Wireless World

ELECTRONICS, RADIO, TELEVISION

JULY 1963

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LOCKED OSCILLATOR DISCRIMINATOR

using the Mullard EH90

AN economical circuit incorporating the Mullard EH90 has been devised for the detection of the frequency modulated sound transmissions, that will be used when the 625 line television system is introduced. This circuit is already appearing in some of the latest dual-standard receivers.

In the locked oscillator discriminator, the mean anode current of the EH90 is a function of the phase of the voltages at the control electrodes—the first and third grids. The tuned circuits at these grids are physically separated but are coupled by the electron stream within the valve. This electron coupling may be regarded as coupling by means of a negative capacitance. The negative sign indicates that energy is supplied by the electron stream, and this implies that amplification can be obtained between the two grids. As is normal with loosely coupled circuits, the phase angle between the two voltages is 90° at resonance. Feedback occurs through the internal capacitance between the two grids, and this maintains oscillation.

If the frequency of the signal applied to the first grid changes, the oscillator remains frequency-locked but the phase relationship between the voltages at the two grids varies in proportion to the signal frequency. The effective sum of the currents appears as an amplitude variation in anode current. Frequency modulations at the first grid are thus converted to amplitude modulations at the anode, and these are subsequently amplified.

LINE OUTPUT PENTODE

for dual-standard Television Receivers

The problem of ensuring comparable line timebase performance in new dual-standard receivers has been simplified by the introduction of the Mullard line output pentode, type PL500. This valve, which has improved performance compared with valves previously used for solus 405-line operation, enables consistency in performance to be achieved despite the fact that the energy requirements for 625-line operation are almost half as great again as for 405-line operation.

An exceptionally high ratio of anode current to screen-grid current is achieved in the PL500 by an entirely new form of anode—the 'cavitrap'. With this construction, secondary-emission electrons from the anode are recaptured by the partitions of the cavitrap anode. Because of the improved current ratio, the PL500 is capable of delivering greater deflection power which helps to prevent any significant change in performance between the two line standards. MVM 1267

EQUALISED HEATING PROPERTIES

OF MULLARD TELEVISION VALVES

All Mullard valves designed for operation in television series heater chains now possess equalised heating characteristics. These characteristics prevent damage to the valve heaters during the warm-up period and eliminate the need for a thermistor.

When the receiver is switched on, if one valve in the heater chain warms up more rapidly than the rest, the increase in the voltage developed across the heater of that valve can exceed the amount (50% above the nominal heater voltage) which can be tolerated during the warm-up period. This can shorten the life of the valve considerably, and to prevent it, heater chains have normally been designed to incorporate a thermistor, which reduces the rate of increase of the heater current, and prevents unequal rises in the temperature of the heaters from producing an excessive voltage across any heater.

WHAT'S NEW IN THE NEW SETS

These articles describe the latest Mullard developments for entertainment equipment

Now, however, Mullard have developed methods of manufacture which produce equalised rates of temperature rise in all their television valves. Extensive tests with a large number of valves in typical heater chains have shown that these equalised heating properties ensure that, without added protection, the voltage developed across any heater will not exceed the permitted 50% above nominal during the warm-up period.

Wireless World

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The Devil We Know

IN these days, when attention is focused on space communication and satellites, the older-established methods of radio communication tend to be overlooked—but by no means neglected, as the recent I.E.E. Convention on H.F. Communication, reported elsewhere in this issue, clearly shows.

Whatever may be the outcome of the present intensive developments in satellite communications it is certain that the existing services are unlikely to become redundant while the volume of traffic continues to expand at its present rate. While new ground is being broken, the known areas are being more intensively cultivated, by methods in many ways as full of technical interest and with results at least as commercially valuable as those so far obtained from more exotic growths.

It was in the early 1920s that the work of Marconi and his colleagues, notably Franklin, resulted in what would now be termed a breakthrough in radio communication. Hitherto the use of ever higher powers on kilometre wavelengths seemed the logical course of development. This was wasteful because of the limitation of aerial size in relation to wavelength and the consequently poor directivity and low *effective* radiated power. Signalling speeds were slow (usually 20 words per minute and only 50 w.p.m. under favourable conditions of atmospheric noise). With the new short-wave beam aerial ranges were increased, using powers only 1/50 of those required on long waves, and signalling speeds went up to 300 w.p.m. At last radio was taking a really significant share of the telegraph traffic and making possible an intercontinental telephone service.

Inevitably the h.f. band (3 to 30Mc/s) soon became congested and the vagaries of the ionospheric climate, then incompletely understood, earned a reputation for unreliability for these services. At this point the majority of telecommunications engineers felt that h.f. had had its day and began to look for escape routes—cables, now revivified by polythene and submerged repeaters; the brute force of scatter rather than specular reflection from the ionosphere; and now satellites receiving and transmitting at frequencies which ignore the existence of the ionosphere altogether. But the fires of radiation in space are at the moment affording scant refuge from the frying pan of the ionosphere and, in spite of intensive forethought and the most meticulous preparation, have succeeded in penetrating the defences of the many of the first communications satellites.

No one doubts that these early troubles will be mastered, but meanwhile the traffic grows and we should be grateful to that minority of engineers who have retained faith in the h.f. bands and worked with ingenuity and persistence to salvage what is now very far from being a wasting asset.

Improvement has come from several directions —a better understanding of propagation conditions, greater flexibility in aerial systems and better discrimination against interference by the use of multi-tone signalling codes and by sophisticated error correction systems.

In addition to long-range forecasts of optimum working frequencies, based on the 11-year sunspot cycle, we now have day-to-day reports on the state of the ionosphere based on world-wide ionosphere soundings. If these are not sufficiently detailed, individual operators can at any hour of the day find for themselves the best frequencies for their own routes by the radar-like method of back-scatter or by the simpler and less expensive "ionogram" produced by sending and receiving a succession of pulses at logarithmically-spaced frequency intervals covering the whole band. This shows not only the frequency limits but also the existence of multipath propagation and therefore the frequencies to be avoided in the pass band.

To exploit the information so obtained calls for skill and agility on the part of operators, and a degree of flexibility in equipment not possible with the early fixed curtain aerial arrays. Universally steerable systems with electronic adjustment of tilt and azimuth can now quickly adapt to changes of bearing and downcoming angles in the radio wave. Even in the present difficult period, approaching sunspot minimum, circuits are being kept open; but both operators and equipment are being worked a little harder.

So, while future satellite systems are being made ready, subscribers should be grateful to those who have kept in good repair the h.f. lines of communication without having to call in the equivalent of Dr. Beeching. There may be even some who will sympathize with the old lady who, when offered a flight in an aeroplane, said that she intended always to travel by train "as the good Lord intended."

Design of Ceramic Loudspeaker Magnets

MAKING THE MOST OF NEW ANISOTROPIC MATERIALS

By A. E. FALKUS,* B.Sc.(Eng.), M.I.E.E.

PERMANENT magnets made from barium ferrite having the formula Ba Fe_{12} O_{19} have been known since 1926. This material in isotropic form has a relatively high working value of magnetomotive force per cm. length, being about 1,000 oersted when working under optimum conditions, as compared with 530 oersted for Alcomax 3 now in common use for loudspeaker magnets.

Unfortunately, the working flux density is very low, being about 1,000 gauss, as compared with a corresponding figure of 10,200 gauss for Alcomax 3. As a result, a loudspeaker magnet using this material would require ten times the cross sectional area and, although the ingredients of the magnet are relatively cheap and plentiful, the cost of the much larger iron circuit renders the design uneconomic, even if the much greater bulk of the complete speaker was not an embarrassment.

It has been found possible to greatly improve the flux-carrying ability of the barium ferrite by grinding the material to a fine powder and then pressing the particles together again in the presence of a strong magnetic field which aligns the particles in the required direction. The pressing is then sintered resulting in a magnet having improved magnetic properties in the required direction. Considerable development was required to produce this anisotropic material on a commercial scale but it is now readily available in this country under the trade names of Magnadur 2 and Feroba II.

The published average characteristics of Magnadur 2 and Feroba II are:—

	(BH) max. (Megagauss-oersted)	Working H at (BH) max. point (Oersted)	Working B at (BH) max. point (Gauss)
Feroba II	3.2	1330	2400
Magnadur 2	3.2	1450	2200

In practice we have found little difference between these materials, although individual magnets vary somewhat from one to another. We are, however, using the figures for Magnadur 2 since most of our work has been done with this material.

It will be seen that the value of (BH) max. for the anisotropic ceramic is little more than half that of the Alcomax 3 alloy, but this is more than offset by the relative cheapness of its basic ingredients, especially for the larger sizes of loudspeaker magnet. The increased value of H and much lower value of B as compared with Alcomax 3, however, renders the enclosed centre pole design uneconomic for the ceramics and a simple ring magnet construction with top and bottom iron collecting plates and central iron pole is the most practical construction. This is shown diagrammatically in Fig. 1.

Applications: It will be noticed that, in addition to the magnetic leakage which occurs above and below the air gap, as in the capped-slug centre pole design (see "Loudspeaker Magnet Design," *Wireless World*, January 1960) there is also a considerable leakage between the top and bottom plates around the outside of the magnet ring. This leakage, which may amount to a quarter of the total lines carried by the magnet, can be serious enough to rule out the use of ceramic magnets for some applications. For instance, it may seriously distort the picture in a television set, it can interfere with the operation of transistors and rod aerials, and may destroy the record on a magnetic tape.

In addition to the lower cost of the ceramic material, its high value of magnetomotive force results in an appreciable reduction in height of the magnet which may sometimes be very useful when the front-to-back dimension of the speaker is severely limited by the space available. It is this feature which has made possible the slim loudspeaker assemblies now so popular for "hi-fi" in the home.

Design Considerations: It will be seen from Fig. 1 that the total flux carried by the magnet divides into two parts. One portion enters the central iron pole-piece or peg, while the remainder passes around the outside of the magnet and may be called the outside leakage.

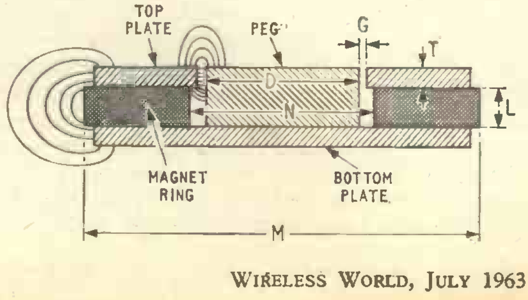
The peg flux in turn divides and a part passes usefully across the air gap while the remainder leaks across above and below the gap.

It was shown in our previous article (see above) that the useful gap flux is

$$\frac{LH\pi DT}{G}$$

where H is the working value of the magnetomotive

Fig. 1. Section of ceramic ring magnet showing stray fields.



*Fane Acoustics Ltd.

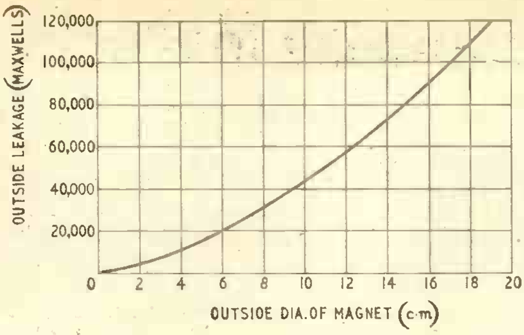


Fig. 2. Outside leakage flux of ceramic magnet.

force of the magnet material and the dimensions are as in Fig. 1.

Also the leakage flux from the centre pole above and below the gap amounts to

$$3.5\ LH\pi D$$

From this it follows that the proportion of the centre-pole flux that passes usefully through the air gap, i.e., the centre-pole efficiency, is—

$$\frac{T}{T + 3.5G} \times 100\%$$

In order to complete the design, however, it is necessary to be able to foretell the amount of the outside leakage around the edges of the magnet ring.

Outside Leakage: The outside leakage may be considered as being in two parts. The first part consists of the magnetic lines passing from the cylindrical edge of the top plate to the cylindrical edge of the bottom plate separated from it by L the length of the magnet. The second part consists of the magnetic lines passing from the flat top surface of the top plate to the flat bottom surface of the bottom plate.

If we consider the edge leakage first, assuming a constant plate thickness, this will be equal to the magnetomotive force multiplied by the cross-sectional area divided by the distance, i.e., proportional to

$$\frac{LH\pi M}{L}$$

Since H is a constant for a given magnetic material it follows that the edge leakage is directly proportional to M, the outside diameter of the magnet.

Similarly the leakage between the flat surfaces of the top and bottom plates is proportional to their area, i.e. to M^2. Thus the total outside leakage may be taken to be

$$C_1M + C_2M^2$$

where C_1 and C_2 are constants depending on the characteristics of the magnet material and the units employed.

To evaluate the constants C_1 and C_2, measurements were made of the outside leakage flux of a large number of different sizes of ceramic magnet assemblies. The values of the outside leakage were plotted against the outside diameter of the magnets and they were found to lie on a smooth curve which is given in Fig. 2. The expression of this curve is found to be

$$\text{Outside leakage} = 1{,}900M + 230M^2.$$

where the outside leakage is in maxwells and M = outside diameter of magnet ring in cm.

Magnet Design for a Specific Performance: To calculate the optimum dimensions of a ceramic ring magnet to produce a flux density of Bg gauss in a gap of width G and depth T and a pole diameter D, we may proceed as follows:—

Ring Thickness:

The magnetomotive force required across the gap is Bg G oersteds. Allowing for a 10% loss to drive the flux through the iron circuit the total m.m.f. of the ceramic ring must be 1.1 Bg G. The thickness of the ring L is therefore

$$L = \frac{1.1\ Bg\ G}{H}\ \text{cm}$$

Peg Flux:

The total gap flux is the gap area, π DT, multiplied by Bg, the gap flux density.

The peg efficiency is

$$\frac{T}{T + 3.5\,G}$$

The total peg flux P is therefore

$$\frac{T + 3.5\,G}{T} \times D\ T\ Bg\ \text{maxwells}$$

Magnet Area:

The magnet must have the correct cross-sectional area so that when carrying the peg flux P together with the outside leakage flux, it is working at its optimum flux density B gauss. The total flux carried by the magnet is

$$P + 1900\ M + 230\ M^2$$

The cross-sectional area of the magnet must therefore be

$$\frac{P + 1900\ M + 230M^2\ \text{sq. cm.}}{B}$$

Inside Diameter of Ring:

Now the inside diameter of the ring N must be at least equal to D + 2 G to allow free passage for the voice coil. In practice it will be found desirable to allow rather more clearance than this and a good plan is to make N = D + 4 G cm.

Outside Diameter of Ring:

Now the outside diameter of the ring is M, its cross-sectional area is therefore

$$\frac{\pi}{4}(M^2 - N^2)\ \text{sq. cm.}$$

Thus, to obtain optimum flux density in the magnet

$$\frac{P + 1900\ M + 230\ M^2}{B} = \frac{\pi}{4}M^2 - \frac{\pi}{4}N^2$$

Solving this for M, we have

$$M = \frac{0.864 + \sqrt{0.746 + 0.001238P + 2.139\ N^2}}{1.362}$$

where M = outside diameter of ceramic ring in cm
P = peg flux in maxwells.
N = inside diameter of ceramic ring in cm.

Example of Complete Design: Suppose we require a ceramic ring to provide a gap flux density B = 12,000 gauss in an air gap of width G = 0.030in and depth ⅛in. with a pole of ¾in diameter.

The mean diameter of the gap = 0.75in + 0.03in = 0.78in.

The cross-sectional area of the gap = 0.780 × π × 0.125 × 6.452 sq. cm. = 1.98 sq. cm.

Total gap flux = 12,000 × 1.98 = 23,760 maxwells.

The centre pole efficiency is

$$\frac{T}{T + 3.5\,G} = \frac{0.125}{0.125 + 3.5 \times 0.030} \times 100\% = 54.3\%$$

The total peg flux P is therefore

$$\frac{100}{54.3} \times 23{,}760 = 43{,}760 \text{ maxwells}$$

The inside diameter of the ring N, is: D + 4G= 0.75 + (4 × 0.030)in. = 0.87in. or 2.21 cm.

The outside diameter of the ring M, is:

$$\frac{0.864 + \sqrt{0.746 + 0.001238 \times 43760 + 2.139 \times (2.21)^2}}{1.362} = 6.57 \text{ cm. or } 2.59\text{in.}$$

The value of the magnetomotive force required across the air gap to give 12,000 gauss is

12,000 G = 12,000 × 0.030 × 2.54 = 914 gilberts.

Allowing for losses in the iron circuit, the total magnetomotive force required from the magnet is

914 × 1.1 = 1005 gilberts.

The required thickness of magnet material is therefore

$$\frac{1005}{H} = \frac{1005}{1450} = 0.694 \text{ cm. or } 0.273\text{in.}$$

The dimensions of the required ring are thus—

O.D.	2.59in
I.D.	0.87in
Thickness	0.273in

Design of Iron Circuit: The thickness of the top plate is usually made equal to T, the depth of air gap required. The peg is normally a parallel slug of mild steel diameter D though if a very deep gap is being employed, it will be found worth while to increase the diameter of the peg below the lowest point of the voice coil travel to prevent magnetic saturation.

The thickness of the bottom plate is usually determined by the cross-section required at the circumference of the peg to carry the peg flux. If the thickness of the bottom plate is S cm. and the working flux density in the iron circuit is not to exceed, say, 14,000 gauss, then it will be seen that

$$S = \frac{P}{14{,}000\,\pi D}$$

This assumes a parallel peg. If the lower portion of the peg is increased in diameter, this larger value may be taken in the above expression for S.

It will often be found in practice, particularly in the larger sizes of loudspeaker, that although it may be desirable to increase the base of the peg to reduce its saturation and permit a thinner base plate to be used, this is impossible as the full length of the peg is required to accommodate the maximum excursions of the voice coil.

It is of interest to note that for maximum gap flux from a given ceramic ring, the top and bottom plates should be made a little less than the outside diameter of the magnet ring. The reason for this is that the outer portion of the ring is providing the leakage flux and this leakage is reduced by removing the iron, as far as possible, from the leakage flux path. This point is dealt with more fully below.

Optimum Diameter and Shape of Plates: As mentioned above, the top and bottom plate should be made smaller in diameter than the magnet ring to reduce the outside leakage and obtain the highest possible flux density in the air gap. In addition, a further improvement can be obtained by chamfering the edges of the plates. Clearly the outer portions of the plates are carrying little of the useful gap flux and a chamfer will increase the leakage path between the top and bottom plate.

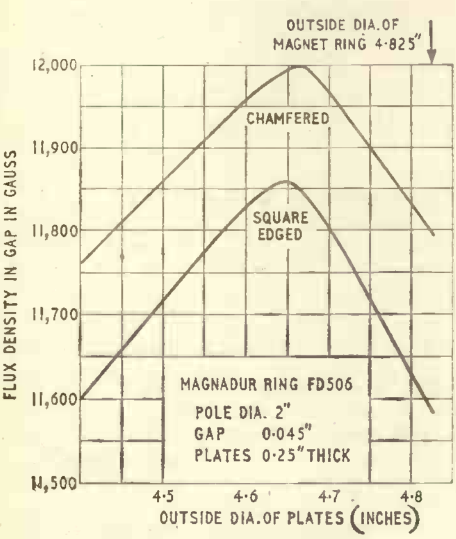


Fig. 3. Optimum diameter of plates.

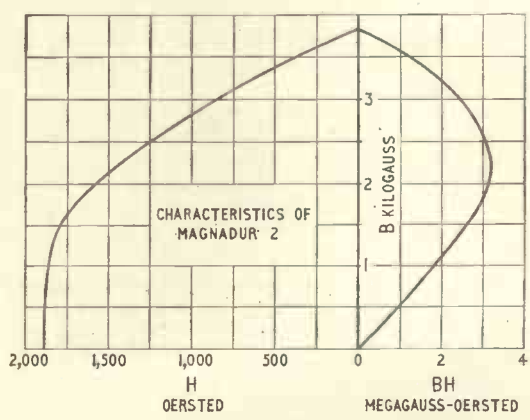


Fig. 4. Magnetic characteristics of ceramic magnet.

To illustrate this point a sample ring of Magnadur 2 measuring O.D. 4.825in, I.D. 2.24in and thickness 0.472in was fitted with top and bottom plates of diameter equal to the ring. The peg was a parallel slug of 2in diameter working in an 0.045in width of gap. Both plates were ¼in thick.

The assembly was magnetized and the flux density in the gap measured. The plates were then removed

TABLE 1
STANDARD SIZES OF MAGNADUR 2 CERAMIC MAGNET RINGS

Ref. No.	Dimensions of Ring: Inside Dia. (Inches)	Outside Dia. (Inches)	Thick-ness (Inches)	Typical Applications: Pole Dia. (Inches)	Gap Width (Inches)	Gap Depth (Inches)	Flux Density (Gauss)
FD 501	0.866	1.77	0.315	0.562	0.030	0.125	9,000
				0.625	0.0325	0.156	7,500
FD 502	0.945	2.36	0.315	0.562	0.030	0.125	13,500
				0.750	0.030	0.125	11,500
FD 503	1.22	2.87	0.394	0.625	0.0325	0.125	15,000
				1.0	0.040	0.187	10,500
FD 504	2.01	4.02	0.394	1.0	0.040	0.156	12,500
				1.5	0.045	0.312	8,000
FD 505	2.01	4.02	0.551	1.0	0.040	0.156	14,000
				1.5	0.047	0.312	9,000
FD 506	2.24	4.76	0.472	1.5	0.047	0.250	12,000
				2.0	0.045	0.250	12,000
FD 507	2.24	5.27	0.551	1.5	0.047	0.250	14,500
				2.0	0.045	0.250	14,000
FD 5025	2.24	6.10	0.690	1.5	0.047	0.250	18,500
				2.0	0.045	0.250	17,000
FD 5037	3.20	7.24	0.728	2.0	0.050	0.312	17,500
				3.0	0.505	0.375	14,500

and reduced in diameter by 0.050in. The magnet was then reassembled and remeasured. This process was repeated a number of times and the results are given in Fig. 3.

The same magnet ring was then reassembled with a new set of plates with the edges chamfered at an angle of 30°. The same series of tests was repeated and the results are also included in Fig. 3.

It will be seen that the maximum gap flux density obtained with the chamfered plates is 12,000 gauss compared with 11,860 gauss for the square edge plates —i.e. an improvement of 1.2%. Further this occurs at a slightly larger diameter for the chamfered plates. The optimum diameter of the square-edge plates is 4.65in, i.e. 0.175in less than the diameter of the magnet and this optimum diameter is fairly critical. In practice, unless the chamfer can be obtained at little extra cost, it is probably not worth while, but each case should be treated on its merits.

Standard Sizes of Ring: Unlike Alcomax 3 magnets where the tooling cost for a new shape is small, and, in fact, seldom charged for by the magnet manufacturers, in the case of anisotropic ceramic rings the tooling cost is considerable and may amount to £1,000 for a large ring.

On the other hand, the shape of the magnetization curve (see Fig. 4) for the ceramic materials is such that we can depart appreciably from the optimum ratio of length to cross-sectional area without any great reduction in the working value of B × H. From the figure it will be seen that working values of H can be used from 1800 oersteds down to 900 oersteds without the B H product falling below 2.6 megagauss-oersteds.

When deciding whether an existing ceramic ring will be satisfactory for any purpose for which an exact fit is not available, these curves will enable the value of the BH to be calculated when the existing ring is used. Providing this value is above about 2.6 the result will probably be satisfactory. As a result of these considerations it is usual to meet most requirements with a series of standard sizes of ring. This method has all the additional advantages of standardization such as ease of obtaining initial samples, etc.

In Table 1 (left) is given a series of nine standard sizes of Magnadur 2 rings which are readily obtainable in this country and which will cater for the majority of applications of ceramic magnets in both small commercial loudspeakers as well as the largest sizes up to 3in pole diameters. It must be understood that the gap dimensions and associated flux densities given in this table are only typical examples of the many different combinations of pole diameter and gap sizes which can be usefully employed with each size of magnet ring.

In addition to this series of Magnadur 2 rings, there are also available nine sizes of Feroba II rings which supplement the available choice of the most suitable size of ring for any particular purpose. These are given in Table 2. It should be noted that these rings are available with a range of thicknesses for each set of diameters so that more latitude is allowed to the designer to obtain the most economical magnet assembly.

Magnetization and De-magnetization: In order to obtain the maximum flux density in the air gap of an anisotropic ceramic loudspeaker magnet it is essential to magnetize it after the assembly of the completed iron circuit. This calls for very powerful magnetizing equipment for the larger rings. To completely demagnetize a large ceramic magnet assembly is very difficult indeed. However, for the purpose of cleaning the air gap of a loudspeaker it is only necessary to reduce the gap flux to zero which

TABLE 2
AVAILABLE SIZES OF FEROBA II CERAMIC MAGNET RINGS

No.	Inside Diameter (inches)	Outside Diameter (Inches)	Thickness (inches) Min.	Max.	Std.
1	1.190	1.990	0.300	0.500	0.300
2	1.180	3.214	0.450	0.600	0.550
3	1.265	3.798	0.500	0.800	0.720
4	2.226	4.031	0.450	0.800	0.454
5	2.200	4.220	0.500	0.800	0.535
6	2.000	4.300	0.500	0.800	0.800
7	2.095	4.875	0.500	0.800	0.550
8	2.095	5.472	0.550	0.800	0.650
9	2.095	5.974	0.550	0.800	0.800

can be done in the same equipment as is used for magnetizing by using a reversed current of suitably reduced amount.

Although it is comparatively simple to reduce the gap flux to zero in this way by trial and error methods, it is usually found that, although the gap flux may be zero, the inner portion of the magnet is magnetized in opposition to the outer portion and it is difficult to remove the top and bottom plates.

Methods of Assembly: Ceramic magnet rings can sometimes be supplied with three or more holes which can be used for brass screws to hold the top and bottom plates together. A simple and more economical method of assembly, however, is to use an epoxy resin adhesive to join the plates to the magnet ring. The top plate is usually provided with tapped holes or other means of mounting to the loudspeaker chassis.

Temperature Effects: The performance of ceramic magnets is affected by changes of temperature to a greater extent than metal magnets. The effects are not, however, enough to alter the performance of a loudspeaker to a perceptible extent except under conditions of very extreme cold, i.e. below $-15°C$.

Oddly enough a ceramic magnet gives its maximum performance at normal room temperature. As it is heated above this point the gap flux density falls off about 0.1 to 0.15% per degree C but on recooling it returns to the original value.

On cooling from room temperature the performance also falls at about the same rate but, in this case, if the temperature drops below $-15°C$ the change becomes irreversable and the magnet does not fully recover on rewarming. This effect is reduced by ensuring that the magnet is operating below the optimum working value of H. For magnets likely to be exposed to extreme cold, therefore, the thickness of the magnet ring should be increased beyond that which would normally be used.

Acknowledgements: The author would like to express his thanks to Mullard Limited for permission to publish the information regarding Magnadur 2 magnet rings and to Swift Levick and Sons Limited for permission to publish the information regarding Feroba II magnet rings.

CAMBRIDGE RADIO TELESCOPE

CONSTRUCTION of the new radio telescope for Cambridge University, which was started in April last year, is nearing completion and is now expected to be finished this autumn. The Ministry of Public Building and Works is constructing this radio telescope at the Mullard Radio Astronomy Observatory at Lords Bridge, Cambridge, at a cost of £450,000. This has been undertaken to enable Professor Martin Ryle and his colleagues at Cambridge University to continue their studies of the structure of the universe. The work of Professor Ryle and his colleagues attracted considerable public interest when it was announced that the results of radio astronomy experiments supported the "big bang" theory of creation of the universe as distinct from the theory of continuous creation.

Apart from the controversial aspects of Professor Ryle's radio astronomy experiments, his name has been linked with a new approach to the problem of constructing large radio telescopes capable of probing millions of light-years away into the universe. The method he has developed, and is to be used in the new radio telescope, is based on the use of two or more aerial elements, whose relative positions may be changed. Observations are made with the aerials in different positions and the results are subsequently combined in a computer at Cambridge University, to provide a radio map of the sky. This method is called aperture synthesis, and has been used in the two large radio telescopes at the Mullard Observatory for the past six years.

The new telescope, which has three paraboloids—one of which moves on rails—will operate in a similar way: the signals from the three dishes will be recorded with the movable dish set in a number of different positions along the half-mile rail track. Then the recordings will be combined, resulting in a map of the sky equivalent to that which would be provided by a radio telescope with a dish of about a mile diameter. Each dish can be steered and used as an individual radio telescope, but normally all three will be controlled in unison from the central control building under the middle dish.

Each parabolic aerial weighs 118 tons and is constructed mainly of galvanized steel sections with an aluminium mesh reflector. The mobile aerial travels along 2,500 feet of 44-ft gauge railway track and is driven through a hydraulic transmission system to give it speeds infinitely variable from zero to one mile per hour. When in motion the carriage travels on eight two-wheeled bogies, but during operation machined pads are lowered to settle on to the rail surface. Once in position, hydraulically operated clamps grip the rail head.

The receivers to be mounted at the focus of the three reflectors will be constructed by Cambridge University, who will also make the main receivers and data recording equipment to match the characteristics of the university computer.

RADIO AND ELECTRONIC COMPONENT EXHIBITION

Reviewed by "Wireless World" staff

As far as the basic components of the radio and electronics industry are concerned the 1963 exhibition could be regarded as indicating that the manufacturers were stabilizing their products. That is to say, rather than introducing new types, gaps in existing ranges of components were filled in. If any trends were obvious these were, as expected, in the fields of miniaturization, integrated circuitry and film components.

Resistors:—Apart from refinements in the now conventional composition and wirewound fixed resistors, the newer metal-film types of the Electrosil, Alma, Plessey, Welwyn and Morganite ranges were of interest. This class of resistor probably represents the best available from the standpoint of reliability. All metal-film resistors exhibit very low noise and the shelf life is claimed to be comparable with that of the best precision wire-wound resistors. Perhaps the most significant property of metal-film resistors is their exceptionally high stability. The manufacturing technique varies from producer to producer. The Welwyn resistors are based on a nickel alloy resistance element deposited on a ceramic substrate. The desired resistance value is then obtained by grinding a helical groove through the film at a specific pitch. The ceramic body and its resistive coating is then protected by an epoxy resin moulding.

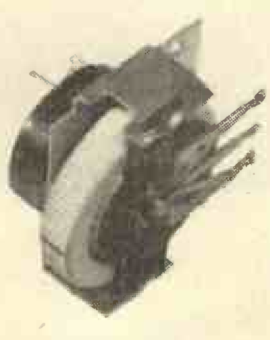
Variable resistors and potentiometers that caught the eye were the miniature carbon potentiometers of the Morganite Resistor Company (these were only 22mm in diameter and had twin-pronged wipers claimed to reduce considerably rotational noise), the plastic-spindled miniature potentiometers of East Grinstead Electronic Components and the edge-operated variety of Egen Electric. This latter type, the 430, is intended for record players and tape recorders and incorporates an "on/off" switch as well as tags suitable for conventional wiring and printed circuit techniques. Mechanical designers faced with the problem of fitting presets where they can easily be adjusted will find their problems eased with the introduction, by A.B. Metals, of a new series of potentiometers that can be adjusted by a finger or by a screwdriver, from both ends. Of the wide range of resistors, fixed and variable, shown on the Plessey stand, a subminiature edge-operated potentiometer, $\frac{5}{8}$in diameter designed for use in hearing aids, attracted much attention. This new type has a moulded track resistive element claimed to give noise-free operation and negligible wear.

Capacitors:—Developments significant in the capacitor industry as a whole were confined mainly to making the components smaller for a given capacitance and working voltage, and the use of new materials. A number of companies introduced tantalum fixed capacitors. The advantages of tantalum capacitors are the extremely low electrical leakage current, high capacitance per unit volume and an exceptional stability over a wide temperature range. A new range of miniature multiplate ceramic film capacitors known as "Caspak" were introduced by Plessey. Four capacitance values are available 0.002μF, 0.047μF, 0.1μF and 0.22μF (all 75V d.c. wkg.). Their low inductance and freedom from "self-healing" properties (which result in random pulse generation) is claimed to make them particularly suitable for use in digital circuits. Both E.M.I. and T.M.C. introduced tubular capacitors using metallized polythene terephthalate. The advantages claimed for this type of dielectric medium include exceptionally high insulation resistance and stable capacitance. Suflex, well known for their plastic film capacitors, exhibited a new 30V range of polystyrene capacitors. These showed a useful reductio. in size over those currently available.

Examination of the various displays of variable capacitors showed a distinct reduction in size of these components since the last exhibition was held.

Chokes and Transformers:—Ardente showed their range of miniature transformers. These were constructed to make them eminently suitable for printed circuitry. The Belclere Company also had a comprehensive range of windings and included a transformer design kit enabling a designer to build a number of prototype components before placing a quantity order. Hinchley introduced a series of portable isolating transformers and their increased range of windings suitable for printed circuits included transformers and chokes using metric lamination sizes more generally used in other European countries.

Parmeko showed for the first time their new range of constant-voltage transformers. These are designed to supply a specified output voltage which remains constant to within $\pm 1\%$ for a wide variation of input voltage. As well as displaying mains and output transformers for well-known thermionic audio circuits, Par-



Egen Type 430 edge-operated carbon potentiometer.

Airmax axial-flow blower, claimed to be the world's smallest, moving about 5cu ft/min at 1,000 r.p.m. Power supply is 26V, 400c/s, 3-phase.

tridge exhibited transformers wound specifically for use with transistor circuitry.

Materials:—The introduction by Mullard of their new transducer material "Piezoxide" attracted considerable interest. This is a ceramic piezoelectric material based on lead zirconate-titanate with additives to give a range of electro-mechanical properties. The substance can be pressed into a variety of shapes. At present four grades are available for applications ranging from sensing heads and acceleration gauges to ultrasonic transducers. A demonstration showed a slab of "Piezoxide" which, when subjected to pressure from a lever operated by a rotary cam, fired a conventional sparking plug. The material is claimed to have great mechanical strength and is impervious to moisture.

With the increasing use of potting techniques in electronic circuitry have come some new developments. On the Midland Silicones stand some interesting non-rigid encapsulating materials were shown. The DP2603 self-healing dielectric gel is supplied as a fluid. This, after addition of a catalyst and curing at a low temperature, develops into a soft gel. It thus forms a protective cushion around circuit components. The gel is claimed to have excellent dielectric properties, low water absorption and a good heat resistance. Because the gel does not get into a hard state, probes can be inserted for circuit testing and faulty components can be replaced. Another compound, MS potting material DP2608, after setting is a transparent, flexible resin suitable for protecting components from vibration and shock, as with the former compound all the components are visible.

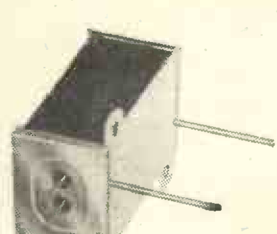
In many cases the protection of a whole circuit by resin encapsulation is impracticable but protection of individual components within the circuit may be considered desirable. This can now be achieved without resort to outlay on special plant, mixing of chemicals or the use of moulding equipment. CIBA (A.R.L.) the manufacturers of "Araldite" make this possible with the introduction of "E-Pak". This consists of cases (supplied in different shapes, sizes and colours) and preformed pellets of "Araldite" epoxy resin, appropriate in shape and size to the component to be protected. The pellets are dry and non-toxic. Under the influence of heat they melt, fill the moulded cases containing the components to be protected and then set to form a high-strength solid.

In the realm of laminated materials, rods and tubing, Bakelite introduced a number of new products. Of these, a styrene/butadiene rubber-surfaced material can be used very effectively for capacitor sealing discs. In the same field, the glass/epoxy, copper clad grade CGE 70 Formica material was shown. The features of this new grade are its retention of mechanical properties at elevated temperatures and low dielectric loss characteristics. Vero Electronics announced that "Veroboard" can now be supplied in a double-sided version and demonstrated samples. They also introduced their 0.1in pitch "Veroboard" which has been developed to cater for high component densities using miniature components.

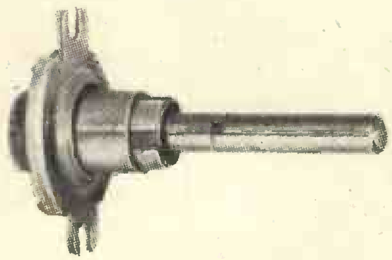
Turning from sheet materials to wires and cables, new ground was broken by B.I.C.C. when they demonstrated their new miniature 75Ω coaxial cable. This had a polythene outer sheath and a polypropylene dielectric. It is available in both single and double braided versions. The same company took advantage of the show to introduce their new miniature connecting wires, with 0.005in p.v.c. insulation. Strand sizes are offered as 7/.0024 or 7/.0036in. Connollys demonstrated their improved "Conterex" enamelled wire. The new variety is claimed to have a superior resistance to heat-shock, longer thermal life, improved solvent resistance and an increased resistance to abrasion. The improvements have been effected by the use of polyester enamelled wires, jacketed with a linear polymer.

Relays:—Could be seen in great profusion over the exhibition hall. As in many other fields the tendency was to miniaturization or to handling greater currents than previously with the same size component. Diamond H introduced a new time-delay relay which can be delayed up to 15 minutes or when ordered especially, up to 25 minutes. The device makes use of a cold-cathode tube and a printed circuit board. Gaining in popularity is the relay which can be plugged into an international octal base. Examples of this type could be seen on the Arrow stand. The 10 amp Type H relay of NSF is a miniature hermetically sealed relay. This relay is believed to occupy less space than any other 4-pole changeover rotary-type relay of similar rating. The cases are hermetically sealed after filling with an inert gas at a pressure five pounds above atmospheric pressure. This technique prevents corrosion and ensures optimum contact performance throughout the working life. A new relay on the stand of G.E.C. differed from other types by the same manufacturer in that the armature operated a sub-miniature microswitch instead of springsets. The operating point of the armature can be set by an adjustable bias spring. Micro-switches give the relay the advantages of a snap-action electrical switch, completely enclosed contacts and facilities for obtaining closer operate, non-operate, hold and release current figures. ERG introduced a new miniature reed relay type AB1434. Features of this type include a very fast operate time, low current consumption, magnetic screening of the coil to eliminate undesirable effects due to interaction with other relays, and the ease of in-

Left: Circuitry encapsulated in Midland Silicones gel Type DP2603



Above: ERG reed relay Type AB1434.



Left: Jackson dual-ratio reduction drive.

Enthoven "Miniscope" soldering iron using a 2.5 to 6V supply. The heating time is five seconds, the iron is switched on by depressing the lever.

terchangeability of the hermetically sealed reed switches.

A relay with no moving parts and, therefore, no contact bounce, was shown by Mullard. A 24V, 60mA lamp is arranged to illuminate four pieces of cadmium sulphide photoconductor. When the lamp is lit, the resistance of the photocells falls from over 10 MΩ to 15Ω. Each cell can dissipate 150 mW and can handle 140 V a.c. or 200 V d.c. At this stage it would not be amiss to mention the relay servicing tools shown by Spear Engineering. The whole set comprises contact adjusters of various shapes and sizes, a spring removal hook and a contact burnishing tool.

Switches:—Originally developed for broadcasting and studio work, the E.M.I. PSI push-button switch is now made available for general use. Up to 14 assemblies are contained in a frame, each consisting of up to 12 changeover contacts. The buttons are illuminated, and can be arranged to interlock, the action of each button in relation to any other being either "gapping" or "lapping." Contacts are either make-before-break or *vice versa*, and are of 30W rating.

Glassware:—To eliminate the sudden and expensive results of arcs and voltage breakdowns in large pieces of equipment such as transmitters, Marconi-Osram have introduced the E3020 surge diverter. This consists of a cold-cathode trigger tube which will operate on an anode voltage of 500V, although withstanding 6kV. The tube will pass 2000A peak and strikes with 2.5kV on the trigger electrode. In use, a transformer is connected with its primary in the supply line to the protected load. If the current through the load rises rapidly due to a flash, the transformer secondary triggers the tube, which discharges the power supply capacitance and operates a relay in its cathode circuit, disconnecting the supply.

A double-triode shown by Brimar is intended for pre-amplifier input and similar low-noise applications. The amplification factor is claimed to be the highest in the world at 140.

Mullard had a new range of valves designed for dual-standard television receivers. U.h.f. signal frequencies are taken care of by the PC88 r.f. amplifier triode and the PC86 self-oscillating mixer. High g_m is obtained by the use of frame grids, and an asymmetrical construction gives reduced interelectrode capacitances.

Flywheel control of line timebase oscillators is probably easiest to arrange on dual standard receivers when a sine-wave oscillator is controlled by a reactance valve. The PCF802 triode-pentode is designed for this application and has a high-μ triode so that the tuned circuit is not excessively damped.

An extremely high-sensitivity instrument cathode ray tube shown by Mullard is the D13-22. This is a five-inch tube, and a new mesh p.d.a. system gives, in addition to high deflection sensitivity, low background illumination. The mesh gives a scan which is less p.d.a.-dependent than is usual, and high contrast is obtained by the use of 15kV on the mesh. P.d.a. ratio is 10 and typical *y* sensitivity is 2.9V/cm.

Two magnetrons and an X-band klystron were featured among the new products of Mullard. The Type YJ1030 is a tunable magnetron intended for use in airborne transponder equipments operating at a frequency of approximately 5.65Gc/s. Special features include a low weight of 7oz and rugged construction. Its very low temperature coefficient of 50kc/s per degree C, ensures good frequency stability. With the maximum pulse input of 1.8kV, 0.8A this magnetron gives a pulse power output of 160W. Maximum pulse duration is 3.0μsec at a duty cycle of 0.002. The other new magnetron Type YJ1040 is a 14kW pulsed variety intended for use in high-altitude airborne radar equipments operating in the frequency range 9.345 to 9.405Gc/s. The new Mullard X-band klystron type YK1040 weighs 4oz and operates at frequencies between 9.0 and 9.6Gc/s; coupled cavity tuning is incorporated. A new X-band klystron developed for f.m. systems, the R9687 by E.M.I., has an improved electron gun design which is stated to be completely free from ion oscillation, thus eliminating spurious modulation of the output. This low-power klystron operates in an external resonator and, in suitable cavities, is useful in the frequency range 6,500Mc/s to 12,000Mc/s. The microwave display of Marconi-Osram featured a wide range of travelling wave tubes. The M.O. ophitron, an electrostatically focused backward wave oscillator, was demonstrated. A new magnetron Type M514 was exhibited by the English Electric Valve Company. It was designed for marine radar equipments and has a peak power output of up to 20kW. The manufacturers claim that life test samples achieved more than 5,000 hours operating time with no detectable change in performance.

Semiconductors:—The predictable trends towards volume microscopic and frequency astronomic show no indication of flattening off, and the term "microscopic" is in no way stretched to describe many modern devices. Power handling capabilities are resolving their conflict with frequency; the prediction, rather recklessly made in the early 1950's, that transistors would see valves off, sounds much less Wellsian than it used to.

Some of the smallest devices were shown by Mullard, who had a planar n-p-n transistor measuring 0.05-in diameter. This is an experimental unit intended for use in microcircuits, and has a β of between 40 and 120 at 10mA collector current. f_t is 300Mc/s. S.G.S.-Fairchild had comparable devices, known as Molytabs. These, again, are 0.05-in diameter, and are electrical equivalents of many of the firm's other units. S.T.C. Miniflake transistors are silicon epitaxial devices supplied without cases for thin-film work. Complete circuits in the S.T.C. thin film range include amplifiers and logic networks, and are standardized at 0.5-in square.

Texas Instruments displayed a number of multiple units—diodes and transistors. A typical unit is the 2A5A1 multiple diode, which consists of ten diodes, with "cathodes" taken to 10 lead-out wires, and two groups of five "anodes" to a further two wires. Closely matched forward characteristics are claimed, and the whole unit is contained in a standard JEDEC TO-5 can. A good example of the modern transistor was also given by Texas 2N2864, which is an n-p-n silicon epitaxial planar unit giving 1W as an amplifier at 100 Mc/s.

Further examples of what can be crammed into a TO-5 were on SGS-Fairchild's stand, where dual transistors and mixtures of diodes and transistors were shown. The firm have extended their range of Micrologic integrated circuits with the μLr and μLd shift register and logic elements. The μLd comprises two double input gates with a propagation delay of 40nsec at 3V and can be used as a gate with up to four inputs, an inverter or a flip-flop. Delay is virtually independent of temperature.

High power and frequencies were noted on several stands and a typical example is the Mullard AFY19,

Riveting machine by Chobert (marketed by Avdel), for quick insertion of rivets and solder tags into metal and plastic. Tool is pneumatically operated.

which delivers 0.4W at 180 Mc/s. In TO-5 form, the unit is rated for 32V maximum collector current, and current gain is over 33 at 100mA. f_t is about 350 Mc/s. Computing diodes by Mullard are well represented by the AAY32 gold-bonded type, which has a 30V p.i.v. rating and a recovered charge of between 20-100 picocoulombs. The experimental planar device possesses a p.i.v. of 50V and a recovered charge of less than 20pC. Both these units are 3.5 mm diameter and 7.6 mm in length.

Ferranti had their new range of silicon integrated circuits which are in two broad classes—linear and digital. A typical "Microlin" circuit consists of a two-transistor complementary linear amplifier made on two silicon chips. The p-n-p transistor is on one chip, and the n-p-n device and five resistors on the other. With a voltage gain of 16, the response is -3dB at about 1Mc/s. Input impedance is about 1 kΩ and output impedance 30Ω. The whole amplifier is in an 8-lead TO-5 case shortened to 0.18 in. The "Micronor" logic elements consist of up to nine transistors or diodes and four resistors in a shortened TO-5.

A.E.I. showed a range of passivated planar epitaxial transistors, particularly fast switching types. Passivation consists of the use of an oxide coating over the junctions, which gives complete protection against ambient gases. Exceptional stability is obtained, and higher breakdown voltages, lower saturation voltages and lower capacitance are among the advantages of the technique.

The limitation of semiconductor rectifiers for power work is the extreme sensitivity to transient overvoltages in the reverse direction. Formerly, attempts have been made to increase the reverse turnover voltage, and it has even been necessary to protect the temperamental silicon with the selenium that it is supposed to supplant. Three firms have introduced rectifiers which do not suffer from high dissipation in the reverse direction and which will operate happily in the avalanche region. A.E.I., S.T.C. and Lucas (G. & E. Bradley) showed examples. A.E.I. had a 1200V p.i.v., 10A silicon device, the SLZ1203A, S.T.C. their R.A.S. 300 1.25A series and Lucas a 400V, 10A unit. A further advantage of the avalanche rectifier is that the rapid current increase at the avalanche point gives a voltage limiting action, which means that a series combination of units needs no voltage dividing resistor chain.

Semiconductors that do not seem to fit tidily into neat categories are E.M.C.'s Quantrol and the Hughes current regulator. The Quantrol is a two-wire device that acts as an a.c. switch. Several megohms are in circuit until the volts across the unit reach the "threshold" voltage, which lies between 20 and 200V. The Quantrol then breaks down in some way and becomes a short circuit. Turn-off is by injecting a direct-current pulse into the unit. This description is, we know, rather vague, but information on the Quantrol is not readily forthcoming.

The Hughes current regulator is also a two-lead unit which exhibits a characteristic something like the output curve of a pentode. Current ranges of 100 μA to 200 mA are obtained at a tolerance of $\pm 5\%$. Between 10V and 40V, current regulation is better than $\pm 1\%$.

An infra-red producing diode was shown by Texas. When the junction is forward-biased, infra-red radiation at a wavelength of 0.897μ is emitted, the power of which increases linearly with current greater than a few milliamps. Modulation frequencies up to 100 Mc/s are usable, and operation is possible over a temperature range of $-195°$C to 125°C. The unit is housed in a TO-18 case, and it is intended for use in short range communications.

Audio:—Exhibits that could fall under the heading of audio were mainly confined to the transducer field, though many well established turntables, tape recorders and motors were in evidence. Greencoat Industries displayed a new three-speed battery-powered record player Type KT9. On the same stand the exceptional stability of their d.c. motors was demonstrated. Cosmocord had a number of new items on show; the RE6 Acos earphone supplied complete with ear clip, ear plug and miniature or subminiature jack plug was designed for use with transistor radios. The Acos Mic 39 was introduced, this has a dynamic insert and has high and low impedance matching outputs. The frequency response of this microphone extends from 80 to 10,000 c/s ± 3dB. The Goldring Manufacturing Company demonstrated a new stereo cartridge the Type CS90. A ceramic cartridge, it uses a diamond replaceable stylus with a 0.0005in tip. The frequency response extends from 30 to 18,000 c/s.

A record changer Model UA15 by B.S.R. measured only $4\frac{5}{8}$in in height from the top of the motor board. The unit has a four-speed turntable and can be supplied for all mains voltages, 50 or 60 c/s, or for 9V battery operation. Other new products on this stand included a ceramic cartridge Type C1 and a "Gardisk" retractable cradle. This device ensures that if the pickup arm is accidentally pushed across the record, the stylus retracts, thus minimizing damage to the record.

In the loudspeaker division of the audio industry, a greater range in sizes of speakers was available and it was also noted that more ceramic magnets were being used. The public address side of Goodmans Industries introduced a new 100W speech loudspeaker. The overall dimensions of this Type PA100 loudspeaker were approximately 2ft 6in × 9in × $3\frac{1}{2}$in. Reslosound included in their new products a 4ft model LS.100A and a 6ft model 6LS line source loudspeakers, intended primarily for sound reinforcement and music relay installations.

Aerial Accessories:—As was expected the main developments in this sphere were concerned with u.h.f. television reception. A new coaxial cable based on the "Aeraxial" range of Aerialite is designed to reduce signal loss from aerial to television set. Designated the Cat.500 coaxial cable, it is constructed with a single 0.056in copper conductor surrounded by a 5-cell air space polythene dielectric. The outer braid is constructed from 0.006in copper braid and this is covered with the familiar brown p.v.c. The total diameter is 0.312in as opposed to the usual 0.275. A 75Ω cable, it has a capacitance of 16.5pF per ft and at 850Mc/s the attenuation is given as 5.4dB per 100ft. Antiference of Aylesbury, to reduce matching losses on their u.h.f. aerials, include a balun which is incorporated in the cable junction unit. The praiseworthy feature of this is that the downlead can be fitted to the balun/junction unit on the ground so that once the aerial itself has been sited the cabled unit can then be fixed to the aerial with the minimum of work.

A handy accessory, this time for the "steam" radio manufacturer, was exhibited by Ariel. This was an aerial switch socket, which when fitted to a transistor radio allows a car aerial to be plugged into the set at the same time disconnecting the built-in ferrite rod aerial. Returning to television reception and the problem of greater attenuation with increase in frequency, Arrell demonstrated a new head amplifier which is intended to be built in the insulator of the driven element, thereby dispensing with the need of any conductor from the element to the amplifier. Power supplies for the unit are fed via the feeder cable.

Thoughtfulness towards the erection engineer is further portrayed by the detachable cable junction box of Belling and Lee. Here the cable is attached to the lower half of the box on the ground; this section can then be attached to the aerial without tools, after the aerial has been fixed. Visits to the J-Beam and Telerection demonstrations showed the accent to be on aerial protection. Domestic aerials of the latter firm were shown cocooned in polythene. Professional aerials of J-Beam were shown with protection materials of polythene and glass fibre.

Instruments:—The traditional methods of aerial installation, i.e., a muttered prayer and a wet finger, will be finally abandoned when u.h.f. aerials begin to sprout from the rooftops, and to take the place of the m.p. and w.f. Belling-Lee have brought out their U.H.F. Signal Strength Meter L.1585. This is essentially a tunable valve voltmeter, and covers 100μV to 10mV on a logarithmic scale. The input circuit is tunable from 470 to 860 Mc/s (channels 21 to 68) and bandwidth is 1 Mc/s. A stabilized reference oscillator works at mid-band to maintain calibration accuracy.

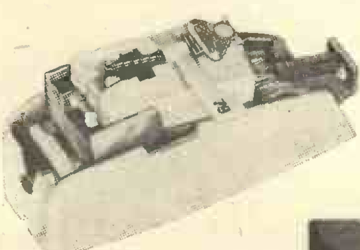
A very sensitive d.c. valve voltmeter shown by Dawe, the Type 611A, has a full-scale deflection of 300μV on its most sensitive range, and an overload capacity of 1.5kV on this range. Ranges are 300μV to 1000V f.s.d. and on the 10mV to 1000V ranges the input impedance is 100MΩ dropping to 10MΩ for 300μV. The accuracy is ±3% over most of the range, this being achieved by the use of a chopper a.c. amplifier/detector technique with a negative feedback amplifier. 50c/s rejection is provided and the amplifier output is brought to the front panel.

G. & E. Bradley were showing their Electronic Multimeter CT471B, a transistor current and voltage meter for a.c. and d.c. measurements. Alternating and direct voltage from 12mV f.s.d. alternating and direct current from 12μA, together with resistance to 1000MΩ are the main functions, while a.c. probes give a response from 10kc/s to 1500Mc/s (2dB down). The instrument is operated by two 1.5V cells.

A complete audio and middle range signal source, with monitored attenuators, is provided by Marconi Instruments' new "2000" range of modular units. The "prime movers" are the TF2100 a.f. oscillator and the TF2101 m.f. oscillator which cover 20c/s-20kc/s at 0.5% distortion and 30c/s-550kc/s at 0.5% respectively, and provide 4V and 1V into 600Ω unbalanced. Three types of attenuator are available, two of them monitored, and all the instruments can be used separately or in a side-by-side mounting case.

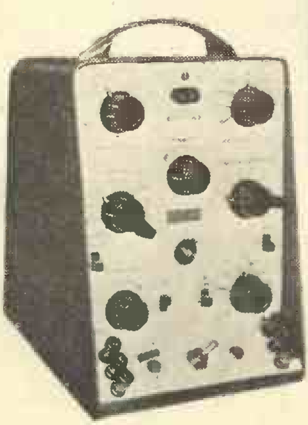
A new transistor oscilloscope was shown by Marconi Instruments, the TF2202 double beam unit. Two identical *y* amplifiers are provided, giving a bandwith of 0-6Mc/s with 100mV/division sensitivity, each division being 0.8cm. Built-in pre-amplifiers can be switched in to increase sensitivity by a factor of 10 or 100 with bandwidths of 0-500kc/s or 20c/s-200kc/s. 350nsec *y* delay is included, and calibration is by a standard waveform. Timebase delay is variable up to 20nsec after the trigger pulse and the sweep covers 5μsec to 5sec. An internal inverter allows operation from a 24V supply as an alternative to the mains.

A new double-beam instrument was also on the Telequipment stand, using a double-gun tube. The D43 employs plug-in *y* amplifiers to ful-

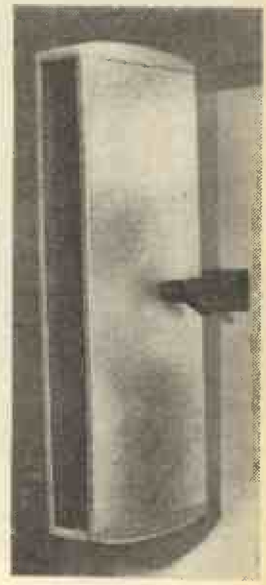


BSR retractable cradle fitted with the CI ceramic cartridge.

Marconi Instruments a.f. oscillator opened for servicing. Instrument still works in this form.



Left: Elliott curve-tracer for transistors, diodes, etc. Families of up to eight curves can be displayed.



Right: Goodmans 100W public address loudspeaker.

fil wide-band, differential and high-gain functions, the maximum bandwidth being 0-15Mc/s at 100mV/cm. Maximum sensitivity is 100μV/cm from 3c/s to 75kc/s and as the tube is fitted with an anode modulator, directly-coupled flyback blanking is simply arranged.

For engineers or lecturers already in possession of an oscilloscope, Elliott have produced a curve tracer to display the characteristics, in families of curves or singly, of most types of semiconductors. The 50c/s mains waveform is half-wave rectified and used to provide the collector voltage, the dissipation during this time being low enough to allow the display of avalanche behaviour. Peak voltage and current are 150V and 1A, and output impedance is low enough to display tunnel diode curves.

The laser appear to be escaping from the physics laboratory into industry, one of the first to emerge being the G. & E. Bradley Type 330. Either ruby or neodymium-doped glass elements can be used, and a 10MW peak pulse power is obtained by the use of a "Q-spoiler" to concentrate energy into one long pulse instead of a succession of shorter ones. The maximum p.r.f. is 120 pulses per hour, depending on cooling arrangements, and the pulse length with Q-spoiler is between 0.1μsec and 10μsec. The nonchalance with which a hole was punched in a razor blade in about a millisecond gave one furiously to think.

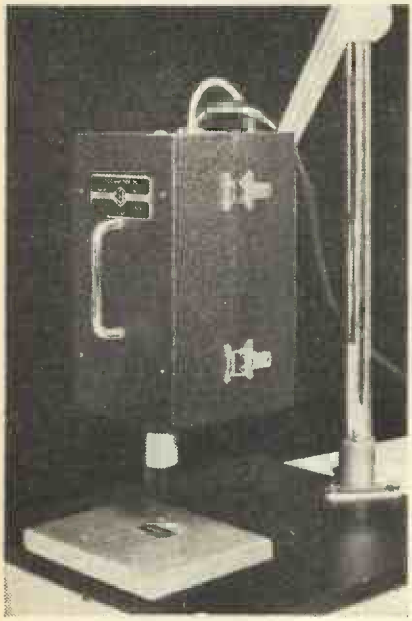
Miniaturization:—Several firms were displaying thin-film networks and assemblies, which now appear to be a commercial proposition. These were of fairly standard form, using borosilicate glass for the substrate, although Welwyn Electric use high-alumina ceramic, claiming better adhesion of the metal films and better thermal conductivity, which eliminates hot spots. Resistors are formed of nickel-chromium alloy to give about 50kΩ maximum on a reasonable area of substrate. Capacitors up to about 10,000 pF/square centimetre can be made by the deposition of successive layers of aluminium, silicon monoxide and aluminium. Working voltage varies between 6V and 100V, depending on capacitance per unit area. Inductors are not often used, and if larger than a few microhenries are made separate wound components. Conductors are of gold (Mullard) chromium-gold alloy (S.T.C.) copper (Welwyn) or aluminium (Morganite), and transistors can be either of ordinary construction or special miniature varieties such as the Mullard ones and the S.T.C. Miniflakes, which can be set into holes drilled in the substrate.

Although not in the same class as thin-film circuitory, the S.T.C. Ministac modulator construction is intended to achieve a similar end, i.e., reduction in volume. Two plastic side mouldings carry a wiring pattern which is cut from standard punched nickel-silver strips. Solder-tags carry components between the two sides, and the wiring pattern makes contact with terminals on two end plates. The complete assembly can be potted for protection.

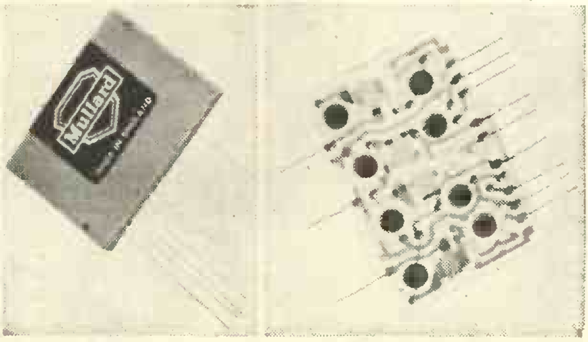
Metalwork:—A new range of sectional chassis were announced by Imhof, known as the Imkit. Standard 19-in panels are used, in depths from 5¼in to 12¼in, and 18 sizes of side frame and eight chassis sizes are produced. The chassis can be mounted horizontally or vertically, or even both in the same unit, and two kinds of rear beam can be supplied to accommodate a variety of plugs and sockets. Nylon rollers are fitted in the chassis.

The standard range of Widney-Dorlec cabinet components are extended by the introduction of a new type with "square" edge and corner fittings. They can be used with the standard parts when stacking is required, or simply for neatness of appearance.

A flexible set of parts for building screened rooms in a variety of sizes is marketed by Belling and Lee. Interchangeable metal units are used, with provision for doors, screened windows, services and lino-tiled floors. The windows are of honeycomb construction and all joints use r.f. mesh gaskets, with the result that attenuation to outside fields, both electric and magnetic, is about 100dB from 1Mc/s to 1000Mc/s. The attenuation to magnetic fields, difficult to provide at low frequencies, is still 60dB at 10kc/s.

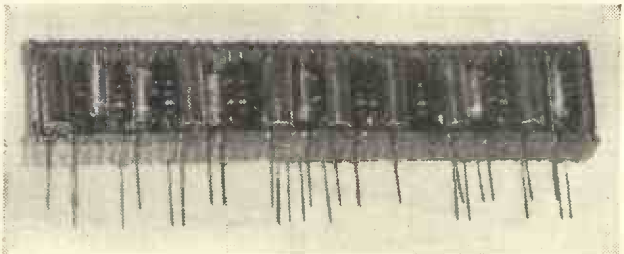


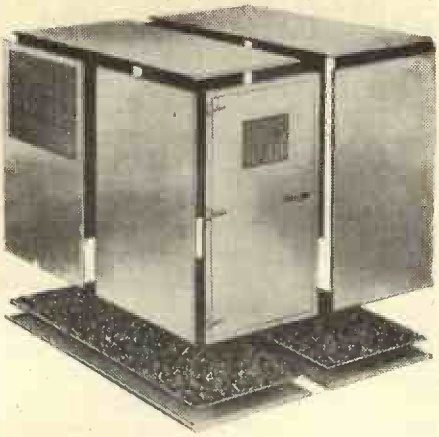
Bradley industrial laser, showing the razor blade being perforated.



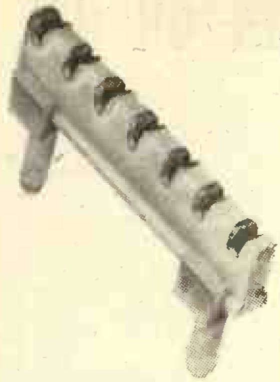
Mullard thin-film circuit. Finished appearance shown on left.

Ministac component wiring module by S.T.C.

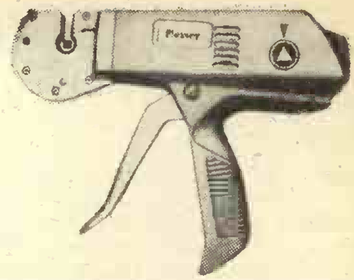




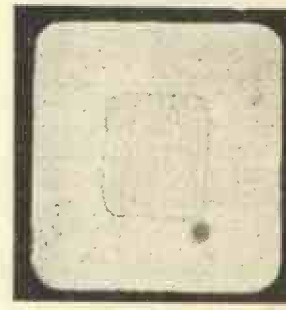
Sectional screened room from Belling and Lee.



Plessey ceramic terminal strip with nickel soldering surfaces.



Above: Plessey universal crimping tool. Below: Cross-section of finished joint shows wires cold-welded into solid mass.



Chassis fittings:—Ceramic terminal strips from Plessey have been improved by the substitution of nickel for the usual silver-plated soldering areas. Trouble has previously been experienced due to migration of the silver, making soldering difficult. The new strips are mounted by separate nylon or metal feet.

Metal chassis and dip-soldering seem hardly compatible, but Sealectro have now introduced the Cloverleaf chassis receptacle, which holds the leads of up to four wire-ended components in a Teflon bush. Component leads are pushed into these bushes, together with additional central pins, if required, and capillary action is employed to allow dip-soldering. The bush is a press-fit in the chassis.

One has seen the insertion of metal bushes and terminals into plastic and even metal sheets, but until now, holes have been required for relatively soft materials fitted to metal. J & S engineers have introduced their Jasflo process which is capable, at its most impressive, of inserting in a 1-in diameter Perspex window into a $\frac{1}{8}$-in mild steel plate by means of a punch. Nylon bushes are fairly run-of-the-mill to this machine, "spread" of the soft material being avoided by the use of a hollow cylinder to contain it during the punching operation.

Heat sinks for semiconductor devices have taken many different forms, the latest being made by Alexander Orba and shown by Vero Electronics. It consists of a slab of aluminium honeycomb with aluminium block embedded in it to take the semiconductor. The honeycomb can be tailored to fit a convenient piece of chassis space.

Crimped contacts for wire terminations are held to be time-saving and reliable, but if a number of contacts of different sizes are to be attached the first of these advantages tends to be reduced. Accordingly, Plessey have designed a crimping tool which is truly universal, in that it will deal with a large variety of contact sizes with no other accessories. The aperture is a "diminishing square," which grips the contact, and pressure is built up by a few squeezes of a trigger. The pressure is self-setting, and as soon as the crimp is completed, the jaws release and operate a counter to record the number of operations.

Assemblies:—Several new Cyldon v.h.f. and u.h.f. television tuners were on the Sydney S. Bird stand, one of them being a transistorized unit. A common-base r.f. amplifier and common-base self-oscillating mixer are used to give coverage on the band 470-854 Mc/s. A three lecher-line input circuit is used to match 50Ω into the base of the r.f. amplifier. The band-pass filter is continuously tuned for a bandwith of 5-7 Mc/s over the range, coupling between primary and secondary being via slots in the screening partition. Power gain, on the average, is 15 dB, with an average noise level of less than 10 dB. I.f. and second channel rejection are at least 50 dB and 55 dB respectively.

For those applications where a standard cell cannot be used because of its low voltage and negligible current, International Electronics have designed a reference power unit, using transistors. In its standard form the modular unit ($6\frac{3}{4} \times 4\frac{1}{4} \times$ 14in) provides a 100V, 100mA output with an output resistance of less than 100mΩ. Stability with input variation is 7,500:1 for ±10% and the temperature coefficient is 0.0004% per degree centigrade. Setting accuracy over ±5V of nominal is better than 1mV.

Cyldon u.h.f. transistor tuner for Bands IV and V, using Texas GMO290 transistors.

Meters:—Moving-coil indicators in new styles by Taylor and by Sifam are designed with the same philosophy in mind and coincidentally bear the same name "Clarity." The Taylor range have square, transparent cases, the clear plastic material, avoiding shadows. The most sensitive movements are 10μA, and self-contained direct and alternating voltage and current indicators are made. Sifam meters are roughly similar, advantage being taken of the case shape to obtain large scale lengths. The most sensitive movement is 25μA. Scale markings are to the new British Standard recommendations, and a fairly thick pointer with a sharp tip is used to provide readability at a distance combined with accuracy at short range.

I.E.E. CONVENTION ON H.F. COMMUNICATION

THAT the h.f. band should have ever-increasing demands made upon it, and that in fact renewed interest has built up in it, could not have been prophesied a few years ago. Yet this was one of the main conclusions which stemmed from this Convention, held from 25th to 27th March, at which 53 papers were presented, and, in the associated Exhibition, a large number of new developments were assembled and demonstrated.

For a considerable time to come it is likely that maximum utilization of the h.f. band (3-30 Mc/s approx.) will be sought because the properties of the ionosphere make possible long-range communication round the world with a relatively low transmitted power. This has special application for "mobile" radio services but the propagation characteristics of the ionosphere have also been fully exploited for point-to-point communication links. The price to be paid for these advantages lies in the possibility of disturbance in the propagation medium causing interruption to the links. There are two ways in which interruption can be caused—either by a "sudden ionospheric disturbance" (s.i.d.) or by an "ionospheric storm." These phenomena and the long-term effects due to sunspot activity and to the fluctuations in the earth's magnetic field have been the subject of investigation for many years. As a result it has been possible to set up a prediction service for the United Kingdom radio links on the h.f. band.

Apart from the short-term interruptions, a general pattern is known to exist for h.f. ionospheric propagation in which stable conditions can be expected during the day- and night-time hours, with deterioration during the transition periods of sunrise and sunset. Also improvement takes place with increased sunspot activity in that the extent of the available frequencies lying between the m.u.f. (maximum usable frequency) and l.u.f. (lowest usable frequency) is at a maximum. In contrast, however, the incidence of s.i.ds. is greatest when sunspot activity is at its highest, resulting in loss of circuit time during the hours of daylight. (It has been established that s.i.ds. occur only when the radio path lies on the sunlit side of the earth.)

Thus it will be appreciated that long-term predictions do not always give the most accurate forecast for the optimum working frequency when propagation conditions are fluctuating violently. An alternative which suggests itself is to make measurements over the radio path to be used, preferably for the whole gamut of the frequencies which have been allocated to the link. Such a method is afforded by "ionospheric sounding", which has been in use for some years as one of the sources of data on the behaviour of the ionosphere as a radio propagation medium. In dealing with "synchronized oblique ionosphere sounding," Dr. R. D. Egan, of Granger Associates, Palo Alto, described equipment and techniques which have been employed under service conditions for sounder frequency control for communication links.

The basis of the method is to transmit pulses over the communication path for which immediate propagation data is required and to display on an "ionogram" the percentage distortion at the receiving end for the whole frequency band. To achieve this the band is scanned in a series of steps, transmitter and receiver being accurately synchronized (within 1 msec) during the scanning process. The ionogram may be produced (either by electrostatic printer or storage-type oscilloscope, depending on whether or not a permanent record is required) with the ordinates representing relative time delay, expressed as percentage distortion, shown against a frequency scale. Thus a form of histogram is produced from which m.u.f., l.u.f., and total multipath distortion can be determined. In the examples which were quoted, pulse lengths of up to 500 μsec were employed and the distortion scale was derived for 100 word per minute (75 baud) teleprinter working.

Aerials: The Convention brought out clearly the pronounced difference in size and complexity which exists between h.f. aerials used for point-to-point working and those developed for mobile services. With so much dependence on propagation conditions the aerial system must obviously be designed to exploit to the full, and to be compatible with, these conditions.

This approach is probably taken furthest with the multiple unit steerable arrays which began with the classic MUSA, and find their latest expression in the G.P.O. experimental MEDUSA* receiving system which has been installed at Cooling in Kent. This site is particularly suitable for such an installation in consisting of flat salt marshes. These give the uniform "ground constants" which are necessary for such spaced aerial systems, and the high ground conductivity required for satisfactory low-angle reception.

The inverted-cone monopole aerials are arranged in two circular groups, each 300 m in diameter and containing some 40 aerials. Their received signals are fed over coaxial cables of equal electrical length (to ±1°) to phasing and combining units after individual amplification in single grounded-grid triode stages. The phasing and combining units have several components including the r.f. diode switches which produce the steering effect. These switches operate in accordance with "phasing instructions" which are calculated by a small special-purpose digital computer for a specific steering programme. The resultant variation in signal strength associated with this scanning action is monitored on a c.r.t. display from which the optimum direction in which the aerial system should be steered is determined.

Another similar type of monopole aerial—the biconical—due to the Admiralty Surface Weapons Establishment, was quoted as having a bandwidth of the order of 2.6:1 over which a standing wave ratio no worse than 0.5 (max:min 2:1) was maintained with a 50/75 ohm coaxial feed and no additional matching and tuning circuits.

For both G.P.O. and A.S.W.E. designs a "ground plane" is provided by a radial wire system, totals of 16 and 36 equally spaced wires being used in the G.P.O. and A.S.W.E. cases respectively.

These aerials represent an example of design to give broad-band characteristics—an approach adopted for most equipment and particularly for the other aerials and associated systems described at the Convention. The demand for this broad-band capability stems from the

* Multiple-direction universally steerable aerial.

requirement to cover the full h.f. band without difficulty and without equipment having to be changed. In turn this arises from the need to vary the operational frequency for changing propagation conditions.

Thus the tendency has been to move away from resonant aerials, e.g., the Franklin type, and to go to the rhombic configuration. It appears that rhombic aerials will continue to be employed for both transmitting and receiving in the h.f. band, and that they will be mounted at more than one height at a given site to deal with a selection of different "arrival angles." (Extended tests on long-distance h.f. circuits have indicated that maximum response in the vertical plane should be at about 8° angle of elevation, this requires that rhombic aerials for 8 Mc/s should be 75 m. high.)

Another method of obtaining broad-band characteristics is used in logarithmic aerials. Sometimes referred to as "frequency independent," they are given their wide frequency response by being made of a series of active elements with their resonant frequencies in geometrical progression. Thus only the elements which are at or near resonance contribute to the array taken as a whole, which, as a result, has a relatively small effective aperture. It is obviously desirable to make each element give the maximum efficiency over the widest possible band, and this is most easily realized either with the folded dipole or the "skeleton broad dipole." The latter is a corollary of the broad dipole array in which the wide dipole limbs are replaced by wire loops which take their outline trapezium form. It is of interest to note that single-strand cadmium copper was found to give increased fatigue resistance and freedom from twisting.

There is some physical similarity between these aerial assemblies and the Yagi array, spacing and element length are tapered, however, in the former. Another point of similarity is the difficulty of analysing them mathematically to give a basis for design. Because of this difficulty Marconi have used u.h.f. scale models to determine by experiment the optimum design parameters. (One of the main problems in the mathematical approach is to assess mutual interactions along the array.) The u.h.f. models themselves are built up from fine wire on Perspex.

A type of aerial which may find increasing favour, at least for reception, is the "sloping vee." Reminiscent of the much longer Beverage aerial, its open ends are each terminated to ground through 800 ohm resistors, the feed point at the elevated end of the vee being from a tapered (600 to 800 ohm) balanced transmission line. Design has much in common with the rhombic aerial, but, as a travelling-wave device, the dependence of the sloping vee on the ground plane reflection process is much greater.

It will be appreciated that ground reflection effect will always be present with the limited directivity of the vertical apertures which are practicable at h.f. (taking the high frequency end of the band, $\lambda = 33$ ft or 10 m at 30 Mc/s). An aspect of the aerial/earth combination which does not usually have significance in the United Kingdom—that of the effective earth resistance of frozen snow—was therefore of particular interest when discussed at the Convention. In the case quoted, that of a mobile set under development for the Army, serious deterioration in performance was cured by the substitution of a counterpoise system for a conventional earth connection with its "megohms per inch" resistance through the frozen soil.

An area in which considerable development work has been expended, largely to meet operational requirements, is that of the "aerial exchange." In general these take a matrix form in which provision is made to interconnect a number of transmitters or receivers with various different aerials in selected combinations. The switches themselves are arranged to possess within close limits the characteristics of the feeder system into which they are inserted, and to have low contact resistance. Thus the switch links for a high-power coaxial system are themselves of similar coaxial construction, while in an open-wire balanced layout the mechanical arrangement is continued in the switch unit—mercury switches with tungsten electrodes being used as the contact elements.

The Telegraph Aspect: Statistics given for growth of traffic over the whole of the Cable and Wireless overseas communication network showed a rate of increase of 60 per cent per annum for the telex and "leased" channels. In contrast the number of radiotelephone channels in the h.f. band is contracting because it is becoming more and more difficult to find room for the much wider band required for the transmission of the nominal 3 kc/s telephone spectrum.

As a result, the majority of the channels in the h.f. band are becoming of the telegraph type. Also, because of its relatively narrow width and the demands being put upon the h.f. band, the conservation of bandwidth within it is becoming increasingly important. Thus, even for the comparatively small spread of say a telex channel, it is clearly worth while to do all that is possible to effect the maximum economy in the use of bandwidth.

These considerations have led to a great deal of development work being done on the encoding of telegraph messages and the modulation processes associated with them, particularly on the production of highly accurate and stable r.f. sources. The inter-relation of these and other apparently dissociated fields is extensive, e.g. modulation rates for telegraph working have usually to be fixed at a value below 200 bauds because of radio link multi-path effects. (Changes of 2 msec. or more have been observed in arrival times when multi-path propagation was taking place.)

In this connection the "Piccolo" system due to the Diplomatic Wireless Service of the Foreign Office was noteworthy because it was an example of telegraph techniques being developed and extended into the field of radio circuit design. This system was of special interest on several counts, particularly with regard to the use of resonators to integrate signal energy and hence to improve error rate at low signal/noise ratios. By allocating an individual resonator to each of 32 tones associated with a specific character in the teleprinter alphabet, a given character is passed through its particular resonator circuit to appear at its output with a much improved signal/noise ratio, whereas other characters (frequencies) are, in effect, rejected. The Piccolo system depends for its efficacy on the resonators being "lossless" (infinite Q), which is achieved by applying positive feedback to each of the tuned circuit (LC) resonators. Under these conditions the resonators behave as oscillators which are quiescent until energized, at which point they maintain oscillation at that level.

Each resonator feeds into a detector, and 100 msec. after the reception of a character tone burst, the outputs of all the detectors are examined in a voltage comparator unit. This unit identifies the output with the highest amplitude, generates a pulse corresponding with it, and sends it out on the appropriate wire. After the selection operation has been completed, the resonators are immediately "quenched" and the detector outputs brought to zero in readiness for the next character.

Since the discrimination in the comparator is better than 0.2V over a range of 0.3 to 10V, this circuit can deal with the corresponding amount of selective fading.

The system operating speed was given as 100 words per min. (10 characters/sec.) with an occupied bandwidth of 470 c/s—the character frequencies extend at 10 c/s spacing from A = 330 c/s, to letter shift = 630 c/s and blank = 640 c/s.

The improvement produced by the system is claimed to be such that errors can be kept below 0.2% when the signal is 4dB below the noise level, and operating conditions are as quoted.

The other, and more conventional, approach to the error problem is based on the principle of automatic demand for, and repetition of, distorted signals immediately following the recognition of their faulty nature. This original method, due to Dr. Van Duuren of the Netherlands Post Office, and using a 7-element code of the R.C.A. (Moore) type, has been under continuous development since its introduction over ten years ago.

In practical terms, the system operates by stopping the teleprinter and sending back a "repeat" (RQ) order to the transmitting end whenever a distorted character is detected. The original character is extracted from a temporary store (usually holding at any instant the last three characters in the message train to cover the system delay) and repeated, if necessary a number of times, until a correct signal is received and printing is resumed.

Thus actual "start-stop" signals are not transmitted, but their equivalent is derived by a decoding process from the intelligence signals. Consequently traffic capacity is established at a high level in relation to the frequency band taken up.

The system employs time-division multiplexing with close synchronization of transmitting and receiving "distributors"—sampling switches or commutators. The distributors are locked to crystal controlled oscillators, and with one as master the slave oscillator is brought into synchronism—"phased"—by reference to signal transitions. One main division of development has been to replace electromechanical devices by transistors, particularly for the synchronizing and phasing processes. It has been found that several advantages have accrued, not only in terms of performance and reliability, but also from the point of view of maintenance and general economy.

Although not strictly in the telegraph context, it seems relevant to note in this section the developments in privacy equipment demonstrated by Standard Telephones and Cables, and the electromechanical filters which were employed in the gear.

The latter consisted of a coupled mechanical system of cylinders and small-diameter rods vibrating in the torsional mode, and embodying the transducer as one of the resonant elements of the filter. The nickel-zinc ferrite used as the magnetostrictive material gives a Q (mechanical) of between 1,000 and 3,000 at 100 kc/s. For applications such as i.f. filters the electromechanical filter offers a number of advantages including small physical size. For instance a 7 kc/s i.f. filter operating at 465 kc/s (skirts of curve 60 dB down within approx. 4 kc/s) had the dimensions $2 \times \frac{1}{2} \times \frac{1}{2}$ in.

The privacy equipment itself was a good example of the miniaturization which can be achieved with modern techniques. Thus it has been possible to compress this 5 band speech scrambler providing 4 privacy channels into a volume of 4 cu ft.

Equipment Design: A pronounced trend in detailed design became evident at the Convention which can be seen in other fields of electronics, viz. the use of solid-state printed-circuit type cards as modular units. With the exception of transmitter output valves, transistors appear to be replacing the valve for all stages in h.f. receiving and transmitting equipment.

Among the many pieces of gear described during the Convention, a transistorized frequency synthesizer by S.T.C. may be taken as typical. (A frequency synthesizer is an extremely stable control source which is arranged to make available for selection a large number of accurately determined frequencies. It is used as a transmitter drive and as a receiver local oscillator control.)

In this case, although light alloy castings were used to provide screening between various sub-units, the whole unit had a volume of only 1 cu. ft. With a complement of some 130 transistors the power consumption is 12W, so that temperature effect may be regarded as negligible.

The synthesizer provides a range of frequencies adjustable in steps of 125 c/s between 3.0 Mc/s and a nominal 7 Mc/s—actually 7 Mc/s less a final step of 125 c/s. This range is obtained by mixing 5 fundamental signals in a mixer and filter chain, and extracting the various outputs from dividing and gating stages.

A somewhat broader design requirement arises from the ever-increasing pressure, common to all users, for economy in the use of manpower. This demand for unattended operation brings with it a number of problems, particularly on the transmitter side.

The solution of the overall problem, that of reconciling flexibility of working, i.e. rapid change of frequency over a wide band, with high equipment working efficiency, has been tackled in two ways. One is to make all the equipment units broad-band in themselves, the other is to adopt "self-tuning" or frequency following techniques.

The former was exemplified by the system, described by B. M. Sosin of Marconi, which utilized broad-band power amplifiers, mixers and ferrite core r.f. transformers. The first of these major components had been made a distributed rather than a pure wide-band amplifier in order to obtain the best working conditions with the varying load presented by an aerial system over a wide frequency range.

Another Marconi paper gave details of medium- and high-power automatically tuned linear amplifiers ($7\frac{1}{2}$ and 30 kW p.e.p.* respectively) in which tuning is effected by taking advantage of the 180° phase difference which should exist between grid and anode r.f. voltages in a correctly tuned amplifier. The two voltages are compared in a phase discriminator and the error signal is used to drive a tuning servo-motor in a relatively conventional loop, feedback being taken, from a generator coupled mechanically to the tuning motor, back to the input of the servo amplifier.

Finally mention must be made of the large number of papers devoted to the "mobile" group of users, largely composed of the armed and public services. Much the same considerations apply to design and policy as for point-to-point communication, especially in terms of flexibility of working and maintenance of emitted frequencies to a high degree of accuracy. The emphasis on compactness is, however, even greater for mobile equipment, and transistorized modular equipment is becoming practically universal in this field.—R. E. Y.

*P.e.p. = peak envelope power.

WORLD OF WIRELESS

Colour Demonstrations

AS a prelude to the international meeting to be held in this country later this year to discuss the choice of a colour television system for Europe, a series of demonstrations of three colour systems (NTSC, SECAM and PAL) is to be given in London to representatives of European broadcasting authorities. These representatives are members of the *ad hoc* colour group of the European Broadcasting Union and delegates from O.I.R.T. (International Broadcasting and Television Organization) representing Eastern Europe. The demonstrations, which start on July 8th, will include both broadcast and closed-circuit transmissions. During the latter artificial interference can be introduced and the effects of long-distance line and phase distortion studied.

These demonstrations, in which the B.B.C., I.T.A. and British equipment manufacturers are participating, will supplement those already given in other countries.

Simultaneous daytime NTSC and SECAM colour transmissions are already being radiated from the B.B.C.'s Crystal Palace station to enable comparisons to be made of the two systems under practical reception conditions. Channels 34 and 44 (horizontally polarized) are being used, with an e.r.p. of 160kW per channel. The latest schedule of these 625-line colour test transmissions, which the B.B.C. has been conducting since last November, is obtainable from the Engineering Information Department, Broadcasting House, London, W.1.

R.T.R.A. Conference

ADDRESSING members of the Radio and Television Retailers' Assocation at their annual conference at Scarborough, F. C. McLean, B.B.C.'s director of engineering, said that the main tasks of the engineering branch of the Corporation at present are: to improve the coverage of the existing 405-line television service; to initiate a second television programme; to make preparations for the changeover of line standards on the existing service to 625 lines; and to plan for the eventual introduction of a colour service. Other tasks in hand include making improvements to the v.h.f. sound service and studying the possibilities of the introduction of stereophonic broadcasting.

Mr. McLean said that he was disappointed in the rate of sale of v.h.f. receivers and also in the performance of some of those which have been sold. "From the point of view of the broadcaster, we would like to see improvements in both these respects. This would also be desirable from the point of view of stereophony where considerable effort has been put into the study of various systems."

Turning to television, Mr. McLean said that at the moment thirty-seven stations are under construction or being planned for B.B.C. 1 and a further twenty stations are envisaged for the future. Seven Band I relay stations have been brought into service in the last twelve months.

Conversion of studio and ancillary equipment for 625-line operation for the second programme is well ahead and work on the u.h.f. transmitters is fairly advanced. The stations included in the initial programme of construction will be sited in the highly populated parts of the country and nearly all of these will be located on existing sites; either B.B.C. or I.T.A. The Corporation is planning to construct some ten u.h.f. stations during the next two and half years. The first to come into service will be the London station, which will start trial transmissions—for many hours a day—next January and will be carrying a complete service as from 1st April. The next station in the chain is to be sited at Sutton Coldfield and is scheduled to come into service early in 1965. The remainder of the transmitters in the initial programme should be completed by the end of 1965 or early 1966 and provide a service to about 60 to 70% of the population.

Michael Peacock, programme chief of B.B.C. 2, said in his address to the R.T.R.A. that "B.B.C. 2 will be fun—new and exciting. B.B.C. 2 will be a balanced programme covering the whole range of television, and will be a planned alternative to our present schedules and at all times I will be trying to give viewers a real choice. Why should we all have to look at sport on a Saturday afternoon?

"B.B.C. 2 will be a tremendous challenge for all of us; for Mr. McLean who takes over the B.B.C.'s engineering division just when it faces the largest programme of work in its history; for the G.P.O. who have to cover the country with a new network of wideband vision circuits to bring B.B.C. 2 to our transmitting stations; for the equipment manufacturers who have millions of pounds worth of orders from us and who face very tight deadlines. It's a challenge, of course, for me and for all my colleagues who will be creating the programme for B.B.C. 2."

R.S.G.B. Jubilee

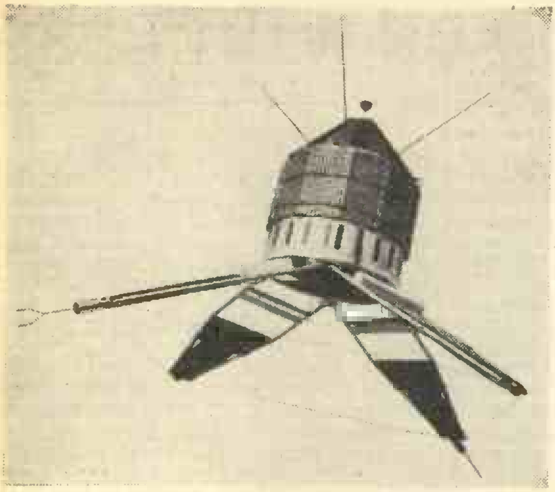
TO mark the 50th anniversary of the founding of the Radio Society of Great Britain, first known as the London Wireless Club and later as the Wireless Society of London, the society has arranged a week's programme of events starting on 1st July and culminating with a Golden Jubilee Dinner on 5th July—the date of the inaugural meeting of the London Wireless Club in 1913. The programme includes visits to the D.S.I.R. Radio Research Station at Slough and the B.B.C. Television Centre and an evening function organized by the London U.H.F. Group.

Wireless World, which was the official organ of the society until it started its own journal in 1925, offers its congratulations to the R.S.G.B. on reaching its half century.

U.K.3—Britain's First Satellite

THE Government has placed a development contract with the Guided Weapons Division of the British Aircraft Corporation for a 140lb research satellite. Known as U.K.3, it is to be built under the guidance of the Space Department of the Royal Aircraft Establishment, Farnborough. It will be the first all-British satellite and is the third in a series of joint Anglo-American scientific research satellites. The first one in the series, known as U.K.1 and also as Ariel, was launched last year and is still in orbit. U.K.2 is undergoing final tests in America and is to be launched later this year. Both of these satellites contain British instruments, but are American built.

U.K.3 will be launched in 1966 by an American "Scout" rocket and will conduct several experiments for the Universities of Cambridge, Birmingham and Sheffield, and for the Meteorological Office and the D.S.I.R. Radio Research Station. These experiments were chosen by the Royal Society and include mapping of noise sources in the galaxy; the measurement of electron density near the satellite; the study of low fre-



Mock-up of U.K.3, Britain's first satellite.

quency radio signals; the distribution of oxygen in the atmosphere; the intensity and distribution of lightning over the earth's surface; and anomalous propagation from world radio beacons.

Hobart Radio Plan

OVER the next ten years British military communications are to be completely reorganized under what is known as the Hobart Radio Plan. The plan, which was drawn up by the War Office, is at present being studied in detail by 16 companies in the telecommunications industry. £750,000 has been set aside to finance these study contracts.

When the plan is put into operation it will change the whole concept of battlefield communications and will cost over £100M. One of the main points of the plan includes scrapping the present "chain of command" system which ties communications to individual brigades having their own signals systems and replacing it with a number of key centres, together with numerous mobile stations, with transmitting and receiving facilities capable of covering the whole battlefield. Other important points include research into the prevention of jamming by the enemy and the provision of flexibility and mobility.

Components Show Attendance.—During the four days of the Radio and Electronic Component Show at Olympia (May 21-24) a total of 48,902 visitors was recorded. Of this number some 2,600 were from overseas. Total attendance was 40% up on the 1961 figure.

A.F.C.E.A.—The June meeting of the London Chapter of the Armed Forces Communications and Electronics Association will be held on the 27th when members and guests will be visiting the Electrical Inspectorate (E.I.D.) of the Ministry of Aviation at Bromley, Kent. Particulars are available from W. G. J. Nixon, 35 Hackbridge Road, Hackbridge, Surrey.

V.W.O.A.—The Veteran Wireless Operators Association of the U.S.A., which has among its aims "the recognition of meritorious service rendered by wireless operators on land, sea and air", has made special awards to two U.K. marine radio officers "for heroic performance of their duty at sea". One was awarded posthumously to C. J. Taylor of s.s. *Blairgowrie* and the other to M. W. Fisher of the freighter *Captain George*. The association's recently introduced De Forest Audion Award has been given to B. F. Miessner, of Florida, "a pioneer in electrical communication".

Radio Industries Club.—Of a total membership of 2,099 in the nine Radio Industries Clubs throughout the U.K., 859 are members of the London club. The new president is Basil de Ferranti, M.P., whose father presided in 1942/3. Owen Pawsey, editor of *Electrical & Radio Trading*, is chairman.

Television Society Council.—At the a.g.m. of the Society the following were elected to fill the vacancies caused by "rotation retirement": W. N. Anderson (I.T.A.); H. W. Barnard (*Wireless World*); H. A. Fairhurst (Rank-Bush Murphy); T. Kilvington (Post Office); A. V. Lord (B.B.C.); G. E. Partington (Marconi's) and B. Marsden (A.T.V.). The chairman for 1963/64 is G. B. Townsend (G.E.C. Electronics). The Society's report for 1962 records a membership of 1,450—an increase of 144 during the year. Two new local centres have recently been formed bringing the total to seven.

Geoffrey Parr Award.—To commemorate the work done by the late Geoffrey Parr for the Television Society, of which he was Honorary Secretary for many years, the council has instituted an international television engineering award to be known as the Geoffrey Parr Award. It will be presented annually to an individual or team for an outstanding contribution to television engineering during the preceding three years. The first award will be made in 1964. The Society's 1963 silver medal, which is awarded for outstanding artistic achievement in television, was presented to Huw Weldon, head of documentary programmes, B.B.C.-TV.

West Germany and west Berlin exported 1,575,845 radio receivers during 1962. Their imports for the same period, which included 345 from the U.K., amounted to 762,397. Incidentally, west Germany exported 338,535 television sets in 1962 and imported 7,285; 12 of which were British.

Both short-wave and medium-wave tests are being conducted on **Ascension Island** preparatory to the building of the proposed transmitting station for the External Services of the B.B.C. It will be used to direct programmes to Africa, Latin America and the Caribbean. The cost, about £1.75M, will be met from the £4.5M grant recently made available by the Government for B.B.C. relay stations in various parts of the world. At present a total of 39 high-power short-wave transmitters, at four sites in the U.K. and one in Malaya, are used together with two m.-w. and several s.-w. transmitters in the Eastern Mediterranean.

B.B.C.'s new television station at **Ashkirk**, Selkirkshire, was brought into service last month and their v.h.f. sound transmitter on the same site is scheduled to come into service on 1st July. The TV transmitter is operating on Channel 1, using vertical polarization, and the three sound transmitters are to operate on 89.1, 91.3 and 93.5Mc/s.

Sound effects records, each containing between 10 and 16 effects including railway, road, aeroplane, animal and electronic music sounds, are being produced by Contrast Sound Productions Ltd., 15 Blackheath Road, London, S.E.10. The records retail at 7s 6d including tax and are free of copyright to amateur users.

The eighteenth annual exhibition and convention of the **Institution of Electronics** is to be held in the Renold Buildings of the Manchester College of Science and Technology from 11th to 17th July. Further details are available from the General Secretary, Pennine House, 78 Shaw Road, Rochdale, Lancs.

The B.B.C. has now concluded the second series of field trials of **the Zenith-G.E. pilot-tone stereophonic system,** using **the Wrotham Third Programme** transmitter on its normal frequency of 91.3Mc/s, but to assist manufacturers in the design of tuner units for export, the test transmissions are being continued each Wednesday between 11-11.30 and 12-12.30.

African TV Plan.—Television services throughout Africa, with the exception of Algeria, will use the 625-line standard. This was decided at the African VHF/UHF Broadcasting Conference held in Geneva in May. All countries have agreed to use 8Mc/s spacing in the u.h.f. band but for v.h.f. operation some will use a 7Mc/s bandwidth. A frequency allocation plan was drawn up for the several thousand transmitters envisaged. This necessitated more than 20 million computer calculations to ascertain the likelihood of interference between stations sharing channels.

Some interesting figures showing **the growth of television** during 1962 have been issued by the European Broadcasting Union. The number of main transmitters increased by about 60 but the increase in low-power rebroadcast transmitters was 250. The countries with the largest growth in these low-power transmitters were Italy 63, France 51, west Germany 47, Yugoslavia 28 and Spain 19. At the end of 1962 there were 378 main stations and 1,296 rebroadcast transmitters in western Europe. Italy has the largest concentration with 629 stations and west Germany next with 479.

7% Rise for B.B.C. Staff.—Some 9,500 salaried staff, including engineers and technicians, of the B.B.C. have received pay increases of 7 per cent. The agreement, which came into effect on 1st June, covers scales ranging from £815 to £3,500 a year. The previous scales were negotiated in April, 1961, when increases of 12½ to 15 per cent were agreed.

The **Board of Trade** have asked us to point out that the figures we gave in last month's issue regarding imports from Japan were only for this year and that the £250,000 worth of components and component parts is additional to the £500,000 worth of transistor radio receivers.

Disclaimer.—In an advertisement on page 18 of the June issue PACO kits were referred to as "the world's only test instruments in kit form." In fact, the Heathkit range of constructional kits supplied in this country by Daystrom Ltd. of Gloucester has for many years included test instruments.

The Cyprus Broadcasting Corporation is extending its existing television service, which at present serves only the Nicosia area, to cover the whole island. A pair of 5kW 625-line transmitters are to be installed at Sino Oros and another pair on Mt. Olympus. Both of these installations will be remotely controlled from Nicosia and are scheduled to come into service by next July. Microwave links will be used to carry programmes from the existing studio to the new transmitters. All the equipment is to be supplied by Pye.

Radio Amateurs' Course.—The Brentford Evening Institute, of Clifden Road, Brentford, Middx., will be running classes for the City and Guilds Radio Amateur's Certificate, on Wednesday evenings, and a morse class for the P.M.G.'s certificate, on Thursday evenings, this coming year. The fee for the Radio Amateur's course, which starts in September and runs for three terms, is £1 10s. The morse course runs for two terms and the fee is £1. The Institute will also run a radio and electronics mathematics class if sufficient applications are received. Further details may be obtained from Evening Institute Department, Education Offices, Town Hall, Chiswick, London, W.4.

Imperial College.—A 150-page book containing details of post-graduate courses and research at the Imperial College of Science & Technology, London, for 1963-64 has been sent to us by the Registrar. The electrical engineering courses, each full-time for one academic year and leading to the award of the D.I.C., include several in the fields of communication and electronics and applied electron physics.

The 8th edition of the list of **European v.h.f. sound broadcasting stations** has been issued by the European Broadcasting Union. It includes some 2,200 transmitters in Band II and they are listed both geographically and in order of frequency. Over half of the transmitters are in Italy which now operates more than 1,200, the majority being of very low power. The cost of the publication, obtainable from the E.B.U. Technical Centre, Brussels, is 50 Belgian francs which includes five bi-monthly supplements.

News from Industry

Grange Associates, of California, are forming a new company in the U.K. in response to the increasing demands for their communications equipment and airline accessories in the Commonwealth. The new, wholly owned, company is to be called Granger Associates Ltd., and will have offices in London. Granger Associates will continue their relationship with Ultra Electronics Ltd., who have served as marketing agents for them in the U.K. since 1961. Major General E. S. Cole, manager of the telecommunications division of Ultra, has been appointed a director of the new company.

Morganite Resistors' newly built factory at Jarrow was opened by the Rt. Hon. F. Erroll, President of the Board of Trade, on 24th May. This is their third factory in the fifteen years they have spent in Jarrow and will provide an additional 56,000 sq ft of floor space.

Dansette Products Ltd. have acquired a modern single-storey factory in Honeypot Lane, Stanmore, Middx., from the Rank-Bush Murphy organization. This will provide Dansette with over 40% more production space.

The Solartron Electronic Group Ltd. have recently received an order from The Sperry Gyroscope Company of Bracknell for a second **247 Analogue Computing System.** The Sperry installation will be the most advanced large simulation centre in Europe.

Patent Infringement.—An action charging patent infringement of techniques incorporated in the Ampex Videotape recorder was filed on 11th April by the Ampex Corporation against Mach-Tronics Inc., of California. The suit requests damages of $3,000,000 plus a permanent injunction against manufacture or sale of recorders infringing Ampex patents. Mach-Tronics was formed a short time ago by a small group of former Ampex employees.

Standard Telephones and Cables Ltd. have received orders to the value of £1.5M from the G.P.O. for carrier telephone multiplex equipment, a large portion of which will be installed in the London radio tower, now under construction.

The Ministry of Aviation has placed an order with **Mullard Equipment Ltd.** for £230,000 worth of transistorized automatic error detection and correction equipment. This equipment, known as A.R.Q., is to be used in the Commonwealth Air Forces' telecommunications network.

The Northern Lighthouse Board have ordered, from **A. T. & E. (Bridgnorth) Ltd.**, a radiotelephone network comprising some 15 installations to cover four groups of Scottish lighthouses—the Shetlands, Orkneys, Hebrides and the West Coast. The network is to be based on the A. T. & E. "800" series of duplex single-channel equip-

A.E.I.-S.T.C. Valve Agreement.—The manufacture and sale of the majority of industrial valves produced at Brimsdown, Middx., and marketed by the A.E.I. Telecommunications Division have been transferred to the Valve Division of Standard Telephones and Cables. The valves transferred to S.T.C. are complementary to their existing range and they will be manufactured at Paignton, Devon. The valves retained by A.E.I. include their photo-electric cells and multipliers, vacuum gauges and tungar rectifiers, and they will be made and marketed by the A.E.I. Electronic Apparatus Division, of Carholme Road, Lincoln.

Racal have been awarded a £50,000 contract to supply the Royal Aircraft Establishment, at Farnborough, with a number of Textran v.l.f. receivers, which they market for Tracor Inc. of America. They are for use in the Establishment's radio-navigation and propagation research programme.

Standard Telephones and Cables Ltd. has acquired the capital of H.F. Industrial Services Ltd., and has made an application to change the name of the newly acquired subsidiary to **Stanelco Industrial Services.** The new company will continue to manufacture process heating equipment and it will be marketed with S.T.C.'s own products under the trade name Stanelco.

Telefunken, of Berlin, has been commissioned by Yleisradio to extend the network of radio links for the Finnish television service. The new 500km link is to connect Kajaani, in central Finland, with the repeater station at Savitaipale.

Products of the CONRAC Division of Giannini Controls Corporation, of California, including a range of general purpose **television monitors,** are to be handled in the U.K. by the Broadcasting Division of Marconi's W/T Company, who have recently become their exclusive U.K. agents.

British Relay.—It is announced by British Relay Wireless & Television Limited that the name of its principal relay subsidiary, British Relay Wireless Limited, has been changed to British Relay Ltd. The name "British Relay" will be used to cover both relay and rental trading.

The **Marconi Marine Company** have obtained exclusive U.K. rights to market the "Explorator" horizontal shoal detector from the French manufacturers, **Companie Générale de Telégraphie san Fil.** The Explorator was shown for the first time at the recent World Fishing Exhibition at Earls Court, London.

Profits after taxation of **Perdio Electronics Ltd.** and their subsidiaries for the year ended 2nd February 1963 amounted to £114,351. This is the first year's trading as a public company and represents an increase of over £54,000 on the previous year's profits.

The net profit of the **Ever Ready Company** for the year ended 2nd March 1963, before taxation, amounted to £3,885,499. This is over £500,000 up on the previous year. Taxation amounted to £1,935,898.

Elliott-Automation group profits, after taxation, for 1962 amounted to £1,513,780; an increase of over £350,000 on the previous year's figure. Group sales reached £36M, against £27M for 1961, and taxation for 1962 amounted to £1,348,400.

OVERSEAS TRADE

The **Royal Netherlands Air Force** has ordered a "Firebrigade" interceptor fighter control system from Elliott-Automation. This system supplements the function of the conventional control room and automatically provides guidance data for fighters engaging a number of supersonic intruders. A "Firebrigade" system ordered by the Royal Air Force last September has now been delivered.

Kuwait.—A consortium of companies, formed by Marconi's Wireless Telegraph Company and N. V. Philips Telecommunicatie Industrie of Eindhoven, have been awarded a contract, valued at £2.8M, to supply and install equipment at Kuwait's new international airport, which is now under construction. The contract calls for telecommunications equipment and several radar and radio navigational aids plus the maintenance during the first year of operation of all the equipment supplied. About £1.6M of this contract goes to British industry.

An order for 2,000 **Icon television cameras,** worth £100,000, has been placed with the Nottingham Electronic Valve Company by Electronic Vertieb, of Dortmund.

A microwave radio link, to connect Kambarangan and Jesselton—the capital of **North Borneo**—has been ordered from the General Electric Company by the Department of Post and Telegraphs, North Borneo. This will be a major addition to the trunk telephone networks of North Borneo and will replace the present v.h.f. link between Kambarangan and Jesselton. The new equipment will operate in the 2,000Mc/s band and has a capacity of up to 300 telephone circuits.

The largest single order for 4½in **image orthicon television cameras,** which calls for 44 Marconi Mark IV camera channels, has been awarded to Marconi's Wireless Telegraph Company by Columbia Broadcasting System Television Network.

Personalities

C. I. Orr-Ewing, O.B.E., M.A., M.I.E.E., M.P., who recently resigned from the Government as Civil Lord of the Admiralty and has received a baronetcy in the Birthday Honours, has been appointed vice-chairman of the Carr Fastener Co. and chairman of the associated company United Dot Products both of which are members of the United Carr Fastener Corporation of Boston, Mass. Mr. Orr-Ewing was a member of the B.B.C. engineering staff until 1949 when he joined the Cossor Group of which he became a director in 1951. He has been a member of Parliament since 1950 and relinquished his association with industry on his appointment as Under Secretary of State for Air in 1957.

Albert H. Mumford, O.B.E., B.Sc.(Eng.), M.I.E.E., who receives a knighthood in the Queen's Birthday Honours, has been engineer-in-chief of the Post Office since January 1960. He joined the Engineering Dept. as a probationary assistant engineer in 1924 at the age of 21. Mr. Mumford, who was in charge of the Radio Branch of the Dollis Hill Laboratory during the major part of the war, has been chairman of the Technical Sub-Committee of the Television Advisory Committee since 1960.

Sir Harold Bishop, who recently retired as Director of Engineering of the B.B.C., has been appointed a consultant to the B.I.C.C. Group. In this capacity he will be primarily associated with matters affecting group policy in certain technical developments. Sir Harold has also been elected a director and deputy chairman of the Telegraph Condenser Company, a member of the B.I.C.C. Group.

The Rank Organisation is appointing a number of specialists to give advice to its industrial divisions. The first three appointments are:—**Dr. J. B. Birks,** reader in physics at Manchester University who specialises in molecular and solid-state physics; **Professor F. Koenigsberger,** professor of machine tool engineering at Manchester University; and **Professor G. A. Whitfield,** head of the department of electrical and control engineering at the College of Aeronautics.

F. N. Sutherland, C.B.E., deputy chairman and managing director of Marconi's W/T Company, has been appointed by the Postmaster General as one of the representatives from the radio industry on the Television Advisory Committee. Since the reconstitution of the committee in 1952 "To advise the P.M.G. on the development of television and sound broadcasting at frequencies above 30Mc/s and related matters, including competitive television services and television for public showing" it has included two representatves from the industry; they are **C. O. Stanley** (chairman of the Pye Group) and, originally, G. Darnley Smith who on his retirement from industry was succeeded by **Dudley Saward** (managing director of Rank-Bush Murphy). There will now be three representatives from the radio industry. Prof. Sir Willis Jackson is chairman of the committee which now has 12 members including the Directors General of the B.B.C. and I.T.A.

F. N. Sutherland

J. D. Tucker

J. D. Tucker, A.M.Brit.I.R.E., recently appointed general sales manager of the Broadcast and Recording Equipment Division of E.M.I. Electronics Ltd., joined the company in 1958. He spent ten years in the B.B.C.'s Engineering Division followed by three years with Associated Rediffusion as assistant head of engineering before joining E.M.I.

R. G. Dancy has been appointed senior applications engineer of the International Rectifier Company (Great Britain) Ltd., Oxted, Surrey. Mr. Dancy, who was at one time with the B.B.C. and later with the Post Office, joined I.R. in September 1959 and two years later he transferred to the American parent Company in California, to manage the instrument laboratory.

R. F. G. Hamilton, B.Sc.(Eng.), M.I.E.E., has been appointed an assistant general manager of Elliott Brothers (London), Ltd. Mr. Hamilton, who is 48, joined Elliotts in January 1960 as technical manager of the Servo Components Division and was appointed manager of the division later the same year. He is succeeded as manager of the Servo Components Division by **J. Blake**, formerly sales manager, who is 38.

D. C. B. Kirk is appointed engineer-in-charge of the B.B.C.'s medium-wave transmitter at Moorside Edge, near Huddersfield, in succession to **W. H. Thorneycroft** who is now engineer-in-charge of the B.B.C. External Services station at Rampisham, Dorset. Mr. Kirk joined the Corporation in 1930 and has been assistant e.-in-c. of the Moorside Edge station since 1959.

J. D. Last, a graduate apprentice of the B.B.C.'s engineering division, has been awarded a B.B.C. research scholarship to undertake research at Sheffield University in the department of electrical engineering under Professor A. L. Cullen. The subject of his researches will concern harmonic generation using varactor diodes and other non-linear devices with particular reference to efficiency and bandwidth.

J. P. Speakman, A.M.I.E.E., has been appointed superintendent of the scientific apparatus department of A.E.I.'s Instrumentation Division at their Barton Works, Trafford Park, Manchester. Mr. Speakman is a council member of the Institution of Production Engineers.

QUEEN'S BIRTHDAY HONOURS

SOME thirty names in the world of wireless appear in this year's list including:—

Baronetcy

C. Ian Orr-Ewing, O.B.E., M.A., M.I.E.E., M.P.; Civil Lord of the Admiralty from 1959 until his recent return to industry. (See p. 338.)

C.B.

Major-General A. M. W. Whistler, C.B.E., late Royal Corps of Signals and chairman of the Joint Communications-Electronics Board.

K.B.E.

Albert H. Mumford, O.B.E., B.Sc.(Eng.), M.I.E.E., engineer-in-chief, General Post Office. (See p. 338.)

C.B.E.

Captain A. J. B. Naish, M.A. (Cantab.), M.Brit.I.R.E., Royal Navy, Electrical Engineering Division, Ship Dept., Bath.
C. Riley, O.B.E., B.Sc.(Tech.), M.I.E.E., vice-chairman and general manager, General Electric Company (Telecommunications) Ltd.
Captain R. F. T. Stannard, O.B.E., D.S.C., R.N. (Retd.), director, London Communications-Electronic Security Agency.
R. V. Whelpton, M.Sc., F.Inst.P., deputy chief scientific officer, Ministry of Aviation.

O.B.E.

D. Best, B.Eng., A.M.I.E.E., chief engineer, Ferranti Ltd., Wythenshawe.
Lt. Col. D. K. Binks, Royal Corps of Signals.
R. J. Murgatroyd, B.Sc.(Eng.), A.M.I.E.E., senior principal scientific officer, Air Ministry.
D. A. Senior, Ph.D., M.A., M.I.E.E., senior principal scientific officer, Department of Scientific and Industrial Research.
Lt. Col. D. L. Sylvester-Bradley, A.M.Brit.I.R.E., Royal Corps of Signals.
G. A. Whitfield, B.Sc., M.I.E.E., Professor and Head of Department of Control and Electrical Engineering, College of Aeronautics, Cranfield.

M.B.E.

G. H. Goldsack, assistant production manager, Muirhead & Company.
W. D. Gorman (ZL2IY), of Wellington, for services to the community, especially in connection with the New Zealand Amateur Radio Emergency Corps (Search and Rescue Organisation).
A. P. Hunt, Head of Wiring Unit, Planning and Installation Department, B.B.C.
H. T. Johnson, chief test engineer, Clifford and Snell Ltd., Sutton, Surrey.
T. Patten, technical superintendent (signals), Royal Air Force, Carlisle.
E. W. J. Pearce, senior executive officer, Government Communications Headquarters, Foreign Office.
L. R. Spicer, cable research and development engineer, Standard Telephones and Cables.
A. G. Stainsby, B.Sc., A.Inst.P., of the Hirst Research Labs. of General Electric Company, where he has been senior group leader in the valve division.
Warrant Officer V. F. M. Thom, Royal Corps of Signals.
Warrant Officer T. A. Vaughan, Royal Corps of Signals.
T. S. Wylie, M.I.E.E., senior executive engineer, General Post Office, Northern Ireland.

I.S.O.

S. W. Broadhurst, A.M.I.E.E., Post Office Research Station.

B.E.M.

Chief Radio Communication Supervisor A. C. Briggs, Royal Navy.
Chief Radio Communication Supervisor R. H. Cannon, Royal Navy.
G. E. Elliott, production superintendent, Plessey Company.
H. W. Hicks, foreman, Electric & Musical Industries.
Chief Radio Electrical Artificer (Air) D. Kiddell, Royal Navy.
Chief Communication Yeoman C. W. Tyler, Royal Navy.

Wireless World

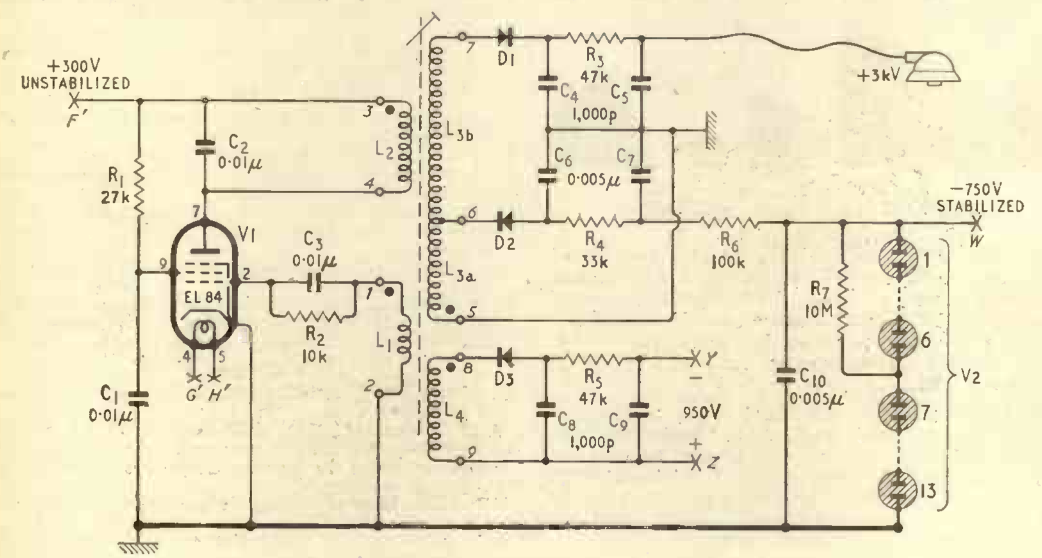
OSCILLOSCOPE

5.—E.H.T. UNIT

IT was hoped that, in this article, we would be able to describe the completion of the instrument, assembly and calibration, but pressure of space has compelled us to confine our attention to the e.h.t. generator.

Three high-voltage supplies are required for the tube as used in this circuit. The post-deflection acceleration electrode is supplied with a positive potential of 3kV. The ratio of p.d.a. to cathode voltage is set by the tube makers and cathode voltage is −750V. These two supplies have a common earth and are obtained from a tapped winding.

The third supply is for the control grid. As we have already mentioned, directly-coupled fly-back suppression is used in the instrument, which means that a capacitor cannot be used to block the path



CIRCUIT DIAGRAM OF THE E.H.T. UNIT WITH DOTS SHOWING STARTS OF WINDINGS AND COMPONENT LIST

Capacitors

C_1 0.01μF 300V
C_2 0.01μF silver mica
C_3 0.01μF 150V
C_4 1000pF 4kV Erie CD7
C_5 1000pF 4kV Erie CD7
C_6 0.005μF 1000V Radiospares
C_7 0.005μF 1000V Radiospares
C_8 1000pF 4kV Erie CD7
C_9 1000pF 4kV Erie CD7
C_{10} 0.005μF 1000V Erie Radiospares

Resistors

R_1	27kΩ	10%	1W
R_2	10kΩ	10%	½W
R_3	47kΩ	10%	½W
R_4	33kΩ	10%	½W
R_5	47kΩ	10%	½W
R_6	100kΩ	10%	½W
R_7	10MΩ	10%	½W

Miscellaneous

D_1 STC Type K8/140
D_2 STC Type K3/35
D_3 STC Type K3/40
Ferrite Rod—Neosid Type F14 $\frac{5}{16}$in dia × 3in.
Small Turret Tags (Radiospares)
V2–13 × Hivac 3L or equivalent
Lektrokit tag strip—LK2221
Anti-corona cap (Radiospares)

between tube grid and time-base output. Some tubes have an additional electrode, called an anode modulator, which can be run at low voltage for this purpose, but in the absence of this, we have a "floating" supply for the tube grid. We then apply the blanking waveform to this supply, which maintains the correct voltage on the tube grid.

These are the outputs, and it will be realized, especially in the case of the 3kV supply, that it is not a very good idea to have too much power available at this voltage. One's instinct for self-preservation dictates that the impedance must be high, so that the voltage collapses if touched by a relatively low-impedance load such as the back of one's hand. This, in turn means that smoothing capacitors must be of low value and, for adequate smoothing, high frequencies must be used. Mains transformers are therefore out, and an oscillator is the only answer.

For precision in measurement, it is necessary for the e.h.t. voltages to be stable. In a tube with its final accelerating anode before the deflection plates, a variation in anode voltage will affect the deflection sensitivity of the tube and the display size will vary in proportion. Brightness will also vary. To get over the problem of sensitivity, tube designers evolved the post-deflection acceleration anode, which takes the form of a helical coil on the bulb of the tube, after the deflection plates. The ordinary anode is now run at a lower voltage, which gives a lower beam "stiffness" and greater deflection sensitivity. As soon as the electrons in the beam pass the deflection plates, they come under the influence of the p.d.a. anode, which restores the brightness lost by reduced anode voltage. The p.d.a. voltage has little effect on deflection sensitivity, so that stabilization is not needed here. The voltage on the pre-plate anode, however, is still critical and must be stable. In most circuits the pre-plate anode is held at about 200V, so that the 750V anode voltage is a negative potential applied to the cathode.

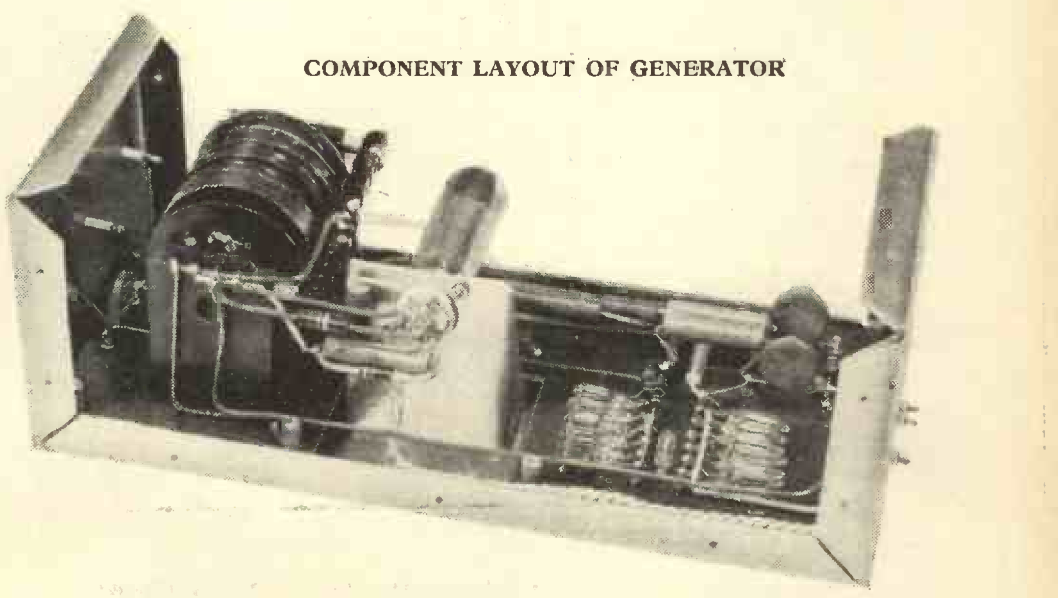
The type of oscillator we have used is the series-fed tuned-anode variety, using the EL84 power pentode. As the e.h.t. output is stabilized, it is not necessary to obtain the h.t. for the oscillator from the stabilized power pack, and "raw" power is used.

The 750V output is stabilized by the string of neon-indicator lamps. This may look a little crude and, at first sight, expensive. But after having tried a directly-coupled feedback loop and one or two other methods, we came to the conclusion that this was the easiest, and, as the neons are not expensive, the cheapest. The cost of these has to be balanced against the price of the double-triode, valveholder, six resistors and a potentiometer used in a valve stabilizer. There was also the problem that, as only one output can be stabilized at a time, the other two varied wildly because the stabilizer tried to adjust them willy-nilly, whether they needed adjusting or not. A neon stabilizer does not suffer from this defect.

Half-wave rectification is used, as the output current is low, and selenium rectifiers have been found suitable. Where cost is not a deciding factor, valve rectifiers are commonly used, their heaters being fed from a couple of turns on the oscillator transformer. The reason for this is that metal rectifiers are not quite as happy at the higher frequencies as valves are, due to their self-capacitance and other effects which are not very well known. However, the frequency at which our oscillator works is kept down to 40kc/s and the S.T.C. rectifiers specified work very well.

The oscillator transformer is air-cored, which entails a fairly bulky component. Ferrite cores are a sight too expensive unless they are bought as surplus stock, and these, of course, cannot be relied on for availability. Constructors who can get hold of them could make a much smaller unit.

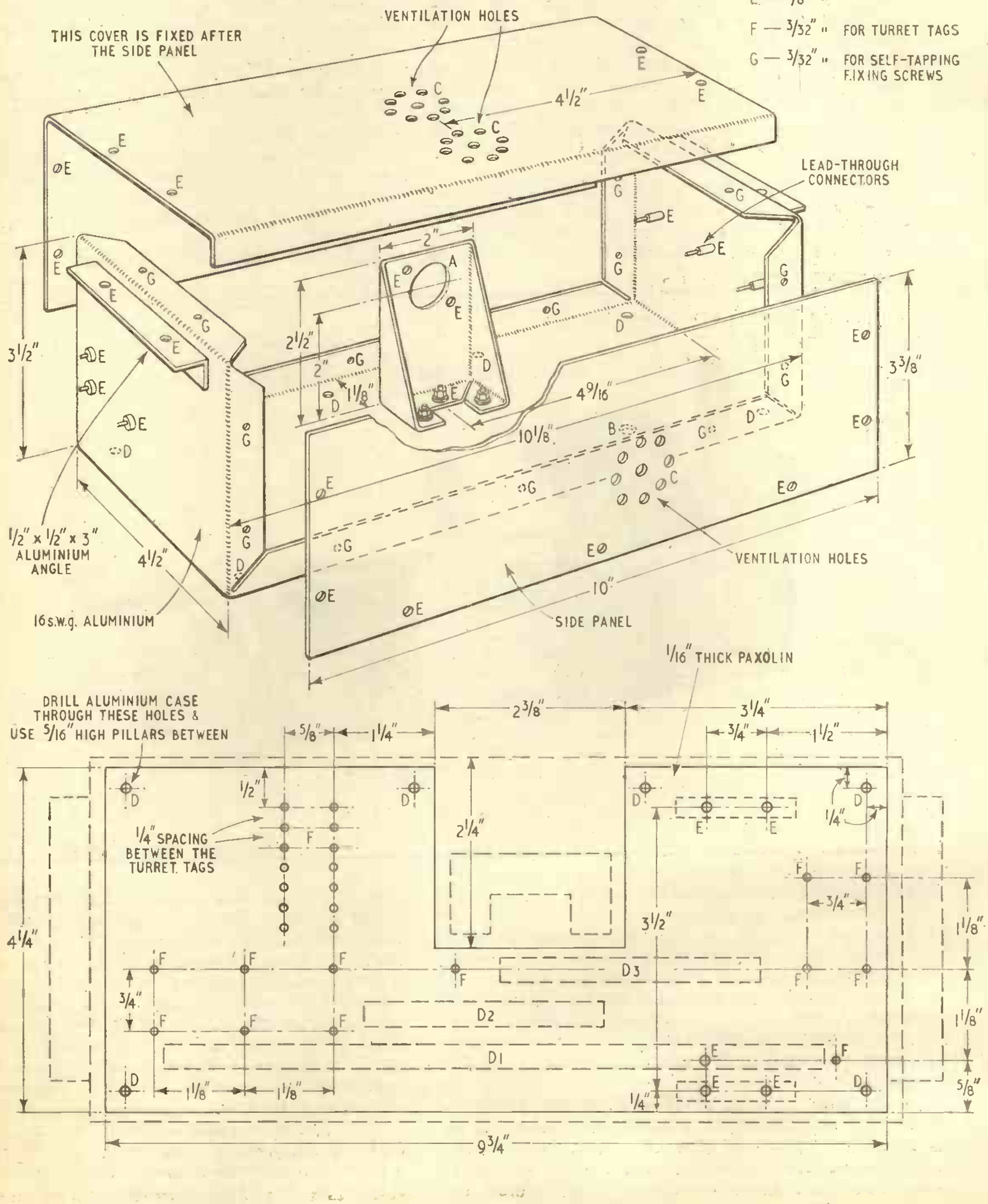
COMPONENT LAYOUT OF GENERATOR

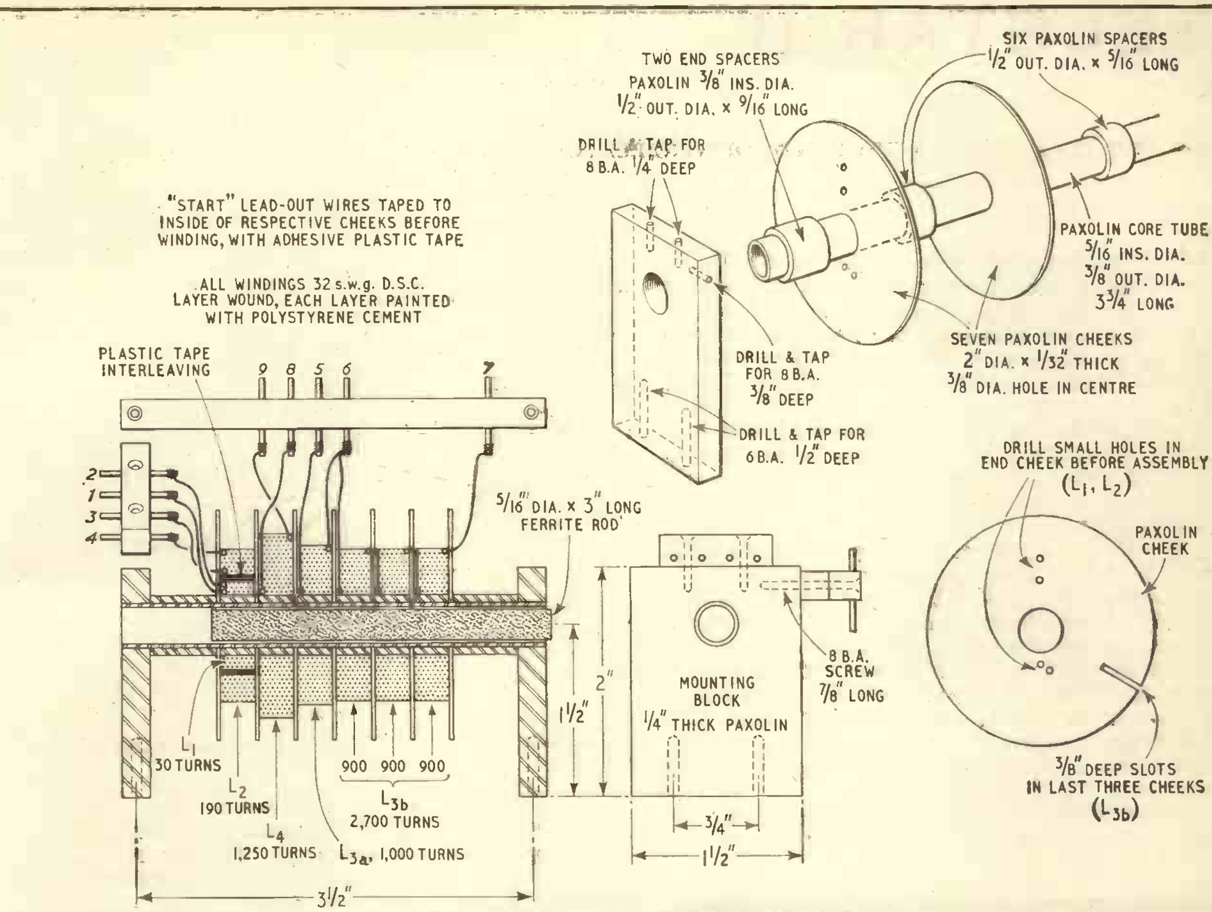


MECHANICAL CONSTRUCTION OF OSCILLATOR CHASSIS

DRILLING

A	3/4" DIA.	
B	1/4" "	GROMMET HOLE
C	3/16" "	VENTILATION HOLES
D	1/8" "	MOUNTING HOLES FOR PAXOLIN BASE IN CASE
E	1/8" "	
F	3/32" "	FOR TURRET TAGS
G	3/32" "	FOR SELF-TAPPING FIXING SCREWS





E.H.T. TRANSFORMER CONSTRUCTION

While we are on the subject of economy, it may be as well to mention tube costs. Several people have written in to say that the DN7-78 is a bit too expensive and can we please suggest a substitute. We are in the process of searching for a cheaper tube, or alternatively modifying the design to enable a less-sensitive tube to be used. Price modifications have directed our attention to the Sylvania-Thorn SE3-A, which, having the anode modulator mentioned earlier, offers the possibility of throwing away the floating output. We intend to investigate this and will report as soon as possible. Several minor modifications have been thought of already, and we will describe these later.

The e.h.t. unit is built on a Paxolin board, and screened by an aluminium box. The oscillator coil former is made from a Paxolin tube and Paxolin cheek discs, fixed together with Araldite adhesive. The ferrite rod is a close fit in the tube and is moved in or out for the required output. Once set, it can be fixed in position permanently with a dab of Araldite.

Layer winding is recommended for the coil, as haphazard pile winding will probably cause breakdown between turns. An additional precaution that must be observed is the insulation of the wire running from the outside of one coil to the inside of the next. The completed coil should be protected by a liberal application of polystyrene solution, which can be obtained from Denco.

There is not very much more one can say about the e.h.t. unit, except to be sure that the screening box makes good contact. If the several kilovolts of 50kc/s can get out, they will, and very peculiar traces will be the result.

Telecom. Textbook

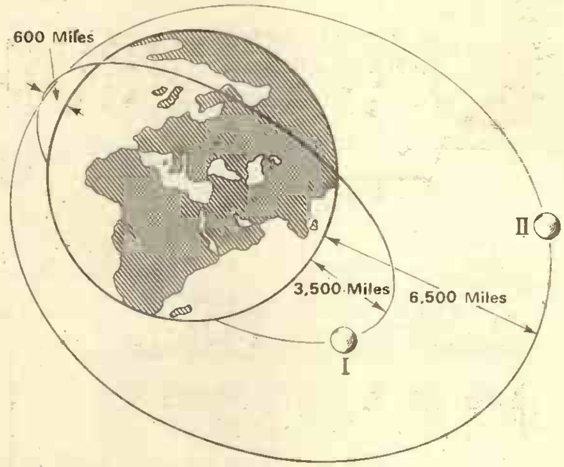
THE first of a series of textbooks for students taking the Telecommunication Technicians' Examination of the City and Guilds of London Institute was published by Iliffe Books a few weeks ago. Entitled "Radio and Line Transmission: Vol. 1," it covers the complete syllabus of radio and line transmission for the second year examination. The relevant part of the third year syllabus will be covered in Volume 2 to be published shortly. The authors of the first volume, which deals with the basic theory and practice of communication systems, are G. L. Danielson and R. S. Walker, who are respectively the head and a senior lecturer of the Telecommunications Department of the Norwood Technical College. Volume 1 comprises 252 pages with 200 diagrams and costs 21s. Further volumes covering the fourth year syllabi are in course of preparation.

TELSTAR II

IMPLEMENTING LESSONS LEARNED FROM TELSTAR I

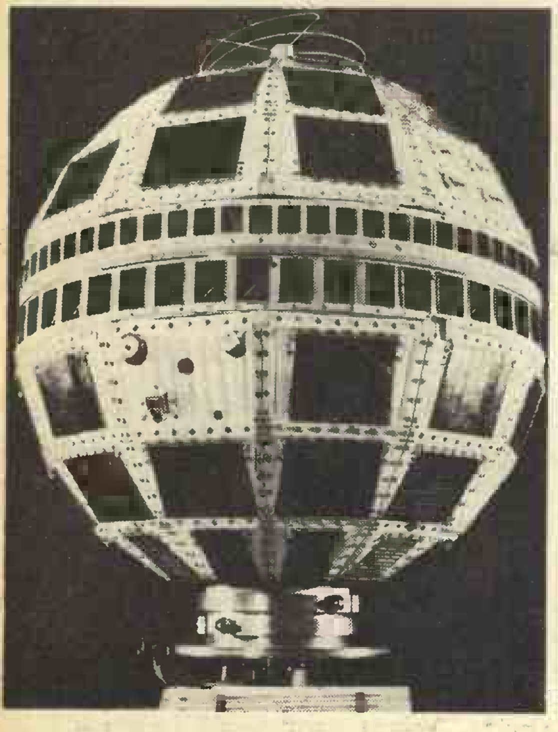
ONE important objective of the second Telstar experimental communications satellite, launched from Cape Canaveral on May 7th, is to learn how to extend the useful life of such satellites by avoiding or overcoming the effects of radiation which twice disabled Telstar I's command circuit. Physically the Telstar twins are identical—an aluminium shell 34½ inches in diameter coated with aluminium oxide and with 72 flat facets. A total of 3,600 solar cells are mounted on 62 of the facets. The new satellite weighs nearly 175 pounds, about four and a half pounds more than its predecessor.

As will be seen from the diagram the elliptical orbit of Telstar II has a much higher apogee than that of its predecessor. This means that the satellite spends less time in the regions of high radiation. It passes through the inner Van Allen belt and can report on the "slot" between the inner and outer belt. The higher apogee also provides about a 50% increase in the time of mutual visibility in the U.S. and Europe during each orbit. The angle of inclination is about 43° with respect to the equator, compared with the 45° of Telstar I.



The approximate orbit of Telstar II compared with that of Telstar I.

The difficulties experienced in commanding Telstar I were diagnosed as being due to the ionization of gases in transistors in the command decoders. To prevent this, "evacuated" transistors are used in one of the decoders of Telstar II. The cap enclosure that surrounds the transistor has been pumped free of air and other gases and sealed.



Slotted aerials for the communications frequencies (4,170 and 6,390 Mc/s) girdle the 34½ inch sphere.

Telemetry reports on some 118 items each minute are transmitted by Telstar II when commanded by a ground station. Telstar I made 112 such reports.

The principal additions include measurements of the command decoder (previously, there had been no specific measurement of the condition of the components in the command decoder), pressure inside the satellite on a continuous scale, and improved radiation measurement—up to 2MeV. Telstar II can send its telemetry reports on the same frequency (4,080 Mc/s) as that used for precision tracking of both satellites. This is something which would be desirable in a commercial satellite communications system.

It also uses the v.h.f. beacon frequency (136 Mc/s) on which Telstar I sends telemetry. This arrangement means that at the end of two years, when the v.h.f. beacon is automatically switched off so that the frequency can be used for other experiments, telemetry can continue on 4,080 Mc/s.

The communications equipment in Telstar II operates on the same frequencies (6,390 Mc/s receiving and 4,170 Mc/s transmitting) as used by Telstar I and the transmitter power is the same, 2.25 watts. The power of the tracking transmitter (4,080 Mc/s) is only 25mW and that of the telemetry transmitter 0.25W.

Both satellites were developed and built by Bell Telephone Laboratories and were launched by the National Aeronautics & Space Administration, the launching costs being borne by the American Telephone & Telegraph Company.

LETTERS TO THE EDITOR

The Editor does not necessarily endorse opinions expressed by his correspondents

Transistor Parameters

IN your May issue, Mr. G. W. Short points out that for a transistor $g_m r_{in}$ is the voltage gain of one transistor feeding into an identical one, where g_m is the common emitter mutual conductance and r_{in} the input resistance, and it is assumed that the collector load resistance is high compared with r_{in} and the output resistance and internal feedback of the transistor may be neglected. This is perfectly true, but what Mr. Short does not seem to realize is that $g_m r_{in}$ is, in fact, the current gain of the transistor under all load conditions, provided, as before, the output resistance and feedback can be neglected. It is thus equal to the common emitter short circuit current gain of the transistor, h_{fe} (α' or β in some people's terminology).

This is not just a peculiarity of the transistor, but applies to any three- or four-terminal network. For consider the four-terminal network shown in Fig. 1,

Fig. 1

where v_{in} and i_{in} are the input voltage and current respectively, and i_{out} is the corresponding short-circuit output current. Then, by the definitions of the parameters, and using the same notation as for the transistor, we have

$$g_m = \frac{i_{out}}{v_{in}}$$

$$r_{in} = \frac{v_{in}}{i_{in}}$$

$$h_{fe} = \frac{i_{out}}{i_{in}}$$

$$\text{Whence } g_m r_{in} = \frac{i_{out}}{v_{in}} \cdot \frac{v_{in}}{i_{in}} = \frac{i_{out}}{i_{in}} = h_{fe}$$

The reason why, for identical cascaded stages, this is also the voltage gain per stage, is because under these conditions the input resistance of one stage then equals the load resistance on that stage. Hence the voltage and current gains must be equal. However, if the stages are not identical, the current gain of any one transistor will still be $g_m r_{in}$, where g_m and r_{in} are the mutual conductance and input resistance of that particular transistor, whereas the voltage gain will be $g_m r_{in}$, where g_m and r_{in} are the mutual conductance and input resistance of that particular transistor, whereas the voltage gain will be $g_m r_{in2}$, where r_{in2} is the input resistance of the succeeding stage.

This means that the simple equivalent circuit of a transistor at low frequencies may be represented as in Fig. 2, which is identical with Mr. Short's Fig. 1 apart from the fact that the current generator may be either $g_m v_{in}$, as per Mr. Short, or $h_{fe} i_{in}$. In what is becoming to be the accepted terminology

$$r_{in} \equiv h_{ie} \equiv \frac{1}{y_{ie}}$$

$$g_m \equiv y_{fe}$$

where h_{ie} is the common-emitter input hybrid parameter,
y_{ie} is the common-emitter input admittance parameter
and y_{fe} is the common-emitter forward transfer admittance.

This equivalent circuit for a transistor is a very good approximation in the great majority of practical circuits at

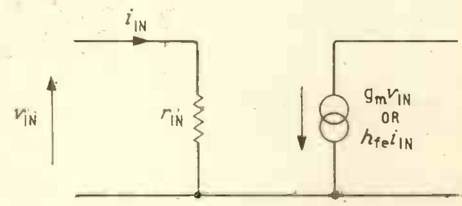


Fig. 2

low frequencies. The error involved in neglecting the output impedance and internal feedback rarely exceeds 10%, which is less than the error normally due to uncertainty in the actual transistor parameters, unless these have been individually measured. The only time when output impedance and internal feedback have a significant effect is when the collector load on the transistor is very high, a rare occurrence. At all other times, the circuit of Fig. 2 is perfectly adequate, and its use greatly reduces the amount of computation necessary, as well as giving a clearer picture of how a particular circuit is operating.

Mr. Short mentions the wide variation of r_{in} with d.c. operating point, and this seems to be widely recognized. However, what does not seem to be commonly known is that, given h_{fe}, r_{in} may be readily estimated for any given operating point.

Consider a transistor, as shown in Fig. 3. This depicts the cross-section of an alloy junction transistor, but the same argument applies to all types of junction transistors. The relationship between the d.c. voltage and current at the emitter junction is that of a junction diode, and is given by the well-known equation

$$I_e = I_o(\exp \frac{qV_{b'e}}{kT} - 1)$$

where I_o is the reverse saturation current of the base emitter diode, modified somewhat by the presence of the collector, I_e is the d.c. emitter current, $V_{b'e}$ is the d.c. voltage appearing directly across the junction (i.e. not necessarily the voltage measured between the accessible base and emitter terminals), q is the charge on the electron, k is Boltzmann's constant and T is the absolute temperature. For a temperature of 25°C, $\frac{kT}{q} = 0.026V^{-1}$.

At about 25°C, I_o will be of the order of a few μA for a germanium transistor, and a few mμA for a silicon one. Thus for all normal operating values of I_e, $\exp \frac{qV_{b'e}}{kT} \gg 1$, and we may write, without sensible error

$$I_e = I_o \exp \frac{V_{b'e}}{0.026}$$

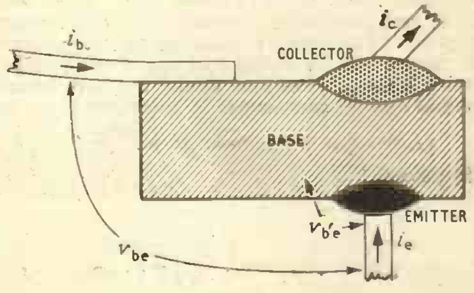


Fig. 3

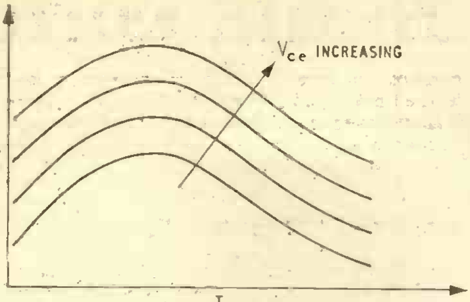


Fig. 4

We are primarily interested in incremental changes of I_e and $V_{b'e}$. Therefore, differentiating

$$\frac{dI_e}{dV_{b'e}} = \frac{I_o}{0.026} \exp \frac{V_{b'e}}{0.026}$$
$$\doteq \frac{I_e}{0.026}$$

i.e. the incremental resistance of the base emitter junction is equal to $\frac{dV_{b'e}}{dI_e} = \frac{26}{I_e}\Omega$ where I_e is in mA, a fairly well-known result.

If the collector is short-circuited to the emitter for a.c., then if i_b is the base signal current, and i_c is the collector signal current, by definition, we have

$$i_c = h_{fe}i_b$$

If i_e is the emitter signal current, then, by Kirchhoff's 1st Law

$$i_e = i_c + i_b$$

Thus

$$i_e = (1 + h_{fe})i_b$$

Hence the signal voltage appearing across the base-emitter junction is given by

$$v_{b'e} = i_e \frac{26}{I_e} = \frac{(1 + h_{fe})26i_b}{I_e}$$

For $h_{fe} \gg 1$, and $I_e \gg I_{cbo}$, the collector base leakage current, this may be approximated with good accuracy to

$$v_{b'e} = \frac{26h_{fe}i_b}{I_c}$$

Now between the external base lead and the base-emitter junction there is an appreciable resistance due to the resistivity of the base region itself. This resistance is termed the extrinsic base resistance, and is denoted by $r_{bb'}$. It varies in magnitude quite considerably between different types of transistors: for a power transistor it may be only 1 or 2Ω, whereas for a germanium low-power type it might be about 50Ω. There may also be some resistance in the emitter lead, but this is normally negligible. The extrinsic base resistance, $r_{bb'}$, has the base current flowing through it, so that the voltage drop across it is $i_br_{bb'}$. The total voltage between the external base and emitter connections is, therefore, given by

$$v_{be} = i_br_{bb'} + v_{b'e} = i_br_{bb'} + \frac{26h_{fe}i_b}{I_c}$$

Therefore,

$$r_{in} = \frac{v_{be}}{i_b} = r_{bb'} + \frac{26h_{fe}}{I_c}$$

In this expression, $r_{bb'}$ is almost independent of the d.c. operating point, decreasing somewhat as I_c increases. h_{fe}, however, depends in a somewhat complicated manner on the operating point, typical curves being shown in Fig. 4. In this figure, each curve is for one value of collector emitter voltage, V_{ce}.

As I_c is reduced, h_{fe} also falls, but at a much slower rate. Hence $\frac{h_{fe}}{I_c}$ increases as I_c decreases, so that for low values of I_c, $r_{bb'}$ becomes negligible in comparison, and $r_{in} = \frac{26h_{fe}}{I_c}$. If, for example, h_{fe} were 50, and $r_{bb'}$ 50Ω, the expression would be accurate within 10% for values of I_c up to 2.6mA. Thus at low values of collector current, given h_{fe}, we can always calculate r_{in}. At higher values of current, we need to know the value of $r_{bb'}$, also. If I_c is very large $\frac{26h_{fe}}{I_c}$ will be very much lower than $r_{bb'}$, and then $r_{in} = r_{bb'}$.

Now since $g_mr_{in} = h_{fe}$

$$g_m = \frac{h_{fe}}{r_{in}} = \frac{h_{fe}}{r_{bb'} + \frac{26h_{fe}}{I_c}} \text{ A/V}$$

Therefore at low values of I_c

$$g_m = \frac{h_{fe}}{\frac{26h_{fe}}{I_c}} \text{ A/V}$$
$$= 39I_c \text{mA/V}$$

and is thus independent of the transistor, and directly proportional to the collector current. As the collector current is increased, $r_{bb'}$ becomes more important and g_m no longer rises proportionately to I_c, nor is it any longer independent of the particular transistor. At very high values of I_c, as before $\frac{26h_{fe}}{I_c} \ll r_{bb'}$, and so

$$g_m = \frac{h_{fe}}{r_{bb'}}$$

Since in this region h_{fe} will almost certainly be falling with increase of I_c, g_m will also now fall with increase in I_c. The typical behaviour of r_{in} and g_m with I_c is, therefore, as shown in Fig. 5.

We can compare the results of these formulae with the figures given by Mr. Short for a particular C111 transistor.

I_c	0.01	0.05	0.2	1.0	3.0	10 mA	measured
g_m	0.4	1.6	7	35	77	190 mA/V	
r_{in}	50	20	10	2.5	1.2	0.7 kΩ	
$h_{fe}(=g_mr_{in})$	20	32	70	88	93	133	
g_m(approx.)	0.39	1.95	7.8	39	117	390 mA/V	calculated
g_m(accurate)	0.385	1.87	7.4	33.4	80.8	190 mA/V	
r_{in}(approx.)	52	16.7	9.1	2.27	0.79	0.345 kΩ	
r_{in}(accurate)	52	17.1	9.46	2.63	1.15	0.70 kΩ	

The approximate calculated values are using

$$g_m = 39I_c \text{mA/V}, \quad r_{in} = \frac{26h_{fe}}{I_c}\Omega$$

and the " accurate " calculated ones using

$$g_m = \frac{h_{fe}}{r_{bb'} + \frac{26h_{fe}}{I_c}} \text{mA/V}, \quad r_{in} = r_{bb'} + \frac{26h_{fe}}{I_c}\ \Omega$$

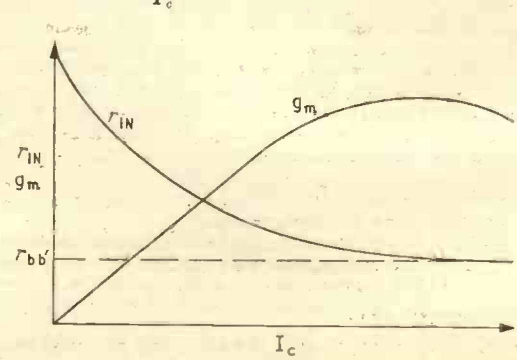


Fig. 5

where $r_{bb'}$ is put equal to 355Ω, this being the value which makes the measured and calculated values agree at I_c = 10mA.

It will be seen that the "accurate" calculated values agree closely with the measured ones over the whole range of collector currents, whereas for the approximate ones, the agreement is good for collector currents below 1mA. The principal discrepancies are probably due to experimental errors in the measurements.

The above formulae are very useful in practice. For example, the 2N2484 planar silicon transistor is quoted as having a minimum h_{fe} of 30 at $I_c = 1\mu A$. Its r_{in} must therefore be approximately 1MΩ under these conditions. Since for low collector currents, r_{in} is proportional to h_{fe}, transistors with current gains above the minimum will have even higher values of input resistance.

Again, some audio amplifiers are fed from sources of very low impedance. An example is a microphone amplifier used with say a 30Ω moving-coil microphone feeding it directly. The microphone impedance is much lower than the input impedance of the first transistor, so that the output current of this is given by $g_m v_{in}$, and v_{in} is determined solely by the microphone, not the transistor. Since at low values of collector current, such as would be used here (say 0.5mA) g_m is independent of the transistor, the output current is also independent of the transistor and no increase in gain would be achieved by using a transistor of higher h_{fe}. The only way to increase the gain would be to increase the collector current of the transistor. A higher current gain transistor would have a proportionately higher input impedance, so that for a fixed microphone voltage, the current into the transistor would be reduced by precisely the same proportion as the current gain was increased. Thus the output current would be the same.

One further point refers to Fig. 3 in Mr. Short's letter, where he suggests that in a wideband i.f. amplifier, the major part of the damping on the tuned circuit may be provided by the input resistance of the succeeding transistor. While theoretically very attractive, in practice this procedure would be very bad. As I have shown above, r_{in} is very dependent on h_{fe}. By its very nature, h_{fe} is very difficult to control at all closely in manufacture and spreads of ± 30% or even more are the general rule. Thus r_{in} will also have a spread of similar amount at a fixed operating current. Allowing for a tolerance in the collector current, the spread in r_{in} will be even greater. Thus, to ensure that the bandwidth of the circuit is reasonably constant despite variations in the transistor input resistance, it is essential that the major part of the damping be provided by a fairly close tolerance damping resistor. If this is in parallel with the input to the transistor, then it is desirable that its value does not exceed $r_{in}/4$, so that only 1/5 of the damping is provided by the transistor. This, of course, reduces the gain (by some 6 or 7 dB if one transistor is "matched" into the next), but loss of gain is the price that always has to be paid for consistency in performance.

The low value of additional damping resistance also has another desirable effect, for it means that the gain of the stage is primarily dependent on the g_m of the transistor, and not on its h_{fe}. Since, as I have shown, g_m at a given collector current does not vary from one transistor to another, this means that the variation in gain will also be reduced considerably. However, in practice, the behaviour at high frequencies is more complicated due to the capacitances occurring within the transistor.

But the same general considerations still apply, and it is still extremely necessary to shunt the input to the transistor with a relatively low value resistor in order to ensure a consistent performance.

London, E.C.1. ROGER CHAPMAN,
Electrical Engineering Department,
Northampton College of Advanced Technology.

The author replies:

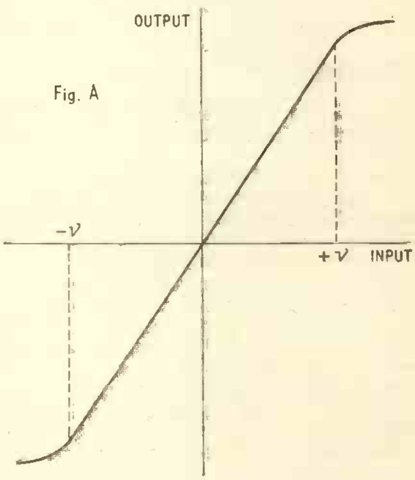
I am grateful to Mr. Chapman for pointing out that $g_m r_{in} = h_{fe}$, which at the time of writing I had not realized.

Mr. Chapman's strictures on my wide-band amplifier idea are just. All the same, what seemed impossible in transistors ten years ago is commonplace today, and perhaps, in another ten years, manufacturers will have learned how to control parameters more closely. Finally, I am relieved to see how well Mr. Chapman's calculated quantities agree with my own (very rough) measurements.

Croydon. G. W. SHORT.

Non-linearity Distortion Measurement

I AM obliged to Mr. Murray and Mr. Richards for their further explanations (in your June issue) of the points I criticized, but I am surprised that they do not accept that for a fair comparison between single-tone and multi-tone testing an essential condition is equal maximum signal amplitude. Nor can I see how this condition excludes the playing of concerted music. It is the elementary condition that must be observed by all responsible for recording on disc or tape, broadcasting by radio, or reproducing sound by amplifiers, if overloading is to be avoided. Yet all these media succeed in handling concerted music. This is so obvious that I did not think it necessary to explain in detail. However, let Fig. A be the dynamic transfer characteristic



of an amplifier. Since Murray and Richards are concerned with "normal operation," excluding overloading, the range to be explored would presumably require a test signal of ± v. A single-signal sinusoidal input would be adjusted to have this peak value. If now even as few as two signals of different frequencies were substituted, each having the same amplitude, the amplifier would obviously be grossly overloaded when peaks coincided. On the other hand if all except one component of a multiple signal having an overall peak value of ± v were switched off, the remaining single signal would have a much smaller amplitude and because it would explore only the "middle-cut" of the characteristic the resulting distortion would be very much smaller and the amplifier would not be properly tested.

It is not in dispute between us that the subjective unpleasantness of non-linearity is due mainly to intermodulation products rather than to harmonics. Indeed I demonstrated the point, also before B.S.R.A., as described by my *alter ego* in your issue of 19th May, 1938. But it is a fallacy to conclude from this that methods of testing which give rise to intermodulation products are necessarily better than those which cause only harmonics. It has been shown by a number of authorities that the ratio between harmonic and intermodulation distortion falls between fairly narrow limits, and provided reasonable conditions are observed it is constant, so that the amount of intermodulation can be reliably predicted by single-signal harmonic measurements, which can be performed with much simpler apparatus. I would not deny that a case might possibly be made out in favour of multi-signal testing, but we must take care not to base it on the fallacy stated above.

Finally I would point out that in calling attention to the importance of high-order distortion I gave cross-over distortion as an example, besides those that involve overloading. This cause is significant with small signals and so is not confined to overloading as suggested by Murray and Richards.

M. G. SCROGGIE.

The authors reply:

As the Editor will no doubt wish to set a limit to this correspondence we will content ourselves by quoting the last paragraph of the 25-year-old article "Debunking Harmonic Distortion" to which "Cathode Ray" has drawn our attention. It reads:—

"Personally I think that the apparatus for analysing harmonic distortion *properly* is almost as elaborate as that for measuring intermodulation, and far less informative. I believe that the latter can be simplified, and will in due course supplant harmonic measurements. Then we shall be in the third distortion era."

We believe that the method to which we drew attention has fulfilled this prophecy.

J. SOMERSET MURRAY,
J. M. RICHARDS.

Phase Splitters

I WOULD like to thank both Mr. Hafler (May issue) and Mr. Baxandall (June issue) for their comments about phase inverters.

I was very interested in Mr. Baxandall's investigations into the overload performance of his amplifier. There is no doubt that amplifiers do possess vastly different characteristics under overload conditions, many give violent low-frequency oscillations due to faulty h.t. decoupling arrangements. One amplifier that I have seen gave good performance until overdriven, after that it was more suitable for giving accelerated life-tests to loudspeakers! I therefore feel that an amplifier should be capable of withstanding 6dB of overload, and preferably more, with no noticeable effect apart from clipping the output signal. I still feel that the split-load inverter is suspect on this account but quite agree with Mr. Hafler that good circuit design may effectively remove this.

Regarding the choice between split-load and long-tailed-pair phase splitters, I agree with Mr. Baxandall that a double valve will give more gain when used as an amplifier with a split load output circuit. This arrangement has however one more effective high-frequency time-constant as compared with the long-tailed pair inverter. Whether this time-constant will materially affect the amplifier stability will depend on the circuit design, but its presence cannot be ignored. It was for this reason that I quoted the long-tailed-pair splitter as having more gain. What I should have said was that the long-tailed pair would give more gain (with a preceding amplifier valve) for the same number of time-constants that are involved in the split-load circuit.

In conclusion I would like to restate my case in that the circuit described is a considerable improvement over the conventional long-tailed pair circuit. I also feel that it has advantages over other phase-splitters, but there are of course many ways of killing a cat!

Bradford. ARTHUR R. BAILEY.

Intuition and Instability

WRITERS of Letters to the Editor are expected to be succinct, and risk seeming merely facile. Evidently G. Edwin (June issue) feels I am perpetrating a conjuring trick in my letter published in the May issue, for he suggests I have hidden the point B up my sleeve. But it was Mr. Edwin who introduced the point B, not I; the system of three true integrators is a legitimate physical system, realizable in control engineering if not in pure electronics. Its Nyquist diagram is simple, since the positive frequency part of the curve crosses the real positive axis only once. To degrade my integrators to elements giving $1/(p+\delta)$, yielding a conditionally stable system, and then to say "All (*sic*) we really need is a physical argument to explain conditional stability" seems to me to be jumping out of the frying pan into the fire.

Nevertheless, we may leave Mr. Edwin to his sidebands and contour integration and, on applying the reasoning I suggested to his Fig. C, verify that this example of conditional stability gives us no difficulty. At point B, $\frac{d|Gain|}{d|\phi|}$ is actually negative, not zero as suggested by Mr. Edwin's sketch. This crossover is therefore like the crossover in my Fig. 2 (May issue), and yields an unstable system when (1, 0) lies to the left of the crossover. Similarly, point A is like the crossover in my Fig. 4, and yields an unstable system when (1, 0) is to the right of the crossover. Hence, for the whole curve, instability occurs if $A<1<B$. This is the same result as Nyquist's, but does not suggest to the unwary that the behaviour of the system at frequencies in the bands near A and B depends on how it would behave, open loop, if tested at frequencies between 0^+ and 0^- and between $+\infty$ and $-\infty$, as—so it seems to me— Nyquist's criterion does.

Cambridge. P. E. K. DONALDSON.

Ionospheric Oblique Sounder

TO determine the best frequency for point-to-point communication in the h.f. band, E.M.I.-Cossor Electronics Ltd., Halifax, Nova Scotia, have developed the Ionosonde Model 8000 which, when used at both transmitting and receiving ends can give, in twelve seconds, all the required information. One Ionosonde sends a succession of 128 pulses at logarithmically spaced frequency intervals from 1.8 to 28.8Mc/s and the second Ionosonde is tuned synchronously to receive them. The band is covered in 2 seconds and a further 10 seconds is required to produce the "ionogram" in the Polaroid camera, seen at the left of the instrument. Frequency is on the horizontal axis and pulses are marked on the vertical time-of-transmission scale, which reveals any multi-path transmission on frequencies which are received, but might give distortion.

E.M.I.-Cossor Ionosonde Model 8000 in portable form.

MONTREUX TELEVISION SYMPOSIUM

OF the 50 papers presented at this year's International Television Symposium—the third in the series held at Montreux—nine were by authors from the U.K. There were papers by several members of the I.T.A. programme contracting companies and also by the German and French television authorities, but it was a talking point that the B.B.C. was absent.

At the exhibition run in conjunction with the Symposium and supported by 20 concerns, there was one U.K. manufacturer—Mole Richardson, the studio lighting specialists—and the G.P.O., but the latter's exhibit consisted of only a "draught screen" type of folding display of 18 photographs of the Goonhilly station. This display was, however, backed up by a very good paper by F. J. D. Taylor, who is in charge of the station. The only British radio equipment seen in the exhibition were examples of Thorn v.h.f. wired television repeater amplifiers, splitter units, equalizers and stabilized power supplies which were on the stand of their American agents—Visual Electronics, of New York.

The Symposium was primarily devoted to operational techniques but there were some supplementary lectures dealing with specific items of equipment some of which were to be seen in the exhibition.

It will be appreciated that with the limitations of space we can but summarize a few of the papers. However, for those readers requiring a complete list of papers we shall be glad to supply a copy of the Symposium programme.

Colour.—Two papers were presented by American authors on colour TV; one on colour receiver servicing and the other giving a survey of ten years of operation of a colour service by the N.B.C. The latter, which was read on behalf of the author by Dr. H. R. L. Lamont, of RCA Great Britain, presented some interesting facts on the present state of the art. There are now some 400 stations equipped to re-transmit networked colour programmes representing a coverage of 98% of all "television homes" in the United States. Of these 400 stations 132 are equipped to originate colour programmes. Incidentally, colour is now transmitted over some 60,000 miles of cable and radio networks. The number of hours of colour programming totalled over 2,000 in the N.B.C. network last year and now 75% of its night-time programmes are broadcast in colour. Questioned afterwards, Dr. Lamont agreed that despite the growth in programme hours the number of colour sets in American homes has not increased as rapidly as did monochrome sets when television was introduced. The paper also dealt with the problems of lighting, because of the critical 20-to-1 contrast range, and of the need for a constant check on the colour rendering as the signal is relayed over the network.

Comparative figures for the operation of high-power u.h.f. klystrons in monochrome and colour television systems were given in a paper by W. Schmidt of the Valvo organization of Hamburg.

Studio Techniques.—Some of the unique features of the Elstree studios of Associated Television were described by Bernard Marsden, deputy technical controller of ATV's engineering department. He dealt at some length with "transistorization" of studio equipment. Although at the time when work on the conversion of the studios started—nearly 4 years ago—it was known that transistors could not replace all thermionic valves the ATV engineers decided that the complete sound installation, the intercom system, vision switching system, sync generators and the video and sync distributing system should be built around transistors. "This very large proportion of equipment has been installed and the reliability, low heat generation and high performance of this equipment has demonstrated that the correct decision was made although this was done at a time when no other installation in the world had taken such a bold step." Mr. Marsden went on to sound a warning on the wholesale "transistorization" of valve equipment. For instance, whereas in the past they have been accustomed to distributing video signals to a number of destinations by the simple expedient of connecting together a number of unity gain

In addition to this stand in the exhibition on which was shown the company's latest cameras and monitoring equipment, Compagnie Francaise Thomson-Houston were demonstrating their O.B. vans in the grounds of the exhibition pavilion.

amplifiers, he suggested that this system can be dangerous if transistors are used. The low impedance of these amplifiers permits any voltage accidentally fed along a signal line to destroy all the equipment in a group of amplifiers and perhaps the equipment feeding the group of amplifiers. ATV's technique is to distribute the signals through resistive attenuator networks to a group of amplifiers each having a gain of 30dB. This means that there is an automatic protection of 60dB between the outputs of each of the distribuion amplifiers which gives safety protection in the case of accidental potentials being applied but also assists in isolation of the separate signals being fed. Another interesting feature which he described is a technique whereby the four outputs from a synchronizing generator are encoded into one signal which when it reaches any one of its 20 destinations in the studios is decoded into its four component parts suitable for driving the equipment. This system gives a four-to-one reduction in cabling and switching equipment.

The planning of the recently completed multi-standard studio centre of ABC Television at Teddington was described by F. H. Steele and some of the techniques employed for switching and distributing vision signals were dealt with by J. S. Sanson.

Automation.—Some stations have introduced fully automated time controlled switching systems which can cover either the complete day's programme or only the busy time of commercial breaks. For the majority of the smaller stations, however, such a fully automated system might not be economically justifiable. In addition their time schedules might not be sufficiently rigid for clock operation. To cater for such needs a simple non-clock system which allows a sequence of events to be preset, but the timing is entirely under the operator's control, was described by H. Mirzwinski and R. G. Moore of Marconi's W/T Company. The basic memory elements are standard 8-pole 25-position uniselectors as used extensively by the Post Office.

The remote control of repeater stations was discussed by a member of the Swiss P.T.T., and an interesting paper on a system of television rebroadcasting stations which is employed in Japan to extend the service area of a main station was given by the Nippon Electric Company. The rebroadcasting stations are unattended and some of them are powered by solar batteries.

Pay Television.—An interesting survey of Pay-TV systems was given by T. M. C. Lance, of Rank-Rediffusion, in which he compared the various off-the-air and wire systems. The major part of his paper, which aroused considerable interest, was devoted to a description of his company's Choiceview system which operates in the 5-10Mc/s band over a multi-core cable such as is used for the Rediffusion television and sound relay system. It employs a simple scrambling device, known as "decoy sync," in which pulses of varying width and timing are inserted in the back-porch of the vision sync signals and are removed by decoding signals sent as a sub-carrier on the cable.

Video Recording.—There were several papers on various aspects of vision tape recording including one by W. Silvie, of Ampex. In it he dealt with colour recording and also the latest refinement in videotape techniques embodied in "Editec." This is basically the Electronic Editor, described in our September, 1962 issue, but with refinements. The "Editec" operates by marker tones, placed on the cue track of the tape, which gate the recording and monitoring circuits and as a result material from many sources—studio, film, slides, tape, etc.—can be automatically introduced to produce a composite whole without any sign of splicing on the finished tape.

A light-weight camera and transmitter for O.B. work was described and demonstrated by representatives of L.E.P. of Paris. The equipment operates on the 819-line standard and has a range of a few hundred yards. It is battery operated and has a power of 2·5W.

Aerials.—Several papers dealt with the design of transmitting aerials. The problems involved when a number of transmitters are operating on different frequencies in the u.h.f. band from the same tower or mast were discussed by F. Kühnemund and H. Laub, of Siemens & Halske. Two papers, one by Karl Buchta, of Siemens & Halske, and the other by L. Richard, chief engineer of Electrobel of Brussels, were concerned with various aspects of television reception particularly for relay systems. Monsieur Richard's paper was of particular interest as it dealt with the problems involved when a multi-standard relay system is employed. This is, of course, the case in Belgium where in some localities is relayed not only the two national standards of 625 and 819 lines on a 7-Mc/s channel with a.m. sound, but also the 625-line 7-Mc/s transmissions with f.m. sound from Germany and the French 819-line 14-Mc/s programmes with a.m. sound.

Surveying the operational organization of the French television service—Radiodiffusion Television Française—Jose Bernhart, head of the department of television operation stated that France's second television network, which will operate on 625-lines in Bands IV and V, will start on April 1st next year.

Satellites.—As mentioned early, F. J. D. Taylor presented a very interesting paper on the Goonhilly Downs station. This was backed up by a well-delivered survey of the results of the Telstar I project given by Eugene O'Neill, of the Bell Telephone Laboratories, who was in charge of the project. The results of the tests have shown that the inter-continental transmission of television material via artificial earth satellites "is completely practicable" although Mr. Taylor stressed that much more research and development needs to be done before a reliable world-wide network could be set up. Technically "we're nearly there," he said, but added that the problems of international agreements on administration, standards, control and finance "loom large."

The subject of "stationary" satellites was discussed in two papers—one by C. Gordon Murphy, who was in charge of the Hughes Syncom project, and the other by Dr. F. Vilbig, of Munich, in which he dealt mainly with the question of television broadcasting from a satellite direct to domestic receivers.

The closing session was devoted to "a look into the future" and Dr. H. R. Cassirer, who is in charge of the Radio and Television Section of UNESCO'S Mass Communication Techniques Division, outlined the potential rôle of television in developing countries, but dealt mainly with sociological and economic problems rather than technical ones. The closing speaker was Dr. Allen Du Mont who briefly outlined the early developments of television, examined the present state of the art and made a few predictions for the future.

At the close of the Symposium the chairman, John H. Gayer, who is head of the International Frequency Registration Board of the I.T.U., presented awards "in recognition of their outstanding contribution to the advancement of television" to Dr. Allen B. Du Mont, of the Du Mont Laboratories, New Jersey, Dr. J. Groszkowski, president the Polish Academy of Sciences, Dr. W. Nestel, of Telefunken, Ulm, and Dr. Maurice Ponte, chairman of C.S.F., Paris.

Because of the Swiss National Exhibition to be held for six months next year, it has been decided not to hold the next Montreux Television Symposium until 1965.

Transistor High-quality Amplifiers

By P. THARMA,* B.Sc.(Hons.)

3—10-WATT AMPLIFIER WITH CLASS B OUTPUT STAGE

IN the June issue a 10W Class AB high-quality amplifier was described. To achieve similar performance with Class B output stages requires great care in design. The various factors to be considered are discussed in this section and a design for a 10W Class B amplifier is given.

With optimum bias the combined transfer characteristic of the two halves of a Class B push-pull stage approximates to a straight line, but a small degree of non-linearity in the region of the cross-over point, where each separate characteristic is exponential, is unavoidable. In this design the " wobble " in the transfer characteristic corresponds to a peak gain deviation of some 5% with optimum bias, and increases very rapidly as the bias deviates (due to spreads, temperature or line voltage variations) from the optimum. The overall feedback reduces this effect (and other frequency dependent effects in the cross-over region) very greatly, but in view of the known high sensitivity of the ear to cross-over distortion some doubt must exist whether the distortion generated is always below the threshold of audibility. Listening tests under a wide variety of conditions are required to establish whether the quality of reproduction is up to the highest standards.

All the objective tests carried out and the results of a number of listening tests suggest that the design is suitable for high-quality reproduction provided care is taken to maintain optimum bias conditions.

Maintaining Optimum Bias Conditions

In order to maintain optimum bias conditions, the quiescent current stability and the thermal stability of the circuit should be adequate.

Quiescent Current Stability:—The variation of the base-emitter voltages of the driver and output transistors cause the quiescent current of the output stage to vary. The thermistor-resistor combination R_{19}, R_{17} (Fig. 14) stabilizes the quiescent current against temperature effects.

Stabilization against supply voltage variations is not essential for mains-operated amplifiers, if the variations are likely to be small (+6% − 10%).

Thermal Stability:—In a Class B output stage, the junction temperature is a maximum at about 0.4 of full power. Whether or not the junction will cool to the quiescent conditions when the drive is removed depends on the thermal stability of the circuit at the elevated temperature. This thermal stability depends among other things on the thermal resistance of the heat sink. With the particular values of Fig. 14, the circuit is stable, with all conditions of drive, up to ambient temperatures of 45°C.

The size of the heat sink is also determined by another consideration, namely, that the junction temperature of the output transistors varies with the signal with consequent change of quiescent current. With high-quality amplifiers this variation of junction temperature has to be kept as low as possible. This necessitates a heat sink much larger than that required from consideration of dissipations.

Power Supply Regulation

It is essential to have a power supply with good regulation, otherwise the loss of power due to line voltage falling with drive may be excessive. The regulation requirement precludes the use of R-C ripple filters in the power supply, so that it is difficult to avoid hum being introduced via the negative line. Fortunately, at low signal levels, where hum is most troublesome, the current drain is low, and this is also the condition when hum is least.

Short Circuit of Output:—It is important to avoid accidental short circuiting of the load of a Class B output stage, as this can damage the output transistors.

Use Of Low-frequency Power Transistors in High-quality Amplifiers

The design requirements discussed in the May issue are

1. that the output transistors should be reverse biased when cut off.
2. that a direct-coupled driver stage should operate at a substantial quiescent current.

In the absence of the reverse bias facility, the cut-off transistor remains conducting after the corresponding driver transistor is cut off. This results in a distortion of the waveform which becomes worse the higher the frequency. In this particular design, the 14mA quiescent current of the driver stage and the provision of reverse bias minimize the distortion.

Circuit Description

The amplifier uses the well-known Darlington quasi-complementary output stage. This has been discussed in detail by Mr. O. Grieter in the May issue. Hence, only a brief description of the circuit is given.

Input Stage:—An OC44 transistor is used in the

*Mullard Applications Research Laboratory.

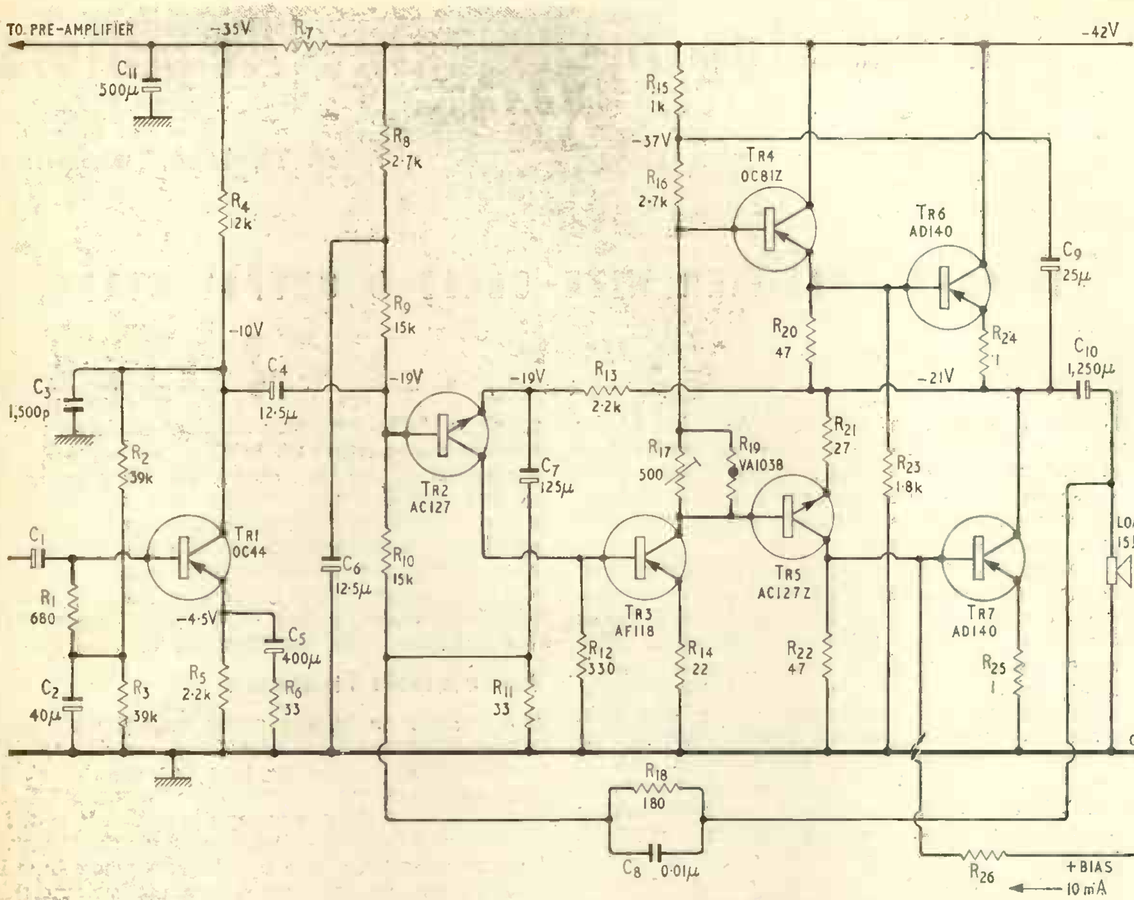


Fig. 14. Circuit diagram of 10-watt amplifier with Class B output stage. (Only one channel shown.)

COMPONENTS LIST TO FIG. 14

Resistors

All resistors ⅛W ± 10% unless otherwise stated.

R_1	680Ω	
R_2	39kΩ	
R_3	39kΩ	
R_4	12kΩ	
R_5	2.2kΩ	
R_6	33Ω	
R_7	Dependent on pre-amp. current drain	
R_8	2.7kΩ	5%
R_9	15kΩ	5%
R_{10}	15kΩ	5%
R_{11}	33Ω	
R_{12}	330Ω	
R_{13}	2.2kΩ	
R_{14}	22Ω	
R_{15}	1kΩ	
R_{16}	2.7kΩ	
R_{17}	500Ω	Pre-set
R_{18}	180Ω	1 watt
R_{19}	Thermistor VA1038	
R_{20}	47Ω	
R_{21}	27Ω	
R_{22}	47Ω	
R_{23}	1.8kΩ	
R_{24}	1Ω	
R_{25}	1Ω	
R_{26}	To give 10mA bias current	

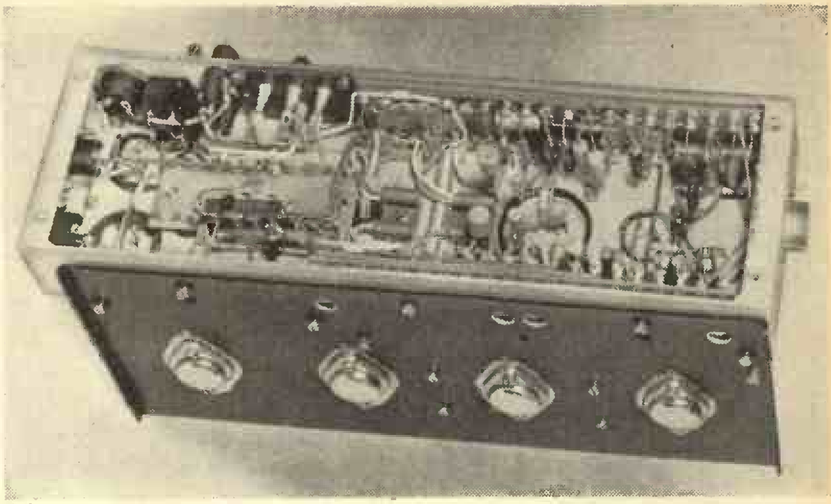
Capacitors

C_1	25μF	Electrolytic	25V
C_2	40μF	,,	16V
C_3	1500pF	Tubular ceramic	
C_4	12.5μF	Electrolytic	40V
C_5	400μF	,,	6.4V
C_6	12.5μF	,,	40V
C_7	125μF	,,	25V
C_8	0.01μF	Paper or polyester	
C_9	25μF	Electrolytic	25V
C_{10}	1250μF	,,	40V
C_{11}	500μF	,,	40V

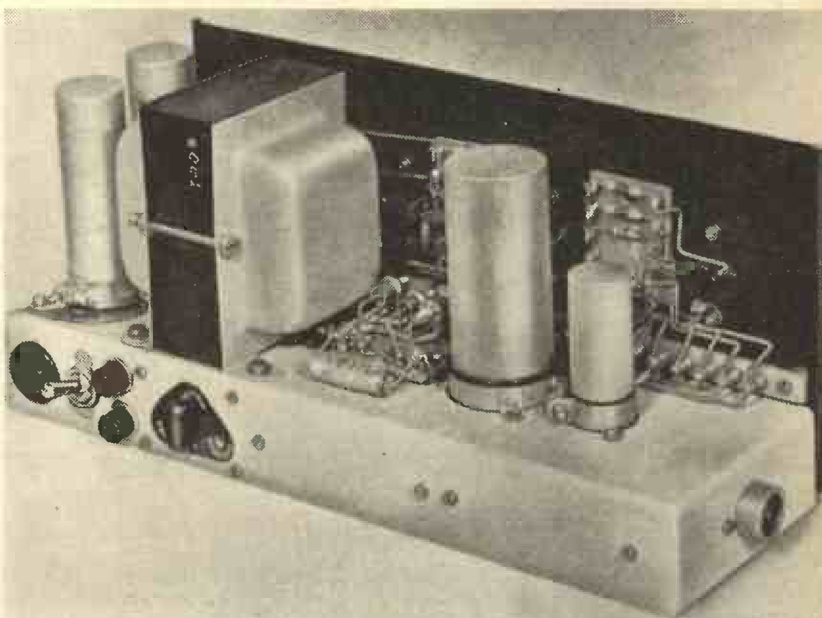
Transistors

Tr1	Mullard	OC44	
Tr2	,,	AC127	
Tr3	,,	AF118	
Tr4	,,	OC81Z	Matched pair
Tr5	,,	AC127Z	
Tr6	,,	AD140	Matched pair
Tr7	,,	AD140	

input stage. The particular form of bias arrangement reduces the effect of R_4 tolerances on the collector-emitter voltage of the transistor. The resistor R_6 introduces a certain amount of negative feedback to reduce the distortion in this stage and also to reduce gain spreads.



Two views of the prototype Class B 10W+10W stereo amplifier.



Main Amplifier:—The AC127 n-p-n transistor Tr2 is direct-coupled to the AF118 high-voltage high-frequency transistor. The low value of resistor R_{12} and the emitter feedback resistor R_{14} are necessary for high-voltage operation of the AF118. This emitter feedback also reduces the gain spread of the AF118. The AF118 is direct-coupled to the p-n-p/n-p-n driver stage which in turn is direct-coupled to the output stage. Resistors R_{23} and R_{26} ensure that the output transistors are reverse biased when cut off. The positive bias voltage can be any value greater than 1V, and R_{26} must be chosen to give a bias current of 10mA.

Negative Feedback:—The main amplifier has an overall negative feedback of about 50dB. This feedback, which is voltage feedback, depends on the source impedance seen by the AC127 pre-amplifier stage and therefore has been considered in conjunction with the collector load of the OC44 input stage.

The feedback voltage is developed across resistor R_{11}. Two feedback paths R_{13} and R_{18} are provided for the feedback current, the main one being via R_{18} (180Ω). R_{13} (which is 2.2kΩ) could be made low to provide the full feedback current, but the series impedance of capacitor C_7 would then introduce an unknown variable quantity in the feedback loop. The values of R_{18} and R_{11} have been chosen in conjunction with R_9 and R_4.

Capacitor C_8 across the feedback resistor removes the overshoot on pulse waveforms.

Heat Sink Requirements:—The driver transistors should each be mounted on a heat sink of at least 35 sq. cm. of 1 mm. aluminium. In practice, the transistors could be mounted on the aluminium chassis on which the amplifier is constructed, provided that this is not also used as the heat sink for the power transistors.

The output transistors should be mounted on a heat sink such that the thermal resistance from junction to ambient is less than 6°C/W. In the prototype 10W+10W stereo amplifier the four output transistors were mounted (with mica insulation) on a 4½in. × 11in sheet of 16 gauge aluminium, finished matt black. This heat sink was found adequate when mounted vertically with free air circulation.

Performance

The sensitivity of the amplifier is 60μA into an input resistance of 680 ohms for a power output of 10W.

The frequency response of the amplifier is shown

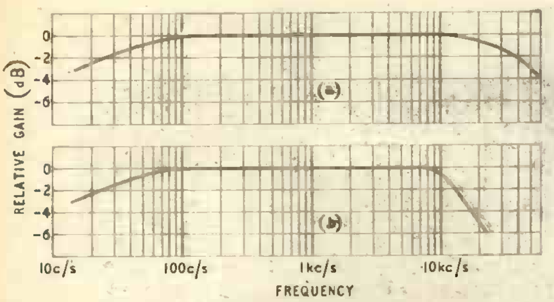


Fig. 15. Frequency response of Class B amplifier (a) at 1-watt and (b) at 10-watt level.

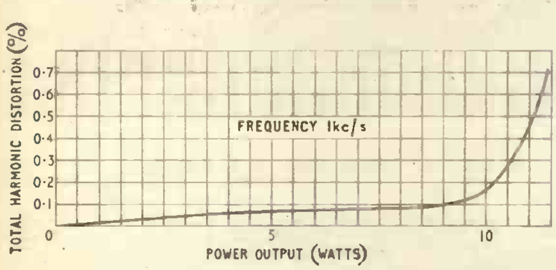


Fig. 16. Total harmonic distortion in relation to power output for Class B amplifier.

in Fig. 15 (a). The response is -3dB at 15 c/s and 50 kc/s. The power response at 10W output is -3dB at 15 c/s and 15 kc/s. as shown in Fig. 15 (b).

The variation of total harmonic distortion at 1 kc/s with power output is given in Fig. 16. The distortion is predominantly third harmonic and is 0.15%at 10W.

The above figures are applicable for a constant line voltage of 42V. Finite regulation in the power supply will, of course, lower the maximum sine-wave power obtainable.

The intermodulation distortion was measured using the modulation method. The maximum gain deviation at full power was less than 1%. This is true only with the optimum bias conditions specified. Any departure from the specified conditions or the absence of bias stabilization can give considerably more intermodulation distortion caused by cross-over distortion.

The method of measuring high-frequency intermodulation distortion was discussed in the May issue. The overall negative feedback of 50dB was necessary to reduce this distortion to the same level as the Class AB amplifier.

The output impedance of the amplifier is less than 0.1 ohm over most of the audio frequency range.

Power Supply Requirements

The current requirements are, for 10W+10W stereo amplifier are 140mA quiescent, 800mA full sine-wave output.

With music operation, the current will be between the above values depending on how hard the amplifier is driven. For full power on music inputs, the average current will be of the order of 250mA.

A mains transformer with primary taps should be used and the tap set to the nominal voltage mains. The d.c. line voltage should not exceed 42V, otherwise, the transistor ratings will be exceeded.

Layout

The layout of the amplifier is similar to the Class AB amplifier described in the June issue. With the Class B design only one heat sink is required for all four transistors. The chassis dimensions are the same as with the Class AB design.

4—5-WATT AMPLIFIER WITH CLASS A OUTPUT STAGE

THIS is a three-stage direct-coupled amplifier with extremely good d.c. stability. The output stage operates in Class A and the 15Ω load is capacitance-coupled to the centre-tapped output choke. The output power obtainable depends on the thermal design of the amplifier—heat sink and ambient temperature requirements. An output power of about 5W under domestic conditions can be obtained with a heat sink which is not too large.

The amplifier uses an AD140 driven by an OC81 preceded by the OC44 h.f. transistor. 26dB overall negative feedback is used and the reproduction in every way merits the description " high quality".

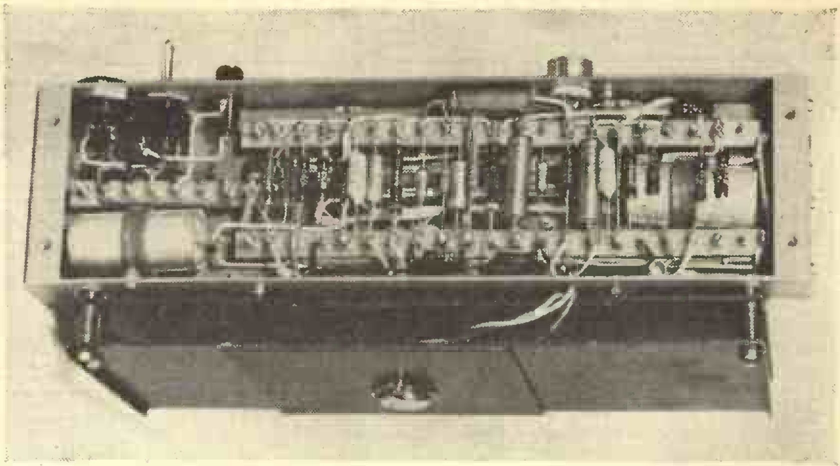
Basic Circuit:—Direct-coupled circuits use fewer components, have lower coupling losses and, when correctly designed, have better temperature stability compared with conventional R-C coupled stages.

In the circuit of Fig. 17(a) the driver transistor Tr2 operates as an emitter follower. This circuit can be designed to have adequate stability. With a slight modification, Fig. 17(b), the circuit can be made virtually independent of transistor characteristics. In the circuit of Fig. 17(b) R_1 and R_2 form a low-resistance potential divider giving a voltage V_1 at the emitter of Tr1. This transistor functions as a difference amplifier comparing the voltage V_1 with the voltage V_2 across the emitter resistor R_5 of the output transistor Tr3. The circuit automatically sets itself so that the difference between V_2 and V_1 is the base emitter voltage of Tr1 (of the order of 150mV). If V_1 is greater than about 3 volts, then V_2 is virtually independent of the characteristics of Tr1.

Line voltage changes cause proportional changes in V_1 and hence in V_2, I_{c3}, and V_{ce3}. The optimum load for maximum power output, thus, does not vary with supply voltage.

Because of the above advantages, the circuit of Fig. 17(b) has been chosen as the basis for the design.

"Excess Drive" Requirements for the AD140:—The AD140 with its common emitter cut-off frequency of the order of 4 kc/s can be used in good quality audio amplifiers provided the drive stage meets certain requirements. This was discussed in the May issue. For Class A output stages the driver stage should be capable of providing drive power in excess of the normal low-frequency requirements of the output stage. The amount of extra drive needed depends on the power versus frequency response requirements of the amplifier. Hence, the emitter follower driver stage should operate at a current greater than the base current of the output transistor. The excess current, again, depends on the power response requirement of the amplifier. The drive system should also be capable of providing excess voltage swing.



Underside view of prototype Class A, 5W + 5W stereo amplifier. The heat sink in this chassis is of 16-gauge metal, with double thickness in the middle section.

The circuit of Fig. 17(b) is modified to meet the above requirements, as shown in Fig. 18. In this circuit R_4 ensures that the driver transistor operates at a current higher than the base current of the output transistor. The potentials V_1 and V_2 are made somewhat lower than the potential of the emitter of the output transistor. This ensures that excess voltage drive is available at the collector of the transistor Tr1. Also the collector current is made much larger than the base current of the Tr2 by appropriate choice of R_3.

Detail Circuit Design:—The AD140 output transistor is preceded by an OC44 h.f. transistor to form the three-stage direct-coupled amplifier. Because of the high gain of the AD140, the driver transistor dissipation can be kept to moderate values. An OC44 is used for the first stage, as this allows large amounts of overall negative feedback to be applied, with ample margin of stability. A small amount of local feedback in the OC44 stage reduces its gain spread.

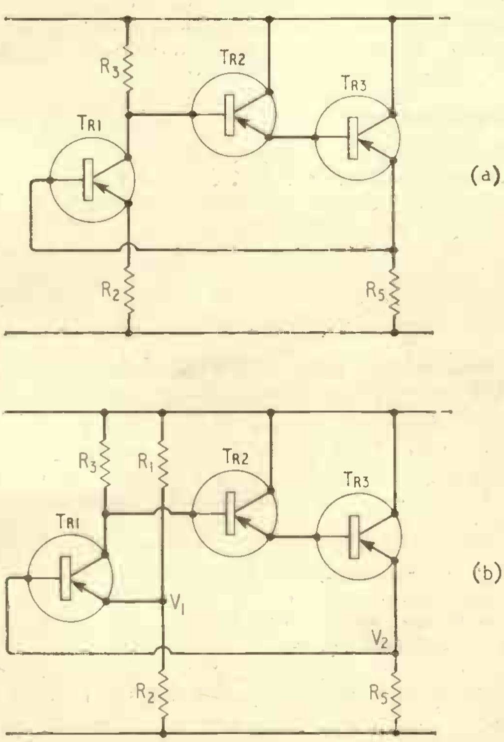


Fig. 17. Basic d.c. circuits of a three-stage direct-coupled amplifier.

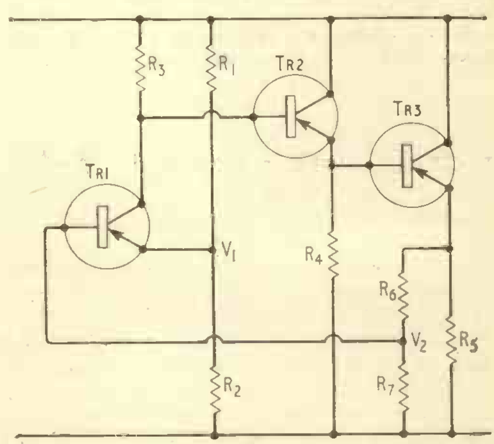
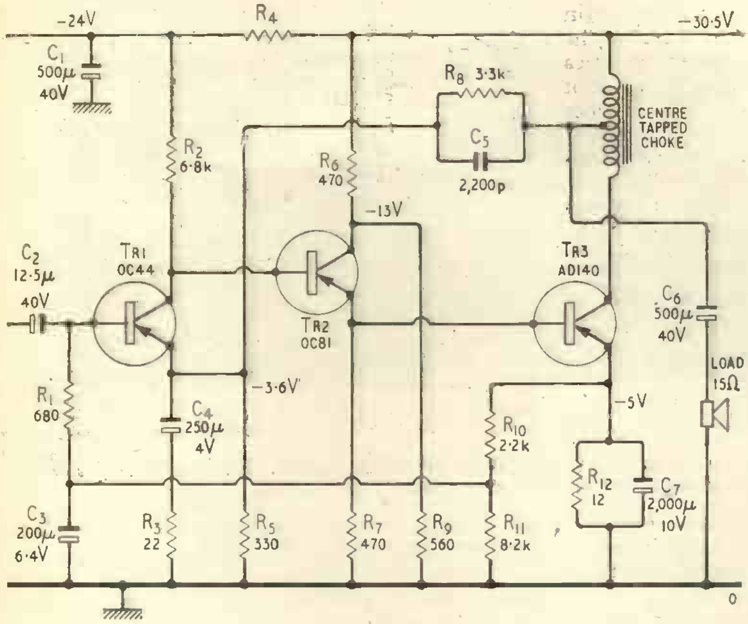


Fig. 18. Modified d.c. circuit of direct-coupled amplifier of Fig. 17. (b).

The circuit of the three-stage amplifier is given in Fig. 19. The reference voltage (V_1) for the emitter of Tr4 (OC44) is provided by resistors R_8 and R_5. The voltage (V_2) which is applied to the base of the transistor Tr4 is provided by resistors R_{10} and R_{11}. Any residual a.c. voltage across R_{11} is prevented from feeding back to the input by capacitor C_3, and the signal input to the amplifier is applied via C_2 across R_1.

Resistor R_8 also serves as part of the potential divider R_8 and R_3, which provides a.c. negative



Resistors			
R_1	680Ω	10%	⅛ watt
R_2	6.8kΩ	10%	,,
R_3	22Ω	5%	,,
R_4	Depends on pre-amplifier drain		
R_5	330Ω	5%	⅛ watt
R_6	470Ω	10%	½ ,,
R_7	470Ω	10%	⅛ ,,
R_8	3.3kΩ	5%	¼ ,,
R_9	560Ω	10%	½ ,,
R_{10}	2.2kΩ	5%	⅛ ,,
R_{11}	8.2kΩ	5%	⅛ ,,
R_{12}	12Ω	5%	3 watt
Capacitors			
C_1	500μF	Electrolytic	40 V
C_2	12.5μF	,,	40 V
C_3	200μF	,,	6.4 V
C_4	250μF	,,	4 V
C_5	2200μF	Ceramic	
C_6	500μF	Electrolytic	40 V
C_7	2000μF	,,	10 V

Choke

Centre-tapped choke, bifilar wound
Inductance of full winding 300mH at 0.5 amps
Resistance of full winding <2Ω

Transistors

Tr1	Mullard	OC44
Tr2	,,	OC81
Tr3	,,	AD140

Fig. 19. Circuit and component list of the 5-watt Class A amplifier.

feedback. Capacitor C_5 across R_8 eliminates ringing on pulse waveforms.

The resistor R_7 provides the bleed current mentioned earlier. The resistors R_6 and R_9 lower the collector-emitter voltage of transistor Tr5 (OC81), thereby decreasing the dissipation to within ratings.

Capacitor C_7 decouples the emitter resistor R_{12}.

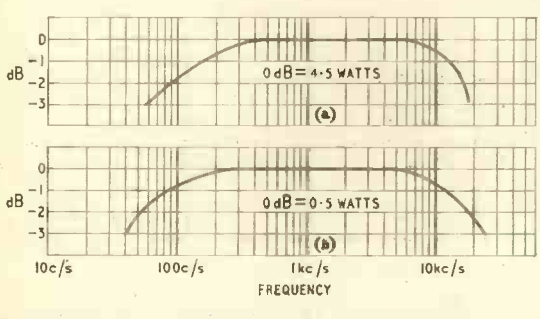


Fig. 20. Frequency response of Class A amplifier, (a) at 4·5-watt (b) at 0·5-watt level.

This capacitor should have a low series resistance and its ripple rating should be equal to the a.c. current in the output transistor.

The 15 ohm loudspeaker is capacitance-coupled to the centre-tapped output choke. The inductance of this choke determines the l.f. response of the amplifier. Its d.c. resistance should be low (less than 2 ohm) to minimize losses in the choke. The 15 ohm load is about the optimum for power outputs of the order of 5 watts using the AD140.

The feedback resistor R_3 and the capacitor C_4 form a phase advance network in the feedback loop. This counteracts the phase lag introduced by the output choke at low frequencies. If the time constants of C_4 R_3 and of the output circuit are made equal, the net phase shift in the feedback loop is zero, resulting in excellent low-frequency stability. Assuming constant loudspeaker resistance, if the choke inductance is reduced to 150mH, C_4 should be 125μF.

Performance

The frequency responses at low and at high power levels are given in Fig. 20. The rise time of the amplifier is 20μsec and there is no ringing or overshoot on pulse waveform.

The total harmonic distortion relative to power output is given in Fig. 21. The sensitivity of the amplifier is 90μA for 5W output. The output impedance is approximately 0.8 ohm at 1 kc/s.

Dissipation, Heat Sink Requirements and Layout:— The maximum dissipation on the output

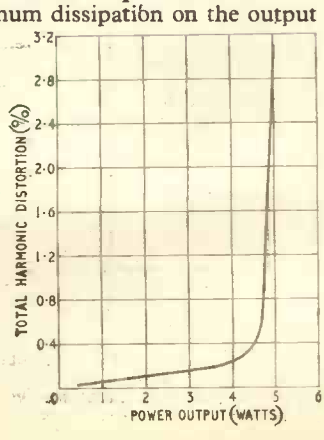


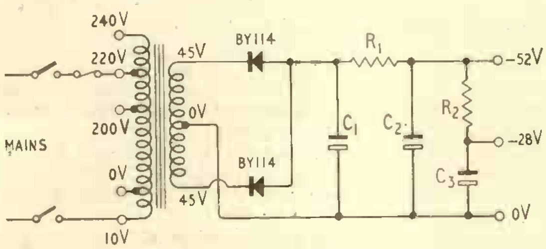
Fig. 21. Total harmonic distortion relative to power output from 5W amplifier.

transistor, allowing for mains variations is 12.5W. The output transistor requires a heat sink 11in × 4¾in of 14 gauge aluminium, finished matt black. The transistor should be electrically insulated by mica washers and two of these heat sinks, in a layout similar to the 10W + 10W Class AB amplifier described in the June issue, are required for a 5W + 5W stereo amplifier. With this layout, the maximum continuous ambient temperature rating is 40°C.

The driver transistor should be mounted on to a heat sink of at least 12 sq. cm. In practice the transistor could be fixed on to the chassis of aluminium.

The layout is similar to the 10W + 10W Class AB design, and a chassis of 4½in. × 11½in. × 1½in. is required for a 5W + 5W stereo amplifier.

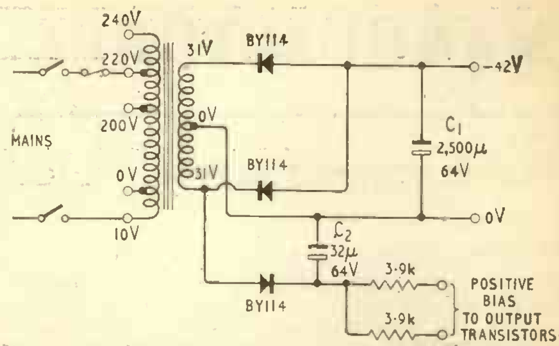
Power Supplies



Power Supply for Class AB Amplifier (10W + 10W). *(Fig. 8. June issue).*

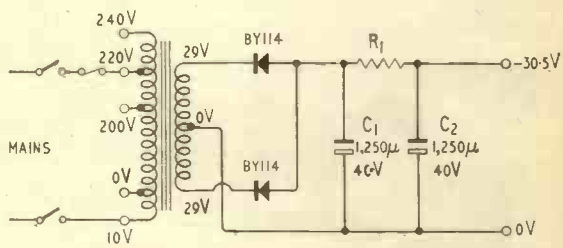
Normal loading	*Current 0.9A*	
C_1+2500μF	*Electrolytic*	64 V
C_2+2500μF	,,	64 V
Low loading	*Current 0.6A*	
C_1+1600μF	*Electrolytic*	64 V
C_2+1600μF	,,	64 V

Voltage across C_1 should be between 58-60V. R_1 and R_2 are selected to give stated voltages.



Power Supply for Class B Amplifier (10W+10W). *(Fig. 14).*

Voltage across C_1 should be 42V with 140mA drain. With 800mA drain, voltage across C_1 should not fall much below 38 volts otherwise the maximum output power will be lower than 10W. Pre-amplifier supply is taken from 500μF smoothing capacitor in amplifier via an R-C filter (C=500μF, 40V).



Power Supply for Class A Amplifier (5W+5W). *(Fig. 19)*

Current 0.9A
Voltage across C_1 approx. 36V
Select R_1 to give 30.5V for amplifier
Pre-amplifier supply taken from 500μF smoothing capacitor in amplifier.

Commercial Literature

The May '63 Farnell **electronic components** catalogue describing the products they distribute to the industry is now available from the Industrial Division of A. C. Farnell Ltd., Hereford House, Vicar Lane, Leeds 2. Some 100 pages are included in the catalogue and in addition to a wide range of electronic components, it covers a number of products for the workshop; ranging from soldering irons and tool kits to rubber mats and industrial storage cabinets. **(301)**

Automatic voltage stabilizers are featured in a leaflet (S612) recently issued by Claude Lyons Ltd., Valley Works, Hoddesdon, Herts. The units described are fitted with new control amplifiers (sensor units) which have adjustable sensitivity controls and permit a stabilization accuracy of ±0.25%. **(302)**

Alfred Imhof Ltd. have recently released a forty-eight page catalogue on their extensive range of **standard instrument cases**. This catalogue, contains full details of over a hundred cases including a new range especially designed for housing printed circuit cards, etc. Details are also given of accessories suitable for use with their cases. These include chassis, chassis runners, etc. The catalogue is available from Alfred Imhof Ltd., Ashley Works, Cowley Mill Road, Uxbridge, Middx. **(303)**

An eight-page application report on **semiconductor devices**, titled "The use of transistors as switches," is available from the Electronic Apparatus Division, of Associated Electrical Industries Ltd., Carholme Road, Lincoln. **(304)**

Heathkit.—A catalogue giving brief details of their kits which cover the audio, domestic radio, test equipment and amateur radio fields, is available from Daystrom Ltd., Gloucester. **(305)**

A leaflet describing instrument **wire coil de-reeling equipment** is available from Shawndel Flyers Ltd., Olympia House, 72 Queens St., Maidenhead, Berks. **(306)**

A short form catalogue giving brief details of their complete range of **servo and simulation** instruments and equipment is now available from Feedback Ltd., Crowborough, Sussex. **(307)**

The Wandel u. Goltermann 300 c/s-1.35 Mc/s a.m. **signal generator** (TFPS-75) and its complementary level meter are described in a WG data sheet. Technical specifications and details are given with application data. Copies of this leaflet are available through their U.K. agents Elliott Brothers Sales Agencies Ltd., Elstree Way, Boreham Wood, Herts. **(308)**

A technical bulletin describing the **Decitrak**, direct-decimal shaft encoder, is available from the makers Theta Instrument Corporation, 520 Victor Street, Saddle Brook, New Jersey, U.S.A. **(309)**

For the convenience of readers a number has been appended to each of the above items so that when applying for literature all that is necessary is to circle the appropriate number on the Information Service form at the back of this issue.

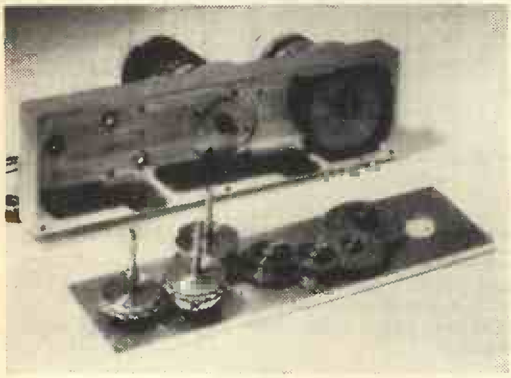
MANUFACTURERS' PRODUCTS

NEW ELECTRONIC EQUIPMENT AND ACCESSORIES

Digitizer

AN electro-mechanical device for converting analogue rotation to digital units or digital information to analogue rotation has been produced by Parish Instruments, Gunnels Wood Road, Stevenage, Herts. It is intended for use in control systems for the translation of digital information into mechanical displacements, velocities or accelerations. Alternatively it can be employed to convert mechanical movements into digital data for recording or computing, etc.

Basically the unit is a mechanical gearbox driving a series of stepping switches. Each of these controls the "on-off" conditions of four lines and steps once for every sixteen steps of its predecessor. By suitable arrangement of line switching, binary, decimal and other



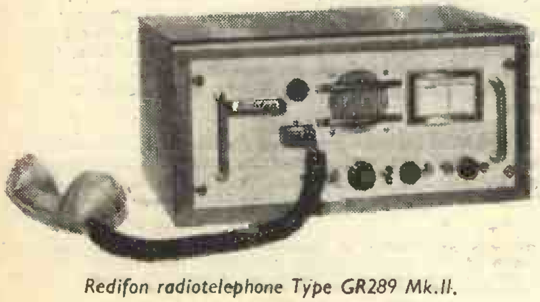
Parish instrument digitizer.

codes can be generated. Control transformers for digital to analogue conversion or a control transmitter for analogue to digital conversion may be fitted. The manufacturers claim that when using a four-switch digitizer, a length of 64in can be read to an accuracy of 1/2024in.

For further information circle 310 on Service Sheet.

Marine Radiotelephone

DESIGNED for inter-ship port control, conveying port radar information, etc., and capable of use for international distress and safety services, the Redifon GR289 Mk. II radiotelephone has 11 channels including a reserve private band coverage. It provides 12W transmitter output on a single channel and measures $16\frac{1}{2} \times 12\frac{1}{2} \times 8$in.



Redifon radiotelephone Type GR289 Mk.II.

The equipment can be remotely operated by a control unit up to 50 feet away. The frequency range of the transmitter is 156.05 to 157.95 Mc/s while that of the receiver is 156.30 to 156.85 (single frequencies) and 160.65 to 162.60 Mc/s (double frequencies). The channel spacing is 50kc/s. The equipment requires a 24V d.c. power supply.

For further information circle 311 on Service Sheet.

Acrylic Spray Coating

SEVERAL applications in radio and electronics are suggested by the makers of Krylon "Crystal Clear" acrylic resin coating which is applied in solution from a pressurized container. It can be used as a moisture and corrosion resistant coating for aerial elements, as a seal for lead-in connections and for insulation (the dielectric strength of the dried film is quoted as 350 to 500 V per mil).

Agents in the U.K. are F. & G. Wentworth & Co., 11 Bruton Street, London, W.1, from whom bulk supplies are obtainable. The retail price is 8s 6d for the 6-oz aerosol can which, incidentally, is sold by dealers in artists materials.

For further information circle 312 on Service Sheet.

Automatic Vidicon

A COMPLETELY automatic vidicon camera channel designed for the aircraft, marine, military and heavy industrial fields has been developed by the Closed Circuit Television Division of the Marconi Company. The only control in the whole channel provided for regular use is a single on/off switch. Automatic sensitivity circuits in the camera housing enable the camera to accept rapid changes in scene illumination, while black level is also clamped automatically over a wide environmental range. The channel will operate from a mains supply or from a lightweight battery. The camera is contained in a cylindrical steel case which is completely watertight.

The camera measures 14.5in. in length and 3.5in. in

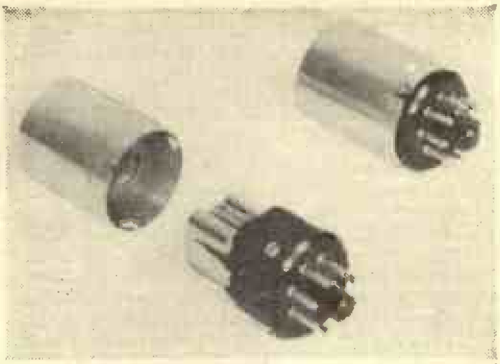
Marconi vidicon camera.

diameter; the weight is 9.5lb. Three versions of the control unit are available and the dimensions vary from unit to unit. International standards between 405 and 819 lines are catered for, others between 99 and 1024, interlaced or random, can be provided. Remote focusing can also be provided if required, the mechanism being accommodated within the basic camera casing.

For further information circle 313 on Service Sheet.

Crystal Oven

A SMALL lightweight plug-in crystal oven Type D2 has been developed by Cathodeon Crystals Ltd., Linton,



Cathodeon octal miniature crystal oven.

Cambridge. The oven is mounted on an international octal base. The unit has been designed to accept two Cathodeon Type 2M crystal units (equivalent to the British D and U.S.A. HC-6/U crystals). The temperature control element is in the form of a bi-metallic thermostat. The chamber temperature setting is 75°C ±2°C but other settings can be supplied on request. The chamber temperature differential is quoted as ±1°C. The dimensions of the oven are given as 31.8mm diameter by 46mm seated height. The weight is less than 36gm. The units cost 36s each.

For further information circle 314 on Service Sheet.

Rechargeable Battery

A 6V Exide battery designed for battery/mains operated television sets is announced by Chloride Batteries Ltd. Known as the Type 3-MFB7, it is intended that two batteries will be used in series to form a 12V assembly and that they will be kept fully charged by a built-in trickle charger in the television set. Thus, when the set is used away from a mains power supply the batteries should enable a full evening's viewing before a recharge is necessary.

The battery consists of three cells in a high-impact translucent polystyrene container fitted with a single lid. To dispense with vent plugs and the possibility of equipment corrosion by escaping gases, a gas-collecting chamber is embodied in the construction of the battery. Terminal assembly is of cadmium-plated mild steel screws with coin slots. The unit can be used in any position and has a capacity of 6 ampere-hours at the 20-hour rate of discharge. When filled, the weight is 3lb.

Exide 6V lead acid accumulator Type 3-MFB7.

For further information circle 315 on Service Sheet.

Matched Resistors

A RESISTANCE unit Type RBL comprising a matched pair of equal-value resistors is announced by Alma Components, Ltd., of Holloway Road, London, N.19. Primarily intended for use in bridge circuits, the components are wound from the same reel of wire on a ceramic former and sealed in an epoxy resin. The direction of winding is reversed at the half-way point in each half of the resistor to keep the inductance to a minimum. Values between 100Ω and 200kΩ in each section of the unit are available. The components are less than 1in long.

For further information circle 316 on Service Sheet.

Synchros and Resolvers

THE Moore Reed synchro range has been extended to include 400c/s size 08 torque receivers, control transmitters, control differential transmitters, control transformers and resolvers. These last mentioned units include high and low impedance types with an accuracy of ±7 minutes of arc. All the units can be operated at a winding temperature of 125°C; flying lead terminations are supplied on all of them. The makers' address is Woodman Works, Durnsford Road, London, S.W.19.

Moore Reed size 08 synchro.

For further information circle 317 on Service Sheet.

Television Camera Kit

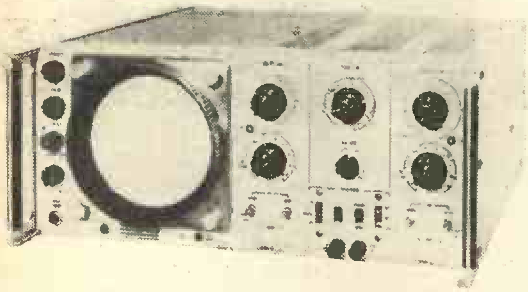
A KIT of parts enabling the home constructor to build a transistor vidicon television camera has been produced by Beulah Electronics. Due to the design of the wideband video amplifier no special test equipment will be required to set up the finished product. The kit features a single printed board and the focus and scan coils, and screening components are combined in a single unit.

Beulah transistor television camera kit.

Mains operated, the completed equipment is claimed to have a bandwidth comparable to that of a normal commercial receiver. The time-base can be run at 405 or 625 lines per second, the frame frequency 50 frames per second in sync with the mains. The frame pulse width is approximately of 4 lines duration and frame blanking width approximately 14 lines. The whole kit can be purchased in four stages if required.
For further information circle 318 on Service Sheet.

Oscilloscope

A LIGHTWEIGHT high-sensitivity oscilloscope using semiconductors, the DuMont/Fairchild Type 704 is available from the U.K. agents Aveley Electric Ltd. The oscilloscope has a sensitivity of 200μV/cm and a bandwidth from z.f. to 500kc/s. Both "x" and "y" amplifiers of the instrument are equal in bandwidth and sensitivity. The cathode ray tube is a new design with a small spot size. The mechanical design of the oscilloscope makes the instrument suitable for bench or rack mounting. A tilt stand is provided for the former mode of use.



DuMont/Fairchild Type 704 oscilloscope.

For further information circle 319 on Service Sheet.

Diecast Boxes

THE current range of Eddystone diecast boxes has been increased by the introduction of a deeper box. The dimensions of this new type are $7\frac{1}{2} \times 4\frac{1}{2} \times 3$in.

The boxes are cast in an aluminium alloy.
For further information circle 320 on Service Sheet.

Mains/Audio Connector

A NEW series of mains or audio 3-pole connectors have been introduced by Cannon Electric; designated the XLR series, they meet the conditions of B.S. 415. The two parts of the connectors are locked together by a finger controlled latch. The barrel of the plug section has finger grips for ease of insertion and withdrawal. The contact material is brass, the pin insulator material a rigid moulded plastic and rubber blend, socket insulator a resilient polychloroprene and the cable relief material Neoprene. A variety of receptacles are available to take the plug. The pins are arranged so that the earth connections make first.

Plug and receptacle of the Cannon XLR Series. The receptacle shown has a chassis insulating shroud.

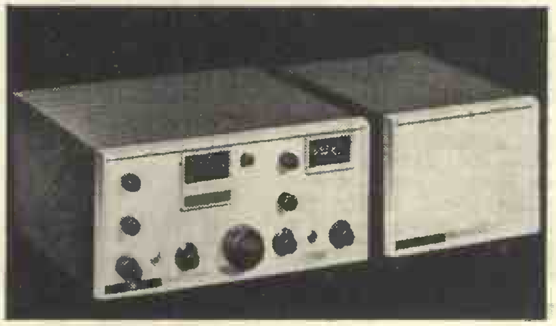
The cable clamp on the cable entry provides two clamping positions for varying cable diameters.
For further information circle 321 on Service Sheet.

Screwdriver with Positioner

A NEW screwdriver incorporating a positioning device which engages and holds screws firmly in position has been announced by Henri Picard and Frere Ltd., 35 Furnival Street, London, E.C.4. Models are available for holding flat and round design, slotted head and cruciform screws. The tools will be of particular use for removing screws without risk of them falling into inaccessible parts of equipment. A slim, spring-loaded tube fits over the shaft of the screwdriver; when this is pushed forward the blade is cleared to allow a screw to be placed in the recess. This and the subsequent release of the screw is a one-handed operation. For normal screwdriver use, the portion of the blade projecting beyond the attachment is sufficient, but the positioner may be detached if desired.
For further information circle 322 on Service Sheet.

Amateur Transceiver

THE 80, 40 and 20 metre amateur bands, with s.s.b., a.m. and c.w. facilities, are covered by the National Radio s.s.b. transceiver, Type NCX-3. Other features of this equipment include a voice-operated relay, push to talk, c.w. break-in, s.s.b./c.w., a.g.c., S-metre and a separate a.m. detector. The specification also includes a 2.5kc/s crystal lattice filter and a balanced modulator providing 40dB suppression of unwanted sideband and 50dB minimum suppression of carrier.



National Radio Type NCX-3 transceiver.

The receiver sensitivity is quoted as 1μV for 10dB S/N ratio. The power outputs are 120W s.s.b., p.e.p., 120W c.w., 30W a.m. and the output impedance matching range is 40-60Ω.

The unit may be operated from a 110V a.c. (50-60c/s) or 12V d.c. supply. Accessory power supply units are available. The U.K. agents for National Radio are Ad. Auriema, Inc., 414 Chiswick High Road, London, W.4.
For further information circle 323 on Service Sheet.

Non-linear Inductance

By "CATHODE RAY"

LAST month we faced the fact that whereas everything sheltering under the vast umbrella called electronics involves non-linear circuits, virtually all the elementary books and most of the advanced ones dodge the issue by assuming linearity. We have, for example, valve and transistor parameters referred to as "constants" when they are not. So general is the assumption of linearity that when we put it aside we feel quite lost without our Ohm's law, the principle of superposition, r.m.s. values, and other trusted concepts. Therefore we introduced ourselves to non-linearity by considering it in one of its simplest manifestations—non-linear resistance. We get this in valves, transistors, thermistors, varistors, etc.

Two guiding principles we relied on are (1) that the average value of any complete cycle of pure sinusoidal waveform (sin or cos) is zero—obvious, of course—and (2) the product of any two such waveforms is also zero unless they have the same frequency. The rule for finding the total of a number of alternating currents in a circuit by taking the square root of the sum of the squares of their separate r.m.s. values seemed to contradict (1) until we remembered that it is special to linear circuits, where the existence of harmonic currents necessitates corresponding voltages, so the equal-frequency exception in (2) applies. The whole idea of r.m.s. values is founded on linearity.

In non-linear circuits a sinusoidal e.m.f. produces harmonic currents, but in accordance with (2) these have no wattage. Here we had to beware of confusing the index of the non-linearity with that of the harmonics produced thereby. Whereas square-law and all other even-index non-linearity produces second and other even harmonics only, so no power is involved and therefore no influence on effective resistance, all odd non-linearity brings in fundamental as well as odd harmonics, and therefore affects the resistance.

Now that we come to non-linear inductance, which we don't have to go far to find since every iron-cored coil has it, we encounter some extra complications:

(a) Inductance is a less simple relationship between current and voltage. Instead of $E = IR$ we have $E = L\,dI/dt$ or, because current and voltage in this case are normally variables, $e = L di/dt$ where di/dt is the usual shorthand for "the time rate-of-change of current".

(b) Whereas there are at least parts of circuits where $E = IR$ is sufficient, because they are nearly-enough purely resistive, inductance necessarily involves appreciable resistance (except, sometimes, within a few degrees of the absolute zero of temperature) and often capacitance, so $e = L\,di/dt$ is only part of the story. Non-linear (i.e., iron-core) inductance additionally involves a more complicated form of resistance—core losses (hysteresis).

(c) Quite often the non-linearity of resistance can be expressed as a reasonably simple equation, but this is unlikely with inductance, especially as

(d) the curve of non-linearity itself varies with the amplitude of the current, and is affected by the past history of magnetization of the iron.

Basically it is the material of which the core is made that is responsible for most of these peculiarities, because, when magnetized by current flowing around it, it increases—usually very greatly—the amount of voltage-generating magnetic flux therein. Inductance being proportional to the amount of flux created by a given current, this is the essential property. It can be depicted in the most generally applicable form as curves of B (flux density) against H (magnetizing force). Because B is flux per unit area of core and H is ampere-turns per unit length of core, such curves enable (at least in theory) the effect of a core of any size and shape made of the material to which they relate to be calculated. So

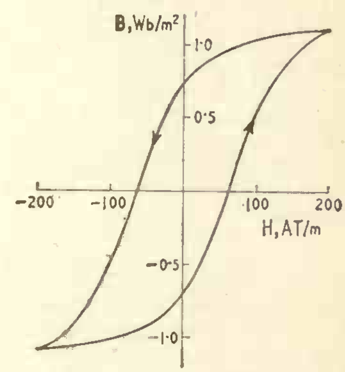


Fig. 1: Typical B/H curve, with scales in m.k.s. units.

their appearance is familiar to anyone likely to be reading this.

Fig. 1 is an example. A curious thing, incidentally, is that the one major pocket of resistance to m.k.s. units is the magnetic materials trade, yet here the m.k.s. system is not least advantageous. Instead of oersteds (which I get mixed up with gilberts) there is a meaningful unit of H:—ampere turns per metre (of core length). And the 4π and $10/4\pi$ drop out altogether, so that the energy stored per cubic metre is simply BH, not $BH/4\pi$. And the unit of flux is such that e.m.f. in volts is equal to its rate of change instead of being 10^{-8} times as much. I suppose it is the metres that people dislike, applied to cores that are usually in the centimetre range. I can only say that since I adopted the m.k.s. system I more often get my sums right, and with far less thought and reference to books. So much for the alleged inability of old dogs to learn new tricks—when the tricks are sensible ones. But that is by the way.

The most striking feature of this sort of curve is that it is like a one-way traffic system. Consequently

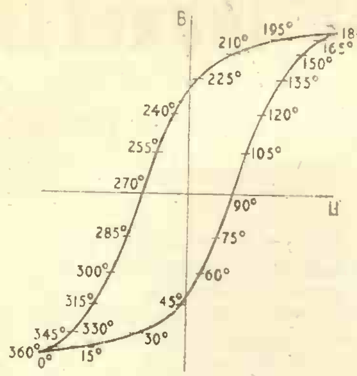


Fig. 2. Hysteresis curve as in Fig. 1, marked with phases of a sinusoidal applied e.m.f.

the value of B depends not only on H but on whether it is coming or going. In fact, this particular material retains about half its maximum flux when there is no magnetizing force at all, and the polarity can be either way, depending on what it was before. That is what I meant by the influence of history. Obviously this curve applies only after H has been varied through at least one whole cycle; it doesn't show what must have happened some time previously when the iron was unmagnetized, as represented by a point at the origin. And, as also stated under heading (d), this curve holds good only for the particular amplitude of H for which it is drawn; increasing or reducing the amplitude would make it trace out a different curve—no part of the one shown would remain. This is obviously a serious inconvenience, though one can get along fairly well by interpolation if a family of curves is available.

As I mentioned earlier, but will not stop to prove because it is in all the relevant books, the energy stored in the material is equal to BH. When an a.c. is sweeping it through the cycles represented, the fact that the up and down curves are different, and enclose an area, means that the energy restored to the circuit is less than that put into it electrically. The difference, represented by the area within the loop, is the energy lost in the core.

The relationship between H and current through the coil is revealed by its unit—the ampere-turn per metre (along the path of the flux). And the voltage generated *per turn* in any coil around the core is equal to dB/dt multiplied by the cross-sectional area of the core.

All this is elementary electrical engineering stuff, in preparation for the first job in hand: to inquire what " inductance " means in this context.

The inductance in henries is commonly defined as equal to the e.m.f. induced when the current is varying at the rate of one ampere per second. That the inductance in a circuit is assumed normally to be constant is shown by the form of the equation almost invariably quoted:

$$e = L\frac{di}{dt}$$

Here the current (i) and e.m.f. induced when it varies (e) are clearly variables, otherwise the equation is not worth writing—to say nothing of the convention that reserves small letters for variables. But where, as in every iron-cored coil, the inductance depends on the amount of current flowing, the equation doesn't tell the whole truth. One would have to write

$$e = f(i)\frac{di}{dt}$$

where $f(i)$ is a probably unspecifiable function of i, and that is a very different matter.

Continuing to assume that we have the relevant information in the form of a B/H curve, such as Fig. 1, how can we use it?

That depends on whether we know i and want to find e, or vice versa. Suppose we apply a known voltage waveform across an iron-cored coil and want to find the waveform of the current. We have already noted that the voltage induced per turn is (in m.k.s. units) equal to the rate of change of flux linked with the turns. And flux is BA, where A is the cross-sectional area of the core, assumed the same all round the core. (If it isn't, the calculation has to be done piecemeal and is much more like work.) So:

$$\frac{e}{N} = \frac{AdB}{dt} \qquad (1)$$

Given e, A and the number of turns N, we can find dB/dt. But what do we do with it when we have found it? Nothing very useful so far as I can see.

It would, on the other hand, be most helpful if we knew B corresponding to each phase of e, because the B/H curve would translate this for us into H, from which we could (knowing the number of turns and length of core) find i.

That problem can soon be solved by integrating equation (1) with respect to t:

$$\int e\,dt = ANB + C$$

where C is the usual constant of integration. The waveform of e will either be pure sine or a Fourier combination thereof, and the integral of $\sin\theta$ is

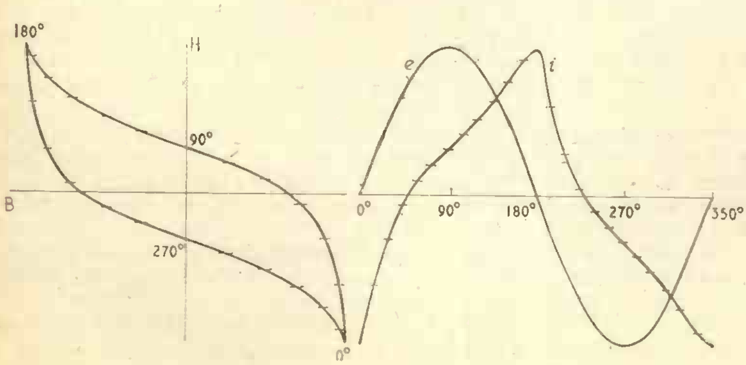
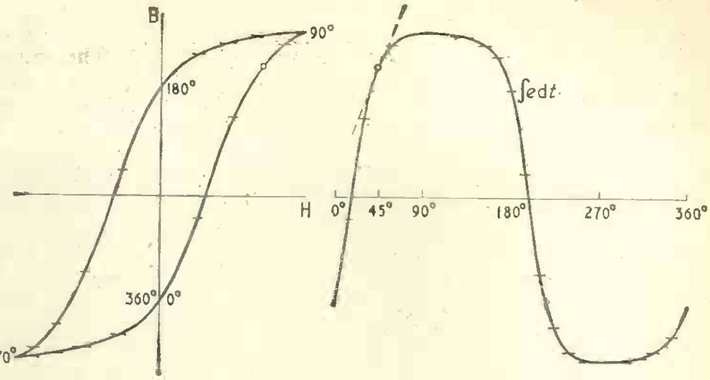


Fig. 3. Diagram of Fig. 2 turned through a right angle for conveniently drawing a H/θ curve, which has the same waveform as the current, i. The e.m.f. e is shown for comparison.

Fig. 4. *Reverse process, for deriving voltage wave across the iron-cored inductor when a sinusoidal current is maintained through it. The curve shown on the right is actually a voltage integral curve, which has to be differentiated to get the voltage waveform, by measuring its slope at each point as shown.*



well known to be $-\cos\theta$. θ in this case will of course be ωt, where ω is, as usual, 2π times the frequency in c/s. This slight complication is taken care of by dividing the $-\cos\omega t$ by ω.

So: $\quad ANB + C = \int e dt$

$$= \int E_{max} \sin \omega t \, dt$$

$$= -\frac{E_{max}}{\omega} \cos \omega t \quad .. \quad .. \quad (2)$$

The first thing is to make sure that we have an appropriate B/H curve, which means one having the correct maximum value of B. Now the values of $\cos \omega t$ range between $+1$ and -1, so $(ANB + C)$ ranges between $-E_{max}/\omega$ and $+E_{max}/\omega$. B/H curves are what is called skew-symmetrical—the left-hand half is a negative mirror image of the right-hand—so provided that the current is purely alternating, which it will be if there is no rectifier in the circuit, the peak negative values of B and H will be numerically equal to the peak positive values, as in Fig. 1. This can only be so if C is zero. That, then, is one complication out of the way:

$$\pm B_{max} = \mp \frac{E_{max}}{AN\omega}$$

This reveals the size in B/H curves we need. If we haven't got it we shall have to sketch one, guided if possible by the next larger and smaller sizes.

Next, we want to find the values of B corresponding to sufficient other phases in the voltage cycle. I suggest every 15°. The numbers by which to multiply B_{max} are $-\cos 0°$ $(= -1)$, $-\cos 15°$ (-0.966), etc. Fig. 2 shows the diagram at this stage.

This, of course, indicates the values of H at these phases. The relationship between them and the current is, as we have already noted,

$$H = \frac{iN}{l} \quad .. \quad .. \quad (3)$$

where l is the length of the core (again, assumed to have constant cross-section). Current being directly proportional to H, we can plot its curve from Fig. 2 and use equation (3) if we want to provide it with a scale in amps. The easiest way of transferring the plots is to turn Fig. 2 on its side, as in Fig. 3. A sine wave is plotted too, to represent e for comparison. The shape of the i curve will be familiar to anyone who has used an oscilloscope on iron-cored coils. But we can take a more intelligent interest in it by tracing its generation as suggested.

Sometimes, as for example when an iron-cored coil is in series with a pentode, a more or less sinusoidal current is passed through it, and one is interested in the shape of the resulting voltage across it. The quickest and most reliable means of satisfying one's curiosity is again an oscilloscope, but again there is something to be said for tracing it out from basic principles.

It might be thought that this can be done simply by following the same procedure in reverse. And it can be done that way, but not quite so simply. It is easy to mark the phases on the B/H curve—in the direction of the H axis this time—and transfer the corresponding B values to get the waveform of $\int e\, dt$. All one has to do now is to differentiate it to get e; but this time we don't have a simple mathematical curve, with a standard differential. There is nothing for it but to measure its slope from point to point and plot that. Fig. 4 shows the procedure.

If all you want is the waveform, you can plot it to a scale of so many divisions up for each division along. An actual scale of e in volts can be found by referring to the scales of B and θ; the latter is also a scale of t if the frequency is known. For example, if f is 50 c/s, then 15° is $15/360 \times 1/50 = 0.00083$ sec.; in that period the slope at 45° rises 0.2 weber/m². According to eqn. (1), then,

$$e = AN\frac{dB}{dt}$$

$$= AN \times \frac{0.2}{0.00083}$$

$$= 240\ AN$$

Fig. 5 shows the resulting voltage waveform, with the current for comparison. The voltage due to a sinusoidal current is notably more peaked than the current due to a sinusoidal voltage (Fig. 3). Note too that in Fig. 5 the voltage peak is rather less than 90° ahead of the current, indicating resistance (i.e., core loss) as well as inductance. In Fig. 3 the peaks are actually 90° out of phase, but the asymmetrical shape of the current waveform shows that its *fundamental* component lags less than 90°.

That reminds me that our main object was not to trace out rather laboriously what an oscilloscope can do f times per second, instructive though that may be, but to inquire into the meaning of inductance in such cases.

Last month we saw that because resistance is a measure of the electrical-energy-dissipating character of a circuit, its assessment should be based on that property. With simple d.c., the rate of energy dissipation (i.e., power, P) is EI. The alternative

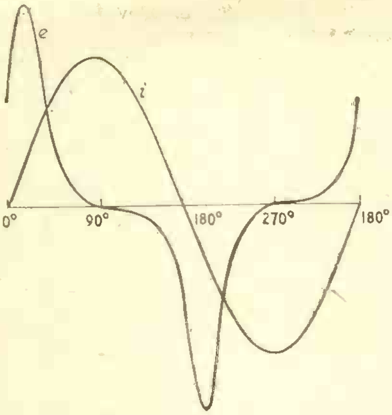


Fig. 5. Waveform of voltage e corresponding to sinusoidal current, i, obtained as in Fig. 4.

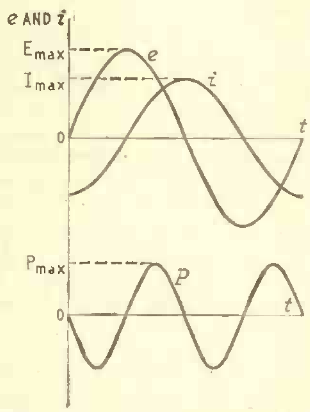


Fig. 6. Sinusoidal voltage and current curves relating to pure inductance, and the corresponding power curve, showing equal energy loan and repayment twice per cycle.

formulae for resistance are P/I^2 and E^2/P, and substituting EI for P in either of these gives us the familiar

$$R = \frac{E}{I} \qquad .. \qquad .. \qquad (4)$$

If anyone objects that I have got it all back to front, because (4) is the definition of resistance, my reply is that this may be so for d.c., but it doesn't answer in more complicated cases, where we have to fall back on the fundamental basis of power dissipation. With a.c., for example, E and I are changing all the time. So the dissipation has to be averaged over a whole cycle. Provided that the circuit is purely resistive and linear, P is again equal to EI, where this time E and I are r.m.s. values, and we again get (4). With pure sine waveform, E and I are $1/\sqrt{2}$ times the peak values, E_{max} and I_{max}. If there is reactance in series with the resistance, it causes a phase difference (ϕ) between E and I, and only the in-phase component of E counts. So $P = EI \cos \phi$. Dividing this by I^2 we get

$$R = \frac{E \cos \phi}{I} \qquad .. \qquad .. \qquad (5)$$

This is valid only for pure sine waves, but one can analyse any other waveform into component sine waves and *in a linear circuit* deal with each separately.

With non-linear resistance, as we have already recalled, a pure E gives rise to harmonic currents as well as fundamental, but as these are not associated with voltages of the same frequencies they can be ignored when calculating the power dissipated. (The same is true if E and I are interchanged). One is then dealing with fundamentals only, as before, and the only complication is calculating the fundamental current due to E (or vice versa). Fortunately one can ignore even-power terms in the current/voltage or transfer characteristic, because they generate harmonics only—no fundamental. So if, for example,

$i = ae + be^2 + ce^3$, where $e = E_{max} \cos\theta$,

for the purpose in view we can ignore be^2:

$i = a\, E_{max} \cos\theta + cE^3_{max} \cos^3\theta$

$= aE_{max} \cos \theta + cE^3_{max} \tfrac{1}{4} (\cos 3\theta + 3 \cos\theta)$

The cos 3θ can also be ignored because it is 3rd harmonic, so the fundamental current is

$i = E_{max} \cos\theta\, (a + \tfrac{3}{4}\, C\, E^2_{max})$

$\therefore I = E\, (a + \tfrac{3}{4}\, c\, E^2_{max})$

and $R = \dfrac{E}{I} = \dfrac{1}{a\tfrac{3}{4}cE^2_{max}}$

Note that the resistance depends on the square of the peak voltage.

If neither voltage nor current is pure and the resistance is non-linear, then there will be power dissipation at other than fundamental frequency, and this must be included when reckoning the resistance—*at the specified amplitude, frequency and waveform.* Not only will there be harmonics of both voltage and current but also intermodulation. So things can get quite complicated.

I have reviewed the theory of non-linear resistance fairly fully because most of it can be used again, with appropriate modifications, for non-linear inductance. The basic difference is that inductance is a measure of energy storage rather than energy dissipation. For comparison with a similar diagram last time, Fig. 6 shows a sinusoidal e.m.f., the resulting current (or, in a non-linear circuit, the fundamental part of it only), and the power p—equal to ei at every instant. For simplicity the inductance is assumed to be free from resistance—impossible, really. So the current lags by exactly a quarter of a cycle.

Now the magnetic energy stored in an inductor depends only on the current. It is shown in elementary books to be equal to $\tfrac{1}{2}i^2L$. The maximum storage occurs, of course, at the peak current; so is I^2_{max} L, twice per cycle. Because the current is sinusoidal, this is equal to I^2L, which reminds us of I^2R—the average rate of energy dissipation is resistance R.

However, this line of thought is not so very fruitful, because there is no means of measuring or calculating the amount of energy stored. But we can make use of our meditations on resistance to the extent that they showed that even in non-linear circuits we had only sinusoidal current and voltage to deal with, provided that one or other of them was pure. And with pure waveform there is ωL, the reactance, equal to the ratio of voltage and current components 90° apart, just as R is the ratio of in-phase voltage to current. So corresponding to (5) for resistance we have

$$\omega L = \frac{E \sin \phi}{I} \qquad .. \qquad .. \qquad (6)$$

Because of the nature of hysteresis curves it is not, in general, practicable to *calculate* the fundamental current due to a sinusoidal voltage (or vice versa), as in the resistance example given; the best one can do in that line is to find the complete waveform graphically as described and use any of the standard methods to analyse it into fundamental etc.

But in practice one would use measuring instruments. The first thing would be to decide whether sinusoidal voltage or current was nearer the working conditions of the inductor in question. Then one would apply the said voltage or current, with amplitude as nearly as possible equal to working conditions; and, of course, the working frequency. The meter for reading the distorted current (or voltage) would have to be of a type, or provided with a suitable filter, to read the fundamental only. And it would be necessary to measure the phase difference, ϕ, between it and the driving voltage (or current), by an oscilloscope or otherwise.

Most often, measurements on inductors are done by specially designed bridges. To get a true result, the generator has to have an internal impedance practically equal to zero (for voltage) or infinity (for current); negative feedback is a great help here. And the detector must reject the harmonics and respond to the fundamental. And there must be provision for measuring the fundamental current amplitude. Then the answer will mean something. Whether it is worth the trouble is another matter.

BOOKS RECEIVED

Fundamentals of Modern Semiconductors by Barron Kemp and R. H. McDonald is a book written for the uninitiated in transistor techniques. Beginning with semiconductotr physics the reader is presented with design manufacture, and applications of most transistor and semiconductor types in use at present. Thin film technology, microcircuits, photo-transistors and parametric amplifiers are among the subjects dealt with. Throughout the book mathematics and formulæ are kept to a minimum. Pp. 160. Howard W. Sams & Co. Inc., 4300, West 62nd St., Indianapolis 6, Indiana.

Electromagnetic Theory by Prof. Erik Hallén. This book is based mainly on the lectures given by the author and his colleagues at Uppsala University and the Royal College of Technology, Stockholm. The work is conveniently divided into six sections, namely electrostatics, direct current, "stationary" electromagnetism, electromagnetic induction, alternating current and electromagnetic field theory. The m.k.s. system is used throughout. A set of problems followed by answers and suggestions is found at the end of the book. Pp. 621. Chapman and Hall Ltd., 37, Essex Street, London, W.C.2. Price 126/-.

Environmental Testing Techniques for Electronics and Materials by Geoffrey W. A. Dummer and Norman B. Griffin. This book, one of an international series of monographs on electronics and instrumentation, surveys this field and most aspects of environmental testing are examined, including a detailed account of the experience in military fields of vibration, shock and satellite environments. As well as dealing with the more general environmental hazards of galvanic corrosion, temperature, vibration and transport, nuclear radiation and acoustic noise hazards are also considered. Pp. 444. Pergamon Press, 4 and 5 Fitzroy Square, London, W.1. Price £5.

Television Deflection Systems, by A. Boekhurst and J. Stolle. One of the Philips Technical Library series this book deals with the problems related to the deflection of the electron beam in the television picture tube. The book is divided into two parts. The first investigates the tube and its associated deflection devices; the second considers external circuits related to deflection techniques. The requirements imposed on valves by these circuits are extensively discussed as are design problems associated with line and field output transformers. Pp. 218. Cleaver-Hume Press Ltd., 31 Wrights Lane, Kensington, London, W.8. Price 42s.

Variable Resistors, by G. W. A. Dummer, M.B.E., M.I.E.E. (second edition). Written to help the user to choose the best component for a particular requirement, special attention has been paid to precision variable resistors. Specialized and experimental types are covered. In this, the second edition, the text has been revised to include data on new commercial types. Pp. 228. Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, London, W.C.2. Price 45s.

International Code Training System, by International Teaching Systems, Inc. A book with three 7-in $33\frac{1}{3}$ r.p.m. records giving textual, diagrammatic and aural aids to learning the morse code, with practice recordings for speeds from three to 22 words per minute. Pp. 96. Howard W. Sams & Co., Inc., 4300, West 62nd St., Indianapolis 6, Indiana. $6.95.

Introduction to Electron Beam Technology, edited by Robert Bakish. Deals primarily with the use of high-intensity electron beams in metallurgy, e.g., melting, welding and evaporation. The design of electron guns is covered in detail and many examples of commercial application are described. Other applications of electron beams included in this symposium by 18 specialist contributors are electron microscopes, microanalysis and the irradiation of materials. Pp. 452. John Wiley & Sons, Ltd., Gordon House, Greencoat Place, London, S.W.1.

INFORMATION SERVICE FOR PROFESSIONAL READERS

Judging by the number of reply-paid forms returned to us each month, this *Wireless World* information service is proving to be very helpful to our professional readers and is therefore being continued.

The forms are on the last two pages of the issue, inside the back cover, and are designed so that information about advertised products can be readily obtained merely by ringing the appropriate code numbers. Code numbers are also provided for requesting more particulars about products mentioned editorially.

By the use of these forms professional readers can obtain the additional information they require quickly and easily.

UNBIASED

By "FREE GRID"

A Procuratorial Clangtron

IN the June issue, under the title of Etymological Exactitude, I suggested the setting up of a commission charged with the task of bringing cosmos out of the chaos of misused and misspelt words which we find despoiling electronics and kindred branches of science. The members of such a commission would have to be not only learned in language and literature, but also masters of mathematics and experienced in engineering as well as being skilled scientists.

By a piece of good luck the Editor has received a letter from a man who would make the ideal Chairman of the commission, for in addition to the qualifications mentioned above he is obviously also a legal luminary because he signs his letter with the pen name of "Procurator," well known in Scottish legal circles but usually Anglicized into Proctor south of the border to describe the man who acts for the Queen in divorce cases.

Unlike the best known of all bearers of this title of Procurator, namely Pontius Pilate, he has no desire to wash his hands of all responsibility, but, on the contrary, has anticipated his future duties as Chairman by accepting my invitation to sit upon one or two rough suggestions I made.

The Editor tells me that he is a very exalted personage in the engineering hierarchy of the B.B.C. who is as familiar with the Olynthiacs of Demosthenes as with the relativity hypotheses of Einstein. He criticizes my neglect of the rule about the use of the supine of the Latin verb when attaching the suffix "or" to certain English words derived from the Roman tongue, and to this charge I would reply: *Peccavi; me pœnitet.*

But, *mirabile dictu* (no neglect of the supine there!), he falls into error himself by saying that what I wrote was "a clanger." The O.E.D. knows not "clanger" but speaks of "clangor," and Dr. Johnson of "clangour." They are, of course, referring to the noise produced by something and not to the actual thing itself; but just as armour is made by an armourer, so, surely, is a clangour made by a clangourer? However the word "clang" is actually an onomatopœic word of Greek origin, and so the correct word for the agency which produces this cacophony is surely clangtron?

For reasons other than that of etymological exactitude the word "clanger" is one which, in the past, I would have hesitated to use. Connotations change with time, and I feel that if "Procurator" had, in his younger days, been heard using it in the streets of one of our two most ancient university cities, the proctor's bulldogs would soon have been asking him politely, as they always used to do, for his full name and college; maybe they would have been a little incredulous when he gave the former, and so possibly have booked him twice.

Exhibition Catalogues

IN the course of the year I usually go to all the exhibitions of a radio or electronics nature and I have noticed that all possess the irritating defect that there is always a very expensively produced catalogue on sale. In this catalogue, sandwiched in among a plethora of advertisements, there is a list of stands with a brief résumé of the exhibits to be found there, and also, of course, a plan showing where to find them.

These catalogues cost 2s 6d or, in the case of the Radio & Electronic Components one, 3s 6d. Surely a much better idea would be that, in return for his 2s 6d the visitor received an inexpensive list of stands and a plan *plus* a strong paper bag containing all the pamphlets that are available in the show.

Now I am fully aware that obstructionists will say that nobody wants a copy of every pamphlet on the stands. This is true, of course, and yet one constantly sees people collecting whole armfuls of pamphlets including many they discard immediately they study them at home. Another argument which will be raised against my idea is that the present style catalogue is heavily loaded with advertisements which help to pay for its costly production, and may even add a bit to the revenue of the exhibition organization.

Now I know nothing of the economics of running an exhibition, but if the revenue from the catalogue advertisements is so necessary, surely every exhibitor could pay so much for having his pamphlets in the bags sold to visitors. A manufacturer could say a lot more in a pamphlet than in a catalogue advertisement.

Speaking from the point of view of the exhibition visitor, I always dislike the way I have to go from stand to stand collecting these wretched pamphlets with the bag getting heavier and heavier all the time. I should like to be able to go from stand to stand with my hands free of all pamphlets and bags, and so indeed I could if my idea were put into practice, for the great beauty of it is that the visitor would not be handed his bagful of pamphlets until he departed from the exhibition; only the simple list of exhibitors and plan of stands would be given him on entry.

Next year the National Radio Show will resume its annual run at Earl's Court. Would it not be possible to start putting my idea into practice then?

Electronic Therapeutics

A VISIT to the Hospital Equipment and Medical Services Exhibition at Olympia a few weeks ago made me realize what wonderful advances electronic therapeutics—if I may coin a phrase—has been making in recent years. Every doctor knows that differential diagnosis is one of the most difficult things in medicine, but so far nobody has produced a computer whereby a doctor could, after "binarising" the symptoms (which is itself an impossible task at present), just shove them into a computer and get the correct diagnosis and treatment.

One of the most interesting electronic exhibits of a non-medical nature was the elaborate communication system whereby a patient can, by means of closed-circuit TV, see and talk with somebody elsewhere in the hospital. This apparatus would be particularly useful for visitors to a patient in an isolation hospital.

I was particularly interested in the microwave hospital cooker. There is nothing new in the principle of this, of course, and it is used by many restaurants, especially quick-service ones of the gulp-it-as-you-go type, which serves hot dogs and suchlike things. I was told on the exhibitor's stand that small items could be cooked in a trice, however long that may be, and a family joint took only a few minutes, but domestic models are not yet available. The frequency used in the model I saw was 2,450 Mc/s, which, to save you getting out your slide rules, is roughly a wavelength of 0.122 metre, i.e., a little short of 5 inches.

"Wire-less"

IN the issue of *Wireless World* for November, 1961, I mentioned that, during the preceding summer I had been to a first-class entertainment in the pierhead theatre of a well-known seaside resort but felt irritated by the trailing cable of the microphone used by a ventriloquist as he moved about the stage and among the audience. I suggested that instead of the cable there should be a microwave link.

Owing to the high praise I bestowed on the quality of the entertainment, the entertainments manager of Southend-on-Sea had little difficulty in realizing that I must be speaking of this famous Essex resort, as indeed I was. The upshot of the whole matter was that he made a few enquiries and came up against various difficulties including the insuperable barrier of the fact that the Post Office was not prepared to allocate a frequency for this service.

There the matter has rested for 18 months, but now the picture has changed entirely. The P.M.G. has allocated a frequency (174.6-175 Mc/s, as mentioned in the May issue of *Wireless World*) and British type-approved apparatus was shown at the Audio Fair in April and also at the Radio & Electronic Component Show in May. On both these occasions I had a very good look at these radio mikes. A power of 10 milliwatts is the limit set by the P.M.G. but the open-air range is several hundred yards which is all that can be desired. The tiny transmitter is small and light enough to be concealed on even a child performer.

I have naturally been wondering if there are likely to be any snags. I think it very unlikely that any practical joker would think it worth his while to invest in duplicate apparatus which might enable him to interpolate into the programme disconcerting remarks of his own.

I still think, as I mentioned in November, 1961, that by its use a ventriloquist would be able to extend his scope very greatly if a very compact receiver and loudspeaker as well as a telearchic lip and eyebrow operator were fitted into his dummy. He would be able to cause it to chatter and gesticulate even when he was a considerable distance from it, such as the full length of the auditorium.

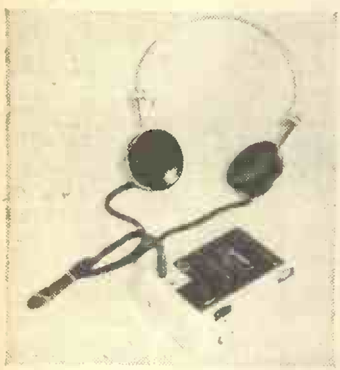
Sexagesimal System

SOME months ago I asked in these columns if any of you could tell me why there are 360 degrees in a circle and also 60 seconds in a minute and minutes in an hour. Some of you blamed the Babylonians, although nobody suggested why they did it.

I find it is dealt with by Dr. A. C. Aitken, in his book "The Case Against Decimalization" to which I referred last December. Dr. Aitken tells us that in 2,000 B.C. the Sumerians used not only decimals but also the sexagesimal system, and that a few centuries later, the Babylonians took both over from them. While the ordinary folk continued to use decimals, the mathematicians and technologists used the sexagesimal system because 60 had more factors than any number less than it. It was these people who have left their stamp on our divisions of time and of the circle.

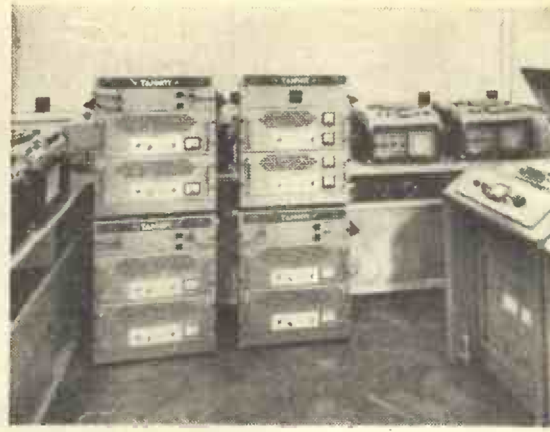
INDUCTION LOOP INTERPRETATION SYSTEM

IN addition to the permanently-wired installations which have been provided for debating chambers and conference halls in all parts of the world (e.g., the United Nations in New York and Geneva, and Church House, Westminster) Tannoy have now developed a mobile radio (inductive) system together with comprehensive facilities not only for multi-lingual translation but also for verbatim recording. These facilities can be provided at comparatively short notice, and subsequently tape copies of speeches can be provided if required through Sound Recording Ltd., a new company in the Tannoy group.



Delegate's receiver unit tunable to six channels.

The new loop system provides 6 channels with carrier frequencies of the order of 100kc/s, each channel being crystal controlled. Microphone outputs go through a volume compression voltage amplifier before being applied to the modulator, giving a change of only 2dB for a 20dB change of input level.



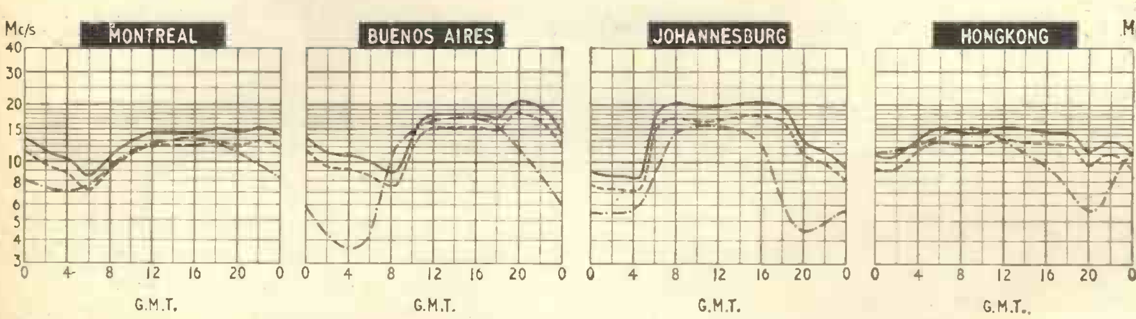
Transmitting amplifiers and recording equipment forming part of the Tannoy radio-inductive simultaneous translation system.

The receivers are superheterodynes housed in high impact plastic cases measuring $4\frac{3}{4}$in × $3\frac{1}{4}$in × $1\frac{5}{8}$in. A ferrite rod high-Q tuned input circuit precedes the mixer which is followed by one i.f. stage with a.g.c. and reflexed for a.f. amplification, a diode detector and an output stage, transformer coupled to the headphones. A socket in the base accepts a jack for charging the sealed nickel-cadmium battery, and combined storage and charging racks, each holding 60 units, have been designed for ease of transport.

Channel selection is by means of an edgewise control switch with a small degree of movement on each position for fine tuning of the carrier frequency. A second control is a combined on/off switch and volume control.

The Tannoy Company of Norwood Road, London, S.E.27, is prepared to undertake the complete simultaneous translation services for conferences of up to 2,500 delegates.

H. F. PREDICTIONS — JULY



——— MEDIAN STANDARD MUF
- - - - - OPTIMUM TRAFFIC FREQUENCY
—·—·— LOWEST USABLE HF

THE prediction curves show the median standard MUF, optimum traffic frequency and the lowest usable high frequency (LUF) for reception in this country. Unlike the standard MUF, the LUF is closely dependent upon such factors as transmitter power, aerials, local noise level and the type of modulation: it should generally be regarded with more diffidence than the MUF. The LUF curves shown are those drawn by Cable and Wireless, Ltd., for commercial telegraphy and they serve to give some idea of the period of the day for which communication can be expected. The LUF curve for Montreal takes account of auroral absorption.

During the summer months in the minimum of the solar cycle past experience has shown that frequencies considerably higher than the predicted standard MUF can at times be received. This effect is mainly confined to daytime on the radio path and has been especially noted on reception in the U.K. from the Far East. The cause is thought to be associated with sporadic-E ionization.

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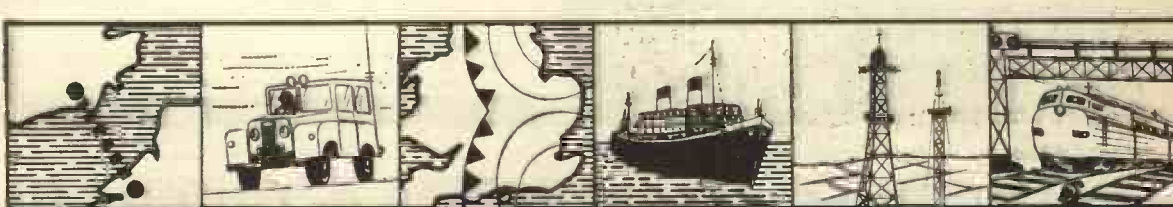
AUTOSPEC is the first single path error corrector to include automatic correction without the need for repetition

AUTOSPEC is a product of the same design team responsible for the production of the world famous AUTOPLEX



MARCONI'S WIRELESS TELEGRAPH CO. LIMITED · CHELMSFORD · ESSEX · ENGLAND

H9A

THIS CATALOGUE IS NOT FOR EVERYBODY

It has been produced for senior designers, engineers and technicians in commercial, civil and military organisations, to provide technical information, dimensions and fixing details, in English and metric units, for all "Belling-Lee" products.

The Catalogue is contained in a very substantial loose leaf binder, thumb-indexed for quick reference. Additional pages covering new products, or any improvements to existing ones, will be distributed from time to time and can readily be inserted, so enabling the volume to be kept up-to-date.

If you are one of those for whom this useful work IS intended but have not yet received a copy, please send us your name and department on your official letter heading, and we will gladly forward one to you.

BELLING & LEE LTD

GREAT CAMBRIDGE RD., ENFIELD, MIDDX., ENGLAND

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FOR DEPENDABLE COMMUNICATION... VERSATILE APPLICATION...CHOOSE THE...

GR410

SSB TRANSMITTER/RECEIVER

(Service Type C14)

Designed for military, security and commercial applications throughout the world—its use by the British Army is a recommendation in itself.

The GR410 SSB transmitter/receiver is a 100-watt p.e.p. transistorised equipment which provides four crystal-controlled channels in the range 2-16 Mc/s; instant selection of either upper or lower sideband effectively doubles the number of channels available when operating SSB.

The GR410 can be matched into any aerial system. It can also be used with existing a.m. telephony and telegraphy systems as a "replacement" equipment. Its versatility, as a mobile, transportable or fixed station, sets a standard unequalled by other equipments of similar type.

Transistors and semiconductors are extensively used; the power consumption on *receive* is only 7 watts. Interchangeable power units are available; 100/125 V or 200/250 V a.c. 50/60 c/s or transistorised d.c. versions for 12 V or 24 V supplies.

Redifon

REDIFON LIMITED Communications Division,
Broomhill Road, London, S.W.18 Tel: VANdyke 7281
A Manufacturing Company in the Rediffusion Group

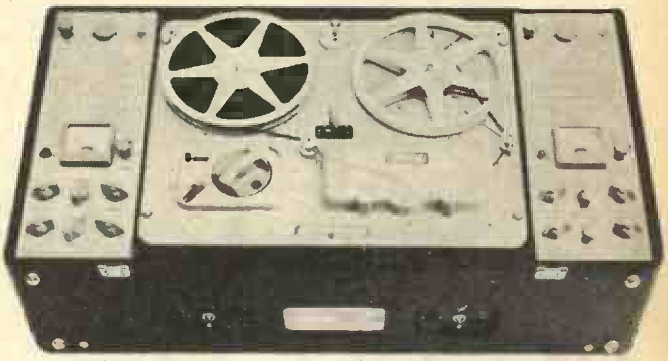
Desk operation by extended local control

GR410 (Service Type C14) being operated as a mobile station

RED 410B

—Vortexion quality equipment

TYPE C.B.L. TAPE RECORDER



The Vortexion CBL recorder has had many detail improvements and additions using the latest stereo deck, " B " type monitoring after record facilities with mixing of inputs on each channel and over 6 watts total output. All the usual features of the " B " recorder are retained including metering of bias and signal plus the ability to record the signal from one track to the other together with additional signal from the mixed inputs. The separate 30/50 ohm balanced line microphone inputs allow for the microphones to be placed at any distance apart according to the result required. The right hand channel may be switched off entirely when only single channel working is desired.

The W.V.A. Recorder is a semi-professional model of the highest quality.

The W.V.B. Recorder is suitable for professional use with after record, monitoring and echo facilities.

The Vortexion 30/50 watt Amplifier can deliver 50 watts of speech and music or over 30 watts of continuous sine wave and the main amplifier has a response of 30 to 20,000 cps within 1 db at 0.1% distortion and outputs for 4, 7.5, 15 ohm and 100 volt line. Models are available with two, three or four mixed inputs which may be low impedance balanced line microphones, P.U. or Guitar inputs.

The 120/200 watt Amplifier can deliver its full audio power at any frequency in the range of 30 to 20,000 cps for which the response is accurate within 1 db with less than 0.2% distortion at 1,000 cps. It can be used to drive mechanical devices for which the power is over 120 watts on continuous sine wave. The input is for 1 mw. 600 ohms, the output for 100-120 volts or 200-240 volts and additional matching transformers for other impedances are available.

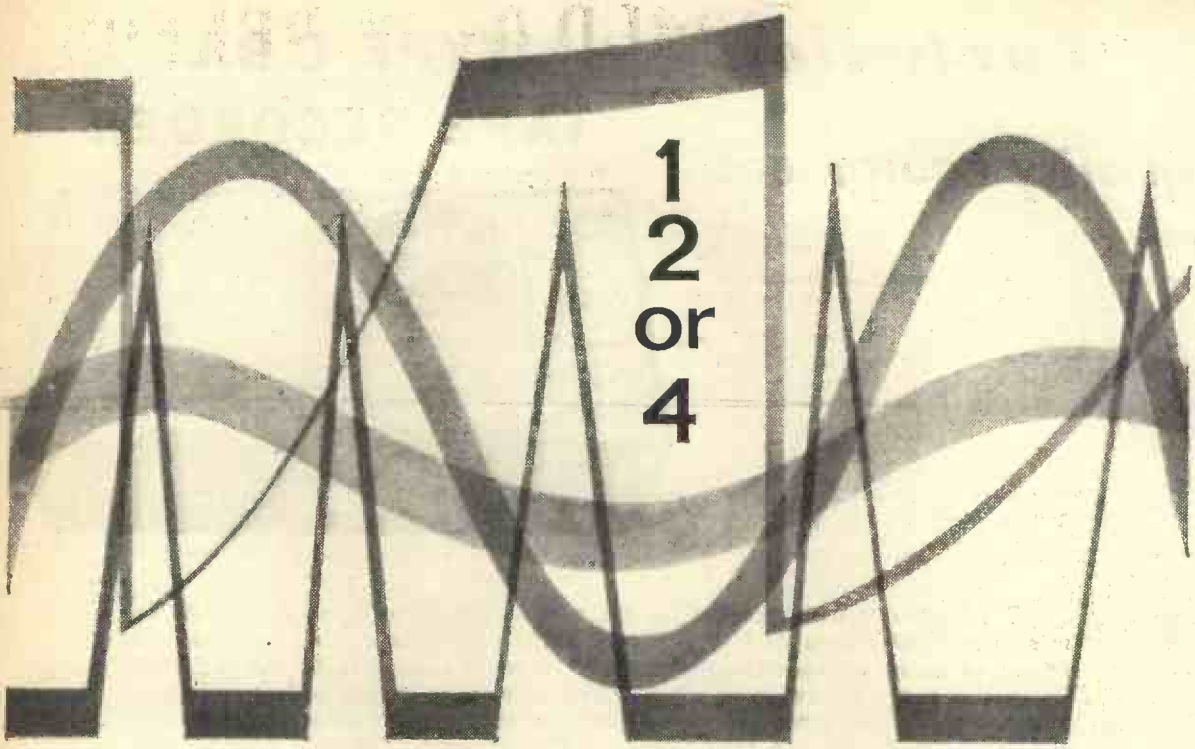
Other items of our manufacture are:

Erase Fader Unit for above recorders.
4 Way Mixer with 10 watt output and tone controls.
Record and Playback Mixer.
2 x 5 Way Stereo Mixers.
12 Way Mixers.
3 Way Mixer and Peak Programme Meter.
4 Way Mixers.
2 way 30/50 ohm in and out stud type Mixers.

Full details and prices of the above on request.

VORTEXION LIMITED, 257-263 The Broadway, Wimbledon, London, S.W.19

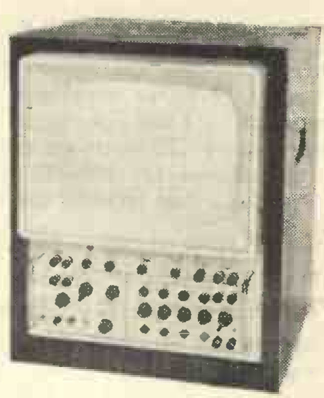
Telephone: LIBerty 2814 and 6242-3 Telegrams: "Vortexion, Wimble, London"



+17

A Beam Switch giving 1, 2 or 4 traces, each with independent Y gain and shift controls, and a 17″ rectangular cathode ray tube—these are just two of the advantages offered by the Airmec Display Oscilloscope Type 279. Although designed primarily for demonstration and instructional use in Schools, Technical Colleges and Universities, the exceptionally large viewing screen (9″x 13″) and a very bright orange trace visible at 50 feet make this Oscilloscope extremely suitable for many other uses, including analogue computers, medical applications and wobbulators.

The Display Oscilloscope Type 279, together with the 4 channel Oscilloscope Type 249 and High Speed model Type 294, forms part of the comprehensive range of high quality electronic instruments which Airmec produce for use in laboratories and workshops.



Y AMPLIFIER
Bandwidth—D.C. to 10 kc/s
Sensitivity—
Greater than 10 cms per volt
Beams—1, 2 or 4 with independent gain and shift controls

X AMPLIFIER
Bandwidth—D.C. to 8 kc/s
Sensitivity—
Greater than 8 cms per volt

TIME BASE 317
Sweep Time—
1 millisecond to 1 second
Beam Switching—Sequential

TIME BASE 318
Sweep Time—
0.5 second to 30 second
Beam Switching—
Incremental Triggered operation

Airmec for peak performance consistently

LABORATORY INSTRUMENTS DIVISION

Oscilloscopes, Wave Analysers, Signal Generators, Phase Meters, Valve Voltmeters, Ohmmeters, High Speed Counters, etc.

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TELEPHONE: HIGH WYCOMBE 2501 (10 LINES)

AP272

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LASKY'S RADIO

★ LARGEST and most COMPREHENSIVE STOCKS of all COMPONENTS, TEST GEAR, etc., and FINEST VALUES IN GREAT BRITAIN

4-SPEED AUTO-CHANGERS

B.S.R. Type UA8 £5 19 6
B.S.R. Type UA14/UA20 .... £6 9 6
COLLARO Studio C60 wired for stereo with monaural p.u. £6 19 6
MAGNAVOX-COLLARO latest model, 4 speed Stereo Auto changer. Fitted diamond stylus and record dust cleaning attachment. Mono £6 19 6
Stereo £7 19 6

GARRARD
Model 209 Mono £7 19 6
Model 209 Stereo £8 19 6
Auto-Slim Mono Plug-in-head £7 7 0
Auto-Slim De Luxe Mono £11 9 0
Auto-Slim De Luxe Stereo £12 5 0
Lab. Model "A" Mono £19 14 0
Lab. Model "A" Stereo £20 10 0
Postage on all above 5/-.

SINGLE PLAYERS
Auto start and stop. Complete with pick-up and crystal cartridge.
GARRARD SRP10. latest model, single player with G.C.8 .... £5 9 11
E.M.I. 4-speed, wired for STEREO, fitted mono cartridge £5 5 0
As above, STEREO £6 6 0
Post on all above 5/-.
COLLARO JUNIOR 4-speed motor and pick-up 69 6.
6 volt battery version, 4-speed with pick-up 69 6.
B.S.R. TU9. non-auto. Turntable and pick-up, 59/6.

TESLA "Sonet" DUOTAPE Recorder

Continental manufactured. 2-speed Tape Recorder with $1\frac{7}{8}$ and $3\frac{3}{4}$ i.p.s. Twin Track Recording to International standards.
● Takes $5\frac{3}{4}$in. spools. ● Fast forward and fast re-wind. ● Record level indicator. ● Inputs for Microphone, Radio and Pick-up. ● For use on 110 and 200/250 volts, 50 c.p.s. mains. ● Digital position indicator. ± In attractive wood case with metal top cover. Fitted with storage compartments and carrying handle. Size 13in. × 10in. × 7in. ● High quality record-replay amplifier with internal loudspeaker provides immediate high quality reproduction. ● Socket for external speaker. ● Tone control.
Supplied with reel of tape, empty spool, microphone and a selection of inter-connecting leads, etc., with canvas waterproof cover. Brand new and unused.
LASKY'S PRICE **24 Gns.** Carr. and Ins. 10/6.

BRAUN Model PC4L
4-SPEED STEREO RECORD PLAYER UNIT.

Incorporates a number of refinements including hydraulic pick-up lift: heavy die-cast metal turntable with rubber mat, and retractable adaptor for large hole 45 r.p.m. records; multi-mains voltage, etc. Lightweight pick-up arm fitted wth an Elac type KST102 stereo cartridge, also suitable for L.P. and 78 r.p.m. mono records. Auto-stop mechanism fitted.
Unit plate size only 12×8in. Depth below unit plate, 3in. Height above top of unit plate, $1\frac{3}{4}$in.
Motor has voltage tappings for use on 110, 160 and 200-250 v. 50 c.p.s. A.C. mains. Hydraulic pick-up lift incorporated, of a fool-proof design, together with a set down position indicator. Speeds, 16, $33\frac{1}{3}$, 45 and 78 r.p.m., 6ft. of mains lead fitted and 3ft. of multi-way cable for pick-up connection also fitted.
Brand new and unused. Fully guaranteed.
LASKY'S PRICE **£12.9.6** P. & P. 5/-.

CELLULOSE WADDING. For lining the interior of loudspeaker enclosures. Width 36in. Any length cut to nearest 6in.
LASKY'S PRICE **2/11** per sq. yard and pro-rata. P. & P. extra.

BY FAMOUS BRITISH MANUFACTURER
STEREO AMPLIFIER

Self-contained integrated stereo amplifier, including combined control unit pre-amplifier. Designed to provide high quality stereo and mono reproduction with a rated output of 6 watts per channel stereo 12 watts mono. Input sockets are provided for the direct connection of most types of tuners and pick-ups, plus tape heads and high quality microphones including moving coil and ribbon. Separate output for feeding a tape recorder available on each channel. Facilities include inputs for Mic. 5 m/v; tape 4 m/v.—equalised for CC1R; R1AA, 4.3 m/v; flat 250 m/v; radio tuner 100 m/v. Overall response 60 cycles—20,000 cycles Controls fitted are bass, treble, balance, volume, phase reverse, stereo sense, and selector Outputs 4, 8 and 16 ohms. Mains voltage 105-240 v. A.C. Attractively styled in free-standing metal case, finished in silver and black. Size: 14×8×4 inches. Suitable for use with any good quality tuner, speaker system, record player, etc. Will form the basis of a high fidelity stereo system. Brand New and Unused in maker's original cartons.

LASKY'S PRICE **£15**
Carriage & Packing 7/6

BY FAMOUS BRITISH MANUFACTURER
AM/FM RADIO TUNER

LASKY'S PRICE **£16.19.6**
Carriage and packing 7/6.

A self-powered tuner covering full VHF Medium and Long wave bands. Excellent quality provides perfect reception, can be used with any good quality amplifier, but especially suitable for the Tudor amplifier described above. Latest type tuning indicator fitted. Multiplex output socket fitted. Separate tuning of AM and FM. Fully variable gain control. For use on A.C. mains 105-240 v. Attractively styled in free-standing metal case finished in silver and black. Size 14×8×4in.

"LINEAR" AMPLIFIERS
"Diatonic" 10-14 watt .... 12 Gns.
"Concord" 30-watt .... 16 Gns.
L45, 4-5 watt £5 19 6
LT45 Tape Deck Amp. .... 12 Gns.
L10 10-watt with pre-amp. .... 15 Gns.
L50 50-watt .... 22 Gns.
L5/5 Amplifier and Pre-amp. .... 12 Gns.
LP1 Tape Pre-amp. .... 9 Gns.

HI-FI TAPE RECORDER HEADS
High impedance Record/Play. Low impedance erase. Upper or lower track. State track required when ordering.
Lasky's Price **29/6** Post free Per pair

MARRIOTT "X" Type $\frac{1}{4}$ track heads, Record/play and erase. **4 GNS.** pair.
$\frac{1}{4}$ Track heads record/play and erase 59/6 pair.

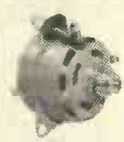
TRANSCRIPTION MOTORS
GARRARD 4HF, stereo or mono, £16 19 6
GARRARD 301 .... £20 12 0
GARRARD 301 (Strobe) £22 0 0
GARRARD A with GC8 .... £19 14 0
GARRARD A with GSC10 .... £20 10 0
PHILIPS AG/1016 .... £12 12 0
Carr. and Ins. 5/-. Also Lenco, Connoisseur, etc.

P.M. SPEAKERS

$3\frac{1}{2}$in.	4in.	5in.	$6\frac{1}{2}$in.	8in.	10in.	12in.
17/6	19/6	10/6	16/-	16/6	25/-	27/6

7×4	9×6	$10\times 2\frac{1}{2}$	10×6	10×7
12/6	22/6	25/-	25/-	25/-

ELECTRIC MOTORS



Brand new tape recorder motors. Single phase, fully shrouded. 200-250 v. A.C. $\frac{3}{8}$ × $\frac{1}{8}$in. spindle with detachable pulley, fitted switch. Suitable for tape decks, record players and many other uses.
P. & P. 3/6. **14/11**

DISTLER MINIATURE MOTORS
6 volt battery operated. P. & P. 2/6. **7/11**

20,000 VALVES IN STOCK AT NEW LOW PRICES
Brand new surplus and imported, also full stocks of B.V.A. valves. List post free.

SUB-MIN COMPONENTS
As used in the smallest Japanese pocket transistor radios. Coils, loudspeakers, I.F. transformers. Ganged Condensers, etc., in stock at lowest prices. Also all T.S.L. transistorised Miniature Units.

TRANSISTORS
All Brand New and Guaranteed
GET.S1! 2/6; GET.S5 2/6; GET.S6 2/6; GET.873A 3/6; GET.874P 3/6; OC44 7/6; OC45 6/6; OC70 6/6; OC71 6/6; OC72 8/-; OC73 16/-; OC75 8/-; OC76 8/-; OC81D 6/6; OC28 19/6; OC81 (matched) 6/6, pair 13/-.
SPECIAL PRICES FOR QUANTITIES.

STAAR KINDER RECORD PLAYER

45 r.p.m., 6 v. Battery operated. Complete with pick-up fitted crystal cartridge. Size only $7\frac{1}{2}\times 6$in. Fitted auto. stop and start. New and perfect. **LASKY'S PRICE 49/6.** P. & P. 2/6.
2 speed model for $33\frac{1}{3}$ and 45 r.p.m. 79/6. P. & P. 2/6.
ONE WATT FULLY TRANSISTORISED AMPLIFIER
Can be used with Staar Kinder to make a fully portable record player. Incorporates two GET 114 and two power transistors, in push-pull output. Fully built. Complete with tone and volume controls, on printed circuit. Size $2\frac{3}{4}\times 2\frac{1}{4}\times 1\frac{1}{4}$in. Uses 9 v. PP11 or similar battery. Complete with 3in. P.M. speaker. **LASKY'S PRICE 49/6.** P. 2/-.

HEADPHONES
High impedance. 14/6 per pair.
A.K.G. Model K.50 Stereo headphones, superb quality moving coil headphones. Low impedance £7/10/- per pair including ear pads.

RE-GUNNED C.R. TUBES (full range stocked).
We shall be pleased to quote on request.

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Few yards from Praed Street. PADdington 3271/2

Both above addresses open all day Saturday. Close 1 p.m. Thursday.

AND 152/3 FLEET STREET, E.C.4. FLEet St. 2833
Open all day Thurs. Closed 1 p.m. Sats.

PLEASE ADDRESS ALL MAIL ORDERS AND CORRESPONDENCE TO OUR HEAD OFFICE :—207 EDGWARE ROAD, W.2.

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CRYSTALS & COMPONENTS. LTD

TEL: TEM. 1189 2. 4. EARLHAM STREET W.C.2.

Near Cambridge Circus. A few minutes' walk from Leicester Square or Tottenham Court Road Underground Stations.
HOURS OF BUSINESS: 9 to 6. Saturdays 9 to 1. OPEN ALL DAY THURSDAY

SPECIAL OFFER

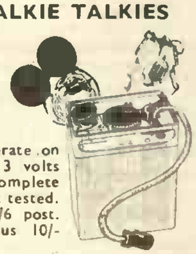
OF 6in. METRO-VIC TEST METERS ALL AT ONE PRICE 25/- FOR CALLERS ONLY INCLUDING 0/20/50 M/A, 0/100 M/A, 0/15 M/A, 0/500 Microamps, 0/50 M/A, 0/300 v. D.C., 0/30 volts D.C. 0/50 volts, 0/100 volts, 0/5 Kv., 0/500 volts, and many others. All in perfect condition (surface mounting).

SELENIUM F.W. HIGH CURRENT BRIDGE RECTIFIERS

18 v.	8 amps. $4\frac{1}{4}$in. sq.	Price	19/6
18 v.	18 amps. $7\frac{3}{4}$in. sq.	Price	39/6
18 v.	36 amps. $7\frac{3}{4}$in. sq.	Price	79/6
18 v.	54 amps. $7\frac{3}{4}$in. sq.	Price	117/6
36 v.	8 amps. $4\frac{1}{4}$in. sq.	Price	39/6
36 v.	18 amps. $7\frac{3}{4}$in. sq.	Price	79/6
36 v.	36 amps. $7\frac{3}{4}$in. sq.	Price	119/6
35 v.	54 amps. $7\frac{3}{4}$in. sq.	Price	235/–
54 v.	8 amps. $4\frac{1}{4}$in. sq.	Price	59/6
54 v.	18 amps. $7\frac{3}{4}$in. sq.	Price	117/6
54 v.	36 amps. $7\frac{3}{4}$in. sq.	Price	235/–

Voltages indicated are maximum input volts and amps. are max. current out. Supplied brand new and guaranteed.
Not government surplus.

TYPE 38 WALKIE TALKIES



Brand new. Operating on 7.4 to 9 Mc/s Trans/Receivers. Complete with headphones, throat microphone, junction box and aerial rods. Operate on 150 volts H.T. and 3 volts L.T. dry batteries. Complete less batteries and not tested. **42/6** per set plus 6/6 post. Or **£4** per pair plus 10/- post and packing.

FIELD STRENGTH METERS 100-150 Mc/s

Contains 0-1 mA meter, 155 valve, chrome telescopic aerial, etc. New condition in black crackle case. Operates on 1.5 v. and 90 v. batteries. Dimensions: 7 x 7 x 7in. **45/-** P. & P. 2/9.

20-0-20 AMMETER

2in. flush mounting. D.C. Brand new 11/6 each, post 1/6.

WOBBULATOR FREQUENCY MULTIPLIER

Band I. Channels 1-13 with 50 micro/ammeter and 0-80 dB attenuator. **£9** P. & P. 10/-.

DOUGLAS AUTO TRANSFORMERS

Auto 115-200-230-250 v.	300 w.	45/–,	P.&P. 5/–
Auto 110-120-200-240 v.	75 w.	16/–,	P.&P. 3/6
Auto 115-200-230-250 v.	500 w.	76/6,	P.&P. 5/–
Auto 115-200-220-240 v.	1 kW.	119/–,	P.&P. 6/6

E.H.T. TRANSFORMERS

E.H.T.1. Input 200/250 volts 50 C/s. Output 2kV. 10 M/a 4v. 1A.0-2-4V. 1.5A. **22/6** p.p. 5/-.
E.H.T.2. Input 200/250 volts 50 C/s. Output 2.5 kV. 10M/a 6.3v. 3A. 2v. 1.5A. 3.5 kV. D.C.Wkg. **22 6** p.p. 5/-.
E.H.T.4. Input 200/250 volts 50 C/s. Output 2,000 v. 15 M/a. 4 v. 1.5 A. 0-2-4v. 2A. **29/6** p.p. 5/-.

TYPE 68 TRANS/RECEIVER

3 to 5.2 Mc/s. Portable station with range up to 10 miles under good conditions. In very good condition, complete with valves, hand mike and aerial rods. **70/-** plus 8/6 carriage and packing. Require 150 v. H.T. 3 volts L.T. and 9 v. G.B.

L.T. TRANSFORMERS

Pri. 240 volts. Output 6.3. volts 5 amps **8/6**, post 2/6, Pri. 240 volts. Output 17 volts 1 amp., **9/6**, post 2/-.

H.T. TRANSFORMERS

Type (350/120) Tapped 200/250 v. input 350/0/350 v. 120 m/A 6.3 v. $3\frac{1}{2}$ amp. 5 v. at 2 amps., **16/6**. P.&P. 3/6. Type 5K Pri. 200/250 v. Output 350/0/350 v. 350 m/A 5 v. 3 amps. Tapped 4 v. 2 v. 2 amps. 10 Kv ins. 20 v. 1 amp 7.5 v. 1 amp. 5 kV. 5 m/A. **Price 25/-.** P.&P. 6/-.

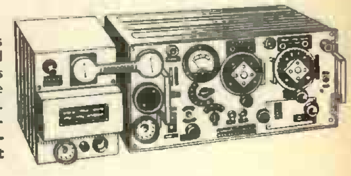
ON VIEW IN OUR SHOP FOR CALLERS ONLY, VERY LARGE RANGE OF TESTGEAR

Including, signal generators, decade resistance boxes, Pen recording Voltmeters and thermometers, Electronic Tuning Forks, etc.

CRYSTALS !!!

LARGE RANGE OF 10X, 10XJ, FT243, FT241 CRYSTALS ALWAYS IN STOCK. Send stamped addressed envelope for free comprehensive list.

WIRELESS SET No. 19



Complete with original power supply unit for 12 volts input. Transmitter/Receiver covering 2-8 Mc/s and V.H.F. 240 Mc/s. 6 valve superhet receiver and 6 valves in Transmitter. Using I.F. of 465 Kc/s. For voice and C.W. In good condition not tested. **£4.17.6.** Plus £1 packing and carriage. **Microphone and headset for this set 17/6 plus 2/6 P. & P. 19 Set Variometers 17/6 plus 2/6 post. Control box for 19 Set 10/- plus 2/- P. & P.**

B.C. 221 FREQUENCY METERS

Every one tested and working in perfect order. Exterior slightly soiled, from **£12/10/-**. Packing and carr. 17/6.

MORSE KEYS

Ex R.A.F. strap on type. Perfect condition **2/6** each **post paid.**

VIBRATOR POWER SUPPLY UNIT

6 volts D.C. input 230 volts 100 mA A.C. output and 6 v. L.T. out. Fully smoothed, with OZ4 rectifier valve. Brand new in steel case with pilot light, on/off switch and Slydlok fuse on front panel. Measures $8\frac{1}{2}$ x 6 x $5\frac{1}{4}$in. **39/6**, plus 6/6 P.&P.

SILICON RECTIFIERS

Westinghouse 1,000 P.I.V. 500 M/a., **9/-** each. 800 P.I.V. 500 M/a **7/6** each. 400 P.I.V. 200 M/a **3/6** each.

ASSORTED PACKETS OF 100 BRAND NEW RESISTORS

Including miniature and high stab. **12/6 POST PAID.** All useful values.

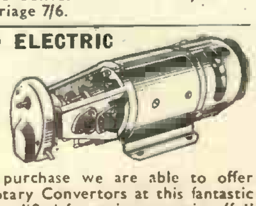
CONDENSERS 100 ASSORTED

Including mica, ceramic, metal tubular, etc. **15/-** post free.

SPECIAL H.D.

50 volts 10 amps transformers 250 volts input. Brand new and boxed. Conservatively rated. **55/-** each. Carriage 7/6.

A GEARED ELECTRIC MOTOR FOR ONLY 9'6



P. & P. 2/6.

Due to bulk purchase we are able to offer these 24 v. Rotary Convertors at this fantastic price. Easily modified for mains operation (full simple conversion details supplied). Complete with 400 to 1 reduction gearbox.

DECCA X.M.5 L.P. PICK-UP HEADS

Brand New 8/6. P. & P. 1/-.

TF 144 G STANDARD SIGNAL GENERATOR

85 Kc/s to 25 Mc/s fully serviced and in perfect condition **£36** post paid.

MOTORS 200 v.-230 v. 50 c.

Shaded pole. Made by Hoover for washing machines. Brand new **30/-** each P. & P. 7/6 also 115 v. A.C. **22/6** each. P. & P. 7/6.

AR 88 LF RECEIVERS

75-550 Kc/s and 1.5 to 30 Mc/s. 110/240 v. A.C. input. In as new condition and fully tested **£30.** Carriage and packing 25/-.

SPECIAL OFFER—TYPE 46 SETS

From 6.4-7.6 Mc/s. Complete with valves, crystals and coil box but having had the original send/receive switch removed. *Without other accessories.* This set is supplied with a substitute switch and full instructions and diagram for wiring in. At **18/6** each or **35/-** per pair. P. & P. 5/6.

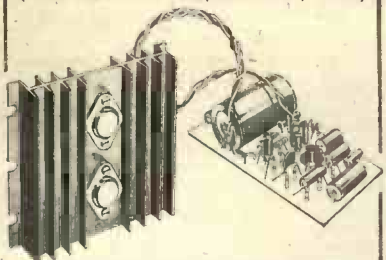
VARIABLE AIR-SPACED CONDENSERS

150 pfd with $\frac{1}{4}$in. spindle	4/6 each
75+75 pfd with $\frac{1}{4}$in. spindle	4/6 each
100 pfd with $\frac{1}{4}$in. spindle	2/6 each
100 pfd pre-set	2/– each
50 pfd pre-set	1/6 each

TERMS OF BUSINESS

CASH WITH ORDER. Handling charge of 1/6 on all orders under 20/- where P.P. is not otherwise stated.

10 WATT TRANSISTOR HI-FI POWER AMPLIFIER
(Based on W.W. Amplifier Nov., 1961.)



6 matched Transistors and Diode. Built on to 4 x 2½in. Printed circuit. Output Transistors bolted to heat radiator. Sensitivity 100 mV into 33 k/ohm for 10 watts. Output impedance less than ¼ ohm. Ideal for use with any valve or transistor pre-amplifier, tuner, pick-up, etc., etc.
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Mains Unit 80/- extra.
Supplied complete with Booklet showing suggested Pre-amplifiers, Mixers and uses for Public Address Hi-Fi and Stereo Hi-Fi. (Booklet separately 1/6.)
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7-TRANSISTOR AMPLIFIER AND PRE-AMPLIFIER
4 watt peak output for 15/16 ohm Speaker. Separate Treble, Bass and Volume Controls. Overall size 6 x 2½ x 2in. Ideal for portable or domestic Record Players, Radiograms, etc. Operates from 12 to 18 volts D.C.
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ERICSSON GS12C (CV-1740) Bi-directional 12-way Selector Tube. 25/-. BRAND NEW

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1985 and 1986 VHF equipment **25/-** P.P. 5/-
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50µA. 2in. MC. Square	35/–
2½-0-2½ mA. 2½in. MC. FR.	12/6
0/40/120 mA. 2in. MC. Square	10/–
50µA 1$\frac{11}{16}$in. MC. Square D.C.	39/6
500µA 1$\frac{11}{16}$in. M.C. Square D.C.	32/6
1 mA. 1$\frac{11}{16}$in. M.C. Square D.C.	27/6
5 mA. 1$\frac{11}{16}$in. M.C. Square D.C.	27/6
300 volt 1$\frac{11}{16}$in. M.C. Square D.C.	27/6
Tuning and Battery Indicator. Size ¾ x ¼in. dial, 400µA	24/6
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21.0060 ,,	33.0000 ,,	39.5555 ,,	40.0000 ,,	40.9633 ,,
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24.0060 ,,	34.4444 ,,	39.6296 ,,	40.1111 ,,	41.6667 ,,
25.0060 ,,	35.0000 ,,	39.6667 ,,	40.1481 ,,	42.0000 ,,
26.0060 ,,	35.5556 ,,	39.7037 ,,	40.1852 ,,	42.3070 ,,
26.6667 ,,	36.0000 ,,	39.7407 ,,	40.2222 ,,	42.5000 ,,
27.7778 ,,	36.6667 ,,	39.7778 ,,	40.2593 ,,	43.3333 ,,
28.8889 ,,	37.0000 ,,	39.8148 ,,	40.2963 ,,	45.0000 ,,
31.0000 ,,	37.7778 ,,	39.8519 ,,	40.3333 ,,	46.5 ,,
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Sound powered, generator bell ringing, 2 line connection. Fully tested, £4/19/6 pair. Carr. 5/-.

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1 mA.	2½" F.M.	D.C.	25/–
30/0/30 mA.	2½" F.M.	D.C.	9/6
350 mA.	2½" F.M.	D.C.	10/6
300 v.	2½" Proj.	A.C.	19/6
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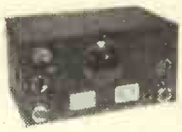

SENIOR MODEL. Supplied complete with full set of 9 coils covering 50 kc/s. to 30 Mc/s. Each receiver thoroughly checked and available as follows:
TABLE MODEL. As new condition £25.
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Two separate instruments housed in polished wood case, 6in. scales with knife edge pointers.
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Amps. A.C. and D.C. 25-50-150-200 A.
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F.M./A.M. 27-143 Mc/s. 110 volt A.C. (transformer supplied for 230 v. A.C.) Improved version of S-27. Tested before despatch. Brand new boxed with instruction manual. **£40** each Carr. £2

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Will detect all types of metal. Fully portable. Complete equipment supplied tested with instructions, 39/6. Carriage 10/6. Battery 8/6 extra.

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Brand new 1962 model. 3 speeds, 3 motors, digital counter, etc. With latest Bradmatic heads and interlock button. Supplied with spare spool, instructions, fixings, 10 gns. each. Carr. paid.

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Famous American Brand Tapes. Brand new, fully guaranteed. 5in.—600ft., 10/6. 5in.—900ft., 13/6. 5in.—1200ft., 17/-. 7in.—1200ft., 13/6, 7in.—1800ft., 18/6, 7in.—2400ft., 27/6. P. & P. extra. S.A.E. for full tape list.

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Supplied with Leads, Batteries and Instructions.

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0/15/150/1,000 v. A.C. and D.C.
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39/6. P. & P. 1/6.

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0/50K/500K/5 meg., etc.
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All primaries tapped 200/250 volts.
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Lead Acid. BRAND NEW. 2v. **1.5 A.H.,** 4 x 1½ x 1in., ¾lb., 5/6. P.P. 1/3. 12v. **0.75 A.H.,** 4 x 3 x 1½in. 2lb., 15/6. P.P. 1/6.

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Pri. 200/250 v. sec., 2,000-0-2,000 v. 500 mA., tapped 1,500 v. New. Boxed, £6/10/-. Carriage 15/-.

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1.2 Ohm 12 Amp. RHEOSTAT Geared slider type, new boxed, 15/6 each. P.P. 3/6.

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For 1½in. dia. panel hole.

0.50μA	39/6	0-300 v. D.C.	27/6
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0-1 mA	27/6	"VU" meter	42/6
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