instrument calibration but obviously, there are a large number of applications where a constant voltage supply of a particular frequency are required. The output frequency can, of course, be made a standard frequency by feeding the amplifier from a suitable frequency source, the resulting output being a supply of constant frequency and voltage. The output voltage may be made any convenient value by changing the ratios of transformers T_2 and T_3, and the amplifier may be used as a low voltage source to feed, for example, a lamp so as to maintain constant light output. This is often difficult with normal d.c. stabilizers owing to the large current and low voltage. By using a high enough frequency any question of flicker can be overcome. If it is desirable to maintain a constant current output in place of the constant voltage the circuit can easily be modified. In this case the primary of transformer T_3 should be placed across a resistor in series with the load and the relay A should be made so that it shorts the output terminals when in the de-energized position.

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New Facilities for Research on Cathode-ray Tubes

The successful production of television cathode-ray tubes on a large scale calls for continuous research into the materials and processes used in their manufacture. Some of the most intriguing problems in this field are provided by the production of the fluorescent screen. For this reason, enlarged facilities, which incorporate a number of interesting new features, have recently been built at the Wembley Research Laboratories of The General Electric Co. Ltd, for intensive work on screening problems.

There are several reasons for increased research activity along these lines at the present time. There are, of course, the aims of the manufacturer to reduce the cost of the screening processes, to use better materials in those processes and to provide cheaper cathode-ray tubes. Then, also, the standards of screen quality required have risen considerably during the last few years. The viewer has become accustomed to larger screens that are completely free from defects. Such characteristics as brightness and picture quality are also continually being improved. As screen sizes increase, these requirements become more difficult to meet. Clearly, any increase in screen area also increases the chances of obtaining a screen defect. Further, not all screening processes used for making existing tubes can be used for the larger sizes without modification. Some of the properties, such as the viscosity and surface tension of the materials used, are critical, so that the process may have to be re-examined before it can be applied to the manufacture of larger tubes.

The development of 21in and 24in screens for future manufacture has made it necessary to increase the size and scope of the research facilities required for this work. Such extensions are now able to accommodate the larger tubes themselves and the greater sizes of the experimental batches to be processed. They will enable large scale experiments to be carried out for testing both the methods and the materials used for screening the tubes. Further work in the new laboratories is devoted to the investigation of more fundamental aspects of filming and screening processes. Among these are investigations into the increased screen efficiency, less tendency towards electron burn, improved colour characteristics, or a combination of these properties.

During the manufacture of the screen, it is vitally important that no unwanted impurities enter the cathode-ray tube bulb or the materials used for screening. As little as 1 part per million of copper, for example, can adversely affect the fluorescent properties of some powders, while even one minute particle of dust would cause a screen defect.

One of the primary considerations in designing the new screening rooms has therefore been the provision of a clean atmosphere. Filtered hot and cold air are brought in through two ducts and mixed to give an atmosphere of the required temperature. This degree of temperature control will enable experiments to be carried out on the effect of temperature on the various screening processes used. Later work may also include the analysis of samples taken from the atmosphere, so that the effect of atmospheric conditions in general (including temperature, humidity and pollution) can be gauged.

Although atmospheric conditions are easily controlled in the laboratory, some of the equipment used there may be open to the atmosphere. In the factory, on the other hand, the corresponding automatic equipment used for mass production would be completely sealed and thus more independent of atmospheric conditions. The overall conditions of cleanliness in the laboratory will therefore approximate closely to those easily achieved in the factory itself.

The development of a new manufacturing process can be broadly divided into two parts, the technique itself and the materials to be used in it. A fluorescent screen is prepared in two stages, known respectively as screening and filming. In the former, the fluorescent powder is allowed to settle on to the inside of the glass bulb through a cushioning liquid. All excess liquid is then allowed to drain off by decanting. Since the phosphor screen at this stage has a granular structure, it is necessary to bridge the gaps by covering the powder itself with a thin skin or foil before the reflecting aluminium coating is applied by evaporation. In this process, known as filming, a thin film of an organic liquid is made to cover the phosphor in one of several ways. For example, the irregularities in the screen structure of the phosphor can be filled with water, which is then frozen. A solution of the film-forming material in a volatile solvent is then made to flow over it and the solvent removed by evaporation. After the film has completely solidified, the temperature is raised, the ice melted and the resulting water dried out of the screen by evaporation.

Alternatively, in the flow filming method, after filling in the structure of the phosphor screen with water, a solution of the film-forming substance may be allowed to flow over it. The film is then dried out as before.

In yet another method, the flotation process, the film is formed on the surface of a water pool covering the screen. This is achieved by dropping a small quantity of a solution of the film-forming material, in a volatile water-insoluble solvent, on the surface of the water and allowing it to spread. When the film has set, the water is syphoned off or decanted away and the film thereby deposited on the screen. Any residual water held in the screen can then be removed by evaporation through the film.

Experimental work on both the flow filming and the flotation filming processes is in progress at the present time.

Running-Voltage/Current Characteristics of Some Glow-Discharge Tubes

By F. A. Benson*, M.Eng., Ph.D., A.M.I.E.E., M.I.R.E, and G. Mayo*, B.Eng.

Typical running-voltage/current characteristics of nine types of recently developed or newly designed glow-discharge tubes are presented and discussed. It is concluded that the kind of gas filling is a most important factor in determining the shape of such characteristics and hence the tube behaviour. Some information is also given about running-voltage drifts which occur after switching on a tube and after changing the tube current.

DETAILED investigations have been carried out during the past few years by several independent experimenters to determine the characteristics and limitations of certain glow-discharge voltage-regulator tubes[1-7]. A number of new types have been produced fairly recently and many of the early types have been modified or redesigned in an attempt to obtain more stable characteristics. Some detailed measurements have been made on several of these tube types, namely, 90C1, 150B2, KD63, QS70/20, QS75/60, QS83/3, QS92/10, G400/1K and QS150/15. Typical running-voltage/current characteristics of these tubes are presented and discussed in this article and some information is given about initial drifts in running voltage and drifts which occur on changing tube current.

The gas filling seems to be a most important factor in determining the shapes of the running-voltage/current and other characteristics and hence the tube behaviour.

Measurements

Each tube was operated in turn from a stabilized variable voltage supply through a suitable series resistor. A meter in the cathode lead was used to measure tube current. Decade resistance boxes across the tube stepped down the running voltage so that it could be recorded accurately by means of a potentiometer.

After the initial drift was complete the running voltage was measured over the specified current range both for increasing and decreasing currents. In cases where hysteresis was present in the characteristic, readings were taken very close together to determine the exact shape of the curve. Some drift in running voltage was noticeable at each change of current and this was most serious at the higher currents as might be expected from previous work on initial drifts[4]. In all cases, drifting was allowed to continue until readings were steady. Running-voltage/current characteristics were also observed on an oscillograph at a frequency of 20c/s using a method previously described[8] and some interesting oscillograms were collected.

Experimental Results

Typical running-voltage/current characteristics are shown in Figs. 1 to 9.

Drifting of running voltage was always opposite in sign during increasing and decreasing current changes. In the cases of types QS83/3, 90C1, QS92/10 and QS150/15 the initial drifts were small and complete in less than 3 minutes and the drifts at each current change were also very small. The initial drift for the 150B2 tube is complete in about 5 minutes. The G400/1K tubes have rather large and prolonged drifts, while the majority of KD63 tubes

show initial drifts of about 20 minutes' duration, and give random voltage fluctuations indefinitely. The running voltage of QS75/60 tubes drifts for 3 to 5 minutes after a change of current and there is appreciable drift in the case
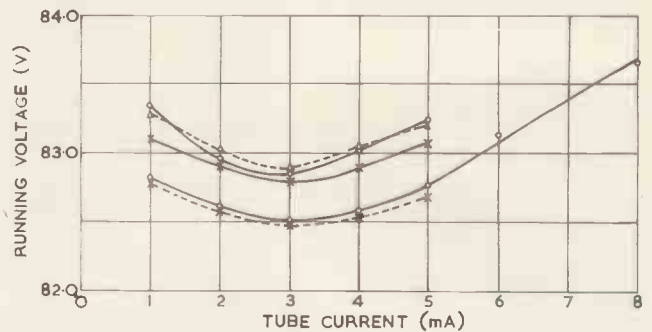

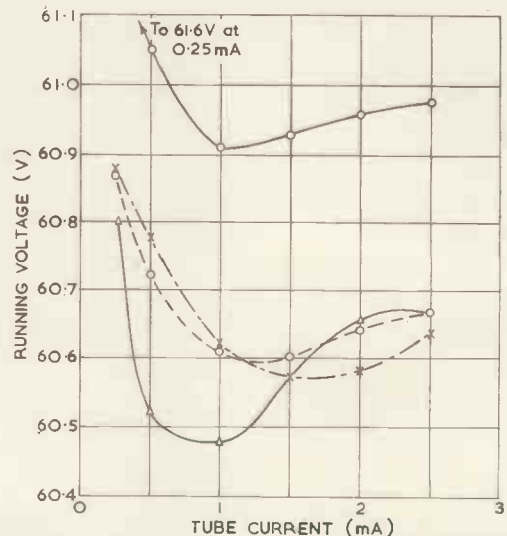Fig. 1. Typical running-voltage/current characteristics for tubes type QS83/3

Fig. 2. Typical running-voltage/current characteristics for tubes type KD63

of QS70/20 tubes when the current is changed, although the initial drift is small and the running voltage becomes stable in less than 3 minutes.

Tube types QS83/3, QS75/60 and QS70/20 are known to contain only neon with a small percentage of argon. It is interesting to see from Figs. 3 and 7 that the characteristics of two of these types, namely QS70/20 and QS75/60, are either straight lines or very nearly linear. The low-current tubes type QS83/3 have V-shaped charac-

teristics, but this is due to the fact that the specified current range is at the low end of an otherwise straight curve. This is clearly seen on Fig. 1 where one tube has been over-loaded and the curve plotted up to a current of 8mA. Some high-current neon tubes show this phenomenon at very-low currents. These results seem to suggest that the KD63 and 90C1 types, whose characteristics are shown in Figs. 2 and 4 respectively, contain only neon and argon.
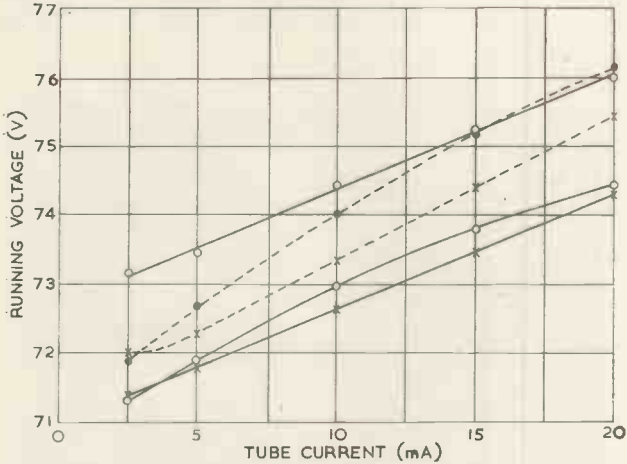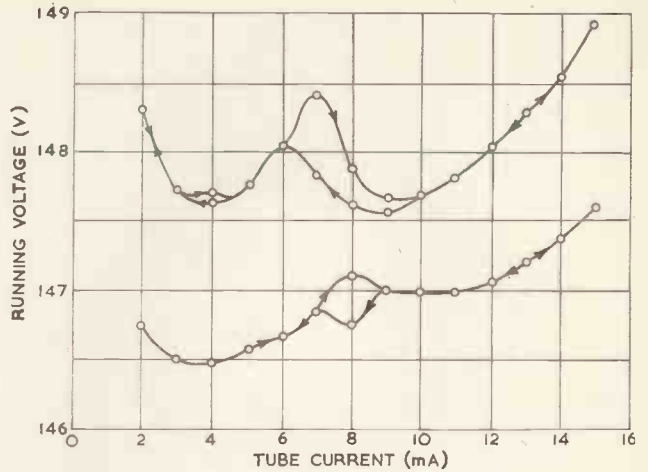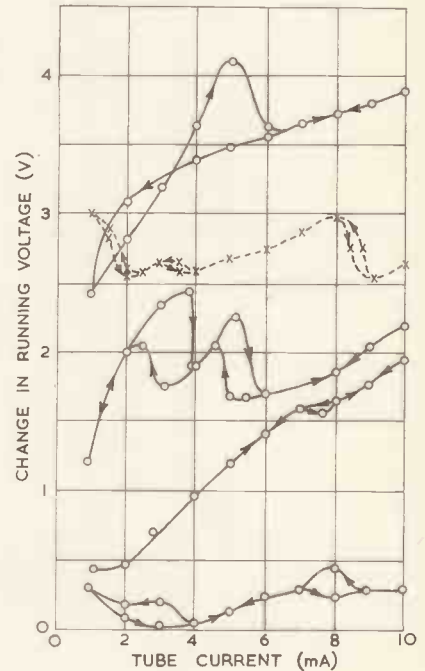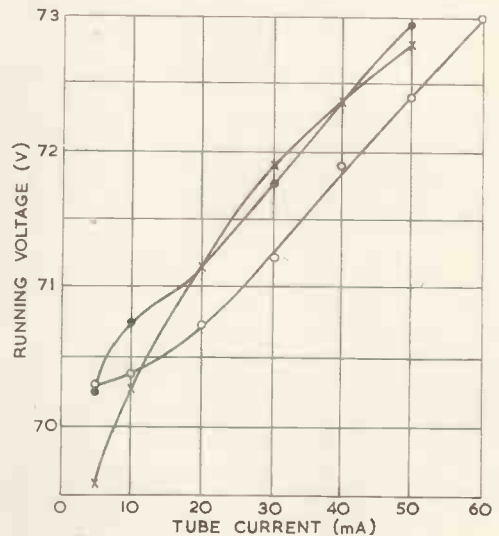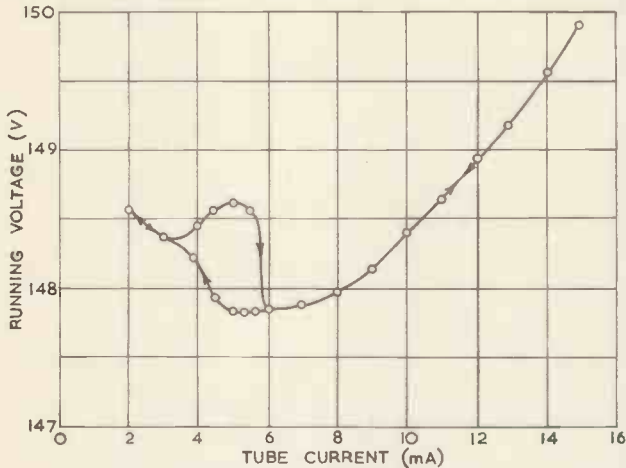

Fig. 3. Typical running-voltage/current characteristics for tubes type QS70/20
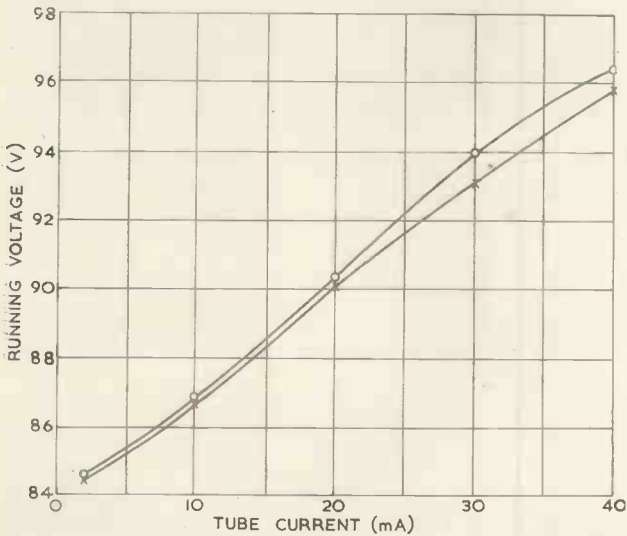
Fig. 4. Typical running-voltage/current characteristics for tubes type 90C1

Fig. 5(above). Typical running-voltage / current characteristics for tubes type 150B2

Fig. 6(right). Typical running-voltage / current characteristics for tubes type QS92/10

Fig. 7(below). Typical running-voltage / current characteristics for tubes type QS75/60

Tube type QS150/15 is known to contain only helium with a small percentage of argon, while type QS92/10 contains helium and neon with a small quantity of argon. Tubes containing helium show hysteresis (see Figs. 6 and 8) and there are rapid jumps in the characteristics coinciding with changes of cathode-glow area. It seems to follow from Fig. 5 that tube type 150B2 also contains only helium and argon.

It should be noted from Fig. 1 that QS83/3 tubes of recent design are remarkably similar and that the regulation is small. Difficulties arise in specifying regulation too because of the V-shape of the curve. Fig. 2 shows that the regulation of KD63 tubes is good and the variations from tube to tube are small. Fig. 9 shows that the G400/1K

tube possesses excellent regulation properties in its specified current range of 2 to 4mA. It will be seen that some of the other types of tubes have large regulations.

The oscillograms of Fig. 10 also show quite clearly the differences in the shapes of the characteristics of the 150B2 and 90C1 tubes. Comparisons of such dynamic characteristics obtained on the oscillograph at a frequency of 20c/s show that there are similarities between corresponding curves. The similarities are not, however, exact.

Fig. 8. A typical running-voltage/current characteristic for a tube type QS150/15
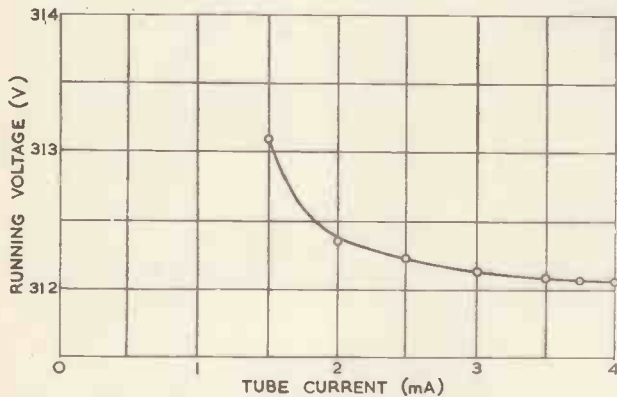
Fig. 9. A typical running-voltage/current characteristic for a tube type G400/1K

Discussion of Results

The marked differences between the characteristics of tubes containing neon and those containing helium are interesting. The differences between such tubes are not, however, limited to the running-voltage/current curves. It has, for example, previously been reported, in a separate paper[9] dealing with the effects of ambient-temperature variations on most of the above types of tube, that the gas filling influences greatly the shape of the running-voltage/temperature curve of a tube and is an important factor in deciding whether a given tube will show a positive or a negative temperature coefficient. It has now been established that most tubes containing neon and argon with no helium have only negative temperature coefficients and the running-voltage/temperature curves are all linear or nearly so. Tubes which contain helium, however, exhibit

minima in their running-voltage/temperature characteristics. There is also some evidence that the kind of gas filling in a glow-discharge tube is one important factor in governing the shape of its impedance-frequency characteristic.

The results obtained are difficult to explain. They seem to suggest, however, that there are larger quantities, or different kinds, of impurities in tubes containing helium. From the curves of Fig. 6 it would appear that no very special precautions are taken in preparing and cleaning the cathode surface of QS92/10 tubes.
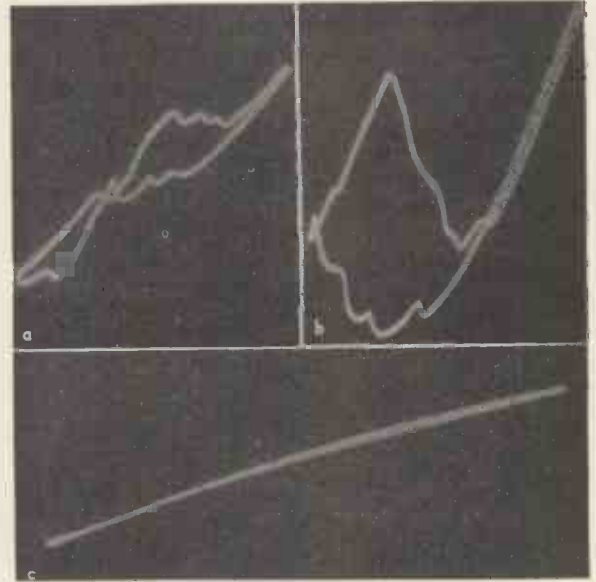

Fig. 10. Typical running-voltage/current characteristics of glow-discharge tubes as observed on an oscillograph at a frequency of 20c/s

(a) and (b) 150B2 tubes operating at a d.c. of 10mA and with an estimated a.c. swing from 5 to 15mA

(c) 90C1 tube operating at a d.c. of 20mA and with an estimated a.c. swing from 1 to 40mA

It should be pointed out that the measurements described in this article were carried out prior to April 1954.

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A Magnetic Tape Recorder for Electrophysiology

By P. E. K. Donaldson,* M.A.

A simple apparatus is described, using readily available commercial components, for recording an electrical signal continuously for a period of up to 20 minutes. The usable dynamic range is 60dB and the frequency response 0 to 2kc/s. This spectrum is useful in electrophysiological work, and it is hoped that the recorder may find application in other fields.

THE usual method of recording the result of an electro-physiological experiment is to photograph with con-tinuously-moving film the screen of a cathode-ray oscillo-scope. The method has the advantage of good fidelity and the apparatus is simple. On the other hand it is not possible quickly to re-examine a piece of record which has just been secured. Further, there occur in physiology highly significant events which it may not be possible to evoke with a stimulus at a particular time. Film being quite expensive, there is therefore a risk that such an event will be missed because the camera was not switched on, or, at the other extreme, that yards of film will be exposed in valueless record. Clearly, there are occasions in which it would be helpful to have an intermediate stage of quick-access storage, using a medium which is not consumed in the process, and an obvious choice lies in magnetic tape.

Frequency Response Required

Generally speaking, the fastest event with which one has to deal in electrophysiology is the mammalian action potential. To reproduce the waveform of this accurately requires the inclusion of frequencies up to 10kc/s. Fortunately, for the kind of work for which this recorder is used, accurate reproduction is not necessary, and a response up to 2kc/s is sufficient. The action potential lasts about half a millisecond, so one is preserving the fundamental frequency and losing the harmonics. A typical slow bio-electric potential is the amphibian ventral root potential, which may last up to half a second. Bearing in mind the difficulties encountered with long time-constant a.c. coupled circuits due to paralysis times, it was felt advisable to aim at an instrument going right down to d.c.

Sensitivity Required

The usual procedure for electro-physiological recording in this laboratory is to use a pre-amplifier and a main amplifier, the main amplifier being part of the oscillo-scope. It is therefore convenient if the recorder can be connected to the output of the pre-amplifier, in parallel with the oscilloscope, and it must be sufficiently sensitive to be fully loaded by the order of output amplitude that the pre-amplifier will give. Very roughly, one encounters

bioelectric potentials in the range 50μV to 50mV. Taking the geometric mean as a typical signal to be recorded, gives 1½mV. The pre-amplifiers used in this laboratory have a gain in the region of 750, so the typical signal enters the recorder at just over 1V. The 50mV signal will require thirty-two-fold attenuation, and the 50μV signal will emerge from the recording process sufficiently recognizable if it is 3 to 4 times the peak-to-peak noise added by the re-corder. This noise should therefore be equivalent to a 10mV signal at the recorder input, or less.

Other Considerations

From the point of view of cost, the machine should use, if possible, a standard type of tape deck and ordinary com-mercial tape. The tape speed should be as low as pos-sible, in order to secure the maximum running time. Non-linearity distortion should be held down to such a point as to be imperceptible by direct visual inspection of known waveforms on the cathode-ray oscilloscope.

Design

After some preliminary experiments, it appeared that a

Fig. 1. The recording channel
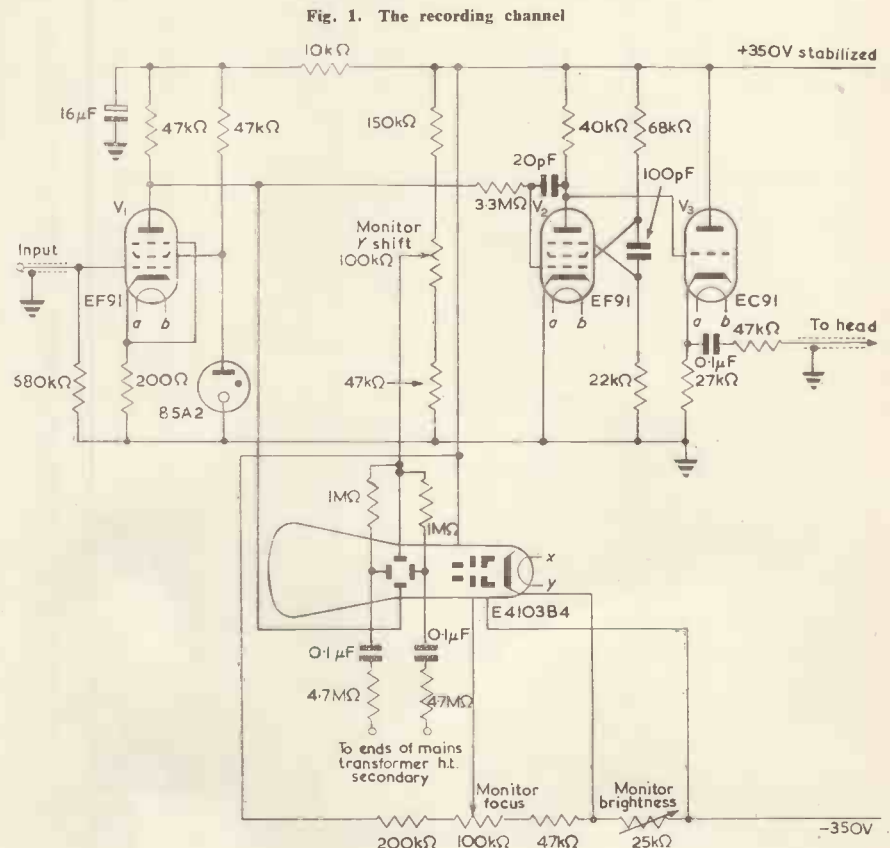
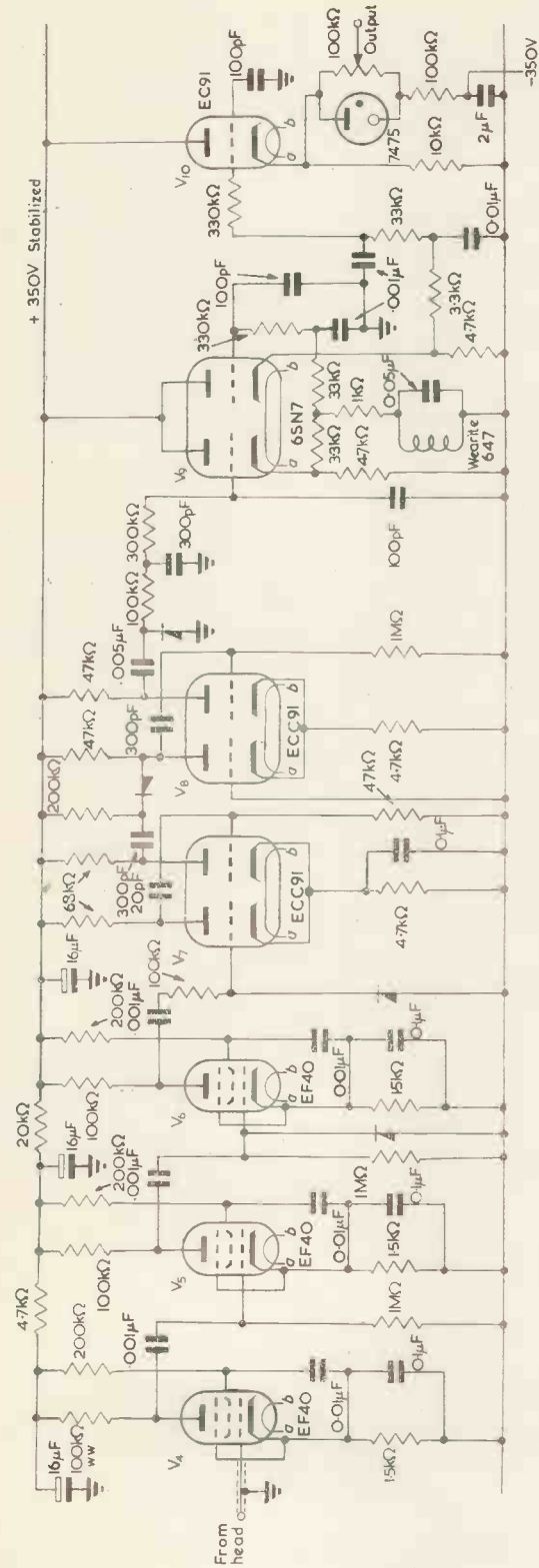* Physiological Laboratory, Cambridge.

Fig. 2. The playback channel

satisfactory approach lay in the use of frequency modu-
lation. A tape recorder using this system has been des
cribed by Molyneux[1] and the instrument to be described
is based on his circuit. Molyneux's recorder is for
cardiography, and an upper frequency response of 100c/s
permits the employment of quite a low carrier frequency,.
well within the normal range of a conventional tapedeck.
To handle a modulation frequency of 2kc/s, the carrier
has to be at least five times this if the problem of filtering
modulation from carrier after playback is not to be too
great. Moreover, for good signal-to-noise ratio the devia-
tion should be wide, but this aggravates the problem of
filtering during the extreme downward swings of carrier fre-
quency, unless the mean carrier is made yet higher. Yet this
is not easy, because of the record-playback head losses at
such frequencies, and there is self-demagnetization of the
tape due to the short-magnet effect unless the tape speed is.
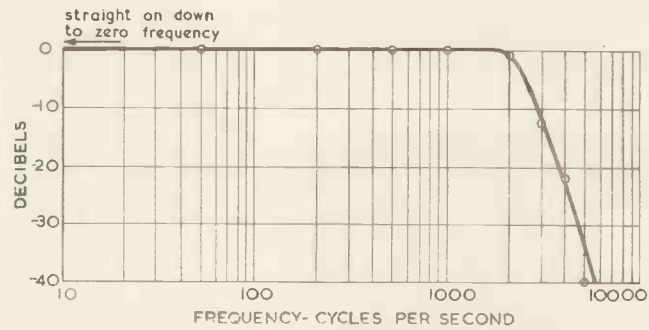

Fig. 3. Measured frequency characteristic of low-pass filter and of the complete apparatus

high. The compromise values adopted are: tape speed
12in/sec. Mean carrier 15kc/s. Deviation 5kc/s, maxi-
mum. With this arrangement the amplitude of the signal
received back from the tape is extremely erratic, but it never
disappears altogether, and with a lot of amplification and
very severe limiting it can be made manageable.

Description

Referring to Fig. 1, the recording channel, a stage of
d.c. amplification feeds the built-in monitor tube (supplied
with a sinusoidal 50c/s time-base) and the v.f.o., which is
a Miller-transitron with a very short flyback time. There
is then a buffer stage, and thereafter the signal passes
through screened cable to the recording head via the re-
cording resistance. No h.f. bias is required, but h.f. erase
power is supplied to the erase head in the normal manner.

Fig. 2 shows the playback channel. There are 3 stages
of amplification, after which the signal is passed to V_{7a},
where negative-going excursions of the wave are clipped
by the crystal diode, and positive going excursions by grid
current in the valve. An amplified, limited, square wave
train appears at the anode which is differentiated, then
amplified by V_{7b}. Negative-going pips only are passed by
the series crystal diode to trigger the flip-flop V_8. Thus
the output at V_{8b} anode is a chain of identical positive-
going pulses, whose spacing depends on the modulation.
If these are passed through a low-pass filter, the modu-
lation is regained.

The filter performance is shown in Fig: 3, and this is
the frequency characteristic of the apparatus as a whole.
It will be seen that the output is well maintained up to
2kc/s, after which it falls steeply. Only one inductor is
used, and this is a standard commercial component, a

Wearite type 647. The filter is cathode-followed out to a simple arrangement for setting the d.c. bias of the output to zero.

Performance

Using a Wright & Weare tapedeck with a special pulley on the motor shaft to raise the tape speed to 12in/sec, the apparatus has a substantially flat frequency response from zero to 2kc/s. Maximum deviation is achieved with an input amplitude of 1V peak-to-peak. Signals undergo amplification over the recording process—about 6dB, and it should be remembered that there is also a reversal of polarity. If the machine be loaded fully with a sine wave input at any frequency between zero and 2kc/s, and the output inspected on an oscilloscope, there is no perceptible non-linearity distortion. At the time of writing, the apparatus has been in use for 6 months and no faults have developed.

Conclusions

The need has been suggested for an intermediate storage system in electrophysiological work, and the requirements of such a system outlined. A machine which fulfils these requirements has been described.

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New Applications for Photocells in Collieries

Mechanization and the modern trend towards fully automatic supervisory and control systems have led to a much wider use in industry of the photocell. In collieries, in particular, photo-eelctric equipment is now finding many new applications and recent examples include such diverse functions as cage-positioning, checking the closing of skip doors, indicating slack rope when a cage is resting on keps, automatically controlling artificial lighting, and providing a warning system for an aerial ropeway. In all these instances the photo-electric equipment makes for safer, more efficient and more economical working.

The following are typical installations and have been made with standard photo-electric equipment supplied by the General Electric Co. Ltd.

Cage-positioning

At Llay Main Colliery in North Wales, near Wrexham, a photo-electric signalling system has recently been installed to speed up coal-winding operations. When a cage reaches the unloading position at the top of the shaft, a lug on the side of the cage intercepts a light-beam shining on a photocell. This at once causes an indicator lamp to light in the winder house, so that the winding engine operator is able to check the cage at the right level. Though the shaft is one of the deepest in the country (it is 1005 yards deep) and deck-changing is employed (that is the two decks in the cage are unloaded successively at the one level so that when one deck has been unloaded the cage has to be raised and repositioned before the other deck can be unloaded) 45 runs an hour are obtained using the photo-electric indicator as a cage-positioning guide.

Both the cages used in the main shaft accommodate four mine cars, two on the top deck and two on the lower deck. The empty cars are loaded into the cages at the top of the shaft, sent down, filled and then returned to the top. The mine cars run on rails and the cages have to be positioned so that the rails in the cage itself are in line, to within ½ inch, with the rails on the landings.

Until recently both decks of the cages were unloaded simultaneously on two different levels at the top of the shaft. This system was quick, but necessitated two separate loading and unloading levels at the top of the shaft, each of which had to be staffed individually. Accordingly it was decided to do away with the lower of these two levels and introduce a deck-changing system, in which the two decks would be unloaded successively at one level. This system, however, necessitates the cage being repositioned after one deck has been unloaded so that, in effect, the cage must be positioned twice under the new system where it had only to be positioned once with the old system. This would have led to a considerable increase in the time spent in positioning the cage with a corresponding large drop in output if an improved positioning system had not been introduced.

A photo-electric relay and associated lamphouse have been installed on the side of the shaft, the beam from the lamphouse falling on the photocell. The signal resulting from this is amplified and keeps a relay in the "open" position. A rubber lug is mounted on the side of the cage in such a position that it will, as the cage rises, intercept the light beam just as the deck of the cage comes flush with the approach rails. As soon as the light beam is interrupted, the photo-electric signal ceases and the relay closes. This completes a circuit which incorporates an indicator lamp located in the winding shed in front of the winder operator. The indicator lamp is illuminated and the operator at once stops the winder, knowing that the cage is now in position for unloading and loading.

After the two filled wagons have been removed from the first deck and replaced with two empty wagons, the banksman at the head of the shaft presses a button which gives a code ring on a bell in the winding shed. The winder operator then sets the winder moving again and the cage is drawn slowly up until a second rubber lug, mounted directly below the first on the side of the cage, interrupts the beam from the lamphouse to the photocell and actuates the indicating lamp once again. This second lug is located so that, when this happens, the second deck is flush with the approach rails and the remaining two filled wagons can therefore be removed and replaced with two empty wagons. After this has been done, the operator at the head of the shaft rings through and the other cage is drawn up as the first cage descends. a similar photo-electric positioning system being used on the other side of the shaft.

A slack rope alarm

At Thoresby Colliery, Edwinstowe, Nottinghamshire, where keps are used for locating the cages, photo-electric equipment has now been installed to ensure that the winding engine will not start to lower the cage until the keps. on which the cages rest while at the top of the shaft, have been withdrawn. If the winding engine paid out several feet of slack rope with the keps still in position, and the keps were then withdrawn, the cage would immediately drop straight down and probably snap the rope.

A photocell and lamphouse are aligned in such a way that metal shutters mounted on the winding drum interrupt the light beam as the drum rotates. When a cage reaches a bank level it actuates a limit switch mounted at the side of the shaft. This brings the photo-electric system into operation and from then on. if the beam is interrupted, an alarm bell rings at once. If therefore the winding engine starts to lower while the cage is resting on the keps, the shutters, as they revolve with the drum and intercept the beam, automatically initiate the alarm. The operator then knows that he must not withdraw the keps until the slack has been taken up again.

Ensuring that skip doors are shut

The Electrical Engineer's Department at Thoresby Colliery has also devised a photo-electric system which prevents the skips entering the shaft if the skip doors are not fully shut. This obviates any risk of a door falling open as the skip descends the shaft.

The skip door when shut is held in position by a catch which drops home. When the door is open and the catch is lifted, a light located on top of the skip comes on and remains on until the catch drops home again. The photo-electric equipment is installed at the top of the shaft so that it is directly opposite this light when the skip is at the top. When a light shines on this photocell the resulting signal is amplified and operates a relay which illuminates a "skip door open" signal in the banksman's cabin and in the winding engine house. As soon as the skip door has shut and the catch has dropped home. the lamp on the skip goes out and the "skip door open" signals are switched off.

The Response Functions and Vector Loci of First and Second Order Systems

By David Morris*, D.Sc., A.M.I.E.E.

(Part 4)

Further Types of Second Order Response Functions and Vector Loci

In this concluding article passive and active second order systems are considered which have a finite response at zero frequency and a quadrature zero-limit at infinite frequency. It is further shown that all second order response loci may be expressed in terms of two basic loci.

Fig. 18 illustrates two passive second order systems that have the same form of response. In Fig. 18(a), if the input is the voltage V_1, and the output is the open-circuit voltage V_2, we may write for sinusoidal conditions:

$$\text{Response} = V_2/V_1 =$$

$$\frac{1/j\omega C + R}{1/j\omega C + R + j\omega L} = \frac{1 + j\omega CR}{1 + j\omega CR + j^2\omega^2 LC} \quad \cdots \cdot (35)$$

* University College of North Wales, Bangor.

Fig. 18. Two passive second order systems

Set $T_0 = 1/\omega_0 = \surd(LC)$, and $Q = (1/R)\surd(L/C)$, and also let $\gamma = $ relative frequency $= \omega/\omega_0 = \omega T_0$. Then:

$$V_2/V_1 = \frac{1 + j\gamma/Q}{1 + j\gamma/Q + j^2\gamma^2} = \frac{Q + j\gamma}{(1 - \gamma^2)Q + j\gamma} \quad \cdots \cdot (36)$$

The same expression serves to describe the response Y/X of the system of Fig. 18(b), if we set $T_0 = \surd(M/K)$ and $Q = (1/B)\surd(MK)$, and use has been made of this fact in assessing the influence of resilience between motor and load in servo-mechanisms[6].

Further examples of systems having similar responses are the two active systems of Fig. 19. A servo-mechanism damped in accordance with the relative velocity between the directing and responding members, as illustrated in Fig. 19(a), has a response as given by equation (36), provided that the time-lag in the amplifier is negligible. In practice, the measure of relative velocity is more frequently achieved as " error derivative " by use of a differentiating circuit as shown in Fig. 19(b). If $R_1 \gg R_2$, the response Y/X is described approximately by a function of the type in equation (36) except at the very highest frequencies.
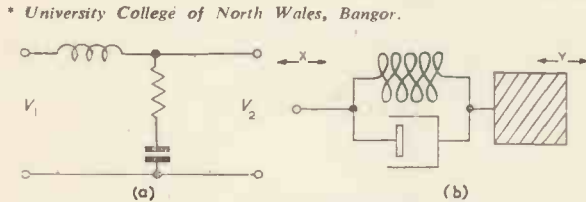
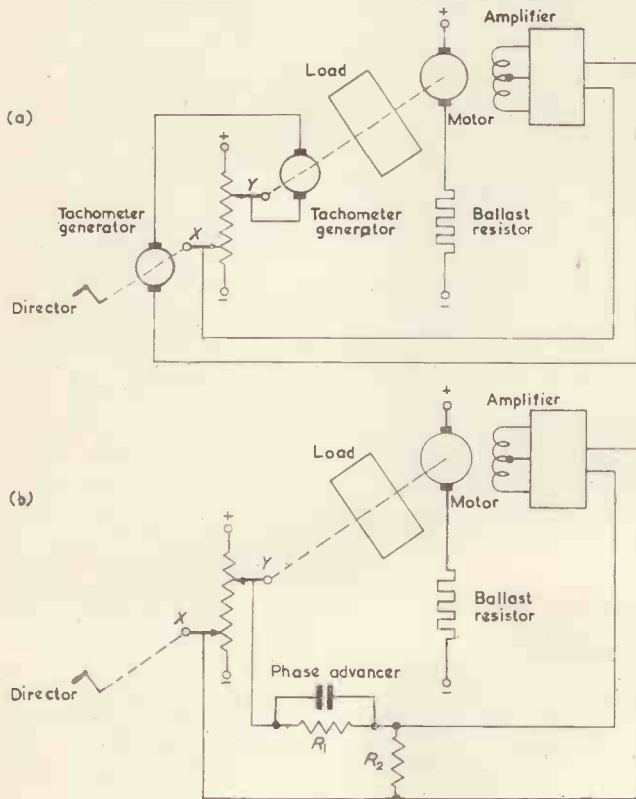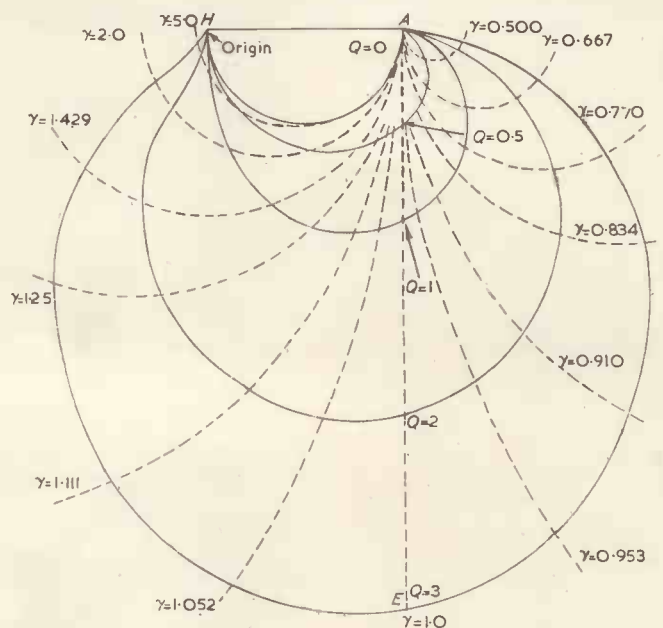Fig. 19. Two active systems having second order responses

Fig. 20. The cordiform loci $\dfrac{1 - j\gamma/Q}{1 - j\gamma/Q - j^2\gamma^2}$ for various values of Q
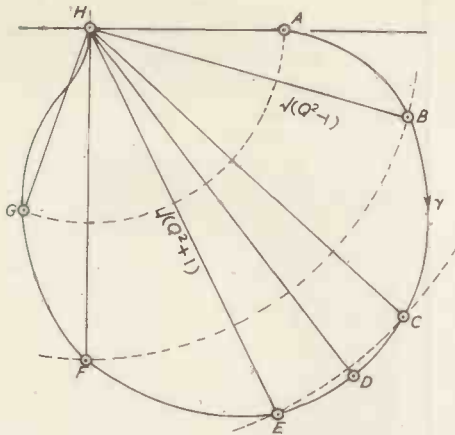
Fig. 21. Special points on the cordiform locus $\dfrac{1 - j\gamma/Q}{1 - j\gamma/Q - j^2\gamma^2}$

$V_2/V_1 = Q_1(j\gamma)$ $V_2/V_1 = Q_2(j\gamma)$ $V_2/V_1 = Q_3(j\gamma)$

$V_2/V_1 = Q_{12}(j\gamma)$ $V_2/V_1 = Q_{13}(j\gamma)$ $V_2/V_1 = Q_{23}(j\gamma)$

Fig. 22. Four-terminal networks with second order transfer functions

The Vector Loci for the Systems of Figs. 18 and 19

The behaviour of the response V_2/V_1, (or Y/X), may be represented by a vector plot of the function (36) as γ varies from zero to infinity. The loci are shown in Fig. 20 for values of Q equal to 0, 1, 2 and 3. These cordiform loci are the mirror images of the loci described in the previous article, the axis of reflection being the line $V_2/V_1 = \frac{1}{2}$.

The Q-value appropriate to any locus is easily determined by inspection, because when the response has unity real part, the quadrature response is Q times the zero-frequency response.

Further properties of the cordiform locus are illustrated in Fig. 21, which is drawn for the particular case $Q = 2$. For the responses of the systems described in the present article, the origin is placed at the " saddle " of the cordiform loci. For this position of the origin, the conditions for maximum mag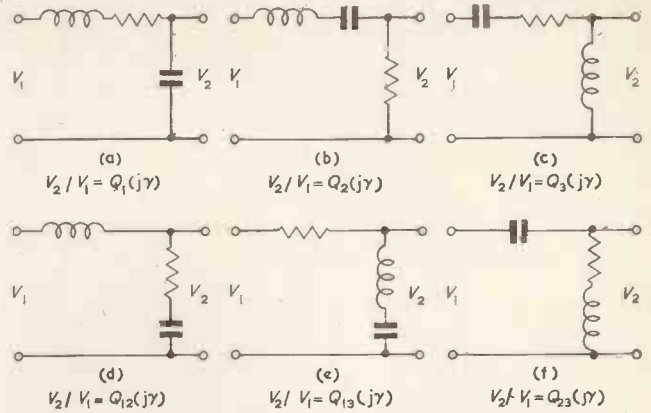nitude of response are given by rather cumbrous expressions. If γ_m is the relative frequency and ϕ_m is the phase-lag for this condition, we have:

$$\gamma_m{}^2 = Q\sqrt{(Q^2 + 2)} - Q^2 \quad \dots \dots \quad (37(a))$$

$$|V_2/V_1|_{max}{}^2 = \frac{1}{1 + 2Q^3\sqrt{(Q^2+2)} - 2Q^2(Q^2+1)} \quad (37(b))$$

$$\cot\phi_m = Q(1 - \gamma^2)^2 - 1/Q \quad \dots \dots \quad (37(c))$$

There are other points on the locus which are described by much simpler expressions, and these are listed in Table 3. The data given in Table 2 of Part 2 are also applicable to this locus, provided that appropriate account is taken of the change of origin, etc.

Relationships Among the Second Order Response Functions

Fig. 22 depicts six four-terminal networks having transfer functions with second order denominators. The circuits (a), (b) and (d) have already received treatment in these articles. The circuits do not require completely individual

TABLE 3

Details of Special Points on the locus of $\dfrac{1+j\ \gamma/Q}{1+j\ \gamma/Q + j^2\gamma^2}$

POINT	γ^2	DEFINITION OF POINT	MAGNITUDE^2	$-$Tan θ
A	0	Zero frequency point Response magnitude unity In-phase response unity	1	0
B	$1 - \dfrac{2}{Q^2}$	Response magnitude $\sqrt{(Q^2-1)}$	Q^2-1	$\dfrac{(Q^2-2)^{3/2}}{3Q^2-2}$
C	$\dfrac{Q^2}{Q^2+1}$	Response magnitude $\sqrt{(Q^2+1)}$	Q^2+1	$\dfrac{Q^2}{2\sqrt{(1+Q^2)}}$
D	See Eqn. 37(a)	Response magnitude maximum	See Eqn. 37(b)	See Eqn. 37(c)
E	1	Response magnitude $\sqrt{(Q^2+1)}$ In-phase response unity	Q^2+1	Q
F	$\dfrac{Q^2}{Q^2-1}$	Response magnitude $\sqrt{(Q^2-1)}$ Quadrature point	Q^2-1	∞
G	2	Response magnitude unity	1	$\dfrac{Q.2\sqrt{2}}{2-Q^2}$
H	∞	Infinite frequency point	0	0

treatment, as their transfer functions can all be depicted by either the circular locus or the cordiform locus.

For the investigation of the inter-relationships among these functions and loci, we define certain quadratic functions of any variable x as follows:

$$\mathbf{Q}_1(x) = \frac{1}{1 + x/Q + x^2} \quad \cdots \cdots \cdots \text{(38(a))}$$

$$\mathbf{Q}_2(x) = \frac{x/Q}{1 + x/Q + x^2} \quad \cdots \cdots \cdots \text{(38(b))}$$

$$\mathbf{Q}_3(x) = \frac{x^2}{1 + x/Q + x^2} \quad \cdots \cdots \cdots \text{(38(c))}$$

$$\mathbf{Q}_{12}(x) = \frac{1 + x/Q}{1 + x/Q + x^2} \quad \cdots \cdots \text{(38(d))}$$

$$\mathbf{Q}_{13}(x) = \frac{1 + x^2}{1 + x/Q + x^2} \quad \cdots \cdots \cdots \text{(38(e))}$$

$$\mathbf{Q}_{23}(x) = \frac{x/Q + x^2}{1 + x/Q + x^2} \quad \cdots \cdots \cdots \text{(38(f))}$$

where the subscripts in the function symbols denote the terms from the denominator that are used in the numerator. The following relationships are then apparent:

$$\mathbf{Q}_1(x) + \mathbf{Q}_2(x) + \mathbf{Q}_3(x) = \mathbf{Q}_{123}(x) = 1 \quad \cdots \text{(39(a))}$$
$$\mathbf{Q}_2(x) = \mathbf{Q}_2(1/x) \quad \cdots \cdots \cdots \text{(39(b))}$$
$$\mathbf{Q}_3(x) = \mathbf{Q}_1(1/x) \quad \cdots \cdots \cdots \text{(39(c))}$$
$$\mathbf{Q}_{12}(x) = 1 - \mathbf{Q}_1(1/x) \quad \cdots \cdots \text{(39(d))}$$
$$\mathbf{Q}_{13}(x) = 1 - \mathbf{Q}_2(x) \quad \cdots \cdots \cdots \text{(39(e))}$$
$$\mathbf{Q}_{23}(x) = 1 - \mathbf{Q}_1(x) \quad \cdots \cdots \cdots \text{(39(f))}$$

Hence, using equations (39(c)) to (39(f)), all the functions (38) can be expressed in terms of the functions $\mathbf{Q}_1(x)$ and $\mathbf{Q}_2(x)$ alone. If we set $x = j\gamma = j\omega/\omega_0 = j\omega T_0$, the functions (38) become the transfer functions of the four-terminal networks of Fig. 22.

Geometrical Relationships Among the Second Order Response Loci

The response function for the circuit (e) of Fig. 22 is $\mathbf{Q}_{13}(j\gamma) = 1 - \mathbf{Q}_2(j\gamma)$. The corresponding vector locus can therefore be found by reversing all the vectors in the $\mathbf{Q}_2(j\gamma)$ locus that formed the subject of Part 2 and shifting the origin to the $\gamma = 1$ point, as shown in Fig. 23. The locus is of practical interest, as it also represents the transfer function of the well-known parallel-T null network.

The response function for the circuit (f) of Fig. 22 is $\mathbf{Q}_{23}(j\gamma) = 1 - \mathbf{Q}_1(j\gamma)$. The corresponding vector locus is
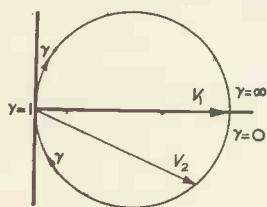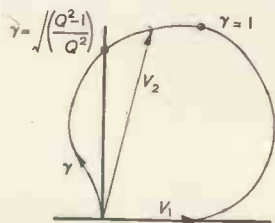

Fig. 23. The locus of $\mathbf{Q}_{13}$ (jγ)

Fig. 24. The locus of $\mathbf{Q}_{23}$ (jγ)

therefore found by reversing all the vectors of the $\mathbf{Q}_1(j\gamma)$ locus discussed in Part 3, and then shifting the origin from the infinite-frequency point to the zero-frequency point, as illustrated in Fig. 24.

The response function for the circuit (c) of Fig. 22 is $\mathbf{Q}_3(j\gamma) = \mathbf{Q}_1(1/j\gamma) = \mathbf{Q}(-j/\gamma)$. The corresponding vector locus is therefore found by reflecting the $\mathbf{Q}_1(j\gamma)$ locus in the real axis, and reversing the direction in which the locus is

traversed for increasing γ, as shown in Fig. 25. This response is of interest in servomechanism theory, as it describes the feedback with respect to displacement derived from a tachometer generator feeding through a circuit such as that of Fig. 22(b) or its equivalent.

The response function for the circuit (d) of Fig. 22 is $\mathbf{Q}_{12}(j\gamma) = 1 - \mathbf{Q}_3(j\gamma)$, in accordance with equation (39(a)). The corresponding vector locus is therefore found by
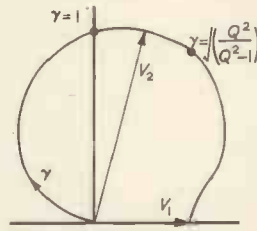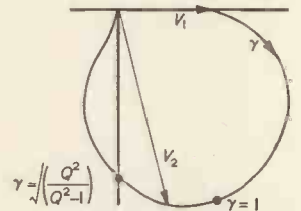

Fig. 25. The locus of $\mathbf{Q}_3$ (jγ)

Fig. 26. The locus of $\mathbf{Q}_{12}$ (jγ)

reversing all the vectors of the $\mathbf{Q}_3(j\gamma)$ locus of Fig. 25, and shifting the origin to the infinite-frequency point, as illustrated in Fig. 26. The locus has already been discussed in detail in connexion with Figs. 20 and 21.

General Conclusion

In this series of articles we have been concerned with first order responses, and with second order responses represented by functions of the general type:

$$\frac{k_1 + k_2 pT/Q + k_3 p^2 T^2}{1 + pT/Q + p^2 T^2}$$

Consideration has been confined to sinusoidal conditions, for which $pT = j\omega T = j\gamma$, and to specific responses in which the coefficients k are either zero or unity. Intermediate values of the coefficients are also possible, but all such responses can be expressed as a circular locus, as a cordiform locus in one of its aspects, or as a combination of these.

The majority of practical systems are of a higher order than the second, but a detailed study of the first and second order systems is worthwhile, because a response function of any order may in principle be expressed as a product of first and second order functions. The determination or combination of these component functions may be difficult in practice, but the mere knowledge that the possibility exists affords an insight into the types of behaviour that may be met.

It is sometimes not possible to express a second order response as the product of two real first order responses (i.e. when $Q > \frac{1}{2}$), and the phenomenon of resonance represents the possibility of a change in kind in passing from first order to second order systems. There are no further such changes in kind when we pass from second order to higher order systems. In higher order feedback systems a change of kind in the form of oscillatory instability is, of course, possible for certain changes in the system parameters, but this possibility is also represented in the second order system when Q becomes infinite or passes to negative values.

REFERENCE
6. Shaft Resilience in Servo-Mechanisms. *Engineering* (Dec. 10, 1954).

Corrigenda

1. In Part 2, the vector in Fig. 11 is drawn for $\rho = -0.4$ and not for $\rho = 0.4$.

2. In Part 3, in the text after equation (34), the reference should be to scales of $\rho = Q(\gamma - 1/\gamma)$ and $1/\rho$. In the penultimate paragraph, the reference should be to Fig. 15 and not to Fig. 17.

A D.C. Coupled Circuit Using Voltage Stabilizing Valves

By G. W. G. Court*, B.Sc., A.M.I.E.E., A.Inst.P.

The use of voltage stabilizing valves as a means of d.c. coupling between different voltage levels is often convenient in electronic circuits. In the circuit described, a chain of such valves has been used to transfer d.c. voltage variations from an initial reference level of 150V positive to a new reference level of 450V negative, with considerably less loss than that which would occur with a resistor chain.

CONSIDER a circuit (Fig. 1) in which a voltage generator e is at a d.c. potential E_0, and is connected in series with a voltage stabilizing valve V_R and a resistor R. The fundamental property of the valve is that, within a specified range of current through it, the voltage drop across it, E_v, is effectively constant. As examples, the VR105 maintains a voltage drop of about 105V, to within 1V, over a current range of 5 to 30mA, and the 85A2 which has an operating voltage spread from 83 to 87V, maintains the stabilized voltage to within 3V, for a current range of 1 to 10mA.
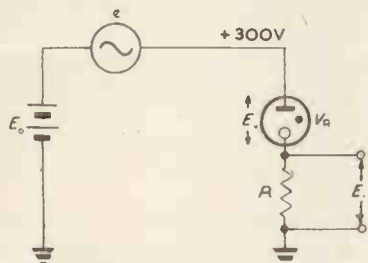
Fig. 1. Basic circuit

Assuming e is initially zero, the voltages across R is E_1, i.e. $(E_0 - E_v)$. If e becomes a value e_1, then the voltage across R becomes $(E_0 + e_1 - E_v)$, i.e. $(E_1 + e_1)$. Thus any change in e is reproduced at the cathode of V_R and the total variation in voltage, at the reference potential E_0, is transferred to a new reference potential E_1.

It is necessary to ensure that the current changes in V_R do not fall outside the specified limits for the valve, and if the changes are not small compared with the operating range, then the change in E_v must be considered. If in the case of a VR105, the current change, for a voltage change at E_0 of e_1, is from 5 to 30mA, then V_R increases by 1V, and the transferred voltage change to the cathode of V_R would be $(e_1 - 1)$.

It is desirable therefore to make R as large as possible, consistent with maintaining the current in excess of the lower operating limit, to keep changes in E_v to a minimum.

* Formerly Dominion Physical Laboratory, Department of Scientific and Industrial Research, New Zealand, now Civil Aviation Administration.

At the same time high values of R keep the static and dynamic loading on E_0 and e respectively, to a minimum, which can be of importance when, as in the example given, the voltage source is the anode circuit of an amplifying valve.

Practical Circuit

In a microwave link it was found convenient to operate the receiver a.f.c. detector circuits and a subsequent d.c. amplifier valve, between 300V positive and earth potential. As a result the a.f.c. control voltage, obtained from the anode of the valve was at a mean d.c. potential of 150V (Fig. 2). The local oscillator of the receiver is a klystron
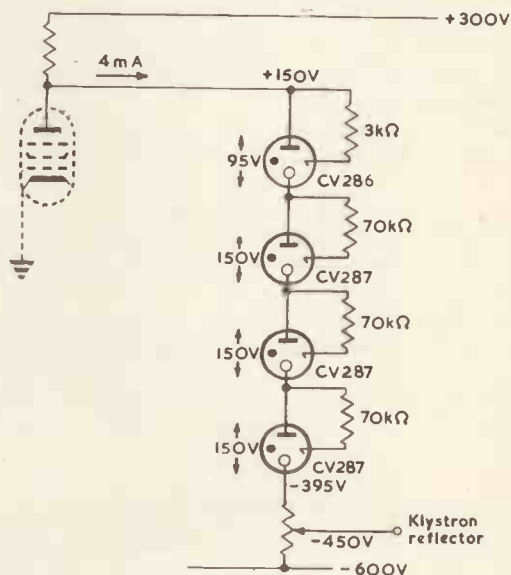

Fig. 2. Practical circuit

and it is highly desirable to operate the main body of it, and thus the resonator, at earth potential. This avoids insulation difficulties and possibility of electric shock during maintenance. The reflector potential is then about 450V negative, and the a.f.c. control voltage must be transferred to this reference potential, i.e. about 600V below the anode potential of the amplifier valve V_1.

If a resistor chain is used between V_1 and a negative potential of 600V, approximately 150/750, or 1/5 of the a.f.c. control voltage may be applied to the klystron reflector. However, if a chain of voltage stabilizing valves is used, as shown in Fig. 2, then practically the complete variation of V_1 anode voltage is realized at the top of the potentiometer connected to the end of the chain. The potentiometer is necessary to allow variation of the d.c. potential applied to the klystron reflector and thus provide the differences in reflector voltage required for different valves. It also provides compensation for slight differences in operating voltages of stabilizing valves. In the circuit given the reflector potential of $-450V$ is obtained with the potentiometer suitably adjusted and about three-quarters of the a.f.c. control voltage, available at the top of the potentiometer, or the anode of V_1, is applied to the klystron reflector. This is a considerable increase on the fraction available by the use of a resistor chain.

The standing current through the chain is about 4mA and for a variation of $\pm25V$ at V_1 anode, the current variation through the stabilizing valves is about $\pm0\cdot5$mA. These values are well within the ratings of the valves used. Approximately $\pm18V$ of a.f.c. control is available at the klystron reflector, which is more than adequate for the frequency control requirements.

This circuit has been in use for several months in the receiver of a continuously operated experimental microwave link, and has proved completely satisfactory. It is apparent that the result could have been achieved by other means, e.g. the resistor chain mentioned, in conjunction with a second amplifying stage. An extension of the requirements, however, to, say, a change of reference level of perhaps 1kV, and a change of control voltage to $\pm100V$, could considerably complicate such methods, whereas the use of voltage stabilizing valves would require only an extension of the chain.

Notes from
North America

IRE National Symposium on Microwave Techniques

The National Symposium on Microwave Techniques will be held in Philadelphia on February 2 and 3, 1956. It is sponsored jointly by the Professional Group on Antennas and Propagation, the Professional Group on Microwave Theory and Techniques, and Philadelphia Section of the Institute of Radio Engineers.

A well balanced programme with technical papers and discussions on all phases of this subject is planned.

Colour Television in Hotel

The first substantial multiple installation of colour television receivers in hotel guest rooms has been completed at New York's Hotel Governor Clinton.

Fifty 21in RCA Victor colour sets have been placed in various rooms and suites as part of the regular furnishings. Seven hundred RCA Victor 21in black-and-white receivers also are in use and the hotel plans to increase the number until television has been installed in all 1 200 rooms.

RCA Victor Research Laboratories

The appointment of Dr. James Rennie Whitehead of McGill University to head the new RCA Victor Research Laboratories has recently been announced. Dr. White-head's work for Canada's largest electronic organization will be in the field of pure physics and electronic research not necessarily connected with the company's projects or developments.

From 1939 to 1951 Dr. Whitehead was associated with the British Government Telecommunications Research Establishment; he is a graduate of the University of Manchester and received his Ph.D. at the University of Cambridge.

The Sperry Detector Car

Illustrated below is one of the Sperry Detector Cars which are used by Canadian National Railways for the routine testing of railway track. They are used to test rails and locate those which have developed internal defects and require replacement.

These test cars are manned by a crew of four specially trained operators. The testing process utilizes electric currents which are introduced into the rail and picked up again by recording devices. Any defect or flaw in the rail causes a voltage drop which is immediately sensed. Inked pens located in the operators' compartment record the voltage dips on a continuously moving paper tape, thereby assuring a perpetual and reliable record of the types of defects found.

Detector car operations are scheduled with minute precision to avoid interfering with scheduled trains. For this reason, the car, which tests at 12 miles/hr, may suddenly dash to a spur track. After the through train has passed, it returns to the same spot and resumes its testing job.

Experience with this type of testing equipment has shown it to be nearly 100 per cent efficient.

LETTERS TO THE EDITOR

(We do not hold ourselves responsible for the opinions of our correspondents)

A Waveform Synthesizer for Technical Training

DEAR SIR,—The article by Mr. T. S. Fox in the September issue is of considerable interest, as we have had an equipment of different design operating in the Electrical Engineering Department at Glasgow University since 1949.

Against our better judgment, we were convinced by our colleagues on the power side that a 50c/s fundamental frequency would greatly extend the usefulness of the equipment. This choice of frequency caused some difficulty in circuit design and, although the equipment has been used extensively for teaching demonstrations during the last six years, on relatively few occasions has the fundamental frequency been of significance.
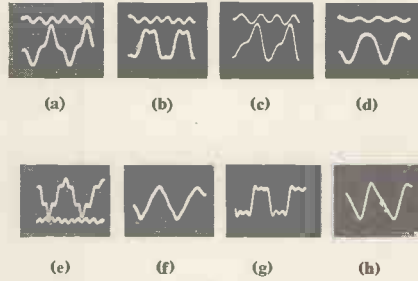
Fig. 3. (a) and (b) Fundamental+2nd harmonic; (c) and (d) fundamental+3rd harmonic; (a) fundamental+5th harmonic; (f) and (g) fundamental +3rd and 5th harmonics; (h) fundamental+2nd, 3rd and 5th harmonics

ing this equipment is largely due to Dr. T. K. Caughey, now Assistant Professor at California Institute of Technology.

An improved model has been considered and tested with one harmonic unit consisting of a simple inductor alternator with a resistance-capacitance filter to produce a good sinusoidal waveform. Phase shifting is performed mechanically and, where a fundamental frequency of 50c/s is required, it is thought that this method will prove the easiest and most economical.

Yours faithfully,

DOUGLAS S. GORDON,
Department of Electrical
Engineering,
The University,
Glasgow, W.2.

Fig. 1. Diagram of harmonic synthesizer

Fig. 1 shows the arrangement of the equipment in block schematic form. In order to keep the equipment reasonably modest in size and cost, only 2nd, 3rd and 5th harmonics are available. A typical oscillator with its synchronizing circuit is shown in Fig. 2. It will be seen that each harmonic is adjustable in phase and amplitude and that provision is made for viewing the complex wave and one harmonic simultaneously on a double-beam oscilloscope. Some typical traces are shown in Fig. 3.

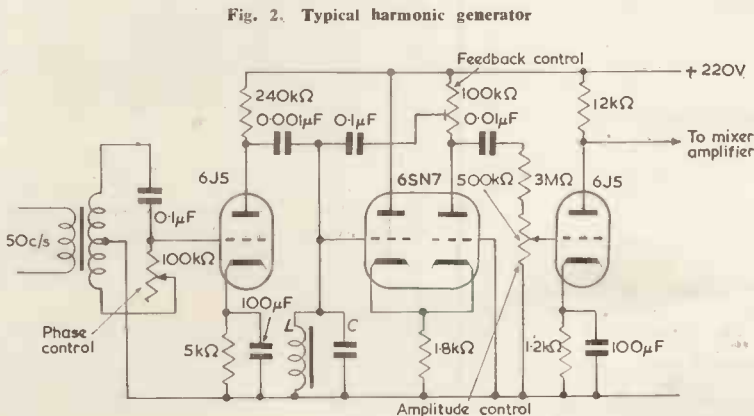The credit for designing and construct-

The Design of Hard-Valve Binary Counters

DEAR SIR,—While I do not wish to denigrate the value of the analysis carried out by Mr. Taub, I would suggest that by far the most important section of his paper is the conclusion.

Here we have the representative of a valve manufacturing company calling for "more detailed information" on valve characteristics.

The necessity for this is admirably illustrated in your September issue. On one page, 387, Mr. Taub assumes a tolerance of + 30 per cent − 50 per cent on average anode current. On another page (advertisement page 72) we are offered a "close tolerance twin triode" whose anode current is 8·5 ±4mA.

Yours faithfully,

E. L. HARRINGTON,
Henbury,
Bristol.

The author replies :

DEAR SIR,—I must thank Mr. Harrington for stressing the importance of tolerances yet again, but his illustration is not as admirable as would appear at first sight. The limits he quotes for the anode current of the type E90CC valve refer to a grid potential of −2·1V, whereas the limits quoted in the article refer to a very small grid potential (about −0·5V) as encountered in Eccles-Jordan circuits. On inquiry from the makers of the E90CC I find that under corresponding conditions (anode voltage = 150V and grid returned to cathode through 47kΩ) the specified anode current is 5·6 ± 0·6mA.

Regarding valves made by the company with which I was associated until recently, much information is given in their catalogue.

Yours faithfully,

D. M. TAUB,
London, S.W.1.
(Formerly Ericssons Telephones Ltd.)

Fig. 2. Typical harmonic generator

Short News Items

Premiums for Technical Writing. Non-professional writers of technical articles dealing with radio and electronics, including specialized applications to any industry, and the editors responsible, are reminded in a leaflet issued by the Radio Industry Council of its premium award scheme, now in its fourth year and nearing the time for judging. Up to six premiums of 25 guineas each are offered yearly in respect of articles which, in the opinion of the Council's panel of judges, are likely to enhance the reputation of Great Britain in radio, television and electronics. The 19 awards so far made have happened to be mostly for articles in radio and electronic journals, but it is pointed out in the leaflet that many industries are increasingly using electronic methods of control and production and articles in the journals serving a wide variety of industries are eligible, provided they can be bought by the public on bookstalls or by subscription. Industries specifically concerned are the motor, aircraft, metal-working, wood-working, and food industries, with wide uses also in hospitals, clinics and research establishments. An innovation now announced is that one of the six premiums will be open for articles published in manufacturers' own journals with an overseas circulation, provided they also can be bought by the public. Details and further information may be obtained from the Secretary, Radio Industry Council, 59 Russell Square, London, W.C.1.

The new Chairman of the General Council of the British Standards Institution is Sir Herbert Manzoni, C.B.E., Engineer and Surveyor of the City of Birmingham since 1935. At the recent Annual General Meeting of B.S.I. Sir Roger Duncalfe, Chairman of British Glues and Chemicals Ltd, was re-elected President and Mr. John Ryan, Vice-Chairman of the Metal Box Co Ltd, was elected as Vice-President on completion of his three-year period of service as Chairman of the General Council. Another appointment was that of Sir Stanley Rawson, Vice-Chairman of John Brown & Co Ltd, who becomes Chairman of the B.S.I. Engineering Divisional Council.

Redifon Ltd announce that aircraft accompanying two South Pole expeditions will be guided over the icy wastes of Antarctica by Redifon radio beacons. The Hunting Air Survey group, now on its way to Graham Land, will operate a Redifon G.40, and the Commonwealth trans-Antarctic expedition will use two Redifon T.1918s. The T.1918 was first shown in public at this year's S.B.A.C. Exhibition at Farnborough.

Royal Society Medals. The following awards of medals have been made by the President and Council of the Royal Society.

The Copley Medal to Sir Ronald Fisher, F.R.S., Arthur Balfour Professor of Genetics in the University of Cambridge, for his distinguished contributions to developing the theory and application of statistics for making quantitative a vast field of biology.

The Davy Medal to Professor H. W. Melville, F.R.S., Mason Professor of Chemistry in the University of Birmingham, for his distinguished work in physical chemistry and in polymer reactions.

The Sylvester Medal to Professor E. C. Titchmarsh, F.R.S., Savilian Professor of Geometry in the University of Oxford, for his distinguished researches on the analytical theory of numbers, and other branches of pure mathematics.

The Hughes Medal to Professor H. S. W. Massey, F.R.S., Quain Professor of Physics at University College in the University of London, for his distinguished contributions to atomic and molecular physics, particularly in regard to collisions involving the production and recombination of ions.

Pye Ltd announce the formation of a French subsidiary company, to be known as Pye (France) S.A. The French company will be primarily engaged in the active introduction into the French market of the entire range of Pye Telecommunications products.

The Radio and Electronic Component Manufacturers' Federation announces that its annual private exhibition will be held at Grosvenor House, London, W.1, from 10-12 April next, with, for the first time, a preview for overseas and other specially invited guests on the afternoon of 9 April. Application for admission to the preview should be made in advance to the Radio and Electronic Component Manufacturers' Federation, 21, Tothill Street, London, S.W.1.

The Mechanical Handling Exhibition and Convention will be held at Earls Court from 9-19 May 1956.

The Radio Industry Council announces that the 23rd annual National Radio and Television Exhibition (The Radio Show) will be held at Earls Court, London, from 22 August to 1 September 1956, with a preview for overseas and other special guests on 21 August.

The first power germanium rectifier for commercial service in Great Britain was manufactured by the British Thomson-Houston Co Ltd, to the order of Imperial Chemical Industries Ltd. The rectifier is rated 1 000kW, 255V, 3 920A and it will operate at continuous full load for long periods. It consists of two cubicles housing a series-parallel arrangement of air-cooled germanium rectifier cells connected to form a six-phase, full-wave bridge. The rectifier is supplied from an existing delta/diametric connected transformer which previously supplied a rotary convertor. The British Thomson-Houston Co is also supplying ten mechanical contact rectifiers, each rated 3 300/4 050kW, 220/270V, 15 000A, to Imperial Chemical Industries Ltd.

Powers-Samas Accounting Machines Ltd, a wholly owned subsidiary of Vickers Ltd, announce a further extension of their manufacturing capacity. At the beginning of this year Powers-Samas took over a large part of the Vickers-Armstrongs works at Dartford, Kent, and now a works of some 200 000 square feet at Southport, Lancashire, is being taken on a long lease from Brockhouse Engineering (Southport) Ltd for the production of punched card accounting machines and equipment. The demand for these machines both at home and abroad is increasing rapidly, stimulated by the latest electronic developments, and it is to help meet this increasing demand that the further premises are required.

RCA Photophone Ltd announce the move of their works and head offices from their previous location at Shepherds Bush to Sunbury-on-Thames, Middlesex, where an entirely new

modern factory and administrative centre has been built to meet the requirements of their expanding business. The address is RCA Photophone Ltd, Lincoln Way, Windmill Road, Sunbury-on-Thames, Middlesex. Telephone Sunbury-on-Thames 3101.

Metropolitan-Vickers Electrical Co Ltd have transferred the Industrial Process Control Engineering Department to the recently formed Electronics Department. Mr. R. H. Kelsall, formerly Assistant Chief Engineer, Industrial Process Control Department, is now Assistant Chief Engineer (Industrial Process Control), Electronics Department. This section is concerned with the industrial application of closed loop control systems in all its forms, including electronic and magnetic amplifiers; the use of computers and associated techniques in conjunction with control systems will also be within its field.

Hoechst Chemicals Ltd announce that the new improved type of polythene which is being manufactured by the Ziegler process is now in large-scale pilot plant production at the works of Farbwerke Hoechst AG., Western Germany. Bulk production is expected to commence at the end of this year, and development quantities for laboratory and factory scale tests are now available from Hoechst Chemicals Ltd, 27, Regent Street, London, S.W.1. New fields of application will be opened up by the advent of Hostalen due to its high softening point, great rigidity, and high resistance to solvents and chemicals.

The Fourth International Instruments and Measurements Conference and Exhibition will be held in Stockholm from 15-23 September 1956. The conference is organized by the Royal Academy of Engineering Sciences and the Swedish Association of Technical Physicists. Further information can be obtained from the Conference Secretary, Mr. Sven Malmstroom, P.O. Box 12035, Stockholm 12.

Marconi's Wireless Telegraph Co Ltd have been awarded a contract, worth more than £250 000, for the complete radar and communications equipment for two destroyers now under construction by Vickers-Armstrongs Ltd. These warships, which are being built for the Chilean Government, will be among the most modern of their class in the world.

Marconi's have also received an order for a complete new high-power broadcasting station, to be sited at Abu Ghraib, near Baghdad. The contract was placed by the Iraq Posts and Telegraphs Department.

The Plessey Co Ltd have released first details concerning the formation of a new company which is to control the establishment and development of a

number of new Plessey enterprises in Great Britain. It is to be called The Plessey Development Co Ltd. The new company is being staffed with a number of senior engineering and production personnel specially engaged for the purpose, together with certain Plessey personnel who have been seconded to the new organization. Directors of The Plessey Development Co Ltd are Mr. A. G. Clark, who is Chairman and Managing Director, and Messrs. E. J. Earnshaw and A. E. Underwood.

Ferranti Ltd have opened a new Research and Development Establishment of their Aircraft Equipment Department at "Westwick", Bagshot Road, Bracknell, Berks. The department will primarily be concerned with the development of new systems and components for aircraft electrical equipment and instrumentation with particular reference to gyroscopic and associated navigation systems. The Chief Engineer is Mr. W. A. Mallinson and the Chief Research Engineer is Mr. J. W. Barnes, late of the R.A.E., Farnborough.

The Lord President of the Council has, with the concurrence of the Chancellor of the Exchequer, appointed Mr. W. Strath, C.B., at present serving as a Third Secretary in H.M. Treasury, to be a full-time member of the Atomic Energy Authority. He has also appointed as part-time members Sir Rowland Smith, Chairman of the Ford Motor Co, and Mr. C. F. Kearton, a Director of Courtaulds Ltd.

Edwards High Vacuum Ltd in the drive for exports are using helicopters to ferry overseas visitors from London Airport to their factory in Crawley New Town, thirty miles away. The flights are provided by Helicopter Services Ltd.

E. K. Cole Ltd have developed a television set to be specially built into a car, and this made its debut at the recent Motor Show at Earls Court.

Cable and Wireless Ltd announce that a new radio telephone service has been opened between Bahrein, Persian Gulf, and Karachi, Pakistan. The service was inaugurated by Shaikh Isa Bin Sulman, eldest son of the Ruler of Bahrein, who spoke with the Postmaster-General in Karachi.

The General Electric Co Ltd have supplied an automatic telephone exchange to Messrs. Chr. Salvesen & Co for installation at their Whaling Station in South Georgia, one of the Falkland Islands Dependencies on the fringes of Antarctica. When installed, the exchange will be the most southerly automatic exchange operating in the world. The components are suitably protected against the extreme climatic conditions which will be encountered by the equipment which must pass through the tropics during its journey to the Antarctic. The equipment is being shipped on the whaling factory ship "Southern Venturer".

"Automation" Meeting and Exhibition. The President of the French Association of Electronic Engineers has announced a meeting and exhibition on this subject to be held in Paris from 18 to 24 June 1956. Details may be obtained from Secretariat du Colloque sur l'Automatique, Chaire de Mecanique, Conservatoire National des Arts et Metiers, 292 rue Saint-Martin, Paris.

Kingston Technical College, Department of Engineering, are to hold Post-Graduate evening courses on Pulse Techniques and Aircraft Electrical Equipment, commencing in the New Year. The former course will start on 17 January and the latter on 12 January. Further details and lecture programmes are obtainable from the Head of the Engineering Department, Kingston Technical College, Fassett Road, Kingston-upon-Thames, Surrey.

Granada TV Network Ltd announce the appointment of Mr. P. J. Peate as Assistant Telecine/Telerecording Engineer. Mr. Peate was previously with the Telerecording Department of the BBC at Lime Grove Studios.

Marconi International Marine Communication Co Ltd have opened new premises at Marconi House, Melbourne Street, Newcastle-upon-Tyne. These premises supersede the old in Pudding Chare, off Collingwood Street, which have housed the Newcastle depot since 1929. Prior to that date the depot had been in Royal Arcade and in Milburn House, Dean Street, where it was first established in 1913.

The Automatic Coil Winder and Electrical Equipment Co Ltd announce a new trading arrangement with Messrs. Blume & Redecker, of Hanover. The effect of the agreement is that the Automatic Coil Winder & Electrical Equipment Co Ltd have taken over sales of the German manufacturer's laminating, wire stripping and coil winding equipment for the United Kingdom and Commonwealth markets, as well as for China, Japan, Argentina, Russia and Russian satellite countries. The English company will continue also to market the range of "Douglas" and "Macadie" coil winders of their own manufacture.

The Society of Industrial Radiology and Allied Methods of Non-Destructive Testing, which was founded at the close of last year, and now has a membership of over 200, is the first professional body in this country endeavouring to co-ordinate all specialists employed in the various methods of non-destructive testing. Its chief concern is to establish and maintain a high standard of technical practice and to facilitate the exchange of information and ideas on matters concerning these rapidly expanding methods of inspection. With these objects in view, a programme of monthly meetings has been arranged by branches of the Society in London, Birmingham, Sheffield and Glasgow. Particulars may be obtained from the Honorary Secretary, D. N. Laurie, 2 Tomswood Terrace, Barkingside, Essex.

BOOK REVIEWS

Electromagnetic Principles of the Dynamo

By E. B. Moullin. 367 pp. 70 figs. Demy 8vo. Oxford University Press. 1955. Price 50s.

THIS very useful book is intended for elementary teaching although it contains some advanced sections.

The first chapter is devoted to basic principles, the general form of the machine is described and many technical terms are defined. Sections are included on torque, e.m.f. of a dynamo, windings, the commutator and the homopolar machine. The book is intended to be read in conjunction with the author's "The Principles of Electromagnetism" to which there are over eighty cross-references, nearly fifty of these being in the first three chapters. Although such cross-references avoid digressions on the theory of magnetism they are disturbing and should be unnecessary in a book costing 50s. On page 1 the reader is told that the references are to the 2nd edition of the previous book but on pages 294, 302 and 311 examples are referred to at the end of the 3rd edition. There are no examples at the end of the 2nd edition.

The second chapter deals with the estimation of ampere-turns on the poles and the method given is illustrated by a numerical example. A valuable feature of the book is that many such examples are worked out in the text and there are 80 questions with solutions at the end. It is surprising to find that the M.K.S. system of units is not used.

Chapter III gives an account of the magnetic effect of the armature current. It includes notes on interpoles and compensating windings and gives a further discussion on torque. Chapter IV covers methods of excitation, load characteristics of generators, generators in parallel and characteristics of motors.

Efficiency and energy losses are discussed in Chapter V. Methods of separating losses into their various components and efficiency testing are given. Some errors were observed here, the most serious being the statement on page 141 that all insulating materials available at present and usable in a machine soften or deteriorate permanently at about 200° F. Chapter VI is allocated to commutation. Information on boosters, balances and the Rosenberg and other special machines is presented in Chapter VII.

It is debatable whether the last supplementary chapter, occupying sixty-one pages and giving much of the electromagnetic treatment needed for a.c. machines, should have been included. It seems that the real reason for putting it in was that it would help the author with his teaching. In fact the reader is warned that he need not study this chapter if he is disinclined to do so. Much of the material given here, however, is not far removed from the main theme.

The book is written in an attractive manner and is clearly illustrated with many diagrams although a few of these are rather small (e.g. Figs. 4-6(a), 4-9(a), 5-14). It will be of great value to engineering students. It is rather expensive but a student who spends 50s. on its purchase will never regret having done so.

F. A. BENSON.

Networks, Lines, and Fields

By J. D. Ryder. 93 pp. 261 figs. Demy 8vo. 2nd Edition. Prentice-Hall, Inc., New York. Bailey Bros. and Swinfen, Ltd., London. 1955. Price 80s.

THIS is the second edition of a book in the Prentice-Hall Electrical Engineering Series which was published initially in 1949. The purpose of the book is to provide an introduction to quantitative communication engineering. According to the preface, the author has attempted to develop the subject of communication networks and lines by describing their performance in terms of certain measured or defined parameters. The study of fields is facilitated by the use of the analogous transmission line. This new edition is somewhat larger than the original and contains a number of new features.

The application of matrices to the solution of steady-state circuit problems has been extended but, in this reviewer's opinion, the book would have benefited if matrices had been omitted altogether. The introduction to the subject in the first chapter is superficial and not particularly well done. The explanation of matrix multiplication contains a mistake which will confuse the reader who attempts the multiplication of two non-square matrices. On page 44 an example is given of the inverse of a second order matrix which is, in fact, the determinant of the transpose of the inverse! This error would seriously impede the progress of the student were it not that in the following section, which purports to explain the use of matrices in circuit calculations, the method shown is not matrix analysis but determinantal analysis; indeed, matrix inversion is employed nowhere in the book. The chapter continues with a vague mixture of general passive network matrix analysis and Strecker-Feldtkeller passive fourpole matrix analysis but it appears to be the latter with which the author is really concerned. The treatment of fourpole interconnexion by the Strecker-Feldtkeller process leaves much to be desired. In the course of the discussion of this topic, reference is made to matrices introduced earlier which are not those of fourpoles and no mention is made of the restrictions under which certain interconnexions are permissible.

Chapter II has been extended to include Foster's reactance theorem and further space has been given to the use

of the Smith chart in transmission line theory in Chapter VII. Three new chapters have been added to increase the scope of the book. These deal with the determination of the parameters of polyphase lines, power transmission lines, and elementary aerial theory. The vector analysis approach has now been adopted in the treatment of time-dependent fields and electromagnetic radiation. Vector theory is developed as it is required and no prior knowledge of the subject is expected of the reader.

The author's aim to demonstrate the unity between the theory of discrete and distributed parameter systems could have been accomplished with greater elegance had the matrix theory of fourpoles been properly and earnestly developed at the beginning of the book. An opportunity to exploit modern matrix techniques has been missed; the papers of Professor L. A. Pipes indicate the possibilities in this direction. However, the book serves the author's purpose and has a place among the many text-books now available on the transmission of electric energy through networks, along lines, through guides, and into space. The book is well printed and attractively bound.

S. R. Deards.

Radio Astronomy

By J. L. Pawsey and R. N. Bracewell. 354 pp. 150 figs. Demy 8vo. Oxford University Press. 1955. Price 55s.

THE subject of this book is the study of astronomy by means of radio waves rather than by light. It is now nearly a quarter of a century since Karl Jansky showed that radio waves are reaching the earth from outer space, and the time is ripe for this authoritative text book on the new branch of science which was founded on his work. The authors of the book are well-known members of the Radiophysics Laboratory in Sydney where so much of the original work on radio-astronomy has been done. They have thus been able to draw on a considerable body of first hand experience and this, coupled with an unusually clear style of writing, makes the book both a valuable contribution to the subject and a great pleasure to read.

About one-fifth of the book is devoted to the techniques of radio-astronomy. There are also separate chapters on the theory of propagation in ionized gases, the effects of the earth's atmosphere on extra-terrestrial radio waves, and some aspects of astrophysics relevant to radio-astronomy. The authors claim in the preface that "the book must cater for those who know astronomy, but not radio and also for those who know radio but little astronomy, and so we have tried to make it readable by anyone with a background of physics". They must be congratulated on the success of their efforts; the treatment of the subject throughout places a welcome emphasis on the essential physical processes which are involved, and there are few radio engineers who would not learn something about their own subject from reading these chapters.

The remainder of the book gives an account of the sun, the moon, meteors and the universe beyond the solar system as "seen" by radio waves. There is also a short chapter devoted to radar echoes from the moon and to the possibility of radar echoes from the sun and planets. One of the principal difficulties in writing a text-book on a rapidly expanding subject is that significant changes in the relative importance of various topics may occur between writing and publication. The present book has not escaped this difficulty and in the light of recent work, particularly on the study of the Galaxy by the 21cm. radiation from neutral hydrogen, it is clear that too little space has been given to a discussion of the radio stars and the Galaxy in comparison with that devoted to the sun. Nevertheless the chapters on the sun are themselves excellent and will be given a particular welcome by radio-astronomers.

In conclusion I recommend this book, which is illustrated with a number of striking photographs, to all whose interests embrace astronomy or radiophysics, and to all scientists and engineers who wish to explore a fascinating new subject with reliable guides.

R. Hanbury Brown.

An Introduction To Process Control System Design

By A. J. Young. 378 pp., 60 figs. Demy 8vo. Longmans, Green & Co. Ltd. 1955. Price 42s.

THE author of this book examines the basic principles in quantitative terms, with emphasis on dynamic characteristics, using only the simplest mathematics. Formulae are given, and the data required in practice are presented in graphical form to facilitate their interpretation and use.

The beginner is led, by logical stages, to an understanding of the principles governing the operation of control systems. At the same time, the experienced engineer will find much that is of interest to him.

The author, elected President of the Society of Instrument Technology in 1954, has had long experience in the field as Head of the Central Instrument Laboratory of Imperial Chemical Industries.

Proceedings Of The Symposium On Printed Circuits

122 pp., 40 figs. Demy 4to. Engineering Publishers, New York. 1955. Price $5·00.

THIS book contains the full versions of the technical papers presented at the 1955 Symposium on Printed Circuits sponsored by the Engineering Department of the Radio-Electronics-Television Manufacturers' Association with the participation of the Professional Group on Production Techniques of the Institute of Radio Engineers. Also included are the pertinent questions and answers of the discussion periods following the presentation of each paper. The subject matter covers all of the methods of printed circuitry currently in commercial use.

ELECTRONIC EQUIPMENT

A description, compiled from information supplied by the manufacturers, of new components, accessories and test instruments.

Wideband Amplifier and Discriminator
(Illustrated below)

THE type 652 is a rugged, precision linear amplifier, with built-in metered voltage discriminator, for use with scintillation and other nucleonic counters. Regulated h.t. and l.t. power supplies are provided for operating an external cathode-follower.

The amplifier provides a gain between 40dB and 80dB, i.e. (100 to 10 000) in 2dB steps. With a minimum rise-time and maximum fall-time, the gain is 3dB down at 1·7kc/s and 5Mc/s. Independently selectable rise- and fall-time constants provided: 0·03 to 10μsec and 0.1 to 100 μsec respectively.

This amplifier, with the "I.D.L." scin-

tillation counter head, type 653, fitted with the appropriate end cap and scintillator, forms a versatile basic unit to meet a wide range of scintillation counting techniques, including beta and gamma ray spectrometry, diagnostic and therapeutic purposes in hospitals, measurements on solid or liquid samples in lead castles, and general routine investigations.

The pulse from the amplifier and discriminator unit may be fed direct to a standard "I.D.L." scaler or ratemeter, or through the "I.D.L." single channel pulse analyzer, type 672, for the scanning of pulse spectra.

Isotope Developments Ltd,
Beenham Grange,
Aldermaston Wharf,
Nr. Reading,
Berkshire.

Fluid Network Analyser
(Illustrated above right)

THIS instrument has been designed to assist in the solution of non-linear network problems which are tedious to solve by the ordinary methods of mathematical analysis.

Such problems arise in the flow of oil, water, gas or air in distribution or ventilation systems. The instrument may be used for the solution of flow problems in fluids to which a general law of the type $P = CQn$ applies, where P = Pressure, Q = Rate of Flow, C = Constant of fluid resistance, n = Index of flow. It is a development of a laboratory instru-

ment devised at Nottingham University as a result of research sponsored by the National Coal Board.

The principle on which the instrument is based is the establishment of a network of linear electrical resistors identical in pattern to the system to be studied. This enables Kirchoff's relationships to be continuously satisfied while the electrical resistances are successively adjusted until the electrical currents flowing in the resistors correspond to the fluid flows in the system.

The currents and pressure drops around the network are read on calibrated meters connected into circuit by means of jacks. The resistors on the instrument, which simulate branches of the system, are brought out to a connexion panel, where they may be connected into a number of junctions. Power packs stabilized against mains supply changes are provided to simulate sources of pressure, e.g. fans, pumps.

Where the system requires it, a separate panel is used incorporating a number of units which simulate loads taking constant flows regardless of supply pressure. These can be connected into circuit in the same way as the resistors representing branches or sections of main.

Nash & Thompson Ltd,
Oakcroft Road,
Chessington,
Surrey.

New Valves

THE Mullard series of noval based valves for use in a.c. mains-operated f.m/a.m receivers has now been supplemented by an equivalent range having a common heater current rating of 100mA. These valves enable the design of efficient f.m/a.m receivers for operation from both a.c. and d.c. mains.

This new range comprises the UCC85 r.f. double triode, the UCH81 triode-heptode, the high-slope variable-mu pentode type UF89, the UABC80 triple-diode-triode, and the UL84 high-slope 12W output pentode. The associated half-wave rectifier is the UY85.

The PCL82 is a noval-based triode-pentode with separate cathodes. It is suitable for use in the frame time-base

circuits of transformerless television receivers employing 90° scanning tubes.

The triode section then functions as a blocking oscillator and the pentode section as a frame output valve.

The PCL82 has a 16V, 300mA heater, and will operate satisfactorily from a high tension line of 170V. The triode section has an amplification factor of 70 and a mutual conductance of 2·2mA/V. The pentode section has a maximum rated anode dissipation of 7W, and a mutual conductance of 7·5mA/V.

Mullard Ltd,
Century House,
Shaftesbury Avenue,
London, W.C.2.

Sweep Frequency Oscillator
(Illustrated above)

THE "Rivlin" sweep frequency oscillator has been designed basically to meet the needs of valve manufacturers who require to test valves under vibration conditions. It is, however, suitable for vibration investigation work generally.

Frequency range of the instrument is 20c/s to 3kc/s, but this can be varied to suit individual requirements. There is provision for either motor drive or manual control. The band to be swept can be adjusted by means of setting the upper and lower limit dials. The output is constant with 3 per cent over the whole range, and the maximum output is 0·1V into 600Ω.

The motor drive is operated by push buttons, i.e. stop, start and reverse. There is a continuous cycling switch so that either one sweep can be performed and then the drive is stopped or continuous sweeping can be obtained.

Rivlin Instruments Ltd,
7a, Maitland Park Villas,
London, N.W.3.

Sealed Relays
(Illustrated above right)

THESE sealed relays are a development of the Pullin S-type range and while using basically the same mechanism as the existing types and being produced in the same ratings, incorporate a much improved sealing method together with a significant reduction in weight and bulk. The main features of the new sealed type are a neoprene gasket, and an
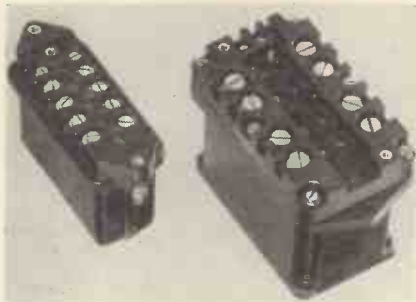
entirely new true wiping action, giving 0·015in sliding movement of the contact surfaces, on which a contact pressure of 35g is exerted. The standard contact material on the normal S-type relays is "Elkonite", a nickel-silver alloy, with precious metal (such as platinum-gold-silver) as an alternative if required. Tests carried out on prototypes have already established that they withstand forces of up to 20g, and vibrations of 0·003in amplitude at 250 to 8 000c/s.

In the above illustration the sealed relay (left) is compared with the weatherproof S2 type.

**Measuring Instruments (Pullin) Ltd,
Electrin Works,
Winchester Street,
Acton,
London, W.3.**

"One-Shot" Cells
(*Illustrated below*)

A NEW cell that operates efficiently without electrolyte spillage at the greatly reduced atmospheric pressures encountered in stratospheric flight has been evolved by Chloride Batteries Ltd.

It is the Exide Z2H11, an unspillable, "one-shot", primary cell developed in conjunction with the Ministry of Supply. Used in batteries of three to provide about 6·75V, it will power the metering and telecommunication equipment of the radar sonde mark 3 meteorological balloon. Of special lightweight design, the cells are primed with electrolyte shortly before the balloon take-off.

Primed cells can stand idle from 15 minutes to seven hours yet still discharge through a fixed resistor of 0·88Ω for a period of not less than two hours to a final minimum voltage of 2·25V. This discharge is in an ambient temperature of approximately 70°F and with the atmospheric pressure reduced progres-

sively during discharge to simulate flight conditions.

In the illustration three of these cells are shown fitted in a mark 3 radar sonde.

**Chloride Batteries Ltd,
Clifton Junction,
Swinton,
Manchester.**

Servograph Recorder
(*Illustrated below*)

FIELDEN Electronics have recently introduced a high performance-low priced recorder known as the Servograph mark II. This extremely versatile instrument is suitable for direct operation from pH meters, CO_2 indicators, smoke density meters, beta gauges, tachometers and many other uses as well as a recording voltmeter and ammeter.

The instrument operates directly from

micro current sources. It can replace any moving-coil indicating meter without imposing any additional load on the source of measurement or involving any loss of accuracy.

The instrument is manufactured in three different models suitable for either laboratory or plant use

**Fielden Electronics Ltd,
Paston Road,
Wythenshawe,
Manchester, 22.**

Oscilloscopes
(*Illustrated above right*)

TWO new general purpose oscilloscopes have been recently developed by Southern Instruments incorporating flat-faced 6in cathode-ray tubes by 20th Century Electronics Ltd. The M972 is a dual gun type and the M974 four-gun. The gun assemblies are entirely separate, enabling full use to be made of independent beam and plate controls without interaction.

Separate identical Y amplifiers for each beam make possible the direct comparison of waveforms.

The gain of each Y amplifier is continuously variable from 80 to 1 500 over a bandwidth from d.c. to 100kc/s. *RC* coupling can be provided by switch
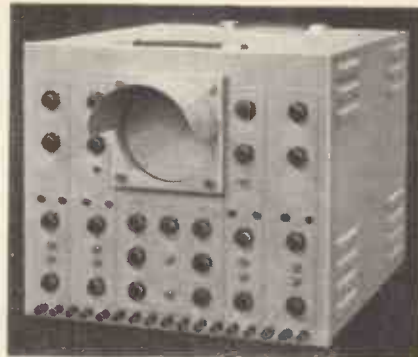
selection and there is a frequency compensated 10 :1 input attenuator.

The M972 has separate identical X amplifiers flat from d.c. to 50kc/s ±1dB with unbalanced input, and the M974 two X amplifiers with equalizing pre-set controls to give exact X axis alignment on all four beams.

The time-base is continuously variable from 2c/s to 30kc/s and can be synchronized internally or from an external signal as low as 100mV. In addition, provision is made for synchronization from contacts on a machine or vibratory device, and for beam triggering from the timing contacts on the company's universal camera.

Time marking by brightening or blanking pulses may be applied by Z axis modulation.

The equipment is designed to a high standard throughout, particular attention having been paid to ease of maintenance.

**Southern Instruments Ltd,
Frimley Road,
Camberley,
Surrey.**

Bench Type Induction Heater
(*Illustrated below*)

THIS is a compact r.f. induction heater suitable for bench mounting. Two types are available with outputs of 1kW and 3kW respectively. The output is variable over a range of 20:1. Provision is made for the incorporation of a process timer, two work stations and remote operation as optional extras.

**Radio Heaters Ltd,
Wokingham,
Berkshire.**

Meetings this Month

THE BRITISH INSTITUTION OF RADIO ENGINEERS

Date: 14 December.   Time: 6 30 p.m.
Held at: The London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1.
Lecture: The Remote Presentation of Radar Information.
By: G. J. Dixon and H. H. Thomas.

North-Western Section

Date: 1 December.   Time: 6.30 p m.
Held at: The Reynolds Hall, College of Technology, Sackville Street, Manchester.
Lecture: The Latest Developments in Computer Design.
By: J. J. Moore.

Merseyside Section

Date: 7 December.   Time: 7 p.m.
Held at: The Council Room, Chamber of Commerce, Old Hall Street, Liverpool 3.
Lecture: The Development of a Design for an Angle Modulation Radio Link.
By: H. C. Spencer.

South Wales Section

Date: 7 December.   Time: 6.30 p.m.
Held at: Llandaff Technical College, Western Avenue, Cardiff.
Discussion: The Training of Radio Engineers.
Opened by: W. J. Thomas, H. Roberts and A. J. Kenward.

Scottish Section

Date: 8 December.   Time: 7 p.m.
Held at: The Institution of Engineers and Shipbuilders, Elmbank Crescent, Glasgow.
Lecture: Automatic Control of Machine Tools.
By: H. Ogden.

West Midlands Section

Date: 14 December.   Time: 7.15 p.m.
Held at: Wolverhampton and Staffordshire Technical College, Wulfruna Street, Wolverhampton.
Lecture: Television Aerial Design with Emphasis on Band III Problems.
By: I. A. Davidson.

North-Eastern Section

Date: 14 December.   Time: 6 p.m.
Held at: The Institution of Mining and Mechanical Engineers, Neville Hall, Westgate Road. Newcastle-upon-Tyne.
Lecture: The Metal Cone Loudspeaker.
By: W. I. Heath.

THE BRITISH KINEMATOGRAPH SOCIETY

Date: 7 December.   Time: 7.15 p.m.
Held at: The Gaumont-British Theatre, Film House, Wardour Street, London, W.1.
Lecture: Handling the new Presentation Techniques.
By: R. E. Pulman.

THE INSTITUTE OF PHYSICS

Manchester and District Branch

Date: 9 December.   Time: 6.45 p.m.
Held at: The Bragg Building, University of Manchester.
Lecture: The History and Applications of Computers.
By: B. V. Bowden.

THE INSTITUTION OF ELECTRICAL ENGINEERS

All London meetings, unless otherwise stated, will be held at the Institution, commencing at 5.30 p.m.

Date: 1 December.
Lecture: TRIDAC A large Analogue Computing Machine.
By: F. R. J. Spearman, J. J. Gait and A. V. Hemingway.

Informal Meeting

Date: 5 December.
Discussion: Private Generation from the Point of view of the User.
Opened by: A. N. Irens.

Radio and Telecommunication Section

Date: 7 December.
Lecture: Some Half-Tone Storage Tubes.
By: R. S. Webley, H. G. Lubczynski and J. A. Lodge.
Date: 12 December.
Informal Lecture: The Television Studio as seen by the Producer.
By: Alvin Rakoff.

East Anglian Sub-Centre

Date: 15 December.   Time: 7.30 p.m.
Held at: The Assembly House, Norwich.
Lecture: Industrial Application of Radio-Active Isotopes.
By: S. Jefferson.

Mersey and North Wales Centre

Date: 5 December.   Time: 6.30 p.m.
Held at: The Electrical Engineering Department, Brownlow Hill, Liverpool.
Lecture: Transistor Power Amplifiers.
By: R. A. Hilbourne.

North-Eastern Radio and Measurements Group

Date: 5 December.   Time: 6.15 p.m.
Held at: King's College, Newcastle upon Tyne.
Lecture: Artificial Reverberation.
By: P. E. Axon, C. L. S. Gilford and D. E. L. Shorter.

North-Western Centre

Date: 6 December.   Time: 6.15 p.m.
Held at: The Engineers' Club, Albert Square, Manchester.
Lecture: TRIDAC A Large Analogue Computing Machine.
By: F. J. R. Spearman, J. J. Gait and A. V. Hemingway.

South-East Scotland Sub-Centre

Date: 20 December.   Time: 7 p.m.
Held at: The Carlton Hotel, North Bridge, Edinburgh.
Lecture: High-Speed Electronic Analogue Computing Techniques.
By: D. M. MacKay.

South Midland Centre

Date: 5 December.   Time: 6 p.m.
Held at: The James Watt Memorial Institute, Great Charles Street, Birmingham.
Lecture: Underwater Echo-Ranging.
By: D. G. Tucker.
(Joint Meeting with the Radio and Telecommunication, and the Supply and Utilization Groups and the Birmingham Centre of the Institution of Post Office Electrical Engineers.)

Rugby Sub-Centre

Date: 14 December.   Time: 6 p.m.
Held at: The Rugby College of Technology and Arts.
Lecture: Atomic Power Stations.
By: D. F. Welch.

Southern Centre

Date: 14 December.   Time: 6.30 p.m.
Held at: R.A.E. Technical College, Farnborough.
Lecture: The Use of Transistors in Computer Type Circuits.
By: G. B. B. Chaplain.

Western Centre

Date: 1 December.   Time: 6.30 p.m.
Held at: Sofia Gardens Pavilion, Cardiff.
Faraday Lecture: Coal Mining Electrically.
By: B. L. Metcalf.

South-Western Sub-Centre

Date: 1 December.   Time 3 p.m.
Held at: The Electricity Showrooms, New George Street, Plymouth.
Lecture: Transistors.
By: R. A. L. Cole.

West Wales (Swansea) Sub-Centre

Date: 8 December.   Time: 6 p.m.
Held at: The Conference Room, South Wales Electricity Board Showrooms, The Kingsway, Swansea.
Lecture: Thermionic Valves of Improved Quality for Government and Industrial Purposes.
By: E. G. Rowe, P. Welch and W. W. Wright.

RADIO SOCIETY OF GREAT BRITAIN

Date: 16 December.   Time: 6.30 p.m.
Held at: The Institution of Electrical Engineers, Savoy Place, London, W.C.2.
Annual General Meeting.

SOCIETY OF INSTRUMENT TECHNOLOGY

Date: 6 December.   Time: 7 p.m.
Held at: Manson House, Portland Place, London, W.1.
Lecture: Planning a Servo-mechanisms Laboratory for Instructional Purposes.
By: E. B. Pearson.

THE TELEVISION SOCIETY

Date: 9 December.   Time: 7 p.m.
Held at: The Cinematograph Exhibitors' Association, 164 Shaftesbury Avenue, London, W.C.2.
Lecture: The Secondary Emission Valve and its Applications.
By: A. H. Atherton.

PUBLICATIONS RECEIVED

ENGINEERS IN THE BBC is an invitation to graduate engineers and physicists to consider a career in the BBC. The booklet says that the Engineering Division, at the beginning of this year, comprised some 4 500 staff, of whom about 600 are fully qualified engineers and physicists, and about 2 300 are engineers who may not necessarily be fully qualified academically. Each year the BBC offers a number of Graduate apprenticeships of two years' duration to engineers and physicists who obtain good Honours degrees. It also has opportunities for men with a pass degree, and a special course is being prepared for them. Copies of the booklet, which is being circulated to universities and technical colleges, can be obtained from the Engineering Establishment Officer, BBC, London, W.1.

WIRELESS WORLD DIARY 1956. Base connexions for 600 current valves, graphical design data and a directory on radio organizations in this country and abroad are included in this diary, which provides in tabloid form the kind of technical and general information frequently required by the radio man. The diary is now in its 38th year of publication. Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1. Price 5s. 10d. (leather), 4s. 1d. (rexine).

POWER FROM THE ATOM is a booklet published by the English Electric Co. Ltd. on the occasion of the "Atoms for Peace" Exhibition held in Geneva in connexion with the International Conference of Scientists on the Peaceful Uses of Atomic Energy, under the auspices of the United Nations, in August, 1955. The English Electric Co. Ltd., Queens House, Kingsway, London, W.C.2.

THE PHYSICS OF THE IONOSPHERE is the report of the Physical Society Conference held at the Cavendish Laboratory, Cambridge, in September, 1954. The Physical Society, 1 Lowther Gardens, Prince Consort Road, London, S.W.7. Price 40s.

THERMIONIC VALVES 1904-1954 contains the lectures, by Sir Edward Appleton, Professor G. W. O. Howe and Dr. J. Thomson on the occasion of the celebration of the jubilee on 16 November, 1954 of Sir Ambrose Fleming's thermionic valve. Also included is the opening address by the Lord President of the Council and an appreciation of Sir Ambrose Fleming and Dr. Lee de Forest by Captain C. F. Booth, and a complete list of the exhibits, which ranged from Fleming's lamps and valves to travelling-wave tubes. The Institution of Electrical Engineers, Savoy Place, London, W.C.2. Price to members 4s., non-members 9s.