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Electronic Engineering

Incorporating
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Managing Editor, H. G. Foster, M.Sc., M.I.E.E.

Vol. XXIII JULY 1951 No. 281

In This Issue

Commentary 243
V.H.F. Common Aerial Working 244
By E. G. Hamer, B.Sc., A.M.I.E.E.
Practical Methods of Waveform Analysis ... 250
By J. B. McMillan, M.A., B.Sc.
Electronics in Duplicating 252
By E. G. Gordon.
A Visual Aid for use in Teaching Vector Diagrams 253
By T. Palmer.
A Judgment Box 256
By W. H. Alexander, B.Sc., A.Inst.P.
Receiving Valves suitable for Electrometer Use ... 258
By G. H. Hay, M.Sc.
An Indoor Television Aerial Array 262
By F. E. Wood.
New Zoom Lens for Television 263
Some Aspects of Electrical Computing (Part 2) ... 264
By J. Bell, M.Sc., M.I.E.E.
Cathode Followers as Low-Noise Input Stages ... 270
By M. J. Tucker, B.Sc.
R.F. E.H.T. Unit for 0.5-3kW 271
Auxiliary Circuits for pH Meter 272
By G. P. Burn.
Control of E.H.T. in Television Receivers 273
A Balanced R.C. Oscillator 274
By D. A. Bell, M.I.E.E.
Moisture in Electrometers 275
By R. H. Mapplebeck.
A Versatile Bridge System for use with Wire Resistance Gauges 276
By M. J. Richard, B.Sc.
Notes from the Industry 277
Letters to the Editor 278
Electronic Equipment 280
Book Reviews 282

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Classified Advertisements, Page 1.
Index to ADVERTISERS, Page 46

for Radar, Research and Industrial Applications

The cathode ray tube is now accepted as an essential component in all electronic equipments where it is required to obtain a rapid indication or display of physical phenomena. As such it forms the basis of oscilloscopes, test apparatus, monitors, flaw detectors and numerous other research, industrial and communications equipments. The Mullard range of cathode ray tubes has now been extended to meet all these applications.

TUBES FOR RADAR DISPLAYS.

Of particular importance among this range are the Mullard C.R. Tubes MF31-22 (12-in.) and MF13-1 (5-in.) both of which are designed to meet the continuous operation and arduous conditions of service encountered in marine radar applications. Having long-persistence aluminised fluoride screens, these tubes are suitable for use in P.P.I. systems.

SMALL TUBES FOR INSTRUMENTS

A variety of 1¾-in. and 2¾-in. electrostatic C.R. Tubes with green, blue or persistent screens are also available. These tubes are all characterised by low inter-plate capacitances and are designed for operation with voltages from between 800 and 1,000 volts. These features, coupled with the fact that the tubes are fitted with standard B9G bases and have a seated length of less than 6 ins., make them suitable for use in small, compact oscilloscopes, and in a variety of industrial, communications and research testing and measuring equipments. All these tubes can be obtained in versions suitable for either symmetrical or asymmetrical deflection.

For larger equipments, a high-grade electrostatic 5-in. tube is also available.

Abridged technical details on the tubes for radar displays are listed below. Full data on the complete range of cathode ray tubes is available on request.

Type	Description	Base	Max. Screen Diameter (mm.)	Max. Overall Length (mm.)	V_h (V)	I_h (A)	Va1 max. (V)	Va2 max. (KV)
MF13-1	5″ radar tube with metal-backed magnesium fluoride screen	Octal	127.5	292	6.3	0.3	450	11
MF31-22	12″ radar tube with metal-backed magnesium fluoride screen	B12A	308	471	6.3	0.3	400	11

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Electronic Engineering

Vol. XXIII. JULY 1951 No. 281.

Commentary

THE Joint Engineering Conference which has just been held in London as part of the Festival of Britain celebrations is an excellent example of the close relationships which have existed for many years between the Institutions of Civil, Mechanical and Electrical Engineers.

With the Festival as the background and with its meetings held within a stone's throw of the South Bank, the theme of the Conference was to record, by papers from authors eminent in their particular spheres, "the contribution to the advancement of civilization made by engineers and scientists of this country during the past hundred years" with forecasts of possible future trends.

It is well that these relationships between the Institutions are so harmonious that no hint of rivalry exists as to which of the branches of engineering has made the greatest contribution. Indeed, as Mr. Glanville, the President of the Institution of Civil Engineers stated at the opening ceremony of the Conference, there were in every branch of engineering the three sides, civil, mechanical and electrical to be considered, and that without taking all three into account no balanced view could be attained.

Whether therefore the roads and piped water supplies of the civil engineer have made a greater contribution to the advancement of civilization than the turbine and jet engine of the mechanical engineer or the transformer and telephone of the electrical engineer is not important. What is obvious is that each branch has played its part and that all three are inextricably intermingled.

In tracing the progress from the ever-recurring date of 1851, not among the least interesting developments is the growth of the three Institutions. The oldest of the Institutions, the Civils, was founded some 130 years ago before the industrial revolution was fully under way and was adequate for the engineers of the day. But as the field of engineering expanded and the inventions of such early pioneers as Stephenson and Watt came into fuller use, the new science of mechanical engineering was born, which led to the foundation of the Institution of Mechanical Engineers whose centenary was celebrated a year or two ago. Thus matters stood until 1871 when the Society of Telegraph Engineers was founded (which later became the Institution of Electrical Engineers). But today widening scope and specialization have led to the creation of a host of institutions and learned societies, each catering for the needs of its specialist members, many of whom are not strictly engineers but physicists or mathematicians.

To Colonel Sir Stanley Angwin, K.B.E., Past President of the Institution of Electrical Engineers was left the task of recording the advances made in telecommunications over the past hundred years. It is interesting to recall that the name "telecommunication" was first accepted internationally at the Madrid Conference in 1932 as "any telegraphic or telephonic communication of signs, signals, writing, facsimiles and sounds of any kind, by wire, wireless or any other systems or processes of electric signalling or visual signalling (semaphores)". Accepting this all-embracing definition we may look in retrospect to 1851 when visual signalling and line telegraphy were the only applications in existence at the time. The electric telegraph of Cooke and Wheatstone patented in 1837, was applied exclusively to the railways which had just come into being, but transmission of the spoken word had to wait until Bell's experiments in 1875 and wireless was to follow Maxwell's predictions of electromagnetic wave propogation in 1864 and the experimental work of Hertz in 1887 before a girdle could be thrown round the earth.

From the first telephone exchange in London in 1879 with its eight subscribers there are today in Britain nearly 5¼ million subscribers any one of whom, by merely raising his receiver, may make his choice from the millions of subscribers the world over. What is remarkable is the fact that this enormous structure of modern telephony has been built up with only comparatively minor changes to those fundamental instruments, the transmitter and microphone.

Progress in that most awe-inspiring of all branches of telecommunications, namely television, was recorded by Sir Noel Ashbridge, Past President of the Institution of Electrical Engineers in his paper on "The British Television Service." As in so many other cases, its foundations were laid upon the vigorous research into fundamentals which was such a characteristic of the latter half of the nineteenth century. The several basic principles in wide use today originated from the work of Crookes in 1879 and from the emission-type photo-electric cell of Elster and Geitel in 1889, and mention must be made of Campbell Swinton and his famous letter to "Nature" in 1908 outlining his method of television which has such a remarkable similarity with present day methods.

* * *

The shortage of raw materials, due, among other causes, to the present Defence Programme is already becoming acute and has led the Ministry of Supply to impose a ban on the use of nickel in the manufacture of certain listed articles as from June 22nd.

While the importance of the Radio Industry in the Defence Programme cannot be over-emphasized, the total quantities of the scarcer materials used by the industry is almost infinitesimal compared with the total requirements of industry as a whole.

The thermionic valve is more important at the moment than the nickel plated soda fountain and it seems essential, if the radio industry is to make its full contribution, that an adequate supply of these materials be maintained.

V.H.F. Common Aerial Working

By E. G. Hamer, B.Sc., A.M.I.E.E.*

In many modern v.h.f. installations several transmitters and receivers may be in use simultaneously at the same station.[1] The first problem involved is to avoid mutual interaction between the various pieces of equipment, particularly from the transmitters to the receivers. This interaction may take place in several different ways of which radiation along common power leads, directly through the cabinets, or via the aerials are the most common. In this article only the latter case will be considered, where a receiver with a wanted input signal of the order of microvolts may have also impressed at its input terminals a locally generated unwanted signal of the order of volts. Although the unwanted signal will be of a different frequency, due to its large amplitude the receiver input stages will be unable to completely reject it, and cross modulation or blocking may take place in the early stages of the receiver. It is evident that aerial filters will be required both in the transmitter and receiver aerial feeders to (a) reduce the unwanted signals from the transmitter at the receiver input and (b) to reduce to a lower level the transmitter spurious outputs which may fall near the received frequency.

This is a technical problem inherent in the economic design of the standard equipment, as each transmitter and receiver could incorporate its own filters; but this would be uneconomical when the equipment is used at a simple station where these problems do not arise. The requisite filters and other units would normally be supplied as separate external units; these units differing to cater for the individual problems involved with any particular combinations of equipments.

A second problem occurs at large stations where the cost of the aerials, feeders, and aerial towers or supports form a large proportion of the total cost, and also in cases where sufficient space does not exist for the erection of a multiplicity of aerials. In such cases it is desirable to combine several sets of equipment to use one aerial. The number of aerial filters required may in some cases be reduced if, say, several receivers operate from one aerial. In such cases, the problem of the design of a wideband aerial whose efficiency and polar diagram do not vary with frequency arises. For this reason it is usually desirable to group the equipment into fairly narrow frequency bands, and to use each group of equipment on one aerial.

The aerial layout and equipment grouping depend on the particular operational requirements of the station involved, but in general they may be classified as follows:—

(a) Groups of receivers working from common aerials.

(b) Groups of transmitters working into common aerials.

(c) At a small station or an intermediate relay station a transmitter and a receiver working simultaneously using the same aerial.

In this article it has been assumed that a suitable aerial is available with the requisite bandwidth, and a constant input impedance over the frequency band considered. A similar problem also exists in regard to the input circuits of the receiver, and the output circuits of the transmitter as their impedance will vary with a change of frequency. It is desirable that the addition of filters, particularly branching networks, should not cause a large change of reactance or resistance at the junction point to the equipment otherwise it may be difficult with standard designs of equipment to match the equipment to the feeder.

If a bad mismatch does occur the equipment may be capable of matching to the feeder but the losses will be

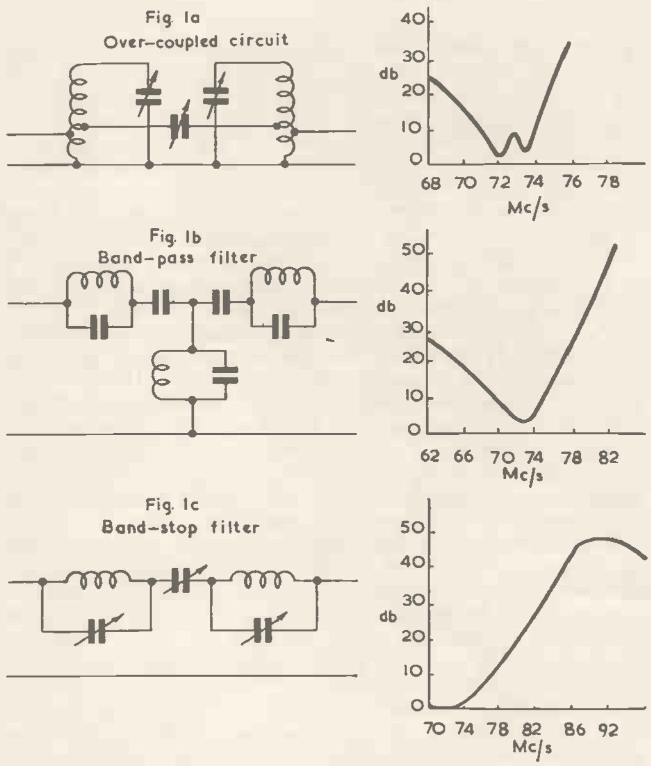


Fig. 1. Receiver aerial filters circuits

increased due to the high standing wave ratio. The filter design should be such that at a stop-band frequency the filter performance should not be effected by the equipment impedance changing from its pure resistive value at the pass frequency.

In all the designs discussed the terminations are assumed to have a constant resistive value over the whole frequency range, and the measurements of insertion loss were made between a signal generator and a test receiver whose output and input impedances were kept at a constant resistive value over the range of frequencies used during the measurements. The input impedance of the receiver was measured and adjusted for the frequencies used by means of a v.h.f. impedance bridge, and the receiver was connected to the equipment under test by means of 100ft of coaxial cable. By using a long length of coaxial cable the test receiver may be kept well away from stray electric fields, hence avoiding spurious pick up; and any small variations of input impedance tend to be swamped by the cable losses.

* *Communication from the Staff of the Research Laboratories of The General Electric Company, Limited, Wembley.*

Receiver Common Aerial Working

Thermally generated noise is the limiting factor in the design of most modern V.H.F. communication receivers and, provided the output impedance of the network feeding the receiver is the same, the amount of thermal noise generated will be the same irrespective of any type of passive network preceding the receiver input circuits. If now, several receivers are connected to a common aerial by means of a passive network, and if no frequency selective network is used, the total received signal power will be divided proportionally to the number of receivers. Any communication channel will hence have a degraded signal-to-noise ratio, as the noise power has remained constant while the signal power has been reduced. To avoid this degradation it is essential that the division into a number of circuits shall take place at some point where the signal-to-noise ratio has been already determined. In this way the signal and noise powers are reduced proportionally and no degradation of service in any one communication channel will take place. Wide separation of the receiver frequencies means that passive frequency selective networks may be used, and in this case the degradation due to the division of signal power does not occur. But with close frequency separation the filter problems are difficult technically, expensive, and pass-band losses are large. Usually a common pre-amplifier followed by a separating network is to be preferred. In this case the total combined signal is applied to each receiver, and the receiver alone is responsible for the selection of the correct communication channel, in fact a similar state of affairs to that obtaining when each receiver has its own aerial. A broad band pre-amplifier should be used before channel-splitting takes place, and a grounded-grid triode stage which has an inherently low noise-factor may be used for this purpose. In the case of high received frequencies, or a very wide band amplifier two low noise-factor amplifier stages may have to be cascaded.

The channel-splitting may be done in several ways, but where a large number of channels is involved, a convenient way is to form a low-pass filter section, with the valve input capacitances as the shunt elements (see Fig. 2). If the shunt capacitance is fixed, and also the cut-off frequency, all other line constants can then be determined (see Appendix I).

In the design of the low-pass filter section it has been assumed that the shunt element consists of the valve input capacitance only; but due to the fact that the grid input impedance has a resistive component, extra resistance will be shunted across the filter. This causes a progressive loss of signal and first-stage noise along the line section and eventually, if sufficient separating sections are in use, the noise due to the separating valve will degrade the signal excessively. Where a small number of separating valves is used (say up to 10), and the filter characteristic impedance is small compared with the resistive component of the valve input impedance, this effect may be neglected. But it is this effect which determines the maximum number of separating valves which may be used with a given pre-amplifier. The larger the pre-amplifier gain the greater may be the number of receivers connected to the separating unit.

The anode load of the final pre-amplifier valve will be the characteristic impedance of the low-pass filter section, and this will determine the stage gain. Sufficient gain must be available to swamp any noise due to the separating valves, even if only a small number is used, and this condition will determine the minimum number of pre-amplifier stages required. If the required bandwidth is not too great the valve anode load may be matched to the low-pass filter input by means of a π coupler circuit. (See Appendix I).

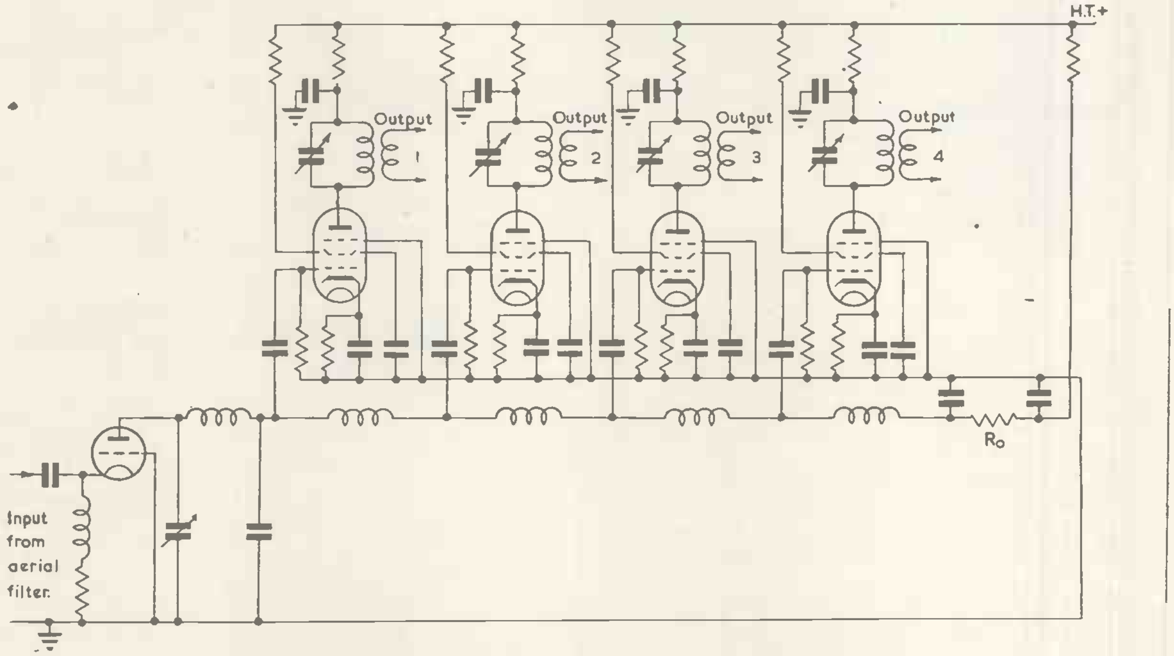


Fig. 2. Circuit diagram of unit for feeding 4 receivers from a common aerial

An additional aerial filter unit may be required to reduce the unwanted inputs to a low level, and several forms of suitable filters are shown in Figs. 1(a), 1(b), 1(c). Usually the received frequencies will be in one band, and the unwanted local transmitted frequencies in another band. The graphs alongside Figs. 1(a), 1(b), 1(c), show the measured performance of typical filters of the type shown, where the wanted pass-band is 70-74Mc/s, and the unwanted stop band 86-90Mc/s.

The choice of type of filter depends upon the pass and stop-band requirements, the over critically-coupled circuit of Fig. 1(a) is suitable when a narrow pass-band is required, and a rapid attenuation outside the pass-band. Fig. 1(b) shows a constant K band-pass filter, where the series elements have been made into a parallel resonant circuit. In the case shown at the pass frequency the element is inductive, but by making the element resonant at a higher wanted stop frequency, the attenuation at the high frequency side of the pass-band increases more rapidly. This type of filter may have one series element resonating below and the other above the pass frequency, thus steepening both sides of the pass-band. When such a filter is designed for a characteristic impedance of 75 ohms a limiting factor is the minimum practical value of the shunt inductance which can be physically obtained with lumped elements. It is this element which determines the minimum pass-bandwidth which can be physically realized.

Fig. 1(c) shows a filter which uses no shunt elements, and

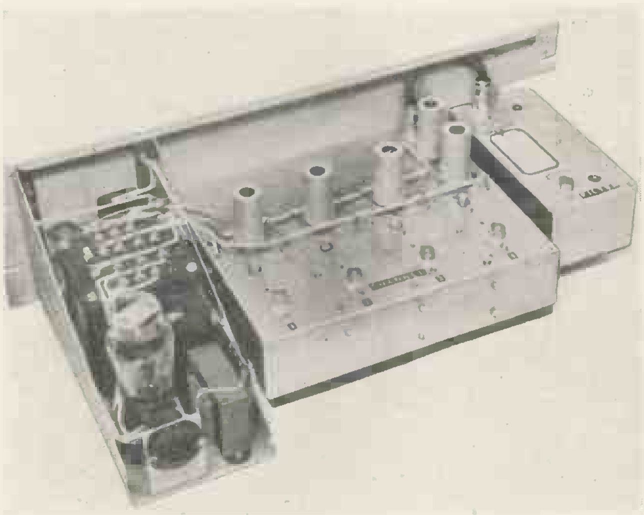


Fig. 3. Unit for working 4 receivers from a common aerial

has a low pass-band loss. The parallel tuned elements are resonated at the wanted stop frequencies which may be chosen sufficiently close together to give a band-stop characteristic. The whole filter then is made series resonant at the pass frequency by means of the centre element. According to whether the pass frequency is below or above the stop frequency the centre element will be a capacitor or an inductor.

The following briefly summarizes the filter characteristics:

(i) Overcoupled Circuits, narrow pass-band;

(ii) Band-Pass Filter, wide pass-band, with resonant elements good stop attenuation;

(iii) Band-Stop Filter, wide pass-band with low loss, narrow stop-band.

Noise power is determined by the input circuits of the pre-amplifier, and any pass-band loss of wanted signal due to the filter will give a decreased signal-to-noise ratio in a communication channel. This could be avoided by incorporating the filter with the low-pass splitting network; and it would also ease the requirements of the filter design due to the much higher characteristic impedance especially in the case of the band-pass filter (Fig. 1(b)). Figs. 2 and 3 show a circuit diagram and photograph of a complete unit consisting of aerial filter and unit for feeding four receivers. The measured noise factors are as follows for the complete splitting unit alone:—

Channel I	Frequency	70Mc/s	Noise	Factor	11db
Channel II	,,	72Mc/s	,,	,,	8db
Channel III	,,	74Mc/s	,,	,,	8db
Channel IV	,,	76Mc/s	,,	,,	11db

If the choke input circuit as shown in Fig. 2 is replaced by a tapped tuned circuit the noise-factor is improved by 2db due to the better matching of the input circuit of the grounded grid stage. The use of a second pre-amplifier would considerably improve the noise factor of the complete unit, and increase the bandwidth, which in the circuit described is limited by the minimum Q of the π coupler circuit. Any increase of bandwith of the circuit described would reduce the power gain of the single pre-amplifier valve, and hence cause much larger noise contributions by the separating valves. The cut-off frequency of the low pass filter is 100Mc/s, and if this were increased to enable the unit to deal with higher frequencies, due to the lower characteristic impedance, the pre-amplifier gain would be reduced, and a second stage would have to be added.

Transmitter Common Aerial Working

When several transmitters are working into the same aerial the factor which principally determines the filter design is the frequency separation of the individual transmitters, and on this basis the following subdivisions are made:—

(a) frequency separations greater than 5 per cent.

(b) frequency separations between 5 and 0.6 per cent.

(c) frequency separations less than 0.6 per cent.

A typical requirement of such filters would be that they should give a minimum stop-band attentuation of 30db, and a maximum pass-band loss of 3db, and present at the aerial junction a high impedance at the stop-band frequency.

If the filter does not present a high impedance at the aerial junction at its stop frequency, a large reactive component of impedance may be present at the output of another transmitter, and cause difficulties in matching its final circuit to the feeder cable.

FREQUENCY SEPARATIONS GREATER THAN 5 PER CENT.

Filters for wide frequency separation may be of several varieties and may consist of lumped elements and have a band-stop characteristic, see Fig. 1(c), or more con-

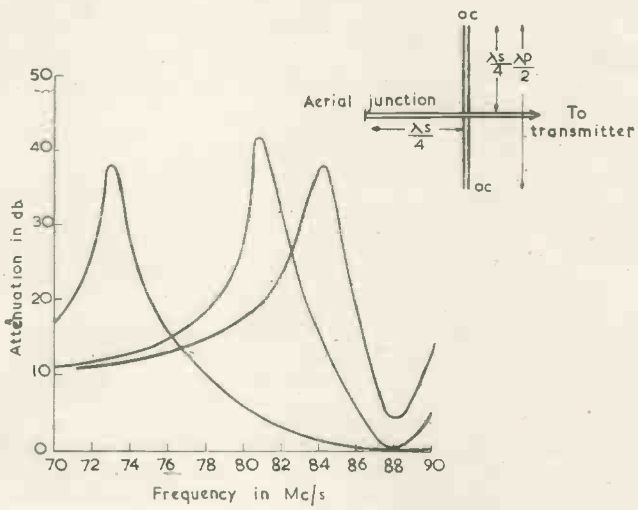


Fig. 4. Measured loss of coaxial filters

veniently be formed by using lengths of coaxial cable. Coaxial cable filters may consist of an open circuited quarter-wave cable, which produces an effective short circuit at the cable junction; this short circuit is transformed to a high impedance at the aerial junction by means of a second quarter wave cable (see Fig. 9). At the wanted pass frequency the quarter wave stub is

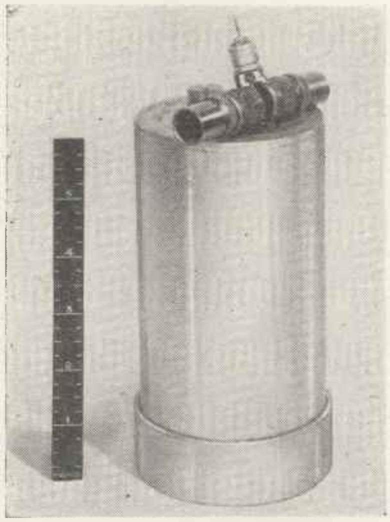
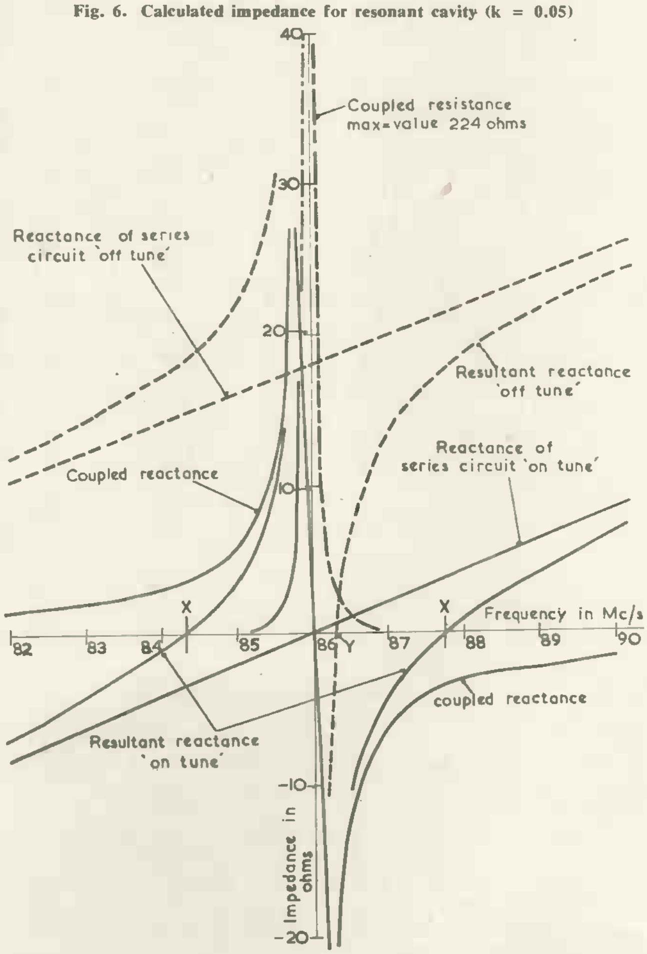


Fig. 5. Top-capacity loaded resonant cavity

resonated by means of a second stub which may be either short circuited or open circuited.

If a short circuited stub is used there will be two stop frequencies, one of which is at zero frequency, and a pass frequency between them, giving in practice a pass frequency below the stop frequency. When an open circuited resonating stub is used the stop frequencies will be above and below the pass frequency which itself is the arithmetic mean

Fig. 6. Calculated impedance for resonant cavity (k = 0.05)



of the two stop frequencies. For reasons of economy short circuited resonating stubs would be used for pass below stop frequency, and open circuited stubs for pass above stop frequency. Several such filter units may be cascaded to form a band-stop section, or alternatively the filter may be designed originally to have a band-stop characteristic.

Fig. 4 shows measurements made on typical coaxial cable-type filters, and it will be seen that as the pass and stop frequencies are brought closer together, the stop-band attenuation remains constant, while the pass-band attenuation increases. For a given pass-band attenuation this limits the minimum separation of the frequencies, and with the types of cable used in the frequency range 70-90Mc/s, the minimum separation for a 3db pass attenuation is 5 per cent.

This rise of pass-band attenuation, and also the maximum stop-band attenuation obtainable are due to the losses in the coaxial cable sections. In the ideal case the resonant stub would present an infinite impedance across the feeder at the pass frequency. Due to the losses, however, a finite resistance is shunted across the feeder, and the closer the pass to the stop frequency the smaller the resistance shunted across the feeder. It is this effect which gives a minimum frequency separation for a given pass-band loss. For the same reason the quarter-wave open circuited stub does not present a zero impedance at the cable junction with the feeder, and the stop attenuation is restricted to a finite value. The stop attenuation depends only on the

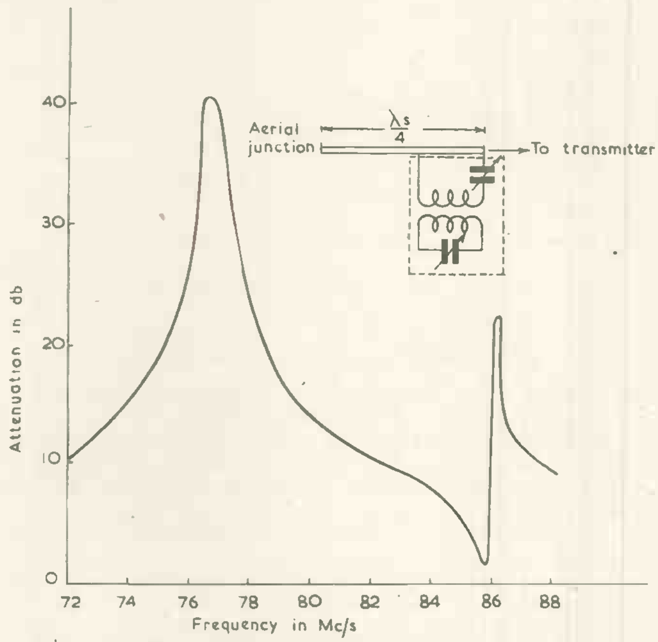


Fig. 7. Measured attenuation of coupled high Q circuit, with series circuit off-tune

losses in the quarter-wave stub, and does not depend upon the separation of the pass and stop frequencies. Due to these effects the transformed impedance at the aerial junction is not infinite, but in all cases is still very large compared to the characteristic impedance of the cable, and its effect is negligible and will not effect any of the other branch arms of the complete filter network.

FREQUENCY SEPARATIONS BETWEEN 5 PER CENT AND 0.6 PER CENT.

If in the coaxial cable filters discussed the stub elements are replaced by a high Q resonant circuit, a much smaller frequency separation may be used for a given pass-band loss. Fig. 5 shows a photograph of a circuit of the type used, it consists of a short circuited length of coaxial line with the open circuited end loaded by a capacitor, enabling the physical size of the circuit to be reduced to reasonable dimensions. The circuit is coupled to the line by means of a coupling loop which itself forms part of a series tuned circuit shunting the line. (Fig. C Appendix II). By making the coupling loop itself a series-tuned circuit the separation between pass and stop frequencies may be reduced. Fig. 6 shows graphically the calculated coupled impedance due to the cavity as the frequency varies. At the resonant frequency for a high Q circuit all other effects are swamped by the coupled resistance component; but off resonance the coupled reactance is the determining factor. The effect of the series-tuned circuit is to cause the total reactance to become zero at two discreet points either side of resonance points X on Fig. 6. If the series loop is off-tuned a sufficient amount one zero reactance point can

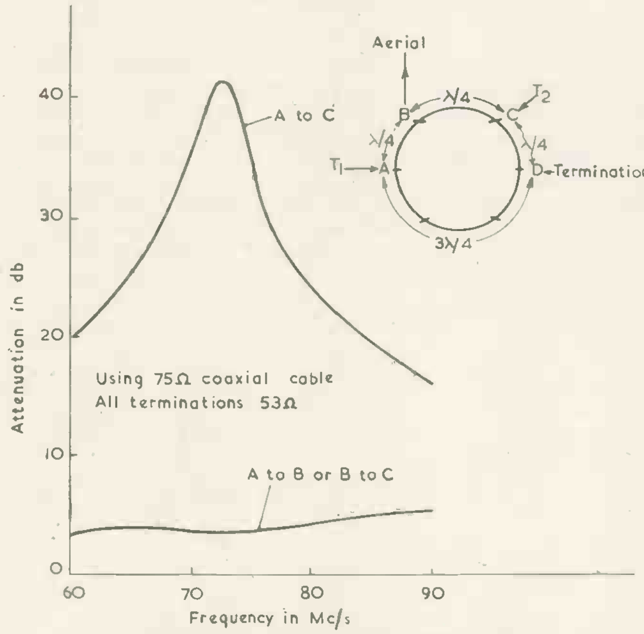


Fig. 8. Measured attenuation of coaxial ring hybrid

be brought much closer to the resonant pass frequency, point Y on Fig. 6. This effect is shown by the dotted curves in Fig. 6, and Fig. 7 shows the measured attenuation with frequency for a combination of such a circuit and a quarter-wave coaxial cable. From the curves of Fig. 6 it is also seen that the minimum coupling is determined by the Q of the coupled circuit and the permissible pass-band attenuation.

As the coupling is reduced the zero reactance points are brought closer to the resonant frequency, and by adjustment of the coupling and the series loop two separate stop frequencies could be provided. It would appear at first sight that an increase in Q value would have little effect, as the reactance curve away from resonance is only effected to a second order by changes of Q value; but for a given coupled resistance at resonance, a higher Q value means a lower coefficient of coupling. This reduced coefficient of coupling reduces the coupled reactance in proportion and enables the zero reactance frequencies to be brought closer to the resonant frequency. It will also be seen that the limit the zero reactance point Y may be moved towards the resonance point is determined by the coupled resistance component, as eventually, if point Y is moved too far towards resonance, it will be completely swamped by the coupled resistance.

FREQUENCY SEPARATIONS OF LESS THAN 0.6 PER CENT.

With very small frequency separations the design of a suitable filter becomes complex, and the filter itself elaborate. The pass-band loss would probably exceed 3db and in such cases a non-frequency selective network is more attractive. For these close frequency separations a coaxial ring hybrid branching circuit (see Fig. 8) may be used, although the minimum pass-band loss will be 3db.

The hybrid ring circuit may be used as a branching network whereby several sources may feed a common output, or it may be used as a frequency selective 4-terminal network. If it is used as a filter network, and all elements are reactive its pass-band attenuation will be small. It is only when the hybrid is used as a branching circuit that its minimum pass-band loss is 3db, due to the losses in the resistive terminations. In certain cases where the aerials have both to be fed from the two transmitters the energy usually dissipated in the termination may be usefully used; but one transmitter will feed both aerials in phase, while the other transmitter will feed the aerials in anti-phase.[5] Fig. 8 shows the measured performance of a typical coaxial hybrid or, as it is sometimes known, "Rat Race" formed from coaxial cable. The hybrid is seen to be a wideband device, and it can be extended to more than two transmitters In this case the pass-band loss will increase as the number of input terminals is increased. A simplified theoretical treatment of the hybrid is given in Appendix III.

Common Aerial Duplex Working

When a transmitter and receiver are working duplex the frequency separation is usually large, and for this application filters formed from coaxial cables may be used. The amount of attenuation required depends upon the individual designs of the units in respect of spurious out-

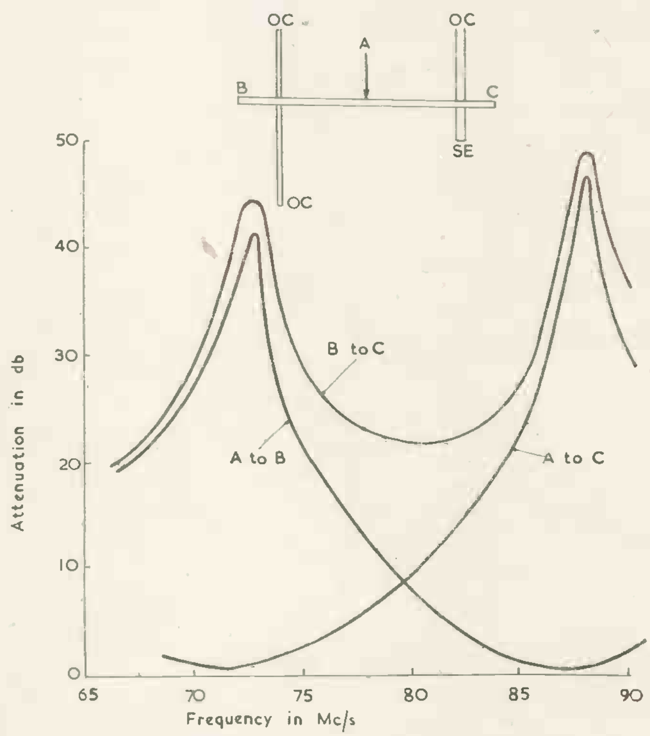


Fig. 9. Measured performance of branching filter

puts and responses. If, say, a 40db attenuation at the transmit and receive frequencies, and a general attenuation of at least 20db in the rest of the band is sufficient, two coaxial cables combined as a branching filter would be sufficient, as shown in Fig. 9, where B would be connected to the receiver or transmitter, and C to the transmitter or receiver respectively, and A to the aerial. This figure also shows the measured performance of a typical branching filter, each arm being formed from a single section coaxial cable filter. In certain applications where high powered transmitters are in use the attenuation in the receiver arm at the transmitter frequency may have to be greater than 40db; in this case a double section coaxial cable may be used, and the stop frequency attenuation will be increased to 80db.

Conclusions

For most passive filter requirements a unit formed from lengths of coaxial cable would be satisfactory. In the event of frequency spacings less than 5 per cent resonant cavities, or a hybrid ring branching filter would have to be used. The hybrid ring branching filter would not be suitable for connecting more than two equipments due to the large pass-band loss, except in special cases where multiple aerials are in use for other reasons. Where several receivers are to be connected to a common aerial a pre-amplifier with a low noise-factor should be used. The number of stages of pre-amplification depends mainly on the total bandwidth to be received, and to a smaller extent on the number of receivers being connected to the common aerial. If only two receivers with a wide frequency spacing are in use a coaxial cable type frequency selective filter could be used more economically. This type of filter would be suitable in the majority of cases where duplex working with a common aerial is required.

In general with these types of simple filters the stop-band loss is of the order of 40-45db, and the maximum pass-band loss 3db; although in favourable circumstances the pass-band loss will be less than 3db.

Appendix I

LOW PASS FILTER

$R_o = \sqrt{L/C}$

$L = R_o/\pi f_c$

$C = 1/\pi f_c R_o$

$f_c = 1/\pi\sqrt{LC}$

If C = 10pF and f_c = 100Mc/s

Then R_o = 320 ohms and $L = 1.2\mu$H

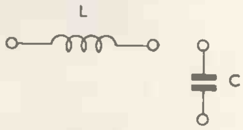


Fig. A

"π" COUPLER

See Ref. (2) and (3) where

R_o = characteristic impedance of low-pass section.

X_a = Output capacitance of pre-amplifier valve.

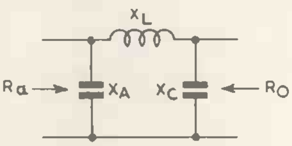


Fig. B

$$X_A = -R_a X_L/R_a \pm \sqrt{(R_a R_o - X_L^2)}$$
$$X_c = -R_o X_L/R_o \pm \sqrt{(R_a R_o - X_L^2)}$$

Appendix II

Suffix L for loop

Suffix C for cavity

Coupled impedance due to cavity = $(\omega M)^2/Z_c$

Total Primary Impedance $Z_p = R_L + j\omega L_L + 1/j\omega C_L + (\omega M)^2/R_c + j\omega L_c + 1/j\omega C_c$

If k = coupling Coefficient = $M/\sqrt{L_L L_c}$

and at resonance $j\omega L_L + 1/j\omega C_L = 0$

$j\omega L_c + 1/j\omega C_c = 0$

$Z_{po} = R_L + \omega^2 k^2 L_L L_c/R_c$

$Z_{po} \approx \omega^2 k^2 L_L L_c/R_c$

$\therefore Z_{po} \propto k^2/R_c$

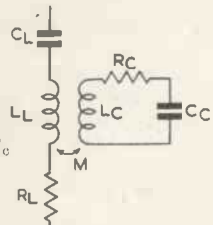


Fig. C

For cavity and loop shown at 86Mc/s

ωL_c = 24 ohms $= -1/\omega C_c$ and if Q = 1,000 R_c = 0.024 ohm

ωL_L = 92.5 ohms = $-1/\omega C_L$ and if Q = 100 R_L = 1 ohm

Total primary impedance may be evaluated for other frequencies, and for values where series coupling loop and cavity do not resonate at the same frequency, and results for k = 0.05 are shown in Fig. 6.

Appendix III

I_s is the input at A due to Input I

I_n is the output at C due to Input I

If the hybrid is formed into a symmetrical circuit a simple analysis may be applied[4] when:

$$I_s = 1/2[I_{sc} + I_{oc}] \text{ and } I_R = 1/2[I_{sc} - I_{oc}]$$

where I_{sc} is input current when all centre connecting leads (shown dotted in Fig. D) are short circuited together, and I_{oc} is input current when all centre connecting leads are open circuited, and considering one-half of the network only.

If R_o = characteristic impedance of cable, and

$$R_1 = R_2 = R_o\sqrt{2}$$

To determine I_{sc},

Input impedance due to $\lambda/4$ cable is ∞

Input impedance due to $\lambda/2$ cable is $R_o/\sqrt{2}$

$$\therefore I_{sc} = E\sqrt{2}/R_o$$

To determine I_{oc},

Input impedance due to $\lambda/4$ cable is $R_o/\sqrt{2}$

Input impedance due to $\lambda/2$ cable is ∞

$$\therefore I_{oc} = E\sqrt{2}/R_o$$

Hence $I_{sc} = I_{oc} = E\sqrt{2}/R_o$.

$\therefore I_R = 0$ and attenuation from A to C is infinite

$$I_s = E\sqrt{2}/R_o$$

Input impedance at A and C is $R_o/\sqrt{2}$

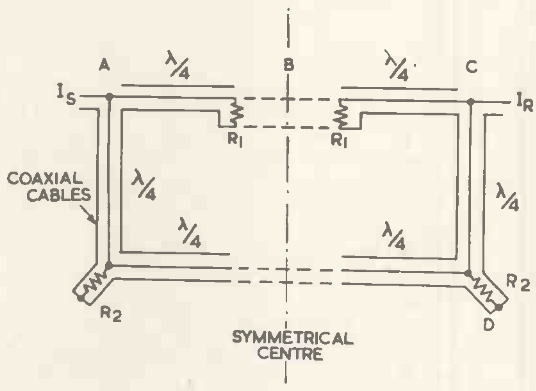


Fig. D

In an actual filter the two R_1 resistances are combined to give a value of $R_1/2$ and this is actually the termination of the aerial feeder; there is no physical resistance $R_1/2$.

Resistances R_2 are combined to form a common resistance $R_2/2$ at point D, and this is a terminating resistance. When two transmitters are combined by such a filter unit the resistance $R_2/2$ at D must be capable of dissipating half the total transmitter power, unless two separate aerials are being fed.

Other values of R_1 and R_2 may be used, and in general the product of $R_1/2$ and $R_2/2$ must be equal to $R_o^2/2$, hence the ring may also be used as a matching network by the choice of a suitable coaxial cable.

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Practical Methods of Waveform Analysis

By J. B. McMillan, M.A., B.Sc.

Wave Analyser Type 705

THERE are two different forms of wave analysers in common use for the determination of the amplitudes and frequencies of the components in a complex signal.

In the first method, to be discussed briefly, the signal is applied to an audio-frequency amplifier, which is made frequency selective by the use of a circuit employing, say, a parallel-T network of the form shown in Fig. 1. If a signal containing a component of frequency f_o is applied to the input terminals of this network and the condition

$$f_o = \frac{1}{2\pi RC}$$

is fulfilled, there will be zero output from the network for the frequency f_o, while components of other frequencies will develop a signal across the output terminals. When this circuit is used as the negative feedback circuit in an amplifier no feedback occurs at frequency f_o with resulting maximum gain, while negative feedback occurs at the other component frequencies in the input signal causing considerably decreased gain at these frequencies. Application of this principle is found in the A.F. Analyzer, Type 1401, marketed by Messrs. Dawe Instruments, Ltd. In this analyser, the parallel-T network is the feedback chain from output to input of a three stage direct coupled amplifier, the output of which is applied to a valve voltmeter with an approximately logarithmic scale. The resistance elements R are variable, controlled by a large dial directly calibrated in frequency, while the capacitors are switched to give a frequency coverage of 25 to 8000c/s in five ranges. The parallel-T network provides constant percentage selectivity at all frequencies of 3db attenuation at about 1 per cent off the frequency to which the analyser is tuned. This type of instrument is used mainly for analysis with sound level meters, vibration meters, etc.

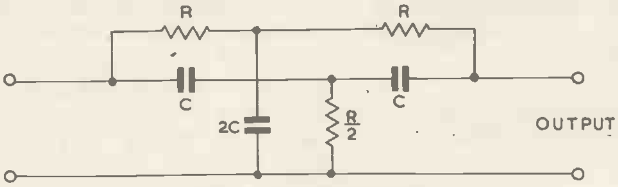


Fig. 1. Parallel-T network

Where more precise measurement is required the second method of analysis is usually employed. The input signal is heterodyned in a balanced modulator by a variable-frequency local oscillator to produce from the component to be measured an intermediate-frequency signal which is passed to a highly selective I.F. amplifier; the output of this amplifier is measured by a valve voltmeter. The accuracy of such an instrument is dependent upon the careful design of the local oscillator to produce low distortion, good frequency stability and constant amplitude, and of the balanced modulator to suppress spurious cross-modulation products. An instrument of this type covers the whole audio-frequency range without switching and, by deriving the selectivity from a fixed-tuned I.F. amplifier, gives a constant bandwidth of a few cycles per second at all frequencies under measurement. An instrument incorporating the above features is Messrs. Dawe Instruments' Wave Analyser, Type 705, of which a functional diagram is shown in Fig. 2.

The local oscillator in this instrument is of the resistance-capacity tuned type. Automatic amplitude control is employed to ensure that the amplitude of oscillation is constant as the frequency is varied and that the maintaining amplifier is operated well within its linear range where the distortion is extremely low. The capacitors in the frequency selective circuit are variable giving a range of frequencies from 20kc/s to 36kc/s to produce a difference intermediate-frequency of 20kc/s with an input signal range of 0-16kc/s. For frequency stability reasons, wire-wound resistors are used in the frequency control circuit and the oscillator derives its H.T. from a stabilized power supply. Constancy of output amplitude is obtained by the use of a special lamp in the cathode circuit. This gives automatic control of gain as the output voltage tends to change by virtue of the change of resistance of the lamp as the alternating current through its changes. The output of the oscillator is applied to the paralleled cathodes of the pentodes in the balanced modulator circuit.

The input signal to be analysed, after passing through the meter multiplier switching arrangements, is applied to the control grid of a single valve phase-splitter with equal anode and cathode loads. The push-pull output obtained is then applied to the grids of the two valves in the balanced modulator. If the frequency of the component of the input signal whose amplitude is to be determined is

f_s, the local oscillator should be tuned to 20kc/s + f_s. Signals of frequencies 20kc/s and 20kc/s + $2f_s$ only should appear in the output transformer of the modulator with no trace of the carrier frequency, 20kc/s + f_s, provided the circuit is perfectly balanced. In the instrument under present discussion the reactive and resistive balancing is arranged by means of a differential variable capacitor and a potentiometer chain across the primary of the modulator output transformer. Before operation, the local oscillator signal is reduced to a minimum by these controls, otherwise this signal will introduce errors when measurements are made at low frequencies. Spurious cross-modulation products are at least 65db below the maximum input signal present and hum components at least 75db below the maximum permissible signal on any of the four meter multiplier settings.

In the Wave Analyser, Type 705, the output of the balanced modulator is applied to the meter sensitivity attenuator and switch and then through one stage of amplification to the selective amplifier.

In heterodyne-type wave analysers two main methods are used to obtain selectivity in the amplifiers following the modulator. One consists of a crystal filter followed by tuned stages of amplification: the intermediate frequency used is usually 50kc/s or 100kc/s with this type and the selectivity curve resulting has a flat top of about 4c/s width, while the response is down 25db at about 10c/s off resonance. A second method, used in the Type 705 Analyser, employs resonant circuits with positive and negative feedback arranged to give the required high selectivity. Four similar stages of amplification are employed, each stage consisting of a two-valve amplifier; the circuit diagram of one of these stages is shown in Fig. 3. It is seen that a tuned circuit resonant to 20kc/s is provided in each stage of amplification: to ensure stability of the resonant circuits toroidal inductances and high-capacity silver-mica capacitors are used. Three feedback circuits are provided from the output of the second valve of each stage. The first is a fixed negative feedback path through R_2 and R_3; the feedback through this path stabilizes the gain of each stage. The second is also a negative feedback path from R_1 via R_4, R_5, R_6, R_7 and R_3, while the third is a positive feedback path from R_1 to the grid of V_1 and to earth through the resonant circuit. It is arranged that at the resonant frequency of the tuned circuit the amount of positive feedback is balanced by the negative feedback. At frequencies off resonance, the impedance of the tuned circuit is decreased and hence the amount of positive feedback at these frequencies is less, while the amount of negative feedback remains unaffected. With the negative feedback thus predominating the gain of the stage at these frequencies is much less than at the resonant frequency. This reduction in gain is additional to that due to the normal selectivity of the resonant circuit and hence a very high effective Q for the amplifying stage can be obtained. The effective Q depends on the amount of feedback and is controlled by R_1, which is ganged to the corresponding potentiometers in the other three stages. R_5 is a preset resistance in each stage while R_6 is one section of a four-gang variable: R_5, etc., are adjusted in the initial setting-up to give minimum change of gain when the bandwidth control, R_1, etc., is altered. R_6, etc., is a panel control to compensate for small changes in the amplifier gain which may arise when the selectivity is changed. With the bandwidth control at the maximum selectivity, the attenuation for the four stages is 3db at 3c/s off resonance, 10db at 9.5c/s, 40db at 35c/s and and 60db at 65c/s, which gives selectivity comparable to the crystal filter amplifier already mentioned. At minimum selectivity the attenuation is 3db at 20c/s off resonance, 10db at 50c/s, 40db at 180c/s and 60db at 320c/s. Thus a bandwidth variable by a ratio of approximately six to one is obtained. At low frequencies maximum selectivity is usually necessary, but for frequencies above 500c/s a lower selectivity is often sufficient and this simplifies considerably the tuning of the required component. The lower values of selectivity are also desirable where there are slight variations in frequency of the input signal.

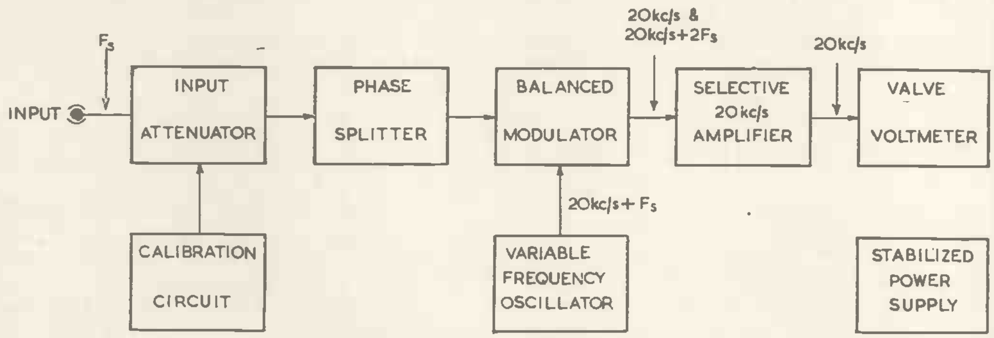


Fig. 2. Functional diagram of Wave Analyser

The output of the selective amplifier is indicated by the linear voltmeter. The valve voltmeter circuit is arranged to limit on large inputs so that the indicating meter, a 0-1mA meter, will not be damaged by occasional overloads.

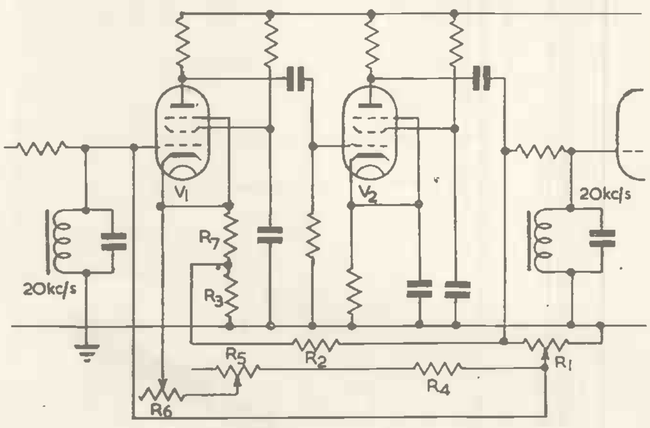


Fig. 3. Amplifier stage of Wave Analyser

The operation of the analyser is extremely simple. The main tuning control, which controls the capacity elements in the frequency selective circuit of the R.C. oscillator is calibrated directly in input signal frequency. There is also a fine tuning control, which is normally set at zero, when tuning, but is useful for final adjustment to the input frequency. Other controls on the main panel are the meter multiplier switch, the meter sensitivity switch, the bandwidth control and the negative feedback control.

Controls required for initial balancing and setting up are located on a recessed panel below the main tuning dial. To analyse a signal of known frequency for harmonics, this signal is applied to the input terminals with the instrument controls set at minimum sensitivity. The main tuning dial is set to the fundamental frequency of the input signal and the meter switches adjusted to obtain a meter reading. The instrument is then tuned to give maximum meter reading and the voltage read. The main tuning dial is now tuned to twice the fundamental frequency and the meter sensitivity increased to obtain a reading. Again a maximum reading is tuned and the voltage read. This procedure is repeated for the third and higher harmonics. To analyse an unknown complex waveform, the meter and the bandwidth control switches are set to maximum and the main tuning dial rotated through the entire range until a reading is obtained; it may be necessary to adjust the meter switches to obtain this reading. Once it is obtained, the instrument is tuned for a maximum and the voltage read. By increasing the sensitivity and tuning through the range, it is possible to select and measure other components; care must be taken not to overload the meter when tuning through the components of large amplitude already measured. When the component frequencies are close together, it may be necessary to make further tests with increased selectivity.

The frequency range of the instrument is 50 to 16,000c/s with an accuracy of ± 3 per cent. There are four input ranges of 0.5, 5, 50 and 500 volts maximum while the meter sensitivity switch gives nine voltmeter ranges of 500, 250, 100, 50, 25, 10, 5, 2.5 and 1, giving a total of 36 full scale ranges from 1mV to 500V. The accuracy on voltage measurements is within ± 5 per cent provided adjacent component voltages are attenuated by at least 10db below the voltage being measured. The input impedance of the Analyser on all ranges is 200,000 ohms.

Electronics in Duplicating

By E. G. Gordon

FOR many years electronic devices have been playing an increasing part in commercial printing; now, both here and in America, they are entering into mimeographing.

Extremely good plastic stencils may be cut electronically by a machine—the Stenafax—recently introduced by the Times Facsimile Corporation, of New York.

Compact and simple to operate, the only visible moving parts of the machine are two cylinders mounted on a common shaft. Copy to be duplicated is wrapped around one cylinder, and a vinyl plastic stencil is attached to the receiving drum.

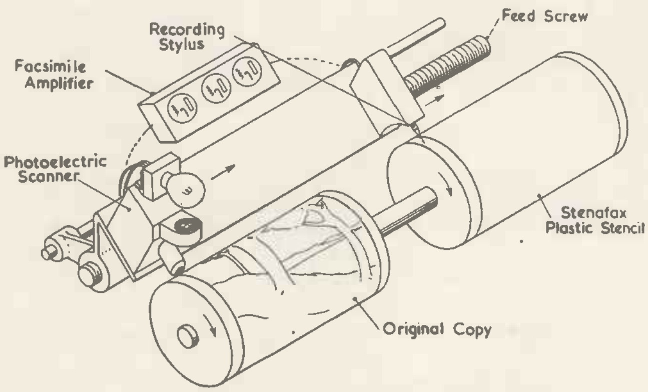
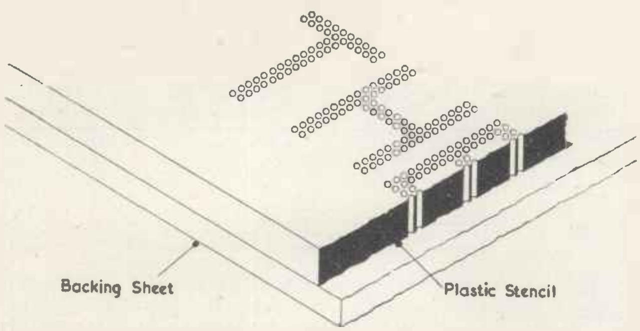


Fig. 1 (above). Stenafax Stencil Cutter

Fig. 2 (below). Cross section of stencil



A photo-electric scanner, mounted on a carriage, scans the original copy as it moves on the cylinder; and a recording stylus, on the same carriage, punches minute holes in the stencil when the scanner "sees" black and sends electrical impulses, which are subsequently amplified, to the circuit activating the stylus.

The carriage is on a feed-screw, and the entire transmission takes only six minutes. Over 10,000 copies, it is claimed, can be produced from these stencils, which are used in the ordinary manner.

In this country, Messrs. Roneo Ltd., are now operating an electronic stencil-cutting service. The stencils, which are of metallized tissue paper, can faithfully reproduce graduations in light and shade. They can be made directly from original photographs or drawings. No intermediate process is necessary.

Fig. 3. Typical reproduction by electronic duplicating

Roneo Ltd. employ similar principles to those embodied in the Stenafax to cut their stencils. However, for the actual cutting an electric arc is used instead of a stylus. The arc varies in intensity, burning away the metallizing of the paper according to the impulses received from the scanner.

Whereas by using ordinary methods the subjects suitable for reproduction by stencils are somewhat limited, by using the electronically cut variety, facsimiles can be made of a very wide range of copy indeed. Advertisements, layouts, engineering drawings, music, letters (manuscript, printed or typewritten), business forms, newspaper clippings, photographs, graphs, etc., present no difficulty.

A Visual Aid
for use in teaching
Vector Diagrams

By T. Palmer *

FOR some students, vector diagrams, as drawn in A.C. theory, tend to have an air of unreality. They are drawn glibly, as aids in finding solutions to problems, and the agreement between these solutions and the answers at the back of the book may "sell" vector diagrams to a student, who, nevertheless, while happily going through the motions of drawing them, remains unconvinced that they do in fact represent relationships between voltages and currents in A.C. circuits. In particular, some students tend to forget the rotation of the vectors.

The writer has tried to develop a visual aid to make the concept of vector diagrams more vivid and accurate than some of the impressions created by his blackboard diagrams. The help this visual aid can give the teacher varies inversely with the standard of his blackboard work, but the device is a complement to, rather than a substitute for, the usual blackboard exposition.

The visual part of the aid inevitably, in these days, takes the form of a cathode ray tube. Let us consider a simple circuit consisting of a variable resistance and a capacitor in series. The problem is to make something which to the students is simply a box connected to the cathode ray tube, on the screen of which it draws the vector diagram for this simple circuit. The circuit of the contents of this box is given in Fig. 3. The box is to have three sockets, *S*1, *S*2 and *S*3: *S*1 for the applied voltage, *S*2 for the voltage across the resistance and *S*3 for that across the capacitor. The vector diagram is to rotate in the conventional counter clockwise direction. As it slowly rotates, and as the resistance is varied, the spokes representing the voltages across the capacitor and across the resistance must change in magnitude and in angular displacement from that of the applied voltage. Since the vector diagram as drawn on the blackboard, or anywhere else, represents a rotating diagram which has been momentarily arrested, our box should contain a switch to enable us to stop the rotation. Switch *SW*1 in Fig. 3 performs this function. Finally there should be some method of identifying the spokes on the cathode ray tube.

Let us first consider the stationary pattern. The essential part of the circuit, *V*4 and *V*5 in Fig. 3, could perhaps be described as a quiescent circular time-base. It is similar to the Watson Watt, Herd and Bainbridge-Bell circular time base described in "The Cathode Ray Tube in Radio Research," published by H.M. Stationery Office. The necessary quadrature voltages are developed by *C*8, *VR*1, *C*9 and *VR*2 from the 6.3 volt winding on the mains transformer, *T*4. (This winding is also connected to the heaters of all the valves.) *R*11 and *C*7 form a simple harmonic filter as suggested by Hilary Moss, Ph.D., A.M.I.E.E., in his article 'Cathode-Ray Tube Traces, Part III," which appeared in the October, 1945, issue of ELECTRONIC ENGINEERING. Godeck's radial time-base, as described on p. 76 of Puckle's "Time Bases," could also have been used; his method of developing the quadrature voltages was preferred to that of Watson Watt in view of its economy in transformers.

Normally *V*4 and *V*5 are cut off by the voltage drop across *VR*7. In this condition the circle degenerates into a spot at the centre of the screen. It can be seen that the cathodes of *V*4 and *V*5 are positive to the negative H.T. rail, while the grids are taken down to this rail by *R*12, *R*13 and *R*16.

For three short periods during each cycle a positive pulse is developed across *R*16, from *R*10, which is in the common cathode circuit of the pulse-generator valves *V*1, *V*2 and *V*3. During these three pulses, the spot is radially deflected, as shown in Fig. 1. In Fig. 1 (i) the spokes are expanded laterally so that arrows may be inserted to show the direction of motion of the spot.

In the pulse generators it will be seen that the grids of *V*1A, *V*2A and *V*3A are taken down to the cathodes by

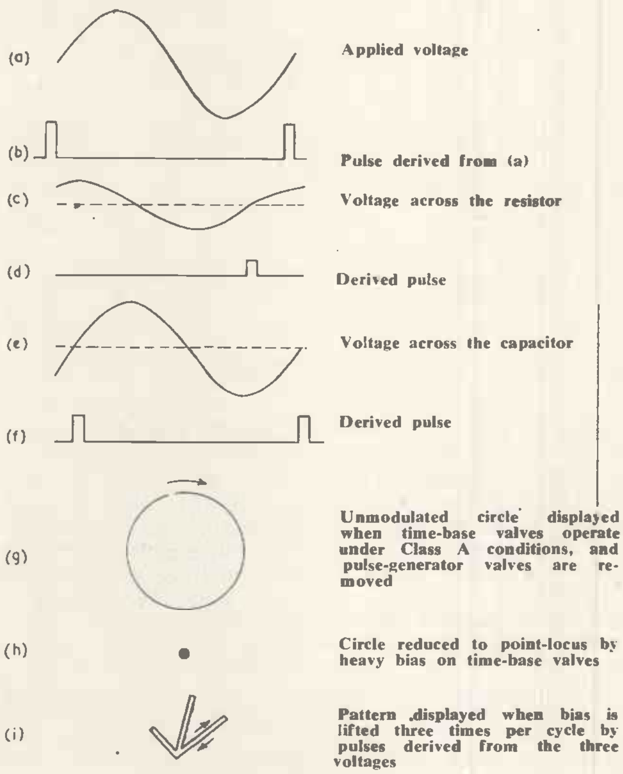


Fig. 1. Derivation of vectors on C.R.T.

*R*1, *R*2 and *R*3, so that there is no standing bias. For satisfactory operation the sinusoidal voltages applied to *S*1, *S*2 and *S*3 should be large compared with the grid base of these valves. To prevent excessive grid current during positive half cycles, the rectifiers *MR*1, *MR*2 and *MR*3 are used. Fig. 2 (b) shows the wave-form of the voltages applied to the grids of the pulse-generators and Fig. 2 (c) shows the wave form of the anode current. The wave form of the voltage developed by this current flowing through an anode load would be the same shape (except for inversion) if it were not for inter-electrode and stray capacitances. The effect of these is well explained in Section 12 Chap. II of "Principles of Radar," second edition, by the Radar School of the Massachusetts Insti-

* *Acton Technical College.*

tute of Technology. In the present application, it is intended to differentiate the waveform to produce short positive pulses. The amplitude of these pulses depends on the steepness of the wave front. Presumably on account of the different effects of the inter-electrode capacitances on different parts of the wave front it was found easier to produce large positive pulses from a cathode,

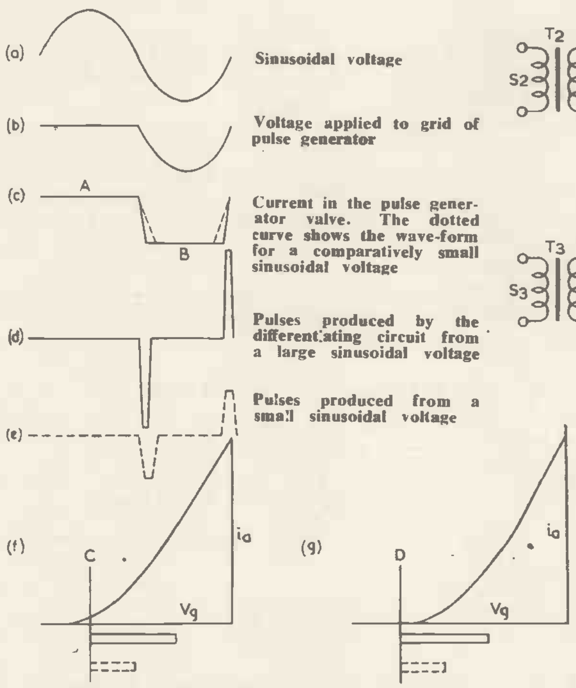
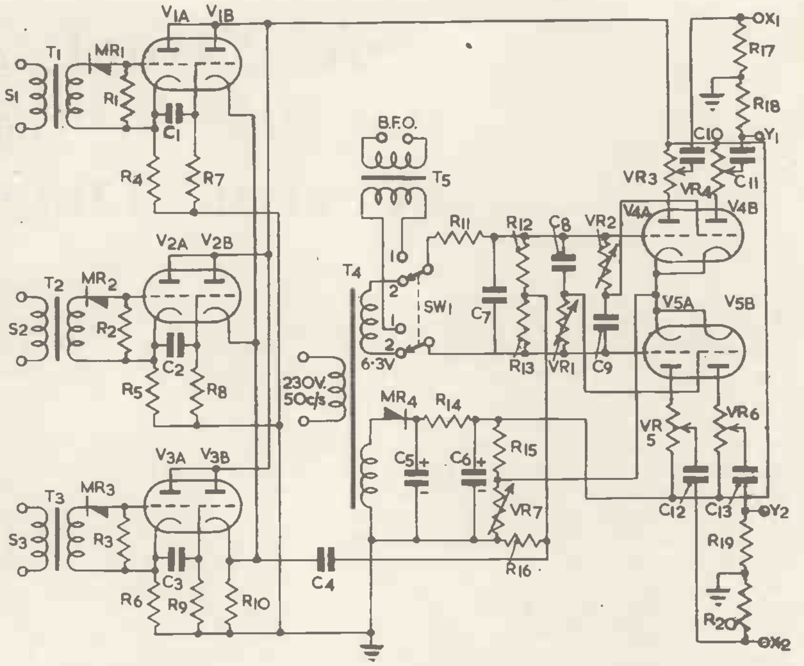


Fig. 2. The effect of the magnitude of the sinusoidal voltage on that of the vector.



R1, R2, R3	100k. ohms
R4, R5, R6	47k. ,,
R7, R8, R9	2.2M. ohms
R10	47k. ohms
R11	5k. ohms
R12, R13	47k. ohms
R14	10k. ohms
R15	220k. ohms
R16	100k. ohms
R17, R18, R19, R20	4.7M. ohms
T1, T2, T3, T4, T5	Radio receiver mains transformers
C1, C2, C3	10pF
C4	0.1μF.
C5	8μF.
C6	16μF.
C7	1μF.
C8	0.5μF.
C9	0.5μF.
C10, C11, C12, C13	.01μF.
VR1, VR2	10k. ohms
VR3, VR4, VR5, VR6	100k. ohms
VR7	20k. ohms
V1, V2, V3, V4, V5	6C8

Fig. 3. Schematic and component values for the visual aid

rather than an anode, load. $C1$ and $R7$ are the differentiating circuit for $V1$A. $V2$A and $V3$A have similar circuits.

$V1$B, $V2$B and $V3$B are used to couple the pulse-generators proper, $V1$A, $V2$A, $V3$A to a common resistor $R10$. This is also in a cathode circuit. As an alternative we might have tried to secure positive pulses by placing $R10$ in the common anode circuit of three valves working with no bias. The application of a negative pulse would produce a positive pulse across $R10$. It was not expected, however, that large pulses could be obtained, since, in this scheme, when a negative voltage is applied to one valve, the other two having no bias are passing a large current. Cathode followers are used instead. Normally $V1$B, $V2$B and $V3$B will be almost cut off by the voltage drop across $R10$. On the application of a positive pulse to the grid of one of these valves, anode current will flow and a positive pulse will be obtained across $R10$. This will tend to cut-off the other two valves, but, since they were almost cut off before, this has little effect on the magnitude of the pulse developed across $R10$.

When $SW1$ is thrown to position 1, the quadrature voltages required for the circular time base are developed from the sinusoidal voltage given by an oscillator working at a frequency slightly less than 50c/s. If it works at 49c/s there will be one revolution of the vector diagram per second. This device for producing rotation is similar to the action in a cathode ray oscilloscope working with a linear time base, when the synchronization is not quite perfect; in this condition the pattern tends to drift across the screen. In the present application the drift is a rotation around the screen. The arrangement is not ideal, but it is simple, and it works. It is, however, fraught with a certain danger: unless the teacher is using an oscillator which quickly attains stability, he should switch it on half an hour or so before it is required; otherwise there will be two kinds of drift, and the frequency drift of the oscillator will be particularly undesirable if the diagram starts to rotate in the wrong direction, when the frequency rises above 50c/s. The slow-motion aspect should be emphasized; otherwise the bright members of the class who have heard of the persistence of vision, will be confused, and will realize that they are seeing something which theory tells them should be obscured by a blur.

If the oscillator has one of its terminals earthed, the transformer, $T5$, is necessary to isolate the earth connexion.

So far no reference has been made to the difference in magnitude of the three vectors. When the construction of the unit was undertaken it was only hoped to show the variation in the phase angles which accompanies the variation of the resistance to which $S2$ is connected. Now that it has been built, it has b en found that a certain setting of $VR7$ permits the unit to represent changes of magnitude in addition. It is thought that the action is as follows:—

From Fig. 2 (c) it can be seen that for all values of sinusoidal voltage applied to a pulse generator, above a certain value, the change of anode current, from A to B, is the same. The change of voltage across $R4$, in the case of $V1$A, is also the same for different values of sinusoidal voltage. The steepness of the wave front, however, varies, since the time required for the voltage across $R4$ to change from a value corresponding to A to that corresponding to B, is determined by the time taken by the sinusoidal voltage to sweep through the grid base of the valve, and the greater the amplitude of the sinusoidal voltage, the shorter is this time. Consequently, the greater the amplitude of the sinusoidal voltage, the steeper the wave front, and since the amplitude of the pulse given by the differentiating circuit depends on the steepness of the wave front applied to it, the greater is the amplitude of the pulse. However, if the pulses, differing in amplitude, both bring the operating point of *V*4 and *V*5 to the linear region of their dynamic mutual characteristic, as shown in Fig. 2 (f) the spokes on the cathode ray tube corresponding to them will be of the same length.

If, however, the bias is adjusted by *VR*7 so that it has the value *D* rather than the value *C*, then as shown in Fig. 2 (g) the effective mutual conductance of the values is different for the two pulses, and the spokes on the screen of the cathode ray tube are of different lengths. No doubt the relationship between spoke length and pulse amplitude would be more linear if pentodes having a variable μ characteristic were used. However the 6C8 double triodes used behave surprisingly well. When the phase angle is large or small, the three spokes really look like the adjacent sides of a rectangle and the concurrent diagonal, but when the phase angle is about 45° there is a tendency for all three vectors to be the same length. Apparently the curvature of the mutual characteristic is not sufficient for this condition.

The method used for identifying the pulses is simple: switch *SW*1 is thrown to position 2 so that the vector diagram is stationary. It will be remembered that socket *S*2 is connected to the variable resistance; if this is reduced to its minimum value, one spoke will decrease in length, and will eventually disappear. The spoke which behaves in this fashion obviously corresponds to the voltage across the resistance. The spoke which corresponds to the applied voltage is easily identified since when the variable resistance is adjusted, while two spokes are changing in length and in angular displacement from the third one, the latter remains constant in length and fixed in position.

In connecting the unit to the series circuit and to the cathode ray tube, there are one or two points to be observed. It is first necessary to ensure that the spokes on the cathode ray tube lie in the same quadrant. When the sockets *S*1, *S*2 and *S*3 have been connected to the circuit, if the three spokes do not lie in the same quadrant, it is only necessary to reverse the plugs in *S*2 and *S*3 until they do.

Having secured three spokes in the same quadrant, it may happen that we see the spoke for the resistance voltage lagging behind that of the applied voltage. This means that the spot describing the circle of Fig. 1(g) is travelling in a counter-clockwise direction. To secure the conventional pattern corresponding to counter-clockwise rotation of the vectors, it is necessary to reverse the connexions to one pair of deflector plates. (Incidentally, the fact that the spot must travel clockwise round the circle is responsible for the oscillator working at a frequency slightly *less* than 50c/s, if it is desired to show the vector diagram rotating in the conventional counter clockwise direction.)

The unit has seven variable resistances; in adjusting them one might begin with *VR*1 and *VR*2. (If desired, these could be made fixed resistors of a value equal to the reactance of *C*8 and *C*9 at 50c/s.) If *VR*1 and *VR*2 are out of adjustment, the pattern on the screen, with *VR*7 giving bias corresponding to Class A operation, will be an ellipse with the major axis inclined to the horizontal. *VR*1 and *VR*2 should be adjusted until the major axis is horizontal or vertical. The pattern may still be an ellipse; this should be transformed into a circle, of as large a diameter as possible, by adjusting *VR*3, *VR*4, *VR*5 and *VR*6. However, it is not sufficient merely to produce a circle: a balanced push-pull circle is required, if the phrase can be permitted. If the circle does not fulfil this requirement, when the vector diagram is rotating, the length of a given spoke varies as it rotates. The desired condition can be attained as follows:—

*VR*7 is adjusted to give a circle as in Fig. 1(g). The spokes now appear on the circle as miniature stubs. Switch *SW*1 is set to position 1: the stubs rotate round the circle. *VR*3, etc., are adjusted to satisfy two conditions:—

(a) the pattern is a circle of large diameter;

(b) as the stubs rotate they are always radial, and of constant length.

Ideally, of course, the four triodes in *V*4 and *V*5 should be matched; but, in the unit constructed, no trouble was taken to check this, and no asymmetry was noticed.

Finally *VR*7 is adjusted, the bias is increased, the circle collapses, and the stubs develop into spokes. It should be remembered, however, that Fig. 2 (f) is a warning that the bias required for representation of magnitude is greater than that required for representation of phase angles only. The adjustment of *VR*7 is best done by setting the resistance, to which socket *S*2 is connected, to give angles of 20° and 70°, approximately, between spokes; *VR*7 is then adjusted until the spokes represent the two sides and concurrent diagonal of a rectangle.

It may be objected that by operating *V*1, *V*2 and *V*3 with cathode loads we are severely taxing the heater-cathode insulation of these valves. So far, however, they have not given trouble. The circuit diagram shows that the unit has its own power pack, but it has been operated from an external power unit which, on occasions, provided 500 volts H.T., and the heater-cathode insulation survived. Incidentally it may be mentioned that the mean anode current drawn by the unit is very low, since most of the valves are pulse-operated.

The components used in the series circuit to which *S*1, *S*2 and *S*3 were connected were a variable resistance of 10,000 ohms and a capacitor of 2μF. The applied voltage was about 130 volts, supplied by a Variac.

Various alternative circuits could have been used in designing this visual aid. A radial time base, such as that of the Radio Research Station, could have been built round *V*4 and *V*5. The saw-tooth voltage required can conveniently be provided by the oscilloscope in which the cathode ray tube is mounted. Its frequency should be high—about 20kc/s—so that, without modulation, the pattern on the screen is a circular blur, composed of spokes

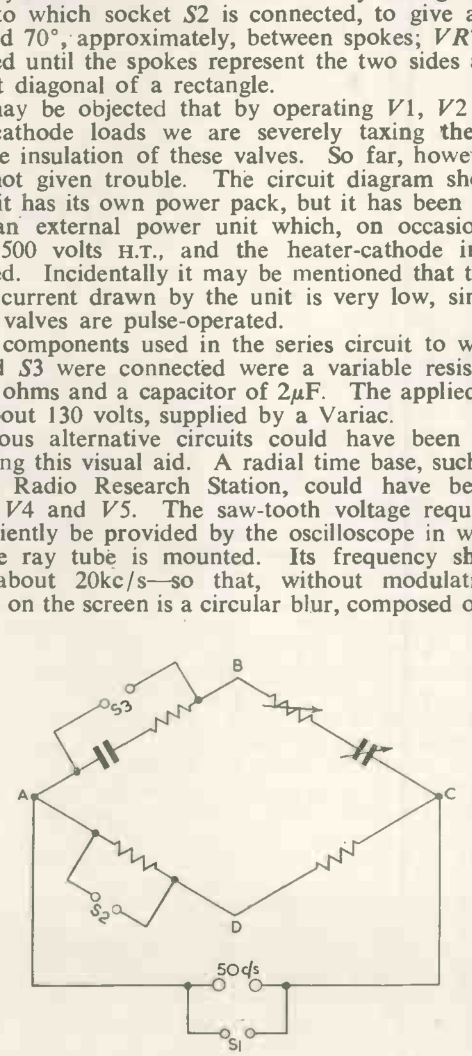


Fig. 4. A.C. bridge used in demonstrations with the equipment

packed so tightly together that they cannot be distinguished one from another. The pulses developed across *R*10 are applied to the grid of the C.R.O. and the brightness control is turned down. This method works satisfactorily, but it only represents phase angles, not magnitudes of vectors.

Alternatively, three cathode ray tubes could be used, each tube having its own radial time base. Each tube displays one vector. The three voltages from the series circuit are each applied to one of the radial time bases, and the quadrature voltages are developed from them. Only one pulse generator is required, fed from the voltage applied to the series circuit. This pulse is applied simultaneously to the grids of all three cathode ray tubes. Without pulse modulation, and with the brightness control turned up, each cathode ray tube displays a circular blur, the diameter of which is proportional to the sinusoidal voltage applied to the radial time base. With pulse modulation, and with the brightness control turned down, each cathode ray tube displays vectors correctly represented in magnitude and in phase displacement. On account of its extravagance, this method has not been tried, but it may well be the most simple method if a high degree of accuracy is required.

The unit shown in Fig. 3 was built to represent vector relationships in simple circuits, but it is thought that it could well be used for more complex arrangements such as A.C. bridges, provided that the arms of the bridge are not of unduly high impedance, so that they are not affected too much by the connexion of the primaries of *T2* and *T3* to them. In this application one may connect *S1* to the applied voltage, and *S2* or *S3* to points *B* and *D* of Fig. 4, and show that the vector *BD* disappears at balance, or, more instructively, one may connect *S1* to the applied voltage, *S2* to the arm *AD* and *S3* to the arm *AB* as in Fig. 4. When the adjustments to the bridge are such that the vector for *AB* and that for *AD* coincide, and are of the same length, the bridge is balanced. When a bridge has been adjusted so that the vectors have the same phase angle, if it is desired to show how adjustments to the bridge vary the magnitude of the vectors, it may be convenient to turn one vector through 180° by reversing the connexions to *S2* or *S3*.

The circuit shown in Fig. 3 was the result of some thought and experiment, but the values of the components were not carefully chosen. Many of the components were chosen from those available when some tag-panels from surplus equipments had been stripped. The values are not critical, and others who may wish to build the unit should have no difficulty in persuading it to draw their vector diagrams for them.

A Judgment Box

By W. H. Alexander, B.Sc., A.Inst.P. *

DECISIONS are often made in such a simple manner that the mechanism involved is scarcely given a moment's thought. In general, however, a decision is reached only after due consideration has been given to the weight or importance of each of the distinct factors which influence it and it is only when one of these factors is of overwhelming importance that the decision resolves itself so simply. The question "Shall I build myself a house?", for example, is settled immediately if one of the factors is that one has no money and no prospects of obtaining any.

The principal difficulty in making a decision lies not so much in estimating the relative weights of the various factors, although this may involve decisions quite difficult in themselves, as in ensuring that the final decision is a true reflexion of these weights. One simple, but effective, method of achieving this end, is to assign to each factor a numerical quantity representing its weight, which quantity is made positive or negative, depending on whether the factor under consideration is for or against the proposal to be judged. This proposal is then accepted or rejected according as the sign of the algebraic sum of the weights is positive or negative.

The Judgment Box described in this article is capable of taking the weighted mean of a number of quantities and is thus well suited to performing the above summation. Ten channels are available to represent up to ten separate factors; each channel having two six-way switches, one above the other, so that the panel has twenty switches arranged in two rows of ten. (Fig. 1). The six positions of the upper switch represent "strongly for", "for", "neutral", "against", "strongly against" and "off", which is the position used when no factor has been allotted to that channel. The lower switch adjusts the weight. When the decision is required, it is obtained by operating a push-button and turning the urgency control clockwise, until the pointer of the decision meter moves from the amber sector into either the green sector to the right or the red sector to the left, thus accepting or rejecting the proposal. The urgency control should not be turned beyond a point previously determined by consideration of how urgently a decision is required. If a decision is required most urgently, or in other words if a decision must be obtained no matter how close, then the urgency control may be turned fully clockwise, but if a clear or large majority decision is necessary, then the urgency control should be turned only a small amount. Unless the decision is clear enough, the pointer will not leave the amber sector, and, in the least urgent position, only a unanimous verdict is sufficient to register as a decision.

The circuit diagram (Fig. 2) shows that the upper switch selects a voltage of +2, +1, 0, −1 or −2 volts (the signs plus and minus meaning in and out of phase with a reference voltage), whilst the lower one varies the resistance by which the selected voltage is connected to

Fig. 1. The Judgment Box.

* *Applications Laboratory, Ferranti Ltd., Edinburgh.*

a line common to all channels. The voltage on this line is measured by the detector and meter circuit, in which the urgency control is merely a variable shunt, spring loaded to prevent accidental overloading of the meter.

Considering the general channel (subscript *i*), the current flowing to the common line will be

$$I_i = (V_i - V)\, G_i$$

where V_i is the selected voltage, V is the voltage of the common line and G_i is the conductance of the path to the common line. Summing this over all channels gives

$$\sum_{i=1}^{n} I_i = \sum_{i=1}^{n} G_i \qquad \sum_{i=1}^{n} V_i G_i - V$$

But $\sum_{i=1}^{n} I_i$ is the total current flowing into one point (if the very small current taken by the meter circuit is neglected and must therefore be zero. So $V = \dfrac{\sum_{i=1}^{n} V_i G_i}{\sum_{i=1}^{n} G_i}$

which is the formula for a weighted mean. In the present instrument n can have any integral value from one to ten. V_i can be $+2$, $+1$, 0, -1 or -2 and G_i can be 1, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, $^1/_5$ or 0, but these fractions could be changed to any required values by altering the resistors on the lower switch.

The types of problem which can be solved by an instrument of this kind are many; perhaps the most obvious being that of making a personal decision such as that mentioned earlier, "Shall I build myself a house?" The man who has to make this decision might allocate the first channel to his own feelings, which are that, although a new house would be desirable, he is quite comfortable at present in his furnished flat. This would merit the position "for" (+1) in the upper switch, while the lower switch would be turned to the most important position (1). The next channel, his wife's feelings, would have the upper switch at "strongly for" (+2) because she is very anxious to have a new house. Proceeding in this manner, he would set the switches for all the factors, press the button and turning the urgency control to the required level would receive the judgment. He would build the house if the pointer entered the green sector, not build it if the pointer entered the red sector, and if it remained in the amber sector he would wait until some circumstance changed and then try again.

Taking the vote of a committee meeting is another possible use of this circuit, and for this purpose the upper row of switches would be separated from the main unit and distributed round the conference table, one to each member of the committee. When a vote is about to be taken the chairman would adjust the weighting switches to give each member the importance which the chairman thinks he merits on the question to be decided. This procedure is not quite so undemocratic as it first appears, for on many questions the opinion of an engineer is of greater importance than that of a salesman, whilst on others the places might be reversed. After the weights have been adjusted, the members then record their votes on their individual switches, each having the choice of casting two votes or one vote, for or against, or abstaining from voting by turning his switch to "neutral." Thus an abstention has the effect of reducing the strength of the decision, whereas the "off" position, signifying perhaps that this member is absent, completely removes from the circuit, the channel concerned. When the votes have been cast, then the decision is obtained in the usual manner.

One of the most interesting ways in which the Judgment Box can be used is in selecting candidates for employment. Some human attribute such as general appearance, command of English or manipulative skill is allocated to each channel and the bottom row of switches is set to the relative importances of these attributes, having regard to the post to be filled. If, for example, a fitter is required, then manipulative skill would be given more weight than English or appearance. Every candidate in turn is then tested in all the attributes and the top row of switches is set in accordance with whether the candidate is very good (+2), good (+1), average (0), poor (−1) or bad (−2) in each attribute. The man receiving a decision in his favour with the lowest setting of the urgency control is the best man for the position. Alternatively, the best post for a given man may be selected by finding which post, as represented by its particular configuration of weights, gives a favourable decision with the least turning of the urgency control.

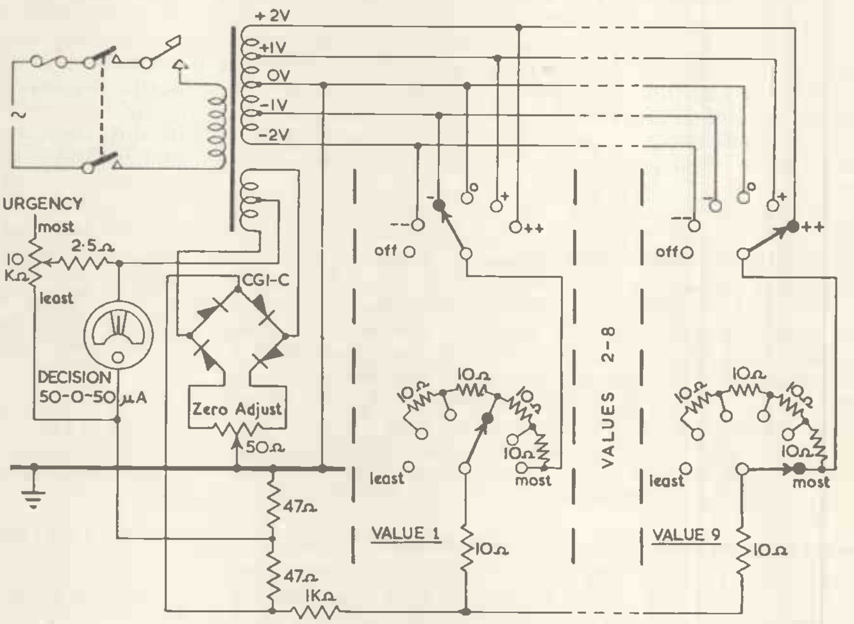


Fig. 2. Circuit diagram of the Judgment Box

The reader will no doubt think of numerous other uses for a circuit of this kind and in addition will probably notice quite a few improvements which could be made to increase the scope of the instrument. Such an improvement would be to replace the switches by continuous controls, the upper one a potentiometer and the lower one a variable resistor, but then a cathode follower would probably have to be inserted between the two controls to prevent scale distortion of the upper control due to variations in the current drawn.

Finally, the author wishes to express his gratitude to Messrs. Ferranti Ltd. for permission to publish this article, and to Mr. M. K. Taylor for his helpful suggestions.

Receiving Valves suitable for Electrometer use

By G. A. Hay, M.Sc. *

THE increasing use of X-rays, radium and artificially produced radioactive isotopes in medical and other work has led to the need for many and varied types of instrument for measuring the radiations involved. These radiations comprise X-rays, gamma-rays and alpha- and beta-particles.

Broadly there are two methods in general use for measuring these radiations, and both depend on their property of ionizing gases. In the ionization chamber method, which was the earliest historically, the ions produced in a gas enclosed in the ionization chamber are collected by an electric field within the chamber. The charge per second, i.e. the current, is measured, and is proportional to the amount of energy absorbed in the gas. In the second method, which at present is capable of much greater sensitivity but somewhat lower accuracy and convenience, the initial ionization in a Geiger-Müller tube due to the radiation is caused to produce an avalanche of ions by collision, thus giving a pulse of current. The average number of pulses in unit time is then a measure of the radiation energy absorbed. A more detailed account of these methods will be found in references 1 and 2.

In the former method, the ionization currents range from 10^{-15} to 10^{-9}A, and it is not practicable to measure them directly with a galvanometer. Usually the current is passed through a high resistance of value 10^{9} to 10^{12} ohms, and the resulting potential difference is measured by applying it between the grid and cathode of a valve.

It is clear that the grid current of this valve must be small compared with the current to be measured, and this has necessitated the development of special electrometer valves. with grid currents ranging from 10^{-12} to 10^{-16}A. This value, of course, relates to *negative* grid current, which flows from cathode to grid when the grid is too negative to attract electrons from the cathode.

Characteristics Desirable in an Electrometer Valve

For many of the applications referred to above, it is necessary that the valve be small, light and relatively non-microphonic, and that its power consumption should be small so that miniature batteries in portable equipment will have a useful life. This requirement makes a filamentary cathode almost a necessity: in mains-operated equipment this is still an advantage as its supply can be most easily obtained from a stabilized H.T. source. There has always been a dearth of special electrometer valves, and to the writer's knowledge the only types available in this country at present are of normal size or even larger. The Victoreen Instrument Co. of America has for some time been producing two sub-miniature types, but these are very difficult to obtain in this country. Mullard Electronic Products Ltd. have recently announced two such types, but they are not yet obtainable (June, 1949). The published characteristics of these four types are shown in Table 1 for reference.

In general, the design of portable battery-operated direct coupled amplifiers for the measurement of ionization currents demands two types of valve. One is a voltage amplifier, which must always have a low value of grid current and preferably a large amplification factor. Its cathode current can be quite small, of the order of a few microamperes. This valve will form the first stage in the amplifier, and the need for its high gain is to be found in the effect on the zero setting of the amplifier of varying filament current. If the temperature of the filament varies, due to either current or ambient temperature changes, the average emission velocity of the electrons will vary. This will cause a change in the position of the space charge, which is best represented by an equivalent change of grid voltage, and may be regarded as a kind of zero frequency noise. This effect, as with orthodox valve noise, is most important in the input stage grid circuit, for there it is greatest in relation to the signal. If the first stage has a gain of unity, as it may well have with many types of electrometer valve, the same problem will be encountered in the grid circuit of the second stage, and there will be a second source of drift of magnitude comparable to the first. The order of this effect is remarkably constant in triodes, tetrodes and pentodes, being about 10mV equivalent grid voltage change for 1 per cent variation in filament current. In the inverted triode, however, the effect is about ten times greater, and this type, although outstanding for low grid current, is unsuitable for general use where the effect is likely to be of importance, and where special precautions are not taken to stabilize the filament supply. It will be seen that the maximum gain available in existing electrometer valves is about four times.

TABLE 1.

VALVE	FILAMENT	I_g	μ	gm
Mullard ME1401	1.25 volts 15 mA	2×10^{-14} A	1.8	70μA/V
Mullard ME1402	1.25 volts 15 mA	5×10^{-15}A	5	75μA/V
Victoreen VX34	1.25 volts 10 mA	10^{-14} A	2	150μA/V
Victoreen VX41	1.25 volts 10 mA	3×10^{-15} A	1	15μA/V

The second type of valve, a current amplifier, may be called upon to perform two functions. The first is that of the electrometer valve in a single stage amplifier of low sensitivity, where low grid current is necessary and a cathode current of 100 to 200μA will enable it to operate a robust microammeter directly. Here amplification factor is unimportant, but a mutual conductance of not less than 100μA/V is desirable. The second is in the final stage of a multi-stage amplifier where the valve is required to operate a meter but where a low value of grid current will not be necessary.

These two ideal types are represented in Table 1 by the VX 41 and ME 1402, and the VX 34 and ME 1401 respectively, but it would seem desirable to have a much larger amplification factor in the first type. In view of the difficulty of obtaining small electrometer valves, it was

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decided some four years ago to investigate the properties of ordinary receiving valves and hearing aid valves. This, of course, has been done by many people, but the types selected have never exactly fulfilled the above requirements. References are given later to the principal workers in this field, to whom acknowledgment is due for many of the ideas collected together here.

Factors Influencing Negative Grid Current

These were first stated by Metcalfe and Thompson,[3] and at the risk of appearing tedious they will be repeated here, as there seem to exist some misconceptions among many who have no intimate knowledge of such valves.

These factors are:

(1) Ohmic leakage,
- (a) across external surfaces
- (b) across internal surfaces;

(2) Electron currents due to
- (a) thermionic emission from a heated grid
- (b) photo-electric emission from the grid, caused by incident light or X-rays;

(3) Positive ion currents due to
- (a) positive ion emission from the cathode
- (b) ionization of any residual gas by collision.

They have been widely discussed in relation to the design of new valves, but one is compelled to adopt a different outlook when only existing valves are available. The following conclusions have been arrived at as a result of the work described in the next section.

Ohmic leakage is rarely insuperable. Leakage inside the valve is, of course, entirely under the control of the manufacturer, but if the pinch and mica supports are kept clean and free from getter the leakage is negligible. Only in a very few types has this leakage been troublesome. The use of ceramic spacers for currents down to 10^{-15}A seems unnecessary. Leakage outside the valve can be made as small as desired by suitable treatment. Bakelite bases are quite unsuitable and must be removed, but there is absolutely no need for a top cap grid connexion. Negligible leakage (for the present purpose) may be attained with only the spacing between the pins of a B7G valve base, or even less, if suitable coatings are applied to the glass. These are described later.

Electron emission from a heated grid will never arise in electrometer valves because the power dissipation is so small. Photo-electric emission, however, is extremely important, a current of 10^{-10} to 10^{-12}A being produced by average daylight incident on the valve. A completely light-tight cover is essential, even the leakage through a small slit being sufficient to increase grid current from 10^{-15} to 10^{14}A or more. It is also probable that the light from an oxide-coated cathode run at its normal operating temperature is responsible for some grid emission. Another source of photo-electric emission has been stated to be the production of very soft X-rays by electron bombardment of the anode: this would be reduced by operating at a low anode voltage, as is described later.

It seems that positive ion currents impose the most serious limitations on the use of ordinary valves as electrometers. The effects of positive ion emission from the cathode are usually reduced in special valves by the use of a space charge grid near to the cathode, and held at a constant positive potential. This has the effect of repelling back to the cathode any positive ions which may be emitted. It may sometimes be possible to use the control grid of an orthodox pentode in this way, but often the characteristics of the screen and suppressor preclude their use as the control grid. One can reduce the positive ion emission materially by operating the cathode at a low temperature, a condition which will also reduce photo-electric emission from the grid. Usually a filament voltage of about one-half of the rated value is suitable, giving a current from two-thirds to three-quarters normal.

Ionization by collision is a function of three main variables, potential difference across the valve, total cathode current, and degree of vacuum. The latter is out of our control, but although special valves may be more completely evacuated than usual, the degree of vacuum in the average modern valve is sufficient for all but the most exacting grid current requirements. Ionization by collision starts at anode voltages in the region of 10, although the cumulative effect does not set in until voltages of 25 or 30 are reached. It is found, therefore, that a material reduction in grid current results from a reduction of anode voltage to 6 or 8 volts, and this occurs even though a higher potential exists on the screen grid. The effect may also be reduced simply by reducing the cathode current, when collision ionization will be reduced in proportion. This is desirable in a voltage amplifier, but impossible in a current amplifier where the cathode current must be sufficient to operate a microammeter.

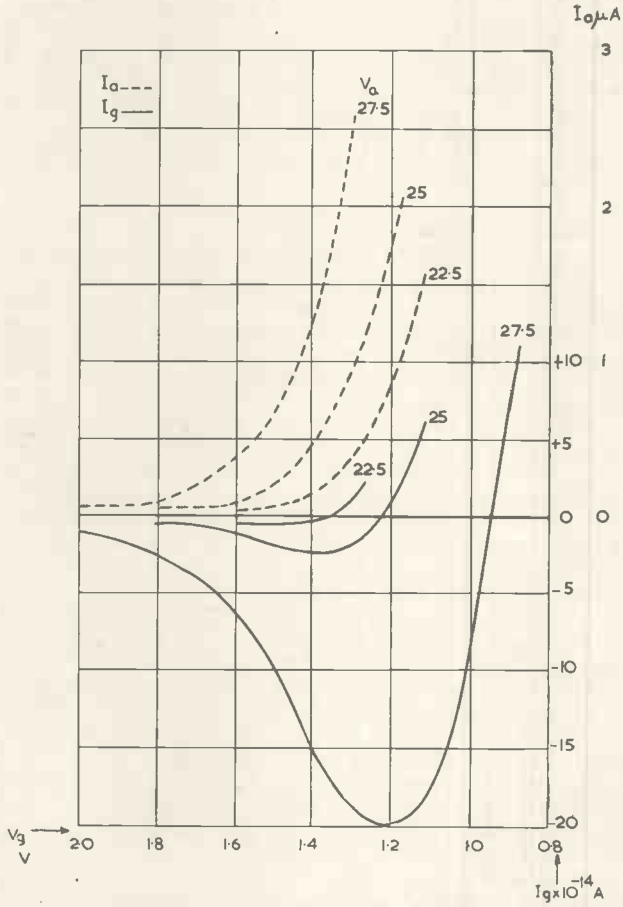

Fig. 1. Grid current and mutual characteristics of Acorn 955 : V_h = 4 volts

Selection of Suitable Valves

Before attempting to select a suitable valve type it is pertinent to decide exactly what it will be required to do in the circuit. For example, if the minimum current required to give full scale deflexion is 10^{-11}A, and the accuracy of indication is to be limited to ± 5 per cent of full scale, (as it might in a small portable instrument), there is little point in going to great lengths to attain a grid current of less than about 2×10^{-13}A, although a smaller value would not be detrimental. The important factor in assessing this value is the probable change in grid current, and under average conditions this is unlikely to be more than one-half of its absolute value. Hence the possible change in the above example is 10^{-13}A, which is 1 per cent of the full scale current, and therefore unimportant. On the other hand, a full scale current of 10^{-14}A, to be read to an accuracy of ± 1 per cent would demand a grid current of under 10^{-16}A, which is beyond the scope of the ordinary valve. The performance which was eventually obtained with one type of receiving valve was thought to be adequate for all normal requirements.

In selecting suitable types for trial, perhaps the most important single factor is the ability to pass a reasonable anode current at a low anode voltage and a value of negative grid bias sufficiently large to eliminate positive grid current. This immediately rules out a large number of short and medium grid base types, leaving only valves designed for the dissipation of larger powers. Unfortunately, these frequently require large filament currents, and so the number of available valves is severely limited. An excellent example of this difficulty is to be found in the Acorn 955, one of the earliest types to be tested. In Fig. 1 is shown the grid current of a single specimen at anode voltages of 22.5, 25 and 27.5 volts, together with the corresponding anode currents. It is clear that the optimum grid current point corresponds to an anode current of only a fraction of a microampere, and if the anode voltage is increased to improve this condition the grid current increases rapidly. Operating conditions are very critical, and different specimens will certainly not be interchangeable.

Experimental Details

At this point it would be as well to comment on some practical points which have been found of importance. Leakage across untreated glass surfaces can be exceedingly troublesome, as glass adsorbs moisture very easily, and the conductivity of the surface film varies with the humidity and with the presence of electrolytes in the film. It was during measurements on the 955 that this problem was considered. At that time (1944) the only method known to the writer was to coat the valve with a film of paraffin wax. This gave very little improvement, and it was reasoned that the wax was simply being coated over the top of the moisture film. The valve was therefore carefully cleaned in alcohol and ether, dried in an oven, and placed in an evacuated desiccator with phosphorus pentoxide. After standing for twenty-four hours, the valve was lowered into molten wax without opening the desiccator. On removal, a film of wax solidified on the glass, and the leakage was found to be very much reduced. It was rather erratic, however, and some trouble seemed to be caused by thick layers of wax, perhaps due to unequal expansion giving rise to frictional charges. In addition, the wax was very fragile. This technique did enable results to be obtained, but it was not until silicone coatings became available that the final solution was reached. All valves for electrometer use are now coated in the following way, using "Teddol" compound supplied by B.T.H., Ltd. The valve is washed in alcohol and ether, and then allowed to stand for a day in a clean but normally humid atmosphere. This is absolutely essential, as the formation of the silicone water-repelling film depends entirely on the initial presence of a film of moisture. The valve is then supported in any convenient way in a large air-tight glass jar, and the uncorked bottle of "Teddol" placed in the jar for about twenty minutes. The vapour escaping from the bottle reacts with the moisture on the glass to form a closely adhering water repelling film. It is then necessary only to remove the valve, scrape the pins, which may have been very superficially corroded, and use in the ordinary way. Subsequent washing and baking, which are usually recommended, have not been found necessary in this application. This treatment has been found sufficient to reduce the leakage between adjacent pins of a B7G valve to less than 10^{-15}A with normally applied voltages.

The apparatus used for measuring grid currents is also worthy of mention, as the technique is somewhat different from that of ordinary small current measurement. The basic circuit is given in Fig. 2; a triode is shown, although tetrodes or pentodes can be measured by making provision for supplies for the other electrodes. The contacts in the grid circuit are normally closed, and are in the form of crossed platinum wires capable of only small separation to minimize changes of capacitance. All grid connexions are insulated on solid alkathene supports. The sensitive micro-ammeter in the anode circuit is used only for indicating small changes in anode current, and it is therefore provided with coarse and fine backing off controls. The total grid circuit capacitance, C_{gc}, is known for each valve, having been measured by an electrostatic method, although any other method of measuring a small capacitance would serve. The valve and its grid circuit are fully screened and enclosed in a perfectly light-tight container.

There are two ways of using this circuit. For currents down to 10^{-13}A, the grid circuit switch is closed and use is made of the 10^{11} ohm resistor. First, the valve is set to the required working point, and the grid current key opened, with the grid balance voltage at zero. Negative grid current is flowing, and the potential of the grid is thus made more positive by the voltage drop across R_g. The anode current meter is set to a convenient point, and the grid key released. The grid becomes less positive and the anode current decreases. It is brought back to its reference position by manipulating the grid balance control, and this voltage then gives the value of $I_g \times R_g$, from which I_g may be calculated.

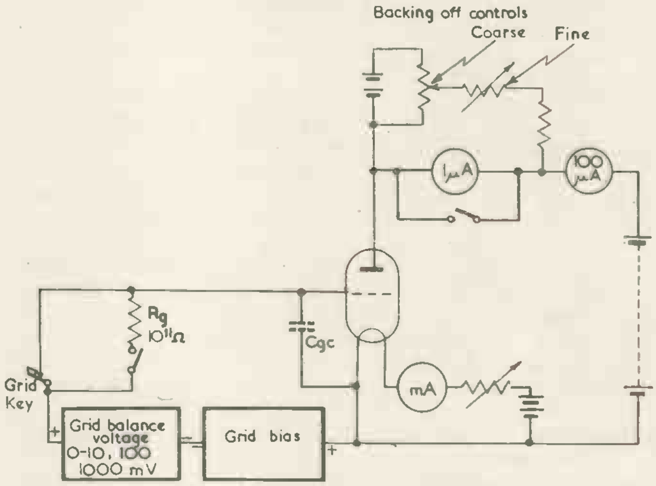

Fig. 2. Basic circuit of grid current measuring apparatus

For currents less than 10^{-13}A, the deflexions thus produced are too small, and the grid current must then be integrated over a time interval. This is done by opening the grid switch, thus disconnecting R_g, and at the desired working point measuring the change in anode current for a given small change, say 10mV, in grid potential. If the grid key is now opened, negative grid current will charge the grid-cathode capacitance so that the grid becomes progressively more positive, as indicated by an increase in anode current. The time taken in seconds for a change of 10mV is recorded with a stop watch. From the relation $Q = V.C.$ we may calculate the increase of charge ΔQ on the grid: $\Delta Q = \Delta V_g \cdot C_{gc} = 10^{-2} \cdot C_{gc}$, and if the measured time is t seconds, then $I_g = \Delta Q/t$ or $10^{-2} \cdot C_{gc}/t$ amperes. This method is limited in sensitivity only by the drifts due to changing battery voltages, because if t becomes of the order of minutes the change of anode current may no longer be entirely due to grid current.

Results of Measurements

The first valve to be investigated was the Acorn 955, (Fig. 1), and although this was used in some radiation

TABLE 2

VALVE	Vf (V)	If (mA)	Va (V)	Ia (μA)	Vg_1 (V)	Vg_2 (V)	Vg_3 (V)	Ig (A)	gm (μA/V)	μ	r_a (MΩ)	REMARKS
RCA954	3.0	—	4.8	6.0	+0.5	+4.5	−2	0.3×10^{-15}	30	—	—	$Ig_2=72\mu A$
Brimar 1C5GT	1.0	60	16.5	20 to 100	—	—	—	10^{-13}	300	—	—	Triode connected
Mullard DL72	0.7	20	9.0	1.0	−2.25	9.0	0	4×10^{-14}	—	—	—	Triode connected
	0.4	15	9.0	1.0	−1.15	9.0	0	2.0×10^{-14}	—	—	—	" "
	0.7	20	6.0	1.0	−1.35	10.5	0	1.5×10^{-14}	—	—	—	Pentode connected
	0.7	20	6.0	0.5	−1.42	10.5	0	1.2×10^{-14}	—	—	—	" "
	0.7	20	6.0	0.5	−1.14	9.0	0	0.9×10^{-14}	—	75	30	" "
	0.7	20	12.0	130	—	—	0	ca 10^{-11}	—	—	—	As current amplifier triode connected
Brimar 3S4	0.7	30	6.0	7.0	—	10.5	0	10^{-14}	—	150	1.5	Half Filament $Ig_2=3\mu A$
Tungsram 3S4	0.7	30	6.0	14.0	—	10.5	0	10^{-14}	—	150	0.75	Half Filament $Ig_2=6\mu A$
Mullard DL92	1.4	30	6.0	80.0	—	12.0	0	2.0×10^{-14}	150	—	—	As current amplifier Pentode connected

measurements, its operating conditions were too critical for general use. In January 1947, Nielsen published some results[4] using a 954 pentode with g_1 and g_2 as space charge grids and g_3 as the control grid. These results have been fully confirmed, but unfortunately the characteristics of the valve so used are poor, although grid currents of 10^{-15}A are easily attainable. Typical results are given in Table 2.

Soon after this a valve for use in a portable radiation meter was required. A 1C5GT decapped and triode connected was found fairly satisfactory as a current amplifier, although the grid current was not less than 10^{-13}A. It was incorporated in a small radiation monitor which has since been in constant use, and no instability due to grid current effects has been observed. It is hoped to publish details of the instrument later. Only two specimens of the valve were tested, but similar results were obtained for both. The valve is relatively bulky, and the filament drain is too heavy for general use.

Two specimens of the Mullard DL72 hearing aid valve were then investigated. It was this type which first showed promise of attaining the performance required for the voltage amplifier referred to above. Using the valve pentode connected, with g_1 as the normal control grid, and the anode voltage about half that of the screen voltage, grid currents of the order of 10^{-14}A were observed. Table 2 shows typical results obtained at various electrode voltages: the effect of varying some of the factors discussed above may be seen. The amplification factor was such that a stage gain of 50 could easily be attained. By triode connecting the DL72 a current amplifier was obtained, with a mutual conductance of 150μA/V. The grid current under these conditions was of the order of 10^{-11}A, although some instability was observed which may have been due to the particular specimen investigated. The filament in all these measurements was operated at 0.7V, 20mA.

Although these results showed that the DL72 was very suitable as an electrometer, it was felt that a valve with more latitude in its operating conditions would be desirable. This required, of course, a longer grid base, and the final answer was found in the 3S4 or its Mullard equivalent DL92. Two 3S4's were first tested, a Brimar and a Tungsram, both bought at random from retailers, and similar results were obtained for both, as shown in Table 2. Subsequently, six Mullard DL92's were tested, of which four were satisfactory; one showed excessive grid current and one had unsuitable characteristics at the low electrode voltages used. (It should, perhaps, be pointed out that these valves had quite normal characteristics under orthodox working conditions.)

It seems, then, that one might expect perhaps 75 per cent of 3S4 specimens to be suitable for electrometer use. Of these, some will have smaller grid currents than others, and these can be reserved for the first stage in the amplifier. As such, an average grid current of the order of 10^{-14}A together with an amplification factor of 150 and an A.C. resistance of 1.5MΩ may be expected. The remainder of the specimens will be suitable as current amplifiers, where an average grid current of 2×10^{-14}A and a mutual conductance of about 150μA/V will be obtained. The 3S4 and its equivalent are doubly useful in that their filaments are centre tapped. For a voltage amplifier where only a small emission is wanted, half of the filament is used with consequent economy in filament power. A very suitable valve holder is the Clix "Fluon" B7G base which is moulded of polytetrafluoroethylene. The insulation afforded by this is entirely adequate for the present purpose.

A more sensitive radiation monitor incorporating an amplifier designed around two 3S4 valves has been constructed, and it is hoped to publish details of this later.

Conclusions

Valves which are readily obtainable today at normal prices may, with little extra treatment, be converted into electrometer valves, suitable either as voltage amplifiers with a grid current of 10^{-14}A and a stage gain of more than ten times that of the best special valve now available, or as current amplifiers with a grid current of 2×10^{-14}A and a mutual conductance at least twice that of existing electrometer valves. The price paid for this performance is a filament current of about two or three times that of the electrometer, and the need for some amount of selection.

In view of these facts, it is surely reasonable to inquire why the performance of existing electrometer valves is not much better. If such results are consistently obtainable with valves not specially designed for the purpose, it would seem that a combination of the two design techniques would result in an incomparably superior product. The above results suggest that it should be possible to manufacture a miniature valve with filamentary cathode, space charge grid, control grid, screen grid and anode, with a grid current of 10^{-15}A or less, and tetrode characteristics resulting in a high value of amplification factor.

Acknowledgment

The author wishes to acknowledge the continued encouragement of Dr. F. W. Spiers, Senior Physicist to the General Infirmary at Leeds.

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An Indoor T.V. Aerial Array

By F. E. Wood.

WITH the opening of the Sutton Coldfield transmitter in mid-December 1949 the writer who operates an amateur transmitting station felt it necessary to take precautions to avoid the possibility of interference from his transmissions being experienced by neighbours with TV. receivers, having regard to the fact that he is resident in a fringe area and that operation of his station is exclusively in the ten metre band, the second harmonic of which could fall in the pass-band of a Sutton Coldfield receiver. It was felt that a perfect alibi would be forthcoming if an interference-free receiver could be shown operating in the same house as the transmitter. The first step, however, was the acquisition of a TV. receiver and it was decided to build the ELECTRONIC ENGINEERING "Home Built Televisor," the experience of others having shown that it is capable of giving excellent results on a standard "H" aerial (with $\frac{1}{4}$ wave spacing) in the district.

In view of the heavy motor traffic passing the writer's residence, noise limiters were added to both sound and vision receivers as decribed in the August 1948 issue of ELECTRONIC ENGINEERING. The televisor was eventually completed and, initial tests with a signal generator having proved satisfactory, consideration was turned to a suitable aerial system and, due to the lack of garden space it was decided that an indoor array would be most convenient, if this were at all practicable. To provide additional gain, in view of this, a single stage pre-amplifier similar to that described in ELECTRONIC ENGINEERING of April 1950 was built and proved most successful.

An exploratory survey of the roof space of the house showed that a close-spaced 3-element array could possibly be installed, although it was obvious that the reflector, at least, would have to be bent back for some way at the ends to accommodate its length in the required direction. In fact, it subsequently became necessary to fold back part of the director also.

Tables were consulted which indicated that with spacings of 0.15λ for reflector and 0.1λ for the director the radiation resistance of such an array might be expected to be around 20 ohms. Since it was proposed to use 75 ohm co-axial cable, the input of the Home-Built Televisor being designed for such operation, it thus became necessary to provide a step-up of about 4 times. This is readily achieved by making the dipole a folded element. In addition, such folding will flatten the response of the system as a whole, which is of advantage in helping to maintain the received bandwidth. Again, it was considered that the normal practice of connecting a co-axial feeder (unbalanced) to a dipole (balanced) could not be considered satisfactory when maximum performance was necessary. Accordingly a simple balance-to-unbalance transformer section was arranged between the feeder and the aerial array proper.

The next point to consider was the material from which the array should be constructed. In this connexion the writer had had considerable success using Telcon 300 ohm ribbon feeder, pattern K.25, as a folded dipole on ten metres and there seemed no reason why it should not be equally satisfactory on the shorter TV. wavelength, particularly as the aerial would be indoors and so protected from the effects of rain which, it had been found, tend to disturb the operation of such a dipole when used in an outdoor array. (Pattern K.35 feeder has now been introduced to overcome this difficulty.) In arriving at the length to which such ribbon should be cut for operation on a given frequency various articles were consulted but no very definite data could be found. The manufacturers stated that tests were not, at that time, conclusive but indicated a length factor of between 0.91 and 0.95, and suggested that a value of 0.93 should be adopted as the best average. To satisfy himself in the matter the writer decided to make some experiments with a piece of this K.25 cable. A length was cut to rather more than half a wavelength at ten metres. Two small copper plates about $\frac{1}{2}$ in. square were made and drilled for use as shorting end-pieces for the length of cable. An extra hole was drilled in the centre of each plate to serve as a supporting point. The ends of the cable were bared and a plate connected to short-circuit each end, the whole length then being slung up on two cords and suspended some ten feet below, and parallel with, a ten metre beam antenna. The exact centre of one conductor of the ribbon was cut and a thermo-couple R.F. ammeter of $\frac{1}{2}$ amp full scale deflexion was inserted. Thus, a complete loop was formed with the meter connected in the centre of one side. Switching on the transmitter connected to the beam aerial excited the ribbon antenna slung beneath and gave a deflexion on the R.F. ammeter. The transmitter was tuned to 28.5Mc/s and left on that frequency. A series of readings was taken, shortening the length of ribbon half-an-inch at a time (equally off each end to preserve the balance of the meter) and it was thus possible to ascertain the length which was resonant at the selected frequency. Knowing this, a length factor was calculated for the type of ribbon cable employed. This proved to be 0.925, a similar value to that suggested by the manufacturers.

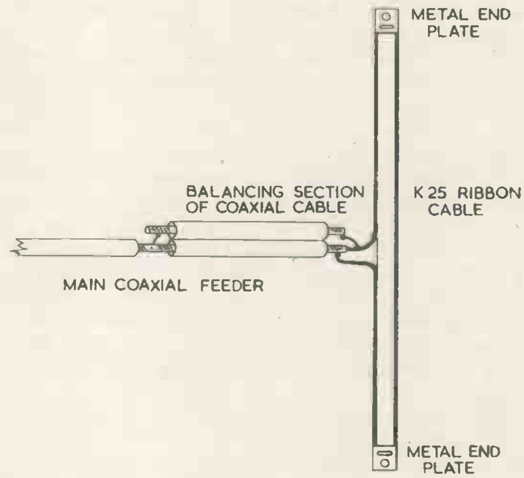


Fig. 1. Folded dipole with coaxial feeder and balancing section.

Stub connexions as follows:—
Braid at one end to centre of main feeder and top conductor of dipole.
Braid at other end to outer braid of main feeder.
Braid of main feeder to bottom conductor of dipole.
(Centre conductor of stub is not connected at either end.)

Having ascertained the foregoing, the construction of the aerial could now be embarked upon, and this proved extremely simple. A piece of the K.25 cable was cut to length for the Sutton Coldfield vision frequency of 61.75Mc/s on the basis of

$$\text{length (ft)} = \frac{492 \times .925}{61.75}$$

The ends were shorted by small copper plates as described above, and the exact centre of one side was cut and the ends bared for half an inch each side. All connexions to the end-plates were soldered up, as also the strands of each end formed at the centre. This completed the construction of the folded dipole and its appearance will be evident from Fig. 1. As was mentioned above, the elements were cut to length for the vision frequency of 61.75Mc/s. Strictly, of course, since the vision frequency is 61.75 and the sound frequency is 58.25Mc/s the aerial should have been cut for $f = \sqrt{(61.75 \times 58.25)}$. However, it was decided that every attempt should be made to achieve maximum performance on the vision channel and that the sound could take care of itself. This has proved entirely satisfactory in practice. The director and reflector are simply lengths of 14 S.W.G. bare copper wire which are cut to the following lengths

$$\text{Director} \ldots \frac{492 \times .9}{f(\text{Mc/s})} \text{ feet.}$$

$$\text{Reflector} \ldots \frac{492}{f(\text{Mc/s})} \text{ feet.}$$

The folded dipole in the array worked out at 7 ft. 5 in. for Sutton Coldfield vision frequency, the Reflector at 7 ft. 11½ in., and the Director at 7 ft. 2 in. The Reflector was spaced 0.15λ from the folded dipole, and the Director spaced 0.1λ (2 ft 4 in. and 1 ft 7 in. respectively). All the elements were mounted by means of Eddystone midget stand-off insulators, Pattern 1019, which were secured to convenient points in the roof timbers by means of ¾ in. screws. The folded dipole was supported on the insulators by holes drilled in the small end plates described above, and the reflector and director were simply twisted round the bolt in the insulator and bolted down. Half an inch or so of the length is, presumably, lost by this method, but this does not appear to have affected the performance in any degree. The height available in the writer's loft was such that, in the desired direction the folded dipole could be accommodated vertically, but several inches at each end of both director and reflector had to be bent back to clear the slates. No unduly adverse effect seems to have been introduced by this expedient. Having taken some pains to construct a reasonably efficient aerial array there would be little point in using anything but a low-loss feeder cable. That finally selected was Ediswan pattern 75/CS/10. This is a particularly satisfactory cable both electrically and physically. The loss is stated to be 1db per 100ft at 50Mc/s, and the centre conductor is a single strand of tinned copper wire of 0.048 in diameter so that fracture of this conductor in use is most unlikely. It was ascertained from the makers that the propagation factor of this cable is 0.67.

The next step was to construct the balance-to-unbalance transformer section. For this, a quarter-wave length of cable was cut, the length being taken as

$$L \text{ (feet)} = \frac{246 \times .67}{f(\text{Mc/s})}$$

Taking the vision frequency of 61.75Mc/s the length became 2ft 8in. An extra inch or two of braid was left at either end for connecting up, and the quarter-wave length of cable was laid along the feeder cable at one end and taped to it. The braid "tails" were soldered up and the feeder and stub were connected to the ribbon dipole as shown in Fig 1, the surplus braid then being snipped off. A stout cord was arranged across the roof space to take the weight of the cable and enable it to be carried away at right-angles to the dipole until it reached a roof purlin to which it could be clipped up. From there it was run to the receiver position on the ground floor, where it was terminated in a Belling-Lee coaxial fitting.

The writer's location is some 200ft above sea level, and the height of the centre of the antenna is about 30ft. It has been in use for several months and, at a range of approximately 65 miles from Sutton Coldfield, has proved very satisfactory. Comparison with a home-built three-element beam erected outdoors at the same height showed only a very slight apparent increase in picture brilliance with the outdoor aerial. Results at this range vary, of course, from day to day, and evening viewing is much better than during daylight. However, results with the home-built Televisor seem to compare very favourably with those obtained with commercial receivers in the locality and used on standard outdoor "H" aerials. The aerial can, therefore, be unhesitatingly recommended to viewers within the main service area who do not wish to erect an outdoor array, and it is thought that it may also prove an interesting aerial for the experimenter sited in the fringe areas.

For completeness a table is appended giving the appropriate dimensions (based on vision frequency) for arrays for all the five channels. The writer has not constructed an array for any channel other than No. 4 (Sutton Coldfield) and in the case of the lower frequency channels (and Channel 1, Alexandra Palace, in particular) it will probably be found necessary to bend over quite an appreciable length of one or more elements in order to accommodate the aerial in the roof space normally available. This might well adversely affect the performance more than the six or seven inches of bending to which the writer had to resort.

	Channels				
	1	2	3	4	5
	45 Mc/s	51.75 Mc/s	56.75 Mc/s	61.75 Mc/s	66.75 Mc/s
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
Reflector ..	10 11	9 5½	8 8	7 11½	7 4½
Dipole ..	10 1½	8 7	8 0	7 5	6 9½
Director ..	9 10	8 6½	7 9½	7 2	6 7½
0.1λ	2 2	1 11	1 9	1 7	1 5½
0.15λ	3 . 3	2 10½	2 7½	2 4	2 2
"Balun" ..	3 8	3 2	2 11	2 8	2½ 5

Although the writer has not experimented with the matter, it is sometimes recommended that, instead of directly shorting the ends of the ribbon dipole with metal tabs, as has been done in this case, they should be connected across a small mica capacitor at each end. Other constructors may care to make the experiment, in which case it is suggested that a value of about 30pF at each end might be adopted as a starting point.

New Zoom Lens for Television

The B.B.C. will shortly add to its television outside broadcast equipment a new Zoom Lens. This device, when fitted to a television camera, enables any part of the scene to be magnified gradually up to five times its original size until a close-up view is obtained.

This lens is a prototype which is to be tried out during selected outside broadcasts. It is a wholly British development and is due to Dr. H. H. Hopkins, a lecturer at Imperial College, London, and the makers, Messrs. W. Watson and Sons, Ltd., of Barnet to whom Dr. Hopkins acts as optical consultant.

This new 5:1 Zoom Lens is a further improvement on the 2:1 Zoom Lens already in use by the B.B.C. Zoom Lenses of various sorts are in use in film production and American television, but the special feature of the new Zoom Lens is that its ratio of 5:1 is appreciably greater than that of any previous lenses and, moreover, the sharpness of the picture is far in advance of any before seen or used.

Some Aspects of Electrical Computing (Part 2)

By J. Bell, M.Sc., M.I.E.E. *

Conversion of a Mechanical into an Electrical Quantity and Vice Versa

In general a computation can only be carried out if the quantities dealt with have the same nature. The initial data may be electrical, but more frequently is mechanical, represented, for example, by the angular position of a shaft which may be constantly changing. It is necessary therefore to use devices which yield electrical quantities of the character chosen for a particular computation, corresponding in value to the mechanical or other input data.

The potentiometer, the Ipot and Resolvers already discussed can be used for this purpose, the potentiometer and Ipot both being capable of representing a linear conversion, or alternatively a non-linear conversion within the particular design limitations of each device.

Another instrument which has recently been developed is called a "Linvar." Its construction is very similar to the Resolver, but the magnetic design is such that instead of producing a sinusoidal output with angle, the output is linear over ±80 degrees of movement. Fig. 12 is a typical voltage/angle characteristic of this instrument.

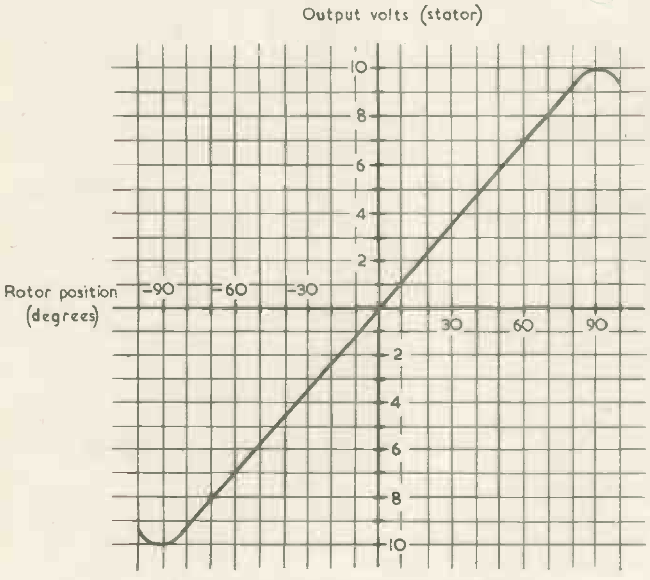


Fig. 12. Voltage/angle relation of Linvar

After a computation has been effected the answer must be given in an acceptable form and this usually involves the conversion of the electrical quantity into a mechanical quantity such as the setting of a shaft, the movement of an instrument or machine, the display of the quantity as on a dial or counter or its recording on a chart.

A simple form of such a convertor is a voltmeter, but in the more general case a servo is used as in Fig. 13 together with a suitable convertor (*C*) of mechanical to electrical quantities, the unbalance of voltage at any time existing between the computed voltage *V* and the output of the convertor *C* causing the servo to operate, the motor *M* driving the load or indicator *L* until balance is obtained. For further details of a servo suitable for this purpose see Appendix.

Many other convertors of different types of signal due to light, heat, pressure, etc., into an electrical quantity can be used in appropriate applications with non-linear functions being introduced, for example, by thermistors, but the extensive range of such applications cannot be covered in this paper.

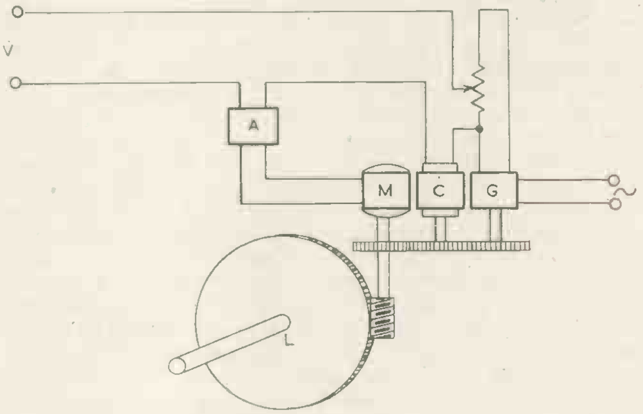


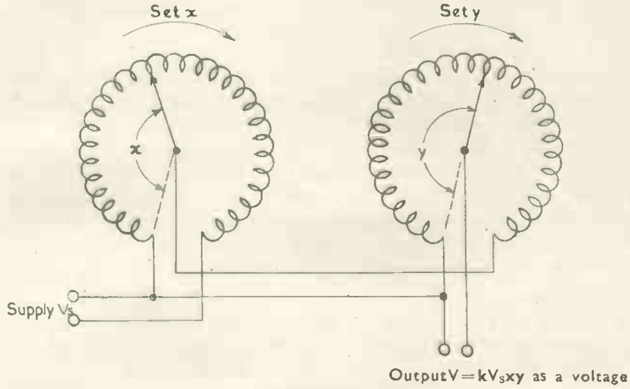
Fig. 13. Voltage to angle convertor

A point of importance in connexion with the conversion of data from mechanical into electrical form is that an amplification of power is possible using these devices. The mechanical input required can be quite small; for example, a Linvar may be operated over ± 60 degrees by a mechanical torque of the order of a few gr. cm. A relatively small movement such as may be given by the deflexion of a beam, diaphragm, etc., may be mechanically magnified or geared up to operate the converting device and a servo following the electrical output may be used in a variety of ways for recording or controlling purposes.

Examples of Computing Processes

These examples are given to illustrate the uses particularly of the newly developed devices. In some cases,

Fig. 14. Multiplication using two Ipots



* *Chief Research Engineer, Muirhead & Co., Ltd.*

where it is possible, however, a resistance potentiometer may be used instead of the Ipot shown.

Ipots

Figures 14, 15, 16, 17 and 18 show the use of Ipots for various functions.

Figure 14 is, as indicated previously, a normal multiplication, but the method can be extended to include a further number of Ipots, up to, say, 4 or 5, since the magnetizing current of the Ipot is sufficiently low not to introduce a serious drop in voltage on the first Ipot, particularly is this the case since it may be assumed that, in general, the Ipots beyond the first are excited from a lower voltage than the voltage applied to the first Ipot.

Figure 15 illustrates the use of an Ipot to obtain reciprocals. The range of reciprocals is, of course, limited, since, as the input approaches zero, the output is required to approach infinity. In practice, the step-up ratio is limited to approximately 6, and the supply voltage in this case, therefore, must be one-sixth of the rated voltage on the Ipot.

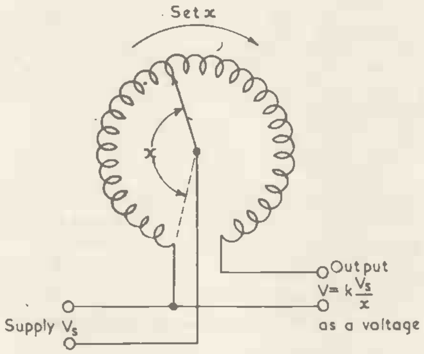


Fig. 15. Reciprocals using one Ipot

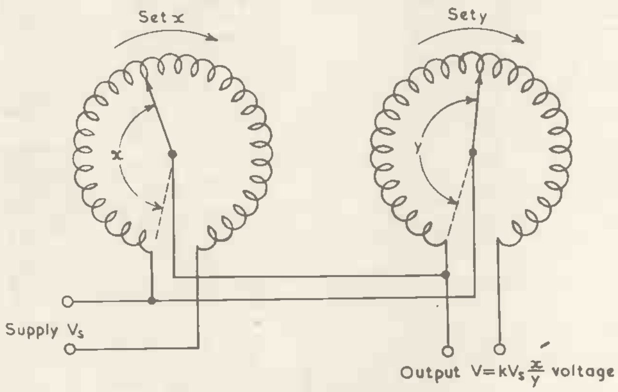


Fig. 16. Division using two Ipots

Figure 16 is a combination of Figures 14 and 15, illustrating the use of two Ipots for division.

Figure 17 is included to indicate the use of Ipots in association with transformers, to obtain a characteristic mathematical expression. In the *Proceedings of the Royal Society* (Vol. 1401 page 457, 1933), Dr. Mallock describes a combination of specially constructed transformers to obtain a similar expression. The Ipot is, however, a much neater device than the special transformers with decade tappings as used by Dr. Mallock.

Figure 18 shows alternative arrangements of Ipots to produce non-linear functions.

Figure 18(a) indicates a normal Ipot in which the second contact is operated by an auxiliary drive which, in effect, determines the scale or slope of the Ipot winding. If the drive to this contact is suitably linked by a cam or other mechanism to the main contact drive then the output from the Ipot is a variable or graded function, but if the drives are not so linked the output is a function of two variables.

Figure 18(b) shows another method of operation in which the output voltage is the sum or difference of x and a function y.

Figure 18(c) indicates the Ipot used in the normal way but having an unusual winding. Instead of the winding being uniformly spaced, it is spaced according to some desired law. There are obvious limitations to the type of law which can be reproduced. The voltage gradient cannot exceed the gradient of a normal linear Ipot, but by winding the turns further apart, a reduction of this slope

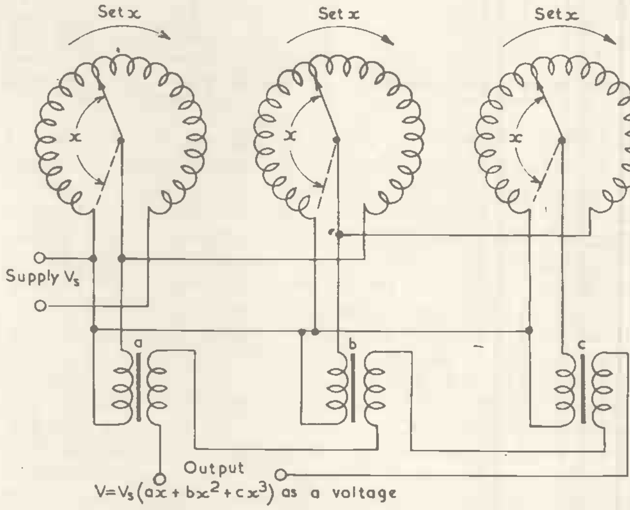


Fig. 17. Multiplication and addition using Ipots and transformers of ratio a, b and c

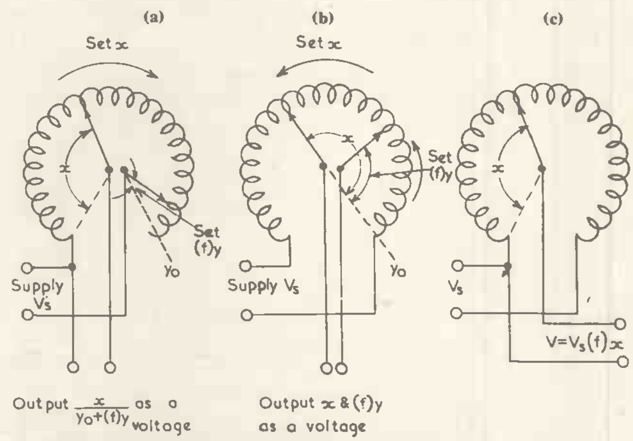


Fig. 18(a) and (b). Non-linear functions by operation of second contact; (c) non-linear function by grading of winding

to about one-fifth can be obtained and, for example, a portion of a square law, or in ballistics a range/time of flight function can be reproduced.

Resolvers

Figures 5, 6, 19 and 20 indicate the use of Resolvers.

As explained above, the No. 1 Resolver cannot be used for precise working on varying voltages, because of the variations of the electrical losses arising largely from the varying permeability of its iron circuit.

The No. 2 Resolver, however, associated with its feedback amplifiers obviates this trouble by drawing current from the amplifiers according to the magnetization requirements.

Referring to Figure 5, it will be seen that the resolution

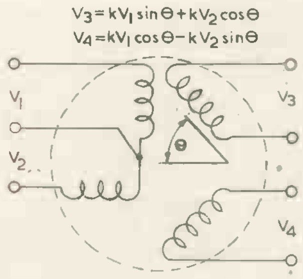


Fig. 19. Resolver No. 1 resolution to new axes

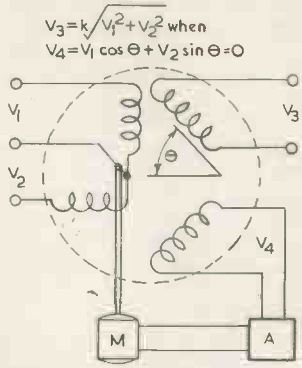


Fig. 20. Resolver No. 1 resolution of Cartesian to Polar

from Polars to Cartesians is indicated, the Resolver No. 1 being excited on one phase of the rotor while, normally, the other phase is short-circuited. An alternative use of the same Resolver is shown in Figure 19, where the rotor is excited from two voltages, one applied to each phase, the combined flux producing corresponding voltages in the two-phase winding of the stator, according to the relative angle between rotor and stator winding axes. Since the applied voltages to the rotor are variable, accuracy of combination is low, and the overall accuracy is of the order of one half to one degree.

Figure 20 indicates the use of the same Resolver for converting Cartesians into Polars. The accuracy again is of the order of one degree, since the input voltages vary from zero to the rated maximum. The figure includes a servo providing automatic operation of the rotor. The winding *V*4 supplies an amplifier and causes motor *M* to run until the voltage in *V*4 is zero. The angle of the rotor thus represents the polar angle, and the voltage on the winding *V*3 indicates the magnitude.

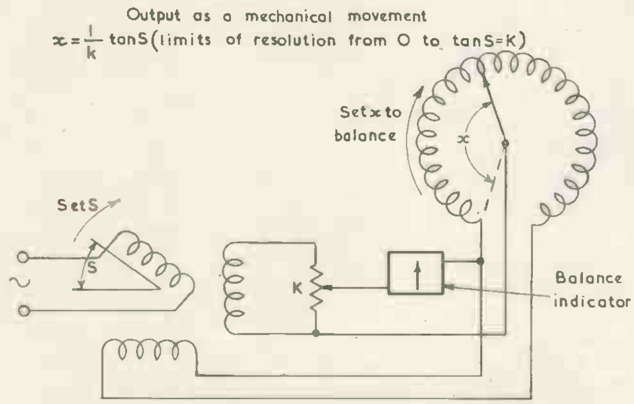


Fig. 21. Resolution by magslip Resolver and Ipot to tangent

Figure 6 shows the use of Resolver No. 2. This figure corresponds to Figure 5, but here the voltage applied may vary from zero up to the maximum rating of the instrument without loss of accuracy. The stator is used for excitation and it is wound with a two-phase winding, having duplicate coils in each phase, as explained above. The applied voltage, V_1 is balanced against the voltage generated in the Resolver, the difference serving as an input to the amplifier. The amplifier gain is of the order of 200, thus for a very small difference in voltage, current is produced which excites the Resolver to the required intensity. In the case shown in Figure 6, no input is applied to the auxiliary winding of the second phase, and current will flow from the amplifier to the exciting winding, in order to maintain zero voltage—thus any reaction, due to load current or inequalities of magnetic circuit in the instrument, will be effectively neutralized by the use of the second amplifier. It will be obvious that the No. 2 Resolver can be used in the other applications shown in Figs. 19 and 20, and with this Resolver, the error, instead of being of the order of one degree, will not exceed three minutes of arc.

Resolver and Ipot

Fig. 21 shows an application of these two devices to determine the tangent of an angle. Here the Resolver provides the sine and cosine of the angle and by means of the Ipot the former is divided by the latter. In this diagram it is implied that the settings of Resolver and Ipot are performed manually, aided by a visual balance indicator; it

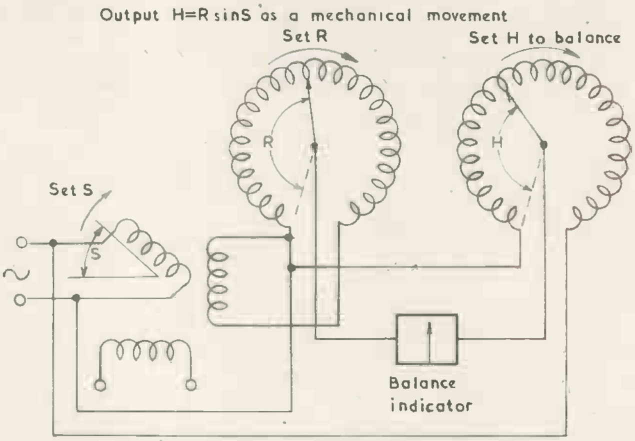


Fig. 22(a). Range to height convertor using magslip Resolver and two Ipots

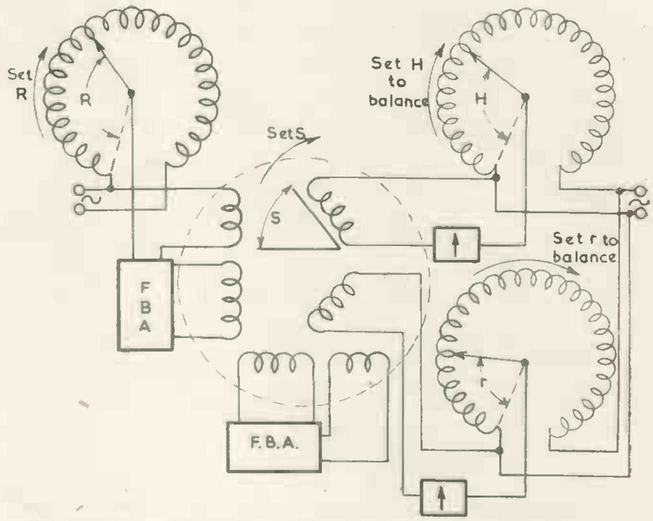


Fig. 22(b). Range to height and ground range convertor using No. 2 Resolver

will be obvious, however, that the action can be made automatic by the addition of an amplifier and servo motor. *K* represents a voltage divider of ratio *K*.

Figs. 22(a) and (b) illustrate the first part of the anti-aircraft predictor problem discussed above, namely range to height conversion. In Fig. 22(a) the No. 1 Resolver is used and the answer *H* is given by the setting of the second Ipot when the voltage is balanced. If two further Ipots are connected in association with the cosine winding of the Resolver then the ground range is also determined. Servos, of course, may be added if desired.

Fig. 22(b) is the corresponding diagram using the No. 2 Resolver. It will be seen that the range is set on one Ipot

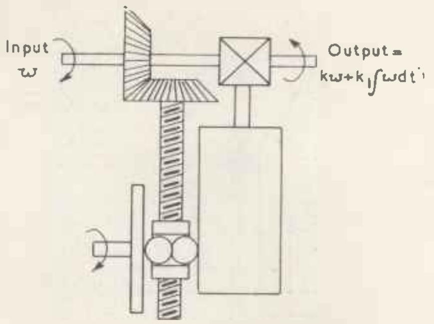


Fig. 23(a). Aided laying (mechanical)

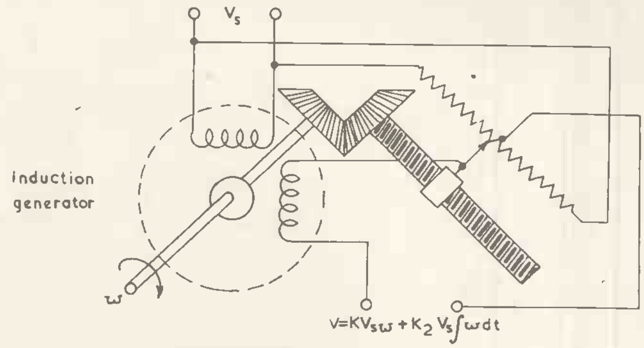


Fig. 23(b). Aided laying (electrical)

only and that the Resolver operates on this voltage producting directly voltages proportional to height and ground range.

Target Following or "Laying"

It has been found by those experienced in the art that "laying" on a target can be greatly simplified by means of a mechanical device which consists of a combination of "velocity" and "direct" laying. The device is such that if the target being followed moves at a constant angular velocity this velocity will eventually be set automatically by the operator in following the target and henceforth he has no further operation to perform until the target changes speed.

The mechanical arrangements and its electrical equivalent are shown in Figs. 23(a) and (b). In the mechanical case, the direct laying passes straight through the differential gear, but at the same time a parallel drive alters the position of the ball carriage in the "disk, ball and cylinder" mechanism. A constant speed drive is applied to the disk and hence the cylinder is frictionally driven at a variable controlled speed; the cylinder drives into the differential and thus the output is a combination of "direct" and "velocity" or integral terms. In the electrical case the Induction Generator gives the "direct" term and the contact position on the potentiometer (or Ipot) gives the "velocity" term. The potentiometer is centre-tapped to provide for ± voltages corresponding to clockwise and anti-clockwise rotations in the mechanical case.

An arrangement of this type might be used for process or mechanism control where a second equipment or mechanism is required to follow the motions of a "master" without oscillation.

Vectorial Addition

As seen above, the Resolver No. 2 may be excited pre-

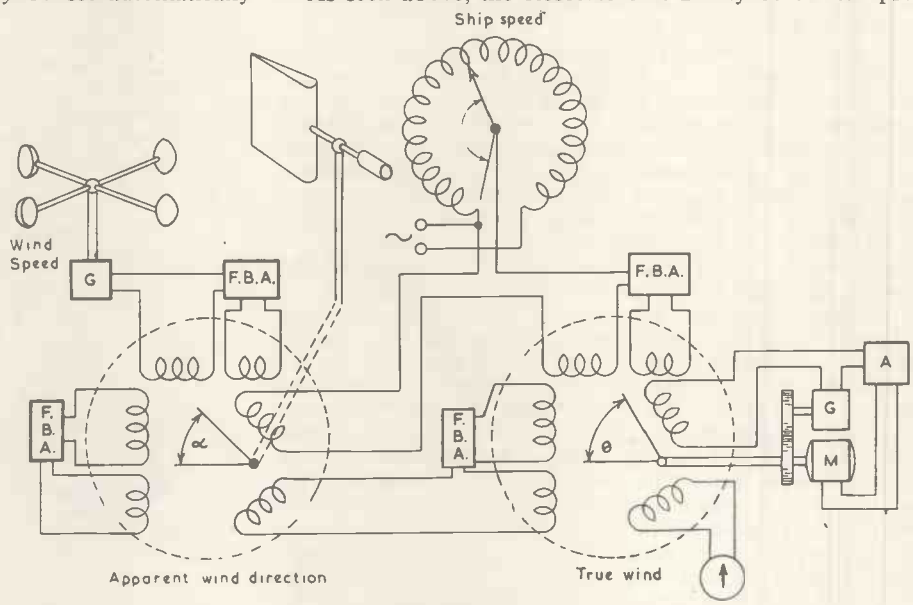
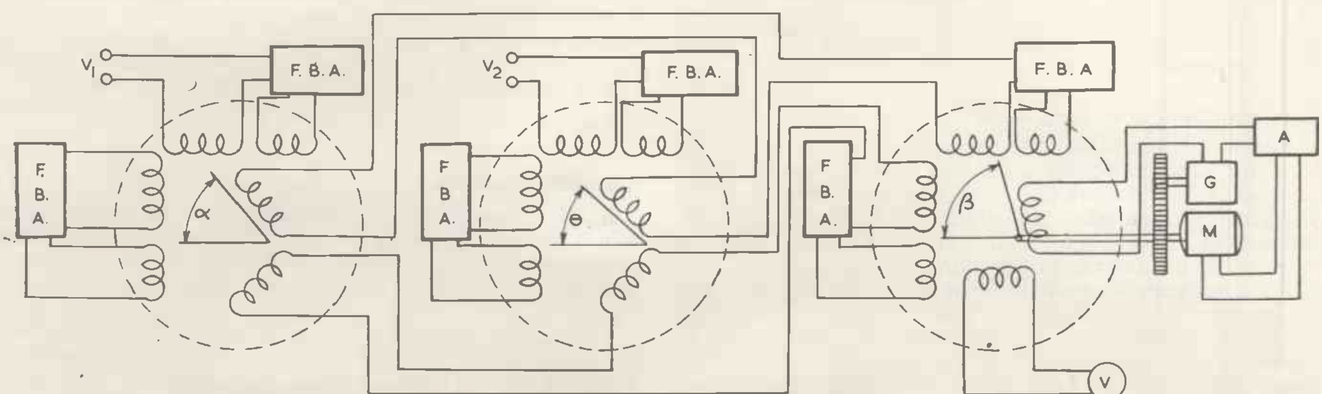


Fig. 24(b). Wind resolution

Fig. 24(a). Vectorial addition



Vectorial addition $\bar{V} = \bar{V}_1 + \bar{V}_2 = \sqrt{(V_1 \sin\alpha + V_2 \sin\theta)^2 + (V_1 \cos\alpha + V_2 \cos\theta)^2}$

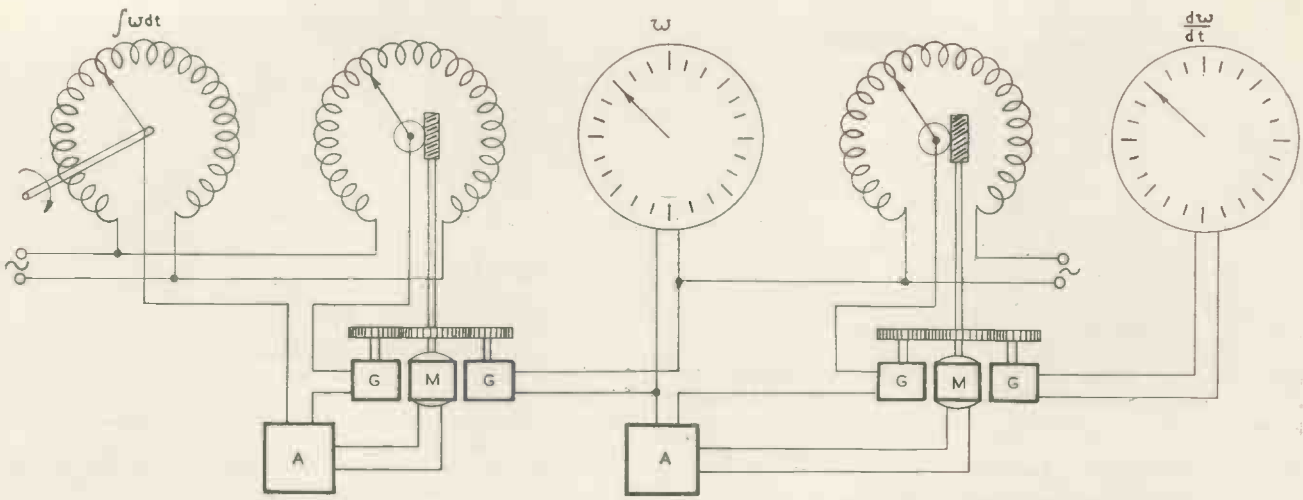


Fig. 25. Differentiation

cisely having a magnetic flux proportional to a given input voltage. Its rotor windings may also be set at any angle to the stator windings or a given datum position; hence the instrument may be used to represent a vector quantity both in magnitude and angle.

If two (or more) Resolvers are used in this way, the applied voltages V_1, V_2, etc., having the same time phase, the corresponding rotor phases of each Resolver may be connected in series as indicated in Fig. 24(a) and the sum taken to excite the final Resolver stator. A servo connected to the rotor of this resolver will run to zero balance, giving the vector angle of the summation and the magnitude will be given by the voltage generated in the other rotor phase. The voltage may be represented as a mechanical output if another servo is added to balance the generated voltage by means of, for example, an Ipot.

A wind Resolver for use on ships for converting "apparent" to true wind, may be regarded as a special case of vector addition where the second vector always has a known angle and hence the second Resolver is not necessary. Fig. 24(b) shows the wind Resolver diagrammatically. Here the anemometer drives a generator producing an alternating voltage proportional to the apparent wind speed. This is fed to a No. 2 Resolver, the rotor angle of which is set to apparent wind direction; the output voltages from the Resolver are thus apparent wind along the fore and aft line of the ship and apparent wind athwart the ship. An Ipot is set, or generator driven, according to ship speed and its voltage added to the apparent wind along and the new component voltages are then combined in a second No. 2 Resolver, the rotor of which is servo driven to a zero balance on one winding. The true wind direction is thus given by the rotor angle and its strength or velocity by the voltage which appears in the other winding.

Differentiation and Integration

The measurement of rate or speed has been examined, and the last method mentioned is a differentiating R/C network. The process can, however, be carried out with the generator and servo technique with greater freedom or latitude in the parameters and successive stages may be used to obtain the second and third derivatives.

An arrangement of this kind is shown in Fig. 25. The voltage to be differentiated is given by an Ipot and may represent a mechanical movement or the position of an object in space measured from a given datum. In the first stage of differentiation the voltage is opposed by a voltage from a second Ipot which is servo driven, a feed-back velocity generator being used to stabilize the servo. A second generator is driven by the servo motor and its voltage is a measure of the rate of change of the initial Ipot voltage. This servo arrangement may at first sight appear to be redundant as the speed at which the servo operates is merely proportional to the speed of the initial input shaft. In some cases, however, it may not be possible to take power from this shaft and the movement may also be smoothed by the servo.

Using the generated voltage a second servo arrangement may be employed, as shown, to obtain the second derivative and so on for the third.

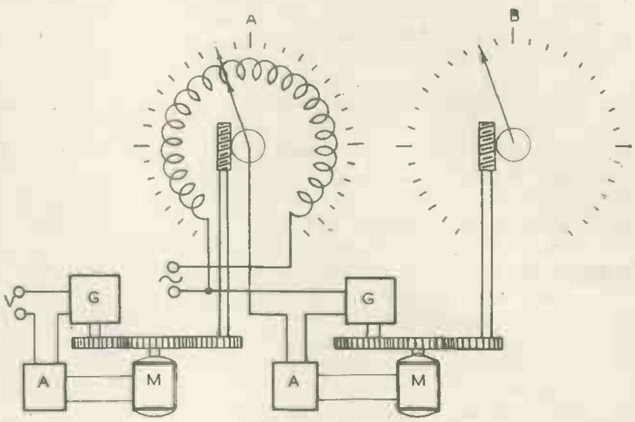


Fig. 26. Integration

Fig. 26 shows the same devices applied to integration. Suppose the input voltage V represents an acceleration derived from a mechanism, or the ordinate of a chart which is being traversed, the first servo shown will integrate the voltage indicating the integral on the dial A. An Ipot is shown also driven by the servo; this is arranged to give a voltage proportional to the first integral and is used as the input to the second servo, the second integral being shown in dial B.

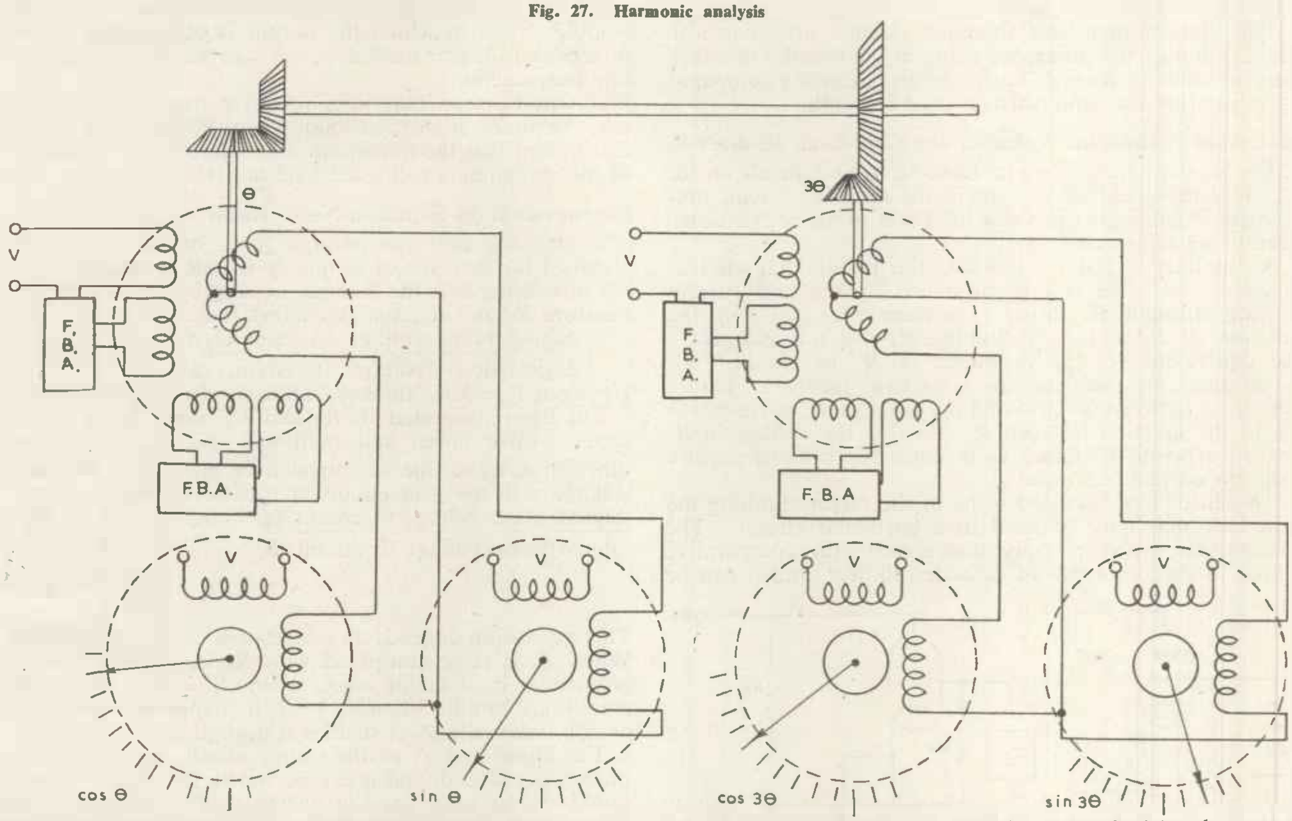
Harmonic Analysis

Graphical harmonic analysis is carried out in a well-known manner by integrating $\sin^2$ and $\cos^2$ terms for the fundamental and any desired harmonics. This method can be made automatic and is shown diagrammatically in Fig. 27.

A waveform or curve to be analysed may be represented by an alternating voltage V and it is assumed that the period of cyclic repetition of this voltage is known or can be estimated. Referring to the diagram, this voltage is applied to many points marked V and as the voltage curve is traversed through its period or cycle, the mechanical shaft is also turned synchronously so that during the cycle the rotor of the Resolver marked θ is rotated through one revolution.

The rotor of the next Resolver, marked 3θ is rotated during the same period through three revolutions and subsequent Resolvers may be geared 5:1 and 7:1, etc., for analysing the higher harmonics, fifth, seventh, etc. It will be observed that each Resolver is excited from the input voltage V and the outputs both sin and cos of each Resolver are taken individually, each to a two-phase motor or indicator. The indicator is fed also with the same voltage V and the indicator will run at a speed during every instant proportional to the instantaneous product of V and $V \sin\theta$ (or $\cos\theta$). The indicator or motor thus effectively integrates over the whole cycle the sin squared or cos squared function of θ. The resulting readings of the two indicators relating to θ, therefore, give the constants in the analysis of the sine and cos terms of the fundamental.

Fig. 27. Harmonic analysis



The succeeding indicators associated with the 3θ Resolver give the corresponding constants for the third harmonic and so on.

Appendix

Notes on Servos

In a practical case of a servo such as used generally for computing purposes, the range of voltage over which the computed voltage (V) operates may be, say, 50 volts. The amplifier can be arranged to give maximum output for something like 50 millivolts input. Thus, if the difference in voltage is 50 millivolts between the convertor (C) in Fig. 13, and the applied voltage (V), the motor will generate full torque.

It is usually arranged that the motor employed is capable of giving an output of at least twice the static friction torque required to operate the device. In can, therefore, be assumed that when the servo has come to rest, no greater difference than 25 millivolts exists between the voltage (V) applied and the convertor (C). This represents approximately 1/2000th of the range of the applied voltage and is a determining factor in the accuracy of setting of the device. It also implies that the gain in the amplifier must be of the order of 1,000 if the motor operates on 50 volts.

In such a servo stabilizing means are necessary and either of two methods is in common use. For 50 cycle servos, it is usual to employ an induction generator, as described above, which is coupled mechanically to the motor (M) shown in Fig. 13, and rotates when this motor is driving the load. The voltage generated is fed into the amplifier input in series with the opposing voltages (V) and (C) in such a manner that the voltage of the generator (G) tends to diminish the input to the amplifier. This has the effect of retarding the motor (M) as it is approaching a balanced position and consequently preventing hunting, but in the balanced position the generator has no output and consequently it does not interfere with the precision of setting of the servo. The proportion of the generator voltage which is used in this way may be controlled by the use of a potentiometer as shown in Fig. 13 and the servo may be over, under or critically damped. The effect of the generator may be regarded as the equivalent of a time-lag and, in a practical case, this may amount to approximately 1/20th second.

The other method of stabilizing, in common use, can be employed where a higher frequency than 50 cycles is used in the computing circuits. It operates satisfactorily from 300 cycles upwards. The stabilization is effected in the amplifier itself. The signal is rectified and differentiated. A combined signal then proceeds to the power stages of the amplifier for supplying the motor. The differentiated signal causes a larger output to be given to the motor under conditions of acceleration and a smaller output under conditions of retardation. The balance between the smoothing and differentiating parts of the circuit in the amplifier is somewhat critical for 300 cycles, but is nevertheless quite practical. The equivalent time lag of a phase advance amplifier can be of the order of 1/100th second.

Cathode-Followers as Low-Noise Input Stages

By M. J. Tucker, B.Sc. *

IT is the purpose of this article to point out that in certain circumstances where a high-impedance low-noise input stage is required, a fairly well-known but comparatively little used modification of the conventional cathode-follower circuit can give a very much improved performance. Gains in signal-to-noise ratio of the order of 20db can sometimes be obtained, and the modified circuit possesses some other advantages: the advantages and disadvantages are summarized at the end of the article. The modification is particularly applicable to the first stage after a piezo-electric crystal pick-up.

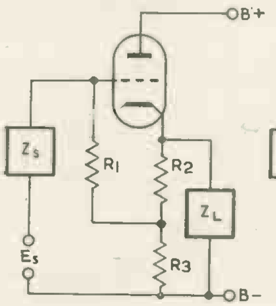
The conventional and modified circuits are shown in Fig. 1(a and b), the difference being in the manner in which the grid bias is obtained. Their performances are compared assuming that the same valve is used for both.

Maximum Permissible Value of the Grid-Leak Resistor

The improvement in signal-to-noise ratio depends on the fact that the grid-leak resistor in the modified circuit may be made much higher in value than that in the conventional circuit (see references).

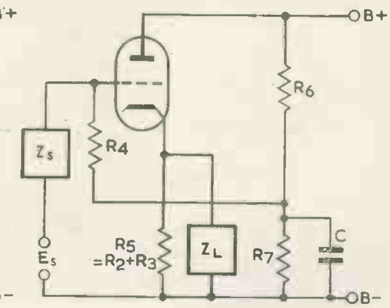
A simplified explanation of why this is so is that whereas in circuit "a" the voltage produced by the grid current flowing through R_1 appears between the grid and the junction of R_2 and R_3 (assuming Z_s will not pass D.C.), the equivalent voltage produced in R_4 in circuit "b" is considerably reduced by negative feedback before appearing between the grid and the point on R_5 corresponding to the junction between R_2 and R_3: the voltage in R_4 has therefore to be larger to produce the same departure from the correct bias point.

Crawford[2] has discussed some of the factors limiting the grid leak that may be used in a particular circuit. The present discussion is only concerned with comparative values in the two types of cathode-follower, and it can be



(a)

Fig. 1(a). Conventional Circuit



(b)

Fig. 1(b). Modified Circuit

shown that as far as grid-current is concerned, R_1 is equivalent to an impedance of $(1 + G)R_1$ in the position of R_4, where G is the voltage gain of the valve defined as the ratio of the voltage across R_3 to that across R_1. G may be complex if Z_L is complex. If Z_L is high, as, for example, will be the case if the output is resistance-capacitance coupled to another valve grid, the gain is approximately constant and is a real number so that the circuits will have the same stability if $R_4 = (1 + G)R_1$. The input impedances will be equal in this case.

If G varies with frequency the relationships become complicated, but it will usually be safe to use the same formula if the value of G taken is the lowest value of its modulus (i.e., its value neglecting phase) within the frequency range over which instability need be feared. This frequency range, which always starts from D.C., extends to a frequency dependent on the type of grid current predominating and on other factors. A practical upper limit is, however, fixed by the fact that grid current cannot in any case cause oscillation at frequencies where the capacitance of the grid circuit to earth has an impedance considerably less than R_1. A type of circuit that might give trouble is one in which the output is capacitance-coupled to a transformer: such a circuit can have a low gain at low frequencies.

It will be seen that in a properly designed circuit R_4 may be made higher in value than R_1 by quite a large factor, and that the maximum obtainable input impedances of the two circuits will usually be similar.

Improvement in Signal-to-Noise Ratio

In deriving the relationships given below, it has been assumed for the sake of simplicity that $R_1 \gg R_3$.

Considering first the thermal noise produced by the leak resistors R_1 and R_4, analysis shows that:

$$\frac{\text{Signal/noise voltage in circuit (b)}}{\text{Signal/noise voltage in circuit (a)}} = \sqrt{(R_4/R_1)}$$

If we put $R_4 = KR_1$, this represents an improvement of $\sqrt{K}$.

For noise generated in R_2 and R_3, noise from the H.T. supply, valve noise, and hum and microphony voltages other than those due to capacitative pick-up or resistance leakage into the grid circuit, it can be shown that:

$$\frac{\text{Signal/noise voltage in circuit (a)}}{\text{Signal/noise voltage in circuit (b)}} = R_4/R_1 \left| \frac{Z_s + R_1}{Z_s + R_4} \right| = K \left| \frac{Z_s + R_1}{Z_s + KR_1} \right|$$

This expression depends on the relative values of Z_s and R_1. When Z_s is large compared with R_1 it represents an improvement by a factor of K, when $Z_s = R_1$ it is approximately 1/2 or 6db, when $Z_s = jR_1$ it is approximately $1/\sqrt{2}$ or 3db, and when Z_s is small it is negligible.

The impedance Z_s of the source usually rises as the frequency is reduced, and it can be shown that in the conventional circuit this causes a corresponding increase in the noise level at low frequencies. It is under just these circumstances that the modification results in the greatest improvement.

In the modified circuit, noise from the H.T. can reach the grid through the potential divider supplying the bias, but as the resistors can be made reasonably high in value the bias voltage is easily decoupled. For very low frequency work the bias may, if necessary, be obtained from a battery: an "Ever Ready" 30 volt unit type B 123 is suitable and has approximate dimensions of 2½in. by 1⅛in. by ⅝in.

Hum, microphony, and noise voltages produced by capacitative pick-up or resistance leakage into the grid circuit are not reduced by using the modified circuit, and noise generated in Z_s is, of course, indistinguishable from signal and cannot be reduced by any input circuit.

As a practical point it should be borne in mind that ordinary composition carbon resistors tend to be noisy, particularly when carrying currents, and should not be used anywhere in the first stage of a low-noise circuit. In

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the author's experience, cracked carbon resistors are reasonably satisfactory in this respect, and can be obtained with values up to 100 megohms or more, according to the manufacturer.

Other Advantages

In the conventional circuit, the input impedance is dependent on the gain and hence on the load impedance, and the output impedance is dependent on the ratio of the source impedance Z_s to the grid leak R_1. This means that both the input and output impedances may vary with frequency, whereas in the modified circuit they are independent of frequency except for the small effect of the grid-cathode capacity.

Summary

The maximum obtainable input impedances of the two circuits are very similar.

The modified form of the cathode-follower possesses the following advantages:

(a) A considerable improvement in signal-to-noise ratio is obtained except in certain cases where the source impedance is low compared with the resistance of the grid-leak resistor in the conventional circuit. "Noise" includes resistor noise, valve noise, fluctuations derived from the H.T., and hum and and microphony from certain sources.

(b) The input and output impedances are independent of frequency.

The disadvantages are:

(a) Two more components are required.

(b) The insulation must be maintained across a higher value grid resistor, (even in the conventional circuit this high insulation has to be maintained between the rest of the grid circuit and earth.)

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2 Crawford, K. D. E. "H.F. Pentodes in Electrometer Circuits." *Electronic Engineering*, *20*, 227, 1948.

3 Tucker, M. J. "A High Sensitivity Photo-electric Cell Circuit." *Electronic Engineering*, *20*, 401, 1948.

Appendix

The derivation of the formula for the improvement in signal-to-noise ratio considering thermal noise in the grid-leak resistors will be given. The derivation of the formula for the other sources of noise is on similar lines.

The thermal noise in R_1 will be considered as a voltage E_N in series with R_1, and that in R_4 as a voltage E_M in series with R_4. E_L is the voltage developed across the load Z_L, E_{GC} the voltage between the grid and cathode of the valve, E_{GE} the voltage between the grid and earth (B −), and E_3 the voltage developed across R_3.

If G is the voltage gain of the valve defined by

$$E_L = G\,E_{GC}$$

then $$E_{GE} = E_L\,(1 + 1/G)$$

It will be assumed that $R_1 \gg R_3$, in which case

$$E_3 = E_L R_3/(R_2 + R_3)$$

Z_S and R_1 form a potential divider on to the grid of the valve, so that

$$E_{GE} = (E_N + E_3)\ Z_S/(Z_S + R_1)$$

Substituting for E_{GE} and E_3

$$E_L(1 + 1/G) = [E_N + E_L R_3/(R_2 + R_3)]\,Z_S/(Z_S + R_1)$$

Simplifying

$$E_L = E_N Z_S/[(1+1/G)(Z_S+R_1) - Z_S R_3/(R_2+R_3)] \quad \ldots\ldots (1)$$

Considering now the output produced by E_S

$$E_{GE} = E_S R_1/(R_1+Z_S) + E_3 Z_S/(R_1 + Z_S)$$

Substituting for E_{GE} and E_3 and simplifying

$$E_L = E_S R_1/[(1+1/G)(Z_S+R_1) - Z_S R_3/(R_2+R_3)] \ldots\ldots (2)$$

Dividing Equation (2) by Equation (1)

$$\text{Signal/noise in circuit (a)} = E_S R_1/E_N Z_S \quad \ldots\ldots\ldots\ldots (3)$$

Considering the output due to the noise voltage E_M in circuit (b)

$$E_{GE} = E_M Z_S/(R_4 + Z_S)$$

or $$(1 + 1/G)E_L = E_M Z_S/(R_4 + Z_S) \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

The output produced by E_S is similarly

$$(1 + 1/G)E_L = E_S R_4/(R_4 + Z_S) \quad \ldots\ldots\ldots (5)$$

Dividing Equation (5) by Equation (4)

$$\text{Signal/noise in circuit (b)} = E_S R_4/E_M Z_S \quad \ldots\ldots\ldots\ldots (6)$$

Dividing Equation (6) by Equation (3)

$$\frac{\text{Signal/noise in circuit (b)}}{\text{Signal/noise in circuit (a)}} = \frac{E_S R_4}{E_M Z_S}\cdot\frac{E_N Z_S}{E_S R_1} = \frac{E_N}{E_M}\cdot\frac{R_4}{R_1}$$

Now the thermal noise voltage produced by a resistor R is proportional to $\sqrt{R}$, so that $E_N/E_M = \sqrt{(R_1/R_4)}$, and

$$\frac{\text{Signal/noise in circuit (a)}}{\text{Signal/noise in circuit (b)}} = \sqrt{(R_4/R_1)}$$

R.F. E.H.T. Unit for 0.5-3 kW

Information received from the Atomic Energy Research Establishment, Harwell, describes an R.F., E.H.T. power unit suitable for supplying counters and photo-multipliers with the necessary operating voltage. It has been designed to provide a high degree of stability of voltage over long periods and to have a low level ripple and spurious pulses at the output. It is of sound construction for use in laboratories in the tropics.

The high voltage is generated by an oscillator working into an R.F. transformer with a high step-up ratio. The output of the transformer is rectified and fed to the output terminal through an accurate potentiometer.

A fraction of the output voltage is compared with the voltage of a Mullard 85A1 neon running at constant current. The difference between these two voltages is amplified and used to control the oscillator amplitude and thus stabilize the D.C. output.

A stabilized low voltage H.T. supply is provided for the directly connected amplifier, oscillator and reference neon.

There are two output voltage ranges—one covering 500 to 1,500 volts, and the other from 1,000 to 3,000 volts, positive or negative. The voltage at the low impedance point will not differ from the nominal voltage read on the potentiometer dials by more than 1 per cent. This voltage will not drift by more than 0.1 per cent in a period of 24 hours, excluding the first half-hour after switching on, due to all causes including mains variations not exceeding 10 per cent.

The D.C. output impedance is less than 5,000 Ω at low impedance point. The maximum current that can be drawn at the output is one milliamp in the 500-1,500 volts range and 500 microamps in the 1,000-3,000 volts range.

The peak to peak ripple level at all frequencies at the low impedance point is less than 1 part in 10^6 of the D.C. component. The components at frequencies higher than 1,000c/s. is less than 1 part in 10^7 of the D.C. component.

Full particulars may be obtained on application to the Atomic Research Establishment, Harwell, Berkshire, mentioning A.E.R.E. Specification No. 115.

Auxiliary Circuits for *p*H Meter

By G. P. Burn *

THE *p*H meter itself is assumed to consist only of an impedance convertor. This article describes the additional circuits which are necessary to enable the meter to read *p*H directly. They are:

(1) An indicating meter with suitable multiplier.

(2) A potential that is equal and of opposite sign to that of the electrode system.

(3) A circuit to increase the sensitivity of the measurement.

When *p*H is measured, a cell is set up, usually of the following form:

Pt/*N* HCl/glass/unknown solution/saturated KCl/AgCl-Ag

The first three items in this cell constitute a glass electrode, which has a potential of the order of 700 millivolts. The last two items are a form of silver electrode which has a potential of about 250mV. These potentials act in opposition giving a net value for the electrode system of about 450mV, the glass electrode being positive with respect to the silver. Now, if the unknown solution is normal HCl, it is desirable that the *p*H meter should read zero. Hence, an extra potential is needed to back off that due to the electrode system, and it is introduced into the feedback circuit of the impedance convertor, which is in series with the measuring cell.

In practice, the adjustment is best made by substituting a known buffer solution, say *p*H4, for the unknown solution, and then altering the backing off potential until the meter reads " 4 ". The relevant control knob may be called " Set Buffer ".

The Temperature Coefficient

The potential arising between two solutions of different hydrogen ion concentration is governed by the following formula:

$$E = 0.1983\, T \log \frac{[H^+]_A}{[H^+]_B} \text{ millivolts} \quad \ldots\ldots\ldots \quad (1)$$

where *T* is the absolute temperature and *A* and *B* are the two solutions. If the concentration of hydrogen ions in *A* is 10^{-1} units of hydrogen per unit volume of solution, and in *B* is 10^{-2} units, then the ratio of these is 10. Since the log of 10 is 1, Equation (1) reduces to:

$$E = 0.1983\ T \text{ millivolts} \quad \ldots\ldots\ldots\ldots \quad (2)$$

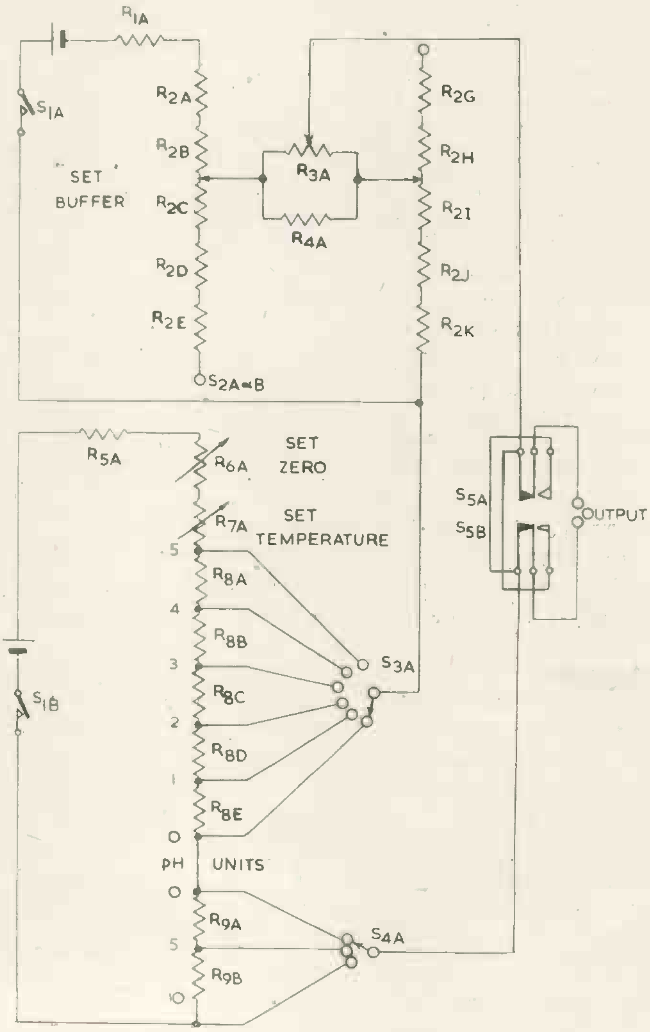
At 0°,

$$E = 0.1983 \times 273 = 54.14\text{mV}$$

This is the potential produced between two solutions at 0°C, the ratio of whose hydrogen ion concentrations is 10. Such solutions are also said to differ by a *p*H of 1.

Over a range of 0°C-40°C, one *p*H unit will give from 54-62mV. Consequently, the meter must contain a suitable shunt so that it can be made to read one *p*H unit regardless of the temperature (a series multiplier can also be used).

The ranges to be provided on a *p*H meter depend partly on the stability of the impedance convertor used, and partly on the accuracy required. The instrument considered drifts 1mV in about 30 minutes. This corresponds to about 0.02 of a *p*H unit. The indicating meter used is 100μA F.S.D., 3½in. diameter, and has a scale marked 0-100, with 50 divisions. It is convenient to have one range of 0-10*p*H units, and a second range 0-1*p*H unit. The first range may be used directly; but for the second range there must be a device to allow for any number of *p*H units up to about ten, the meter reading only being used to interpolate between these fixed units. A resistance chain is employed, developing 54-62mV per *p*H unit, according to the temperature of the electrodes. The polarity of this voltage is such as to offset that due to the junction between the solutions.



R_{1A}	1.8kr	±5%
R_{2A-L}	150Ω	±5%
R_{3A}	9kr pot.	12 watts
R_{4A}	220Ω	±5%
R_{5A}	470Ω	±5%
R_{6A}	1kr pot.	5 watts
R_{7A}	400Ω pot.	5 watts
R_{8A-E}	150Ω	±0.1%
$R_{9A,B}$	750Ω	±0.1%
R_{10A}	4.7kΩ	approx.
R_{11A}	220Ω	±5%
R_{12A}	1kΩ	±5%
R_{13A}	1kr pot.	5 watts

$S_{1A,B}$	DPST	On/Off
$S_{2A,B}$	DP 7-way	Set Buffer Coarse
S_{3A}	SP 6-way	5×1*p*H unit
S_{4A}	SP 3-way	2×5*p*H units
S_{5A}	DPDT	Reversing Switch
S_{6A}	SPDT	Range Switch

Fig. 1. Auxiliary Potentiometer Circuit

* *Dept. of Pharmacology, Oxford.*

The Stability of the Auxiliary Potentials

On the more sensitive range, one meter division represents about one mV. The potential that backs off the cell voltage (about 450mV) must be provided in such a way that it can be set to at least one order of magnitude lower than one mV, i.e., 0.1mV, and it must be stable to a similar order.

Now on a high-resistance wire wound power potentiometer of 3in. diameter, there are about 1,500 turns. If each turn correspondes to 0.1mV, then there may be 150mV across the potentiometer. An additional switch must be provided to give, say 100mV per step. There will need to be about seven steps.

On account of the high order of stability required, ordinary carbon resistors should not be used anywhere in the apparatus.

In Fig. 1, there are two main circuits, energized by two separate 1½ volt dry batteries, and connected in series. The resistors used are of low value, because it is not desirable to introduce too much impedance between the output terminals. The *Set Buffer* fine adjustment is a high resistance potentiometer, shunted by a low resistor, so that it develops about 150mV maximum. This is permissible as no current is drawn from the output terminals.

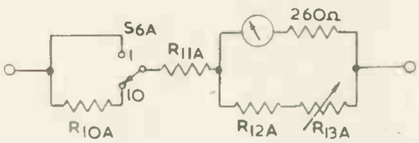


Fig. 2. Indicating Meter Circuit

In determining the value of the indicating meter shunt (*R*12 and *R*13) it is convenient to ensure that at all times it has a finite value. Consequently, the meter is always partially shunted, so the multiplying resistors should have slightly lower values than if the shunt was open circuited at the low temperature end.

In order to be able to read one *p*H unit full scale the indicating meter must be sufficiently sensitive only to need about 50mV for such a reading. The meter used here requires only 26mV. If a less sensitive meter is to be used, e.g., one requiring 75mV full scale, which is in accordance with a standard system, the minimum range will have to be raised to, say, 0-2*p*H units.

Calibration

First calibrate the indicating meter shunt *R*13. Set *S*6A to the one *p*H unit range, set *R*13 to its maximum, and apply 54.1mV to the input of the impedance convertor. Now adjust *R*13 until the meter reads *p*H1. This point on *R*13 corresponds to 0°C. In the same way apply 56.1mV, readjusting *R*13 till the meter reads *p*H1. This corresponds to 10°C. Repeat these adjustments for all the points required using Equation (2) to calculate the calibrating voltage. Now set *S*6 to the 10*p*H units range. Set *R*13 to 0°C, provide an input of 541mV, and adjust *R*10 until the meter reads *p*H10.

Now calibrate the *Set Temperature* control *R*7. Short circuit the input terminals of the impedance convertor. Set *S*4 to 10*p*H units and operate the reversing switch *S*5. Set *R*13 to 0°C and set *R*7 to its maximum. Ensure that the set zero control *R*6 has sufficient scope to set the indicating meter on *p*H10. Increase *R*6, so that it is necessary to reduce *R*7 a little before the meter again reads *p*H10. Now mark this point on *R*7 as 0°C. Now set *R*13 to 10°C, and without touching *R*6, adjust *R*7 till the meter again reads p*H*10. This point corresponds to 10° on *R*7. Repeat these adjustments as required.

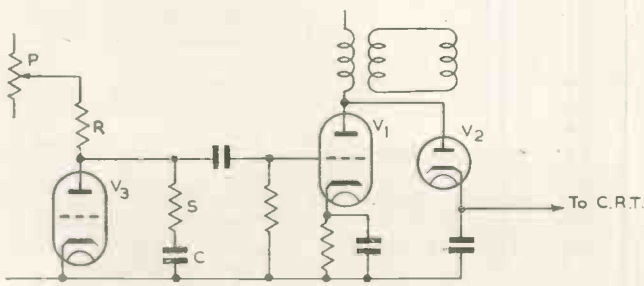
When this circuit is in use, set *R*13 and *R*7 to the same temperature, and adjust *R*6 until the meter reads correctly.

The purpose of the reversing switch is solely to enable the P.D. developed by the auxiliary circuit to be read off on the indicating meter. Normally, this P.D. is applied in opposition to that produced by the measuring cell, and consequently makes the meter read backwards. The correct polarity of the batteries used should be determined by trial and error.

Control of E.H.T. in Television Receivers *

It is well known that for reasons of economy the practice of deriving the E.H.T. for a television receiver from the energy available during line flyback has become common in recent years. This type of circuit entails a problem of E.H.T. control which has been solved in various ways in the past. The problem is concerned with the adjustment of line scan amplitude, an adjustment that naturally tends to alter the rate of change of current in the line scan output circuit and consequently tends to vary the E.H.T. and thus the beam focus. A new and simple solution that has been tried and found to work successfully is described here.

In the figure the valve V_1 is the line scanning output valve and E.H.T. for the cathode ray tube is derived by means of the rectifier diode V_2. The valve V_3 is a discharger valve for the charging capacitor *C*, and this capacitor is charged through the resistor *R* which is connected at one end to the sliding tap *P* on a potentiometer so that the charging voltage may be adjusted and the amplitude of the saw-tooth applied to the control grid of V_1 accordingly varied. The line scan amplitude can thus be adjusted but in the absence of any precaution to the contrary the beam focus will be disturbed because the E.H.T. will be altered by the adjustment. The disturbance of focus is avoided by means of the resistor *S*. As a part of common practice this resistor is included in the discharge circuit of the charging capacitor *C* and is given a small value but, nevertheless, one sufficiently large to cause the valve V_1 to be held in the non-conducting or near non-conducting state during a portion of the flyback period. The proposal that has in practice been found successful to overcome the difficulty of defocus with scan adjustment



is that the resistor *S* should be a variable resistor ganged with the slider *P* so that as, for instance, the charging voltage is increased by moving the slider *P* the resistor *S* is made less effective to cut off the valve V_1. This has the tendency to maintain the rate of change of the current of the valve V_1 more nearly constant during flyback. The E.H.T. and in consequence the beam focus is thus rendered largely independent of the adjustment of line scan amplitude.

* *Communication from E.M.I. Ltd.*

A Balanced R.C. Oscillator

By D. A. Bell, M.I.E.E. *

FOR a research project on servo systems it was desired to generate sinusoidal voltages of very low frequency (of the order of 0.1 to 20c/s) which were accurately symmetrical, i.e., free from even harmonics. The low frequency indicated that an R.C. oscillator should be used, and the elimination of even harmonics suggested some modification of the usual oscillator circuits in order to make the system balanced. The following adaptations are possible in principle:—

(a) Feed-back via a three-stage balanced *R-C* ladder network, as in Fig. 1. Amplitude adjustment would need ganged operation of either R_3 and R_4 or R_1 and R_2, but adjustment of frequency would be more complicated. In the most likely arrangement one would vary simultaneously R_5, R_6, R_{7a} and R_{7b} for fine control and one would have to switch all six capacitors for change of frequency range.

(b) An amplifier with positive feed-back and over-riding negative feed-back, the latter being blocked at oscillation frequency, e.g., by a twin-T network. It is usual in this type to employ several stages in the amplifier, which is undesirable because of the difficulties of inter-stage coupling at 0.1c/s; and a balanced version of the twin-T filter would be comparatively complicated to tune.

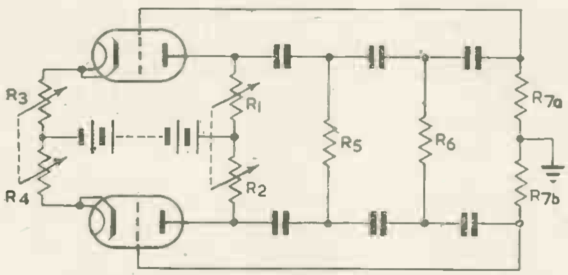


Fig. 1. Balanced version of ladder type R.C. oscillator

(c) The Wien bridge feed-back circuit was therefore chosen as the easiest to tune while requiring only moderate gain in the maintaining amplifier. The Wien bridge has zero phase-shift at working frequency, so it is usually employed with a two-stage amplifier giving a further 360°, and this threatens to introduce an undesired inter-stage coupling; but in a push-pull oscillator a single stage is sufficient, since the anode to grid feed-back connexions are crossed.

The oscillator was therefore based on the complete Wien bridge which is shown schematically in Fig. 2. At the working frequency, determined by the condition $C_1C_2R_1R_2 = \omega^2$, the voltage between *A* and either *C* or *D* is in-phase with respect to the generator *E*, while the voltage at *B* must always be so. The sign of the voltage between *A* and *B* can then be selected by moving the tapping point on R_3 to either side of the balance point, and its magnitude depends on the amount of this off-set from balance, so that this variable allows correct adjustment of the feed-back to suit the gain of the amplifier, independently of the frequency control. The complete circuit, consisting of push-pull amplifier with Wien bridge feed-back circuit, is shown in Fig. 3, and requires only a two-gang variable resistor R_1-R_2 for fine control of frequency, and switching of the two capacitors C_1 and C_2 for range changing. To ensure balanced operation the amplifier was built with a common cathode resistor R_4 of high value (Blumlein's "long-tailed pair" circuit), an arrangement which does not reduce the gain for the desired push-pull mode of operation. The magnitude of feed-back can be made self-adjusting in the usual way, by using a thermistor in place of the part of R_3 which lies opposite R_2C_2, or a lamp for the part of R_3 opposite R_1C_1; but for the very low

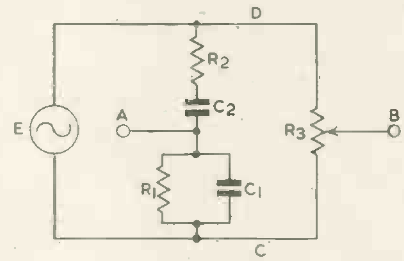


Fig. 2. The Wien bridge network

frequencies required in the present instance the role of such devices is minimized, since it is difficult to get one with a really long time-constant and any variation of the regulating resistance within the period of a cycle of oscillation would cause distortion.

The usual Wien Bridge oscillator circuit, with $R_1 = R_2$ and $C_1 = C_2$ gives a ratio of 1 : 2 for the voltages across the R_1C_1 and R_2C_2 arms of the bridge. For a precisely balanced system it would therefore seem preferable to obtain equal voltages across the arms, by making $R_1 = 2R_2$ and $C_1 = \frac{1}{2}C_2$. The variable resistors could then be made up from a three-gang combination of equal units, one unit being used for R_1 and two in parallel for R_2. (With variable capacitor tuning at higher frequencies, one would use a three-gang capacitor, with one unit for C_1 and two

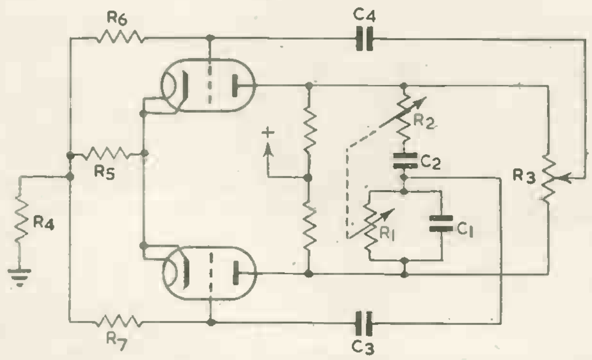


Fig. 3. Circuit of Wien-Bridge oscillator with balanced maintaining amplifier

in parallel for C_2). But so far it has been found satisfactory to use equal bridge elements and rely on the "long-tailed pair" to ensure a good balance in the oscillator output.

The symmetry of the output has been tested through the application of the oscillator in the following way. It

* *Dept. of Electrical Engineering, University of Birmingham.*

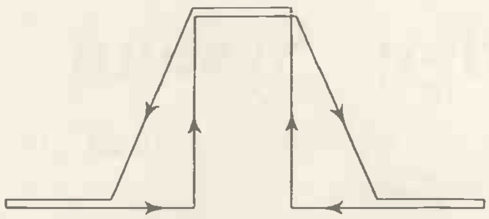


Fig. 4. Superposition of pulses traced alternately in opposite directions

is used to form two symmetrical pulses per cycle, using the full-wave rectifier and clipper circuit described by Sashoff and Roberts† (but without the suppression of alternate pulses) and these pulses are then applied to the Y plates of a C.R.T. which has a sinusoidal time base obtained by connecting the X plates to output of the oscillator. Since the pulses are formed as the oscillator voltage wave passes through zero, they appear at the centre of the C.R.T. screen but with alternate pulses traced in opposite directions. Any lack of symmetry of the pulses is then very apparent, as shown in exaggerated form in Fig. 4, as a failure of the two pulse traces to superimpose.

Apparatus to this design has been built and tested by Mr. A. Kwiatkowski in the Department of Electrical Engineering, University of Birmingham.

† *Electronics*, Sept. 1940, p. 40. "Handbook of Industrial Electronic Circuits" (Ed. Markus & Zeluff) p. 173.

Moisture in Electrometers

By R. H. Mapplebeck *

CONSIDERABLE publicity has recently been given to the design of electrometers, and it is felt that the expression of a few practical notes in regard to leakage may not be out of place.

Whatever the source of D.C. voltage to be measured, whether in electro-medical technique where a silver/silver chloride probe may be in use or in *p*H measurement, certain precautions will be necessary; for however stable the equipment, the effects of local conditions may well give rise to erroneous readings.

Input insulation is obviously of prime importance, for where the impedance of the source to be measured may be of the order of hundreds of megohms, as in *p*H work, it is desirable that the input impedance should not be less than about 10^{12} ohms.

If the electrometer valve has a grid resistor it may well be of this order; which implies that the insulation and other properties of any grid circuit or grid input device must be much greater than this.

In this connexion Polythene has been found very satisfactory. It is a plastic that embodies the characteristics necessary for conditions where the atmosphere has a high relative moisture content as it is highly resistant to moisture penetration, and will not support the growth of moulds or bacteria. It is not brittle, even at temperatures as low as -100°C and has a resistivity of 10^{17} ohms/cm with a power factor of 0.0002 for frequencies between 50 to 10^{10} cycles per second.

Although the electrometer valve is housed in a screened container it is virtually impossible to prevent moisture penetration and it frequently happens that moisture absorbed into the glass of the valve envelope causes either leakage between electrodes or the generation of electrolytic potentials which render any readings quite inaccurate until the unit has been dried out. Such valves are usually designed with the grid outlet as far removed from the outlets of the other electrodes as possible, with the latter taken directly from the pinch, any insulated base being discarded.

Even with these precautions considerable leakage may take place over the glass and one method of avoiding this is to immerse the valve to just short of the pinch in a solution of high-quality moisture resistant varnish (having first de-greased the valve) and dry it in a low temperature oven for some hours.

To test the efficiency of the electrometer input under damp atmospheric conditions is quite a simple matter, provided that the associated amplifier is capable of indicating potentials of the order of one millivolt or less.

It consists firstly in connecting a high value resistor say, 1,000 megohms, to the electrometer input and measuring the voltage due to grid current and noting its sign (E_g). The earthy side of this resistor must then be open circuited and a standard voltage source (E_{s_1}) introduced, such as a Weston Cadmium cell rated at 1.018 volts at 20°C, and its value as measured on the electrometer read off (E_{s_2}). This standard voltage source must also be checked when connected directly to the electrometer, with the 1,000 megohm resistor removed from circuit, to avoid small measurement errors due to differences between the cell's actual voltage and the apparent value which may occur due to calibration inaccuracies.

If there is no leakage or other spurious effect such as contact potential or stray electrolytic potential, $E_{s_2} = E_{s_1} \pm E_g$, depending on the direction of flow of the grid current which, incidentally, may vary considerably in a given batch of valves.

In the absence of stray potentials, if E_{s_2} reads lower than $E_{s_1} \pm E_g$ it indicates a shunt loss (R_s), the resultant voltage being E_{sh} say.

$$\text{Thus } R_s = \frac{E_{sh} \times 10^9}{E_{s_2} - E_{sh}} \text{ ohms}$$

Example

Voltage due to grid current (E_g) reads	-1 millivolt
Standard cell voltage at low impedance (E_{s_1})	1.018 volts
,, ,, ,, ,, high ,, (E_{sh})	1.016 volts
High impedance input resistor	1,000 megohms

$$\text{Therefore } R_s = \frac{1.016 \times 10^9}{(1.018 - 0.001) - 1.016} \text{ ohms}$$
$$= 1.016 \times 10^{12} \text{ ohms}$$

This shunting resistance of about one million megohms due to leakage indicates the necessity for using material having first-class insulating properties if accurate measurements are to be obtained. Not only does this apply to the electrometer unit, but also to the screened input lead and associated apparatus.

If any spurious electrolytic potentials exist they will be indicated by an abnormal reading, but will probably disappear on drying out the electrometer.

The 1,000 megohm resistor used for the high impedance input measurements, if the "Victoreen" type is not available, will probably be of the carbon spiral track variety. It has been found that these latter, possibly due to contact or electrolytic effects caused by moisture, produce an E.M.F. of their own of the order of a few millivolts, giving rise to false readings unless allowed for in computing the input losses. However, such an undesirable state of affairs may be offset by short-circuiting the resistor when not in use, effectively polarizing it.

* *Marconi Instruments, Ltd.*

A Versatile Bridge System

for use with wire resistance gauges in the measurement of slow transient strains

By M. J. Richard, B.Sc. *

WIRE resistance gauges are frequently used in a Wheatstone bridge circuit, completed on the strained specimen and with leads brought out from the four corners. In this way the lead resistance does not affect the balance and the circuit provides good temperature compensation, increased sensitivity and can be arranged to discriminate against unwanted strains. When supplied with A.C. the bridge forms a means of modulating a carrier so that slow transient strains can be handled by a resistance capacitance coupled amplifier followed preferably by a phase-discriminating demodulator and cathode-ray tube. Such a bridge requires an auxiliary circuit for balancing the resistive and reactive components and for calibrating the C.R.T. deflexions in terms of fractional gauge resistance changes. It is also useful to be able to employ the system as a null-point device for the measurement of static strains, i.e., load calibration of the gauges. The following circuit has been in use for more than a year and has proved convenient and accurate to about 1 per cent for strains varying from about 20 micro inches per inch upwards. (In dynamic use the accuracy is limited to about 2 per cent by the resolution of the C.R.T. set by the spot to screen diameters ratio).

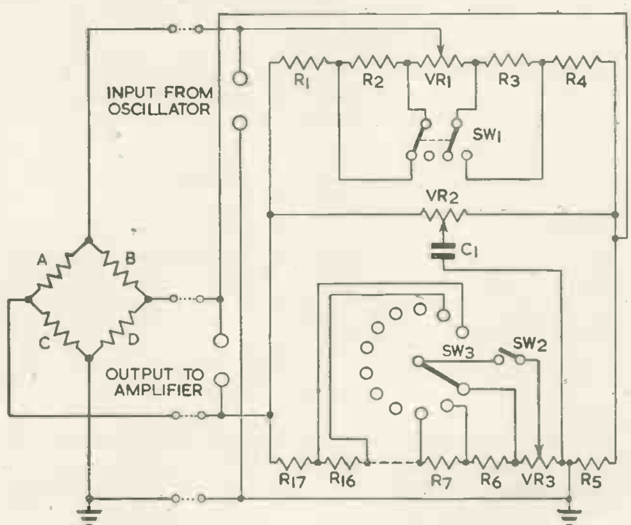


Fig. 1. Circuit diagram of strain gauge bridge

All resistors high stability cracked carbon ± 1 per cent tolerance unless otherwise stated.
A, B, C, D, 200Ω ; (*wire resistance strain gauges*) ;
R_1, R_2, R_3, R_4, 10*k* Ω ; R_5, 20*k*Ω ; R_6 *to* R_{16}, 1*k*Ω ;
R_{17}, 8*k*Ω ; VR_1, 10*k*Ω (*helical potentiometer*) ; VR_2, 20*k*Ω ;
VR_3, 1*k*Ω (0.25 *per cent linear accuracy*) ; C_1, 0.0005μF.

The strain gauge bridge arms A and B (Fig. 1) are paralleled by a resistance chain of which the helical potentiometer VR_1 and the range extending switched resistors R_2, R_3, form the resistive balance control. The arms C and D are paralleled by VR_2 and C_1, which together form the reactive balance control, and also by the resistance chain R_5, R_6 to R_{16} (eleven resistors) and VR_3. These latter constitute the calibrating and static strain measuring resistances, and are made from 1 per cent tolerance cracked carbon resistors and a variable precision potentiometer. In static use the bridge is first balanced for no-load as indicated by a central trace on the C.R.T. The switch (SW_2) is then closed and the coarse and fine calibrating controls (SW_3 and VR_3) adjusted to secure balance for each value of load applied. In dynamic use the balance

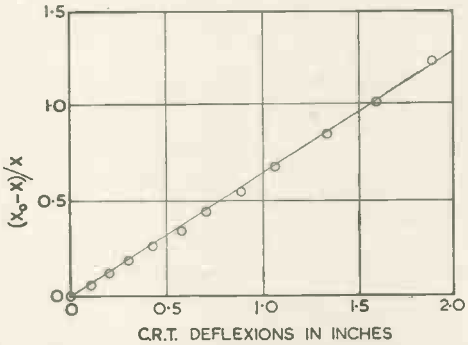


Fig. 2. The linear relationship obtained between $(X_0-X)/X$ and the corresponding C.R.T. deflexions

control (VR_1) and amplifier gain are first adjusted to position the transient pulse so that it occupies most of the C.R.T. screen. A value suitable to the magnitude of the strain pulse is set on the calibrating controls with SW_2 open. Closing the switch then introduces a known bridge unbalance. To eliminate errors due to trapezium distortion in the C.R.T. a photograph is made of two single stroke time-base traces, one with SW_2 open and one with it closed. The separation of the two slightly divergent lines on the film is then measured at points corresponding, on the face of the tube, to those at which the height of the transient pulse is required.

It can be shown from the balance condition that if X_0 is the total value of R_6 to R_{16}, R_{17} and VR_3, and X is the value remaining when balanced for a given strain, then neglecting small quantities of the second order

$$K(X_0 - X)/X = S.e$$

where e is the strain, S is the gauge factor (strain sensitivity of the gauges) and K is a numerical factor depending on the value of gauge resistance and the arrangement of the gauges on the specimen and can be readily calculated for a particular case. Hence it follows that for an unstrained bridge the equivalent fractional gauge resistance change introduced by operating SW_2 is proportional to $(X_0 - X)/X$. Fig. 2 shows a plot of this function against C.R.T. deflexions and it is seen to be linear, although the largest value of the function is equivalent to gauge resistance changes approaching the yield point of the gauge wire.

Acknowledgment

The author is indebted to the Metal Box Company, Limited, for permission to publish this note.

* *Research Division, The Metal Box Co. Ltd., Acton*

NOTES FROM THE INDUSTRY

Cambridge Summer School in Automatic Computing, 1951. A summer school in programme design for automatic digital computing machines will be held in the University Mathematical Laboratory at Cambridge during the period September 11-21, 1951. It will be along the same lines as one held last year.

It is now widely recognized that these machines can make a large contribution towards the solution of a great variety of problems in mathematics, physics, engineering and other subjects. The course will give a basic training in the mathematical use of machines, dealing with the processes employed and their embodiment in programmes which specify the operation in detail. Lectures and practical classes will be held in the design of programmes for the Edsac, the machine which has been built in the laboratory. It will be shown how the same principles may be applied in designing programmes for other machines.

A detailed syllabus and form of application for admission may be obtained from G. F. Hickson, M.A., Secretary of the Board of Extra-Mural Studies, Stuart House, Cambridge, to whom the completed application form should be returned not later than July 14, 1951.

Electronics Exhibition. The sixth annual Electronics Exhibition, organized by the North-Western Branch of the Institution of Electronics, will be held at the College of Technology, Manchester, on July 24 (from 2.30 p.m. to 9 p.m.) and on July 25 and 26 (from 10 a.m. to 9 p.m.).

An extensive programme is planned including, in addition to the products of the usual exhibitors, a non-commercial section composed of exhibits from the universities and from scientific associations.

There will be an exhibition of modern scientific films; demonstrations of the Compton Electronic Organ, of the Ferranti Logical Computor, and of Television reception on home constructed receivers. An amateur shortwave radio transmitter/receiver will operate throughout the period of the exhibition.

Admission will be by tickets obtainable from Mr. W. Birtwistle, Hon. Secretary, N.W. Branch, Institution of Electronics, 17 Blackwater Street, Rochdale, Lancs. Catalogues will be available early in July.

A Summer School on the Theory of Dielectrics will be held at the University of Liverpool from July 19 to 21, beginning at 10 a.m. on July 19. Lectures will be given by Professor H. Fröhlich, Dr. B. Szigeti and other members of the Department.

The course is intended mainly for research workers in Government and industrial research laboratories who wish to familiarize themselves with the theoretical aspects of subjects with which they are concerned on the experimental side. The following subjects will be treated in the lectures: dielectric constant and loss: general theory and applications; connexions between structure and dielectric properties; atomic mechanisms of polarization; phase transitions, and electronic processes in dielectrics.

The Summer School will be followed by a Conference on Dielectrics from July 23 to 25. The speakers include Dr. L. Hartshorn, Professor H. Fröhlich, Professor J. G. Kirkwood, Professor J. C. Slater, Mr. M. Magat, Professor C. P. Smyth and Dr. S. Whitehead.

Particulars of both Summer School and Conference may be obtained from Dr. Szigeti, Department of Physics, The University, Liverpool 7, or from the Deputy Secretary of the Institute of Physics, 47 Belgrave Square, London, S.W.1.

Fellowship of the Royal Society. At the meeting of the Royal Society recently His Royal Highness the Duke of Edinburgh, K.G., was formally admitted into the Fellowship of the Society.

Harwell offers course on Electronics. Physicists and engineers who wish to obtain specialized knowledge of electronic instruments used in nuclear physics, radio chemistry and work with radio isotopes, are being offered a course at the Atomic Energy Research Establishment, Harwell.

The course will last for one week, starting on Monday, July 23 and ending on Friday, July 27, and will deal specifically with the use of electronic equipment for detection and measurement of radiation. On each day the morning will be devoted to lectures and the afternoons to practical work. Design, use and maintenance of counters, D.C. pulse amplifiers, kick sorters, scalers and registers and automatic equipment will be included in the syllabus.

Lecturers and demonstrators will be specialists from the Atomic Energy Research Establishment.

Candidates for the course will be expected to have a background knowledge equivalent to degree standard in physics or electronics.

The number that can be accepted on the course is limited to 12, but if there is sufficient demand, further courses will be arranged. The building used will be the A.E.R.E. Isotope School, which is outside the security fence and the subjects will be entirely unclassified.

The fee for the course is 12 guineas. Living accommodation (at Buckland House, near Faringdon, one of the A.E.R.E. Senior Staff hostels), transport and morning and evening meals will be provided at a charge of 5 guineas.

Application for admission to the course should be made as soon as possible to the Electronics Division, A.E.R.E., Harwell, Didcot, Berks.

Mr. O. W. Humphreys appointed Director of G.E.C. Research Laboratories. The General Electric Co., Ltd., has appointed Mr. O. W. Humphreys, B.Sc., F.Inst.P., M.I.E.E., Director of the Research Laboratories of the company. Mr. Humphreys has been the manager of the laboratories for the past two years, having been appointed to that position following the death of Sir Clifford Paterson.

Relations Between Amplitudes of Harmonics and Intermodulation Frequencies (p. 230, June issue). Owing to an unfortunate confusion between two versions of this paper, the wording of the last paragraph referred to a different condition of test from that assumed in Table IV, and should be replaced by the following:

"6. As regards *audio distortion*, if the first order sum or difference tone ($f_1 \pm f_2$) only is measured, this will not take into account the distorting effect of odd power terms in the characteristic. This test would, for instance show zero distortion for a well balanced push-pull stage.

Moreover, from Table IV it appears that the ratio of the per cent of the first order sum or difference tone to the per cent 2nd harmonic is but little affected by the amount of high order terms in the characteristic, if we make the total peak input the same for the two tests.

It has long been recognized that a measurement of 2nd harmonic alone (or even of R.M.S. total harmonic distortion) is a very poor criterion of audible distortion, owing to the far greater annoyance value of the higher order distortion products. Table IV shows that a measurement of first order difference tone is no better: a survey of the other tables, making due allowance for the fact that the total peak input with two tones must not exceed that for a single tone, indicates that similar conclusions apply to measurements of other difference tones. Thus it appears that a measurement of all individual harmonics, with appropriate weighting (see Shorter, Electronic Engineering, October, 1950, and subsequent correspondence) is a better method for testing distortion than the current types of intermodulation test, which involve a measurement either of the first order difference tone, or of the R.M.S. sum of the intermodulation tones (see Warren and Hewlett, Proc. I.R.E., April, 1948).

The measurement of intermodulation tones should show up high order distortion more than the conventional test for second and third harmonic only if the total peak input for the two tones were greater than that of the single tone."

Letters to the Editor

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

Mechanized Reasoning

Dear Sir,—In the article on "Mechanized Reasoning" by McCallum and Smith, and in your Commentary on it in the April number of ELECTRONIC ENGINEERING, you state that the first apparatus equipped with mechanical reasoning was the logical truth calculator developed by Kalin and Burkhart. There have, in fact, been a number of machines built to carry out logical operations; one may mention among others, Earl Stanhope's Demonstrator in the early nineteenth century, which in effect was a logical slide rule (cf. Harley's description of it, *Mind*, 1879, pp. 192-210). The first machine, however, to perform logical inference was that of Stanley Jevons built in Manchester (cf. Proc. Roy. Soc., 1870) and used by him as a teaching instrument at Owen's College (now The University of Manchester) where he was Professor of Logic. Jevons (as well as being one of the founders of modern economics) was a pioneer of symbolic logic and added materially to its development as a systematic study.

Though this machine was constructed purely on mechanical principles operating by a system of levers and pulleys, and looked rather like a miniature piano, the principles it worked on were much the same as that described in the article on "Mechanized Reasoning" in your April issue, except of course, that it did not use electro-mechanical methods. It proceeded by developing the Boolean expansions of the premises (in the form of logical truth-tables), and then eliminating inconsistent combinations. The answer to the problem was obtained by reading off the remaining combinations. By means of what he termed the "indirect method" (which resembles the *reductio ad absurdam* method in mathematics) Jevons reduced the process of inference to a few uniform operations of classification, selection and elimination of contradictories. As he said of his machine in the Royal Society paper "It is an analytical engine of a very simple character, which performs a complete analysis of any logical problem impressed upon it. By merely reading down the premises or data of an argument on a keyboard . . . . the machine is caused to make such a comparison of those premises that it becomes capable of returning any answer which may be logically deduced from them. It is charged, as it were, with a certain amount of information which can be drawn from it again in any logical form which may be desired. The actual process of logical deduction is thus reduced to a purely mechanical form and we arrive at a machine embodying the 'Laws of Thought.'"

References to Jevon's machine as a precursor of the electrical relay machine have been made in *Nature*, Vol. 165, p. 197, 1950, and in *Mind*, April, 1951. In the light of the growing interest in the construction of logical machines, it seems only just that Jevon's contributions to the "mechanization of logical inference" should be more widely recognized today. Indeed, anyone interested in this field will find Jevon's writings still worth-while reading.

Yours faithfully,
W. MAYS,
University of Manchester.

The authors reply :

Dear Sir,—We would point out that we did not make the statement to which Mr. Mays takes exception, viz., that the Kalin-Burkhart machine was the first logical computor; this statement appeared in the Commentary only.* We felt that the Kalin-Burkhart computor was worthy of mention as a modern development, but that a survey of early work would fall outside the scope of our article.

We are in entire agreement with Mr. Mays' views on the importance of Prof. Jevon's contributions to the art, and join him in commending their study. At the same time we would urge that due attention be given to other writers of this period. As an example we would quote the Rev. Alfred Smee, Surgeon to the Bank of England, who in the year 1815 (only four years after the publication of Boole's "Mathematical Analysis of Logic") published a work entitled "The Process of Thought adapted to Words and Language, together with a description of the Relational and Differential Machines." This gave a specification for two machines of a nature even more embracing than Jevons'. These were admittedly impracticable (one was estimated to be about the size of London!), but their conception was surely a notable achievement.

Yours faithfully,
D. M. McCALLUM and J. B. SMITH,
Edinburgh.

* *See "Giant Brains, or Machines that think" by E. C. Berkeley (Wiley & Son) Ed.*

Fatal Shock from Television Receivers

Dear Sir,—Your editorial in the June issue mentions the recent case of a young child receiving a fatal shock from a television receiver. Further you state that the television receiver of today is just as safe as any other well made electrical domestic appliance including a radio receiver.

I should like to point out that the so called A.C./D.C. television, or radio, receiver under certain circumstances is not completely safe. These circumstances arise because the A.C./D.C. technique provides no isolation from the mains supply and the chassis is directly connected to one side of the mains. In the case of an A.C. mains supply, one side being "earthy," the input of the receiver should be connected so that the chassis is at earth potential. Even if the precaution is taken by the retailer supplying the set. danger can arise as it appears general practice to use a reversible two pin plug and socket on the back of the receiver. If the receiver is moved, or the plug is pulled out, no marking is available to allow the plug and socket to be replaced as it was previously.

In the case of the D.C. mains supply, there are installations existing where the positive terminal of the mains is at earth potential. Under these circumstances the receiver chassis is always at full mains voltage; there is just no alternative.

If we accept, therefore, that the chassis of a television, or radio, receiver of the A.C./D.C. type will, under certain circumstances, be at full mains voltage relative to earth the question arises as to how this can constitute a potential source of danger as a domestic appliance. I have tabulated a list of what I believe to be the main contributory causes.

1. Inexperienced people removing the back cover of the receiver and touching the chassis with the set switched on.
2. Protrusion of metal grub screws in control knobs.
3. Metallic loudspeaker grille becoming shorted to chassis.
4. Apertures at the rear of the receiver sufficiently large to allow a child's finger to enter and touch the chassis.
5. Single pole (instead of two pole) switches used as an ON/OFF switch may still leave the chassis live.

If we ignore item (1) (we do so at our own peril!) the remaining "faults" should be capable of easy remedy. Item (2) is a common source of potential danger as I learnt on a recent visit to some friends where their television set was connected so that the chassis was live. Further, their 2-year-old daughter is a confirmed knob twiddler.

Surely we should produce a radio or television receiver which could not become a potential source of danger in the home; it would be a very good selling point for any manufacturer.

Yours faithfully,
A. M. MORGAN VOYCE.
Pershall, Staffs.

The Influence of High-Order Products in Non-Linear Distortion

DEAR SIR,—In Mr. Callendar's letter in the October, 1950, issue of ELECTRONIC ENGINEERING he states that "tests on actual valves under various Class A and Class AB conditions give a percentage of harmonic relative to that of corresponding intermodulation which did not agree well with the calculations" (based on the power series). This appears to differ from the fairly good agreement obtained by Warren and Hewlett in their article "An Analysis of the Intermodulation Method of Distortion Measurement" in Proc. I.R.E. (U.S.A.) April, 1948, p. 457. Would Mr. Callendar kindly give us the details of the results referred to ?

Yours faithfully,
F. LANGFORD-SMITH,
Amalgamated Wireless Valve Co.,
Ptd., Ltd.
Sydney, Australia.

Mr. Callendar replies:

Dear Sir,—In reply to Mr. Langford-Smith, I agree that Warren and Hewlett give good evidence for believing that amplifier valves, when run under conditions of reasonably low distortion, give results agreeing well enough with the assumption of a short power series for their characteristics. My tests were actually made upon valves used as mixers for two high frequency inputs, and, though the effect of various bias points was investigated, it cannot be said that conditions approximated closely to those of a low distortion audio amplifier. The statement in my previous letter would therefore be less liable to misinterpretation if the words "Class A" were omitted.

Yours faithfully,
M. V. Callendar,
Southend-on-Sea, Essex.

Television for Radiomen

Dear Sir,—Referring to the argument on page 151 of the April issue of Electronic Engineering, it is a great pity that Mr. Jones, although quite correct in his attitude, chose to confuse the issue by producing Fig. 1(c), which appears to me to be, at best, irrelevant. The question posed by Mr. Turner is, in effect, this: Is Fourier Analysis just a convenient mathematical trick or do we, in fact, have present all the frequencies obtained by this method?

May I suggest that there is no answer to this question, because the question itself is meaningless. Mr. Turner, and not Mr. Jones, confuses the physical phenomenon, the only truth about which is the arrival of energy in pulses, with the mathematical means used to express it quantitatively.

This can be achieved in many ways.

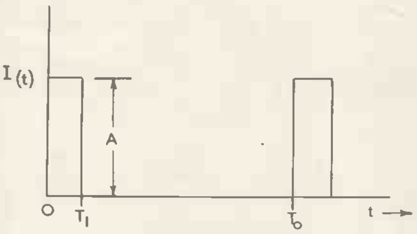


Fig. 1. Pulses for analysis

Thus the pulses shown in Fig. 1 may be represented by a discontinuous function

(a) $I(t)=A \quad O+nT_o<t<T_1+nT_o$
$I(t)=O \quad T_1+nT_o<t<(n+1)T_o$
where n is the integer,

by (b) $I(t)=1(t) \quad t=O+nT_o$
$I(t)=-1(t) \quad t=T_1+nT_o$

where $1(t)$ is the Heaviside Unit Function

or by (c) $I(t)=a_o+a_1 \sin nt+a_2 \sin 2\omega t + \ldots + b_1 \cos nt + b_2 \cos 2nt + \ldots$

or by (d) $I(t)=\sum_{s=1}^{s=\infty} C_s J_n(a_s t)$

Where J_n is the Bessel Function of nth order or in fact as a series the terms of which are almost any kind of orthogonal functions. The expression (a) is just as true—but no truer—than any other, and the choice between them is to be made purely as a matter of convenience. There is no question of using mathematical "tricks".

If we produce such pulses by means of, say, a opening and closing switch, we have absolutely no means of telling whether the source of power does, in fact, produce all the frequencies obtained by Fourier analysis, because they are merely one of many correct ways of describing what is happening.

Thus when we are designing an amplifier to deal with such pulses we call it a wide-band amplifier as it must pass the necessary number of harmonics. Alternatively, it must not distort the shape of the pulses and these two statements are quite equivalent.

We could design this amplifier without any reference to harmonics, but considering instead its response to a unit function—a method quite commonly used.

It is, however, clearly true that to say "harmonics are rested in the leading and trailing edges and the flat top of the pulse" is totally misleading. The harmonics are not "rested" in anything, but represent a way of describing quantitatively the waveform as a whole, including the interval between pulses.

Yours faithfully,
T. Horrocks, B.Sc.(Eng.), A.M.I.E.E.,
Liverpool 14.

Electron Flash in Research

Dear Sir,—While tests were being conducted on an X-ray generator, violent surging was noticed. The surging occurred at the start of exposures and did not always take place. The exposure times on such equipment may be quite short, even as short as one cycle and the load may well be in the order of 15 to 25kW. The primary timing circuit is so arranged as to close the primary contactor at the best phase position to offset surging. The violent surging of the primary current will, of course, lead to the development of correspondingly high voltage surges in the secondary.

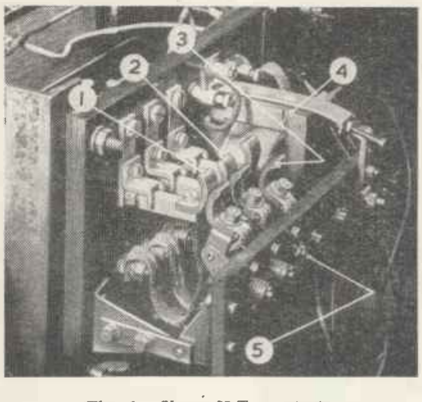


Fig. 1. X-ray H.T. contactor

Quite apart from the inaccuracies in the exposure time the high transient voltages that are developed can cause considerable damage to the secondary winding of the transformer, H.T. cables, H.T. sockets, high voltage rectifying valves and x-ray tubes. Having checked up the phasing of the contactor coil and its relation to the contactor armature closing time by the use of a cathode-ray oscillograph, it is unusual to find any current surging taking place on switching on. It will be seen in

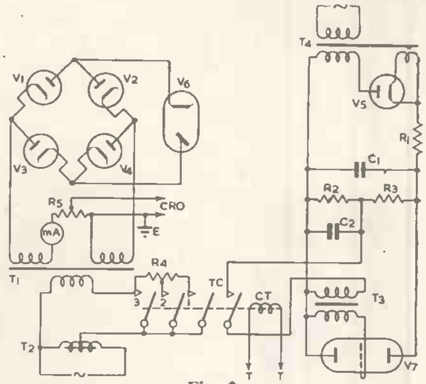


Fig. 2.

V_1, V_2, V_3, V_4—High voltage valves.
V_5—Rectifier for electronic flash unit 3kV.
V_6—X-ray Tube load.
V_7—Electronic flash tube.
C.R.O. to C.R. Oscillograph recording current wave trace.
T_1—Main high tension transformer.
T_2—Auto-transformer to provide H.T. voltage control.
T_3—Flash tube trigger transformer.
T_4—Flash unit H.T. and filament transformer.
T—Exposure timer circuit.
R_1—Charging current limiting resistor.
R_2, R_3—Voltage divider for trigger capacitor.
R_4—Buffer surge resistor.
R_5—C.R.O. voltage drop resistor.
C_1—Main storage capacitor for electronic tube discharge lamp.
C_2—Trigger storage capacitor.
C.T.—Contactor operation coil.
T.C.—Trigger timing contacts.

Fig 1 that as an extra precaution the contactor is arranged to close the primary circuit via a two step buffer resistance. If surging persists after these precautions have been taken, insecure connexions in the primary circuit or contactor bounce is suspected. The spring tension of the step contacts is so arranged to provide sufficient contact pressure without producing too great a load on the contactor energy coil. It was decided to attempt some photo records of the contactor behaviour using the electron speed flash lamp. A spare pair of contacts T.C. (Fig. 1) were used to provide the trigger timing for the discharge lamp. The closing time of these contacts was made adjustable in relation to the position of the magnetic armature 4, Fig. 2. The record shown in Fig. 2 was obtained, which clearly shows the contact 3 to have bounced open. It will also be seen that the magnetic armature 4 is completely closed. Further adjustments to the spring tension and the voltage feed to the contactor coil completely cured this fault.

Yours faithfully,
A. G. Long,
East Finchley, London, W.3.

Colour-Coded Wiring

Dear Sir,—Standardizing a silver background would avoid the expedient of dropping a digit when numbering racks or cables.

A gold starter colour would disclose that wire ends had not been curtailed since numbering.

Yours faithfully,
S. J. Dagg,
London, S.W.3.

ELECTRONIC EQUIPMENT

A selection of the more interesting apparatus, components and accessories compiled from information supplied by the manufacturers

Sunvic Cold Junction Thermostat
(Illustrated above)

THE Sunvic cold junction thermostat is designed to overcome the difficulties and problems of cold junction control. It is mains operated. Once installed, it requires no further attention and will stabilize the cold junction temperature to better than 0.1°C.

A cylindrical aluminium body is drilled to house the thermocouple and thermometer. Around this body is wound a small heater, controlled by a proportioning thermostat, giving control to within 0.1°C. The aluminium body is enclosed in a bakelite cylinder and the control mechanism is sealed.

The instrument is set to a temperature between 42°C and 48°C. The number of thermocouples which can be accommodated will depend on their size. The diameter of the space available is ¾in. and should accept a minimum of six couples.

**Sunvic Control, Ltd.,
10 Essex Street,
Strand, London, W.C.2.**

Strain Recording Equipments
(4-channel Recorder illustrated below)

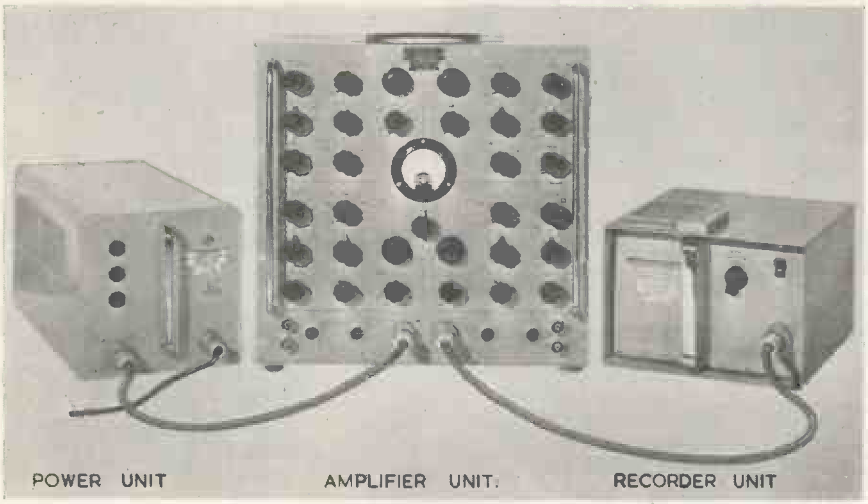
IN engineering experimental work it is often desirable to record variations in resistance (as with wire resistance strain gauges) and also capacitance (as when using capacitance change pressure-sensitive pick-ups) or inductance (as in inductance type accelerometers or displacement pick-up). The Kelvin Hughes 1 and 4 channel strain recording equipments can accommodate all of these types of inputs. In addition, the 1-channel equipment has an input of small D.C. signals.

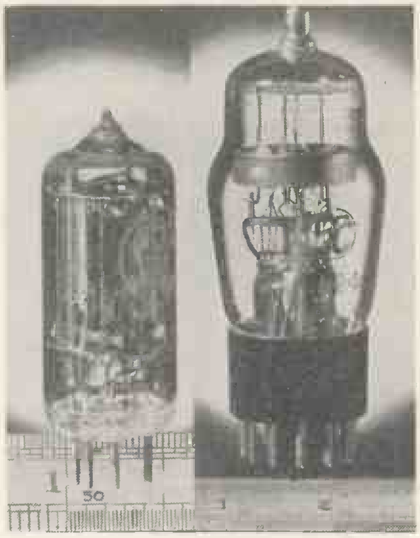
A record of the phenomena under observation is produced on a Kelvin Hughes recorder, using Teledeltos paper. In the 4-channel equipment, full scale deflexion of the recorder pen can be obtained for a change of resistance of the pick-up device of only 0.006 per cent, or a change of capacitance of 1pF, over a frequency range of 0-80c/s.

A modulated carrier system is used so as to avoid the drift and other difficulties associated with high gain D.C. amplifiers. The pick-up device in use is incorporated in a bridge, which is energized by a 2kc/s oscillator. The bridge is initially balanced, and any change in impedance of the pick-up device will cause an unbalance signal to be produced. This is passed through an A.C. amplifier, and then to a phase-sensitive demodulator. The demodulator output is proportional to the 2kc/s unbalance signal from the bridge, and the polarity of the output depends on the phase of the unbalance signal as compared with a reference signal obtained directly from the oscillator. This output is fed directly to a D.C. coupled push-pull output stage. which operates the moving coil recorder.

The phase distinction provided by the phase sensitive demodulator is necessary in order to determine the sense of the change, e.g., whether a strain gauge has extended and so increased in resistance, or contracted and thus decreased in resistance.

**Kelvin & Hughes (Industrial) Ltd.,
5 Caxton Street,
London, S.W.1.**





New Type Gas Discharge Tubes
(Illustrated above)

TWO new cold cathode glow discharge tubes have been developed by Standard Telephones and Cables, Ltd., for general counting use: the G10/240E unidirectional ten-point "Nomotron" and the G1/370K high speed trigger tube. The G10/240E is perhaps the more interesting in that it embodies an entirely new approach to the problem of circuit simplification and higher speeds in the gas tube art.

The G10/240E "Nomotron" enables up to ten pulses to be counted and the results stored in a single tube by means of a glow discharge which advances in steps according to the number of impulses received. Only a single pair of input terminals is required, one of these normally being earthed, unidirectional transfer of the discharge from step to step being accomplished by means of the electrode geometry. The tube has been developed to use an anode supply of 300-350 volts, and operates at all pulse repetition speeds from zero (random pulses) to rates in excess of 25,000 pulses per second.

The tube has ten storage cathodes from any one of which an output pulse may be obtained. The storage cathodes co-operate with a common anode and ten internally connected transfer cathodes to which the pulses to be counted are applied. The storage and transfer cathodes are arranged alternatively to form a circular array of glow discharge gaps with the common anode. The storage cathodes are asymmetrically shaped, and each is so formed that a stable glow discharge may be maintained immediately adjacent the transfer cathode next in the sequence of discharge rotation around the tube.

The G1/370K trigger tube has been developed as a general purpose, high speed, high input impedance cold cathode trigger tube especially suitable as a driver for the G10/240E "Nomotron." This tube includes a priming gap across which a very small auxiliary discharge is permanently maintained to overcome "statistical" delay of firing of the trigger gap.

Deionization is extremely rapid, and, due to the rigid shielded construction, together with the auxiliary priming discharge gap, the characteristics are extremely stable and reproducible from tube to tube.

The G1/370K trigger tube is designed to operate from the same anode supply as the G10/240E "Nomotron," namely 300-350 volts D.C., and does not vary in performance whether dealing with entirely random pulses or with a succession of pulses up to a repetition rate in excess of 100,000 pulses per second.

Standard Telephones and Cables, Ltd., Connaught House, Aldwych, London, W.C.2.

Audix Schools Broadcast Equipment

THE Audix Receiver Amplifier, R.A.11 illustrated above is made to feed up to six loudspeakers. The normal Audix features have been built into this superhet receiver with certain refinements. Also incorporated are: a small speaker for monitoring the programme, tuning indicator for accurate station setting and special tone control.

For mains switching a key is provided so that the receiver cannot be switched on accidentally or by an unauthorized person when the key is removed. A socket is available for connecting a gramophone unit if required. The mains supply is 200-250 Volts, 50c/s. The power output is 10 watts with less than 2 per cent harmonic distortion. Output impedance is 3 to 15 ohms, with a pick-up input impedance of 100,000 ohms.

Audix B.B., Ltd., Hockerill Works, Bishop's Stortford, Herts.

Television Cables

THIS new cable, manufactured by J. Day and Co. (Derby Works), Ltd., is polythene insulated, and can be obtained in the following types: coaxial twin, solid dielectric, semi-airspaced and screened and unscreened feeders.

The characteristics of polythene are: elongation at break (20°C) 450-500 per cent; brittleness temperature lower than $-35°$; dielectric strength (0.03in.)V/mil. 1000, and permittivity 2.3 (50c/s to 10^9c/s). Where applicable R.F. cables are manufactured in compliance with GDES.23 (1948).

Polythene is specially pigmented with carbon black for tropical use or for use in places where high non-ageing properties are desirable.

J. Day and Co. (Derby Works), Ltd., Harrow Manor Way, London, S.E.2.

Ferranti High Speed Test Set
(illustrated below)

THE purpose of this equipment is to achieve a marked increase in the speed of calibration of single phase house service meters without sacrificing the accuracy which is demanded by B.S.37.

The method uses a rotating substandard high torque meter which is never required to run at less than a quarter of its full load speed. This meter has no registers or contactors but gives its output photoelectrically by means of beams of light shining through holes in a disk on to a light sensitive cell.

When testing meters at high loads the output of the photoelectric cell is amplified and drives a stroboscopic lamp which illuminates the disk of the meters under test and enables their speeds to be adjusted so that they are in step with the standard. At low disk speeds this method cannot be used. The photoelectric cell output then drives a series of cyclometer counters. one per meter under test, and these enable the meters to be timed in a similar way to the stop-watch method. The difference is that in this new method the meter under test is timed in terms of the speed of the standard so that error is given direct without calculation, and the load need not be maintained accurately.

Any meter with full load speeds between 12 and 48 R.P.M. and carrying any stroboscopic pattern of between 100 and 200 divisions can be tested without any alteration of the substandard. This is achieved by using a precision decade current transformer between the meters under test and the master substandard, and by arranging that three separate frequencies in the ratio 4:1, 2:1 and 1:1 can be obtained from the substandard by using three sets of holes in the substandard disk arranged in concentric circles of 200, 100 and 50 holes. The same arrangement is used on light loads tests to cause the counters to record 1000 impulses for an integral number of revolutions of a correctly adjusted meter.

The counters may also be used on full load tests in order to time meters and thus measure their actual errors either before or after adjustment by a stroboscope, but this is not normally required.

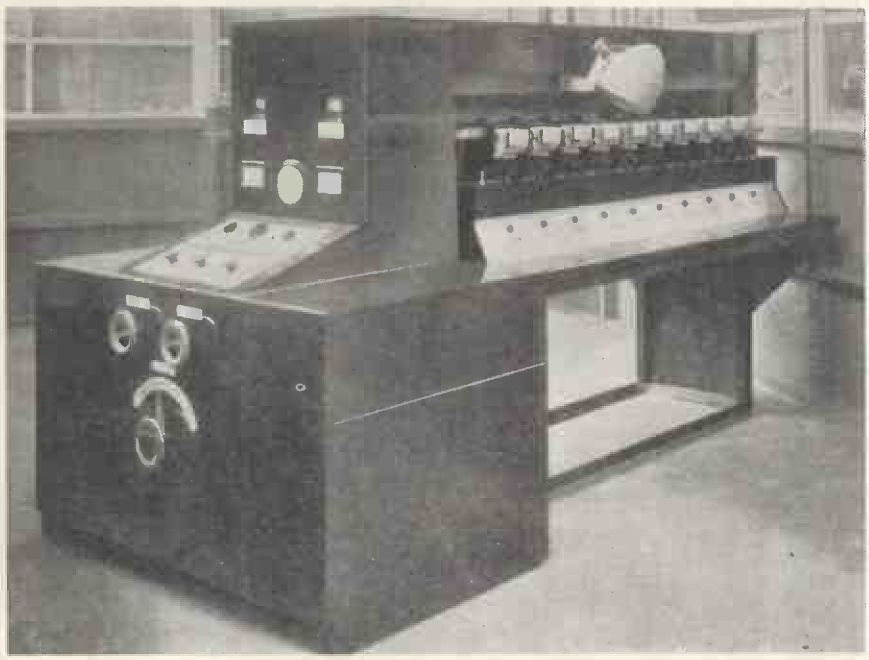
One complete equipment comprises a test set and up to five double sided test benches of which only one is being exhibited. Each bench holds 20 meters (10 per side) so that the test set energizes up to 100 meters which may be calibrated by two testers.

The two stroboscopic lamps are movable throughout the length of the five benches to enable the testers to place them over each meter in turn. Under each meter position is mounted a counter for testing the meter on low loads, the counter stop-start switch and an indicating lamp switched on by the tester to signify that the meter requires adjusting.

The meter under test is calibrated at three points, full load current at 1.0 and 0.5 power factor lag by stroboscopic illumination of its disk and at 1/20 load by the counters.

The equipment is made to calibrate meters up to 50 amps. capacity and of differing speeds and stroboscopic patterns by the use of one rotating substandard meter.

Ferranti, Ltd., Hollinwood, Lancs.



BOOK REVIEWS

Conductimetric Analysis at Radio-Frequency

By G. G. Blake, F.Inst.P., M.I.E.E. 1st Edition. 109 pp., 40 figs. Chapman & Hall, Ltd., London. 1950. Price 15s.

THE scope of this book is indicated exactly by its sub-title. It is no more, and no less, than a description of a "New Technique for Titration."

The author gives an historical account of the developments which have led to his final design for an R.F. conductivity measurer. The basis of the method is the estimation of the electrolytic resistance of a solution being analysed or titrated, by the use of an R.F. oscillator. In his "Q-metric" method he describes how change in conductivity of a solution can be measured by the alteration of the value of the resistive element in an oscillator tank circuit. Amplitude of oscillation is related to the conductivity of a solution contained in a thin glass-walled cell. His present method utilizes the change in impedance between two electrodes on the outside of such a cell, by arranging the cell to form a series impedance between a constant output oscillator and a detector unit. Description is very detailed, and more than sufficient constructional data is given.

The reviewer would have liked some theoretical treatment of the essentials, some discussion of the application of the author's methods to commercial design, fewer extravagant suggestions for untried or experimental applications (such as are contained in Chapter 9), and a more critical and detailed assessment of the advantages and disadvantages of his methods by comparison with standard designs. For example, the method seems to be suitable only for comparison: determination of absolute *p*H would seem to be outside its range. Nevertheless, within its appointed scope the method is an extremely sensitive one, and represents a considerable technical advance, particularly in micro-titration.

This book should prove interesting as a purely practical introduction to a new field. Its excellent layout, with detailed references and good indexing, add considerably to its value.

C. J. DICKINSON.

Radar Systems and Components

By Members of the Technical Staff of the Bell Telephone Laboratories. 1,042 pp. D. Van Nostrand Co. Inc. and Macmillan & Co. Ltd. 1949. Price $7.50.

IN this volume fifteen papers, which have already been published in the Bell System Technical Journal, have been collected together with the aim of presenting a detailed account of the radar development carried out by the Bell Laboratories during the war. The papers are all written by the workers concerned and so contain authoritative accounts of the topics discussed. The work of other research groups is only mentioned where necessary for an understanding of the work done by Bells.

In the main chapters, those on magnetrons, reflex oscillators, aerials and receivers, an account of the basic theory is followed by detailed description, well illustrated by photographs and diagrams, of the various production models manufactured by the subsidiary company, Western Electric. There are many useful tables and charts, which for example in the three papers on cavity resonators provide the necessary information to carry out a design on paper. The other chapters deal with modulators, T-R cells, crystals and valves for I.F. amplifiers, and again performance curves are prominent. The ever-present problem of ensuring that the performance of an operational radar is kept up to scratch is well covered in the paper on test sets. Naturally in a book of this size a few errors have crept in, two of the worst being on page 377, where the section on the power received from a target is very wrong, and on page 890 where the voltage standing wave ratio is incorrectly defined.

While individually the papers are excellent, the reviewer feels that the value of this book could have been greatly increased by more editorial supervision. Each paper has been written as an entity and cross references between chapters are pitifully few. Duplication of material, even to the extent of reproducing several of the figures twice, has also resulted. The only descriptions of complete radar systems are in the first chapter, where some early naval fire-control sets are discussed—these are not typical of the sets in use at the end of the war. There are some noticeable omissions from the subjects treated: one would expect to find in a book on radar a chapter on waveguides, and servomechanisms might also have been included.

Because of these faults, this book cannot be recommended for the student who is looking for a connected account of the subject. Its principle value is to the specialist who has not had access to the original papers, and for the wealth of historical information on the development of the various components associated with radar.

J. BROWN

Primary Batteries

By G. W. Vinal. 336 pp., 101 Figs., 1st Edition. John Wiley & Sons., Inc. New York. Chapman & Hall, Ltd., London. 1950. Price 40s.

THIS comprehensive treatise by an American author, who for over 20 years has been chief of the National Bureau of Standard's Division of Electrochemistry, covers in an easily-assimilated and well-illustrated way the history, theory, manufacture, materials, chemical reactions and operating characteristics of primary batteries. Several new and little-known types are described, examples being silver-oxide and chloride batteries, mercuric-oxide and vanadium batteries, and fused electrolyte batteries. Two important chapters deal with the now widely-used air-depolarized and copper-oxide/caustic-soda batteries. The effects of low temperatures on ordinary dry cells and the proposed modifications to improve them are dealt with in another interesting chapter. There is also a useful section on standard cells covering construction temperature coefficient, drift, hysteresis, effect of impurities in the materials, life and precautions to be observed during use.

As it is not surprising in a book covering such a wide field there are a few sections in various parts which would have been much improved by enlargement, for example, in discussing the current which standard cells can supply, the author gives very little information to the reader. It is a pity that he does not give a value for the "negligible" current which does no harm to a cell. He might also have improved the book by giving the characteristics of each type of cell when discharged at very small currents. This subject is important for many applications and the information is not easily available even for the well-known types of cell.

One good feature of the book is that it contains well over 200 valuable references for the reader who wishes to go into the subject more fully.

The book should be of great value to all users of cells and in particular to students in electrical engineering and physics, battery manufacturers and research workers engaged in new battery developments. Unfortunately the price in the U.K. is rather high.

F. A. BENSON

Reports on Progress in Physics. Vol. XIII

Executive Editor: A. C. Strickland. 424 pp. The Physical Society. 1950. Price £2 10s.

THE Physical Society is doing a valuable service in issuing its annual Reports. In recent years attention has been diverted from new advances in fundamental knowledge itself as distinct from advances in its application. The writing of books is a slow—and usually ill-paid—process, and survey-articles of the kind given here do a great deal to fill the gap between the current research paper and the textbooks of the next decade.

The present volume is one of the best of the excellent series which have been issued since the end of the war, covering a range from such almost personal problems as "The Investigation of Eye Movements" to the description of new results in astronomy.

In each article there is much to interest the specialist, but the main object is to give those working in different fields of physics a clear picture of the present "state of the art" in fields which have been advancing too rapidly to be easily followed except by their own devotees.

Of particular interest to electronic engineers is the article on Radio Astronomy by M. Ryle. By the use of ingenious integrating systems Ryle and others have managed to detect radiations from outer space developing a thousand times less power than the noise power of the aerial itself. Thus the power received from the undisturbed sun has been measured down to a received level of 10^{-14} of a microwatt, using an effective aerial of 100 sq. metres. Naturally, in physics one does not expect to get something for nothing and the price in this case is a million times loss in bandwidth, but the achievement is impressive enough nevertheless.

Other articles are on infra-red solar spectroscopy; the propagation of shock waves in fluids; ferromagnetism and magnetization curves; the atmospheres of the planets; paramagnetic relaxation; cyclic particule accelerators, and mesons. The last is by Professor C. F. Powell who is himself responsible for much of the work described. More than half a dozen particles are now believed to exist with masses between those of proton and electron, and the rate of discovery has been so great that even the most recent of textbooks are quite out of date.

It is impossible to discuss the main points of interest of all of the articles, but every one has parts which are of extremely general interest. To pick just one example, how many people know that the temperature and pressure in a shock wave in air are sufficient to cause the oxygen and nitrogen to combine so that the characteristic "smell" of an explosion is produced in part from the air itself?

The quality of production is, as usual, uniformly high, and though the unavoidably high price is a pity, it is by no means excessive for what is, in effect, a set of nine complete monographs.

J. H. FREMLIN.

Communication Circuits

By L. A. Ware and H. R. Read. 403 pp. 3rd edition. John Wiley & Sons, Inc., New York. Chapman & Hall, Ltd. 1949. Price 40s.

THIS is the third edition of a well known work, and is a very good textbook on transmission lines and waveguides.

The first chapter, entitled "Transmission Line Parameters" deals with coaxial and open wire lines as field problems; lines with lumped constants are treated as a special case. The next ten chapters deal in detail with the theory of networks, transmission lines and filters. Then follow three chapters on waveguides, and a final chapter on transmission line experiments.

The chapters dealing with waveguides are less complete than those on line transmission but, within limitations admitted by the authors, provide an excellent introduction to the subject. The fields in cylindrical and rectangular guides are treated as solutions of Maxwell's Equations; the effect of finite conductivity in the walls is covered. (The skin depth implied by a comment on p. 248 would appear to be low by a factor of 1,000.) A good feature of Chapter 13 is a very clear introduction to the concepts of phase and group velocities.

The book is concluded by a set of nine appendices. The first six of these cover subjects which are mathematically more difficult than the main body of the text. There is an excellent introduction to Fourier Series; Maxwell's Equations are derived in cartesian and cylindrical coordinates, and there is a useful introduction to Bessel and Hankel Functions.

The remaining appendices are wire tables and tables of hyperbolic functions.

Rationalized M.K.S. units are used throughout.

S. S. D. JONES.

An Introduction to Electronics

By J. Yarwood. 329 pp. + ix. 1st Edition. Chapman & Hall, 1950. Price 28s.

IN view of the many (mainly American) books on general electronics, it is perhaps surprising to find another, but it is possible that the author is right when he says in his foreword "... that there is yet a place for an English text book ..." It is intended to develop a knowledge of electronics from the basic electricity and magnetism of the student, and to this end starts with four chapters on fundamentals which then lead on to valves, their uses and finally particular valve circuits. The final chapter is on U.H.F. valves, which although useful and informative, seems a little out of place, especially as the earlier chapters have not been written in a "frequency conscious" manner and the waveguide, that *sine qua non* of modern U.H.F. work, has hardly been mentioned.

The treatment is suitably pitched for the intended reader and is distinctly mathematical where necessary. It is largely fundamental and theoretical and describes very little of immediate practical use, and does not cover complete circuits or equipments or many of the neat tricks of design and circuit work so useful to the practical engineer. It is illustrated with many line drawings, some of which are incredibly badly lettered and others inaccurate, and is adequately documented with literature references. The author does not hesitate to mention individual manufacturer's names from time to time—a useful and practical point often faintheartedly avoided in some books. Chapters worthy of special mention are those on electron optics, the electron microscope and the cathode-ray tube.

The volume, considered just as a book regardless of its text, does not seem up to the standard usually associated with its publisher, and the general style, at least to this reviewer, seemed to be somewhat second-rate, but perhaps a better production would have unduly increased the already rather high price. However, it it a book with uses and should be borrowed and then perhaps bought by those who require a general introduction to the subject or a refresher course on electronic fundamentals.

E. D. HART

Transformers: Their Principles and Design for Light Electrical Engineers

By F. C. Connelly. 483 pp., 179 Figs., 24 Tables. 1st Edition. Pitman & Sons, Ltd. 1950. Price 35s.

THE principles and design of transformers, over the large range of applications in which light electrical engineers are interested, is not one of the easiest subjects to present. There are so many factors that rise to important dimensions in differing combinations. While simplifications are always possible,

BOOK REVIEWS (Continued)

there are dangers that important aspects may be overlooked.

The author of this book has collected, ably sifted and arranged his material extremely well. The first six chapters deal with fundamental principles, methods of representation, and the relative magnitude of different factors for various applications. Leakage inductance and capacity effects are deferred to a later stage. Chapter 7 introduces the reader to practical design of small power transformers, taking him through several examples. Later chapters introduce magnetic leakage effects, more detail on core excitation, transients, operation beyond saturation, and are interspersed with practical chapters dealing with tappings and tap-changing, three-phase transformers, rectifier supplies, high voltage types, auto transformers, regulators, variable ratio devices, vibrator supplies, instrument audio frequency and television types. A closing chapter contains most of the useful data in the book for design work, for handy reference.

The book is intended for laboratory workers, designers and users of transformers within this comprehensive range. It can well be recommended for use in technical training organizations, at least as a library acquisition. It makes good reading, and the reviewer would recommend that most of the book be read, before using it as a reference work. This would be time well spent. However, the author has evidently taken considerable pains to ensure that anyone who wishes to apply one section without having read preceding sections, will not be likely to misconstrue information given.

Technical criticisms that the reviewer noted in reading the book are of such minor nature that mention here could well prove misleading. Typographical errors are very few. The author's objective, to present a comprehensive coverage for all the light electrical industries, has been well attained, and the book fills a place that should assure it a wide reception.

N. H. CROWHURST

Technical Instruction for Marine Radio Officers

By H. M. Dowsett, M.I.E.E., F.Inst.P., and L. E. Q. Walker, A.R.C.S. 699 pp., 700 illustrations. 9th Edition. Iliffe and Sons, Ltd. 1950. Price 60s.

WITH the publication of the ninth edition, the "Handbook of Technical Instruction for Wireless Telegraphists" has had its title amended to "Technical Instruction for Marine Radio Officers" in recognition of the fact that over the course of the years the duties of the marine officer have been progressively supplemented.

The object of the book, namely, to provide simple instruction in general radio principles and practice for those who operate marine wireless equipment, remains unaffected; and the groundwork covered provides a complete theoretical course for the P.M.G's certificates—the syllabus for which, together with a specimen question paper, is now included as an appendix.

Revision has been carried out on an ambitious scale. Additional chapters on the cathode-ray oscilloscope, ultra high-frequency generators and radar recognition systems have been included; and descriptions of new communication apparatus placed in service during and since the war replace those of apparatus now out of production. The additions include 193 new illustrations and the typematter has been re-set, so that all the additional information is contained in a volume that is convenient and easy for constant handling and reference.

Piezo Electrical Crystals and their Application to Ultrasonics

By Warren P. Mason. 508 pp. Macmillan & Co., Ltd. 1950. Price 56s.

THE research work of the Bell Telephone Laboratories has been made public over the last few years through the medium of a series of technical books covering many aspects of their work.

The latest edition in no way departs from the high standard set by the previous volumes, and Dr. Mason's work supplies a great deal of new information on the physical properties and the application of all aspects of piezo-electric crystals. The book can be considered as a companion volume to Mason's previous work on electromechanical transducers and much of the application theory follows similar lines. It is to be regretted, however, that a number of the symbols employed differ between the two works, thus complicating comparisons between piezo-electric and electro mechanical transducers.

The work covers natural crystals as well as the many new synthetic formations and includes a concise consideration of the properties of ammonium dihydrogen phosphate and ethylene diamine tartrate. Both these crystals can be now readily grown on a large scale, the former being used as a substitute for Rochelle Salt in underwater transducers, and the latter as a replacement for quartz in electrical wave filters.

In the ferro-electric class of crystal, consideration is given to potassium dihydrogen phosphate, and from the point of view of ultrasonic transducer applications, the more important barium titanate crystal. The use of this crystal in a ceramic multi-crystalline form is rapidly gaining prominence as a transducer, for it can be easily moulded into various forms and can be made equally efficient as a source of ultrasonic power at all points on its surface.

The measurement of the properties of solids, liquids and gases by means of ultrasonics is also covered. Factors not easily established by other means, such as the adiabatic compressibility of liquids and Young's Modulus in solids can be measured; in most cases these measurements are based on the observation of the velocity and attenuation of longitudinal waves propagated with the medium.

Generally, the book is well presented but assumes that the reader has a very adequate knowledge of mathematics. A certain amount of its value as a reference book is also lost through a rather brief index.

Finally, it is an intriguing thought to note that if a piezo-electric crystal is operated on resonance, efficiencies as high as 90 per cent can be achieved in the conversion of mechanical to electrical energy.

A. E. CRAWFORD.

Better T/V Reception

By Woodrow Smith and R. L. Dawley. 141 pp. Editors and Engineers Ltd. Price $2.50.

"BETTER T/V Reception in Fringe and Low-Signal Areas" is intended for the aid and guidance of those interested in television reception in fringe areas. It discusses various types of equipment, and their practical results, with very little mention of abstract theory.

This book is entirely devoted to problems related to reception of the V.H.F. television channel 2 to 13, which are, of course, the American bands of transmission.

The Practical Electrical Reference Book

384 pp. Odhams Press, Ltd. 1950. Price 9s. 6d.

THIS book is divided into thirty-six sections, and different authors have contributed to make up each one. The contents cover fundamentals, generation, measuring instruments, factory regulations, electricity in several different fields, cinema equipment, British Standard, and I.E.E. Regulations, to mention but a few subjects.

There are over 150 tables, and several hundred diagrams and illustrations.

Wireless Servicing Manual

By W. T. Cocking. 296 pp. 121 diagrams. 8th Edition. Iliffe and Sons Ltd., 1950. Price 12s. 6d.

THE eighth edition of the "Wireless Servicing Manual" has been revised and brought up to date; in particular the chapter on television receiver defects has been completely rewritten. Apart from domestic sets, short-wave receivers and convertors are covered, and there is also a special chapter devoted to servicing with the cathode-ray oscilloscope. Methods of ganging receivers of both the "straight" and superhet types are given in detail, and the all-too-common problems of hum and distortion are treated with the same thoroughness.

A useful appendix contains much information of the kind constantly required in everyday servicing work, and a very complete index has been provided to give the book added value for reference.

CLASSIFIED ANNOUNCEMENTS

The charge for these advertisements at the LINE RATE (if under 1" or 12 lines) is: Three lines or under 7/6, each additional line 2/6. (The line averages seven words.) Box number 2/- extra, except in the case of advertisements in "Situations Wanted," when it is added free of charge. At the INCH RATE (if over 1" or 12 lines) the charge is 30/- per inch, single column. Prospectuses and Company's Financial Reports £14 0s. 0d. per column. A remittance must accompany the advertisement. Replies to box numbers should be addressed to: Morgan Bros. (Publishers), Ltd., 28, Essex Street, Strand, London, W.C.2, and marked "Electronic Engineering." Advertisements must be received before the 14th of the month for insertion in the following issue.

OFFICIAL APPOINTMENTS

ADMIRALTY. Applications are invited from Engineering, Electrical and Ship Draughtsmen for temporary service in Admiralty Departments at Bath. Candidates must be British subjects of 21 years of age and upwards, who have had practical Workshop and Drawing Office experience. Salary will be assessed according to age, qualifications and experience within the range £320-£545 per annum. Applications giving age and details of technical qualifications, apprenticeship (or equivalents) Workshop and Drawing Office experience, should be sent to Admiralty (C.E.II, Room 88), Empire Hotel, Bath. Candidates required for interview will be advised within two weeks of receipt of application. W 137

ADMIRALTY. Vacancies exist for Electrical and/or Mechanical Engineering Draughtsmen in Admiralty Research and Development Establishments located in the vicinity of Weymouth, Portsmouth, Teddington (Middlesex), and Baldock, Herts. Draughtsmen experienced in light current, electro-mechanical, precision mechanical and electronic equipment are particularly needed. Candidates must be British subjects of 21 years of age and upwards, who have had practical workshop experience (preferably an apprenticeship) together with Drawing Office experience. Appointments will be in an unestablished capacity but opportunities may occur for qualified staff to compete for established posts. The salaries offered, depending on age, experience, ability and place of duty, will be within the range £320—£560 p.a. Hostel accommodation is available at some Establishments. Applications stating age and details of technical qualifications, apprenticeship (or equivalents), Workshop and Drawing Office experience, should be sent to Admiralty (C.E.II, Room 88) Empire Hotel, Bath, quoting DM/R.D. Original testimonials should not be forwarded with application. Candidates required for interview (at London or Bath, whichever is nearer) will be advised within two weeks of receipt of application. W 2984

ASSISTANT DIRECTOR required by Ministry of Supply in Bucks. Candidates must be British of British parentage, should have had practical engineering training and either (1) an Honours Degree in Electrical or Mechanical Engineering or (2) be corporate members of one of the Institutions of Civil, Mechanical or Electrical Engineers or have passed recognised exempting examinations for associate membership. Essential qualifications: experience in the control of scientific and professional engineer staff and recent design and/or manufacturing experience in two or more of the following fields (a) radio (including radar); (b) electronic valves or components; (c) aircraft radio and radar installations and aerial systems; (d) long range radio telecommunication systems; (e) siting and installation of ground radio and radar equipment including aerial systems; (f) siting and installation of ground radio aids to navigation including aerial systems. A knowledge of current uses and development trends of G.P.O. five unit telegraph equipment, scheduled servicing of radio and radar installations and design of vehicle radio and radar installations an advantage. Salary: £1,420-£1,650 not established. Application forms obtainable from the Ministry of Labour and National Service, Technical & Scientific Register (K), York House, Kingsway, W.C.2, quoting D.229/51 A. Closing date 20th July 1951. W 2936

CANADIAN RED CROSS Memorial Hospital, Taplow, Maidenhead. Technician required for the Special Unit for Research in Juvenile Rheumatism, to assist in the development of electrical and mechanical recording apparatus. A practical and theoretical knowledge of electronic and mechanical engineering is essential. Salary scale £370 to £435 per annum. Applications stating age, qualifications and experience, together with copies of three recent testimonials, should be sent to the Administrative Officer. W 2948

ELECTRICAL ENGINEERS and Physicists are invited by the Ministry of Supply to apply for the following appointments in the grade of Senior Scientific Officer or Scientific Officer at Research and Development Establishments near London. (1) Electrical Engineers qualified in radio communications with an interest in the engineering of development prototypes. (2) Physicists with experience in electronic circuitry problems for measurement of high speed transients. (3) Experimental physicist with experience of metallurgical techniques. (4) Physicist with interest in application of electronic methods to potical instrumentation techniques. Candidates should possess a 1st or 2nd class Honours Degree or equivalent qualification. For the senior grade the minimum age is 26 and at least 3 years' post-graduate research experience is required. Salary will be determined on age and on an assessment of the successful candidate's qualification and experience within the ranges: Senior Scientific Officer £670 to £860; Scientific Officer £380 to £620. Rates for women somewhat lower. Posts carry benefits of F.S.S.U. Application forms obtainable from Ministry of Labour and National Service, Technical & Scientific Register (K), York House, Kingsway, W.C.2, quoting A.162/51 A. Closing date 13th July 1951. W 2941

ENGINEER I for Ministry of Supply needed at an Establishment in S.E. England. Qualifications: British of British parentage; regular engineering apprenticeship; either corporate membership of Institutions of Civil, Mechanical or Electrical Engineers or possess exempting qualifications; design experience of radio/or radar equipment and in the engineering of development prototypes for production; a knowledge of aerial design and of airborne equipment an advantage. Salary range: £997-£1,192 not established, periodical competitions for establishment. Application forms obtainable from the Ministry of Labour and National Service, Technical & Scientific Register (K), York House, Kingsway, W.C.2, quoting D230/51 A. Closing date 13th July, 1951. W 2937

IMPERIAL COLLEGE of Science and Technology. (City and Guilds College.) Lecturer required in Electrical Engineering Department from 1st October, 1951, commencing salary between £600 and £750 in the Lecturer scale (according to experience and qualifications) with F.S.S.U. and Family Allowances. Industrial or analogous experience desirable, with special interests and experience in radio engineering, with particular reference to micro-wave technique. Applications, accompanied by full statements of qualifications and with references, should be sent to the Head of the Electrical Engineering Department, City & Guilds College, Exhibition Road, London, S.W.7, not later than 16th July 1951. W 2950

PADDINGTON GROUP Hospital Management Committee. Applications are invited for the post of Senior Technician in the Department of Electro-Encephelography at the West End Hospital for Nervous Diseases, 73, Welbeck Street, London, W.1. Applicants should have a knowledge of electronics and previous experience in E.E.C. recording is desirable. The salary for the post, which is subject to review, is on the scale of £375 × £15 to £405, according to experience. Applications stating age, qualifications and experience, together with the names and addresses of two referees, should be sent to the Administrative Officer as soon as possible. W 2947

PROFESSIONAL ENGINEERS in Government Departments. The Civil Service Commissioners announce an Open Competition for permanent appointments of Professional Engineers, General Service Class (Main and Senior Grades). Applications should be made as early as possible. The vacancies at present announced are in the Admiralty (about eight in the Main Grade and at least one in the Senior Grade), but vacancies in other departments may be announced later. The duties in the Admiralty cover the production of mechanical, electrical and electronic equipment for H.M. ships and include design for production, correlation of manufacturing requirements and capacity, advice on production methods, preparation of estimates and, in certain cases, material inspection and functional testing. Candidates must be at least 30 years of age on 1st January 1951. Minimum qualifications: generally Corporate Membership of the Institutions of Mechanical Engineers or Electrical Engineers is required, together with evidence of apprenticeship or pupilage and subsequent engineering experience. Exceptionally, candidates of high professional attainments without some or all of these qualifications may be admitted. Salary scales: London, Men: Main Grade—£750-£1,000; Senior Grade—£1,050-£1,270. Women: Main Grade—£650-£850; Senior Grade—£900-£1,100. Provinces, Men: Main Grade—£720-£960; Senior Grade—£997-£1,192. Women: Main Grade—£620-£810; Senior Grade—£860-£1,040. These rates are at present under review. Further particulars and application forms from Secretary, Civil Service Commission, Trinidad House, Old Burlington Street, London, W.1, quoting No. S86/51. W 2955

RADAR AND ELECTRONIC technicians required for employment in various parts of Scotland. Salary in scale £380 plus £20 to £500 according to age and location. Applicants should preferably have had experience of Service radar or computing instruments. Apply in writing giving details of age, experience and qualifications to A.D.M.E., 3 A.A. Group, Riccarton House, Currie, Midlothian. W 2930

RADIO ENGINEER required by Government Department. Should have industrial experience or service in a Research Establishment. A knowledge of V.H.F. communication techniques is desirable with ability to prepare technical reports and to analyse experimental data. Ability to service and maintain receivers and high-grade measuring equipment. Willingness to serve overseas (Europe). H.N.C. or City & Guilds Final. Salary £600-£700 p.a. Unestablished. Apply for application forms to Ministry of Labour and National Service, Technical & Scientific Register (K), York House, Kingsway, W.C.2, quoting D260/51 A. Closing date 14th July 1951. W 2963

SENIOR PRINCIPAL PRODUCTION ENGINEER, Admiralty Production Pool. The Civil Service Commissioners invite applications from men for one or two permanent appointments as Senior Principal Production Engineer. Candidates must have been born on or before 1st January 1920. Candidates must be Corporate Members of the Institution of Mechanical Engineers and/or the Institution of Electrical Engineers or show evidence of exceptionally high professional attainment. They must have had a wide general engineering background, including apprenticeship, and have had extensive experience in the engineering production field. Salary £1,500-£1,750. Further particulars and application forms from the Civil Service Commission, Scientific Branch, Trinidad House, Old Burlington Street, London, W.1, quoting No. S.4038/51. Completed application forms must be returned by 19th July, 1951. W 2956

THE CIVIL SERVICE COMMISSIONERS give notice that an Open Competition for pensionable appointment to the Assistant (Scientific) Class (Basic Grade) will be held during 1951. Interviews will be held throughout the year, but a closing date for the receipt of applications earlier than December 1951 may eventually be announced either for the competition as a whole or in one or more subjects. Successful candidates may expect early appointments. Candidates must be at least 17½ and under 26 years of age on 1st January 1951, with extension for regular service in H.M. Forces, but other candidates over 26 with specialized experience may be admitted. All candidates must produce evidence of having reached a prescribed standard of education, particularly in a science subject, and of thorough experience in the duties of the class gained by service in a Government Department or other civilian scientific establishment or in technical branches of the Forces, covering a minimum of two years in one of the following groups of scientific subjects: (i) engineering and physical sciences; (ii) chemistry, bio-chemistry and metallurgy; (iii) biological sciences; (iv) general (including geology, meteorology, general work ranging over two or more groups (i) to (iii) and highly skilled work in laboratory crafts such as glass-blowing). Salary according to age up to 25: Men £215 (at 18) to £330 (at 25)—£455; rather less in the provinces and for women. Opportunities for promotion. Further particulars and application forms from Civil Service Commission, Scientific Branch, Trinidad House, Old Burlington Street, London, W.1, quoting No. S 59/51. Completed application forms should be returned as soon as possible. W 2923

OFFICIAL APPOINTMENTS (Cont'd.)

UNIVERSITY OF ADELAIDE. Department of Electrical Engineering. Applications are invited for appointment as Lecturer in Electronic Engineering. Salary range: £600—£50—£1,000 Australian. Commencing salary according to qualifications. The original application must be sent to the undersigned, and one copy must be lodged with the Secretary, Association of Universities of the British Commonwealth, 5, Gordon Square, London, W.C.1, from whom full particulars of terms of appointment and a statement about the Department of Electrical Engineering may be obtained. Applications will close on 31st July 1951. A. W. Bampton, Registrar, University of Adelaide, Adelaide, South Australia. W 2940

SITUATIONS VACANT

A HOUSE (married accommodation) is available for senior radar, radio and electronics engineer to carry out development work on modern project in special English Electric Laboratory within 50 miles of London. Salary according to qualifications. Send details quoting ref. 456E to Central Personnel Services, English Electric Co. Ltd., 24/30, Gillingham Street, London, S.W.1. W 2945

A HOUSE (married accommodation) is available for competent engineer able to take charge of team operating telemetry equipment in the field and in laboratory not far from London. Important defence project. Starting salary £600-£800 per annum according to qualifications. Send details of qualifications and experience, quoting ref. HHE, to Box No. W 2944.

A HOUSE (married accommodation) is available for an experienced electronics engineer capable of developing antivibration means for electronic equipment. Location is special laboratory within 50 miles of London. Starting salary £600-£800 per annum according to qualifications. Send details of qualifications and experience, mentioning ref. 850B, to Central Personnel Services, English Electric Co. Ltd., 24/30, Gillingham Street, London, S.W.1. W 2946

A LARGE AIRCRAFT FIRM in the Midlands has vacancies for men with experience in construction and/or maintenance of electronic equipment. Service as radio or radar technician in H.M. Forces an advantage. Vacancies also exist for men with tool room experience and some interest in electronics. Interesting work with good prospects. Apply stating age, experience, etc., to Box No. W 2911.

AN ENGINEER is required age 28/30 for development work in process controls specializing on application of electronics, the post is a new one and will call for the capacity to work independently. Essential qualifications are age 28/30 with Degree or Higher National Certificate in Electrical Engineering. The successful applicant will be posted in East Anglia and would be required to do a certain amount of travelling. There is a superannuation scheme entry to which is dependent upon a satisfactory probationary period. The salary offered is £680 per annum. Write giving details of qualifications and experience. Box No. W 1328.

A NUMBER of Senior and Junior vacancies for Radio. Radar. Electronic. Television, etc.. Development. Service Engineers, Draughtsmen Wiremen. Testers. Inspectors, etc. Urgently required. 30 Television Service Engineers. Write in confidence: Technical Employment Agency. 179 Clapham Road. London, S.W.9. (BRIxton 3487.) W 113

A RESEARCH TEAM being built up on a new project of national importance and great technical interest requires the services of a few experienced physicists, or electrical engineers, preferably with a mathematical inclination. Candidates should be British-born subjects between the ages of 25 and 35. The posts carry good salaries and prospects and are pensionable. They are situated in the Greater London area. Write, quoting the reference GL, to Box No. W 2926.

A SERVICE ENGINEER is required by a London Company to undertake the repair and maintenance of electronic medical instruments throughout the British Isles. Applicants should be at least 25 years of age and should have had previous experience in instrument servicing. Write stating qualifications, experience and age to Box No. W 2979.

A SPECIAL vacancy occurs for a draughtsman with experience in detailing light mechanical or electronic equipment. The post is permanent and pensionable. Apply in writing to the Personnel Manager, Plessey Co. Limited, Ilford, quoting reference E.D. W 2829

ASSISTANTS of various grades for Research and Development work on Computers required by a large N. Kent Engineering firm. Qualifications: B.Sc., Higher National Certificate, Intermediate B.Sc. or equivalent. Salaries according to qualifications and experience. Write giving full particulars to Box No. W 2939.

A TECHNICALLY qualified man to take charge of a small relay section developing new types of relay. The applicant must be able to undertake the theoretical as well as the practical side of light electro magnetic mechanisms. Apply giving full details of experience to Personnel Officer, Ericsson Telephones Ltd., Beeston, Nottingham. W 1320

A WELL-KNOWN company in the London area has a vacancy for a senior qualified electronic engineer. Applicants should have had experience in communications equipment, feedback amplifiers or centimetric technique. Applications which will be treated in confidence, should be accompanied by full details of education and career to date, and salary required, quoting reference R.E.D. Box No. W 2981.

BELLING & LEE LTD., 540 Cambridge Arterial Road, Enfield, Middlesex, wish to engage a specialist to conduct aerial research and development, particularly at television frequencies Applicants must possess scientific qualifications together with considerable experience in the field; must be imaginative and original, and able to work with minimum supervision. Excellent research facilities are available and an attractive salary will be offered to the right applicant. W 134

BELLING & LEE LTD., Cambridge Arterial Road, Enfield, Middlesex, require research assistants in connexion with work on electronic components, fuses, interference suppressors and television aerials. Applicants must be graduates of the I.E.E. or possess equivalent qualifications together with similar laboratory experience. Salary will be commensurate with previous experience. Applications must be detailed and concise, and will be treated as confidential. W 138

COMPETENT mechanical and/or electrical engineering draughtsmen required for design work in connexion with a cyclotron being constructed for cancer research. Salary in accordance with age and experience. Apply in writing giving full details of qualifications and previous appointments and including references, to the Senior Cyclotron Engineer, M.R.C. Cyclotron Section, P.O.W. Camp, Scrubs Lane, London, W.12, quoting reference E.E. W 1313

APPLICATIONS are invited by a company located in South West of—but close to—London for the following staff: Senior Designer Draughtsmen, Draughtsmen, Junior Draughtsmen. The company's operations, which are on a considerable scale, are solely concerned with pure research and development work in the fields of Electronics, Electricity and intricate mechanisms. The working conditions are ideal and the draughting equipment is modern and of high quality. The positions offered are permanent, the salary will be generous and there is a pension scheme. The present staff of the company are aware of this advertisement. Applications in the first place will be seen by the Managing Director only and there need be no apprehension in the mind of any intending applicant of any breach of confidence. Applications should contain full personal particulars, details of education and all positions held subsequently and should be addressed to the box number given and marked "Managing Director." W 1322

DESIGNER - DRAUGHTSMEN with Higher National Certificate, University Degree or similar qualifications and with 2-4 years experience are required for work with experimental research teams in mechanical and radio engineering. Applications giving age and record should be sent to the Personnel Officer (Ref. GBLC/133), Research Laboratories of the General Electric Co. Limited, East Lane, North Wembley, Middlesex. W 2927

DEVELOPMENT ENGINEER. A large engineering establishment in the N. Kent area requires the service of a Development Engineer with technical and practical experience in electronics. Preferred minimum qualifications the Higher National Certificate in Electrical Engineering. A knowledge of Servo Mechanisms would be an advantage. Reply, stating age and giving full particulars of experience and salary required to Box No. W 2938.

DEVELOPMENT ENGINEERS required for the Line Telephone Transmission Section. Applicants should possess Degree or equivalent qualifications. Salary according to age and experience. Apply in writing giving full particulars of education, experience and salary required. Siemens Brothers & Co. Limited, Ref. 715/21, Woolwich, S.E.18. W 2884

DIGITAL COMPUTERS: Ferranti Limited, Moston, Manchester, are engaged upon the long term development and exploitation of digital computers. This interesting work covers vacuum physics, the electronic and electrical properties of materials, computing and pulse circuit techniques, electrical and mechanical recording, electromechanical mechanisms, precision mechanical engineering and power supply equipment. In the course of this work there are occasional vacancies for senior engineers with wide experience from whom enquiries will be welcomed at any time. There are immediate vacancies for: (1) Engineers and Scientists for research and development work in the above fields. Qualifications include a good Honours Degree in Physics or Engineering, or equivalent experience. Salary according to qualifications and experience in the range £450 to £1,000 per annum. Please quote Ref. D.C.E. (2) Technical Assistants for experimental work in the above fields. Qualifications are a Degree or Higher National Certificate in Engineering, or equivalent. Salary according to age and experience in the range £350 to £650 per annum. Please quote Ref. D.C.A. The Company has a Staff Pension Scheme and will give housing assistance in special cases. Application forms from the Staff Manager, Ferranti Limited, Hollinwood, Lancs. W 2825

DIRECTOR of Engineering required to take charge of a highly technical Research and Development Company in the Greater London area (a subsidiary of a large Engineering Public Company). Applicants must possess a First Class Honours Degree and must have specialized in Electronics. Considerable experience is essential in the direction and management of research establishments, and the ability to guide and supervise teams of project engineers, design offices and model shops. Position carries a high salary, the possibility of an exceptional house and excellent long term prospects with pension facilities. All replies will be treated in full confidence. Write giving full details of qualifications, past experience and salary required to the Managing Director. Box No. W 1324.

DRAUGHTSMEN. Immediate vacancies exist for Senior and Junior Draughtsmen with light mechanical, electrical, or radio engineering experience to work on new project in a rapidly expanding industry. Applicants should have sound knowledge of materials and engineering methods. Production design experience would be an additional qualification. Good salaries offered to capable men seeking a progressive position in Bedfordshire. Applicants should write giving full details, quoting ref. ADD to Box No. W 2931.

E. K. COLE (Electronics Division) offers excellent opportunities for young Draughtsmen of Ordinary National Standard to gain experience in the Development of Radar, Communications and Nucleonic Equipments. Also a limited number of vacancies for Senior Draughtsmen with experience of this type of work. Apply giving details of experience to Personnel Manager, E. K. Cole Limited, Malmesbury, Wilts. W 2971

CLASSIFIED ANNOUNCEMENTS
continued on Page 4

E. K. COLE LTD., have vacancies in their Electronic Division at Malmesbury, Wilts., for senior and Intermediate Draughtsmen in the Development Drawing Office, for work on Radar, Communications and Electronic Projects. Previous experience in this field desirable but not essential. Apply in writing to the Personnel Manager, Ekco Works, Malmesbury, Wilts. W 2934

ELECTRICAL ENGINEER not over 30 with interest in general physics required for interesting work connected with the manufacture and development of infra-red spectrometers. A Degree in electrical engineering or physics is desirable. Apply, giving full details of qualifications, experience, age and salary to Sir Howard Grubb, Parsons and Co., Walkergate, Newcastle-on-Tyne, 6. W 2973

ELECTRONIC ENGINEER required with sound knowledge and experience in design and manufacture. Good prospects in modern West Country factory. Send full details to Box No. W 2957.

ELECTRONIC ENGINEERING. Junior Design, Development and Sales Engineers required. Permanent progressive posts for suitable young men. Apply in writing to Leland Instruments Limited, 22-23 Millbank, London, S.W.1. W 2953

ELECTRONIC ENGINEERS, age 22-30 for aircraft instrument firm for development laboratory, in Guildford area. Applicants should possess a Degree or National Certificate in electrical engineering and preferably have some experience in electronics and/or electrical instruments. Apply stating experience, qualifications and salary required to Box No. W 2924.

ELECTRONIC/ELECTRICAL Engineers required with Higher National Certificate (Electrical) and at least four years' experience of Radar. Apply Employment Manager, Vickers-Armstrongs Limited (Aircraft Section), Weybridge. W 2900

ELECTRONIC/ELECTRICAL Engineer required with Degree in Physics or Telecommunication Engineering, and at least four years' experience of Radar. Apply Employment Manager, Vickers-Armstrongs Limited (Aircraft Section), Weybridge. W 2899

ELECTRONIC ENGINEERS required by Airmec Laboratories Limited, Cressex, High Wycombe, Bucks, to be employed on interesting Government and commercial development work. Salary according to experience. Write giving full details to Personnel Officer. W 2985

ELECTRONIC TESTERS and Trouble Shooters required for West Midlands organisation. Previous experience essential, Factory and Television experience desirable. Good pay and prospects. Box No. W 1314.

ELECTRONIC TUBE Development and Manufacture. Engineers and Physicists required for progressive technical and supervisory positions in our development and manufacturing departments. Successful applicants will have exceptional opportunities for advancement in the rapidly expanding electronics industry. Qualifications: Good Degree in engineering or physics. Previous experience desired but not essential. Applicants graduating this year and free of National Service obligations will receive special consideration and, after appointment, will be given comprehensive training. Salary according to age and experience but will not be less than £425 per annum for Honours Graduates at age 21. Application should be made to Personnel Officer, Mullard Radio Valve Company Limited, New Road, Mitcham Junction, Surrey. W 2952

ENGINEER or Physicist required to take charge of section developing thermionic transmitting valves. Honours Degree in physics or electrical engineering or equivalent essential. Previous experience of transmitting valves desirable. Salary according to experience and suitability. Apply Personnel Manager, Standard Telephones and Cables Limited, Ilminster, Somerset. W 2967

ENGINEER required to be responsible for short run production of a variety of electronic and V.H.F. radio equipment. Good technical knowledge and practical experience of job breakdown and prototype work essential. Preference given to a young man who is conversant with A.I.D. requirements, with ability to control electronic test. Location is Luton Airport. State salary required and quote ref. 900 to Central Personnel Services, English Electric Co. Limited, 24-30 Gillingham Street, London, S.W.1. W 2968

ENGINEERING Draughtsmen, aged 22-28, having Ordinary or Higher National Certificate in Electrical or Mechanical Engineering, required for development work by well-known Instrument firm for factory in Guildford area. The engineering department is engaged on experimental work on aircraft electrical instruments, electronic equipment and servo systems. Interest in this type of work very desirable in view of close association between draughtsmen and engineers engaged on development projects. Write stating qualifications, experience, salary required to Box No. W 2912.

ENGINEERING establishment, West London area, require several first-class Project Design Engineers for work of an intricate mechanical and electro-mechanical nature. Only qualified men capable of undertaking complete design of projects, under guidance of Chief Engineer and Chief Design Engineer, will be considered. Experience in either of the following fields will be advantageous: Printing Machinery, Automatic Feeding Apparatus, Teleprinter principles and Electronic Controls. Write in first instance giving full experience and qualifications to Chief Engineer, Box No. W 136.

ESTIMATING AND PLANNING ENGINEER required by Airmec Laboratories Ltd., Cressex, High Wycombe, Bucks. Applicants should be fully experienced in the Electronic and Light Engineering Industries. Salary according to age, qualifications, and experience. Apply giving full details to Personnel Officer. W 2986

EXPERIENCED Estimator required by large light electrical engineering company situated in London area. For this position experience in the preparation of detailed estimates involving machine work and assembly of light electrical equipment is essential. Preference will be given to applicants with practical training and some experience in planning or jig and tool design. Permanent position, staff pension scheme and excellent prospects. Kindly state full details of experience with age and salary required to Box No. W 2951.

FERRANTI LIMITED, Moston Works, Manchester, have staff vacancies in connexion with long term Development Work on an important Radio Tele-Control Project. (I) Senior Engineers or Scientists to take charge of research and development sections. Qualifications include a good Degree in Physics or Electrical Engineering and extensive past experience in charge of development work. Salary according to qualifications and experience in the range of £1,000-£1,500 per annum. Please quote reference R.S.E. (II) Engineers and Scientists for research and development work in the following fields: Radar, radio and electronic circuits, micro waves, high power centimetric valves, vacuum and/or high voltage techniques, servo control and electro-mechanical devices. Qualifications include a good Degree in Physics or Electrical Engineering or Mechanical Science, or equivalent qualifications. Previous experience is an advantage but is not essential. Salary according to qualifications and experience in the range £420-£1,000 per annum. Please quote reference R.T.E. (III) Technical Assistants for experimental work in the fields listed in (II) above. Qualifications required: a Degree or Higher National Certificate in Electrical or Mechanical Engineering or equivalent qualifications. Salary in the range of £260-£550 according to age and experience. Please quote reference R.T.A. The Company has a Staff Pension scheme, and will give housing assistance in special cases. Application forms from Mr. R. J. Hebbert, Staff Manager, Ferranti Limited, Hollinwood, Lancs. W 2764

INDUSTRIAL RADIOLOGIST required to undertake full responsibility for a modern X-ray department, using both Tubes and Radio Active Elements. Materials range from small components in special alloys, to large component castings. The department services a large works situated in the Midlands Area, engaged on an important field of aeronautical engineering. Applicants must be A.I.D. approved Radiologists. Applications should state full qualifications and salary required to Box No. W 2932.

INSPECTOR required to be responsible for inspection of electronic V.H.F. Radio equipment. Age preferably 28-35. Familiar with A.I.D. requirements. At least five years experience of inspection and testing. Salary according to qualifications. Please write giving qualifications, experience, age and salary required quoting ref. 899 to Central Personnel Services, English Electric Co. Ltd., 24-30 Gillingham Street, London, S.W.1. W 2965

INSTRUMENT WIREMEN required for high priority projects and other electronic work. Theoretical knowledge not essential, but practical experience in wiring to schematic diagrams important. Excellent rates with good opportunity for progress. Apply in writing, giving details of past employment and experience to Labgear Limited, Willow Place, Cambridge. W 1318

LABORATORY ASSISTANT for north east coast area for development work in connexion with the manufacture of radio resistors. Applicants should be at least Inter B.Sc. standard (electrical engineering or physics) and have some knowledge of electronics. Practical industrial experience would be an advantage but not essential. Box No. W 2969.

LABORATORY ASSISTANT required by Loudspeaker Manufacturers. Experience in a similar capacity, together with some knowledge of Drawing Office practice an advantage. The work is interesting and varied and the situation offers scope for initiative. Write giving full details of age, experience and salary required to Electro Acoustic Industries Limited, Broad Lane, London, N.15. W 2964

LABORATORY ASSISTANTS for development work on Cathode Ray, Photo-electric and other types of Television Vacuum Tubes. Preference given to applicants with Inter-B.Sc. or equivalent, and with completed National Service. Good Canteen. 5-day week. Pension Scheme. Write giving age, experience and salary required to Cinema-Television Limited, Worsley Bridge Road, Lower Sydneham, S.E.26. W 2962

LEADING MANUFACTURER of Aircraft Instruments and Electronic equipment invites applications for a vacancy in the Aeronautical Service Department. Duties will include installation, flight testing and servicing, for which a thorough practical and theoretical knowledge of A.C. and D.C. amplifier systems is required. A knowledge of Electro-Mechanical servo and synchronous transmission systems would be of advantage. Preferential consideration would be given to applicants with previous electronic experience in possession of Higher National Certificate (or equivalent), or who have served a recognised engineering apprenticeship with subsequent experience in a technical capacity. Must be prepared to travel. Position will be permanent and pensionable after a qualifying period. Commencing salary £450 p.a. Apply giving full particulars of age, qualifications and experience to Box No. A.C. 63166, Samson Clarks, 57-61 Mortimer Street, London, W.1. W 2949

MARCONI'S WIRELESS Telegraph Co. Ltd., have vacancies for project engineers in their Broadcasting Division. Applicants must have experience in installation, operation and maintenance of broadcasting or television transmitting or studio equipment. Some design experience would be an advantage. Successful candidates will be paid a salary in the grade of £440 to £880 p.a. the starting point being determined by the applicant's qualifications and experience. The Company operates a staff pension scheme. Please write, giving full details, quoting ref. 466B to Central Personnel Services, English Electric Co. Limited, 24-30 Gillingham Street, London, S.W.1. W 2972

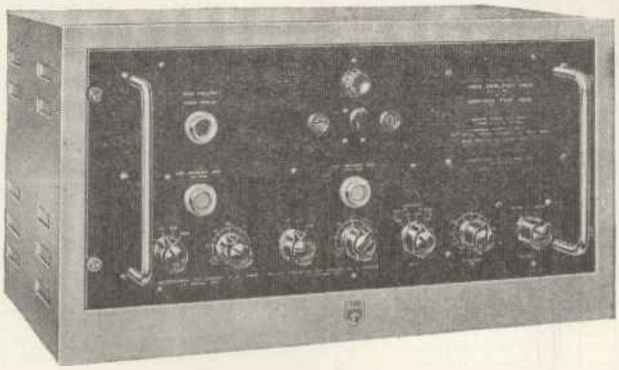
MARCONI'S WIRELESS Telegraph Co. Limited, have vacancies for technical assistants for Contract work in their Broadcasting Division. Applicants should have works experience, preferably in the planning and progressing of production. Some experience of broadcasting or television equipment would be an advantage. Successful candidates will be paid a salary in a grade which rises to a maximum of £515 p.a. A Staff Pension Scheme is in operation. Please write giving full details and quoting reference 847A to Central Personnel Services, English Electric Co. Limited, 24-30 Gillingham Street, London, S.W.1. W 2974

McMICHAEL RADIO LIMITED, require qualified draughtsman with experience in the mechanical design of radio and electronic instruments for the government services. Salary will be commensurate with ability. Write stating age, training, experience and salary required to the Chief Engineer, Equipment Division, McMichael Radio Limited, Slough, Bucks. W 2976

McMICHAEL RADIO LIMITED, require senior project engineers in their equipment division development laboratory at Slough. Training and experience in the field of applied

CLASSIFIED ANNOUNCEMENTS
continued on Page 6

EKCO
LINEAR AMPLIFIER
1008A



A general purpose A.C. amplifier developed in conjunction with the A.E.R.E., for use in the field of nuclear physics and the inspection and accurate measurement of small waveforms. The maximum overall amplification is 1,600,000 over the frequency range of 20 c/s to 500 Kc/s. Very low noise level allows useful amplification of signals of a few microvolts; stability is better than 1%.

Please write for catalogue giving specifications, prices and delivery dates of the complete range of Ekco electronic equipment for the radiochemical laboratory.

EKCO

Electronics

Stand No. IC
British Instrument Industries Exhibition

E.K.COLE LTD. (Electronics Division) 5 VIGO STREET · LONDON, W.1

British Radio Invites You!

Do you realise that the Radio Show in London this year will be the biggest show of Radio, Television, Telecommunications and Electronics the world has ever seen · In addition to the wide range of exhibits which will be on show, visits to actual installations can be arranged for interested visitors · Special arrangements have been made to welcome a record number of overseas visitors · Will *you* be coming? There is a heavy demand for accommodation in England this year, so it is advisable to book your travel and hotel accommodation early.

British National Radio Show

EARLS COURT · LONDON

August 29—September 8

Information brochures may be obtained from

THE RADIO INDUSTRY COUNCIL · 59 RUSSELL SQUARE · LONDON WC1 · ENGLAND

Telegrams: Oidarion, Westcent, London

electronics (including communications) and experience of working with government departments are the chief qualifications required. Salary will be commensurate with ability. Write stating age and full details of training, qualifications and experience to the Chief Engineer, Equipment Division, McMichael Radio Limited, Slough, Bucks. W 2977

OPPORTUNITY OFFERED to young engineer with electro-mechanical experience to train as draughtsman. Age limit 25 years. Applicants should have had at least 2 years' workshop experience and must be studying or have completed O.N.C. Salary paid during training and excellent position given after satisfactory probationary period. Location of work is Bedfordshire. Apply giving full details and mentioning ref A.F.I. to Box No. W 2935.

PERMANENT, progressive, interesting position with a West Midlands concern in newly formed Electronic Section, to assist Chief Engineer. Previous development experience essential. Development of test gear and general electronic equipment. Please state salary required. Box No. W 1315.

PHYSICISTS or Physical Chemists required for laboratory in Northamptonshire to carry out varied and interesting work on new ceramic and metallic materials. Applicants should have a good science Degree and be familiar with techniques for measuring magnetic and dielectric properties. Experience in designing radio and electronic components from these materials an advantage. Salary £450-£650 according to qualifications and experience. State full particulars to Box No. W 2925.

PHYSICISTS required by well known firm of instrument makers in London for laboratory work in connexion with the development of scientific instruments and apparatus. Previous experience not necessary but applicants should preferably hold a Degree in physics or light electrical engineering. Apply giving full details of training and experience and stating age and salary required to Box No. W 2978.

PRODUCTION ENGINEER to qualify as Manager of production for high-grade electronic instruments at new factory in Surrey. Must be good organiser, able to expand production by drive and initiative while maintaining quality. Excellent prospects for the right man in a new and expanding venture. Full details to Box No. W 2891.

PROMINENT AIRCRAFT firm in Greater London area, commencing new project of great National importance, offers unique opportunity for advancement. High salaries with monthly staff status and Pension Scheme offered to suitably qualified applicants. Electronic Engineers with 1st Class Honours Degree in Mathematics or Engineering preferably with several years' practical experience, though not essential. Apply, stating age, nationality and experience, to Box Ac.58212, Samson Clarks, 57-61, Mortimer Street, W.1. W 131

QUALIFIED JUNIOR ENGINEERS required for development work on various kinds of Vacuum Tubes used in Television, Radar and allied subjects. Good Canteen. 5-day week. Pension Scheme. Write, giving personal details, experience (if any) and salary required to Cinema-Television Limited, Worsley Bridge Road, Lower Sydenham, S.E.26. W 2961

RADIO - RADAR Development Engineers urgently required, accommodation available. Applications are invited from Senior and Junior Development Engineers, preferably with experience of Radar or microwave technique, who are capable of developing equipment or components to Service Specification. Successful candidates will be employed on work of great National Importance. Write quoting reference CHC. (5) to Personnel Officer, General Electric Co. Ltd., Radio & Television Works, Spon Street, Coventry. W 2903

REQUIRED. Electronics/Electrical Designer, take charge design and development wide range covering, electronic welding and process controls, small spot welders, rectifier units up to 50kW. Valve and relay circuitry experience essential. Should have Degree or equivalent, with practical outlook. State age, experience and salary required. Hirst Electronic Development Limited, Dermody Road, London, S.E.13. W 1323

RESEARCH PHYSICISTS and engineers with 2-4 years post-graduate experience at university or in industry will be required this summer by the Research Laboratories of The General Electric Co., Limited, North Wembley, Middlesex. A small number of appointments will be made in the fields of electronics, vacuum physics and light mechanisms. Starting salaries will be attractive and prospects excellent. Applications will be considered now from candidates who may commence work during the next six months. Details of academic qualifications, age and experience should be sent in confidence to the Personnel Officer (Ref. GBLC/136). W 2933

SALES MANAGER. Interesting opening for qualified Chemical or Mechanical Engineer with first-class organising ability and experience of Chemical Plants to take charge of Sales of Automatic Control equipment with wide range of applications. University trained preferred. Apply fully stating age, education, positions held and salary expected to Box No. W2980.

SENIOR AND JUNIOR Electronic Development Engineers required for work of high priority. Degree or inter-B.Sc. desirable. Salary £400-£750 p.a. according to qualification and experience. Write stating full details to Personnel Manager, The McMurdo Instrument Co., Ltd., Ashtead, Surrey. W 2907

SENIOR DEVELOPMENT Engineers required for Carrier Telephone work in S.E. London area. Applicants should state age and details of experience and salary expected. Box No. W 2885.

SENIOR DRAUGHTSMAN required for interesting work on electronic equipment, design and small quantity production. Experience an advantage, also ability to work on own initiative. Good prospects and five day week. Apply Personnel Manager, Dynatron Radio Limited, Ray Lea Road, Maidenhead, Berks. W 2929

SENIOR DRAUGHTSMEN urgently required for appointment to posts carrying design responsibility on Quantity Radar production. A wide mechanical and electrical background on this type of work is essential coupled with considerable experience in the rapid handling of production line design and process problems. Salaries will be commensurate with experience and abilities. Apply in writing quoting Ref. EWS to Decca Radar Limited, Shannon Corner, Kingston By-pass, New Malden, Surrey. W 1316

SENIOR ENGINEER wanted for experimental work on servo-mechanisms for modern high-speed project in special English Electric Company Laboratory. Good experience in servo loop design essential. Honours Degree preferable. Progressive position, with commencing salary £700-£900 p.a. Write, giving full details and quoting ref. 844B, to Central Personnel Services, English Electric Co., Ltd., 24-30 Gillingham Street, London, S.W.1. W 2863

SENIOR MECHANICAL Designer is required by the Research Laboratories of The General Electric Co. Limited, East Lane, North Wembley, Middlesex, for work in the field of radio communications, including airborne equipment. Good experience and academic qualifications are essential. Applications should be sent to the Personnel Officer (Ref. GBLC/208), giving details of age and record. W 2954

SPERRY GYROSCOPE CO. LTD., Great West Road, Brentford, Middlesex, require Electro-Mechanical Engineer. Good academic qualifications and recognised apprenticeship desirable. Experience in electrical and electro-mechanical methods of computation; servo theory, and instrument design preferred. Apply with full details of experience and salary required to the Personnel Manager. W 124

SPERRY GYROSCOPE CO. LTD., Great West Road, Brentford, Middlesex, require Electronic Engineer. Good academic qualifications and recognised apprenticeship desirable. Required for development work on control systems. Experience of D.C. amplifiers and computing devices an advantage. Apply with full details of experience and salary required to the Personnel Manager. W 126

SPERRY GYROSCOPE CO. LTD., Great West Road, Brentford, Middlesex, require Mechanical Engineer. Good academic qualifications and recognised apprenticeship desirable. Preferably experienced in one or more of the following: precision mechanical design; hydraulics or pneumatic servo systems; servo theory, aerodynamics. Apply with full details of experience and salary required to the Personnel Manager. W 128

THE CAMBRIDGE INSTRUMENT Co. Ltd., have a few vacancies for Test room assistants and scientific instrument assemblers. The work is interesting and offers good prospects to suitable applicants. Call or write to Cambridge Instrument Co. Ltd., Sydney Road, Muswell Hill, N.10. W 2905

THE PLESSEY COMPANY LIMITED, Ilford, requires engineers and draughtsmen for design and development of radio and television components, F.H.P. Motors, and small electro-mechanical devices. An engineering Degree is desirable for senior positions, and qualifications not less than H.N.C. are needed for Junior positions. Several years production experience is essential for all positions. Full particulars to Personnel Manager, The Plessey Company Limited, Ilford. W 2960

THERE ARE a number of vacancies suitable for Honours Graduates in physics, electrical or mechanical engineering or mathematics or a good general Degree covering two or more of these subjects, for both research and development work in the following fields: Radio and Line Communications, Radar, Electronic Instrumentation, Microwaves, Ultrasonics, Vacuum Techniques and Electromechanical Devices. Salary according to qualifications and experience consistent with general present-day levels. There are vacancies for which considerable post-graduate experience is required and others for which previous experience is not necessary. Consideration will be given to students taking finals during the current academic year. Prospects of promotion are good and the posts all fall within the Mullard Company's Superannuation Scheme. Apply Personnel Officer, Mullard Electronic Research Laboratory, Salfords, Nr. Redhill, Surrey. W 2896

VALVE ENGINEER with experience on small transmitting valves required for new section in important organisation. Knowledge of design and production desirable. Write with full details, experience and salary required. Box No. W 2958.

WANTED a graduate in Civic Chemistry or Electrical Engineering, or equivalent, to be trained in the Capacitor Laboratory on the development of new materials and the exploitation of new manufacturing techniques. No previous experience is necessary and there are excellent prospects of advancement. Apply to Personnel Department, Standard Telephones and Cables Limited, North Woolwich, stating age, qualifications and salary required. W 2928

WANTED Junior Engineers for work on telemetry in the field. Experience desirable but not essential if otherwise well qualified. Headquarters near London. Salary according to experience. Write giving full details mentioning ref. HHE, to Box No. W 2959.

YOUNG MAN required to train as laboratory technician in the Department of Physics, University of Bristol. Should have completed National Service. Previous experience not essential but an interest in electronics would be an advantage. Salary £195-£334 15s. according to age and qualifications (with membership of superannuation scheme), Apply in writing to the Registrar, The University, Bristol, 8. W 1321

SITUATIONS WANTED

GRADUATE ENGINEER with experience over a wide field seeks a position of trust and responsibility in Administrative or Sales Department. Box No. W 1327.

TRAINING OFFICER (Electronics), A.M.I.E.E., etc. Experience power, radio, television, initiating and conducting training schemes, writing, design. Desires responsible post. Box No. W 1325.

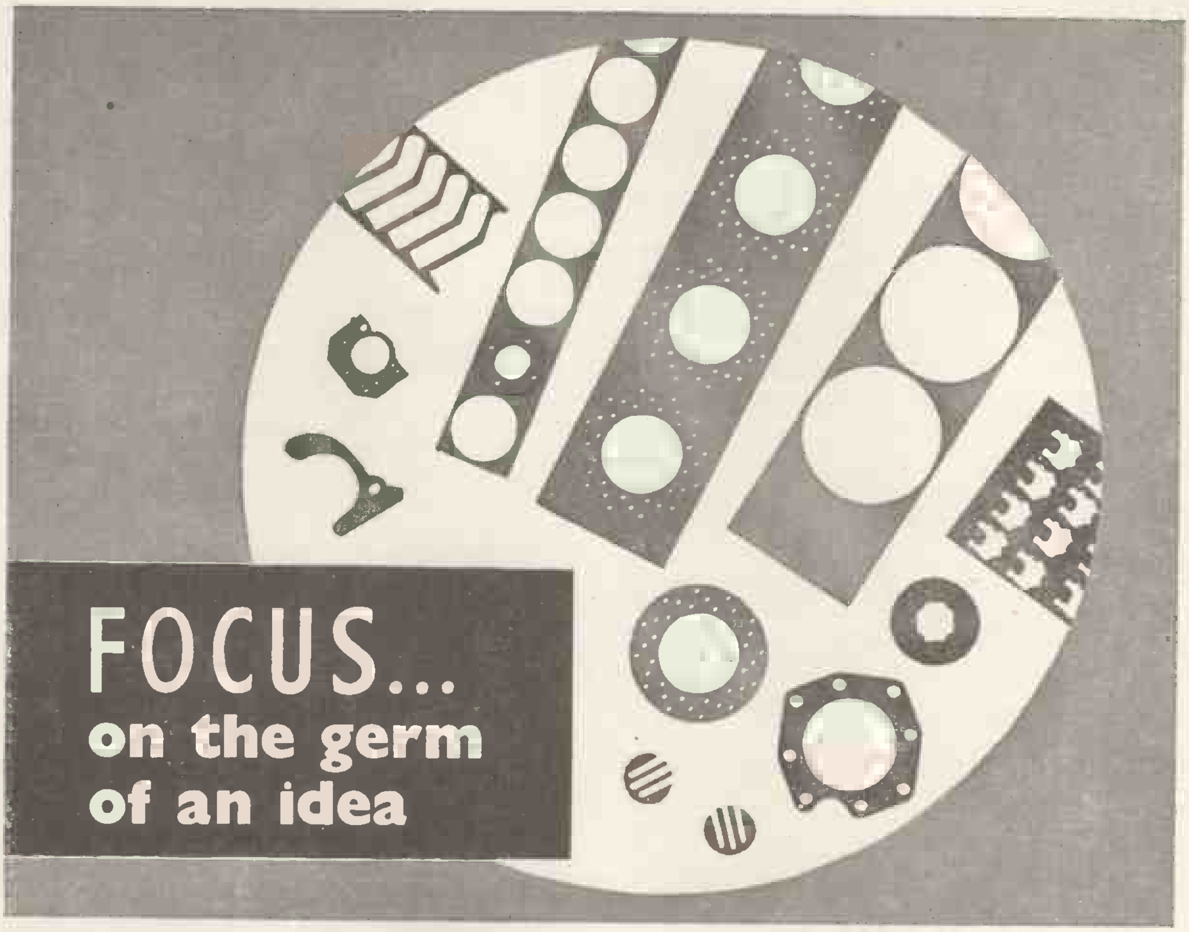
FOR SALE

AMERICAN MAGAZINES. One year post free. "Radio Electronics." 32s. 3d.: "Audio Engineering," 28s. 9d., "Radio and Television News." 36s.: "Popular Science," 28s. 6d. S.A.E. for full list from Willen Ltd., (Dept. 9), 101 Fleet Street, London, E.C.4. W 108

CRYSTAL CALIBRATOR WAVEMETER (230v AC) 20-80 mc/s £25. Marconi TF 390 Sig. Gens. (2) similar frequencies. Cossor D.B. 'scope. Model 339A, as new £45. BM/XKDS. London, W.C.1. W 1326

CRYSTAL SET COMPONENTS. Germanium and Crystal Diodes. Permanent and cats-whisker detectors and crystals. Coils—tuning condensers — headphones — complete receivers. Lists on application. British Distributing Co., 66 High Street, London, N.8. W 1319

CLASSIFIED ANNOUNCEMENTS
continued on Page 8



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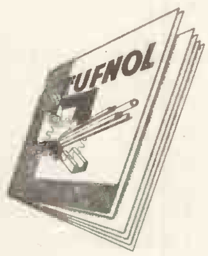

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100-L	2000 va.	230/115	8 a.	9 a.	0-230	25 watts	17 17 0
100-LM	2000 va.	230/115	8 a.	9 a.	0-230	25 watts	18 12 0
100-Q	2000 va.	115	15 a.	17.5 a.	0-135	20 watts	18 9 0
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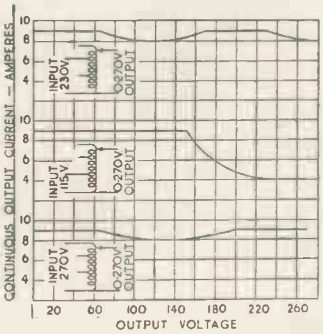

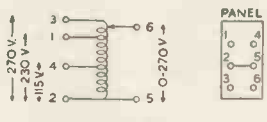

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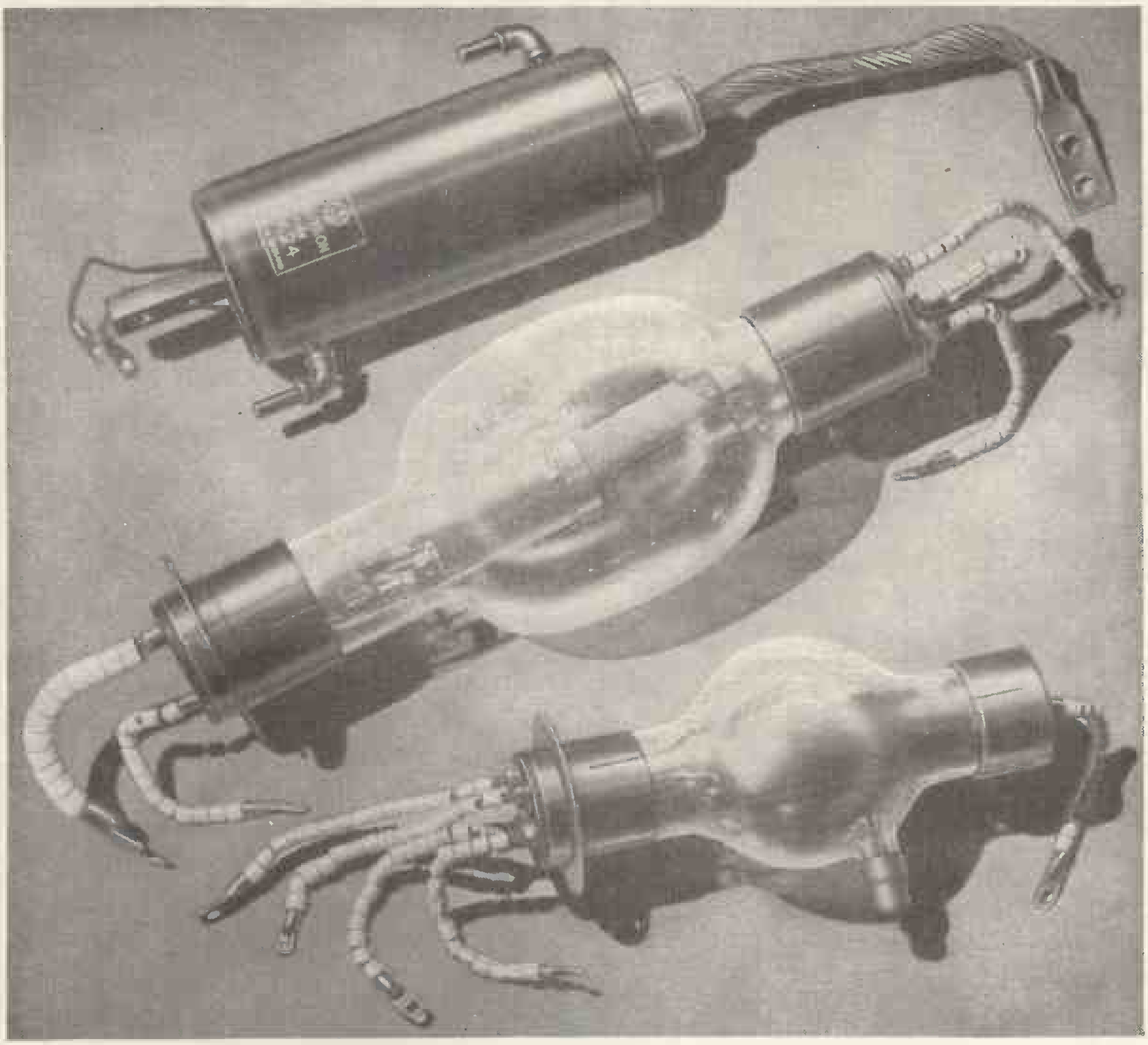

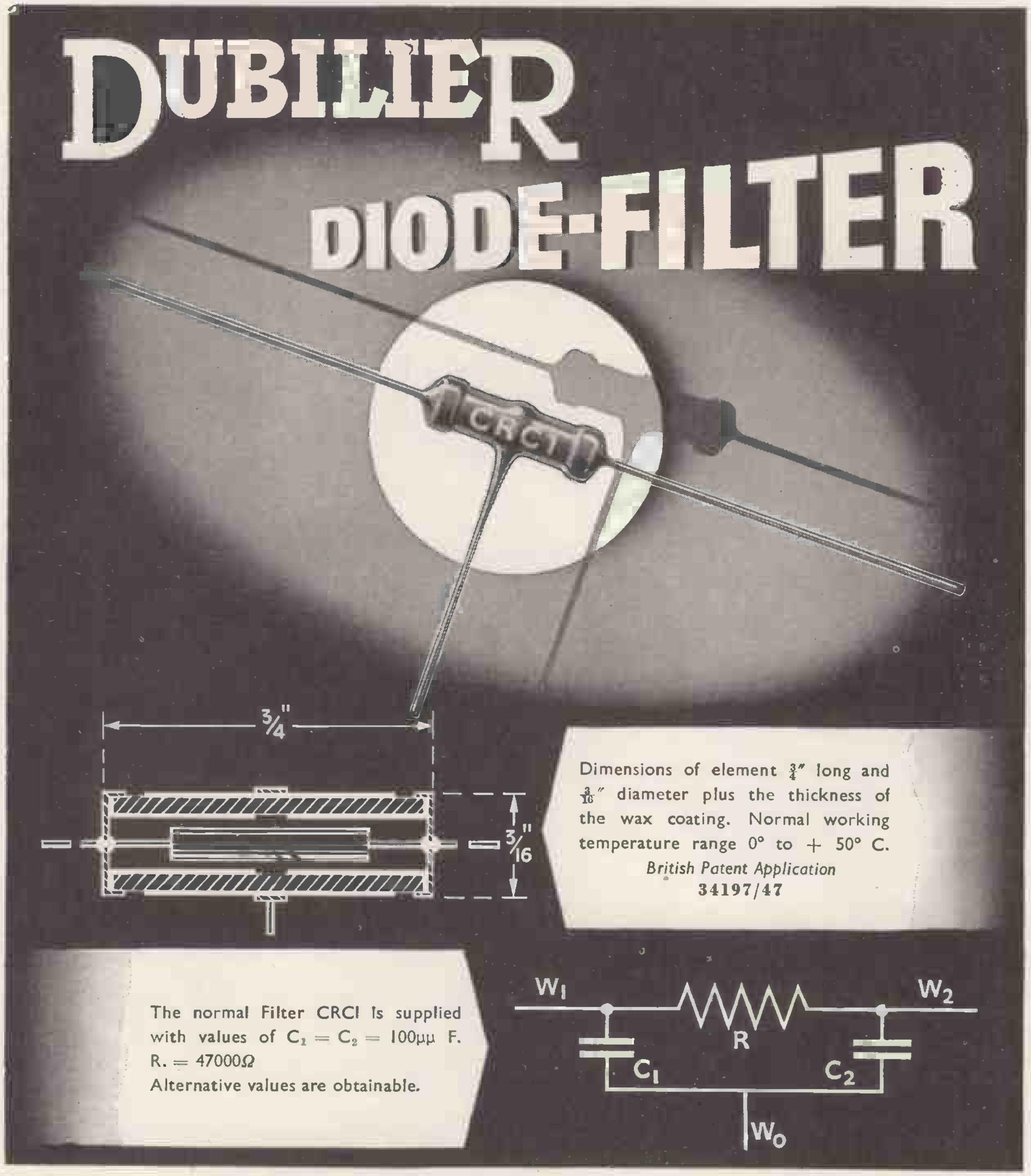

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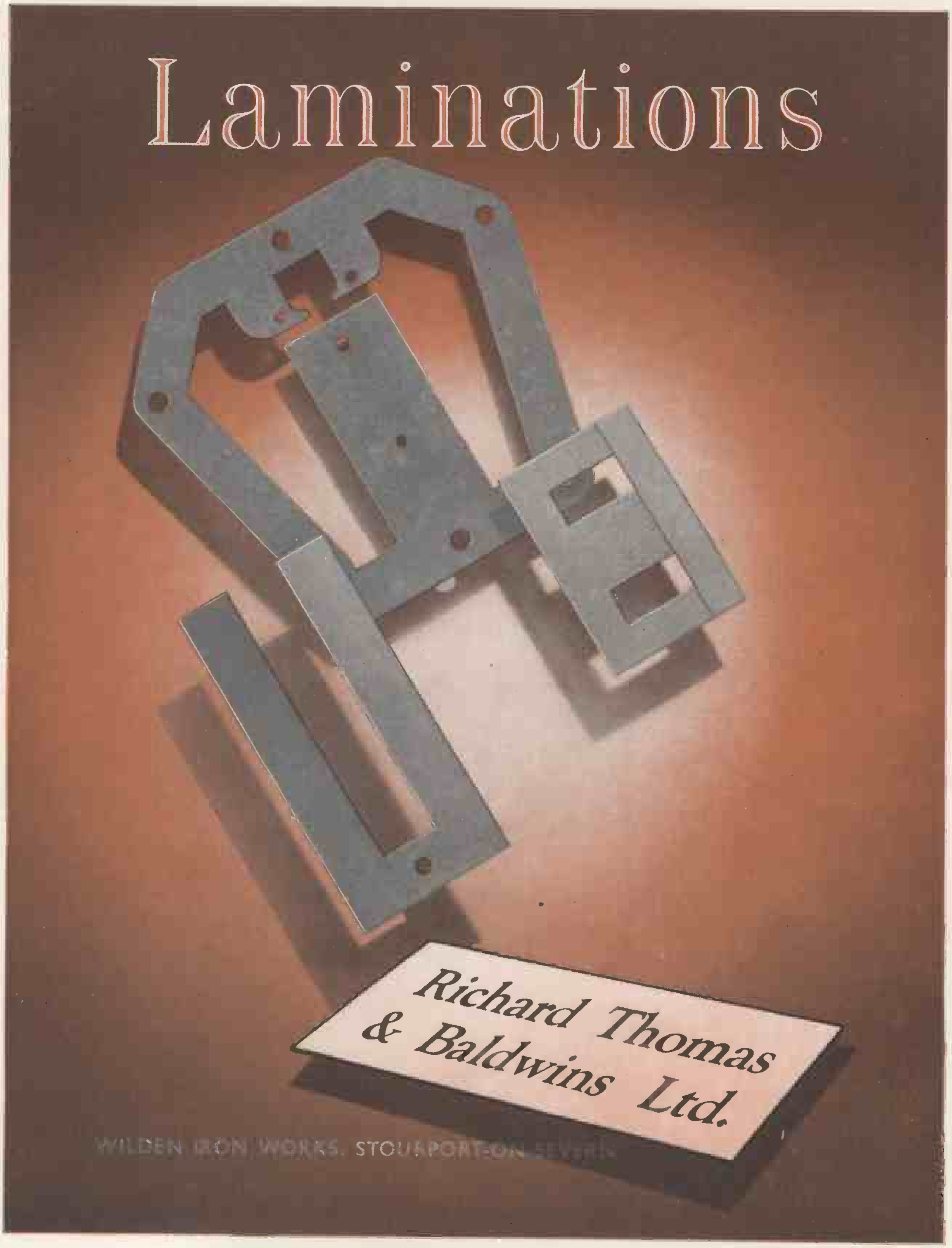
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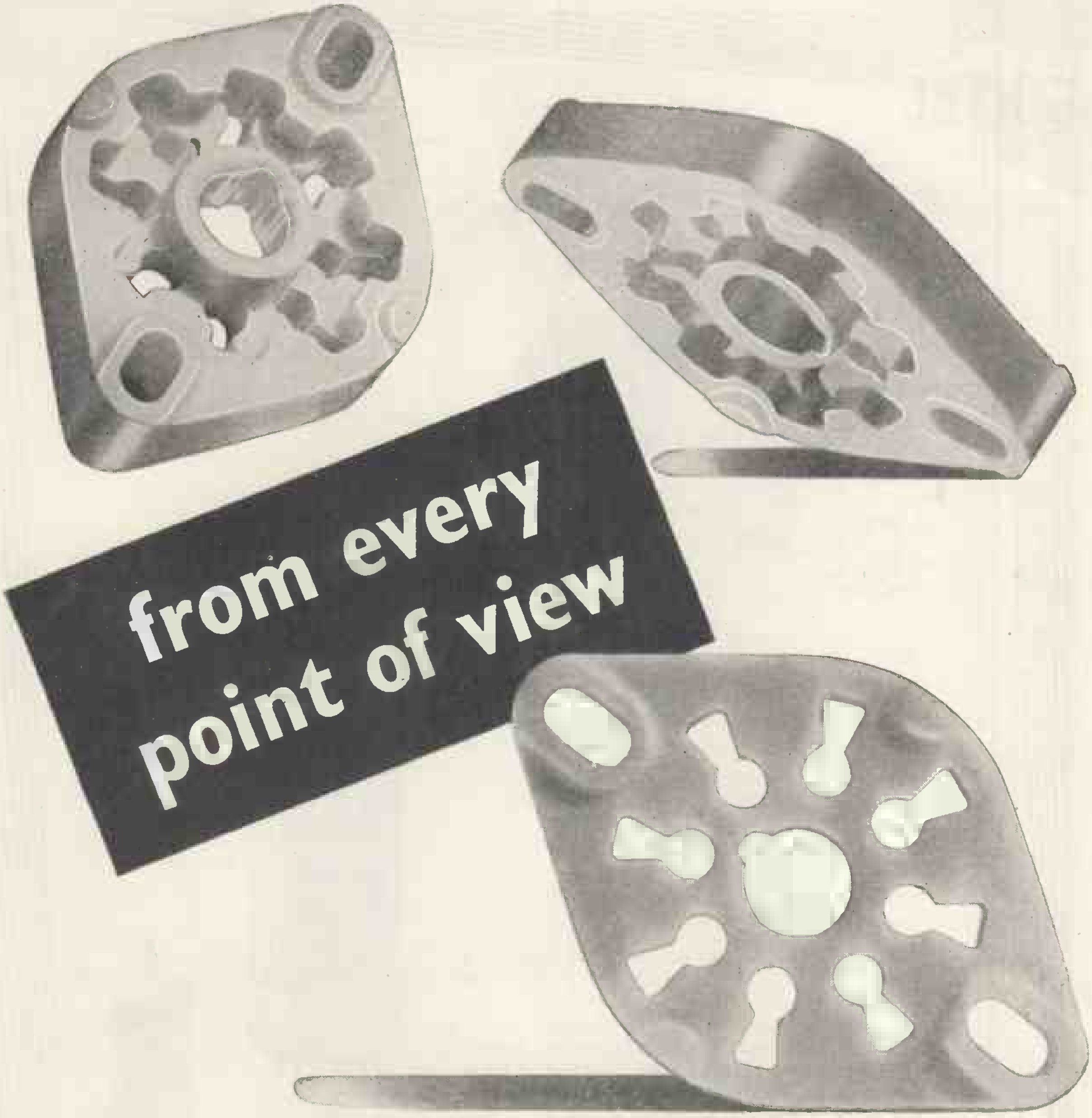
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Vol. XXIII — **JULY 1951** — No. 281

In This Issue

Commentary ... 243
V.H.F. Common Aerial Working ... 244
By E. G. Hamer, B.Sc., A.M.I.E.E.
Practical Methods of Waveform Analysis ... 250
By J. B. McMillan, M.A., B.Sc.
Electronics in Duplicating ... 252
By E. G. Gordon.
A Visual Aid for use in Teaching Vector Diagrams 253
By T. Palmer.
A Judgment Box ... 256
By W. H. Alexander, B.Sc., A.Inst.P.
Receiving Valves suitable for Electrometer Use ... 258
By G. H. Hay, M.Sc.
An Indoor Television Aerial Array ... 262
By F. E. Wood.
New Zoom Lens for Television ... 263
Some Aspects of Electrical Computing (Part 2) ... 264
By J. Bell, M.Sc., M.I.E.E.
Cathode Followers as Low-Noise Input Stages ... 270
By M. J. Tucker, B.Sc.
R.F. E.H.T. Unit for 0.5-3kW ... 271
Auxiliary Circuits for pH Meter ... 272
By G. P. Burn.
Control of E.H.T. in Television Receivers ... 273
A Balanced R.C. Oscillator ... 274
By D. A. Bell, M.I.E.E.
Moisture in Electrometers ... 275
By R. H. Mapplebeck.
A Versatile Bridge System for use with Wire Resistance Gauges ... 276
By M. J. Richard, B.Sc.
Notes from the Industry ... 277
Letters to the Editor ... 278
Electronic Equipment ... 280
Book Reviews ... 282

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Classified Advertisements, Page 1.
Index to ADVERTISERS, Page 46

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The cathode ray tube is now accepted as an essential component in all electronic equipments where it is required to obtain a rapid indication or display of physical phenomena. As such it forms the basis of oscilloscopes, test apparatus, monitors, flaw detectors and numerous other research, industrial and communications equipments. The Mullard range of cathode ray tubes has now been extended to meet all these applications.

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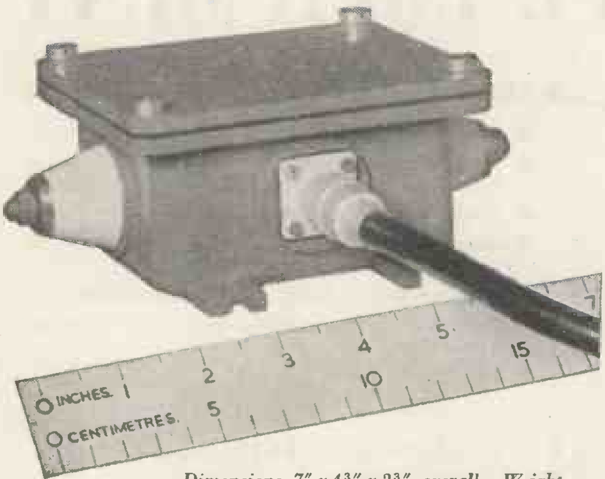

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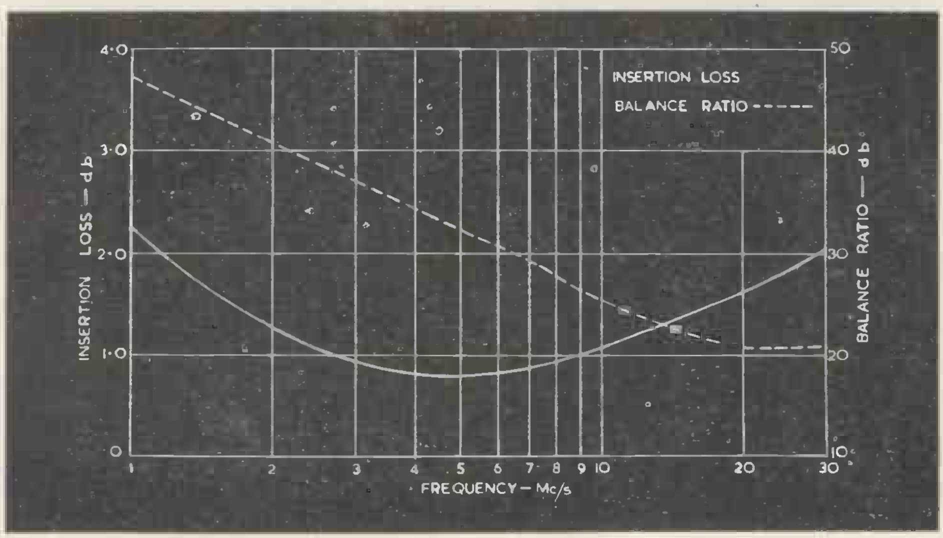

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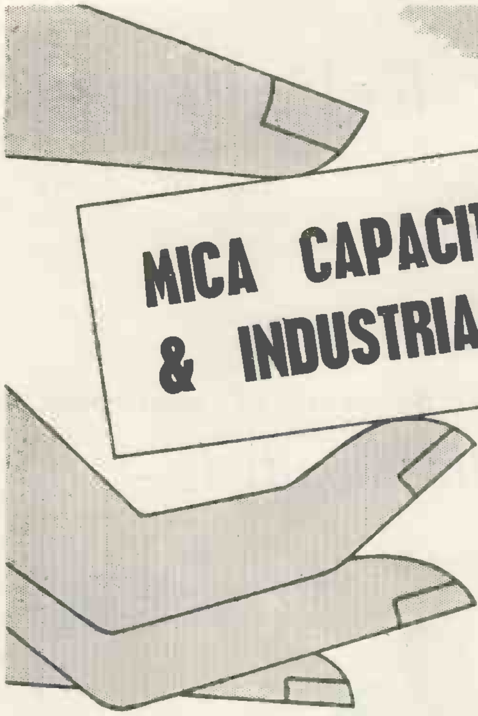

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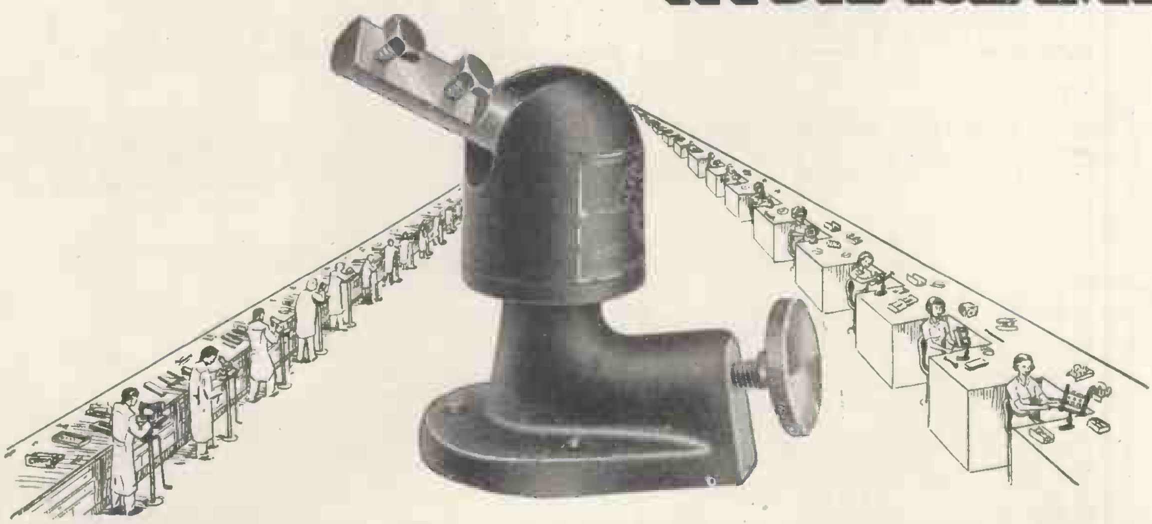

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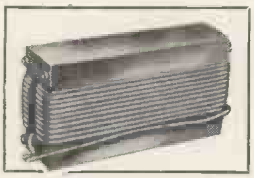

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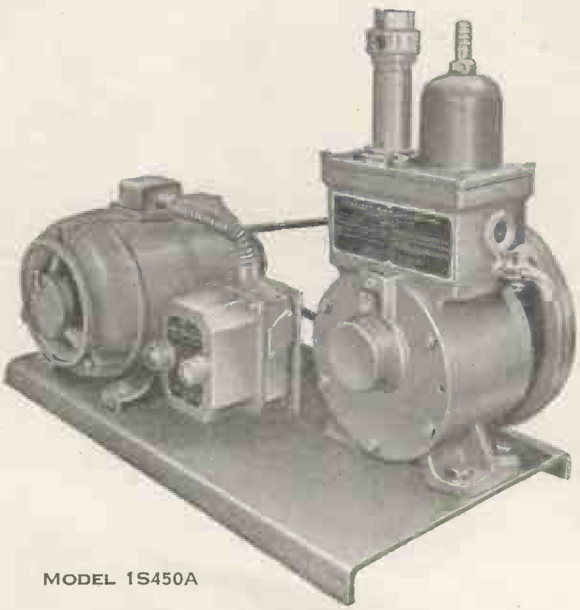

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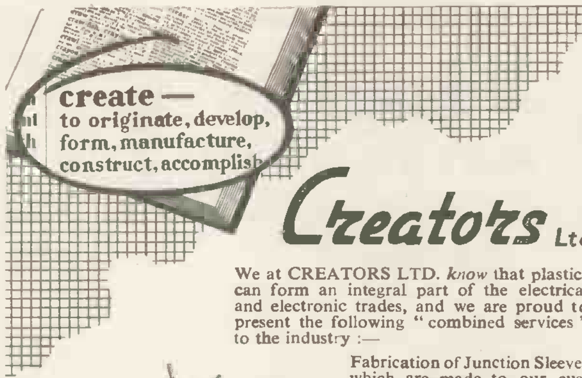
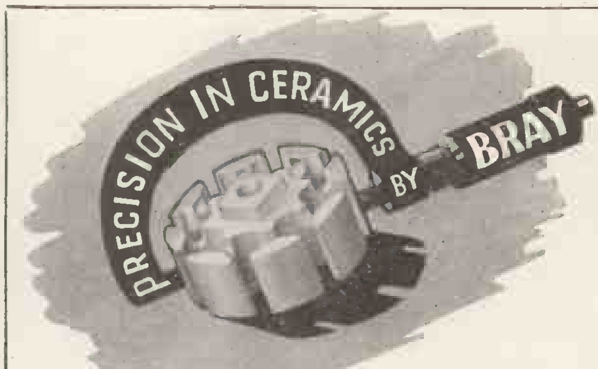


create —
to originate, develop,
form, manufacture,
construct, accomplish



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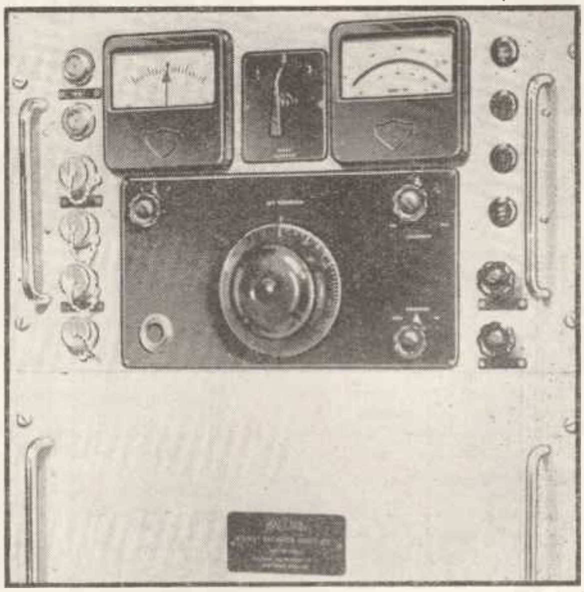

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INDEX TO ADVERTISERS

Airmec Laboratories Ltd. 25
Amplivox Ltd. 44
Audigraph Ltd. 44
Automatic Coil Winder & Equipment Co., Ltd., The .. 30
Automatic Telephone & Equipment Co., Ltd. .. 26

Baldwin Instrument Co., Ltd. .. 45
Bell & Croydon, John .. 43
Belling & Lee Ltd. .. 12
Bird & Sons Ltd., Sydney S. .. 42
Bray & Co., Ltd., George .. 42
British Manufactured Bearings Co., Ltd. 23
British Mica Co., Ltd. .. 44
British National Radio School, The .. 39
British Physical Laboratories Ltd. .. 42
British Thomson-Houston Co., Ltd. .. 13

Castle Engineering Co. (Nottingham) Ltd., The .. 39
Chance Bros. .. 32
Chapman & Hall Ltd. .. 283
Cinema-Television Ltd. .. 20
Cohen, Sons & Co., Ltd., George .. 41
Cole Ltd., E. K. .. 5
Creators Ltd. .. 42

Davis (Relays) Ltd., Jack .. 44
Donovan Electrical Co., Ltd., The .. 39
Drayton Regulator & Instrument Co., Ltd. .. 41
Dubilier Condenser Co. (1925), Ltd. .. 14

Edison Swan Electric Co., Ltd., The .. 22
Edwards & Co. (London), Ltd., W. .. 36
Electro-Alloys Ltd. .. 43
Electronic Instruments .. 41
E.M.I. Institutes Ltd. .. 41
E.M.I. Parent Co. .. Cover i
English Electric Co., Ltd., The .. 17
Erie Resistor Ltd. .. Cover ii

Ferranti Ltd. .. 15
Fox Ltd., P. X. .. 35

General Electric Co., Ltd., The .. 11

Henley's Telegraph Works Co., Ltd., W. T. .. 43
Hunt Ltd., A. H. .. 28

Johnson, Matthey & Co., Ltd. .. 3
"J.B." Service, The .. 44

Lewis & Co., Ltd., H. K. .. 44
London Electric Wire Co. & Smiths Ltd. .. 34
Lyons Ltd., Claude .. 10

Marconi Instruments Ltd. .. 35
Measuring Instruments (Pullin), Ltd. .. 33
Metropolitan - Vickers Electrical Co., Ltd. .. 9
Mica & Micanite Supplies Ltd. .. 43
Mond Nickel Co., Ltd. .. Cover iii
Muirhead & Co., Ltd. .. 16
Mullard Ltd. .. 24 & 36
Murex Ltd. .. 38

Nagard Ltd. .. 34
N.S.F. Ltd. .. 27

Oxley Developments Co., Ltd. .. 43

Painton & Co., Ltd. .. 32
Pitman & Sons, Ltd., Sir Isaac .. 40
Pye & Co., Ltd., W. G. .. 8

Radio Industry Council .. 5
Radiospares Ltd. .. 8
R.C. Radio Electric Ltd. .. 44
Reosound Engineering & Electrical Co. 40

Sankey & Sons Ltd., Joseph .. Cover iv
Savage Transformers Ltd. .. 40
Scientific Acoustics Ltd. .. 40
Small, William H. .. 43
Southern Instruments Ltd. .. 37
Spencer, Franklin Ltd. .. 33
Standard Telephones & Cables Ltd. .. 21
Steatite & Porcelain Products Ltd. .. 19
Sullivan Ltd., H. W. .. 38

Telegraph Construction & Maintenance Co., Ltd., The .. 37 & 46
Thomas (Richard) & Baldwins Ltd. .. 18
Transradio Ltd. .. 39
Tufnol Ltd. .. 7

Vortexion Ltd. .. 31

Walter Instruments Ltd. .. 29
Wilkinson, L. .. 44

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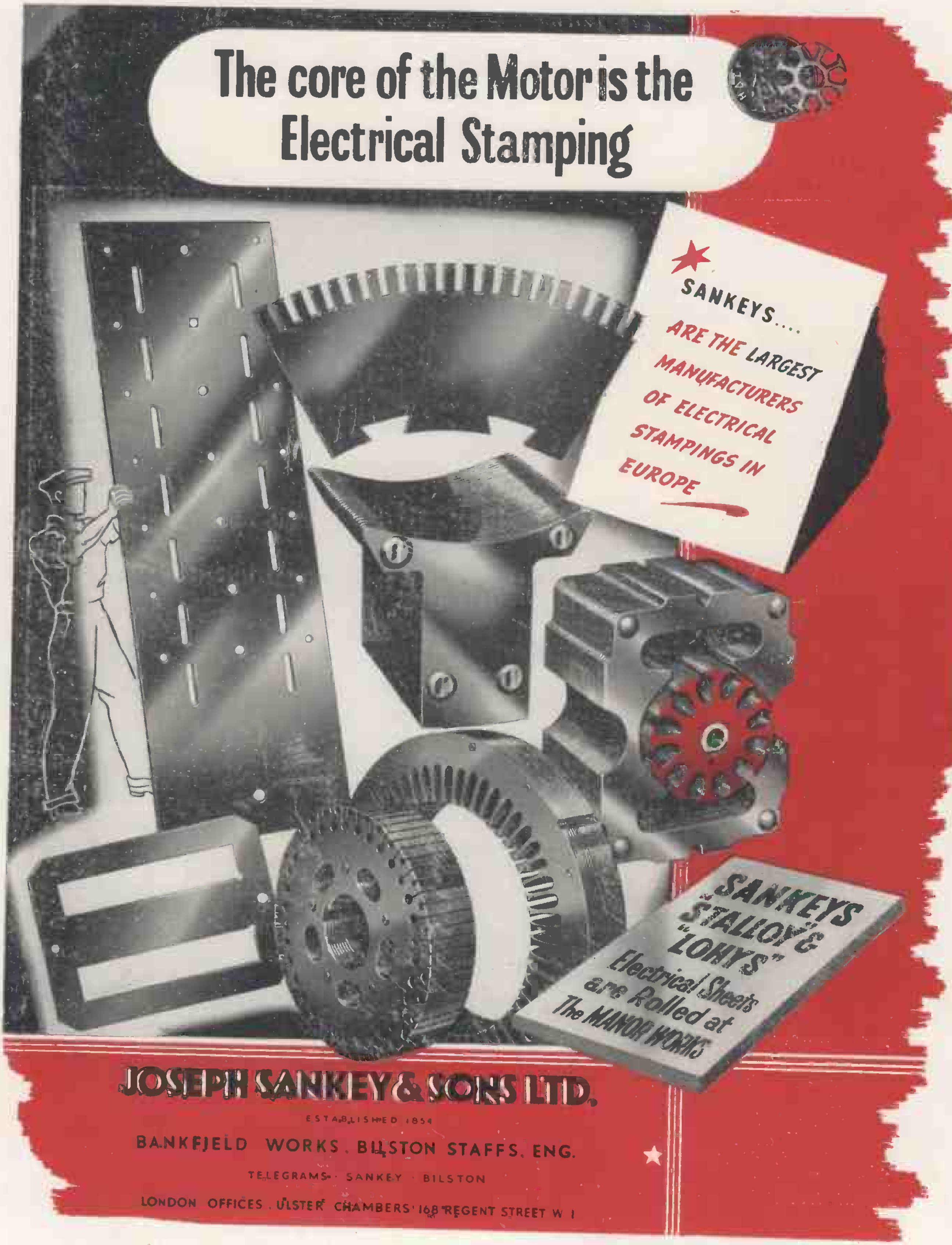
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