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Commentary

INTEREST in the fully automatic process controlled factory has been considerably aroused by the address given last November by Sir Ben Lockspeiser, Secretary of the Department of Scientific and Industrial Research to the Working Conference on Research and Productivity. It is all the more unfortunate therefore that in the space devoted in the Press to this intriguing subject so much of what he said was misinterpreted.

In the lay mind there is the impression that the automatic factory is a completely new idea made suddenly possible by electronics and that very shortly such factories will spring into being in which raw materials will be fed in at one end and from the other will pour forth in abundance finished products such as motor cars, refrigerators, television sets and the like. By some magical assembly of servo mechanisms and electronic "brains" the whole process will be carried out continuously without human intervention and all we have to do to initiate this process is to press a button.

Nothing is further from that envisaged by Sir Ben Lockspeiser and it may be well worthwhile to probe a little deeper into what is meant by automatic process control and the automatic factories.

Automatic process control is no more than the logical development of the automatic devices which have surrounded us for centuries and the only new thing is the name we now give it. The classical automatic control device is, of course, the governor on the original steam engine of James Watt and it was brought into being to replace the boy—the human operator in twentieth century parlance—on the steam valve and so provide an automatic means of keeping the engine speed constant irrespective of load fluctuations.

But such error-actuated devices to replace the human operator go further back than the governor on the steam engine. It can be claimed with justification that the temperature-compensated pendulum invented by Harrison in 1726 is such a device, and going back still further into the past so is the turret clock of Salisbury Cathedral which struck a bell to mark the passage of the hours.

This was made in 1386 and as a point of interest it still survives.

As man improved his tools and processes or invented new ones it was only natural that he should fit his various automatic devices to relieve him of the tedium of frequent correction. When he made his first windmill he arranged matters so that it could of its own accord always face the direction of the wind and what he had done in fact was to construct an "automatic factory" which would mill his corn for him as long as the wind blew.

Since the industrial revolution of some hundred and fifty years ago we have made enormous strides both in the intricacy of our machines and in the ingenuity with which we control them, and automatic control of the machine is a feature of our age.

During the last war the need for munitions of all kinds in enormous quantities forced us to review many of our manufacturing methods. Jobs had to be broken down and operations simplified so that what had previously demanded judgment and experience could be performed by unskilled labour working automatic controlled machines.

These techniques were incorporated in the post war development and were further improved and adapted to meet the demands made by such new products as jet engines where an extremely high degree of accuracy is required.

The simple capstan lathe turning out its small finished parts is an automatic factory in itself and so at the other end of the scale are the continuously operated processes common to oil refining. Many of the manufacturing processes in chemical engineering are almost entirely "workerless" in that they are self-operated and electronically controlled, with minimum overriding human command.

What then is this new vision of the "push button" factory? Our capstan lathe has to be set up initially and adjustments have to be made by trial and error until its product conforms to standard. Once set up, it will continue to operate, but it cannot inspect its own workmanship nor can it correct for deviations. Neither can it count and batch.

It would not be economical to control the capstan lathe by electronic methods, but in the more complicated operations and processes where stage by stage control is essential electronics has already taken over many of the existing hydraulic, pneumatic and mechanical methods with remarkable results. To this extent the automatic factory is already in being.

What has taken us by giant strides towards our new conception of the automatic factory is the electronic computor and we are now in fact contemplating the marriage of the computor to the machine tool. To this union the title of "automation" has been given.

The computor with its facilities for memory storage lends itself admirably to advance programming and it now appears practicable to make it control a machine tool performing intricate machining operations.

The combination of these two will undoubtedly form the basis of the automatic factory of the future. We have a long way to go before every industrial process is a push button operation, but we can expect to see some notable advances before many years have elapsed.

AN AUDIO-FREQUENCY METER

for Graphing Frequency Variations in the Human Voice

By P. G. M. Dawe*, M.A., M.Sc., and J. A. Deutsch*, M.A.

An instrument is described which produces a d.c. output voltage directly proportional to the frequency of an input voltage. It is used to operate a pen recorder, and it will follow variations in input frequency with a lag of approximately one cycle on the input waveform, since no integrating networks are used. The instrument is being used to aid psychological investigations into the mechanism of voice production.

IN certain psychological experiments into the mechanisms controlling the production of a singing tone by the human voice it is necessary to have some means of recording small frequency variations produced when a subject is asked to sing a given note, or to move from one note to another under various imposed conditions. The audio-frequency meter here described is an instrument designed for this purpose, to give a d.c. or slowly varying output voltage which will be practically instantaneously proportional to the frequency of the input voltage. This output is used to operate a pen recorder. The frequency ranges which the instrument is designed to cover are from 90 to 180c/s and from 180 to 360c/s, these being the ranges of most interest in examining the behaviour of the human voice.

It is useful to have the frequency converted into a continuous d.c. output because it is possible to use a pen recorder with comparative economy. The instrument extends greatly the range of usefulness of any pen recorder when frequency measurement is needed, for the frequency response of the pen recorder needs only to be as good as the fluctuations of the frequency and not as the frequency itself.

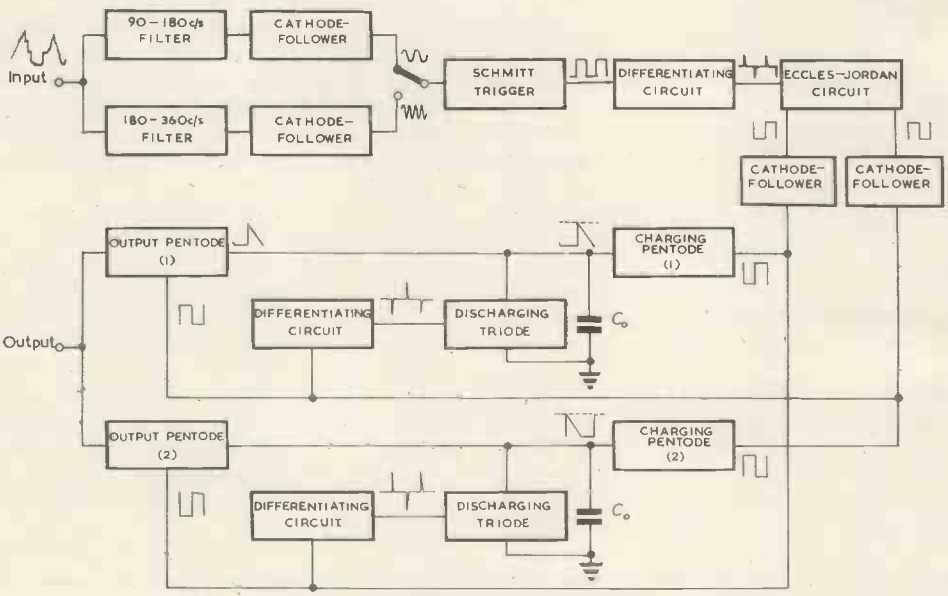

Fig. 1. The audio-frequency meter

Second, the frequency meter has conveniently been employed not only as a recording instrument alone but also as an integral part of the other experimental apparatus. The d.c. derived has been used to control the frequency output of an oscillator, the sound of which has been fed back greatly amplified to the subject. It has been possible, for example, to invert the perceived direction of error of the voice, or to exaggerate the frequency change in the same direction.

Finally, it is considered that this type of frequency metering may be useful in studies of speech recognition, where a number of meters could be used in parallel to cover various frequency ranges. The sensitivity of this type of frequency meter approximates closely to that of the human ear both in its capacity to "recognize" small frequency differences and its resolving power in time,

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since no integrating device is incorporated in its design.

Circuit Arrangement of the Instrument

A block schematic of the instrument is shown in Fig. 1, together with the waveforms at the various points of the circuit. It is seen that the basic principle on which the instrument operates is by recording, for each cycle in turn, the charge or voltage acquired by a capacitor, this being made proportional to the frequency of the input wave. A square wave is first produced from the input frequency the period of which is used to determine the voltage reached

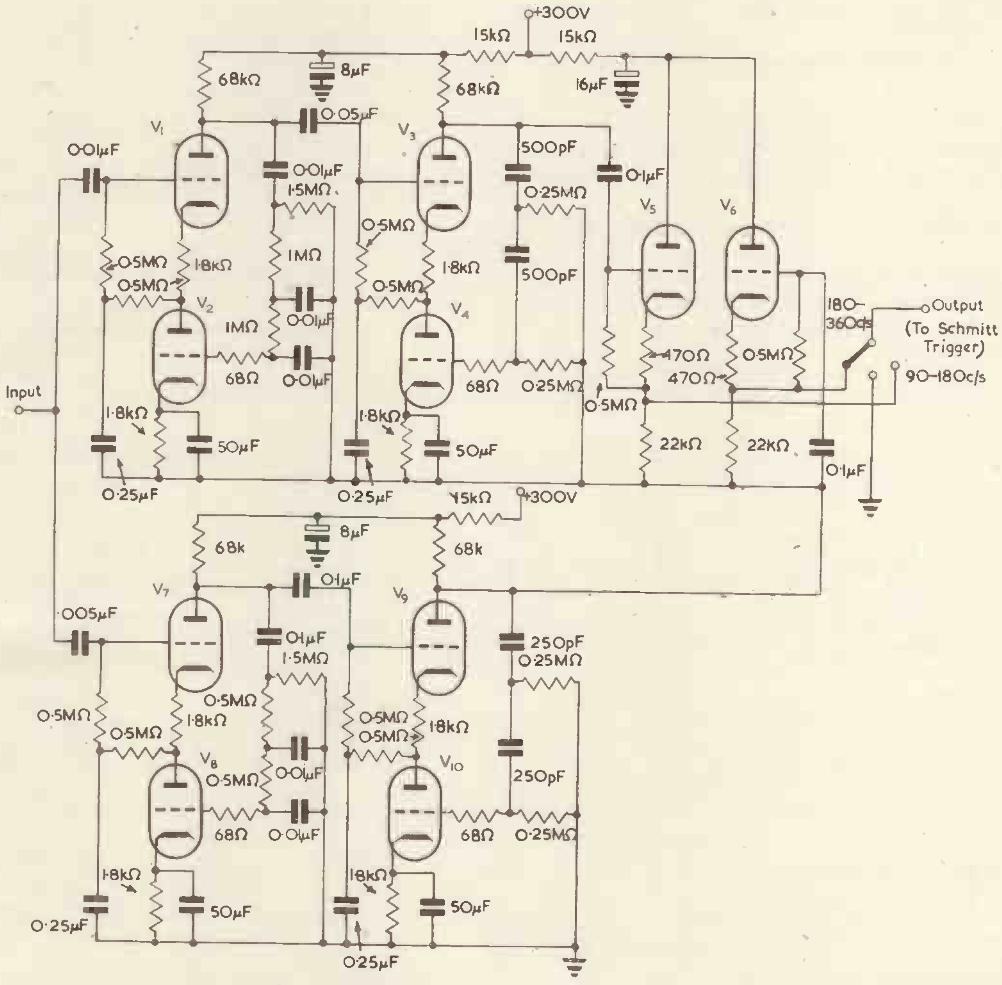


Fig. 2. Filter circuits for the octaves 90 to 180c/s and 180 to 360c/s

by two capacitors C_0. Each capacitor is charged through a pentode on alternate half-cycles of the square wave by using this wave as a switching waveform applied to the control grids of the pentodes. The d.c. voltage acquired by the capacitors is then a measure of the frequency of the input wave.

The principle of operation for the meter is similar to that used recently, for example, in an instrument designed to detect small frequency shifts in a 10kc/s source[1], and in a pulse interval meter for physiological use[2]. However, the basic principle was developed independently in prototype form by J. A. Deutsch, working in London at the Department of Phonetics in 1950, and the particular application of it in this instrument may be of some general interest.

The Filter Circuits

The input wave is fed directly to the paralleled input of two filters which separate the two octaves, 90 to 180c/s and 180 to 360c/s. Each filter consists of two *RC* type valve resonant circuits joined in cascade, each circuit using a double triode valve and a two-mesh *RC* network. The two filters are identical except for the values of *R* and *C*. The circuit for these filters is shown in Fig. 2, together with their subsequent cathode-follower stages. For each resonant circuit the two triodes are connected in series across the h.t. supply, the input signal being injected into the grid of the upper triode, while the control grid of the lower triode is fed with the phase shifted voltage from the output of the *RC* network.

The principles of design of this type of resonant circuit was first discussed in the literature by Dr. E. E. Schneider[3] and it may be noted that such circuits have an inherently low Q value, since this is proportional to the square root of the effective stage gain across the *RC* network. In the case of the two valve circuits used in Fig. 2, the effective overall gain, *m*, developed across the *RC* network, between the grid

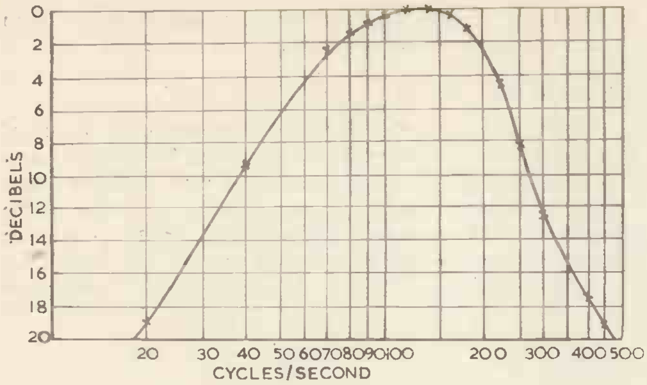


Fig. 3. Response characteristic for the 90-180c/s filter

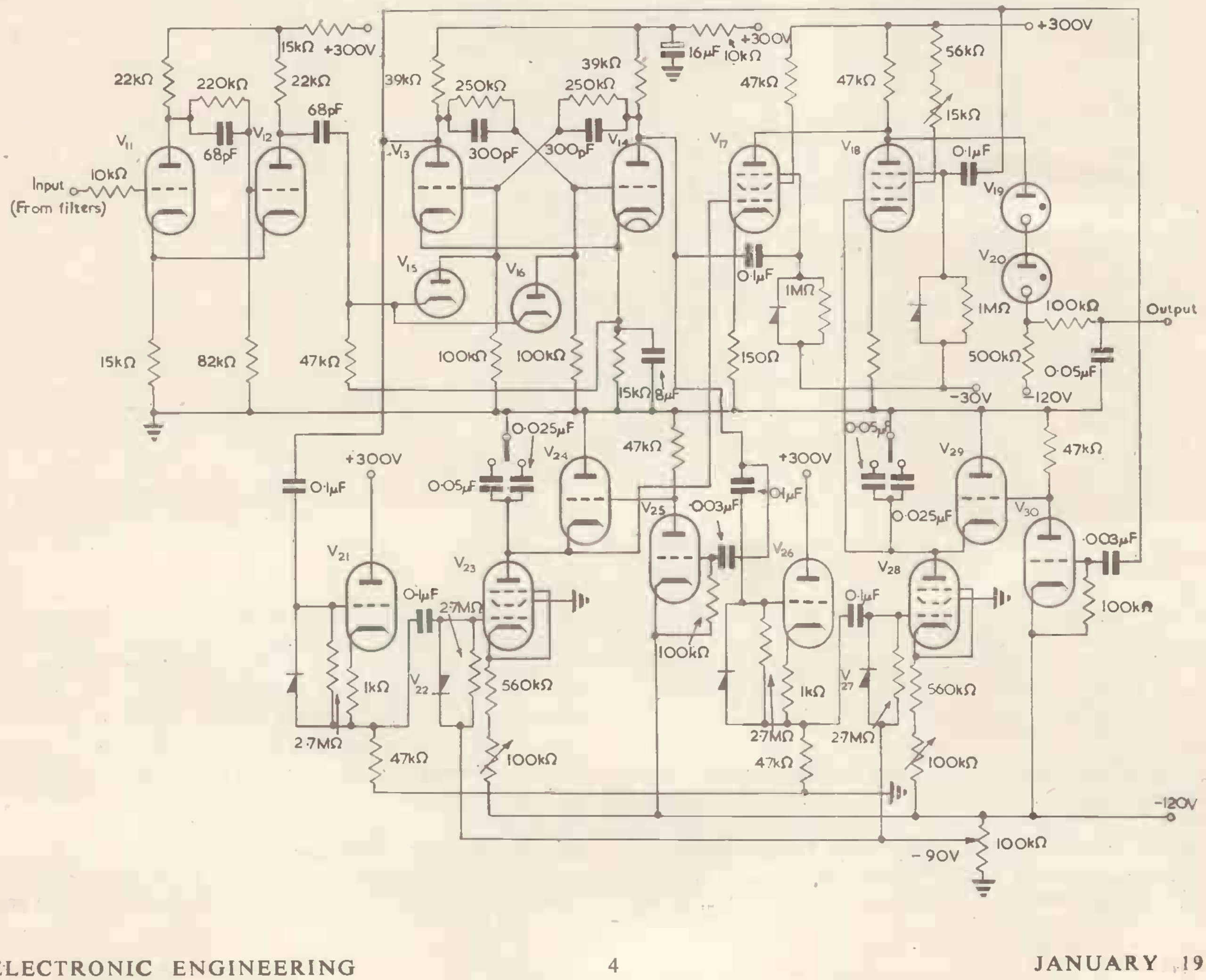
of the lower triode and the anode of the upper triode, is approximately 55 times. Where m is considerably larger than unity, and the capacitors have negligible losses, the expression for the Q of these resonant circuits may be reduced to $\sqrt{\frac{m}{3}}$

This gives Q values for the circuits used of approximately 2·5. Such low Q values, however, are not any particular disadvantage in this instance since the purpose of the filter is to discriminate against the harmonics in the input wave. It is found that for a frequency at the lower edge of the pass-band, i.e. 90c/s, an attenuation of greater than 10dB may be obtained for the third harmonic, greater than 15dB for the 4th, and 20dB for the 5th, respectively. For higher frequencies, within the pass-band, the suppression of harmonics is correspondingly better, but even at 90c/s this type of filter proves satisfactory when used with quite complex input waves. Fig. 3 shows a characteristic of the 90 to 180c/s filter, the two resonant circuits being tuned to 110c/s and 170c/s.

The Square Wave Generators

The square waves controlling the charging period of the output capacitors are derived from the filtered input wave in two stages. The filtered wave is first fed to a Schmitt trigger circuit which gives a square wave of the same frequency as the triggering waveform. This square wave is differentiated by the following short time-constant *RC* network, to produce further triggering pulses. The negative going pulses are fed via diodes to an Eccles-Jordan circuit, each negative pulse causing this circuit to switch over. Two square waves are therefore obtained from the two Eccles-Jordan valves, of one-half the frequency of the input waveform to the instrument, and 180 degrees out of phase with each other. These are therefore used as the switching waveforms in the following

Fig. 4. Square wave generators and the output stages for the frequency meter



output circuits. This method of obtaining the switching waveforms avoids any small variations in mark-space ratio which may otherwise occur by variations in the backlash (i.e. switching potentials) of the Schmitt trigger, and ensures that the two output capacitors are charged for equal intervals of time, each corresponding to one complete period of the input waveform. Fig. 4 shows this part of the circuit together with the following output stages.

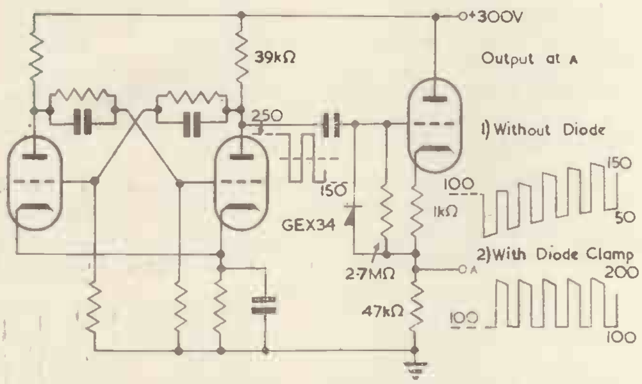


Fig. 5. The use of a restoring diode to maintain a short time-constant at the output of the square wave generator

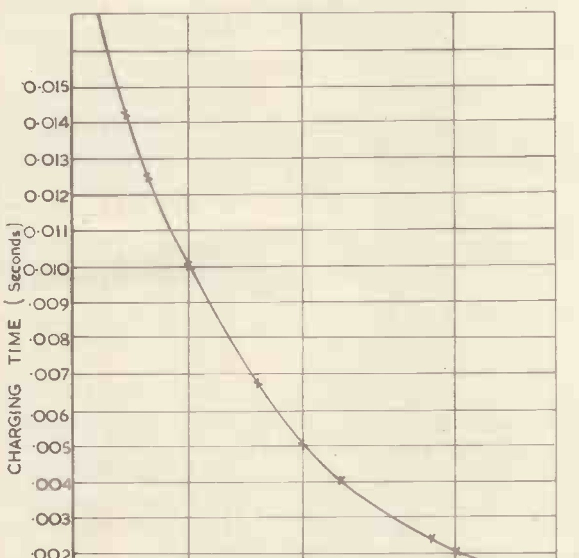


Fig. 6. Graph relating capacitor charging time with the logarithm of the input frequency

The switching waveforms are fed to the output circuits via two cathode-follower buffer stages, one following each of the Eccles-Jordan valves. The coupling networks both to these cathode-follower valves and from them to the output stages are provided with diode clamps to allow the coupling capacitors to discharge or charge rapidly to a new steady value on the application of an input waveform. For the circuit shown in Fig. 5, where the right-hand anode of the Eccles-Jordan pair is cut off and at 250V above earth, there will be a steady change of average voltage at this anode of 50V when the input wave comes on, since a 100V square wave will now be produced at this anode. The coupling capacitor would therefore tend to discharge slowly by 50V through the grid leak in order to maintain the same effective d.c. level at the cathode of V_2. The clamping diode, however, will cause the capacitor to discharge rapidly by the full value of the 100V anode swing, so that the output from the cathode will be a 100V square wave added to the previous d.c. level at the cathode. Without the diode, the slow variation in charge on the coupling capacitor can make the output circuit sluggish in coming into operation, since the output level from the cathode-follower may at first be too negative to enable the square wave to be effective in switching the charging valves on and off.

The Output Stage

This consists, as previously stated, of two capacitors which are charged during alternate half-periods of the switching waveform (one period of the input waveform) to a voltage

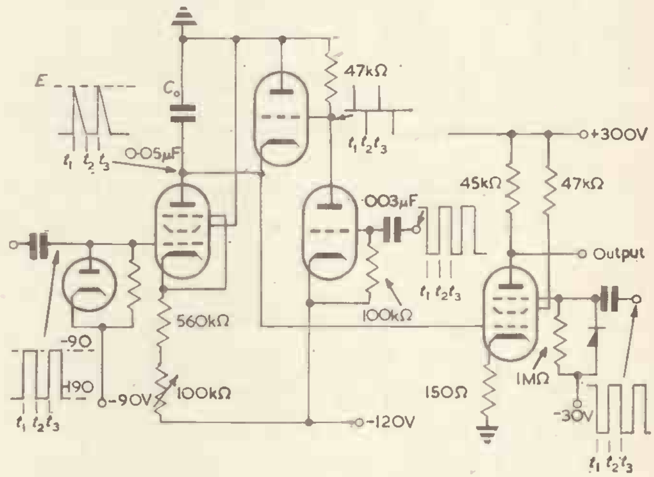


Fig. 7. Operation in detail of one side of the output stages

proportional to the period of this wave, and whose voltage during the ensuing half-cycle is held constant and used to determine the grid potentials and therefore the anode potentials of two output valves. These are operated in parallel so that the d.c. output voltage is determined over the whole cycle of the switching waveform. They are switched so that one is supplying the output potential while the grid capacitor of the other is being charged.

A further coupling capacitor and clamping diode is used to couple the square wave output from the cathode-follower, $V_{21,26}$ to the pentodes, $V_{32,28}$, charging the output capacitors (see Fig. 4). In this case the diode clamp holds the d.c. level of the pentode control grid at the bias voltage of the grid leak return, – 90V, and the 100V square wave subtracts on this level, so switching the pentode (see Fig. 7).

The capacitors are charged negatively from earth through pentodes having a high value of cathode load to give an approximately linear charging characteristic.

It should be realized that if the pen recorder is to have a logarithmic frequency scale, the charging characteristic for the capacitors will need to be of a special form. If the capacitors are charged linearly for a time given by the reciprocal of the input frequency, the relationship between charging time, or voltage, and the logarithm of the frequency is as shown in Fig. 6. Since this is a curve, the frequency compression at the top end of the scale would be unduly large. Ideally, a straight line is required, for then the characteristic of the instrument would correspond closely to to the logarithmic discrimination of the ear. However, it is found in practice, that the small curvature of this relationship over the range of interest can be fairly well compensated for by the curvature of the mutual characteristic of the following output valve, whose grid voltage is taken from across the capacitor. It was not considered necessary therefore to complicate the circuit at this point in order to get an exact logarithmic relationship, especially since calibration can be very easily performed, and the frequency ranges being used at any given time were small, usually about 30c/s in width. The capacitors therefore provide a voltage of the correct magnitude and sign for connecting directly to the grids of the output valves, which are operated without grid leaks in

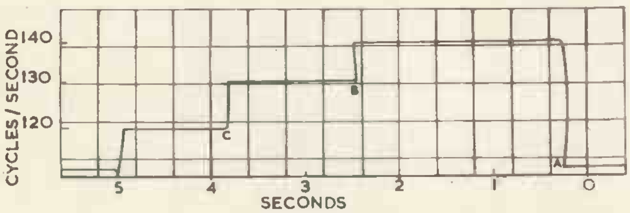


Fig. 8. Copy of pen recording for 3 steady frequencies from an oscillator of 120, 130 and 140c/s

(Recording paper stopped at B, C and D while oscillator frequency was changed.)

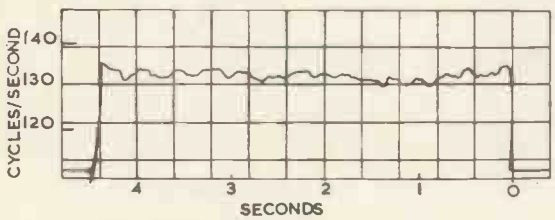


Fig. 9. Copy of pen recording for voice singing at 130c/s

order to avoid any slow discharge of these capacitors. They are discharged only at the end of a complete cycle of the switching waveform, their voltage being held constant during the latter half of the cycle, since the pentode is then non-conducting. The discharging is done by differentiating the appropriate switching waveform and using the amplified trigger pulse simply to discharge the capacitor through a triode switched on by the pulse. The duration of this discharge is not particularly critical, provided that it is short compared with the charging time, and if small capacitors and correspondingly small charging currents are used, a discharge almost to earth potential can be obtained quite satisfactorily. Fig. 7 gives a separate diagram of this part of the circuit with the waveforms at the various points to make the operation clear.

It is obviously of some importance that the paralleled output valves be well matched if a high sensitivity is required without the appearance of any ripple voltage at the output. Some selection of valves may therefore be necessary at this point, but this is minimized by the addition of some negative feedback in the form of a cathode resistor to make the grid base less dependent on the valve characteristics, and also by providing for a variable adjustment of the screen voltage on one of the output valves. Any residual a.c. ripple may be removed by the addition of a small capacitor across the output of the stage, provided that the time-constant introduced by it is not excessive. The valve used in this application was the 6F33 short suppressor grid base pentode. It is seen that two small neons are used to back off the h.t. voltage from the output, and the residual ripple is removed by the use of a 100kΩ series resistor and a 0·05μF shunt capacitor.

Sensitivity and Results

The instrument was used in conjunction with a Southern Instruments pen recorder Type M.944 and d.c. amplifier Type MR.341 B, to give an overall sensitivity of 1cycle/mm deflexion. Sensitivities greater than this may be obtained from the instrument but were not required in this application. The input voltage required is 10V r.m.s.

Four records obtained are shown in Figs. 8-11. In Fig. 8 the record shows the 140c/s output from an oscillator and loudspeaker system, the sound being switched on at A. At B and C the oscillator output is changed to give 130c/s and

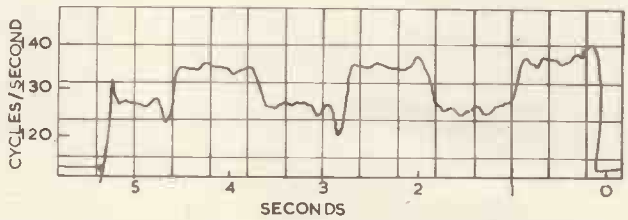


Fig. 10. Copy of pen recording for voice singing between 125c/s and 135c/s

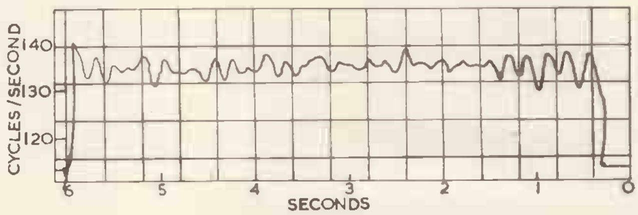


Fig. 11. Copy of pen recording of more resonant voice singing a 125c/s note from memory

120c/s to provide calibration levels. In Fig. 9 the record shows the human voice attempting to pitch a 130c/s note from memory, while in Fig. 10 the response of the voice is shown when attempting to move steadily between two frequencies of 125c/s and 135c/s, as remembered from the two sounds given previously. Fig. 11 shows a more trained singing voice producing a 135c/s note.

Acknowledgments

The authors wish to gratefully acknowledge the encouragement and financial help given to them by the Medical Research Council which made this work possible, and the facilities afforded by the Department of Phonetics, University College. London, and the Institute of Experimental Psychology, Oxford.

Dawe Instruments Ltd., of Ealing, are planning to produce a commercial version of this frequency meter which may be of interest to a wide variety of users.

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A Novel Gas-Gap Speech Switching Valve

By A. H. Beck*, B.Sc., A.M.I.E.E., T. M. Jackson* and J. Lytollis*, M.A.

A new gas discharge circuit element is described. It has the following properties; low resistance (circa 100Ω) when struck, the resistance being constant for all frequencies up to at least 50kc/s, the reactive component of the impedance is negligible and the noise voltages are at least 60dB below signal levels. The development of such devices considerably simplifies major problems in electronic telephone exchange design.

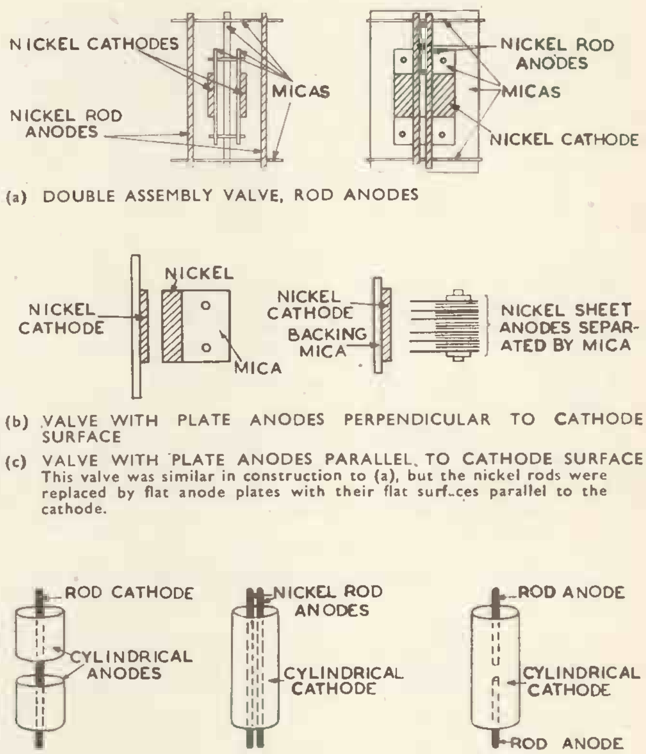
THE all-electronic telephone exchange has been the subject of much research in the last decade. One of the simpler ways of making such an exchange seems to be the direct replacement of the crossbar switch by electronic devices, each junction of the mechanical switch being replaced by a suitable electronic device. The more obvious requirements of such a device are:

1. That it can be switched rapidly from a high (practically infinite) a.c. impedance to a low (practically zero) a.c. impedance.
2. That it shall transmit voice frequencies at milliwatt power levels without either frequency or amplitude distortion.
3. That it shall not introduce electrical noise.
4. The device should form part of the line circuit and the switching operation should be performed by pulses in the line circuit.

A cold-cathode gas-filled valve is an obvious device to investigate for the purpose outlined because the glow discharge can be initiated and extinguished directly by pulses, and there is a definite break between the conducting and non-conducting state within a time of the order of 1 millisecond. There are other advantages in using a cold-cathode gas-filled valve. When in a non-conducting state the valve consumes no power; rapid fault diagnosis is possible because the glow is easily visible; and such valves have long lives.

The main difficulty to be overcome is that of providing a sufficiently low resistance path for reasonable direct currents in the conducting state. Bell Telephone Laboratories[1] have produced a diode gas-gap using a hollow cathode discharge which gives a small power gain in the frequency range of 50 to 3 000c/s and operates with direct currents in the range 10 to 20mA. It is not known whether this valve can be switched and used directly in the line. This article describes an electrode arrangement for gas-filled valves which gives a noise free, low resistance path for d.c. and a.c. signals, the upper frequency for the a.c. signals being at least 50kc/s. This device satisfies the other requirements stated in this introduction. Several different electrode structures are possible and two practical valves using the arrangement are described.

The electrode arrangement consists essentially of a cathode with two electrodes acting as joint anodes equally spaced from the cathode surface. These anodes can be of any geometrical shape provided a normal projection from them in the direction of the cathode will meet the cathode surface. There is a limit to the anode-cathode separation, depending on the nature and pressure of the gas filling. Fig. 1 shows various electrode arrangements which have been found to work satisfactorily. Figs. 2 and 3 show the variation of anode gap resistance with cathode current and frequency respectively. The gap resistance can be measured directly using an a.c. bridge. It can be seen that



(a) DOUBLE ASSEMBLY VALVE, ROD ANODES

(b) VALVE WITH PLATE ANODES PERPENDICULAR TO CATHODE SURFACE

(c) VALVE WITH PLATE ANODES PARALLEL TO CATHODE SURFACE
This valve was similar in construction to (a), but the nickel rods were replaced by flat anode plates with their flat surfaces parallel to the cathode.

(d) CENTRAL CATHODE
(e) CENTRAL ANODES PARALLEL TO EACH OTHER
(f) CENTRAL ANODES OPPOSITE EACH OTHER

Fig. 1. Various structures for double anode valve

the gap resistance is substantially independent of frequency but varies inversely with the total current through the valve. The apparent increase of resistance at low frequencies is caused by the impedance of blocking capacitors used in the measuring circuit becoming appreciable at these frequencies. Below a current of 10mA there is a rapid increase of gap resistance, but above this current the variation of resistance with current is gradual. The gap resistance is substantially non-reactive, there being no frequency dependent inductive component present such as is normally found in diode electrode arrangements. It is also noise free.

Fig. 4 shows the d.c. characteristics of a typical valve using the electrode arrangement already described and Fig. 5 shows the circuit used to measure the characteristic. The

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anodes were controlled by separate h.t. supplies, and these supplies were first adjusted so that the currents in the two anode circuits were equal. The voltage of each supply was then adjusted so that one anode source was raised in voltage by steps of 5 volts, while the other anode source was lowered in steps of 5 volts. The currents in each anode

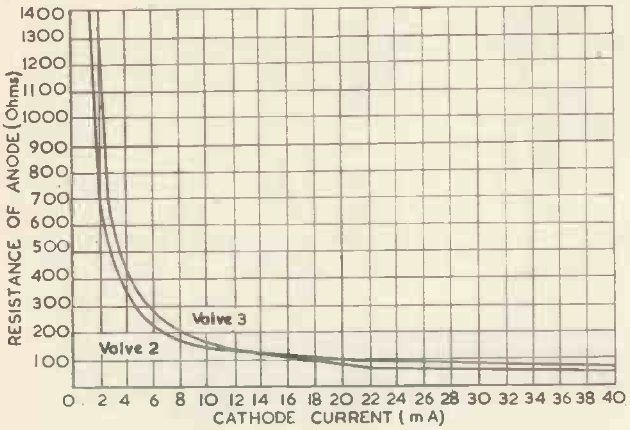


Fig. 2. Variation of resistance with cathode current

Valve No. 2—½ millimetre gap between anodes. 30mm Hg. pressure of neon-argon gas mixture.

Valve No. 3—½ centimetre gap between anodes. 30mm Hg. pressure of neon-argon gas mixture.

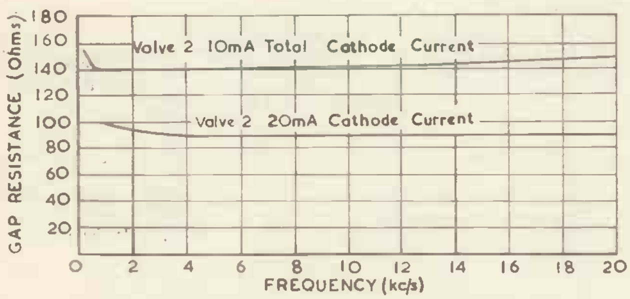


Fig. 3. Variation of gap resistance with frequency

Valve No. 2—½mm anode gap. Neon-argon gas mixture at a pressure of 30mm Hg.

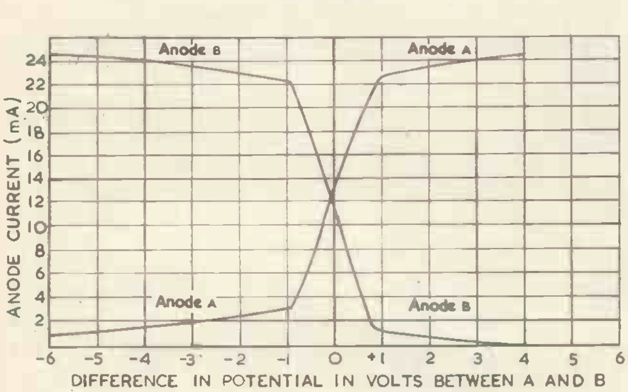


Fig. 4. Anode characteristic of double anode valve

Valve No. 3—½mm anode gap. Neon-argon at 30mm Hg. pressure.

circuit were measured for each 5 volt variation, and the voltage difference between the anodes was also measured. The characteristic shows that about the point where the anode currents are balanced there is a region where a small change in voltage on one anode produces large current variations in the two anode circuits. It is also obvious that as the current in one anode circuit increases, there is a corresponding decrease in the other anode circuit of approximately the same amount, so that the cathode current remains constant. The linearity of the graph in the working region shows that distortion will be negligible. The graph also shows that this electrode arrangement has the important property that a surge of voltage in one anode circuit will not extinguish the discharge so that the valve ceases to operate. Such a surge will merely cause one anode to stop taking current, the whole of the current through the valve being taken by the other anode until the surge has passed. This is a useful characteristic for telephone line operation.

Valves incorporating the double anode electrode arrangement

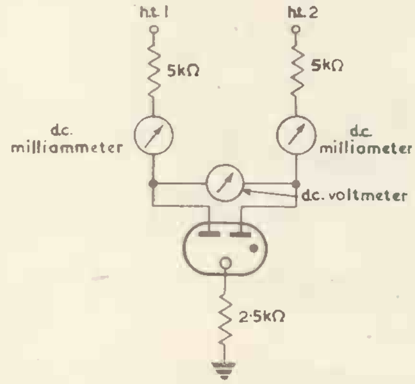


Fig. 5. Test circuit for d.c. characteristic

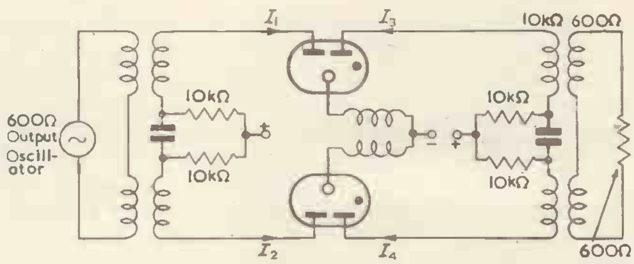


Fig. 6. Use of the double anode valve as a switch directly in the telephone line

I_1, I_2, I_3, I_4 = 10*mA*

ment can be used for speech transmission in a circuit similar to that shown in Fig. 6. The valves are acting effectively as switches in the line. In a 10kΩ impedance circuit the total loss due to a pair of valves acting as one stage is less than 0·2dB.

To enable valves using the electrode arrangement to be switched directly using pulse voltages in the line it is necessary to have stable, reproducible electrical characteristics. For instance, the maintaining voltage, V_m, of all valves should be within the limits of ±5 volts if V_m is of the order of 100 volts, and the breakdown voltages, V_b, should be within the limits of ±10 volts if V_b is of the order of 250 volts. It is also necessary to have a large difference between the maintaining voltage and the breakdown voltage of the glow discharge. V_m is controlled by the nature of the gas filling, current density, cathode material and state of the cathode surface. V_b is also controlled by these factors, but in addition it is a function of the product of gas pressure and electrode separation.

During study of the geometrical design factors necessary to ensure a low resistance gap between the joint anodes, experiments were undertaken to relate gas pressure and electrode separation to gap resistance. This was done by taking a valve with an electrode separation of fixed value and measuring the resistance between the anodes when the valve was still on the pump bench so that the gas pressure could be varied at will. The current in the discharge was kept constant at 20mA. The results for helium are shown in Fig. 7. It shows that there is a sudden sharp increase in resistance when a given pressure is reached for a particular electrode separation. Argon gave similar results. Fig. 8 shows a similar graph for neon-argon-hydrogen gas mixture and here, after the sudden increase to a high value there is a rapid decrease to a fairly low resistance once more. It is interesting that there is normally a blue coloured anode glow on the anode surface when there is a glow discharge in

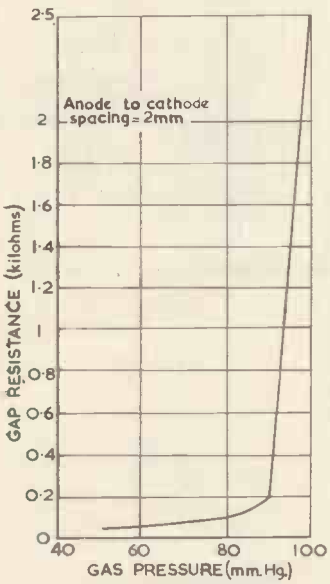


Fig. 7. Variation of anode to anode resistance with gas pressure (helium)

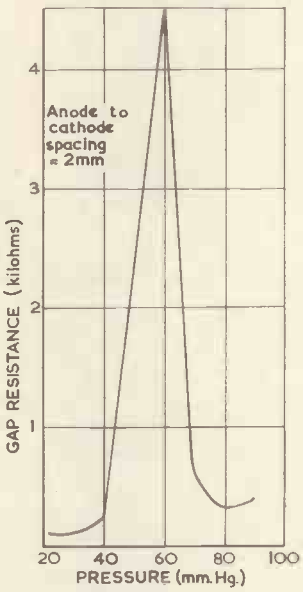


Fig. 8. Variation of anode to anode resistance with gas pressure (neon-argon-hydrogen (9 : 1 : 7))

neon-argon-hydrogen gas mixture and yet this glow is not present at low pressures when a low anode to anode resistance is observed, but appears suddenly when the sharp increase in anode to anode resistance takes place. This argues the sudden formation of a space charge sheath on the anode, because anode glows are formed when a space charge exists in the anode region. Probe measurements confirmed that space charge sheaths do form on the anodes at the pressure at which the gap resistance suddenly increases to high values.

The above results show that the anode-cathode gap values cannot be increased indefinitely in order to secure a high V_b because there is a critical distance at a given gas pressure beyond which a low gap resistance cannot be obtained. However, it was found that this distance was sufficiently great for a large $V_b - V_m$ difference to be obtained while still retaining a low gap resistance if helium was used as a gas filling and the pressure was suitably chosen.

Another requirement when considering pulse breakdown is that the gap shall always break down when a pulse of given amplitude is applied to one or both of the electrodes.

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

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

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

Formative delay time necessitates the application of pulse voltages with amplitudes greater than the normal d.c. breakdown voltage of a gas-gap in circuits where pulse techniques are used to initiate the discharge. The difference in voltage between the pulse amplitude required to produce breakdown and the d.c. breakdown voltage is called the "overvoltage". Early measurements upon speech-gap tubes showed that the overvoltage required to produce breakdown depended upon:

(1) History of the cathode (i.e. whether it has been conducting or left idle).
(2) Pulse width.
(3) Light falling on the electrodes; photo-electric effect.

There are several ways in which the photo-electric priming can be produced. An internal priming source can be incorporated in the valve, or an external agent such as an ultra-violet light source can be arranged to prime a bank of tubes. Another method of priming is to introduce a radioactive substance into the valve, so that ionization is produced by radioactivity. The availability of tritium, a weakly radioacitve substance with a half-life of $\simeq$ 12 years and radiation energy of $<$10keV, which can be used with safety within a glass envelope has greatly increased the attraction of this latter form of priming. The advantage of the method is that no electrical power is consumed to produce the priming.

Theory of the Low Resistance Anode to Anode Gap

Probe[2] and other measurements[3] recorded in original published papers have shown that the negative glow is a plasma region, there being high equal concentrations of positive and negative ions here. Concentrations of 10^9 ions/cm^3 have been calculated from measurements made, and Emeleus[4] quotes a figure as high as 10^{11} ions/cm^3. The conductivity of the space between the anodes operating under the conditions outlined in this report is therefore high, and a low resistance might be expected from this consideration. On the other hand, it is difficult to see why a change of one volt at either anode should cause the anode concerned to take all the current formerly being received by the other anode, which is normally only about 1mm away.

Fig. 9 shows graphs of gap resistance against gap length for an experimental valve containing one fixed and one mobile anode. The electrode assembly was otherwise similar to that of normal valves except that a larger area cathode had to be used, and therefore high total currents were required to cover the whole cathode surface with a glow discharge. At a current of 15mA per anode an irregular curve was obtained. This was because there was a relatively dark patch on the cathode surface between the

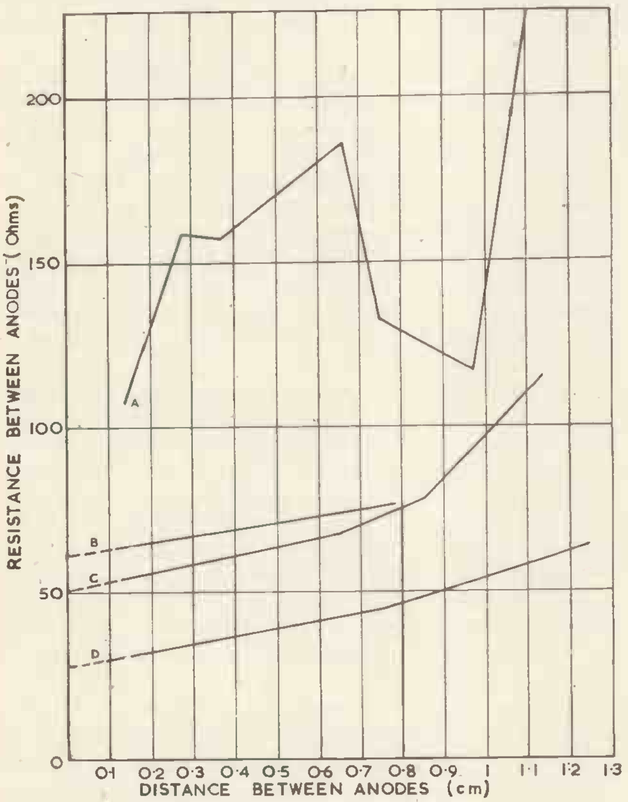


Fig. 9. Variation of resistance with gap length

A—15*mA per anode*
B—20*mA per anode*—*slope* = 2·34 Ω/*mm*
C—20*mA* ,, ,, ,, = 3·0 Ω/*mm*
D—30*mA* ,, ,, ,, = 2·2 Ω/*mm*

anodes, and when the moveable anode was over this area the resistance between the anodes was high, but as soon as the anode moved over a part of the cathode where the negative glow was normal, the resistance of the gap decreased. At the maximum spacing the resistance increased suddenly because this was the edge of the negative glow region, and the mobile anode was moving out of contact with the plasma. The graphs for higher currents show that there is a steady, small increase of gap resistance with gap width, this increase being only a few ohms per millimetre. The slopes of the graphs at the two higher currents are sensibly the same.

The conclusions drawn from the results are that a field theory of the switching action cannot be substantiated, and that a theory on the conductivity of the plasma can only be advanced if some boundary condition at the anodes is postulated to account for the large residual resistance which is obtained for zero length when the graphs are extrapolated.

Probe measurements were next made to elucidate what happens to the plasma potential when one anode is raised and then lowered in potential so that it draws maximum current and then minimum current. A valve similar to that represented in Fig. 10 was used, and the measuring circuit is shown in Fig. 11. The anodes were connected directly to the variabe h.t. sources 1 and 2, and the probe potential was varied by means of a potentiometer supplied from h.t. source 3. The currents in the anode circuits were measured by low resistance milliammeters, and the probe current was measured by an accurate multi-range microammeter. The probe potential relative to earth was measured very accurately with a standard potentiometer, and the same instrument was used to measure the anode voltages

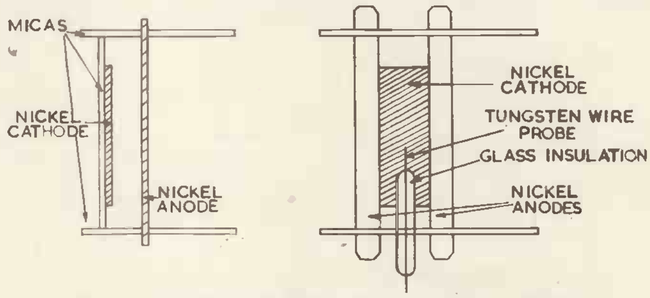


Fig. 10. Double anode valve with probe between anodes

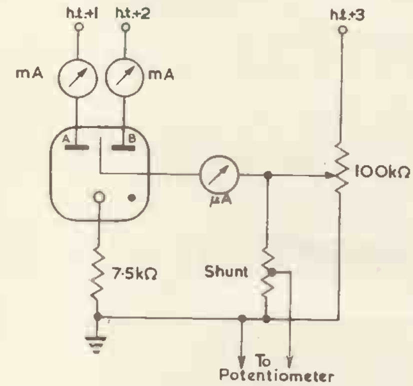


Fig. 11. Circuit used for probe measurements

accurately. Since there was practically no resistance in the anode circuits, the shunt current did not affect the anode voltage when the potentiometer was connected between anode and earth. The probe potential measured by the potentiometer must be corrected for the potential drop across the microammeter.

The probe characteristics and anode voltages were measured (A) with the anode currents balanced at 10mA, (B) when anode A was raised in potential until anode A drew 20mA current and anode B drew zero current, (C) when A was lowered in potential until A drew zero current and B drew 20mA current. Fig. 12 shows the probe characteristics for these three states, and Fig. 13 shows the plots of the i^2/V characteristics for the same states for electron currents above the knee part of the probe characteristics. Langmuir probe theory[1] requires that the i^2/V characteristic should be linear except near the space potential, and from the slope of the line the number of electrons per cm^3 of the plasma can be calculated.

RESULTS:

(a) Potential of anode A	=	263·2 volts
,, ,, ,, B	=	263·12 ,,
Space potential (from graph)	=	263·82 ,,

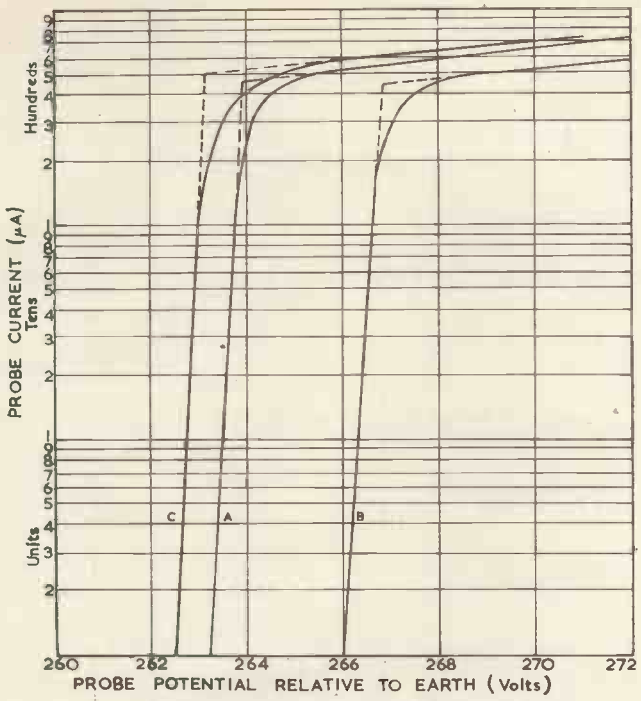


Fig. 12. Probe characteristics for balanced and unbalanced states of anode currents in a double anode valve

(b) Potential of anode A = 266·9 volts
„ „ „ B = 263·24 „
Space potential (from graph) = 266·8 „
(c) Potential of anode A = 258·44 volts
„ „ „ B = 263·04 „
Space potential (from graph) = 263·15 „

Electron temperature (from slope of graphs in Fig. 12) = 1 144°K

Number of electrons per cm³ (from slope of graphs in Fig. 13) = $3·7 \times 10^9$

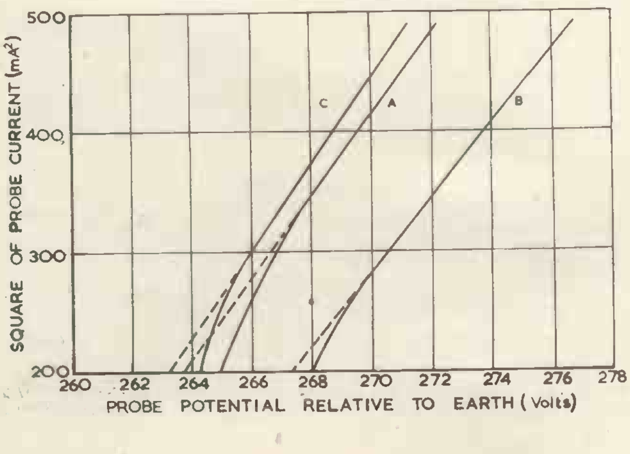
Conclusion

It is seen that the space potential appears to be positive with respect to the anode potential in the balanced state. Contact potential difference between probe and anodes is concluded to be the cause of this.

The results now make clear the switching action of the double anode valve. As one anode is raised in potential the plasma potential follows the potential of the highest electrode with which it makes contact and leaves the other anode at a potential which is now negative with respect to the plasma potential, and so this anode takes a smaller electron current. The other anode takes a greater electron current because the h.t. voltage determines what the cathode current shall be, and so the current through the valve remains approximately constant. If the plasma potential rises to a voltage such that the lower potential anode is several volts negative with respect to the plasma potential, then the current to this anode falls to zero, and the other anode takes all the current passing through the valve. If one anode is lowered in potential, the plasma potential remains close to the potential of the other anode since it still follows the potential of the highest electrode with which it is in contact. The anode which is being lowered in potential therefore draws less and less electron current as it goes negative with respect to the plasma potential until the cut off point is reached. The low electron temperature of the space around the anodes shows that the electrons have low energies and therefore a small negative difference of potential between the anode and the plasma will be sufficient to repel the electrons and reduce the electron flow to the anode.

If the anodes are not in intimate contact with the plasma then the above mechanism cannot work, and this explains why a space charge sheath on the anode causes a high anode gap resistance. It also explains why a patchy glow produces a high gap resistance, because the anode over the part of the cathode where the negative glow is absent or of low intensity will have little influence on plasma potential.

Fig. 13. Probe characteristics for balanced and unbalanced states of anode currents in a double anode valve



Practical Valves

Multiple Gap Valve

For convenience in circuit design it is desirable to have a valve containing a number of gaps, and a valve containing ten gaps is particularly suitable for telephone work. To meet this demand the multiple gap valve shown in Figs. 14 and 15 was devised. The assembly consists of a cylindrical common cathode made of nickel. The surface is divided into ten equal areas by vertical mica partitions which radiate from the axis of the cylinder to make a flush contact with the cathode surface. The partition micas are located in slots cut in the top and bottom micas which close the ends of the cathode cylinder. The anodes, two in each sector, are mounted at a distance of 2mm from the cathode surface, and are located in the end micas. At the centre of the cathode cylinder a vertical tungsten wire is mounted along the axis to serve as a photo-electric primer to all gaps. This priming device was for experimental purposes only, because although it is a simple means of priming, its power consumption is too high for practical purposes.

A number of these multiple gap valves have been made and they have been found to operate satisfactorily in switching circuits. Great care is necessary to keep the cathode spacing constant at 2mm in all ten gaps, because a difference of 0·25mm in this dimension can cause a breakdown voltage difference of 20V. V_m is constant to a few volts within one valve, but over a number of valves this characteristic can vary considerably unless care is taken in processing and ageing. The valves work well under pulse conditions with pulse widths of 100μsec and overvoltages of 40V. There is a difference in the d.c. breakdown before and after a glow discharge, this difference being about 15V. Typical values of parameters for this valve are:

Breakdown voltage before glowing	= 330V
„ „ after glowing	= 315V
Maintaining voltage	= 165V
Gap resistance	= 100Ω

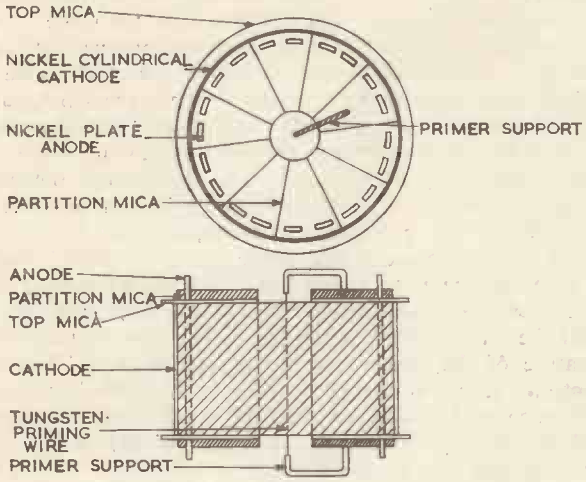


Fig. 14. Multiple gap valve

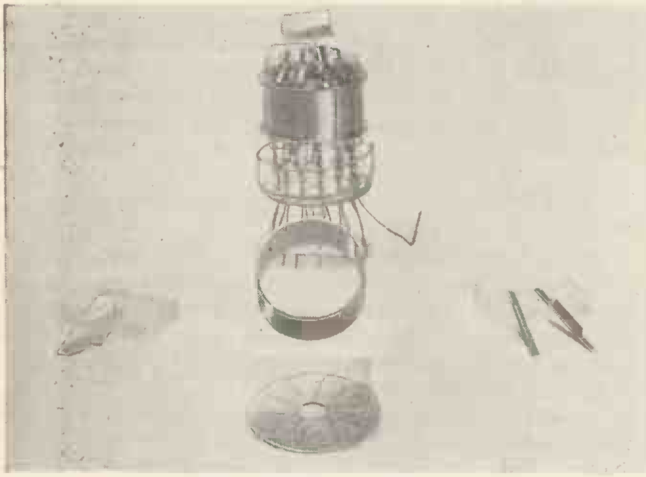


Fig. 15. Multi-gap valve and component parts

SINGLE GAP VALVE

This valve is illustrated by Fig. 16. The assembly is cheap and easy to produce, and the pinch seal acts as a convenient mount. Both sides of the cathode are covered by the glow discharge, and this eliminates the need for any micas. However, the anodes must be branched as shown so that they are in contact with the glow plasma on both sides of the cathode otherwise control of the plasma potential is lost and a high gap resistance results. Molybdenum is used as the cathode material because stable, reproducible electrical characteristics can be obtained with this metal if the cathode is thoroughly cleaned by subjecting it to heavy d.c. glow discharge currents. Also, the maintaining voltage of molybdenum cathodes in helium at the pressure used in these valves is 110V, which is several tens of volts lower than the maintaining voltage for a nickel cathode. This lower potential simplifies the circuits used in connexion with the valve. Priming is achieved by the use of radioactive material. Typical characteristics for these valves using helium and neon as gas fillings are:

HELIUM FILLED VALVES	
D.C. breakdown voltage	= 240±10V independent of glow history
Maintaining voltage	= 113±2V
Gap resistance	= 100Ω
NEON FILLED VALVES	
D.C. breakdown voltage	= 280±20V
Maintaining voltage	= 105±2V
Gap resistance	= 200Ω

These figures relate to valves where the effect of wall charges upon breakdown voltage is not directly controlled

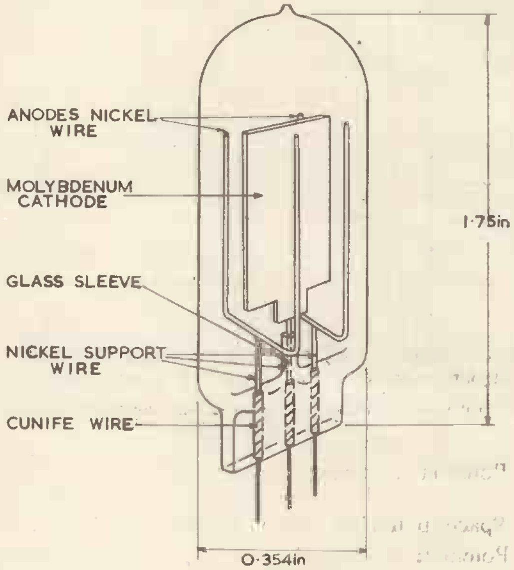


Fig. 16. Unit speech gap valve

by a connexion to the sputtered metal layer in the inner surface of the envelope. Recent work suggests that such control reduces the spread in V_b and can increase the $V_b - V_m$ gap if the potential at which the sputtered layer is maintained is correctly chosen.

Conclusion

The operation and characteristics of the speech gap have now been described. Specific embodiments of the ideas presented have been directed mainly towards the utilization of these devices in telephony, but it is clear that there are many other fields in electronic development where their use would be advantageous. It is hoped that this article may stimulate interest in such development.

Acknowledgments

The authors wish to acknowledge their debt to their colleagues who have assisted in the design and construction of experimental valves and to the management of Standard Telecommunication Laboratories Ltd. and Standard Telephones & Cables Ltd. for permission to publish this article.

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A Low-Frequency Pulse-Train Generator

By J. E. Flood*, Ph.D., A.M.I.E.E., and J. B. Warman*, A.M.I.E.E.

The pulse generator uses multi-cathode gas-filled counter valves to produce pulses whose make-to-break ratio can be adjusted between 1 : 99 and 99 : 1 in steps of one per cent with an accuracy of one part per thousand. The pulse repetition frequency covers the range 5 to 50c/s, with an accuracy determined entirely by the external oscillator used to drive the pulse generator. The pulses can be sent continuously or in trains of from 1 to 11 pulses with a pause between each train which is adjustable between 66msec. and 4sec.

MULTI-ELECTRODE cold-cathode glow-transfer valves[1-6] provide a useful technique for measuring time intervals by counting cycles of oscillation from a source of known frequency. The counters can be used to control circuits for producing pulses of accurately determined length and pulse repetition frequency (p.r.f.) provided that the frequencies required are within the operating range of the multi-cathode valves. A pulse-train generator using multi-cathode counter valves is described in this article.

The instrument provides pulse-trains whose make-to-break ratio can be adjusted between 1 : 99 and 99 : 1 in steps of one per cent with an accuracy of one part per thousand. The p.r.f. covers the range 5 to 50c/s with an accuracy determined entirely by the external oscillator used to drive the pulse generator. The pulses can be sent continuously or in trains of from one to eleven pulses with a pause between each train which is adjustable between 66msec. and 4sec. These ranges were chosen because the instrument was designed for investigating the performance of circuits and mechanisms used in automatic telephony. The circuit of the instrument is divided into two sections : the pulse generator and the control circuit. Both of these circuits use the Dekatron type of multi-cathode counter valve[2].

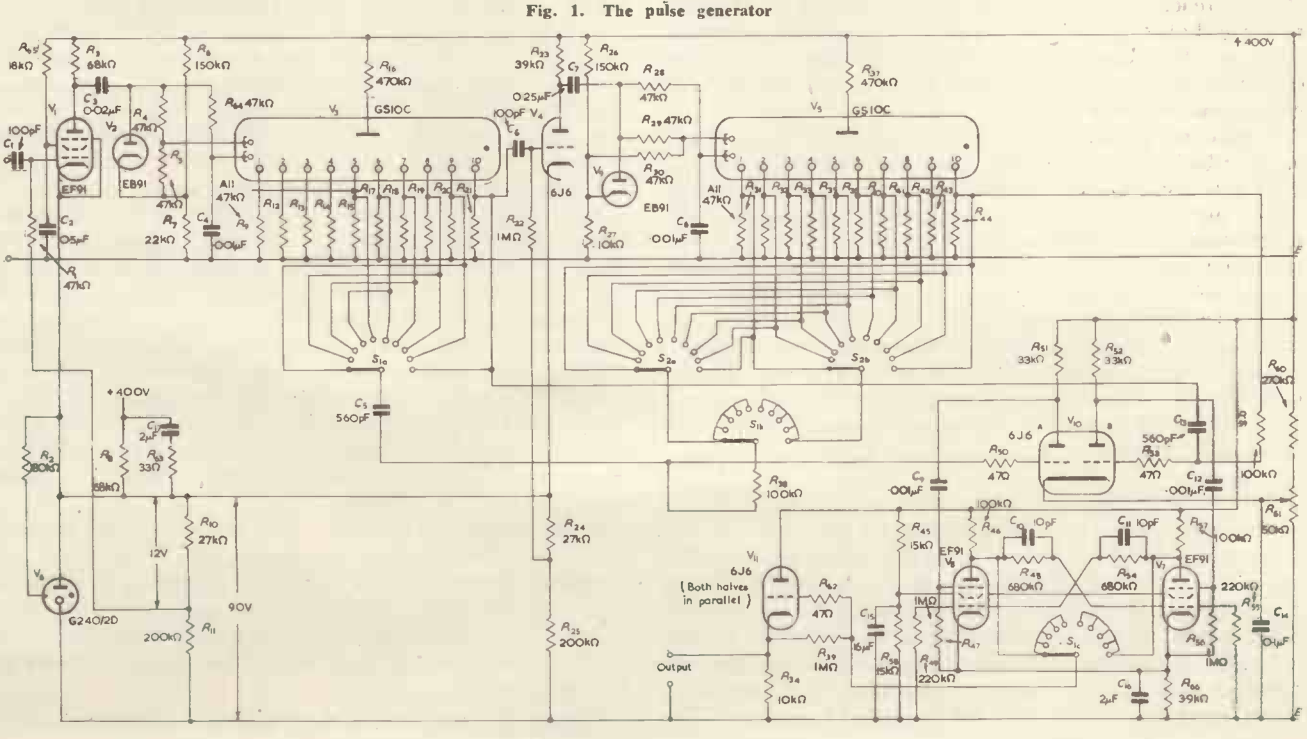
* Siemens Brothers & Co. Ltd.

The Pulse Generator

The pulse generator circuit is shown in Fig. 1. Two Dekatron stages are connected in cascade to provide a frequency-division circuit which divides by one hundred. This frequency-divider is driven by an external square-wave generator which is set to a frequency of 100 times the required output frequency. The Dekatron circuits have been found to operate satisfactorily up to a speed of 5kc/s, so reliable operation of the first divider stage sets an upper limit of 50c/s to the repetition frequency of the output pulses. The maximum p.r.f. could be increased by reducing the division ratio, but this reduces correspondingly the number of steps in which the make-to-break ratio can be adjusted. The output pulses are generated by a trigger circuit which is operated by the frequency divider at the beginning of each cycle of 100 input pulses and reset at a subsequent position in the cycle determined by the setting of two switches, thus generating a pulse-train of known make-to-break ratio. The operation of the circuit is described in detail below.

The Dekatrons V_3 and V_5 have driving circuits of a conventional type comprising valves V_1, V_2 and valves V_4, V_9 respectively. Positive pulses drive the control grids of the valves from beyond cut-off into grid current, causing large negative pulses to be produced at the anodes. The negative

Fig. 1. The pulse generator



Pulse at the anode of each valve is applied to two potential dividers ; one divider, consisting of two resistors, applies half the pulse voltage to the first guide electrodes and the second divider, consisting of a resistor and capacitor in series, applies to the second guides a pulse with an exponential rise and fall. Thus at the beginning of the input pulse, the first guide immediately becomes the most negative electrode and the glow transfers to it from the preceding cathode. The potential of the second guide falls, at a rate determined by its *RC* network, to a value more negative than the first guide so that the glow again transfers. At the end of the input pulse, the first guide returns immediately to its positive bias voltage at which it is clamped by the diode. The second guide rises more slowly to the same bias voltage and when its voltage exceeds that of the next cathode the glow transfers to the cathode, thus completing one step forward. Valves V_7 and V_8 form an Eccles-Jordan trigger circuit which is operated by gating circuits formed by the two halves of V_{10} and which drives the cathode-follower output valve V_{11}.

At the beginning of each cycle of operation cathode 10 of V_3 and cathode 1 of V_5 are conducting. Valve V_7 is then conducting and V_8 is biased off, corresponding to the " break " condition. The first input pulse steps the glow in V_3 to cathode 1 and subsequent pulses step the glow further. Each time cathode 10 of V_3 conducts it delivers a pulse to V_4 which steps V_5. When the glow reaches the cathode to which S_1 is set, a pulse is delivered to the grid of V_{10a} by means of C_5. However, this does not cause the valve to conduct unless its bias has already been partly offset by a potential applied to its grid through R_{38} from that cathode of V_5 to which S_2 is set. Thus, only when the cathodes in V_3 and V_5 to which S_1 and S_3 are set are both conducting is valve V_{10a} turned on. The anode of V_{10a} applies a negative pulse to the suppressor grid of V_8, thus changing the trigger circuit from the position corresponding to break (V_8 on) to that corresponding to make (V_7 on). Valves V_3 and V_5 continue to step and when cathode 10 of V_5 is conducting, its rise in potential reduces the grid bias of V_{10b}. When the glow in V_3 also reaches cathode 10, the pulse applied through C_{13} to the grid of V_{10b} turns the valve on. This applies a negative pulse to the suppressor grid of V_7, changing the trigger circuit back from " make " to " break " and the cycle of operations recommences.

A practical difficulty arises in the operation of the circuit as described above. If switch S_1 were set to cathode 1 of V_3, this valve would deliver its pulse before C_5 had time to charge up to the bias voltage from valve V_5. Consequently, the pulse would fail to turn on V_{10a}. This difficulty is overcome by taking outputs only from cathodes 5 to 10 of V_3. Positions 1 to 4 on S_1 use the same cathodes of V_3 as positions 6 to 9 but, to compensate for this, when S_1 is in the first five positions the connexions to S_2 are reversed so that pulses are produced, having a ratio complementary to that required. This is corrected by taking the output signal from V_8 instead of V_7, thus producing an output pulse-train having the required make-to-break ratio.

The Control Circuit

The control circuit is shown in Fig. 2. This contains two Dekatron valves : V_7 which is used for counting the number of pulses to form the train and V_{12} which is used for measuring the length of the pause between pulse-trains. Each of the three groups of cold-cathode triodes V_{13}, V_{14}; V_{15}, V_{16} and V_{17} to V_{19} are arranged in the well known manner[5] so that one valve in each group is always conducting, the conducting valve being extinguished by the striking of another. The control circuit receives pulses from the pulse generator over lead A and receives pulses over lead B from a multivibrator circuit which is not shown in Fig. 2.

When the start key (*KST*) is normal, valves V_{14}, V_{16} and V_{17} are made conducting and the Dekatron valves V_7 and V_{12} each have the glow set to cathode 0. When the start key is thrown, the operating circuits of the valve stages are completed. Contacts KST_1 and KST_2 complete the operating circuit for valve V_9 which provides a delay in starting determined by the time taken to charge C_{32} to the striking voltage of the valve. By adjusting the variable resistor R_{76}, the interval between throwing the start key and the commencement of pulse sending can be varied between a negligible amount and seven seconds. When valve V_9 strikes it reduces the grid bias voltages of the gating valves V_2, V_3, V_4, V_5 and V_{10} from 60V to 10V to enable them to accept pulses. Valve V_{10} is also turned on at its suppressor grid because V_{17} is conducting. The pulses which V_{10} receives from lead B are therefore applied to the drive circuit of Dekatron V_{12} which measures the inter-train pause. Repeated pulses step V_{12} until the glow reaches that cathode to which S_2 is connected and so causes valve V_{18} to strike. This extinguishes V_{17} and feeds a pulse via C_{19} to strike V_{15}. Valve V_{15} extinguishes V_{16} and raises the potential of the guide electrodes and cathodes 1 to 11 of V_{12}, thus resetting the glow to cathode 0.

When V_{17} extinguishes, valve V_{10} is turned off at its suppressor grid to prevent further stepping of V_{12}. When V_{18} strikes, gate V_5 is turned on at its suppressor grid to connect pulses from lead A (via V_2) to the drive circuit of Dekatron V_7 which counts the number of pulses in the train. When the glow steps from cathode 0 to cathode 1 this strikes V_{19} and extinguishes V_{18}. This closes gate V_5 and opens gates V_4 and V_3 by turning on their suppressor grids. V_4 continues the stepping of V_7 with subsequent pulses from lead A and V_3 sends out these pulses by means of the Carpenter relay in its anode circuit. This circuit action avoids any possibility of a distorted first impulse being sent out. If gate V_5 is opened by V_{18} during a pulse on lead A the first pulse fed to V_7 will be clipped, but this pulse is not sent out. In order to avoid clipping of the second pulse (which is the first sent out) when the make-to-break ratio is 99 : 1 and the speed is 50c/s, the circuit comprising V_{17}, V_{18}, V_{19} must operate in 0·2msec. This is ensured by using the G1/371K type valve[5] which has a deionization time of the order of 30μsec.

The pulses which are applied to V_4 in order to drive V_7 are of the opposite sense to those applied to V_3 to drive the relay because they are inverted by valve V_2. This causes the Dekatron to step when the relay releases, i.e. at the end of each output pulse. When the glow in V_7 reaches cathode 2, this strikes V_{16} which extinguishes V_{15} and so prepares the Dekatron V_{12} for counting the next inter-train pause. When the glow in V_7 reaches that cathode to which S_1 is set, V_{17} is struck. Valve V_{17} extinguishes V_{19} and strikes V_{13} which resets the Dekatron V_7 by raising the potential of the guide electrodes and of cathodes 1 to 11. This also closes the gate valves V_3, V_4, V_5 on their suppressor grids and opens gate V_{10}.

Pulses from lead B are now fed via V_{10} to step the Dekatron V_{12} for counting the next inter-train pause. The circuit has completed a whole cycle of operations and is now in the same state as it was immediately after the operation of the start delay circuit except that V_{13} is operated. However, V_{13} is extinguished when the glow reaches the second cathode of V_{12} and strikes V_{14}.

The circuit thus continues to generate, alternately, inter-

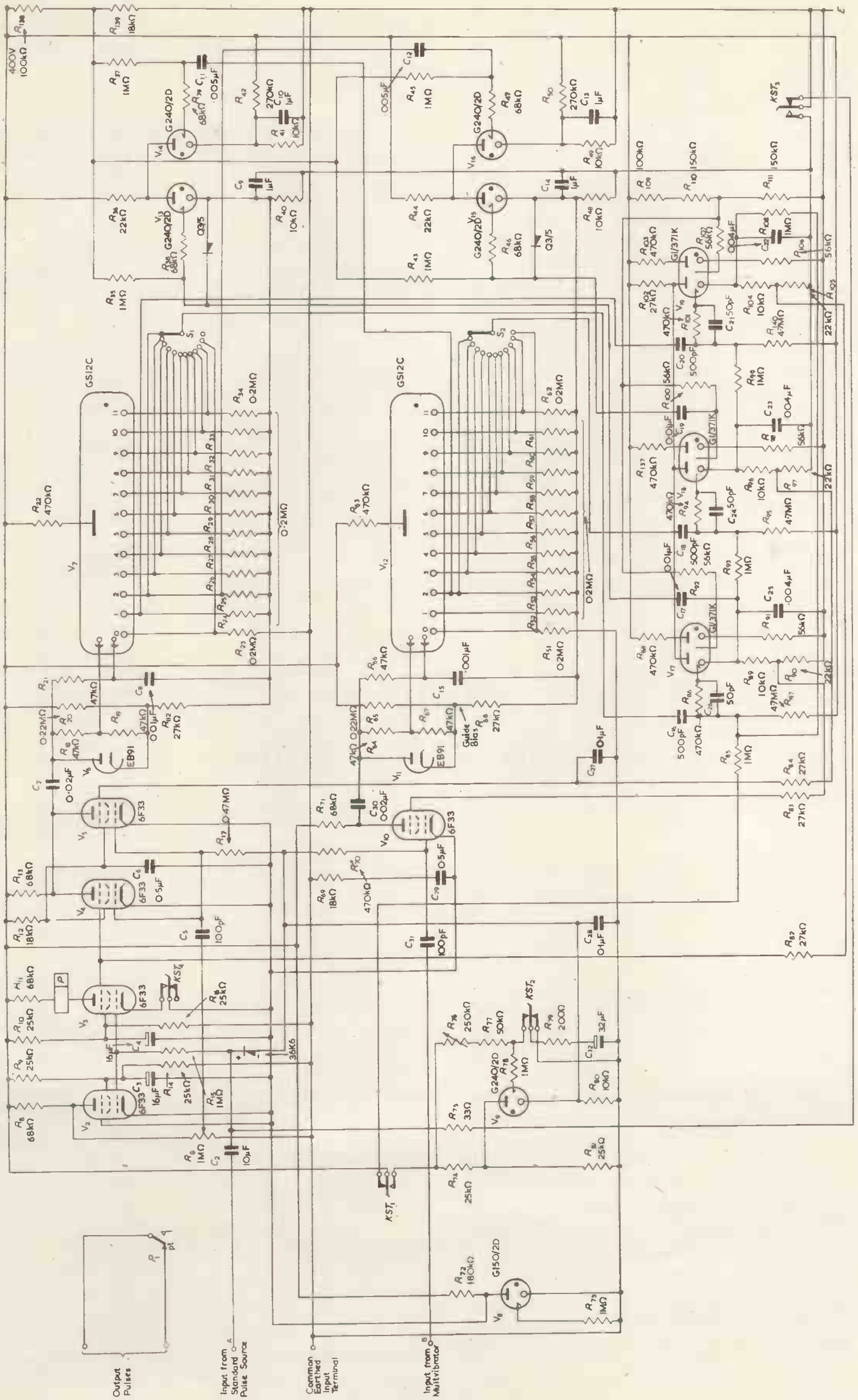


Fig. 2. The control circuit

G

train pauses of the duration set by S_2 and pulse-trains having the number of pulses set by S_1 for as long as the start key (*KST*) is operated. The multivibrator which drives the Dekatron V_{12} can be set to any frequency between 3 and 30c/s and V_{12} can be set by S_2 to count any number of cycles between 2 and 12, thus producing any desired inter-train pause between 66msec and 4sec. If the inter-train pause is not required to be entirely independent of the p.r.f., the multivibrator can be dispensed with by driving the inter-train pause counter from the pulse-generator. The inter-train pause can then be adjusted between twice and twelve times the pulse repetition period. If switch S_1 is set to its last contact position, so that valve V_{17} is disconnected from the cathodes of V_7, there is no inter-train pause and output pulses are produced continuously.

Oscillograph measurements have shown that the current waveform of the output valve (V_3) repeats the waveform of the pulse generator with negligible distortion, even on the initial pulse of each train. Accurately timed pulses of voltage are therefore available across the anode load resistor R_{11}. The difference between the operate and release lags of the relay, however, causes distortion of pulses derived from its contacts of up to 1msec, depending on their adjustment. If the pulses are required to operate relay contacts and this amount of distortion is not permissible, the distortion due to the relay must first be measured on an oscillograph and then corrected by altering the ratio setting of the pulse generator by the corresponding amount.

Conclusion

The instrument has been constructed in the laboratory and has given satisfactory service. In order to ensure reliable operation of the circuits the h.t. supply must be stabilized to within ±5 per cent.

Acknowledgments

Acknowledgment is made to Siemens Brothers & Co. Ltd for permission to publish this article. Thanks are also due to Mr. D. M. Bibb for his assistance in constructing and testing the apparatus.

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Stabilized D.C. Supplies using Grid-Controlled Rectifiers

By L. Knight*, A.M.I.E.E.

A simple method is described whereby thyratrons can be operated as grid-controlled rectifiers to give a stabilized d.c. supply. Mention is made of some of the special design considerations involved and a typical practical circuit is given together with curves of the voltage regulation obtained.

THE most popular type of stabilized h.t. supply uses a valve in series with the load and regulation is obtained by varying the d.c. resistance of the valve. With an h.t. current of 1 ampere or more this system becomes clumsy. Not only is it necessary to use a number of valves in parallel but the power dissipated by them becomes excessive. A more economical method is to use thyratrons as grid-controlled rectifiers.

The simplest way of controlling a thyratron rectifier is by what is known as the magnitude method of control, so called because the mean anode current is made dependent on the magnitude of a d.c. voltage applied to the grid. The basic operation of this method can be understood from Fig. 1. V_a is the anode voltage during a positive half-cycle and V_c the corresponding value of the critical grid voltage for a typical thyratron. The anode will not start to conduct until V_c falls to the actual grid potential V_g. A small change in the level of V_g will cause a significant change in the firing point and therefore in the mean current.

An alternative method of regulating the output is by phase-shift control. Here an alternating voltage of fixed magnitude is applied to the grid and its phase relationship to the anode voltage varied to control the firing point. Phase-shift control circuits are rather more complex and will not be dealt with here.

A simple magnitude control circuit is shown in Fig. 2. V_3 is a voltage reference tube whose burning voltage is slightly higher than the desired output voltage. In order to keep it conducting a small auxiliary d.c. supply has been connected in series with the main one. V_3 maintains the slider of the potentiometer at a fixed potential above the negative output terminal. If the output voltage falls the thyratron grids become more positive with respect to the cathodes. The valves then fire earlier in the cycle, thus giving a compensating increase in output. Conversely, if the output voltage rises the grids become more negative giving a compensating fall in output.

* *The British Tabulating Machine Company Limited.*

This circuit is not very successful in dealing with variations of mains voltage. If, for example, the mains voltage rises not only does the anode voltage increase, but the critical grid voltage becomes more negative. Both these factors conspire to increase the output voltage and the control circuit is not capable of giving adequate correction. A simple remedy,

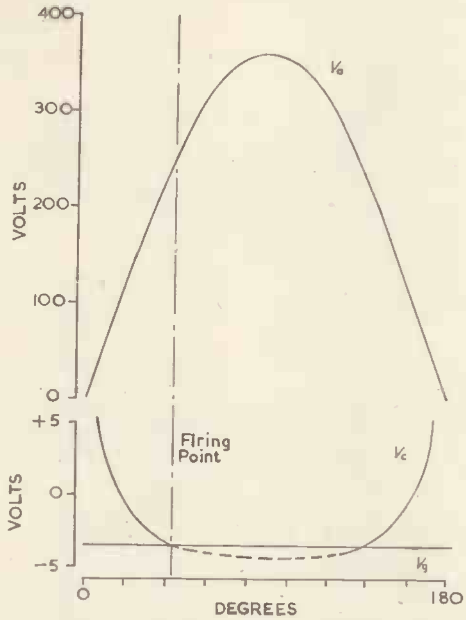


Fig. 1. Voltage waveforms of basic thyratron rectifier

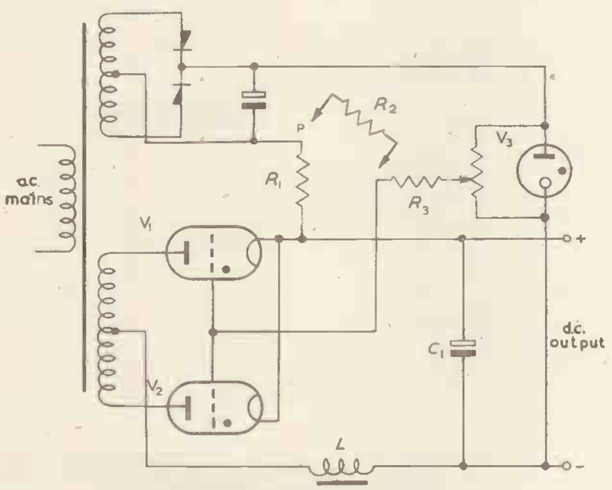


Fig. 2. Basic stabilized supply

described by Trucksess[1], consists of applying to the grids an additional correcting bias which is dependent on the mains voltage. With the circuit in Fig. 2 this can be done merely by adding the resistor R_2. As the mains voltage increases the voltage drop across R_1 will also increase making P more negative with respect to the cathodes. A proportion of this change is now transmitted via R_2 to the grids and causes a reduction in the d.c. output.

If the voltage change which the grids receive via R_2 is too great there will be over-compensation and the output will fall as the mains voltage increases. By suitably proportioning the

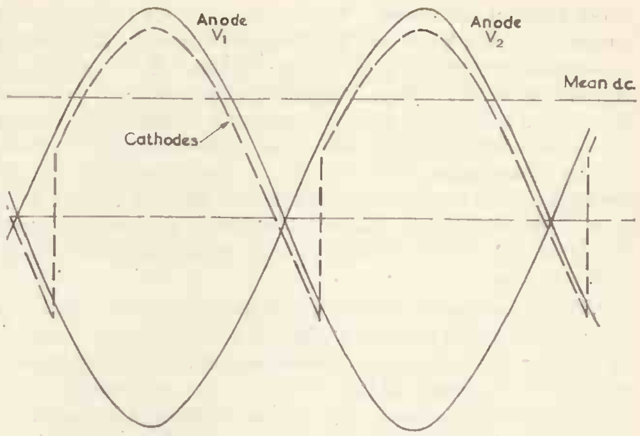


Fig. 3. Voltage waveforms of circuit in Fig. 2

resistor values it is possible to obtain almost perfect compensation over quite a large range of mains variations. The control bias from the reference tube via R_3 then serves to correct only for imperfections in the control from R_1 and for variations in load.

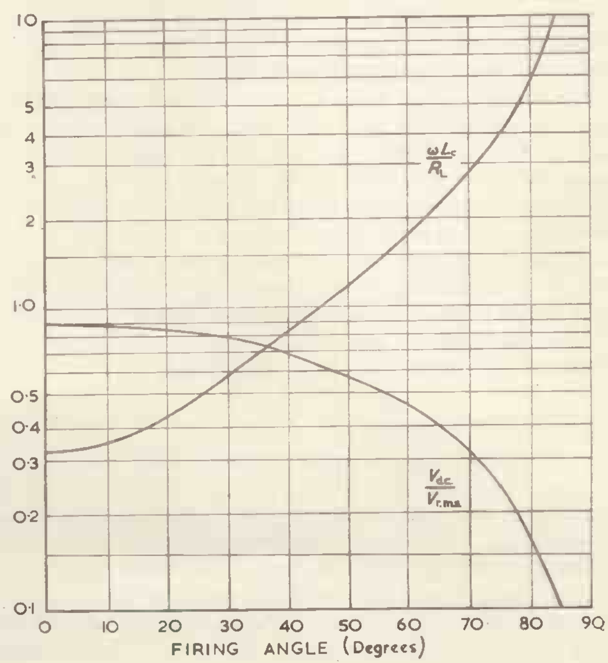
Fig. 2, therefore, constitutes the basis of a simple stabilizing circuit which is capable of handling large mains variations and moderate variations in load. The operation, however, is not quite as simple as may at first appear and it is proposed now to study it in greater detail.

The Smoothing Choke

In particular it is important to examine the action of the choke L which, apart from its obvious function of smoothing

Fig. 4. Variations of critical inductance and d.c. output voltage with firing angle

$\omega = 2\pi$ times mains frequency, L_c = critical value of inductance, R_L = load resistance, V_{dc} = d.c. output voltage + d.c. voltage drop in smoothing choke + voltage drop in one thyratron, V_{rms} = r.m.s. value of anode transformer secondary voltage (one leg to centre tap). It is assumed that ωL_c is large compared with $1/\omega C_1$.



plays another vital role. At the end of each half-cycle the tendency of anode current to cease will cause a back voltage to develop across the choke. This voltage will maintain the cathode potential below that of the anode and, provided that the inductance is high enough, the anode will continue to conduct until the next valve fires. The anode and cathode voltage waveforms with respect to the centre-tap of the anode winding on the transformer will then be as in Fig. 3. It will be noted that the anode-cathode potential of each thyratron just before it fires is nearly twice the instantaneous anode voltage.

If the inductance is dropped below a critical value one valve will cease to conduct before its successor fires. As soon as it ceases to conduct the cathode potential will then become positive with respect to the anode winding centre-tap by the voltage across C_1, that is, the output voltage. Consequently, the anode-cathode voltage of the second valve will be low or even negative at the time it should fire. It will fire late or even fail to fire altogether and the output voltage will fall to a value which allows the valves to fire earlier. The circuit may reach equilibrium with a low output but more often a sustained and rather violent low frequency oscillation will build up.

It is therefore essential to the proper working of the circuit that a choke input filter is used and that the inductance of the choke should be high enough to ensure continuity of current. The critical value of inductance L_c can be obtained from Fig. 4, which is based on curves derived by Overbeck[2]. L_c will be greatest when the firing angle is at its maximum and when the load is lightest. When determining the minimum permissible value of the choke inductance it is advisable to allow a safety factor of about 50 per cent to allow for the effects of voltage drop in the thyratrons and for any unbalance in their charactertistics.

It should be noted that with a very light load the value of the critical inductance is very high. Thus, if the power supply is liable to be operated with no load an internal load resistor should be incorporated, the value of this resistor being chosen to bring the maximum value of L_c to a reasonable value. In cases where there may be considerable variation of the load current the choke will need to have a high inductance at low current and a small inductance at high current. A "swinging" choke will then prove most economical.

Fig. 4 also enables the d.c. output for any firing angle o be ascertained. The minimum obtainable firing angle wll usually be just under 10° and the maximum which will normally be required is about 50°. From Fig. 4 it will be seen that this range of firing angles is sufficient to give a range of about $1\frac{1}{2}$: 1 in the value of V_{dc}/V_{rms}.

As the firing angle becomes greater the a.c. ripple on the output increases and better smoothing becomes necessary. As a rough guide it may be taken that with a firing angle of 50° the ripple will be four times as great as with a full-wave diode rectifier giving the same d.c. output.

The Thyratrons

An important consideration is that of which type of valve to use. Mercury vapour thyratrons require that rather exacting precautions be taken with regard to the ambient temperature and to the warming-up period. Thyratrons containing inert gas are therefore preferable.

With these latter types measures must be taken to delay the application of inverse voltage when anode current ceases. If a sufficiently high inverse voltage is reached before deionization is complete, the residual positive ions will be driven into the anode with such high velocities that many will become trapped. This results in clean-up of the gas and produces a marked shortening of the valve life. A limiting value for the product of the rate of decay of anode current and the rate of increase of inverse voltage is usually quoted

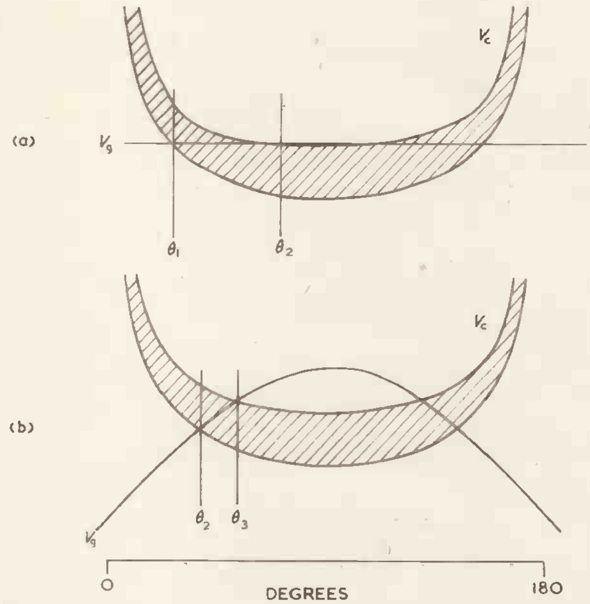


Fig. 5. Effect of adding a.c. to the d.c. bias

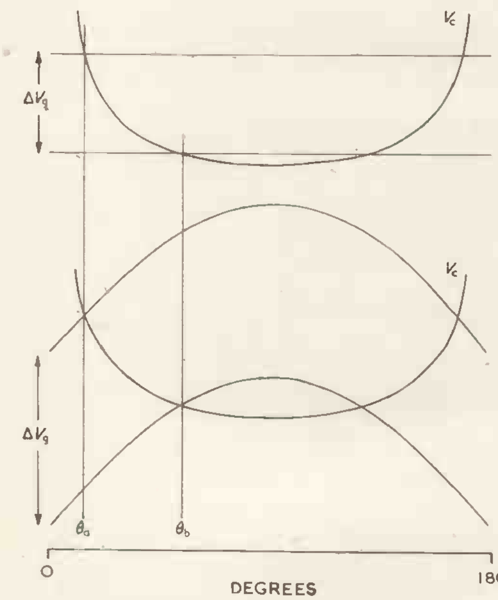


Fig. 6. Effect on sensitivity of a.c. added to the d.c. bias

by the valve manufacturer. Normally, it is possible to keep well within this figure by placing a suitable capacitor and resistor in series from anode to cathode[3]. The capacitor, together with the leakage inductance of the transformer, slows up the rise of the inverse voltage. The resistor damps the tuned circuit thus formed and prevents oscillation.

It has been supposed hitherto that the circuit will behave symmetrically, each valve conducting for 180°. With the circuit given this might be far from the actual case. The grid characteristics of thyratrons are liable to vary quite considerably from one valve to another and to change with age. Fig. 5(a) shows the possible variations in the critical grid

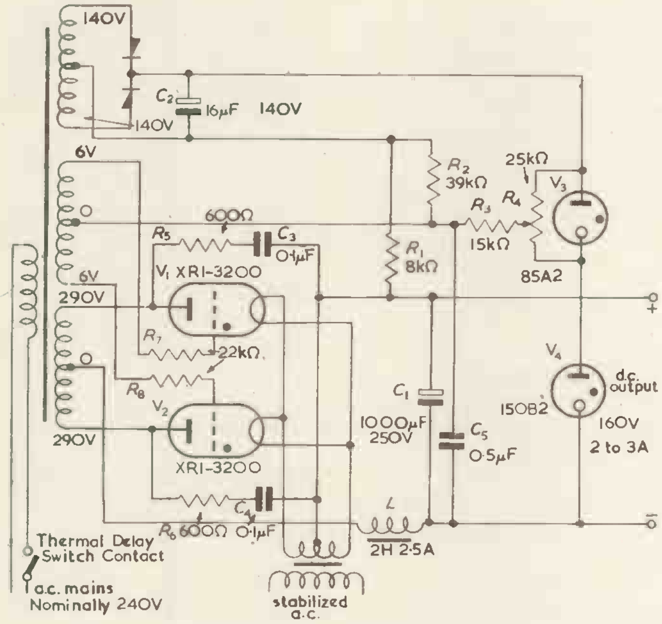


Fig. 7. Practical stabilized supply

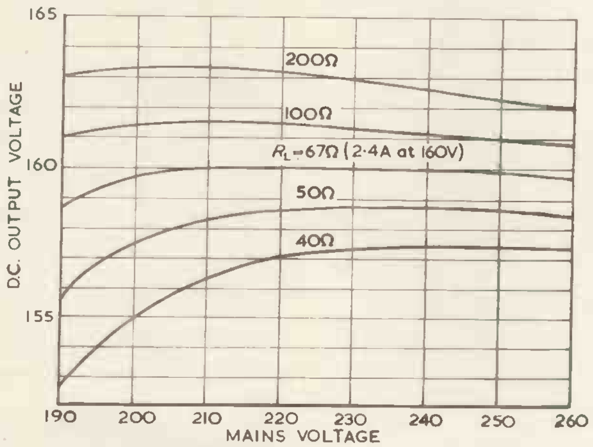


Fig. 8. Regulation of practical stabilized supply

voltage curves for a typical thyratron. With a grid bias level V_g the firing angle might be anywhere between θ_1 and θ_2, a range of about 45°. If the two valves in a full-wave circuit had extreme and opposite grid characteristics there would be a marked inequality in the firing angles and in the mean current of each valve.

The symmetry can be greatly improved by superimposing a small alternating voltage on to the d.c. bias. Ideally this voltage should lag on the anode voltage by 90° but, providing the firing angle is never to be greater than about 50°, it is almost as effective, and more convenient, to have the grid and anode in phase. Fig. 5(b) shows how the addition of the a.c. reduces the spread of possible firing angles.

Fig. 6 shows the bias variation $\triangle V_g$ required to vary the firing angle between two arbitrary points θ_a and θ_b. It will be seen that $\triangle V_g$ is increased when a.c. is added to the grid bias. In the interests of obtaining the greatest possible sensitivity, therefore, the alternating voltage should not be larger than is necessary to ensure a reasonable firing symmetry.

The thyratron anode current will have approximately a square waveform at all firing angles and thus the transformer design will be similar to that for a normal full-wave rectifier.

A Practical H.T. Supply

As an example of a practical h.t. supply using magnitude control, Fig. 7 gives the circuit of one which was built for an electronic calculator requiring 160V at a current that would remain fairly constant at about 2·4A.

Performance curves are given in Fig. 8. No tests of the long term stability have yet been made but some estimate can be made of what drift to expect. The only components whose characteristics are liable to show any significant variation are the thyratrons. As they age the critical grid voltage curve may be expected to change gradually by one or two volts and the output will then change by approximately the same amount.

The capacitor C_5 gives the control circuit a greater gain at high frequencies and was found to give some assistance in dealing with sudden fluctuations.

It is advisable to keep the filament voltage of any thyratron as close as possible to the nominal value. In the calculator for which this power supply was designed there was already a stabilized a.c. supply for the other valves and this was also used for the thyratrons. The requisite delay in applying anode voltage to the thyratrons was provided by a thermal switch contact in the anode transformer primary circuit.

Conclusion

From experience with power supplies such as described above the author feels that they are very convenient for applications where the load is reasonably constant and the output voltage regulation is not required to be better than about 1 per cent. Although the advantages are most pronounced with high output currents this type of circuit is still attractive at lower currents. Using the miniature 2D21 thyratrons, for example, it is possible to construct a very compact stabilized supply capable of comfortably delivering 200V at 150mA.

Acknowledgment

The author expresses his thanks to the British Tabulating Machine Company Ltd. for permission to publish this article.

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C-Band Weather Radar

As aircraft speeds have increased it has become increasingly important for the pilot to have in the cockpit a means of detecting and avoiding unfavourable weather or of navigating safely through it. For this purpose, radar, which in the past decade has become an essential in the study of cloud physics and storm structure, appears to be the answer.

In order to appreciate the importance of radar as a means of weather penetration, it must be understood that the heavy turbulence and hard cores of thunderstorms are usually associated with regions of rapid change in rate of precipitation. These areas of high precipitation gradient give rise to strong radar echoes, and appear on the radar display in terms of varying degrees of brightness. In seeking out these areas the radar beam must penetrate the intervening space in which rain will be falling. It is important that the rainfall in this space should not attenuate the radar signal so much that the response from the critical region is lost. The attenuation experienced is a function of the frequency of the radar and the rate of precipitation. Thus, in heavy rain the range of the radar could be reduced to the point where it would fail to detect the area of turbulence until it was too late for evasive action to be taken.

One of the first extensive flight evaluations of a 3cm navigational radar as a storm detector concluded that "radar was of value," but suggested that "a different, lower frequency would be better suited for this application."

The wavelengths allocated on a world-wide basis for airborne radar under the Atlantic City Regulations are approximately 3cm, 5·5cm and 9cm, and an investigation of the relevant factors at these three wavelengths has been made at McGill University, Montreal.[1] This report shows that intervening rainfall causes attenuation such that the detection range of thunderstorms and heavy turbulence by 3cm (X-band) radars is very seriously limited. Attenuation is appreciable in the case of a 5·5cm. (C-band) radar, but the sensitivity changes more gradually with intervening rain. A 10cm radar can cope with almost any amount of intervening rainfall, but is an unlikely choice because of its greater size and weight and its relatively small angular resolution for a given mirror aperture.

At any wavelength the attenuation suffered is dependent on the product of precipitation rate and the extent of the rain along the line of the radar beam. A frontal line of showers is likely to involve the passage of the beam through several hundred mm.h^{-1} miles of rain—perhaps up to 900.

In the comparison of the relative advantages of C-band and X-band having typical values of transmitted powers and mirror apertures, it was shown[1] that, for amounts of intervening rain up to 200mm.h^{-1} miles, the X-band equipment gives greater ranges than the C-band. With this amount of intervening rain, both wavelengths have a limiting range of 31 miles. As one proceeds to greater amounts of intervening rain, the range at X-band drops off very rapidly, so that with twice the above amount of intervening rain the range is about 7 miles. At C-band, on the other hand, the same 400mmh^{-1} miles of rain only reduces the range to 27 miles—a drop of less than 15 per cent.

The report concludes that—"Sensitivity at 3cm varies very rapidly with the amount of intervening rain, and this rapid variation in itself would lead to uncertainty in interpreting signals. Five hundred mm.h^{-1} miles of rainfall is enough to render 3cm equipment practically inoperative. At a wavelength of 5·7cm attenuation is appreciable but the sensitivity changes more gradually with intervening rain, and the range would never be reduced by more than 30 per cent."

These are considerations of sensitivity. For the same size mirror C- and X-band equipments will differ also in resolution, the shorter wavelength equipment giving a correspondingly narrower beam, with correspondingly higher resolution. But attenuation will introduce distortion into the pictures, altering outlines and casting shadows of nearer showers on more distant ones. Thus, the initially better resolution of the shorter wavelength may well be more than cancelled out by the higher attenuation.

The recommendation for the development of C-band radar, which was the result of the above investigation, led to a debate in the United States as to the relative merits of C-band and X-band. There seemed little argument as to the better penetration of heavy rainfall by the former, but there was some question as to the need for this higher degree of penetration.

An actual evaluation of C-band radar was therefore undertaken by United Air Lines who, in June 1953, installed in a DC-3 aircraft an experimental 5·5cm radar developed for them by the Radio Corporation of America. This was designed to meet operational requirements which called for penetration of 60mm/h rainfall to a depth of 15 miles.

Flight Test Results

The evaluation by United Air Lines, which is covered in detail in their report[2], concludes that C-band radar fully meets the requirements of this specification.

During the tests 40 flights were made totalling 133 hours of flying, 80 hours of which were in the immediate vicinity of thunderstorms. The illustrations shown here were obtained on these flights.

Fig. 1 is a photograph of the radar presentation of an approaching line of storms 100 miles long. The aircraft continued to fly into the storm, and Fig. 2 is the picture at the height of the penetration. It shows how the radar makes it possible for a pilot to pick his way through narrow corridors.

In order to delineate the areas of rapid change in precipitation rate, with which the worst turbulence is associated, circuits were incorporated in the experimental equipment which blank out echoes above a predetermined intensity. This produces on the p.p.i. picture a dark area within the white trace of a storm area, this dark area corresponding to the region of greatest turbulence. This has been called iso-echo contour presentation, the outer contour of the area delineating a line of constant rate of rainfall. Fig. 3 is a photograph of the core of a storm without iso-echo blanking. When blanking is switched on the appearance changes to that of Fig. 4, indicating how the iso-echo technique picks out the area of greatest precipitation gradient. This technique has been found essential for determining those corridors in storm areas which may be safely traversed by an aircraft.

Comparisons between the results given by C- and X-band radars indicated that the X-band gave appreciable attenuation and distortion when flying in or near rainfall rates which were not excessive; there was no evidence of these on C-band. In addition, the X-band radar tended to show prominently areas of light rain which are of no consequence in aircraft navigation through thunderstorm areas.

Echoes Associated with Hail and Tornadoes

Previous observations with X-band radar had indicated that there were no significant features on the p.p.i. screen to allow hail to be distinguished from rain. In the C-band radar investigation, however, as experience was gained in interpreting the patterns on the screen, it became apparent that fingers or hooked fingers projecting from a thunderstorm echo were characteristic of hail shafts. One of these hooked fingers is shown dead ahead in Fig. 5 and at the tip of this hook grape-size hail was encountered. These were not always observable, but it was the considered opinion of the observers that C-band radar is capable of warning the pilot of the imminence of severe hail four times out of five.

During the time of the C-band radar tests opportunities to make radar observations in the neighbourhood of storms in which tornadoes were reported were relatively few. Although storms that were encountered failed to produce patterns that could be called indicative of tornadoes, the radar was shown to provide indirect evidence which will permit the pilot to avoid these violent storms by exercising ordinary good judgment in avoiding all sharp-edged iso-echo contours and, probably more important, in being highly suspicious of any finger-like projections from such echoes. United Air Lines continued their study during the summer of 1954, with further evaluation of radar detection of tornadoes in mind.

These detailed studies have culminated in the adoption by the Airline Electronic Engineering Committee in the United States of specifications for a 5·5cm weather radar which represents the combined recommendations of the airlines for a unit of optimum performance.

The Radio Corporation of America has now announced an equipment engineered to these specifications, and designated the AVQ-10. It includes many of the features of the set used in the United Air Lines tests with particular emphasis on ruggedness and reliability. The total weight is less than 120lb, and the equipment comprises a stabilized 22in. aerial, transmitter-receiver unit, p.p.i. indicator, control panel, and an accessory unit. The equipment features a specially developed magnetron which, in contrast to previous military magnetrons, was designed with long life and reliable performance as the primary considerations. It has a peak pulse power of 75kW in the 5·5cm band.

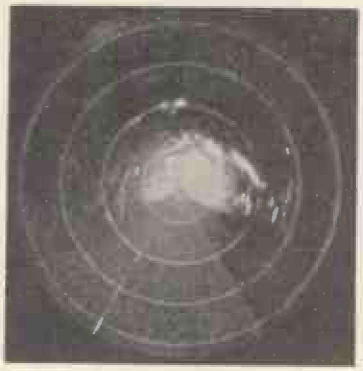

Fig. 1. Approaching line of storms 100 miles long

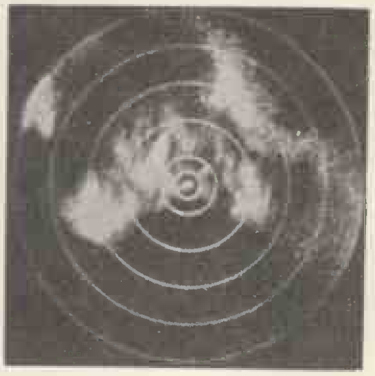

Fig. 2. Height of penetration of storms shown in Fig. 1

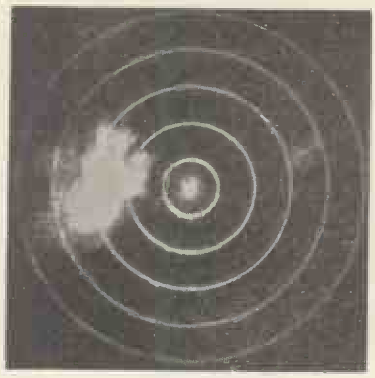

Fig. 3. Core of storm without iso-echo blanking

Fig. 4. Core of storm with iso-echo blanking

Fig. 5. Indication of hail

In the years to come airborne weather radar will, it is hoped, ensure the dependability and comfort of airline flights as they safely navigate the storms which frequently lie across their routes. If this type of radar lives up to expectation, the risk of blundering into an area of intense turbulence will be minimized, the expensive and dangerous hail damage to aircraft will be eliminated, and long-term savings of time and money will be realized by the reduction of flight-path deviation required by the new method as compared with the wide skirting of complete storms at present necessary.

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A Versatile Output Transformer for Surge Generators

By J. D. Harmer*, B.Sc., and J. R. Howells†, B.A.

The problem arose of designing a transformer which would match the surge generator of a recurrent surge oscillograph to a wide range of load impedance without disturbing the form of the surge. A toroidal transformer is described in which auxiliary windings are used to reduce leakage inductance and so suppress troublesome natural oscillations in the transformer windings. Oscillograph records show the performance of a transformer in which a surge at 2kV, having a front rising in 0·1μsec and a tail of 500μsec duration, is transformed to one of 1 000, 500 or 250V. The form of the surge is accurately reproduced at these tapping points over a wide range of load impedance.

THE response of apparatus to electrical surges can be studied using a recurrent surge oscillograph. This instrument comprises a recurrent surge generator and oscillograph with synchronized time-base for observing the effect of the surge at various points in the apparatus. To be able to test a variety of apparatus with a single instrument, a wide range of time scales is required for the oscillograph time-base. The voltage surge generated requires a steep front when the fast time scale is used, and a long tail for the slowest time scale. The provision of a range of time scales is not difficult. Surges having a front lasting a fraction of a microsecond and any length of tail consistent with the surge repetition rate can be generated using a thyratron.

A more difficult problem is the provision of a transformer for matching the surge generator to the wide range of load impedance which occurs in practice. Leakage inductance and inter-winding capacitance disturb the form of the voltage surge, an effect which can often be compensated by additional filter circuits, but only for a particular load impedance. This article describes a form of matching transformer suitable for surge generators, having many tapping points to which a wide range of load impedance can be applied without impairing the shape of the voltage surge.

The Basic Transformer

An efficient basic matching transformer comprises a single layer toroidal winding for the higher voltage circuit on a ring shaped core. The lower voltage winding can be tapped into this winding if an auto-transformer is suitable, or a separate second winding placed turn for turn over a section of the first. The toroidal form of winding has an intrinsically low leakage inductance, and a single layer winding minimizes capacitance between separate sections of the winding. When a second winding is wound turn for turn upon the first and the start of each is arranged to have a common surge potential, there is no surge voltage between turns of the primary and secondary windings, so that the inter-winding capacitance has no effect.

In its elementary form, the single layer toroidal auto-transformer possesses some leakage inductance, so that the steepness of the front slope of a sharp surge applied to the whole winding is reduced when it appears at a tapping point feeding a resistive load. The presence of stray capacitance, associated with this leakage inductance, is shown by overshoot and there can be subsequent oscillation of the voltage surge at a tapped point not connected to a burden. These unwanted effects could, of course, be eliminated either by confining the use of the transformer to surges with a limited front slope, or by reducing the tail length of the surge which the transformer is required to match, when the core and whole transformer could be made smaller, resulting in a corresponding reduction in leakage inductance and winding capacitance.

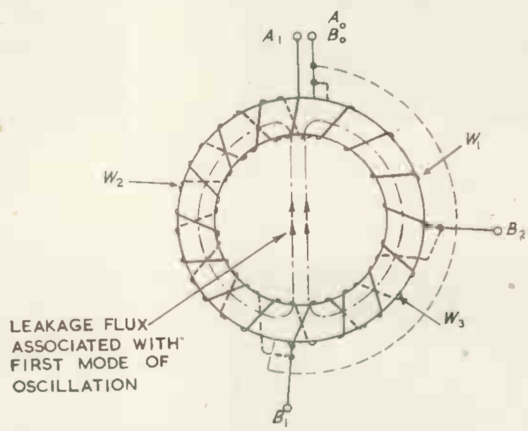

Fig. 1. Arrangement of auxiliary windings on toroidally wound auto-transformer

On the other hand, the following arrangement considerably reduces leakage inductance, without impairing other characteristics, so enabling a single transformer to match surges having the shortness of front and length of tail encountered in recurrent surge measurements.

Leakage Inductance Reduced by Auxiliary Windings

Fig. 1 shows a diagram of a toroidally wound auto-transformer on a ring shaped core. The full winding W_1 is distributed uniformly round the core, commencing at A_0 and finishing at A_1. When a step function surge is applied between A_1 and A_0, the voltage appearing at any tapping point on W_1 (such as B_1 or B_2) will be a proportionately reduced copy of the surge together with oscillating components due to distributed inductance and capacitance of the winding. For a uniform winding, the possible modes of oscillation are such that the voltage distribution along W_1 is approximately sinusoidal, having antinodes at A_0 and A_1. The voltage distribution of the first mode is thus a half sine wave having a node at the centre tapping point B_1. The second mode is a full sine wave having nodes at the quarter (B_2) and three-quarter tapping points.

* *Formerly British Thomson-Houston Co. Ltd.*
† *British Thomson-Houston Co. Ltd.*

The first mode of oscillation can be eliminated by reducing the leakage inductance associated with this mode. The magnetic flux associated with the inductance flows round the core from A_0 to B_1, returning across the air space in the centre of the ring from B_1 to A_0, and from A_1 to B_1 round the other half of the core, returning across the same air path, as shown in Fig. 1. This flux is eliminated by an auxiliary winding W_2* having half the number of turns of the full winding, which starts at B_1 and is wound in the reverse direction from, but turn for turn upon, the full winding up to A_1. The start of W_2 is connected to B_1, and its finish to A_0.

This auxiliary winding W_2 has no effect upon the main flux circulating in the core, since it is effectively a half winding similar to A_0B_1, and in parallel with it. But it presents a closed circuit to leakage flux associated with the first mode of oscillation, and therefore diminishes this flux and discourages the associated oscillation. A step function surge applied to A_1 is by this means more faithfully reproduced at half its value at B_1.

The same principle of using an auxiliary winding can be applied to the remaining section of the winding several

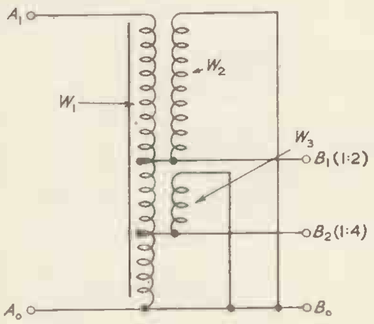

Fig. 2. Connexion of auxiliary windings on auto-transformer

times in succession to overcome the higher order modes. This enables transformer ratios up to 2^n to be obtained, where n is any integer up to the number of auxiliary windings applied. A second auxiliary winding W_3 is shown applied over a quarter of the full winding in Fig. 1. It extends from and is connected to the quarter tapping point B_2, up to B_1, where it is connected to A_0. Fig. 2 shows the method of connecting the auxiliary windings more clearly.

The description just given is for a step down transformer having ratios 1 : 2 and 1 : 4. The same arrangement can be used in reverse as a step up transformer having ratios 2 : 1 and 4 : 1.

Figs. 1 and 2 show only two auxiliary windings for clarity. The transformer described in the following paragraph had three auxiliary windings, permitting three tapping points on the full winding.

A Transformer for Surges of 2kV

A transformer has been constructed which will transform surges of 2kV having a front rising in 0·1μsec and duration of 500μsec to surges of 1 000, 500 or 250 volts. It faithfully reproduces the form of the applied surge for any load down to an impedance of 1·5kΩ referred to the 2kV winding (i.e. 375Ω at 1kV, 94Ω at 500V, or 24Ω at 250V).

The core is of crystalloy, a ring 5in diameter and cross-section 4sq.in, having an air-gap of 0·001in.

As little insulation as possible is used to keep the wires close together and to the core, in order to minimize leakage inductances. For this reason, thermex insulated copper wire is used, and the whole winding impregnated with a solventless varnish of the polyester type—a voidless insulation permitting high electrical stress without corona discharges.

The core is covered with 0·01in thick elephantide bound with two layers of glass tape 5mil thick. The main winding comprises 464 turns of 32 s.w.g., tapped at 58, 116 and 232 turns. Over this is wound turn upon turn in the reverse direction three auxiliary windings of 58, 116 and 232 turns each, connected in the manner described in previous paragraphs. Before applying the auxiliary windings, strips of thin insulating film of a plastic material compatible with the polyester impregnation were placed over the edges of the toroidal main winding. The completed windings were

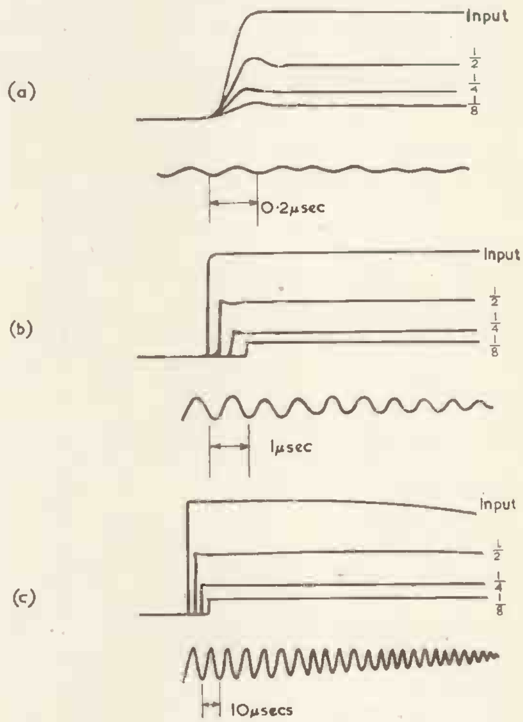

Fig. 3. Oscillograph records of surge appearing at $\frac{1}{2}$, $\frac{1}{4}$ and $\frac{1}{8}$th tapping points not connected to any burden

then covered with two layers of glass tape, and impregnated under vacuum.

Oscillograph records of the input and output surges at the half, quarter and eighth tapping points on open circuit are shown in Fig. 3. The record in Fig. 3(a) has a fast time-base, and shows how the rise time of the front is preserved without exciting much oscillation. Fig. 3(c) is a record with slow time-base, showing the duration of the tail. In each record, the trace at successive tapping points was moved horizontally to the right to separate the surge starting points and so show the front rises more clearly.

The front rise time of 0·1μsec and the tail duration of several hundred microseconds shown in the records of Fig. 3 were maintained for all load conditions described in the specification.

Acknowledgments

The authors wish to thank Mr. L. J. Davies, Director of Research of the British Thomson-Houston Co. Ltd., for permission to publish this article.

* *British Patent Application 866/53.*

Wide-Range Operation of Grid-Controlled Rectifiers

By D. H. McEwan*, B.Sc., A.M.I.E.E.

A method of controlling thyratron conduction over a wide range from a d.c. control signal is described and the steady-state characteristics of a d.c. power amplifier employing this method of control in a bi-phase rectifier circuit are discussed and experimental results given.

THE use of controlled rectifiers of the thyratron type as a means of obtaining a variable unidirectional current from an a.c. supply is now common in many control applications and offers certain advantages over machine amplifiers, particularly with regard to speed of response.

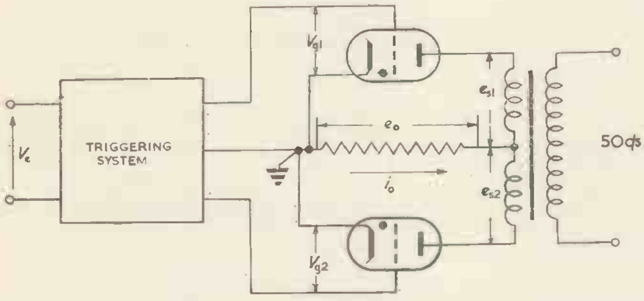

Fig. 1. Basic arrangement of bi-phase circuit supplying resistive load

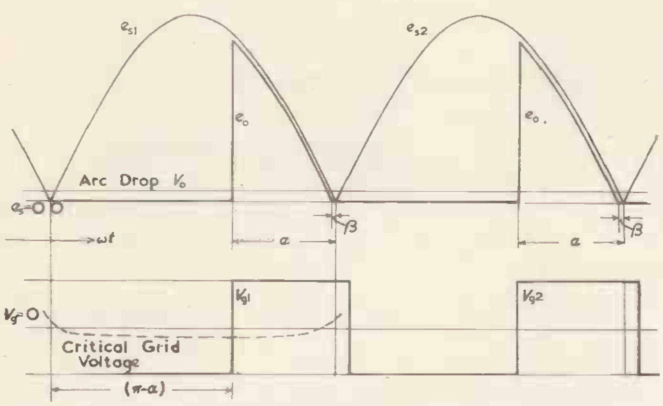

Fig. 2. Trigger voltage V_g and load voltage e_o for conduction angle α in system of Fig. 1

The comparatively high voltage rating of most thyratrons suitable for power control purposes allows good forcing action to be obtained when used as elements in a servo system, and for a given a.c. supply e.m.f. the maximum forcing action will be obtained if the output from the rectifier system is continuously variable from zero up to the maximum possible value as a function of the control signal, which is very often a d.c. "error" signal of small magnitude.

In the course of work carried out on servo systems employing controlled rectifiers, a power amplifier was required in which the conduction angle α (Fig. 2) could be controlled over as wide a range as possible by a signal V_c (Fig. 1) varying over a range of a few volts d.c.

It was decided to investigate the possibilities of a method of control based on the "grid-leak" system which has been used on mercury-arc rectifiers[1]. The "variable-leak" method of trigger voltage control which was developed, is described in the section that follows and has been in use in an experimental thyratron amplifier for a considerable period.

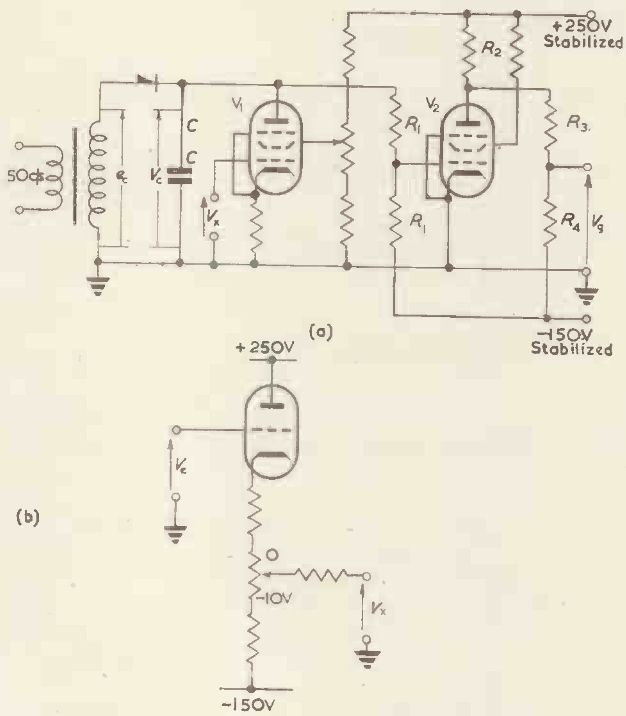

Fig. 3(a). Trigger control (one phase); (b) zero adjustment

Triggering System

To control thyratron conduction, a grid-cathode voltage V_g is required which remains below the critical value up to the point in the positive half-cycle of anode supply e.m.f. e_s at which conduction is required, rising rapidly above the critical grid curve at this point (Fig. 2), a rapid rise being desirable in order to prevent variations in the striking point due to variations in the control characteristics of the thyra-

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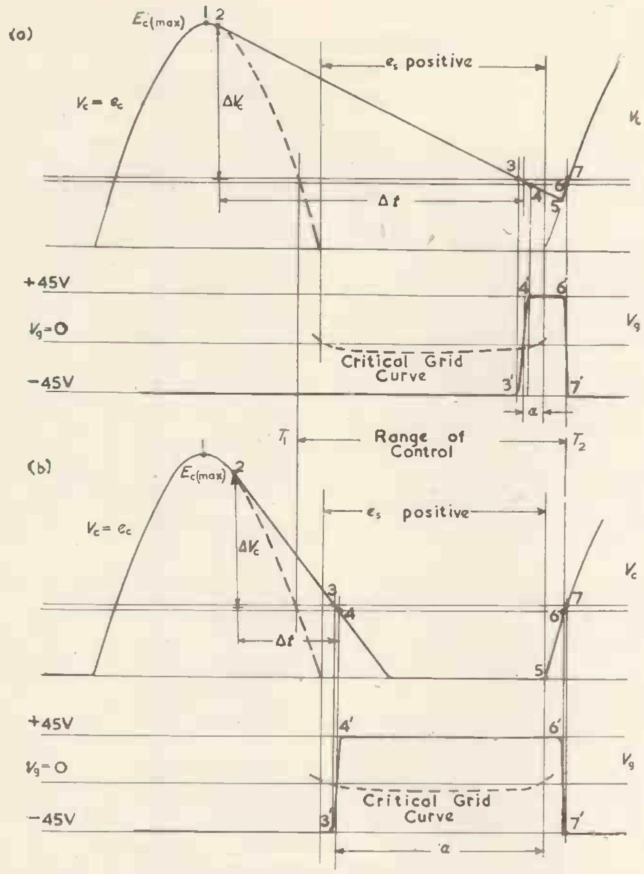


Fig. 4. Waveforms for (a) small, (b) large conduction angles

tron. A short trigger pulse is often used since V_g need exceed the critical value only long enough for ionization to occur, but in a system designed for values of α up to 180° pulse triggering in the range of α from 90° to 180° may give undesirable results when supplying an active load such as the armature of a d.c. motor in a feedback system. The form of the voltage used is as shown in Fig. 2, crossing the critical grid curve at $\omega t = (\pi - \alpha)$ and remaining above the curve slightly beyond $\omega t = \pi$.

In order to vary α as a function of V_e and V_x, the latter is used to control the rate of discharge of a capacitor C (Fig. 3(a)), charged during the appropriate half-cycle through a half-wave rectifier and auxiliary transformer, the secondary e.m.f. e_0 of which is 180° out of phase with the anode supply e.m.f. e_s of the corresponding thyratron. Referring to Fig. 4, C is charged to a peak voltage $V_{o(max)}$ at the point 1 and is subsequently discharged almost linearly by the pentode V_1 at a rate dependent on the control voltage V_x. When V_c falls below +150V, valve V_2 begins to cut off and the output voltage to the thyratron grid rises rapidly from a negative limit well below the critical grid voltage curve to a positive limit well above it, the limits being fixed by the values of resistors R_2, R_3, R_4. The actual rate of rise of V_g depends on the rate of fall of V_c and the cut-off characteristics of valve V_2, the rise being sharper for large values of α, since the slope of the V_c curve is greater for this condition.

Figs. 4(a) and 4(b) show the approximate conditions for α in the region of zero and 180° respectively. The capacitor voltage V_c follows the e_c curve to the point 2 beyond which de_c/dt has a greater (negative) value than dV_c/dt as determined by the current through valve V_1. C then discharges almost linearly to 3, V_g rising through the triggering value during 3-4 and remaining at the upper limit from 4 to 6, at which point V_c has again risen sufficiently to allow V_2 to begin conducting, and V_g drops sharply to its lower limit. The rise in V_g can be made to occur at any point in the range $T_1 - T_2$ by suitable variation of the control voltage V_x.

The oscillograms of Fig. 5 illustrate the process described above, showing V_c and V_g for successively greater values of V_x. The traces on the double-beam oscillograph were set initially so that the points 3 and 3′ of Fig. 4, were coincident, no further adjustment being made for subsequent exposures. Oscillograms 3 to 12 cover the range of α from 0 to 180°, the rise of V_g in 1 and 2 occurring beyond $\omega t = \pi$, where the anode supply e.m.f. e_s is negative and conduction does not normally result unless the load is such as to make the net anode-cathode p.d. sufficiently positive. The curvature of the V_c decay line shown on the oscillograms is due largely to the shunting of capacitor C by the input resistance of the oscillograph d.c. amplifier.

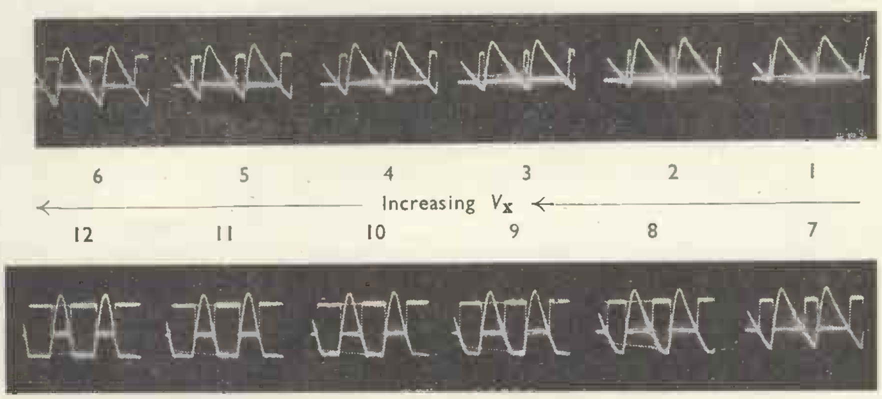
The control characteristics can be readily estimated on the basis of Fig. 4. Assuming a steady capacitor current i_x, its value for a particular conduction angle α is $C.\Delta V_c/\Delta t$, ΔV_c and Δt being found for each value of α by drawing the lines 2 to 4 tangential to the e_c curve. The relationship between α and i_x calculated for three values of $V_{c(max)}$ using a 0·1μF capacitor and supply frequency 50c/s is shown by the curves of Fig. 6(a). The relationship between α and V_x will be of the same general form, the extent of the deviation depending on the variation in the transconductance of valve V_1 over the range of discharge current.

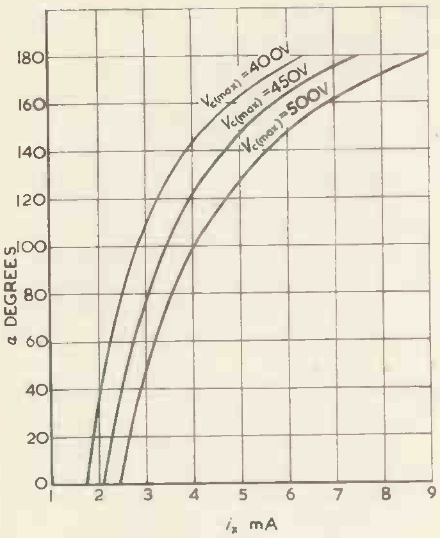
In the trigger circuit as used in the power amplifier, the control voltage V_x is obtained from a cathode-follower stage (Fig. 3(b)) which allows the output to be adjusted to zero by means of the potentiometer, for zero input V_e to the amplifier.

The measured relationship between α and V_x or V_e obtained from oscillograms of the p.d. across a thyratron when supplying a pure resistance load, is shown in Fig. 6(b).

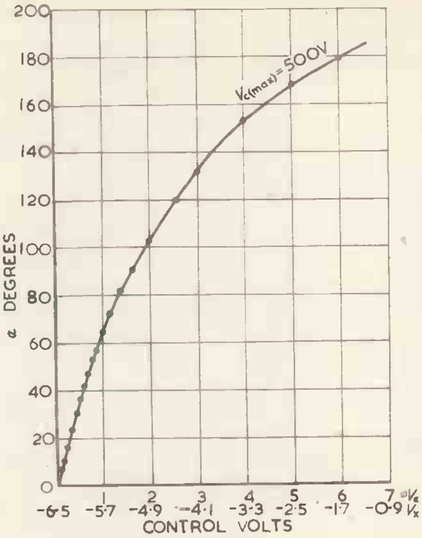
In the section that follows, the steady-state characteristics

Fig. 5. Oscillograms showing effect of varying the control voltage V_x

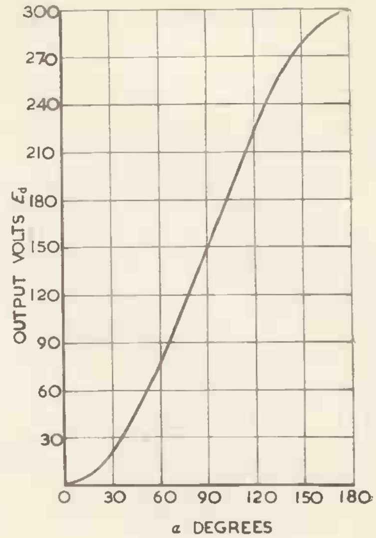


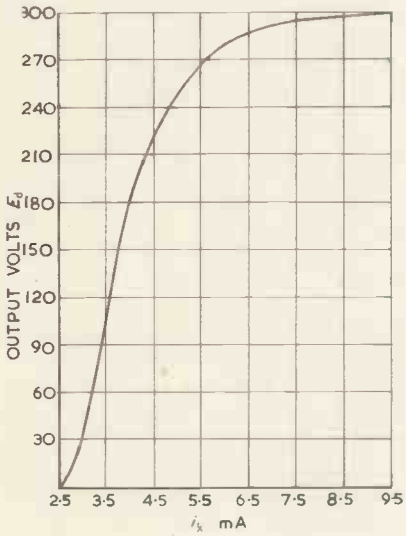


(a)

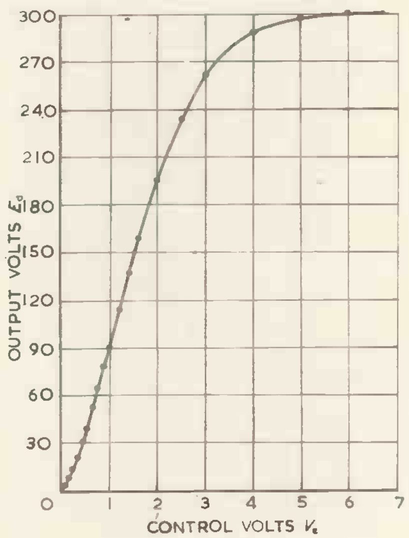


(b)





(a)



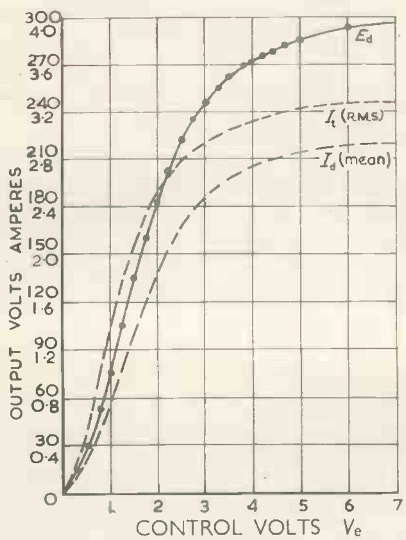
(b)

Fig. 6 (top left). (a) Calculated α/ix characteristics
$(0{\cdot}1\mu F,\ 50c/s)$
(b) measured α/V_e characteristic

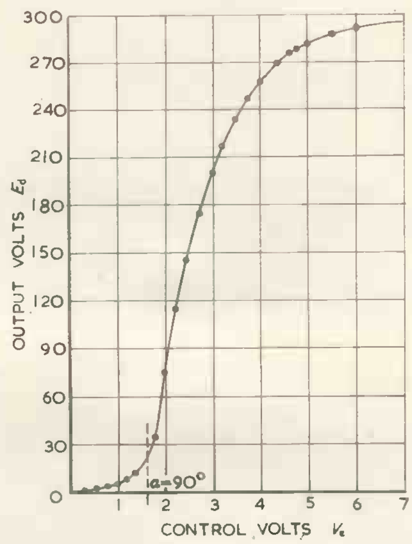
Fig. 7 (top right). Calculated E_d/α characteristic
($E_s=350V$ r.m.s., $V_o=15V$)

Fig. 8 (left). (a) Calculated E_d/i_x characteristic
($E_s=350V$ *r.m.s.*, $V_{e(max)}=500V$)
(b) measured E_d/V_e characteristic
($E_s=350V$ *r.m.s.*, $V_o\simeq15V$, *high resistance load*)

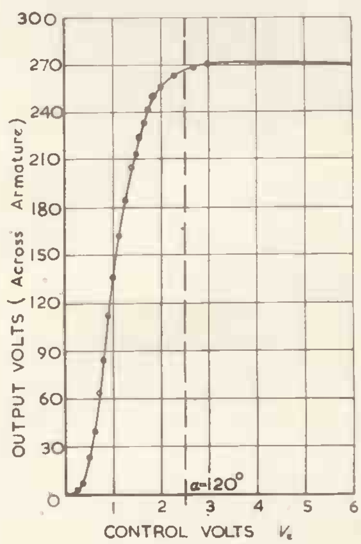
Fig. 9 (below). (a) Measured characteristics, resistance load$\simeq100\Omega$
($E_s=350V$ *r.m.s.*)
(b) measured characteristic, highly inductive load
($R\simeq100\Omega$, $L\simeq20H$, $E_s=350V$)
(c) measured characteristic, motor armature load
(*230V d.c. shunt motor, armature resistance = 16Ω. No load current 0·5A*, E_s = *240V r.m.s.*)



(a)



(b)



(c)

of the amplifier are estimated and compared with the measured values.

Amplifier Characteristics

In a bi-phase controlled-rectifier system feeding a non-inductive resistance load from a sinusoidal supply e.m.f. of peak value $E_{s(max)}$, the mean output voltage E_d is given by:

$$E_d = 1/\pi \int_{\pi-\alpha}^{\pi-\beta} (E_{s(max)} \sin \omega t - V_o)\, d\omega t$$

$$= E_{s(max)}/\pi\,(\cos \beta - \cos \alpha) - V_o\,(\alpha - \beta)/\pi \quad \ldots\ldots \quad (1)$$

where V_o is the arc drop, assumed constant, and $\beta = \sin^{-1} V_o/E_{s(max)}$ as in Fig. 2. If $E_{s(max)}$ is much greater than V_o, expression (1) simplifies to:

$$E_d = E_{s(max)}/\pi\,(1 - \cos \alpha) - V_o\,\alpha/\pi \quad \ldots\ldots\ldots \quad (2)$$

Fig. 7 shows the relationship between E_d and α for a system in which $E_{s(max)} = 350\ \sqrt{2}$ and $V_o = 15$V, calculated from equation (2). Using Fig. 7 and the α/i_x curve for the particular value of V_c employed (500V) the estimated E_d/i_x characteristics of Fig. 8(a) were obtained. This indicates the form of the E_d/V_x relationship to be expected, and may be compared with the measured characteristics of Fig. 8(b), obtained with the amplifier supplying a high resistance load of negligible inductance. The α/V_e relationship was also checked from these results and found to be in good agreement with that shown in Fig. 6(b).

The output/V_e characteristics (a) with a resistance load of approximately 100 ohms and mean load currents up to approximately 3A, are shown in Fig. 9(a). The thyratrons and supply transformer used were such that a maximum mean output current of 5A at 300V could be obtained.

The steady-state characteristics of the amplifier supplying (b) a highly inductive resistance load and (c) a d.c. motor armature load, are shown in Figs. 9(b) and 9(c) respectively and are in agreement with the values calculated on the basis of the α/V_e relationship given by the triggering system. It is noticeable that in (b), the output does not vary with V_e to any great extent in the range corresponding to α values from zero up to about 90°, since in this range, the load current is discontinuous, and the high inductance prohibits the rapid variations in instantaneous current possible with the previous type of load. This does not imply that no benefit is gained by having the conduction angle α controllable down to zero, since with this type of load, current decay can be assisted by invertor action, and an improved transient response obtained with the wider range of control of α.

In case (c) with the amplifier feeding the armature of a separately excited motor, Fig. 9(c) shows the E_d/V_e relationship with the motor on no load, when it is seen that the main variation in output occurs for values of V_e in the range corresponding to α values from zero up to approximately 120°. Again improved transient performance will be obtained in a servo system if α is variable over a wider range, since with the armature stationary, maximum current and torque will be obtained only if $\alpha \approx 180°$.

Conclusions

The method of trigger voltage control employed gives variation of the conduction angle α over a range of approximately $-10°$ to $+200°$ as a function of the controlling voltage V_e, the form of the control being such that when applied to a thyratron amplifier feeding a resistive load, the mean output voltage is a reasonably linear function of V_c, from zero up to approximately 80 per cent of the maximum value, the average voltage gain obtained in the present case being of the order of 100. The system was developed primarily for investigating transient and stability conditions in a thyratron feedback amplifier controllable over the full range, but it is felt that there may be industrial applications where the method could be considered as an alternative to the more established methods of thyratron control from a d.c. signal.

Acknowledgments

The experimental work was done in the Department of Electrical Engineering, University (now Queen's) College, Dundee, and acknowledgment is made to Professor E. G. Cullwick for the use of apparatus in the Department, and to my father, Mr. W. R. McEwan, for much valuable assistance and advice.

REFERENCE

1. Rissik, H. Mercury-Arc Current Converters.

New Marconi Training College

As announced in our December issue the new Marconi College, construction of which began in 1953, is now completed. Entirely new lecture, tutorial, laboratory and administrative accommodation is now contained under one roof, and provides every facility for technological training in the field of electronics for nearly one hundred students and residential accommodation for fifty.

The College now possesses two lecture rooms, ten laboratories, a workshop, a drawing office school, a technical library and a quiet room, in addition to teaching staff rooms where personal tutorials and group discussions take place.

Most of the students are either the Company's own graduate engineers and student apprentices, or nominees of overseas Governments, public bodies or clients of Marconi's Wireless Telegraph Co. Ltd. Private fee-paying students are only accepted after these priority demands have been met.

Main courses in Radio Engineering, Radar Engineering, Industrial Electronics and Television Engineering form the backbone of the College's activities. These courses are of approximately five months' duration and each course concentrates on developing the ability of the student to appreciate in detail the performance, design and measuring techniques involved in the particular circuits and systems. In many cases students need to build up their initial knowledge of the fundamentals of electronics before joining a five months' Engineering Course, and they take a preliminary course for ten weeks. Training on specific equipments is becoming a major responsibility of the College, and a number of short duration courses are already available. These are required mainly by those from overseas who will have the responsibility of maintaining and possibly installing such equipments in their own countries.

Tuition is at an advanced level, the ideal qualifications for admission being a university degree in communications or electronics, although a degree in science, engineering or mathematics, or equivalent qualification, is acceptable, provided some knowledge of radio has been obtained. Training is largely individual, the students working in pairs or groups of three when in the laboratories.

In an industrial college such as this, contact with research and development laboratories is direct. The College staff have attachments to the laboratories and the Company's engineers visit the College to lecture on their specialised subjects.

The previous Marconi College building is now being converted as an extension to the existing hostel, where each student has a private study-bedroom.

Marconi College is easily the oldest foundation of its type in the world, having been inaugurated by Marconi himself fifty-three years ago. The present Principal is Mr. R. E. Burnett, M.A. (Oxon), A.M.I.E.E., A.Inst.P., and the Director of Studies is Mr. R. G. Hulse, B.Sc.

The London-Sydney Cable Circuit

By A. H. Harris*, A.M.I.E.E.

In order to provide improved communication facilities between Australia and the United Kingdom a direct cable telegraph circuit between Sydney and London—a total of 15 000 miles—has recently been established. This is the longest submarine cable circuit or " chain " as it is usually referred to which has so far been operated and the following article describes briefly the technical problems involved.

THE cable route which is shown on the map (Fig. 1) comprises 7 cable sections, 2 landline sections and 9 intermediate stations, a list of which is given in Table 1. The intermediate stations serve a dual purpose. In the first place they function as repeaters for amplifying and regenerating the signals and secondly they act as collecting or disposal points for local traffic. This local traffic may be fed into the chain when the terminals are clear and similarly through a suitable selective mechanism controlled by the sending terminal, traffic may be " dropped " at any selected intermediate station.

On any unloaded cable, the transmitted signals are subject to considerable attenuation and phase-shift, these factors depending upon the electrical characteristics of the cable and the frequency of the signals. At each repeater station, therefore, a suitable equalizing network is required to reshape the signals ; the longer the cable the greater is the difficulty experienced in obtaining optimum working conditions for the network and the relay-amplifier unit which works in conjunction with it.

TABLE 1
Regenerator-repeater stations on 15 000 mile cable telegraph circuit

REPEATER STATIONS	CONTROLLING ORGANIZATION
Southport	Overseas Telecommunications Commission (Australia)
Norfolk Island	" " " "
Suva (Fiji)	Cable and Wireless Ltd.
Fanning Island	" " "
Bamfield	Canadian Overseas Telecommunication Corporation
Montreal	" " " "
Halifax (Nova Scotia)	" " " "
Azores	Cable and Wireless Ltd.
Porthcurno (Cornwall)	" " "

After reshaping and amplification the signals are passed to the regenerator mechanism from which a substantially perfect replica of the original signal is retransmitted into the next cable in the chain. The regenerator is a synchronous electro-mechanical system in which provision is made for midway selection of the incoming signalling period, thus ensuring that each selection point occurs at a moment when failure is least likely to occur. The permissible range or margin for distortion on an average circuit is 50 per cent of the full signalling period (Fig. 2).

The signalling code employed on the submarine cable circuit is the three condition " cable-code," using the standard Morse alphabet. In this code a dot is represented by a negative impulse, a dash by a positive impulse and a space by no current, all signals being of equal length (Fig. 2).

Particulars of the lengths and types of submarine cable in use on the various sections of the Sydney-London circuit are given in Table 2. It is interesting to note in passing that the 3 466 mile submarine cable between Bamfield and Fanning Island is the longest in the world.

On the section between Sydney-Suva there is a single-

*Cable and Wireless Ltd.

Fig. 1. The cable route

channel duplex telegraph circuit with relaying and regenerator points at Southport and Norfolk Island. This circuit is linked at Suva with one channel of a 3-channel time-division multiplex system extending from Suva to Bamfield with a relay station at Fanning Island. The Suva-Fanning Island and Fanning Island-Bamfield submarine cables are continuously loaded and the signalling speeds are therefore

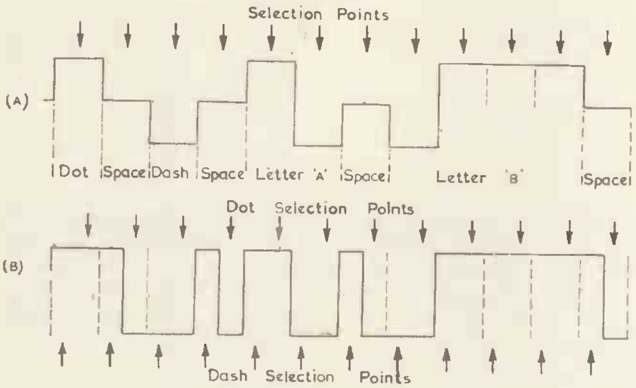


Fig. 2. Forms of code

(A) *Normal cable code.* (B) *Double-current cable code (same signals as in* (A) *).*

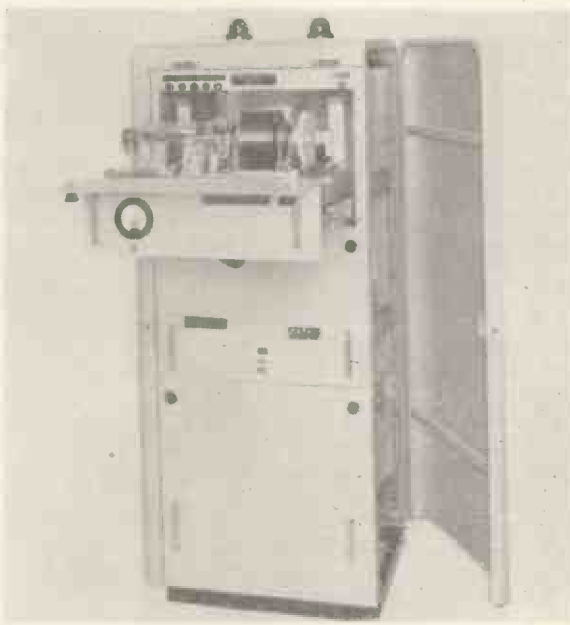
TABLE 2

CABLE SECTION	CABLE MILEAGE (NAUTICAL)	TYPE OF CABLE
Sydney—Southport	504	Unloaded submarine cable
Southport—Norfolk Island	846	,, ,, ,,
Norfolk Island—Suva	980	,, ,, ,,
Suva—Fanning Island	2 053	Continuously loaded submarine cable.
Fanning Island—Bamfield	3 466	,, ,, ,,
Bamfield—Montreal	2 710	Landline (Voice Frequency Telegraph circuit)
Montreal—Halifax	2 660	,, ,, ,,
Halifax—Azores	1 903	Unloaded submarine cable
Azores—Porthcurno	1 378	,, ,, ,,
Porthcurno—London	278	Landline (Voice Frequency Telegraph circuit)

considerably higher than those of the other submarine cables in the chain which are unloaded. The loaded cables can only be operated on a simplex basis and in order to cater for the peak traffic loads in either direction arrangements are made to work them in the direction Australia to the United Kingdom during the Australian day and in the opposite direction during the United Kingdom day.

At Bamfield the Sydney channel is relayed on to the landline circuit across Canada to Halifax, Nova Scotia. A multi-channel voice frequency telegraph system operates on the landlines one channel of which is keyed by the incoming signals from the submarine cable circuit. In order to do this the 3-condition cable-code signals are converted to a 2-condition code known as double current cable-code (Fig. 2), in which a Morse dot is represented by 2 elements " Mark," a Morse dash by 2 elements " space " and a letter-space by one " mark " element followed by a " space " element. The conversion from one code to the other is effected by suitable mechanism incorporated in the regenerator equipment at the relay station.

At Halifax the signals are translated back to 3-condition cable-code and passed on to the unloaded Halifax-Azores Porthcurno submarine cable circuit. Further conversion takes place at Porthcurno, the United Kingdom relay station, to fit in with the voice frequency telegraph system in operation on the Post Office landline circuit to London. In this connexion it may be mentioned that a frequency shift keying system for 3-condition code has recently been developed, overcoming one of the disadvantages of double-current cable code, that is, the high baud speed (double that of cable-code) required for a given rate of transmission of intelligence. In this latest



Cable & Wireless time division multiplex equipment.

system the mid-band frequency corresponds to the cable-code spacing periods and a shift of 50c/s up or down represents the dots and dashes respectively.

Sydney signals are received finally at the Central Telegraph Office in London, a direct printer being used for reception. This instrument prints the messages on a running tape which is gummed to a message form for delivery.

The planning of this circuit has involved the collaboration with Cable and Wireless Limited of four other Commonwealth telegraph undertakings, namely, the Overseas Telecommunications Commission (Australia), the New Zealand Department of Post and Telegraphs, the Canadian Overseas Telecommunication Corporation and the United Kingdom Post Office. It is a tribute to the smooth working of the Commonwealth organization that the circuit was brought into operation without encountering any serious technical or operational difficulties.

Acknowledgments

The writer is indebted to Cable and Wireless Ltd. for permission to publish this article.

Class-C Amplifier and Oscillator Design

(A Simplified Method)

By L. T. Apps*, A.M.I.E.E.

A simplified method of r.f. power amplifier and oscillator design is presented. This is based on Terman's method of approximate analysis, but short cuts are used in the form of charts or nomograms.

SEVERAL well-known methods of class-C analysis are available to the designer[1,2,3,4], and of these the Terman and Roake procedure[4] is probably the most widely used at the present time. Accurate results are yielded by this system but the sequence of analytical steps can be tedious when an optimum design is required or when the user is not familiar with the method.

To simplify the procedure in such cases the following method has been prepared. It will be seen that basically it consists of two charts, Fig. 2 and Fig. 3, which enable a complete analysis to be made using the valve characteristic curves and direct current values only. This can result in a considerable saving of time especially when a quick estimation of performance is required.

Fig. 1 shows the waveforms which apply in this class of service and indicates the abbreviations used in the text.

Fig. 2 enables the relationships of the anode circuit to be studied when either the angle of current flow or the anode voltage swing is varied. This is similar to a chart by Scott[5].

Details of the grid circuit are found from the chart in Fig. 3. The main curves deal with the grid current and drive power relationships. The inset curve deals with the bias equation.

Fig. 4 is a typical set of constant current valve characteristic curves which are used in the following example of this method of analysis.

The curves apply to a 3J/160E forced air cooled triode. Maximum ratings for class-C telegraphy operation are as follows:—

Maximum direct anode voltage	3kV
Maximum direct anode current	2·2A
Maximum direct anode dissipation	1kW
Maximum usable emission	10A
Maximum direct grid dissipation	75W
Maximum frequency for above ratings	120Mc/s

The valve amplification factor is 19.

Consider the case where it is desired to obtain the maximum power output at an anode voltage of 2·5kV using a flow angle of 140°.

From the characteristic curves, Fig. 4, point A is indicated as giving a good anode voltage excursion without undue grid current. The ordinates of this point are $V_{a(min)}$ 400V and $V_{g1(max)}$ +350V. Current values at this point are $I_{a(pk)}$ 3·6A and $I_{g(pk)}$ 1·4A. Making a maximum emission current of 5A, which is well under the maximum rating value of 10A. Using Fig. 1 the two known values are the angle of flow required and the anode voltage swing, 140° and 84 per cent. Connecting these points and using the other three scales as indicated it is found that the anode efficiency will be 73 per cent, and the direct anode current 0·225 of the peak value while the anode load ratio is 1·73.

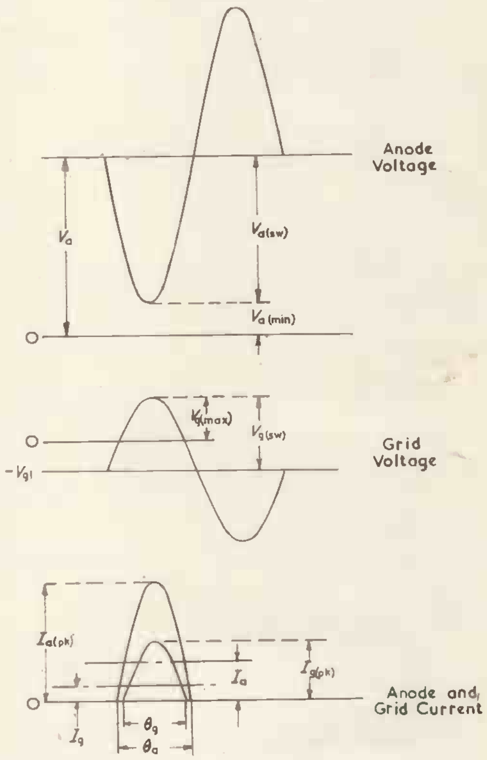


Fig. 1. Waveforms illustrating the abbreviations used

The following relationships may now be worked out:—

Direct anode current, I_a	= 810mA (3·6 × 0·225)
Power input	= 2025W (2500 × 0·810)
Power output	= 1480W (2025 × 0·73)
Anode dissipation	= 545W (2025 − 1480)

The figure of power output found is a calculated value only and in service circuit transfer losses, etc., must be subtracted from this value when arriving at the true output.

The anode load impedance is found by applying the ratio found from the chart to the anode voltage excursion and the direct anode current.

Anode load impedance = 1 500 ohms (2 100 ÷ (810 × 1·73))

* *Standard Telephones & Cables Ltd.*

The grid bias voltage must now be calculated. The standard formula is used for this purpose.

$$-V_{g1} = \frac{V_a}{\mu} + \left(V_{g(max)} + \frac{V_{a(min)}}{\mu}\right)\frac{\cos\theta_a/2}{1-\cos\theta_a/2}$$

The value of the last term may be found from the inset curve on Fig. 3. In this case $(\theta_a = 140°) = 0{\cdot}52$.

$$-V_{g1} = 2\,500/19 + (350 + 400/19)\ 0{\cdot}52 = -326\text{V}$$

The peak r.f. grid voltage $V_{g(sw)}$ is, therefore, 326+350 =676V. The ratio of the bias to r.f. grid voltage is now required. In this case this figure is 0·48.

Referring to Fig. 3 the horizontal scale is entered at 0·48 and the left-hand scale readings obtained as shown. The grid circuit angle of flow is about 122° which determines the direct grid current ratio of 0·175 and the grid drive power ratio of 1·85. Using these figures the grid circuit relationships may now be obtained.

Direct grid current, I_g	=	245mA (1·4×0·175)
Bias source loss	=	80W (326×0·245)
Total grid drive power	=	148W (80×1·85)
Grid dissipation	=	68W (148−80)
Bias resistor	=	1330Ω (386÷0·245)

When the analysis is complete, allowance must be made for the grid drive power if the case considered is a self excited oscillator. In such an application the total grid drive power must be deducted from the calculated output power.

It will be seen that the above analysis applies to a reasonable state of affairs as no maximum ratings are approached and a reasonable efficiency has been obtained.

To show the relative accuracy of this simplified analysis the same basic parameters were used for a design using the original Terman method. The values obtained are tabulated on the following page.

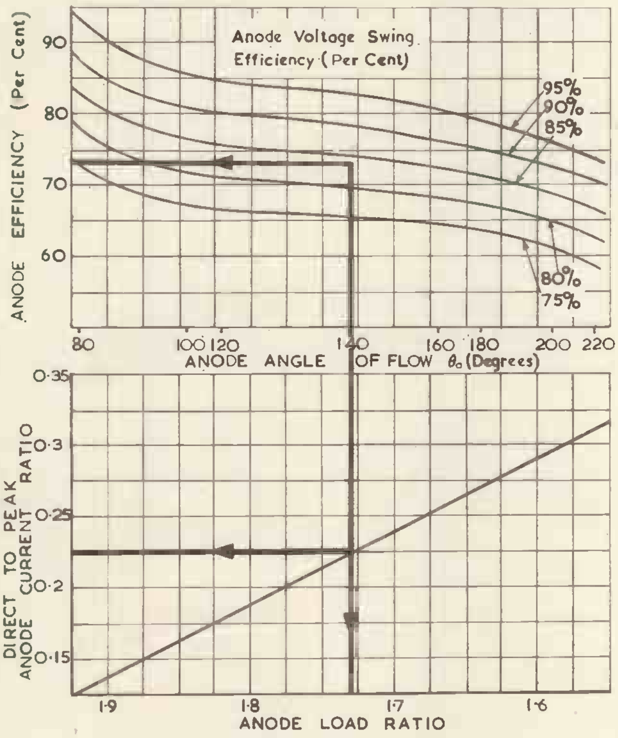


Fig. 2. Anode circuit relationships

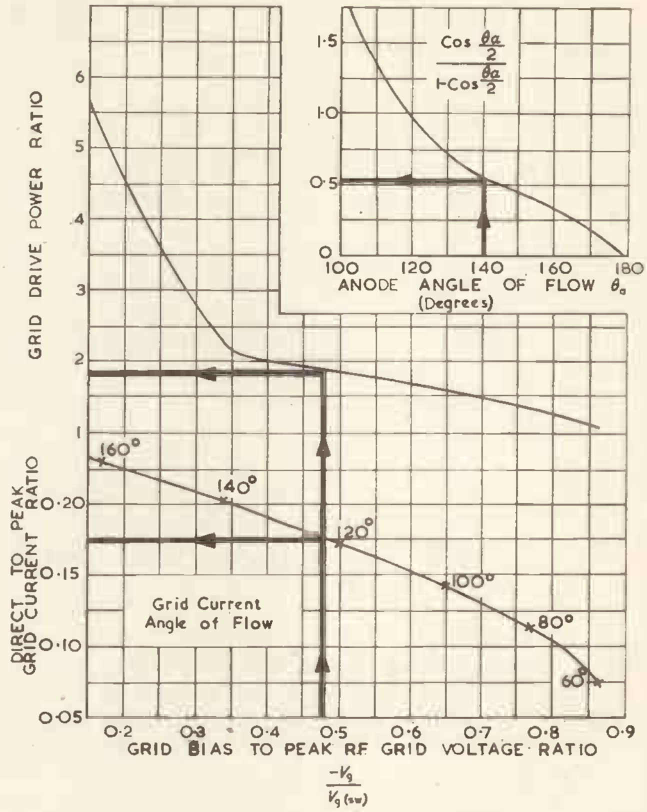
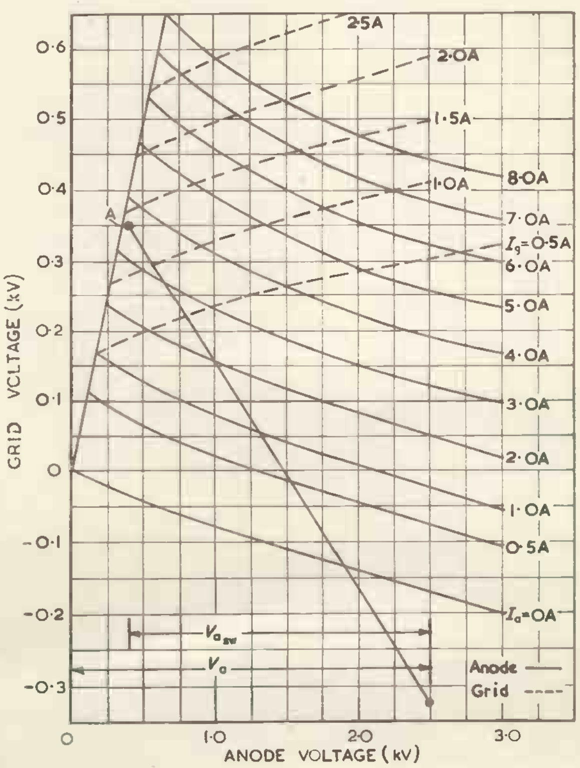


Fig. 3. Grid circuit relationship and cos θ values

Fig. 4. Characteristic curves for valve type 3J/160E



H

	Simplified Method	Terman Method	Difference (per cent)
Direct anode voltage (V)	2·5	2·5	—
Direct anode current (mA)	810	870	<7
Direct grid voltage (V)	−326	−326	0
Direct grid current (mA)	245	245	0
Peak r.f. grid voltage (V)	676	676	0
Grid bias resistor (Ω)	1330	1330	0
Grid dissipation (W)	68	70	<3
Direct power input (W)	2025	2170	<7
Anode dissipation (W)	545	610	<10
Power output (W)	1480	1560	5
Load impedance (Ω)	1500	1420	6
Anode efficiency (per cent)	73	72	$<1{\cdot}4$

From these figures it will be seen that this method gives an overall accuracy of result within 5 per cent of that obtained by the original method on which it is based.

It will be seen that this method enables an analysis to be made rapidly and without reference to harmonic analysis or similar methods. If required, a closer check of the conditions obtained may be made using the methods based on Ref. 1 or 3.

Acknowledgment

The author wishes to thank Standard Telephones and Cables Ltd for permission to publish this article.

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An Electronic Nyquist Diagram Plotter

By J. L. Douce*, M.Sc.

An electronic unit is described which derives the ratio of two sinusoidal voltages of the same frequency. The result is displayed on a conventional c.r.t. giving the information as a point on the complex plane. A frequency ratio of 20 to 1 is covered using two ranges: by a suitable choice of components the operating region may be extended to include from very low frequencies $\sim 1c/s$ to about $10kc/s$.

IN the design and construction of feedback systems, such as servomechanisms or high-quality audio amplifiers, it is essential to obtain the response of the system to a sinusoidal input. For a linear system, the output is sinusoidal, of the same frequency as the input, but differing from the input in amplitude and phase. Thus the gain of the system is, in general, a complex quantity, and may be represented by a point on the complex plane.

Plotting the open-loop gain for several values of input frequency, the resultant locus is termed the Nyquist diagram for the system considered. From this diagram, conclusions may be drawn regarding the stability of the closed-loop system[1].

Previous systems described for automatically recording the Nyquist diagram rely on electro-mechanical devices to find the ratio of the two signals. This method can give results of high accuracy, but often the cost and complexity of such a device is not worthwhile. The unit to be described is electronic throughout, involving 16 pentode valves and 15 diodes. The ratio of the two voltages considered is obtained as two voltages, representing the in-phase and out-of-phase components of the gain of the element. Thus by applying these potentials to the X and Y plates respectively of a C.R.T. the gain is obtained as a point on the complex plane.

Principle of Operation

Let the two signals to be compared be:

$$e_1 = e_i \sin \omega t$$
$$e_2 = e_o \sin (\omega t + \phi).$$

The unknown gain of the element is given by:

$$e_2/e_1 = e_o/e_i\ [\cos\phi + j \sin\phi] \quad \ldots\ldots\ldots\ldots (1)$$

The operation of the unit is as follows. The signal e_1 is amplified and clipped to give rectangular pulses in-phase and 90° out-of-phase with e_1. These pulses are used to gate the "output" signal e_2, giving a signal whose mean voltage is proportional to the in-phase and out-of-phase components of e_2.

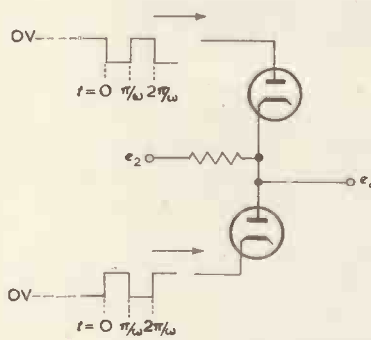


Fig. 1. The basic gating element

The basic element is shown in Fig. 1. The diodes are non-conducting for the first half-period, and clamp the output at 0V for the remainder of the period.

Hence the output is given by:

$$e_{out} = e_2 = e_o \sin (\omega t + \phi) \qquad 0 < t < \pi/\omega$$
$$= 0 \qquad \pi/\omega < t < 2\pi/\omega.$$

The mean value of the output is:

$$e_{mean} = \omega/2\pi \int_0^{\pi/\omega} e_o \sin (\omega t + \phi)\, dt$$
$$= 1/\pi\ e_o \cos\phi$$

* Manchester University.

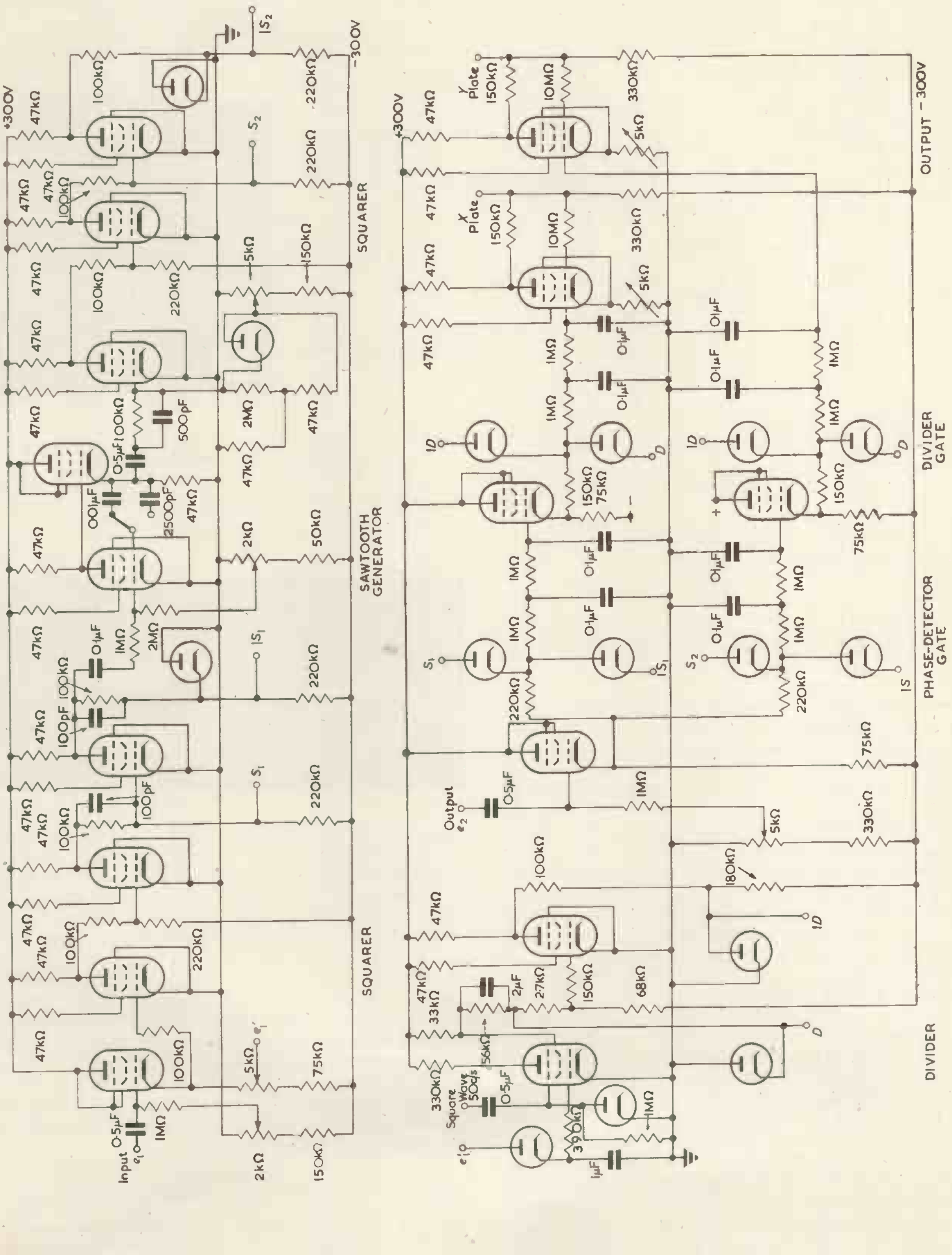


Fig. 4. The circuit of the plotter

Thus the mean output voltage is proportional to the component of the signal e_2 which is in phase with e_1.

To derive a square wave, 90° out-of-phase with the waveform e_1, the initial square wave is passed through a Miller

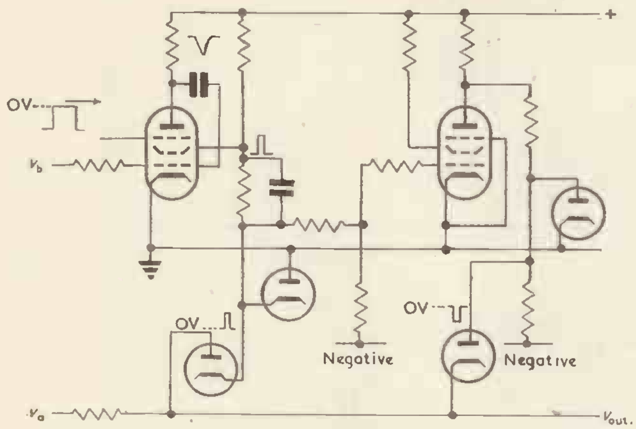


Fig. 2. The divider circuit

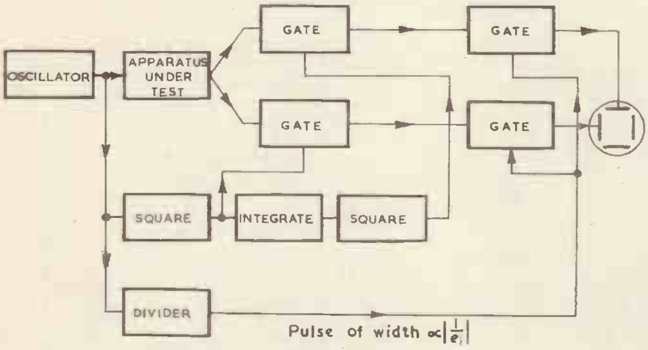


Fig. 3. Arrangement of the plotter

integrator[2]. This gives a sawtooth waveform, and the output waveform passes through its mean value at a time $\tau/4$ after the square wave transient occurs, where τ is the period of the input waveform. Thus by passing the sawtooth waveform into a squaring stage, the required waveform is produced.

Having derived two voltages proportional to the in-phase and out-of-phase components of the signal e_2, the gain of the element is given as proportional to these signals divided by the modulus of the signal e_1. This operation is performed using an electronic analogue divider[3]. This element is essentially a suppressor switched Miller integrator, with the input voltage v_b applied to the grid through a resistor. The rate at which the anode potential falls is proportional to the voltage v_b, and hence the run-down time is inversely proportional to v_b. While the anode potential is falling, the screen current is small, and hence the screen provides a large positive-going pulse of duration inversely proportional to v_b. This pulse is used to gate the input v_a, giving a waveform whose mean potential is proportional to v_a/v_b. This process is illustrated schematically in Fig. 2.

A block diagram of the complete unit is shown in Fig. 3.

The complete circuit of the unit is shown in Fig. 4 (page 33). The equipment is built on two chassis, one containing the gating waveform generator and the other the switching units. Type EF50 valves are used throughout, but the unit would be rendered more compact by using double triodes for cathode-follower and amplifier stages.

The observed waveforms, for a typical input, are shown in Fig. 5.

Experimental Results

The response of the unit is tested using a variable-frequency phase measuring device previously described[4]. This is shown in the block diagram Fig. 6(a). As the potentiometer is

Fig. 5 (right). Observed waveforms

(a) *input* e_1 (b) *input* e_2 (c) *in phase component of* e_2 (d) *out of phase component of* e_2.

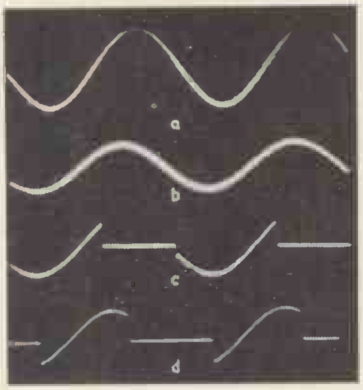
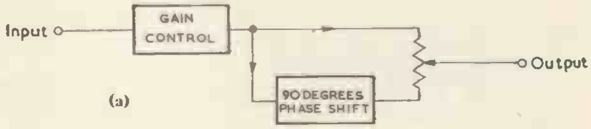
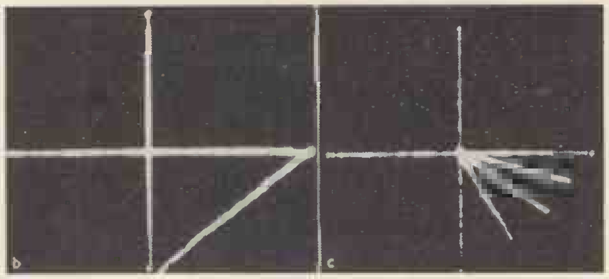


Fig. 6 (below). (a) Test apparatus (b, c) response of the unit





varied, the phase difference between input and output varies continuously from 0° to 90°, and it may be shown that the gain locus on the complex plane is a straight line. The experimental locus is shown in Fig. 6(b). Fig. 6(c) shows the effect of varying the gain of the element for several constant settings of the phase-shift control.

Conclusion

An electronic unit has been described which provides two voltages proportional to the in-phase and out-of-phase gain of a unit, for a sinusoidal input. This gives a convenient representation of the gain of the element using a conventional c.r.t.

Frequent adjustment is found unnecessary, and the unit is invaluable for demonstrating the transfer functions of both active and passive linear networks.

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An Alternating-Voltage Stabilizer

with Form-Factor Correction

By D. J. R. Martin*, B.Sc., A.Inst.P.

A description is given of a unit which provides a constant-voltage supply for variable loads up to 150W. The output voltage is 240V and varies by less than ±0·2 per cent for changes in line voltage of ±12½ per cent, frequency changes of ±4 per cent and load changes between 50W and full load. Sinusoidal input waveforms suffer negligible distortion; with distorted input waveforms the form-factor is automatically corrected by simultaneous stabilization of the rectified-mean and r.m.s. values of the output voltage.

THE stabilizer to be described was designed to satisfy the general need for an a.c. supply which would maintain a constant voltage to within a fraction of 1 per cent in spite of wide changes in mains voltage, applied load and frequency. Rapid response was considered essential, and a further stipulation was that the waveform of the mains supply, if originally sinusoidal, should suffer negligible distortion by the stabilizer. At the same time the unit was required to be of only moderate size and cost. These requirements have been met, and the stabilizer incorporates an additional facility which corrects the form-factor of a distorted input waveform by simultaneous stabilization of the rectified-mean and r.m.s. voltages; this unique course is simpler than providing a waveform that is truly sinusoidal regardless of input waveform, and for most purposes is as useful.

The controller circuit uses a novel extension of the "series impedance" principle, in which a pair of valves is operated in push-pull without any standing direct voltages. In the present case, the preceding amplifier stage is also entirely a.c.-operated, and direct coupling is used to the controller valves themselves; control is obtained by variation in the negative feedback applied over the two stages. The deviation-detector circuit uses a neon stabilizer and a Thermistor as reference elements for stabilization of the rectified-mean and r.m.s. voltages respectively; correction of the latter quantity is effected by the injection of suitable harmonics into the output.

The complete unit has been built on a chassis measuring 16in by 9in; no attempt at miniaturization or extreme economy of space has been made.

The Controller

Fig. 1 shows the circuit diagram of the complete stabilizer. The unstable mains input is first boosted by the auto-connexion of transformer T_1 to a value which is about 20V above the required output voltage when the input voltage is at its lower limit. The variable excess over the required value is dropped across the primary of transformer T_2, which reflects the impedance of valves V_1 and V_2. These valves are operated with an alternating control signal on the grids. The screen-grids are also operated from an a.c. supply, but small rectifiers are interposed to prevent the screen-grids emitting on their negative half-cycles. The control-grids are resistance-coupled to the anodes of the preceding valve, a double triode; this valve is also operated without any standing direct voltages. An arbitrary signal from the input transformer is injected into the cathode circuit of this stage, and control of the output impedance of the complete controller circuit is obtained by variation of the degree of negative feedback applied to the grids of V_3 via resistors R_{11} and R_{12}.

This variation in feedback is effected through the Metrosil† disks M_1 and M_2. Metrosil is a semi-conductor having a non-linear voltage-current characteristic. For small values of alternating voltage it may be regarded as having a variable a.c. resistance whose magnitude is a function of the direct current flowing through the substance. In this application, the two Metrosil disks form part of the negative feedback network, and a direct current flows differentially through them, controlling their a.c. resistance and thus the degree of negative feedback.

Stabilization of the Rectified-Mean Voltage

From this point, it is a straightforward matter to arrange for the provision of a suitable control signal. A portion of the stabilizer output is rectified and smoothed and compared with a stable direct reference voltage; the difference is amplified and used as the control signal. In Fig. 1, V_8 is the sample-voltage rectifier; the smoothing circuit is formed by R_{20}, R_{21}, C_9 and C_{10}; V_7, an 85A1 neon stabilizer, provides the stable reference voltage, which also feeds the screen-grid of the voltage amplifier V_6. V_5 is a cathode-follower, necessary to supply the current (up to about 50mA) taken by the Metrosil disks.

The h.t. supply for V_5 and V_6 is derived from the unstabilized mains input and accordingly is subject to the same fluctuations. This arrangement, in conjunction with the stabilized feed for the screen grid of V_6, causes the fluctuations to be passed on directly, through V_5, to the Metrosil disks, and the chosen circuit values are such that a considerable measure of self-stabilization results; this reduces the required control signal from the deviation detector and a more stable output voltage is thereby achieved.

The direct current in the choke L_1 causes a voltage drop on account of the inherent d.c. resistance of the latter. To prevent this voltage from biasing the grids of V_3 positive, a third Metrosil disk M_3 is introduced, in series with the resistor R_{15}, whose resistance is chosen to be approximately equal to that of each half of L_1; by returning the centre-tap of transformer winding A-C-B to the junction of these two components, instead of to earth, compensation is obtained. An alternative measure would be to employ a double-wound transformer in place of choke L_1.

The fact that the neon stabilizer is fed from an unstable

* British Scientific Instrument Research Association.

† Marketed by Metropolitan-Vickers Electrical Co., Ltd.

supply precludes realization of the maximum stability obtainable from this valve. However, a considerable measure of compensation for its incremental resistance is obtained through the positive feedback introduced by the common cathode resistor R_{16}, whose optimum value was found experimentally. If the utmost stability is required a separate reference neon tube may be used, supplied from the output of the stabilizer, and the first tube retained for the screen supply of V_6.

porates a supplementary deviation-detector which is sensitive to the r.m.s. value of the output voltage. Any departure of the r.m.s. voltage from the pre-set value results in a 100c/s (nominal) signal being applied to the grid of V_6, and subsequent intermodulation with the fundamental frequency causes odd harmonics to appear in the output in such a phase as to correct for the discrepancy in the r.m.s. voltage. This facility in no way interferes with the operation of the principal deviation-detector, which maintains the

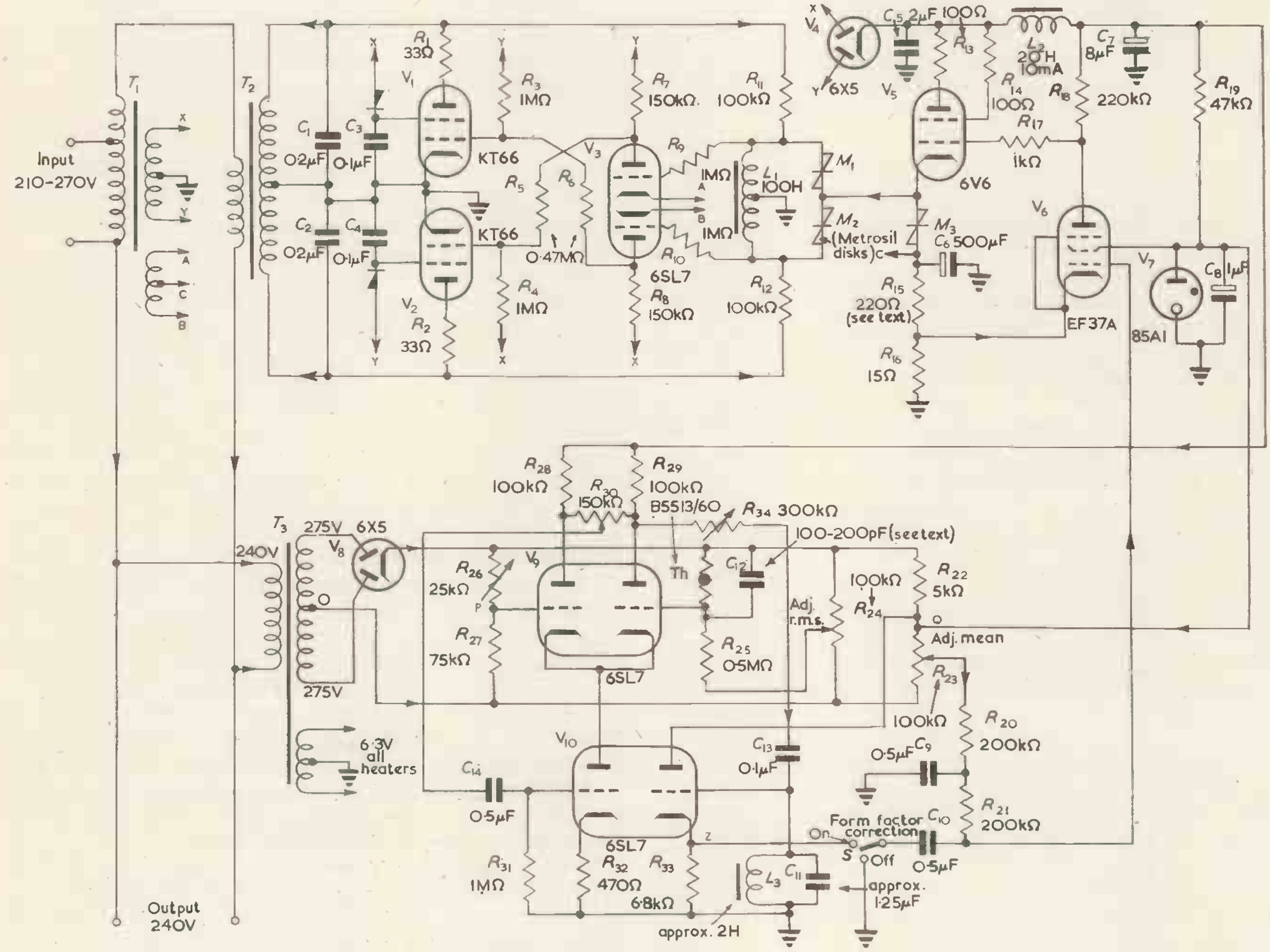


Fig. 1. The voltage stabilizer

T_1 = 75*W*. *Pri*: 240*V*. *Secs*: 300*V* (*auto*); 325-0-325*V*(X-Y); 7-0-7*V*(A-C-B).
T_2 = 50*W*. *Pri*: 100*V*. *Sec*: 800-0-800*V*.
T_3 = 30*W*. *Pri*: 240*V*. *Secs*: 275-0-275*V*; 6·3*V*, 5*A*.
L_1 = 100*H*, *centre-tapped; zero polarizing d.c.; "Mumetal" core.*
L_2 = 20*H*, 10*mA*.
L_3 = *approx.* 2*H*.
M_1, M_2, M_3 = *Metrosil disks; 1in diam. annular 1/16in thick; M_1 and M_2 should be matched.*
Th = Thermistor type B5513/60 (S.T.C.) heater not used.

Form-Factor Control

Some waveform distortion might be expected on account of the non-linearity of the Metrosil characteristic, but in practice the alternating current in each disk is a small fraction of the direct current, and the distortion is negligible. It is assumed, however, that the d.c. supply is well smoothed, for any ripple distorts the output waveform by the introduction of odd harmonics. This property of the circuit is turned to useful account, for by introducing a controlled amount of second-harmonic ripple on to the direct current, the form-factor of the mains supply may be corrected or modified as required. The circuit shown in Fig. 1 incorporates a supplementary deviation-detector which is sensitive to the r.m.s. value of the output voltage.

rectified-mean voltage at its own, and possibly different, pre-determined value.

The r.m.s.-sensitive detector is a Thermistor bridge, supplied with a full-wave rectified a.c. derived from the stabilizer output. Rectification leaves the r.m.s. value unaltered, while introducing a predominant second-harmonic component and suppressing the fundamental. The output from the bridge is amplified by V_9 and filtered to provide the necessary 100c/s control signal. The Thermistor bridge needs temperature compensation, though this has not been shown in the diagram; it may conveniently be provided by a type KB2322/80 Thermistor, suitably shunted, inserted in series with R_{26}. Thermistors vary widely in their characteristics, and the correct value of shunt in each individual case has to be found by experiment.

When the circuit is initially put into operation, R_{26} is adjusted for a null balance between points P and Q. R_{30} is adjusted for maximum discrimination against in-phase components, that is, for minimum signal at point Z when the grids of V_9 are strapped together. R_{34} should be set for the minimum value consistent with adequate filtering of the signal at Z (this adjustment is a compromise between maximum r.m.s. stability and permissible distortion on a sine-wave input). Capacitor C_{12} phases out the quadrature component inevitable from a Thermistor bridge, and its correct value is quickly found by experiment. The mean and r.m.s. values of the stabilized output are independently pre-set by R_{23} and R_{24} respectively. Switch S cuts out the form-factor correction and is useful during initial adjustments.

Performance

The output voltage of the stabilizer is constant to within $\pm 0{\cdot}2$ per cent against changes in mains voltage of $\pm 12\frac{1}{2}$ per cent (i.e. the stabilization ratio is 63 : 1) and frequency changes of ± 4 per cent for any load from 40W to 150W. If the input waveform remains unaltered the response time to voltage and load changes is of the order of 1 cycle. A change in the r.m.s. value of the input voltage in the absence of any corresponding change in the rectified-mean value needs a longer time (about one second) for complete correction, due to the lag introduced by the Thermistor.

If a fixed load may be guaranteed, the power output may be increased to 600W by shunting the controller transformer with a suitable resistor and increasing the rating of T_1. The power output may also be increased by restricting the permissible input voltage range; for example, if the total input-voltage excursion does not exceed 10 per cent between limits, the stabilizer may be modified to work over the continuous load range 40 to 400W.

Over a period of continuous running for one month, the output voltage has never gone outside the 0·2 per cent limits for all normal changes in input voltage, frequency and ambient temperature.

Acknowledgments

The author wishes to thank the Council and Director of the British Scientific Instrument Research Association for permission to publish this article, and Dr. A. J. Maddock, in whose department the research was carried out, for advice on its preparation.

Electronic Machine Tool Control

The Applications Laboratory of Ferranti Ltd. has recently developed a computor capable of controlling a machine tool, as for example a milling machine.

The whole system comprises:

(1) A tape perforator by which the planning engineer instructs the computor to perform the operation required. This involves coding the dimensions of the article, together with machining instructions as perforations on a strip of paper tape.

(2) A tape reader which transfers the instructions coded on this tape to the computor.

(3) The computor itself which takes this basic information and calculates precisely the movements which the table of the machine tool will have to make to cut the required shape.

(4) A magnetic tape recorder which records the instructions for these movements.

(5) The machine tool itself complete with tape-controlled servo-mechanisms and measuring devices which move under the control of the tape playback unit.

The method of measurement employed is based on the use of Merton diffraction gratings[1]. The accuracy of the whole system is limited by the accuracy of the machine tool itself.

Illustrated is a simpler application in the form of a small drilling machine. This has a table which can be positioned to within two ten-thousandths of an inch merely by setting up the required dimension on a group of dials. In this case the instructions are so simple that no calculations as such are required, and there is no necessity for a computor. Only a simple addition to this machine is needed to enable it to read the position of a group of holes directly from punched paper tape if it is required to repeat a sequence of holes in an item such as a gear plate.

1. Diffraction Gratings in Industry. *Electronic Engng. 26*, 213 (1954).

New Australian Army Midget Radio

A portable radio station that will operate efficiently even after being submerged in water or mud has been developed in Australia.

Called the A510 Portable Wireless Station, it is made by Amalgamated Wireless (Australia) Ltd., at their factory at Ashfield, Sydney.

The unit was designed for the Australian Army which wanted a light, portable radio transmitter and receiver with a range of at least 4 000 yards for battalion communication.

It had to be rugged, simple to operate and so designed that it would fit into ordinary army webbing equipment.

The A510 weighs 37lb (half that of current portable radios used by the Australian Army); it can be carried easily by one man in an infantryman's basic pouches attached to his belt; and simple on-off switches are the only controls. It can be used for telegraphy or telephony.

The frequency band, 2 to 10Mc/s, enables communication to be established quickly and clearly, day or night and in any weather, and the general performance is claimed to be superior to that of previous portable radios used by the armed services.

Although as a portable set it has a range of about five miles, a fixed wire aerial increases the range to 500 miles under good conditions.

British forces in Malaya have tested the equipment exhaustively under actual fighting conditions with outstanding success.

It is understood that the British Army has placed an order worth £A250 000 for these equipments.

It is of interest to compare the A510 with the huge mass of equipment which was necessary for radio communication in the 1914-18 war. Sometimes this was carried in special packs by five or six horses. Another method was to mount it on two four-horse limbers. A later refinement was a mobile transmitter and receiver mounted on a motor tricycle.

Notes from North America

A New Beam Switching Tube

A NEW type of beam switching tube is being developed by the Burroughs Research Centre, Paoli, Philadelphia, for use in computors.

The tube employs the beam forming properties of crossed electric and magnetic fields, the latter being provided by a small circular permanent magnet placed externally round the tube.

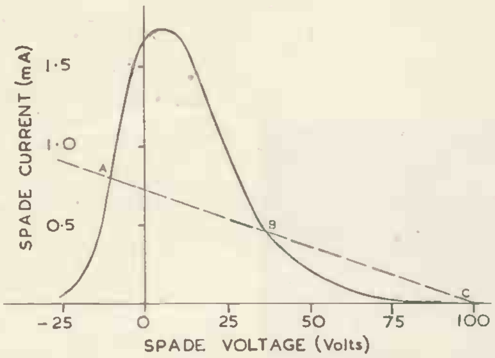
Internally, the tube is composed of ten groups of electrodes mounted radially about a central cathode. The basic elements of each group are:

1. A spade to form and lock the beam.
2. A grid to switch the beam.
3. A target to give a useful output.

By forming the beam on any one spade an output signal is produced on the corresponding target plate. Since the beam may be automatically formed and locked on any spade, there are ten discrete outputs associated with the tube.

An eleventh stable state occurs when all the elements of the tube are positive with respect to the cathode. This is the *clear* condition in which there is no output to any target plate.

By lowering the voltage of any one spade from the clear condition, the following characteristic curve is obtained.



Spade-current/spade voltage.

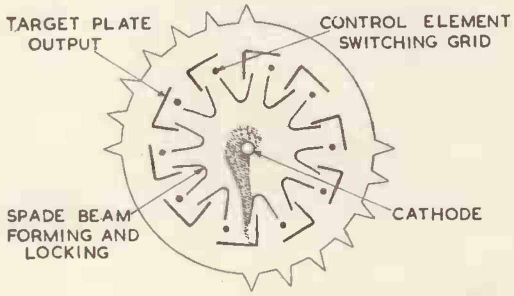
Of the three possible operating points, A, B, and C, only A and C are stable, while B is unstable.

When the tube is in the clear condition, all the spades are in state C. By lowering the voltage of any one spade beyond point B with a suitable series load, it will assume its other stable state, which is at near-cathode potential. This affects the relationship between the electric field and the magnetic field so that the beam forms to that spade in the manner shown.

Over 90 per cent of the beam is utilized in producing an output with a pentode type characteristic. The remainder is used automatically to form and lock the beam in position. This is obtained without suppression, and a wide variety of target resistor load lines can intersect the constant current portion of the curve with negligible crosstalk.

When a beam has been formed on a spade it can remain there indefinitely, or it can be advanced by lowering the associated grid voltage.

A voltage drop on the switching grid will disturb the electric field so that enough of the beam is deflected to the leading spade to cause that spade to assume its other stable state (A). The beam will now be formed on this spade.



Cross-section of beam switching tube showing beam forming.

Because of their shape and position, the grid electrodes give a very uniform switching action. This action is in the order of 0·1 microsecond, and draws negligible current.

Since the switching grid will affect the beam only in the region associated with the grid, the grid electrodes are connected in two groups, the odd numbered grids in one group and the even numbered in the other. In this way it is possible to use a d.c. input and still secure single position stepping which eliminates the necessity for a critical pulse width for this type of operation.

I.R.E. Awards

THE Institute of Radio Engineers has awarded Harald T. Friis, Director of Radio Research, Bell Telephone Laboratories, the IRE Medal of Honour. The award was made for his outstanding technical contributions in the expansion of the useful spectrum of radio frequencies, and for the inspiration and leadership he has given to young engineers.

The Morris Leibmann Memorial Prize was given to Arthur V. Loughren, Director of Research, Hazeltine Corporation, for his leadership and technical contributions in the formulation of the signal specification for compatible colour television.

Bernard Salzberg, Naval Research Laboratory, Washington, D.C., received the Harry Diamond Memorial Award.

The Vladimir K. Zworykin Television Prize Award goes to Harold B. Law, RCA Laboratories Division, Princetown, N.J., for his contributions to the development of the shadow-mask tri-colour television picture tube.

Seventy-six leading radio engineers and scientists were elected Fellows of the Institute by the Board of Directors at a meeting held in November. The grade of Fellow is the highest membership grade offered by the Institute and is bestowed only by invitation on those who have made outstanding contributions to radio engineering or allied fields.

Among the overseas recipients of the Fellow award are T. E. Goldup, a director of Mullard Ltd, and G. W. O. Howe, who until his retirement was Professor of Electrical Engineering of Glasgow University.

LETTERS TO THE EDITOR

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

Relay Scale-of-Two Circuits

DEAR SIR,—It was with interest that we read the article by Mr. R. C. M. Barnes. Recently we developed a scale-of-two circuit for use on low voltage, i.e. 2 to 6 volts for model control work. This circuit was designed to switch on then off a certain piece of equipment by remote control, and we think that other readers may find the circuit of use and interest.

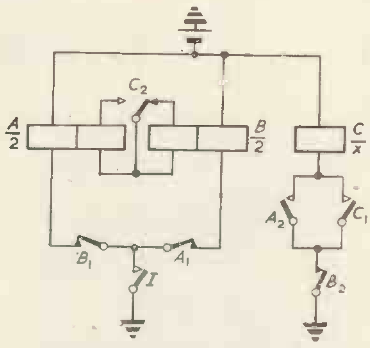


Fig. 1. Scale-of-two circuit for use on low voltage

The circuit is shown in Fig. 1. For normal work a coil resistance range of 50 to 200 ohms has been found satisfactory—50 ohms for 2 to 3 volt operation and 200 for 6 volts. The action of the circuit is, I contact makes and completes the operation circuit for both $A/2$ and $B/2$, however the fact that the one coil of $B/2$ is short-circuit makes that relay slow to operate. $A/2$ is therefore in a "fast to operate" condition and operates, contact A_1 must be the first to break, and do so before A_2 operates, so that the coil of $B/2$ is disconnected. A_2 makes the operating circuit for C/x and it operates with the contacts C_1 locking the relay.

Contact C_2 takes the short-circuit off $B/2$ coil and puts it across $A/2$ coil. Thus when the pulse is finished, $A/2$ has become slow to operate, $B/2$ fast to operate and C/x remains in an operated condition.

A further operation of the impulse contact (I) will cause $B/2$ to operate, with B_1 preventing the slowed $A/2$ relay, and B_2 contact releasing C/x.

Thus all contacts are, after the release of $B/2$, in a normal state.

While the circuit is quite useful for low voltage work it suffers from the trouble that at the end of an impulse the operated relay—either $A/2$ or $B/2$ is in a slow-to-release condition, this makes the maximum number of pulses per minute a matter of about 200. If, however, another contact was placed in series with each "slugging" coil so that the coil would not become short-circuit until the particular coil had released, then the circuit should be capable of about 600 impulses per minute.

Yours faithfully,

JAMES S. KENDALL.

Kendall and Mousley,
Birmingham.

The Author replies:

DEAR SIR,—I find Mr. Kendall's scale-of-two circuit interesting as it uses a principle of varying the relative operating speeds of two relays which I had not seen before. With a power supply of only 2 volts it is probably best to forget all those circuits in which relays operate on less than full line voltage. If we assume that the circuit is to be controlled over one wire (relay contact I), my Fig. 12(a) is a competitor, but it uses two rather specialized relays which might not be so readily available as the three relays in Mr. Kendall's circuit.

My Fig. 23(a) suggests another way of tackling this problem with three relays. The incoming signal could operate a relay I with two K contacts (as described in the last paragraph of my article). There is little to choose between this and Mr. Kendall's circuit. Personally I would prefer to use the adaptation of Fig. 23(a) if the circuit has to operate frequently, because it avoids the timing feature and can therefore tolerate a lower standard of mechanical maintenance.

Yours faithfully,

R. C. M. BARNES.

Electronics Division,
Atomic Energy
Research Establishment,
Harwell.

The Determination of the Dynamic Properties of Crystal Diodes

DEAR SIR,—There are three methods by which crystal diodes have been used in amplifiers to impart non-linear characteristics. The first method makes use of the property that the dynamic or a.c. resistance of a crystal varies with the quiescent or d.c. current passing through it, and hence the transmission loss of an attenuation pad, in which crystals are incorporated, may be varied by means of a d.c. control current[1,2]. The second application merely uses the diode as a voltage controlled switch to introduce either an attenuating resistance or feedback[3]. The third method combines both properties, the crystal shunting a high resistance so that when the diode is conducting the high resistance is by-passed by the low resistance of the crystal, and when the control voltage causes conduction to cease, the high resistance is introduced[4].

In all these methods the dynamic properties of the crystal are important, and although the dynamic resistance may be obtained from the static voltage current curves, certain unexplained occurrences in the characteristics of an amplifier, utilizing method three, caused a brief investigation of the dynamic properties.

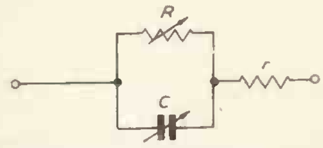


Fig. 1. Equivalent circuit of a crystal diode[5]. For low values of the bias current $R > r$ and this condition enables balance of the bridge circuit in Fig. 2 to be obtained

A Wien bridge circuit described in the literature[1] was first used, but as a meter for determining the quiescent current through the crystal was required, and also since the capacitance of the crystal (see Fig. 1) made the balance point difficult to determine, the variation of the Schering bridge shown in Fig. 2 was used and found satisfactory.

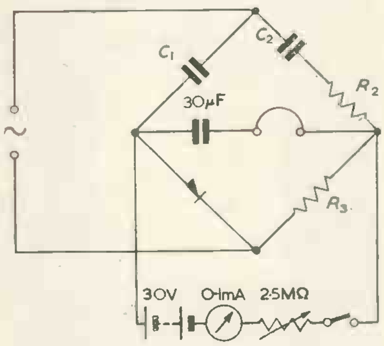


Fig. 2. Bridge circuit at balance

$$R = \frac{C_2}{C_1} R_3 \text{ and } C = \frac{R_2}{R_3} C_1$$

The dynamic resistance determined by this method was about half that determined from the static curves, and also it decreased both with frequency and with the a.c. voltage applied. It was also found that the capacitance was non-linear as expected. The results fully explained the behaviour of the amplifier.

The work described in this letter was carried out at the Admiralty Signal and Radar Establishment, and the writer is indebted to the Admiralty for permission to publish this letter.

Yours faithfully,

G. STUART-MONTEITH

Admiralty Signal, and Radar
Establishment.

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2. FRACASSI, R. D. The Compandor in N1 Carrier. *Bell Lab. Rec. 31*, 452 (November, 1953).
3. BAXTER, I. G. A Square Root-Law Circuit. *Electronic Engng. 26*, 97 (1954).
4. HOLBROOK, G. W. A Variable Gain Amplifier. *Electronics 25*, 200 (April, 1952).
5. TORREY and WHITMER. Crystal Rectifiers. *Radiation Laboratory Series No.* 15 (McGraw-Hill, 1948).

ELECTRONIC EQUIPMENT

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

Electronic Recorder

(*Illustrated below*)

THE Cambridge Electronic recorder is of the continously balancing type, the rebalancing of the measuring circuit being effected by means of a small servomotor. Any voltage error due to unbalance is converted into a 50c/s signal of appropriate phase and after electronic amplification, is applied to the servomotor to drive it in such a direction as will restore balance. Damping of the recorder movement is obtained by feeding, to a suitable point in the amplifier, the voltage from a tachometer generator coupled to the servomotor.

For most applications the instrument is supplied as a recording potentiometer

for the measurement of small d.c. potentials, but alternatively the measuring circuit can be arranged as a low resistance current measurer, as a d.c. bridge or, with certain limitations, as an a.c. bridge or potentiometer. Full scale sensitivities down to 1mV are possible.

The electronic recorder is available for single or multipoint recording. Single point recorders use a syphon type pen and provide a continuous line record. Multipoint records utilize a turret marker which picks up ink from reservoir pads and prints a circular dot on the chart. Either 2, 3, 4 or 6 circuits are selected in turn by the recorder mechanism and the records printed in distinct colours at the rate of 10 points per minute.

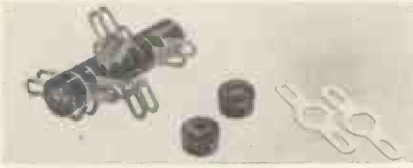
Cambridge Instrument Co Ltd,
13 Grosvenor Place,
London, S.W.1.

Tag Assemblies

(*Illustrated above right*)

THE McMurdo Instrument Co. announce that they are now in full production with their "Unitag" tag assemblies. These enable stand-off insulators and tag strips to be built up by the user to suit individual needs.

They are built up along 6 B.A. screws or studding using the bakelite bushes as spacers between the tags. The bushes



have hexagonal interlocking sections which prevent rotation and also permit three alternative orientations of the tags.

"Unitags" are supplied loose in lots of 100 pairs of bushes and tags. Preassembled units complete with mounting brackets can also be obtained from Harwin (Engineers) Ltd., 101 Nibthwaite Road, Harrow, Middlesex.

McMurdo Instrument Co Ltd,
Victoria Works,
Ashtead, Surrey.

Soldering Iron Bits

SOLDERING iron bits having a corrosion resistive metal coating are being manufactured in a variety of sizes by B & P Radio. It is claimed that these bits have a life 7 to 10 times greater than an ordinary copper bit and that bit changing is facilitated since seizure between the bit and the soldering iron is eliminated.

B & P Radio Ltd,
Langham Parade,
Tottenham,
London N.14.

Scintillation Phosphors

(*Illustrated below*)

ISOTOPE DEVELOPMENTS have now increased their range of scintillation phosphors to include the new, high-activity scintillator, "Pamelon".

This material, which gives good light response and other essential characteristics, provides an overall phosphor which is comparable with many of the present crystalline materials that are difficult to grow and fabricate. The energy yield and fast decay time of "Pamelon", coupled with its availability in large sections, at low cost, make it a versatile scintillator for use in connexion with alpha-, beta-, gamma- and X-rays.

Another item of interest to workers in the nucleonic field is the "I.D.L." ready-for-use sodium iodide capsule. Difficulties have been encountered in the past where the hydroscopic raw crystal has been supplied to customers and wastage has occurred in their having to polish and encapsulate the crystal. The "I.D.L." range of capsules includes a cylindrical crystal to give optimum response from the standard British photomultipliers, as well as smaller capsules containing cubic crystals for directional scintillation heads.

Isotope Developments Ltd,
Finsbury Pavement House,
120 Moorgate,
London, E.C.2.

Low Voltage Stabilized Supply

(*Illustrated above*)

THE type 38 electronic voltage stabilizer will supply 0 to 2·5A at from 0 to 15V. The stability is such that a mains fluctuation of ±10 per cent causes a change of output not exceeding 5mV. The output ripple is not more than 3mV r.m.s. under the worst conditions. The time for full correction of mains changes or small load current changes is about 1msec. The reference voltage for the unit is supplied by a Mullard 85A2 used in a balanced d.c. amplifier circuit.

Servomex Controls Ltd,
Crowborough Hill,
Jarvis Brook,
Sussex.

Ohmmeter

(*Illustrated above right*)

THE Ohmmeter Type 861 is intended for production and laboratory continuity testing, and enables the value of any resistance between 1Ω and 10MΩ to be rapidly determined. A large meter, having a scale length of approximately 7in is employed.

The instrument operates from normal a.c. mains supply, the d.c. test voltage

being obtained from an internal stabilized source. Six resistance ranges are provided, each range, selected by push-button switching, being a multiple of the meter reading, except in the case of the highest range which has a separate scale calibrated from 0·1MΩ to 10MΩ.

The instrument is suitable for bench use or for mounting in a 19in. rack.

Airmec Ltd,
High Wycombe,
Buckinghamshire.

Relay

(Illustrated above)

THE type 2 400 relay, the latest addition to the range manufactured by Magnetic Devices, has been designed to suit present day electronic circuits both as regards size and sensitivity. Measuring only 2½in high by 1in by 1⅛in, the contacts are readily accessible on removal of the dust cover and all connexions are made from the underside. Both light and heavy duty contacts are available and a sensitivity of 4mA with a 10kΩ coil has been achieved with adequate contact clearance and pressure.

Magnetic Devices Ltd,
Exning Road,
Newmarket.

Valve Screens

(Illustrated below)

A NEW range of valve screens, with associated coil springs have been made by Plessey for use in conditions requiring robust components with efficient performance under tropical conditions.

The screens are available in two diameters to suit B7G or B9A valveholders, and in the three standard lengths recommended by the Radio Components Standardisation Committee.

They can be supplied in either brass for use with silver plated valve skirts, or aluminium with cadmium plated skirts. In the case of brass screens, the contacting face is silver plated, but with aluminium screens the contacting face is clean metal. In either case the remaining inner surface and the whole outer surface are protected by a matt black stove-enamelled finish which assists in dissipating the heat generated in the valve.

The Plessey Co Ltd,
Ilford, Essex.

Coaxial Relay

(Illustrated below)

THE coaxial relay type A.07 is for use inside apparatus where space is limited. Instead of the normal plug

and socket arrangement connexion to the relay is by lengths of coaxial cable brought straight out through fittings which allow them to emerge in any desired direction. The action of the relay can either be simple changeover or changeover and earth, i.e., the unused line can be earthed to minimize cross-talk.

Besson & Robinson Ltd,
6 Government Buildings,
Kidbrooke Park Road,
London, S.E.3.

New Valves

(EIT Illustrated above right)

MULLARD have recently commenced manufacture of a high speed decade counter tube. This tube, the EIT is of the hard-vacuum type and is, therefore, capable of very high counting speeds; counts of 30 000 per second being readily attainable.

The basis of the Mullard EIT is a ribbon-shaped electron beam which can be deflected into ten well defined positions by the input signals. In any of these ten positions the beam passes through one of ten apertures in a cylindrical anode and impinges on a fluorescent screen, causing a spot of light to appear opposite the appropriate figure

("0" to "9") marked on the tube envelope. As the last position is passed by the beam a signal can be generated to re-set the tube to "0" and simultaneously apply a counting pulse to the next tube in the chain.

"Special Quality" versions of the voltage reference tubes types 90C1, 85A2 and 150B2 are now being made available. The new tubes are tested to withstand impacts of 500*g* and vibrations of 6*g* at 175c/s. They are available in two forms, one with pins and one with flying leads. The M8098 (pins) and M8142 (flying leads) are electrically equivalent to the 85A2; the M8206 and M8207 to the 90C1 and the M8163 and M8208 to the 150B2.

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

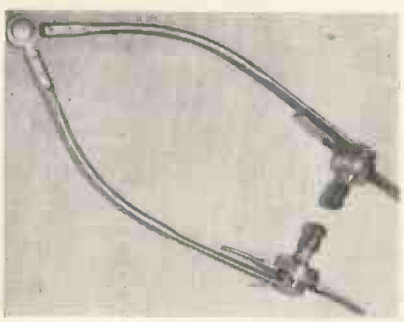
Stethophones

(Illustrated below)

STETHOPHONES (Foot's induction phones) are earphones which have no trailing wires and are not plugged in to a point. They are operated by the magnetic field set up by a wire or copper tape encircling the area in which they are to be used, thus the wearer has complete freedom of movement. An audio power of some 3 to 4W is adequate to cover an area of 200 to 500ft².

They are intended primarily for aiding deaf people in cinemas, churches, etc., and for use in hospitals. For the latter purpose a special type (illustrated) are made having short extensions which are made to revolve so that the pole pieces always remain in a vertical position (for maximum sensitivity) even when the wearer is lying down.

The Magnetic Broadcasting Co Ltd,
Suffolk Hall,
1 Upper Richmond Road,
London, S.W.15.



BOOK REVIEWS

Magnetic Amplifier Circuits

By Dr. W. A. Geyger. 277 pp. 120 figs. Demy 8vo. McGraw-Hill Publishing Co. Ltd. 1954. Price 42s. 6d.

THE publication of any new book dealing with magnetic amplifiers constitutes a welcome event since the magnetic amplifier art, though boasting many thousands of technical papers, reports and patent specifications, is peculiarly short of works of reference. Dr. Geyger's book covers the field in a comprehensive manner, but it falls short in some respects of the aims expressed in the closing paragraphs of his preface. Far from being an introduction to the subject for the benefit of newcomers to the field, the book is of greater use to engineers already possessing a wide experience of magnetic amplifiers. This derives from the fact that the emphasis is placed very markedly, as the title makes clear, on magnetic amplifier circuits, the material being presented without rigour and at "technician" level. The engineer finds a large selection of useful circuits which he can analyse in greater detail by methods well known in the art. The technician will obtain from the book a superficial knowledge of magnetic amplifier applications, and the student will most likely conclude that the subject is extremely involved and still wonder at the end of the book exactly how a magnetic amplifier works and how one sets about designing one. There are two extraordinary omissions in a book of this sort. Firstly, nowhere is there to be found a simple analysis underlining the basic operation of the elementary transductor in the transient and steady state condition, and secondly, the book is entirely without photographic illustrations of any sort. The newcomer, therefore, is unable to establish, except in a very nebulous way, the relationship between the multitude of circuits and their realization in a practical form.

The author has adopted a classification of magnetic amplifier types, and in general a chapter is devoted to each one of these. He makes the broad distinctions between "non-feedback", "internal feedback", and "external feedback" types and sub-divides these according to the number of cores required and the nature of the output signal, e.g. "Duo-directional half-wave output". This, as the author mentions, is just one of several forms of classification, and though it works tolerably well, there is of necessity an appreciable amount of duplication of material and some paragraphs are reiterated verbatim in several parts of the book.

The book offers only slight assistance in matters of design and here the emphasis is placed upon the "load line" construction based on non-dimensional characteristics obtained experimentally. This technique has now been superseded by more refined mathematical methods except in cases when low grade core materials are used.

Chapter X introduces amplifiers of the "internal feedback" type and in the ensuing pages many circuit arrangements are discussed. An unfortunate feature, however, is that no distinction is made between inherent "half cycle" response amplifiers and those of a more conventional sort. It is the reviewer's opinion that the terms "control current" and "control voltage" are not always used in the right places and occasionally misleading generalizations are made. For example, on page 149 a group of single-core circuits is shown and lower down on the page it is stated that a power gain of 10^6 or 10^7 may be obtained with such arrangements. In fact, the circuits shown might yield power gains of perhaps 100 but hardly any more. One must go to the well-known auto-excited shunt amplifier (mentioned in the following chapter) in order to obtain the high gains referred to by the author.

The book closes with three chapters entitled "Second Harmonic Circuits", "Technical Properties of Magnetic Amplifiers", and "Typical Applications of Magnetic Amplifiers". The first of these gives a short account of various magnetic modulator arrangements, and though stressing the great zero stability obtainable from these, fails to give any clue why this should be. The next chapter, consisting of seven and a half pages, lists a dozen features applicable to magnetic amplifiers in general and offers some very brief notes on time-constant and illustrates a method for measuring this. The final chapter, also a short one, comes as a considerable anti-climax since the only application discussed in any worthwhile detail concerns the control of an a.c. servo motor and, even here, the material has been substantially covered in earlier chapters.

Broadly speaking, it is considered that Dr. Geyger's book represents a useful addition to the literature and the copious references at the end of each chapter add materially to its value. It is recommended to all those actively engaged in the application of magnetic amplifiers, but others will not derive the benefits the book has to offer until thev themselves have fully grasped the basic principles governing the magnetic amplifier behaviour.

A. E. MAINE.

Electronics

By Thomas Benjamin Brown. 545 pp. 396 figs. Demy 8vo. John Wiley & Sons, New York. Chapman & Hall Ltd., London. 1954. Price 60s.

IN his preface, the author of this publication, who is Professor of Physics at the George Washington University, answers his own question, "Why another book on Electronics?", by explaining that among the wealth of literature he has been unable to find any book which by itself is a suitable text for a basic course in the subject. To try to satisfy this need he has drawn on many years of teaching experience and presented the information given to his own students. This includes physical, analytical and graphical explanations of the phenomena encountered in electronic devices, illustrated by 43 "demonstration experiments", 37 "experiments" (carefully designed and detailed) and 266 original problems. Undoubtedly his course in Electronics is an excellent one, but is his book "planned to meet the needs of the classroom and the laboratory", best suited to the requirements of students taking courses under other teachers? The experiments, interspersed with the text, although providing many good suggestions for instructors, might be irritating to a reader using the book for collateral study, and their omission (on the grounds that similar work will be included in any well-designed course) would have allowed, within the same compass, certain sections to be explained in greater detail. For example, the dependence of the conditions for oscillation on valve characteristics is not developed, and there is an interesting method of graphical analysis for a radio-frequency amplifier (Chapter X, Section 13), which might be difficult to understand at a first reading.

Throughout the book, the emphasis is on the internal operation of electronic devices in their various applications, and there are very few applications which are not included, but one would expect some mention of television camera tubes, as the theory of photo- and secondary-emission is dealt with quite fully, and the transitron and Miller integrator, both of which depend on fundamental valve properties.

The development is from the characteristics and uses of diodes, through triodes, tetrodes and pentodes, feedback circuits, oscillators, special functions (differentiators, integrators, reactance valves, mixers, "flip-flops", etc.) to modulation processes, u.h.f. electronics and electronic instruments, with three chapters near the middle of the book on electron emission and the effects of gas in two- and multi-electrode tubes. These chapters are in greater detail than is usually found and the treatment is good, although one may wonder if the average student has sufficient background of pure physics for complete understanding. The forty-four pages on u.h.f. electronics give an up-to-date and adequate account of the progress in this field including the klystron, magnetron and travelling-wave tube.

The appendices contain notes on laboratory procedure and equipment, units, tube data (essential for the solution of many of the problems) and two (Schottky effect, and crystal rectifiers and transistors) which might be better incorporated in the text.

The considerable use of graphical methods of explanation is a valuable feature and the associated diagrams, and circuits, are clearly drawn, but there are some omissions, misprints, and variations as between symbols used in the text and on diagrams.

This is a useful book, probably more so to teachers than students and in this respect not quite successful in fulfilling the aims of the author.

A. W. HARRIS.

Audio Frequency Power Measurements

16 pp., 8 figs. Demy 8vo. Her Majesty's Stationery Office. 1954. Price 1s.

THIS booklet is number 8 in the series of "Notes on Applied Science". The series is produced by the National Physical Laboratory to provide industrialists and technicians with information on various scientific and technical subjects which is not readily available elsewhere. This particular booklet deals with power measurements by means of electrostatic, thermal and electrodynamic wattmeters, over the range 25c/s to 30kc/s, approximately the audio frequency range.

The electrostatic instrument is delicate and has a slow response, but is singularly free from frequency or power factor errors. It has been calculated that there is no significant error in the instrument itself at any frequency less than 1Mc/s. In practice there are errors in the auxiliary resistors which, at present, limit the maximum frequency for accurate measurements to about 30 000c/s.

The accuracy of the thermal wattmeter is dependent on the law of response of the thermo-junctions used and is very much less than that of the electrostatic instrument. It is, however, cheap and its errors are not usually dependent on frequency up to about 30 000c/s, when the quality of the auxiliary resistors may impose a limit.

The electrodynamic wattmeter is robust and has a quick response. It is the most suitable of the three types for general measurements. There is, however, considerable difficulty in maintaining accuracy at the higher frequencies. If, however, feedback amplifiers are used to supply the wattmeter coils it is possible to construct an instrument with the same upper frequency limit (30 000c/s) as the electrostatic and thermal types.

Crystal Rectifiers and Transistors

Edited by M. G. Say. 168 pp. 152 figs. Demy 8vo. George Newnes Ltd. 1954. Price 21s.

THIS book, as explained in its preface, has been made up from information already published or supplied by the several firms now producing semi-conductor devices.

While the average general reader will welcome any book that saves him having to hunt through numerous periodicals and makers' data sheets in order to cover the subject, it must be realized that knowledge is being gained in this field at such a rapid rate that the situation changes even between a piece of development work being completed and its subsequent original publication.

The additional time lapse necessary to republish all the collected information in book form cannot but increase this drawback.

Dr. M. G. Say has collected together an array of facts, manufacturers' data and tables, but he has given very little indication of their relative positions and merit in this new field.

Furthermore, the book brings together much of what has been said in the past, without at the same time giving indication of the present situation or future trends.

Separate chapters are provided on fundamental semi-conductor matters, silicon crystal rectifiers, germanium crystal rectifiers, point contact transistors, junction transistors, transistor testing, photo transistors and applications.

The last chapter, "Applications", is particularly disappointing to circuit designers, crying out for information on the method of selecting transistor operating conditions, on the choice between one type and another, and on the likely spread of characteristics with time, temperature and transistor to transistor. The book confines itself to very generalized statements, and the approach is descriptive rather than analytical.

While the book is certainly useful it could so easily have been much better.

G. GRIMSDELL.

Automatic Digital Computation

National Physical Laboratory. 296 pp. Demy 8vo. Her Majesty's Stationery Office. 1954. Price 21s.

THE International Symposium on Automatic Digital Computation held at the National Physical Laboratory, Teddington, in March, 1953, was the third of its kind in this country. These summarized reports on the discussions are based on notes taken at the time by the various reporters, checked and supplemented by reference to a magnetic tape recording of the proceedings. It has, of course, been necessary to condense the reports of the discussions in order to keep the record to a reasonable size.

Microwave Theory and Techniques

By H. J. Reich, P. F. Ordung, H. L. Krauss and J. G. Skalnik. 878 pp. 150 figs. Demy 8vo. D. van Nostrand Co. Inc., Toronto & New York. Macmillan & Co., London. 1954. Price 75s.

THE branch of engineering which deals with radio frequency energy at centimetre wavelengths is extremely well documented, and in the last eight years a wealth of new material has been published. Even so, "Microwave Theory and Techniques" by Reich, Ordung, Krauss and Skalnik is a welcome addition to the available literature on this subject. Its 900 pages present clearly and logically a comprehensive treatment of the fundamentals of electromagnetic theory underlying electronic engineering at microwave frequencies, together with a competent review of current practice. The book will provide nothing intrinsically new to the established engineer working in this field, but gives the present state of knowledge in such a lucid and complete way that it will certainly be a "jumping-off ground" for new thought and development; to quote the authors' preface, "This book is intended primarily as a textbook for a senior or first-year graduate course in microwaves. It may also be useful to research workers and practising engineers as a reference book."

After an introduction of 30 pages devoted to vector analysis, there are two excellent chapters of electromagnetic fundamentals. There is no novelty in the approach, but the reader is carried "painlessly" through the theory necessary for the understanding of the arguments developed later in the book. The authors, in all their theoretical explanations, have the rare gift of making the relatively complicated seem simple; how often the reverse is the case in technical literature! As a sound academic approach to transmission lines, the third chapter cannot be equalled, and this is followed by a similarly good chapter on impedance matching. The Smith impedance chart is used frequently in these chapters to explain the matching techniques described.

The hundred pages comprising the chapter on "Waveguides" are in some ways a little disappointing. The theoretical explanation of waveguide propagation by the application of boundary conditions to the solutions of Maxwell's equations is well done. The reviewer considers, however, that the physical explanation of this propagation in terms of an analysis of the interference pattern formed by successive reflexions in the waveguide, frequently quoted from Southworth is unnecessary, as is the description of the various hypothetical devices for launching higher order modes, also quoted from the same source. The analysis of the single-wire surface waveguide is carried out well.

In writing the practical chapters, namely those on "Waveguide and coaxial components", "Antennas", "Measurements" and "Microwave resonators" the authors were faced with the dilemma of writing an up-to-date progress report of current developments or of explaining the simple ideas and problems of engineering at centimetre wavelengths. The first course has the obvious danger of obsolescence in a very short time; in the second case, the appeal of the text would be restricted to the student and the newcomer. A fair compromise has been reached by basic descriptions occasionally illustrated with modern practice. There is only the briefest mention of the manufacturing aspect of microwave components and devices; ease of manufacture, and ability to be reproduced accurately are cardinal features of microwave engineering.

The remainder of the book gives a full account of valves for use at centimetre wavelengths as amplifiers and oscillators. In particular, the authors deal with microwave triodes and tetrodes, klystrons, travelling wave tubes and magnetrons. The theory of operation of each type of valve is developed, including the results of analysis of magnetron operation carried out by Hartree's mathematical group, but this theory is purposely of a simplified nature. A number of particular examples of valve are examined, and their characteristics, use, performance and structure described. The valves are of American origin in every case. This section of the book, dealing with valves, is obviously directed more to the student than to the established engineer.

Each chapter is well provided with examples and a comprehensive bibliography, together with references interspersed in the text. The bibliography is particularly useful, since in many cases the authors could only give brief attention to interesting points. An excellent feature is the index of mathematical symbols which appears at the end of the book. All the symbols used in the book are listed together with the page of the text on which each is defined. The typography throughout is of a poor standard, and one feels that more photographs would have been helpful. On the whole, however, "Microwave Theory and Techniques" deals fully and adequately with what has become a very wide subject, and is certainly one of the best books of its kind published to date.

J. W. SUTHERLAND.

Electrical Measuring Instrument Practice

By E. H. W. Banner. 130 pp. 40 figs. Demy 8vo. United Trade Press Ltd. 1954. Price 15s.

BASIC electrical measuring instruments are not exactly the most glamorous equipments in the electrical world. Major Banner has therefore made no attempt in his book to speak of their charms. Instead, he has produced a small book giving a review of present-day practice of both the construction and the use of these instruments. Electronic instruments are not dealt with, except for a few cases of the very simplest type.

The book begins with a chapter giving useful facts on Standards and Specifications for instruments including Inter-Service Specifications. This information, which includes notes on sizes, shapes, and patterns, could prove useful to manufacturers as well as users. This is followed by some information on design points such as dial marking and scale shapes. There are also tables giving the functional analysis of the various types of indicating instruments, and showing the different parameters they could be made to measure when suitable transducers or auxiliary equipments are used.

All the different types of basic movements are described in some detail, followed by a description of special instruments such as power factor and frequency meters. This section forms a useful review of the various instruments on the market. Some information is then given on resistance measurement, but it is regrettable that the work of Evershed is not even mentioned in the bibliography.

The ranges and characteristics of the normal industrial double pivoted instruments are tabulated together with suggested types for various electrical measurements. The alternative approach to this choosing of a certain type for a particular measurement is, of course, the multi-range instrument. These are described, and an attempt is made to show how wide a field these may be made to cover.

The last chapter deals with the type of instrument perhaps best known as "test sets". Here we find descriptions of the type of instruments aimed specifically at a particular range of tests. The instruments themselves are often manufactured by assembling several individual instruments in the same case.

It is unfortunate that once again we have in this book a standard of illustration, particularly the drawings, which is much below that which we would expect to find in a book of this size and price.

J. R. BOUNDY.

A Guide to Amateur Radio

38 pp. Demy 8vo. 6th Edition. Radio Society of Great Britain. 1954. Price 2s. 6d.

THIS edition is completely new and up to date. The guide is intended chiefly for the newcomer to amateur radio who should find within its pages all that he needs to know about learning the morse code, studying for the Amateur Radio Certificate and obtaining an amateur radio licence. There is an extensive section on practical designs of transmitters and receivers.

Radio Laboratory Handbook

By M. G. Scroggie. 436 pp. 299 figs. Demy 8vo. 5th Edition. Iliffe & Sons Ltd. 1954. Price 25s.

THIS reference book on laboratory electronic techniques is intended for both professional engineers and amateurs. It first describes the layout and furnishing of an up-to-date laboratory, and then the various types of apparatus available. Both commercial instruments and improvised equipment are covered. Later chapters deal in detail with methods of making measurements and tests of every kind. Finally, a large section is devoted to general principles and reference material of everyday use to the radio engineer.

Television Simply Explained

By R. W. Hallows. 196 pp. 97 figs. Demy 8vo. 2nd Edition. Chapman & Hall Ltd. 1954. Price 10s. 6d.

THE aim of this book is to explain in simple language to ordinary non-technical people what television is and how it works. The author has a gift of making a difficult scientific subject easy for the ordinary mind by the apt use of analogy and by particularly lucid exposition.

Short News Items

The General Electric Co. Ltd. has been awarded a contract worth two and a half million dollars for extensions to the telephone system of Haiti, in the Caribbean, which for 150 years has been an independent republic. Besides extensions to telephone exchanges in Port-au-Prince and other towns, as a result of which some 3 300 new subscribers will be connected, the contract provides for the building of 500 miles of open wire trunk line routes.

An International Analogy Computation Meeting will be held in Brussels from 27 September to 1 October this year. This is being organized by the Societé Bélge des Ingénieurs des Telecommunications et d'Electronique, the Societé Belge des Electriciens and the Societé Belge des Mecaniciens. The Organizing Committee would like to know, as soon as possible, the names and addresses of those who intend taking part in this meeting as well as the form of participation, i.e., whether they intend submitting a paper, exhibiting equipment or simply attending the various functions. All communications should be addressed to M. P. Germain, Institut de Physique Appliquée, Université Libre de Bruxelles, 50 Avenue Franklin Roosevelt, Brussels.

Borough Polytechnic announce a course of five lectures on the writing of technical reports which will be given by Mr. G. Parr on Thursdays at 6.30 p.m. commencing on 20 January. The fee for the course is £1 1s. The course will cover the preparation of reports, collection of data and practical advice on the submission of papers and publications. Enrolment forms can be obtained from the Secretary, Borough Polytechnic, Borough Road, London, S.E.1.

The University of Liverpool, Department of Extra-Mural Studies, announce, among others, post graduate courses on the following subjects. An Introduction to Servomechanisms, on Tuesdays from 5.30-7 p.m. commencing 18 January. The Design and Analysis of Scientific Experiments, on Wednesdays from 7.30-8 p.m. commencing 12 January. The fee for each course is £2 2s. and enrolment forms may be obtained from the Director of Extra-Mural Studies, 9 Abercromby Square, Liverpool 7.

The Electro-Physiological Technologists' Association will be holding their next general meeting on Saturday, 5 February, at the National Hospital, Queen Square, London, W.C.1. The meeting will consist of papers and demonstrations of particular interest to electro-physiologists. Non members are welcome on application to Mr. G. Johnson, Hon. Secretary, Hurstwood Park Hospital, Haywards Heath, Sussex.

LEO Computers, a wholly-owned subsidiary of J. Lyons & Co., has now been formed, "to carry on the business of manufacturers of and dealers in all forms of electrical or automatic computors and office machinery and automatic control equipment, etc." It was seven years ago that Lyons began their investigation into the possibilities of harnessing electronic computors to everyday commercial office work, and since the beginning of 1954 LEO has been engaged in full-scale clerical work in Lyons offices. The new company will be marketing LEO at around £90 000, but medium-sized companies will also be able to profit from the new electronic office by renting time for individual jobs.

The Independent Television Authority has appointed Mr. P. A. T. Bevan to be its Chief Engineer. Since 1934 he has been a member of the Engineering Division of the BBC and latterly was a senior member of their Planning and Installation Department. He has been associated with most of their major engineering projects, and was one of the pioneer team responsible for developing the technical facilities for starting the BBC's Television Service from Alexandra Palace in 1936, and for its subsequent expansion. Since the war he has been mainly concerned with the development of v.h.f. broadcasting. Mr. Bevan is the author of a number of important papers in the radio and television field and has been awarded the Duddell Premium which is the premier award for radio work given by the Institution of Radio Engineers.

Marconi's Wireless Telegraph Co. Ltd. have recently shipped to Belgium a high power h.f. communication transmitter type HS.51. This transmitter has been manufactured for the Belgian R.T. and T.—the equivalent of the G.P.O.—and is to be installed by Marconi engineers at Ruisselede, Belgium.

BINDING OF VOLUMES

Arrangements for the binding service are being continued this year, and the 1954 volume can be bound at an inclusive charge of £1.

Copies will be bound, complete with index and with advertising pages removed, in a good quality red cloth covered case blocked in gold on the spine.

Home and Overseas readers who wish to have their copies bound are asked to comply with the following instructions :—

(1) Tie the twelve issues (January to December, 1954) securely together before parcelling.

(2) Enclose a remittance for £1 and a gummed label bearing the sender's name and address.

(3) Enclose the copies, remittance and label in a closed parcel and address to :— The Circulation Dept. (E.E. Binding), 28, Essex Street, Strand, London, W.C.2. (No other correspondence is necessary.)

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The following are also available from our Circulation Dept. :—

A limited number of Bound Volumes for 1953 & 1954. Price, Two Guineas, post free.

Binding Cases for twelve issues. Price 5s., postage 6d.

The Index for Volume XXVI (1954) free.

The Third Biennial British Plastics Exhibition will be held at Olympia, London, from 1-11 June this year.

Redifon Ltd. of Wandsworth, are to supply equipment for a complete broadcasting station for Radio National de Peru. The station, which will be sited at Piura, is due to be opened in June.

The Royal Society have made the following awards of medals for 1954. The Copley Medal, Sir Edmund Whittaker. The Rumford Medal, Dr. C. R. Burch. The Royal A Medal, Sir John Cockcroft. The Hughes Medal, M. Rylie.

E. K. Cole Ltd. announce that Mr. A. J. Brunker is relinquishing his position as General Export Manager to become Chief Engineer of the Company. Mr. W. M. York, who as an Executive Director already controls Ekco Publicity and the Heating Division of the Company, will, in addition, now direct the E. K. Cole Ltd. export activities covering radio, television, plastics and cine equipment.

Honeywell Brown Ltd., manufacturers of industrial instrumentation and automatic controls for space heating, ventilating, and air conditioning, have opened an area office in Cardiff. The office is at 95 Exchange Buildings, Mount Stuart Square, Cardiff, and is under the supervision of Mr. L. G. A. Gabe.

Mr. F. H. McCrea has been elected chairman of the Dubilier Condenser Co. Ltd.

Furzehill Laboratories Ltd. have transferred their Head Office, including their Sales, Accounts and Designs Section, to new and more extensive premises at 57 Clarendon Road, Watford, to which all sales and technical inquiries should be addressed in future. The telephone number is Gadebrook 4686.

Silentbloc Ltd., manufacturers of flexible bearings and anti-vibration devices, have vacated their premises in the Notting Hill Gate district of London for a new factory at Crawley. All correspondence should now be addressed to Manor Royal, Crawley, Sussex.

The Directors of Associated Technical Manufacturers Ltd. announce that the Company's name has been changed to Permanoid Ltd.

Meetings this Month

THE BRITISH INSTITUTION OF RADIO ENGINEERS

Date: 26 January. Time: 6.30 p.m.
Held at: The London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1.
Lecture: A Survey of Tuner Designs for Multichannel Television Reception.
By: D. J. Fewings and S. L. Fife.

West Midlands Section

Date: 12 January. Time: 7.15 p m.
Held at: Wolverhampton and Staffordshire Technical College, Wulfruna Street, Wolverhampton.
Lecture: Electronics in Materials Handling.
By: L. Landon Goodman.

North Eastern Section

Date: 12 January Time: 6 p.m.
Held at: Neville Hall, Westgate Road, Newcastle upon Tyne.
Lecture: Some Circuits Associated with Wave Form Monitors.
By: E. T. Warburton.

Merseyside Section

Date: 6 January. Time: 7 p.m.
Held at: The College of Technology, Byrom Street, Liverpool, 3.
Lecture: Some Interesting Applications of Electronics to Photography.
By: D. M. Neale.

North Western Section

Date: 6 January. Time: 7 p.m.
Held at: Reynolds Hall, College of Technology, Sackville Street, Manchester.
Discussion: Problems in the Design and Production of Car Radio.
Opened by: C. L. Caiger.

South Wales Section

Date: 12 January. Time: 6.30 p.m.
Held at: The Glamorgan Technical College, Treforest.
Lecture: Electronic Counting Devices.
By: F. H. Gage.

Scottish Section

Date: 13 January. Time: 7 p.m.
Held at: The Institution of Engineers and Shipbuilders, Elmbank Crescent, Glasgow.
Discussion: Channel III Commercial Television.

THE BRITISH SOUND RECORDING ASSOCIATION

Date: 21 January. Time: 7 p.m.
Held at: The Royal Society of Arts, John Adam Street, London, W.C.2.
Lecture: High Fidelity Reproduction.
By: N. C. Mordaunt.

THE INSTITUTION OF ELECTRICAL ENGINEERS

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

Radio Section

Date: 12 January.
Lecture: Thermionic Valves of Improved Quality for Government and Industrial Purposes.
By: E. G. Rowe and W. W. Wright.
Date: 24 January.
Lecture: Radio Aids to Navigation.
By: F. J. Wylie.

Measurements Section

Date: 18 January.
Discussion: The Human Operator in Closed Loop Control Systems.
Opened by: C. Holt Smith.

Faraday Lecture

Date: 27 January. Time: 6 p.m.
Held at: Central Hall, Westminster, London, S.W.1.
Lecture: Courier to Carrier in Communications.
By: T. B. D. Terroni.
(Admission by ticket obtainable from the Institution.)

North Western Centre

Date: 18 January. Time: 7.30 p.m.
Held at: The Free Trade Hall, Manchester.
Faraday Lecture: Courier to Carrier in Communications.
By: T. B. D. Terroni.

North Western Measurements Group

Date: 25 January. Time: 6.15 p.m.
Held at: The Engineers' Club, Albert Square, Manchester.
Lecture: Current Summations with Current Transformers.

North Western Radio Group

Date: 5 January. Time: 6.45 p.m.
Held at: The Engineers' Club, Albert Square, Manchester.
Lecture: The Experimental Synthesis of Speech.
By: W. Lawrence.

South Midland Centre Radio Group

Date: 24 January. Time: 6 p.m.
Held at: The James Watt Memorial Institute, Great Charles Street, Birmingham.
Lecture: Some Applications of Electronics to Telecommunications.
By: C. E. Calverley.

South Midland Supply and Utilization Group

Date: 10 January. Time: 6 p.m.
Held at: The Imperial Hotel. Birmingham.
Lecture: A Brushless Variable Speed Induction Motor.
By: F. C. Williams.

Rugby Sub Centre

Date: 11 January. Time: 7 p.m.
Held at: The Temple Speech Room. Rugby.
Faraday Lecture: Courier to Carrier in Communications.
By: T. B. D. Terroni.

Southern Centre

Date: 12 January. Time: 6.30 p m.
Held at: The University, Southampton.
Lecture: Mechanical Aspects of Aircraft Generation Equipment.
By: W. R. Hinton.
Date: 21 January. Time: 6.30 p.m.
Held at: R.A.E. Technical College, Farnborough.
Lecture: The Possibilities of a Cross-Channel Power Link between the British and French Supply Systems.
By: D. P. Sayers, M. E. Laborde and F. J. Lane.
Date: 28 January. Time: 6.30 p.m.
Held at: The Technical College, Weymouth.
Lecture: Transistor Circuits.
By: G. B. B. Chaplin.

Oxford District

Date: 12 January. Time: 7 p.m.
Held at: The Demonstration Room, Southern Electricity Board, 37 George Street, Oxford.
Lecture: The Future of Electronics in Industry.
By: E. R. Davies.

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Date: 11 January. Time: 5 p.m.
Held at: The Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2.
Lecture: Electronic Switching and Common Control in Auto Exchanges.
By: T. H. Flowers.

RADIO SOCIETY OF GREAT BRITAIN

Date: 28 January. Time: 6.30 p.m.
Held at: The Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2.
Presidential Address.

TELEVISION SOCIETY

Date: 19 January. Time: 7 p.m.
Held at: The Royal Institution, Albemarle Street, London, W.1.
The Fleming Memorial Lecture: The Perception of Colour.
By: W. D. Wright.

PUBLICATIONS RECEIVED

SILICONE INSULATING COMPOUND is a leaflet describing a non-melting silicone grease for waterproofing and insulating ignition systems and electrical equipment. Midland Silicones Ltd., 19 Upper Brook Street, London, W.1.

FREQUENCY SHIFT KEYING EQUIPMENT FOR RADIO TELE-TYPEWRITER APPLICATIONS is an illustrated brochure covering the Plessey Company's range of telecommunications equipment, produced in collaboration with International Aeradio Ltd. The Plessey Co. Ltd., Ilford, Essex.

DAWE INSTRUMENTS IN INDUSTRY describes how Dawe instruments aid production in various industries. Copies are obtainable free of charge from Dawe Instruments Ltd., 99 Uxbridge Road, London, W.5.

POLISH TECHNICAL ABSTRACTS in English and Russian, the first of which appeared recently, are to be issued quarterly by the Central Institute of Technical and Scientific Documentation, Warsaw.

EVERSHED PROCESS CONTROLLERS MARK 3 and EVERSHED ELECTRONIC PROCESS CONTROL are two brochures produced by Evershed and Vignoles Ltd., Acton Lane Works, Chiswick, London, W.4. They are available free of charge on application.

SELENIUM is a survey published by Her Majesty's Stationery Office for the Department of Scientific and Industrial Research. It reviews the sources, production and uses of this semimetal which has become increasingly important to the electrical industry in recent years. Price 1s. 6d.

THE PSYCHOLOGY OF INVENTION IN THE MATHEMATICAL FIELD by Jacques Hadamard is a book which investigates the role of the unconscious, the relating between intuition and logic, and other aspects of scientific invention. It quotes extensively from letters and writings of more than forty persons. Dover Publications, Inc., 920 Broadway, New York, 10. Price $1.25.

EVERYBODY'S BOOK OF ELECTRICITY by R. Barnard Way is a revised edition of a first introduction to the principles of electricity and a simple explanation of modern electrical appliances and machines. Percival Marshall & Co. Ltd., 19-20 Noel Street, London, W.1. Price 3s. 6d.

RESEARCH DEVELOPMENT ACHIEVEMENT is a pictorial survey of recent activities of the General Electric Company in selected fields of endeavour. The General Electric Co. Ltd., Magnet House, Kingsway, London, W.C.2.

INVENTORIES OF APPARATUS AND MATERIALS FOR TEACHING SCIENCE, VOL. III PART 4 contains information about the organization of the teaching of electricity at the Ecole Supèrieure d'Electricité (France), The Royal Technical College, Stockholm, and in Great Britain. Each subdivision describes the general organization of the school and its teaching programme. Contents of the courses is given in detail, including lists of apparatus, equipment and machines. Unesco, 18 Avenue Kleber, Paris 16. Price 15s. 6d.

ROYCE ELECTRIC BOX TYPE FURNACES is a brochure describing these furnaces which are manufactured in two standard ranges, type RBM which is suitable for heat treatment processes up to a maximum temperature of 1000°C and type RBH for temperatures up to 1250°C. Royce Electric Furnaces Ltd., Sir Richard's Bridge, Walton-on-Thames, Surrey.

PYE SCIENTIFIC INSTRUMENTS is a catalogue which supersedes all previous issues and includes only those instruments in current production W. G. Pye & Co. Ltd., Granta Works, Cambridge.