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What to look for in the good sets besides the Mullard Picture Tube

The outward sign of a good set is the Mullard picture tube. What goes on behind the scenes is not so obvious but every bit as important. Typical of the contribution which Mullard make to the design of the modern TV receiver is the PL500 line output valve.

for picture quality

Mullard

scores all along the line

Dual-standard television receivers must accommodate the 625-line definition of BBC2 and the 405-line definition of BBC1 and ITA. On what part of the receiver does the increased line definition make its biggest impact? BBC2 requires a scanning frequency of 625 x 25 lines per second whereas BBC1 and ITA require one of only 405 x 25 lines per second (there being 25 complete pictures of 625 or 405 lines every second). Since the deflection power required rises with this scanning frequency, the line timebase must therefore be capable of supplying some 50% more power for BBC2, and this must be provided by the line output valve. This valve is required to operate with its anode at a lower potential than its screen grid. Thus, a large screen-grid current, and therefore high power, can result which can limit the usefulness of the valve. In the Mullard PL500, however, screen-grid current is minimised by the specially constructed anode. With this—see illustration—partitions recapture secondary-emission electrons from the anode which cannot therefore contribute to the screen-grid current.
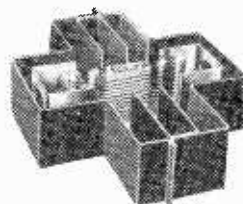
"Cavitrap" anode of Mullard PL500

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Earls Court In Retrospect

THE Jonahs who derived some morbid satisfaction from the prospect of a revived TV and Radio Exhibition which in floor area and numbers of exhibitors was but a pale reflection of former glories have been feeding their humour on the records of attendance which show a marked decline compared with those of the previous Show, in 1962.

Speculations as to the cause of this drop in the numbers of paying visitors range from the reduced scale of "live" entertainment and absence of leading popular entertainers, continued hesitancy to take advantage of the industry's change to 625 lines and the B.B.C.'s duplication of existing types of programme and, in the absence of colour, the lack of any comparable technical development to arouse the curiosity of inquiring minds.

While we are not prepared to argue on the validity of the first two theses we do not believe that public interest in technical matters in general is waning. On the contrary, any working models or dissected diagrams explaining the inner workings, such as were to be found on the Armed Services stands and here and there among the set makers' cabinets, could be relied upon to arrest aimless perambulation and in most cases to hold an audience which threatened to block even this year's wide gangways. And since it is relevant evidence, we may be permitted to report that sales of technical literature from our own stand were higher than ever.

From this we conclude that, if the attendance figures were low, the quality was higher and deserving of more grown up treatment than was apparent from the sales approach of some of our manufacturers. We are speaking now of the image (to use the current jargon) presented to the customer who sees only the public stands. By contrast the trade demonstration rooms were well furnished with chassis, tuner units and circuit diagrams in addition to the refreshments and comfortable armchairs, a brief glimpse of which is all most visitors see as they pass under the eye of the commissionaire at the door. We are not suggesting that firms can afford to extend hospitality on this scale to every show visitor; what we do suggest is that the technical features in the demonstration rooms, which are accessible to dealers and journalists and which, in our view, make the Show worth while, should be brought out into the open for all to see.

The future of the Show will be influenced by these considerations, but even more so by the attitude of its organizers and of the British radio industry as a whole towards foreign imports: though there must always be argument over the size of quotas the industry must learn to live with them. What useful purpose is served by compelling dealers and customers to visit peripheral shows to make comparisons? Let us make an end of pretence and bring them all under one roof (there is plenty of room!) before importers get set in the habit of running their own isolated parties. The German radio industry has for some years said that it would admit our products to its own exhibition and turn international if we would do the same for theirs. The Dutch Firato always has been international and the Paris show admitted foreign exhibitors last year.

Unless we have one big show with all available products represented under one roof we might just as well leave the customer to do his shopping in the local High Street, but if we do this we lose the stimulus of the special occasion which is necessary to induce some people (buyers and sellers) to do anything at all!

Does our industry think that by keeping foreign products out of the Show the customers will not find them; or does it think that comparison will be more difficult if the customer is made to take a bus or taxi to collect first-hand information? We have no doubts that he will find what he wants, and if it is foreign he may have to pay more or may think he is paying less for it. How much easier for him to decide on true value if he can see all the goods under the same roof.

E.H.T. UNIT

THE original e.h.t. supply, although perfectly satisfactory under normal conditions, can be troublesome after the unit has been on for several hours, and also where mains regulation is poor. As only the −750 V line is stabilized on the orginal unit, any large variations of mains supply voltage will cause noticeable changes in trace brightness. The other undesirable effect is that as the ferrite core of the e.h.t. transformer warms up after some hours of use, its characteristics change, producing changes in the output voltages.
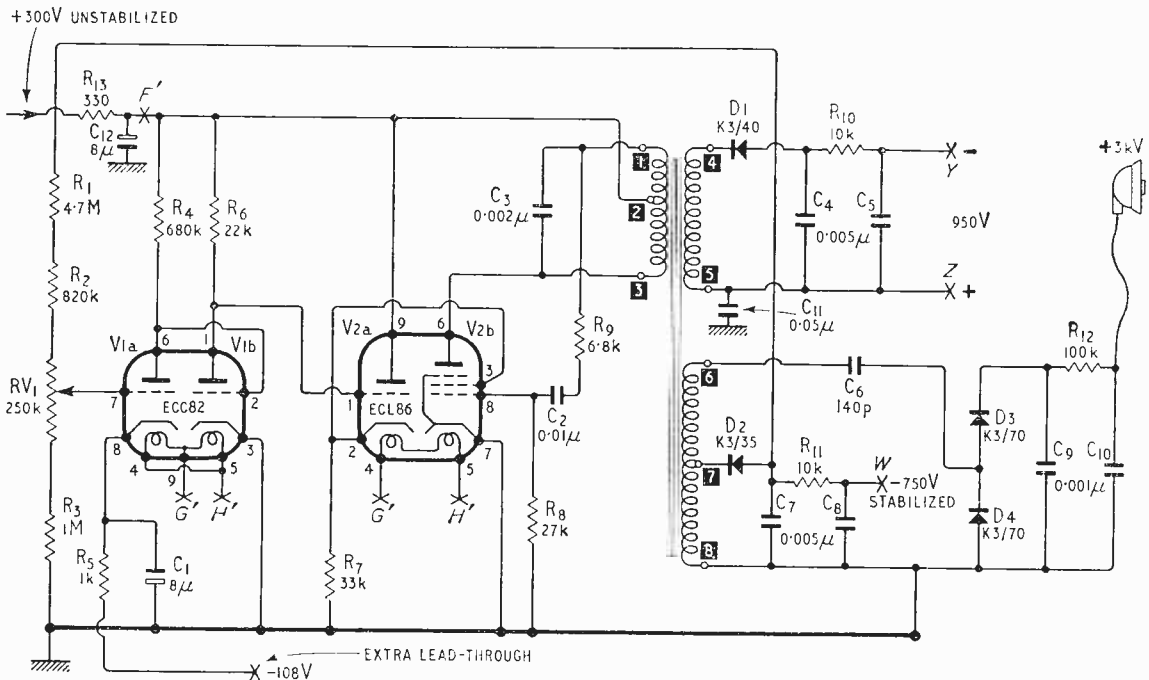
This new unit stabilizes all the lines against mains variations and also stabilizes the −750 V line against load changes. No overheating problems occur with the Ferroxcube core used. The derivation of the 3 kV p.d.a. supply from a voltage doubler makes for an easier-to-wind transformer, and also for a higher impedance (2 MΩ) supply which is desirable from the safety point of view.

The pentode section of the ECL86 (V2b) forms a Hartley oscillator running at about 50 kc/s. The primary voltage is stepped up and rectified to provide the three supply lines. The Hartley oscillator was chosen for use in this unit as experiments showed that the output voltages could be substantially varied by adjusting the screen-grid voltage of the oscillator.

The action of the stabilizer is as follows. If any change of voltage takes place on the −750 V line, a fraction of this change is fed back, suitably amplified, and applied to the screen grid of the oscillator to correct for the change in output. As it is required to correct for relatively slow changes in output a d.c. amplifier is needed. It is obvious that any changes due to mains variations on the other supply lines will also be corrected for. Should there be a change, however, in loading on the −750 V line the stabilizer will correct for this but there will be some change on the other lines. This change of voltage on the other lines with variation of load is, however, not important, as the only effect it will have is on the law of the brightness control potentiometer. For example, if the brightness is turned up, the load on the −750 V line increases and its output voltage tends to fall. The control amplifier increases the screen voltage of the oscillator to maintain the −750 V line at its correct value, but in so doing the voltage on the 950 V line will increase slightly thus altering the grid-cathode voltage of the tube.

For a stabilizer of this type to function effectively a large fraction of any change in output voltage should be fed back to the control amplifier. To obtain a large signal change at the input of the control amplifier it is necessary to employ a negative line for the following reasons. Assume that the cathode of the control amplifier is returned to chassis and that the required grid-cathode bias is about 7.5 V. The −750 V line must then be attenuated

Circuit diagram of modified e.h.t. supply unit.

ALTERNATIVE DESIGN FOR "WIRELESS WORLD" OSCILLOSCOPE USING A VALVE STABILIZER

Overall dimensions of this alternative chassis are the same as those of the original.

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

H — $3/8''$ DIA.

THIS COVER IS FIXED AFTER THE SIDE PANEL

VENTILATION HOLES

$5\frac{1}{4}''$

$3/4''$

$3\frac{1}{4}''$

$3\frac{1}{4}''$

$3\frac{1}{4}''$

$3\frac{3}{8}$

$3\frac{1}{2}''$

$1/2'' \times 1/2'' \times 3''$ ALUMINIUM ANGLE

$4\frac{1}{2}$

$7/8$ DIA.

$1/4''$

16 s.w.g. ALUMINIUM

DRILL ALUMINIUM CASE THROUGH THESE HOLES & USE $5/16''$ HIGH PILLARS BETWEEN

VENTILATION HOLES

$10''$

SIDE PANEL

$1/16''$ THICK PAXOLIN

$1/4''$ $5/16''$ $1/2''$ $1/2''$ $1/4''$

$2\frac{3}{4}''$

$9/16''$ $5/8''$ $7/8''$ $1/8''$ $3/4''$ $3/4''$ $1\frac{1}{4}''$ $1/4''$

$1/4''$

$1/4''$

$1/2''$

$7/8''$

$1/4''$

$1\frac{3}{16}$

$4\frac{1}{4}''$ $1\frac{1}{8}''$

$1''$

$1\frac{3}{16}''$

$1\frac{5}{16}''$

$1\frac{1}{16}''$

$1/4''$

$9\frac{3}{4}''$

GROMMET THROUGH METAL CHASSIS FOR E.H.T. LEAD

Transformer winding details.

by 100 times for correct biasing of the control amplifier. This also means that any error voltage fed back is also attenuated 100 times. For example with a 10% change in output, i.e. 75 V, the change in the input voltage of the amplifier is only 0.75 V. If, now, the cathode of the amplifier is returned to a stable negative source (-108 V is used), for correct biasing of the amplifier the output of the -750 V line need only be attenuated about 7.5 times and therefore the signal change at the input is 10 V which is adequate for correct working of the amplifier.

The use of the negative line connection to the cathode of the first stage of the d.c. amplifier also serves another essential purpose. As the output of the 750 V line is negative with respect to chassis, an increase in output voltage means that the 750V line goes more negative. To get the correct phase of control voltage at the screen of the oscillator value, it is necessary to use a two-stage d.c. amplifier. If the cathode of the first stage were connected to chassis the grid of the second stage would be positive. By connecting the cathode of the 1st stage to a negative supply the grid voltage of the second stage can be made negative to the required value by choice of anode load and anode current of the first stage. The high-impedance output of the d.c. amplifier cannot be connected directly to the low impedance screen-grid circuit, and so a cathode follower (V2a) is used between the amplifier and oscillator screen grid connection.

The dimensions of the unit are such as to allow assembly in the same box as the original e.h.t. supply. Provided the specified layout is followed no problems should be encountered with the unit. Particular care should be taken in the construction of the transformer as, at the fairly high voltages present, breakdowns in the windings could occur if careful layer winding and inter-layer insulation were not used. The transformer is constructed on two U-shaped Mullard Ferroxcube cores Type FX1036. A cardboard former of the dimensions shown in the diagram is first made and then painted with several layers of polystyrene solution. The primary winding consisting of a single layer of wire is then

Test Voltages

	Anode	Cathode	G1	G2
V1a	-1.7	-108	-110	—
V1b	$+90$	0	-1.7	—
V2a	$+290$	$+90$	$+90$	—
V2b	$+290$	0	-28	$+90$

Readings taken with 20kΩ/V meter; h.t. supply 295V; normal brightness.
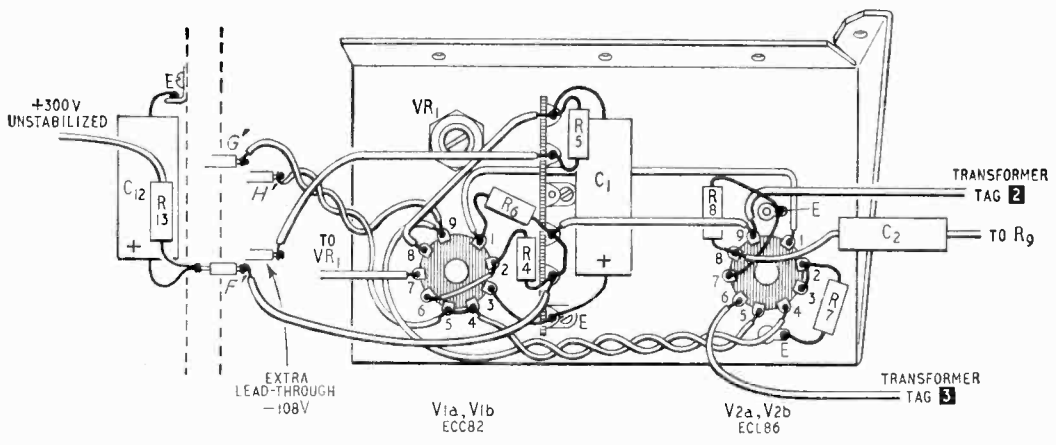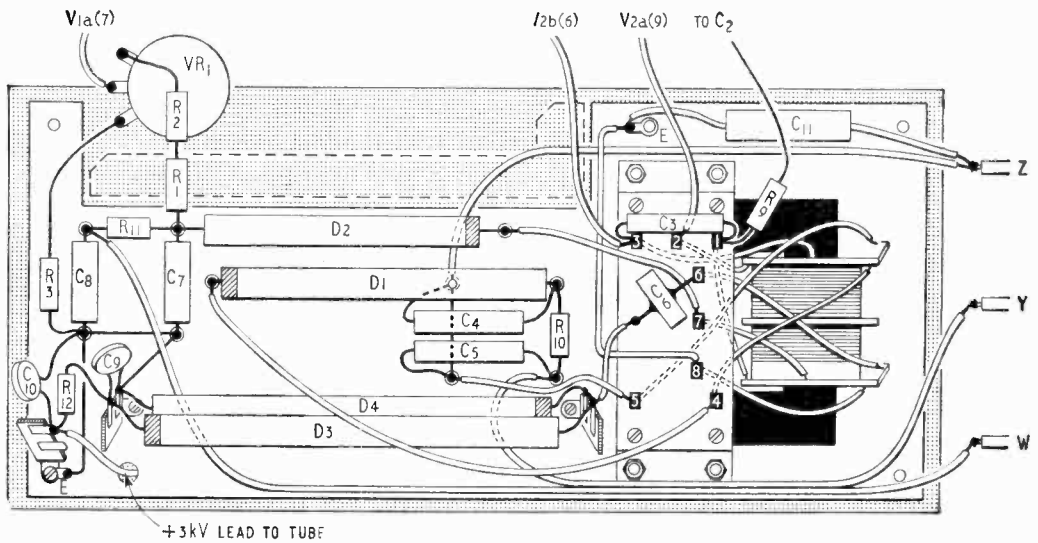
Practical wiring diagram.

put on. The connections are brought out from holes in the former and the whole winding is covered in a layer of thin paper and painted with poly-styrene solution. A dividing section is now glued in place with polystyrene solution to form two sections, the smaller of which is over the 20-turn grid winding of the primary. This smaller section is now layer wound with 340 turns, occupying about 11 layers. Each layer is painted with polystyrene solution and covered with paper before the next layer is put on. The bigger section is now wound with 570 turns, roughly 12 layers, centre tapped; each layer is again painted with cement and covered with paper. Two pieces of paper of 0.006-inch thickness are inserted in the gaps of the U cores and the whole assembly is clamped in its brackets, the ends of the windings being taken to the appropriate connections on the transformer tag board. The wire used for all the windings is 32 s.w.g., d.c.c.

Setting up of the unit is simple, and the only instrument is a 20 kΩ per volt meter with ranges up to 3000 V d.c. The correct power supply (295 V) is connected to the unit and after a few minutes warm-ing up time the −750 V line is set up using the pre-set control on the d.c. amplifier input. All the other

voltages should now be checked. The stability of the unit is such that with a load of 100 μA on the −750 V line, there is only a change of 3 V on this line with a mains variation of ±5%. This is more than adequate to ensure that there is no change in sensitivity of the tube.

Mobile Radio Channel Spacing

THE limited frequency bands available for mobile radio operation in the U.K. has inspired Pye engineers to develop equipment with 12.5 kc/s channels as compared with the current 25 kc/s spacing in this country and 30 kc/s in the U.S.A. In the United States, of course, they have the additional advantage of geographical spac-ing and also utilize a wider frequency band. The new Pye equipment, which relies on LC filters for frequency separation, was demonstrated at a recent exhibition of communications equipment in London. During a mobile demonstration in the West End there was little, if any, breakthrough to adjacent channels when once the vehicle was half-a-mile from the transmitting aerial which was on the roof of the Hilton Hotel. Amplitude modulation is used. It is understood the Post Office is to conduct tests with the 12.5 kc/s equipment.

NATIONAL TV & RADIO SHOW

TECHNICAL HIGHLIGHTS AND DESIGN TRENDS

OFFICIALLY known as the "Thirtieth National Radio and Television Exhibition" the TV and Radio Show, as it is described on the catalogue, provides a good opportunity for seeing most if not all the significant developments in the British domestic radio industry during the past year.

The transistor, for many years synonymous with and confined to the cheaper and noisier personal portables, has now proved its worth for really high-quality sound reproduction and is in process of establishing itself in low-noise television tuners.

Although the major steps of adopting an extra line standard and of moving to ultra-high frequencies were surmounted two years ago, experience has indicated many opportunities for improvement both in television receivers and aerial systems.

Television Receivers

Now that B.B.C. 2 is established, at least in the London area, all receiver manufacturers were showing their second or even third generation dual-standard receivers. Mean level a.g.c. is, however, still universally employed and in most receivers some form of a.c. coupling is used to the picture tube. The 23 in tube size appears to be increasing in popularity, but considerable interest was aroused by the appearance of the 11 in mains "full performance" portable (K.B., R.G.D.). Transistor TV receivers, apart from the 8½ in Perdio were still noticeably absent although Ever Ready were demonstrating a 7 in receiver powered from a dry battery, and Mullard had introduced a narrow-neck 11 in tube for use in "full performance" all-transistor receivers. Tran-

sistorized u.h.f. tuners were featured in several mains receivers (K.B., Thorn) which probably heralds the hybrid receiver as a production item in this country.

System switching and programme changing have generally been greatly simplified in that the system switch is often mechanically coupled to the tuner switch so that the viewer automatically changes from 405 to 625 when switching to B.B.C. 2. Push-button tuning for both v.h.f. and u.h.f. tuning was also featured, notably in the Bush and Murphy receivers, high-stability oscillators being employed to avoid the necessity for automatic frequency control.

Flywheel synchronizing is available in all receivers, but in some cases it is an optional extra for use in fringe areas only. The sine-wave line oscillator circuit appears to be gaining in popularity, due to its high degree of frequency stability.

Separate tuners are used for u.h.f. and v.h.f. reception, but on u.h.f. the v.h.f. mixer is often employed as an additional i.f. amplifier. Most manufacturers employ 2 vision i.f. amplifiers (the first stage being common to sound and vision on 405 lines) and one sound i.f. amplifier (Alba, Thorn, Decca, Sobell). In these receivers frame grid valves are used. Philips, however, employ a 3+2 i.f. amplifier. In many receivers (Thorn, Alba) the video amplifier is employed as an inter-carrier sound amplifier (6 Mc/s) but in others (Philips, Bush) the inter-carrier signal is taken from the video detector. In the Sobell range of receivers the inter-carrier sound signal is derived from the cathode circuit of the video amplifier.

Mean level a.g.c. is used exclusively, the a.g.c. potential being derived from the grid circuit of the
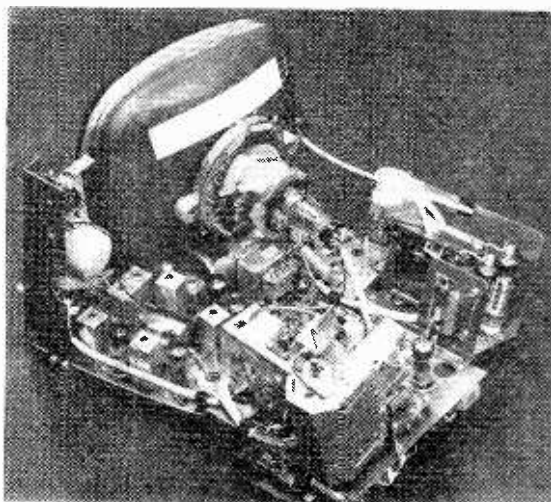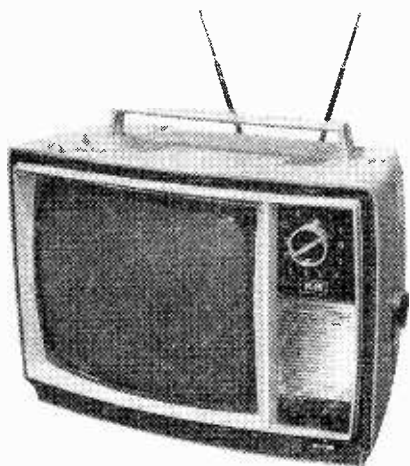
K.B. "Featherlight" 11-in mains portable television receiver and (right) the chassis with units hinged back for servicing.

REVIEW

IN BRITISH RECEIVERS

synchronizing pulse separator valve. However, in the basic chassis designed by Plessey and used in various forms by several firms, an amplified mean level system is incorporated, the a.g.c. amplifier being driven from either the anode or the cathode of the video amplifier depending on the system in use. With these types of a.g.c. systems the mean level of the a.c. component of the video signal is held constant and on negative modulation a very large d.c. "sit-up" on low-key scenes would tend to drive the video amplifier beyond cut-off if d.c. coupling from the video detector were retained. In most receivers, the video amplifier is d.c. coupled on 405 lines and a.c. coupled on 625 lines to overcome this problem. Conventional sync separator circuits are employed since there is no special requirement for noise protection in the u.h.f. bands.

In most receivers flywheel synchronizing circuits are employed although in one or two they take the form of a plug-in unit. The double diode phase detector is commonly employed, but Philips use a triode circuit. Line oscillators show increasing tendency towards a sine-wave circuit in which the oscillator is formed by the pentode section of a triode pentode, the triode being used as a reactance valve to control the frequency. Notable exceptions are in the Thorn receivers where a blocking oscillator is employed and in the Plessey chassis where a rather unusual form of multivibrator circuit is used.

The basic Plessey circuit is shown in Fig. 1 in which it will be seen that a triode heptode valve is used as a multivibrator with cross coupling between the second control grid of the heptode section and the triode. The d.c. control potential from the phase
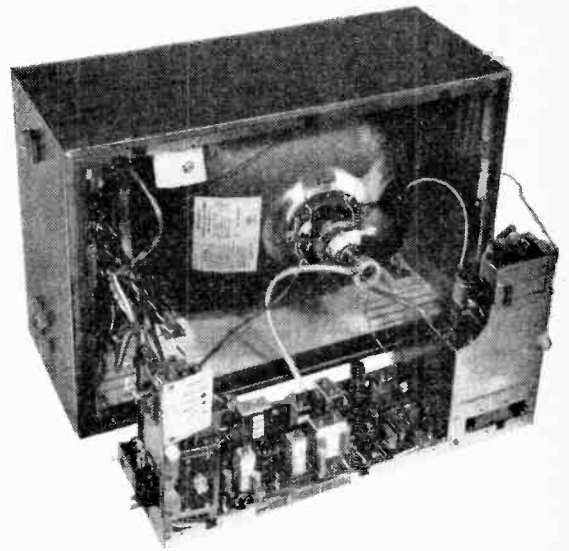
Thorn " cool-running " layout with main unit removed. A mains transformer is used instead of the usual heater series resistance.

detector is applied to the first control grid to vary the heptode cathode current. Variation of the heptode current causes the drive to the triode to vary with amplitude and hence the frequency is varied. The advantage of this circuit arrangement is that the multivibrator offers a very high impedance load to the phase detector circuit. Stabilization of the free running frequency is achieved by the tuned circuit connected in series with the heptode anode load resistor.

Stabilized line deflection circuits are now almost universally employed. In these circuits a pulse from the line output transformer is rectified by a non-linear (voltage-dependent) resistor (v.d.r.) and a negative bias applied to the grid of the line output valve (Fig. 3). If the flyback pulse varies in amplitude
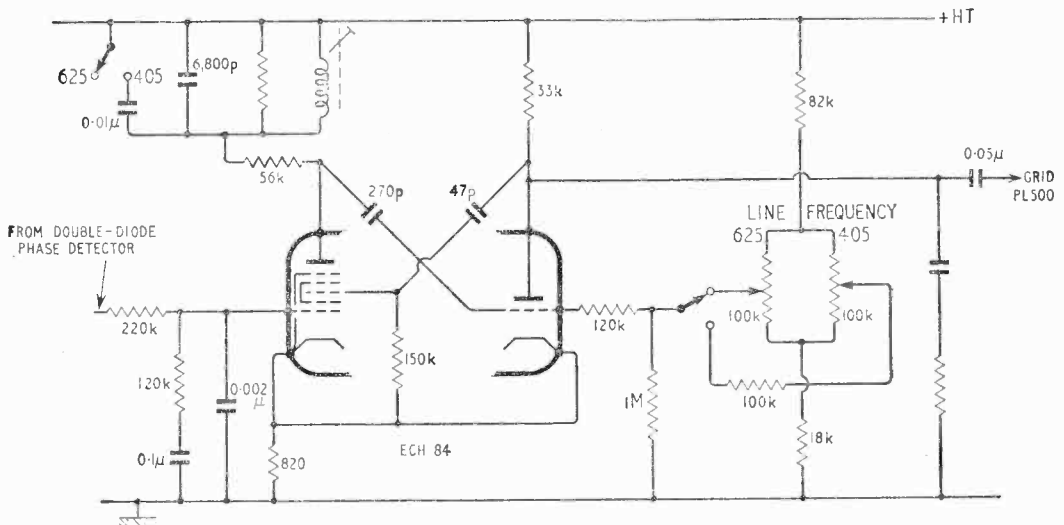

Fig. 1. Triode-heptode line timebase circuit (Plessey).

the grid bias of the line output stage varies and tends to maintain the flyback pulse at a constant amplitude. The line output valve is operated above the "knee" of its anode characteristic in this type of circuit and this avoids the generation of Barkhausen oscillations which could interfere with u.h.f. reception. Stabilization of the vertical timebase is most often achieved by operating the oscillator from the line boost potential with an additional v.d.r. to stabilize the potential applied to the oscillator.

The mechanical design of receivers has improved considerably over the last two years most chassis being very clean and accessible for servicing. Particular attention has been paid to the use of non-inflammable materials in particular in the construction of the line output transformer. A vertical chassis or a horizontal chassis mounted at the bottom of the cabinet tend to be the most popular with fold-out arrangements to facilitate servicing. Printed circuit panels are exclusively used, sometimes one large panel (Thorn) or two smaller panels carrying the i.f. and video circuits separated from the timebase circuit. An unusual feature of the Thorn receivers is that a small mains transformer is employed in place of the more usual mains dropper. This considerably reduces the ambient temperature in the receiver, which it is claimed, will improve the long-term reliability. In the 11 in K.B. receiver a diode in series with the heater chain is used in place of the mains dropper, again to reduce power dissipation by converting the heater waveform to that of a half sine wave.

The Ever Ready Company feature a fully transistorized portable receiver with a power consumption of only 3 watts, (405 lines) and 3.3 watts on 625 lines. This receiver, designed in conjunction
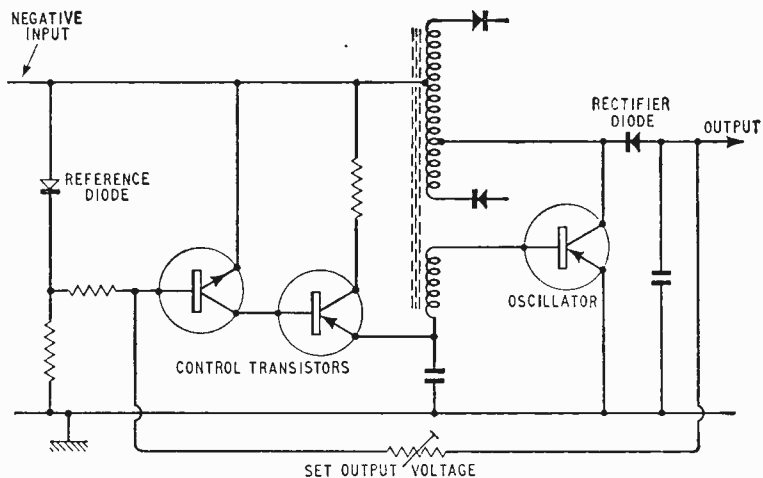

Fig. 2. Stabilized power supply circuit used in the prototype Ever Ready battery-driven television receiver.

with the Ferguson laboratories, shows that operation from non-rechargeable dry batteries is feasible. The price of the battery which has been specially developed for this purpose is expected to be 12s 6d and is estimated to have a life of some 40 hours. The receiver incorporates a 7 in picture tube with a 42° deflection angle and 28 mm neck. The weight of the receiver including battery, is approximately 16 lb and it measures 9 in × 8 in × 13 in. The picture tube is a Mazda experimental type V3271. It is just over 12 in in length and is operated at 8 kV. The unusual features of the receiver are, first, that the e.h.t. is not obtained from the line timebase but from a separate e.h.t. generator consisting of a free-running blocking oscillator driving a 5-stage Cockroft-Walton multiplier. The maximum load capability is about 35μA. The second unusual feature is the stabilized power supply generators, the basic circuit of which is shown in Fig. 2. To minimize the dissipation which would occur in a conventional regulator a free running blocking oscillator is used. The frequency of the blocking oscillator is varied by the control circuit which employs two transistors and a Zener diode to maintain a constant output voltage. The stabilizer operates with an input voltage variation of between 7½ and 12¼ volts.

The receiver employs a 3-stage vision i.f. amplifier, video detector, emitter follower and video output stage. A mean level a.g.c. system is used with a damping diode to control the gain of the i.f. stages. The sound channel consists of 3 i.f. amplifiers and a 4-transistor audio output circuit. A 3-transistor synchronizing pulse separator is employed and the vertical timebase consists of a blocking oscillator, emitter follower, and output stage. The line timebase consists of a blocking oscillator, controlled by a conventional phase detector which drives the
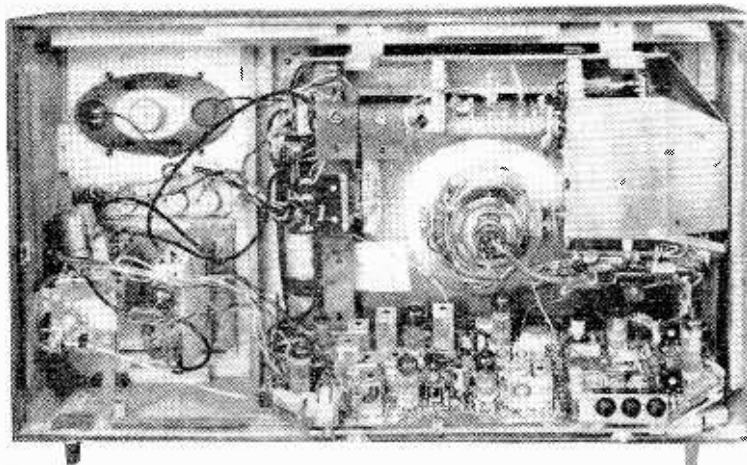
G.E.C.-Sobell-McMichael television chassis in which the main unit is placed near the bottom of the cabinet and can be tilted forward for ease of access during servicing.

output stage. The complete receiver (405 line version) employs 31 transistors and 25 diodes, 10 being employed in the e.h.t. generator.

A complete dual-standard hybrid receiver was shown by Mullard to illustrate the optimum exploitation of available types of valves and transistors. This receiver features a completely transistorized audio channel in addition to the i.f. amplifiers and tuners so that the sound signal is available immediately the receiver is switched on. Also incorporated in the receiver is a brightness correction circuit for reinserting the d.c. component in the displayed picture. The degree of transistorization achieved in this receiver has reduced the power consumption from about 160 watts for a conventional receiver to some 95 watts. A completely transistorized full performance miniature receiver employing an 11 in picture tube (A28/13W) operating at 11 kV was also shown by Mullard. This tube employs a 90° deflection angle and a 20 mm neck diameter to reduce the scanning power requirement. Also featured in this receiver was the new video transistor BF109 and the fast switching line output transistor AU103. The receiver has a power consumption of about 13 watts (625-line operation) and is designed for opera-
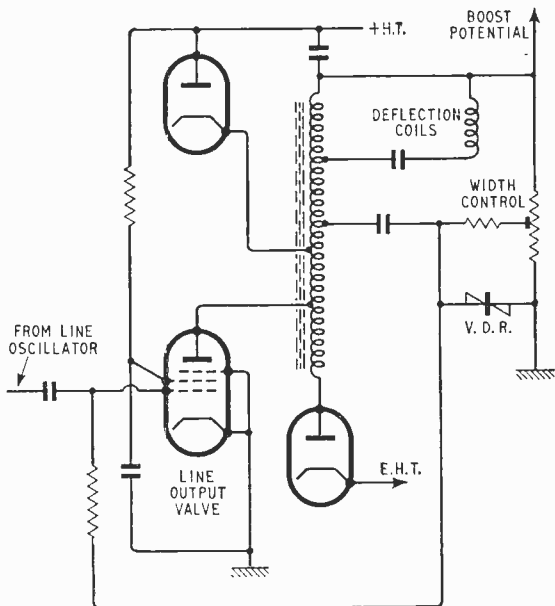
Above: Fig. 3. Basic stabilized line deflection circuit.
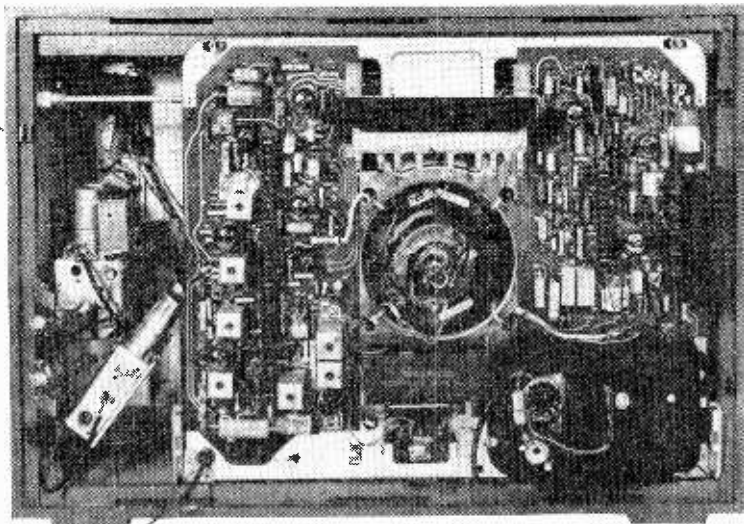
Defiant (C.W.S.) chassis (left) in normal working position and (below) tilted forward for access to back printed circuit.

tion from the normal supply mains or rechargeable battery. The receiver employs 29 transistors and 18 diodes. A 3-stage vision i.f. amplifier precedes a double diode video detector circuit which has been developed to minimize switching. The video emitter follower drives the sync separator a.g.c. system and video output stage. A 2-stage sound i.f. amplifier is used to drive a 4-transistor audio circuit output. A 3-stage vertical timebase is employed which incorporates a blocking oscillator, emitter follower and output stage. The line oscillator is a sine-wave type for good frequency stability and ease of system switching with its frequency controlled by a reactance transistor. A shaping amplifier drives the output stage which also is used to generate the e.h.t. A 3-transistor stabilized circuit is employed to minimize supply potential variations.

A simple vertical timebase circuit was demonstrated by Thorn-A.E.I. In this circuit the flyback pulse from the anode of the vertical output valve is fed back to a triode to form a multivibrator. One
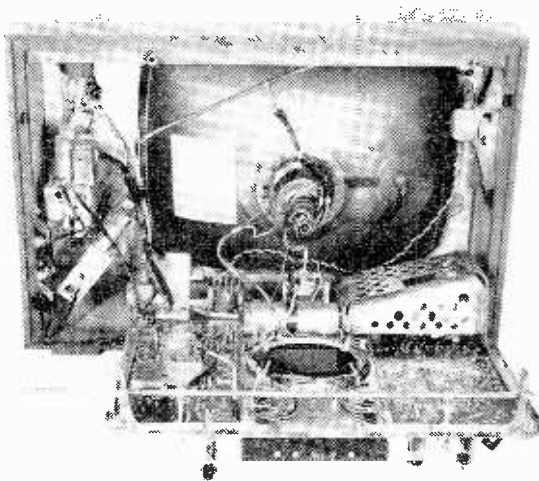
of the problems with this type of circuit is that of line pulses from the deflection coils being fed back to the oscillator and destroying the interlace. Particular care has been taken in the feedback loop and in the construction of the deflection coils to minimize such feedback and this together with the short conduction time for the oscillator ensures excellent interlace. For reception of noisy signals a diode in the synchronizing channel is used to clip the separated vertical sync pulse and so to maintain a more stable interlace. The circuit was developed around the 30PL14/PCL88 or PCL85 valves. A stabilized line output stage using the PL500 valve and an e.h.t. of 18 kV was also demonstrated.

A development in picture tube construction seen last year on the Continent, but new to this country was shown by both Mullard and Thorn-A.E.I. under the names of "Panorama" and "Rim-guard" respectively. These tubes feature a steel band around the edge of the screen which completely prevents implosion and hence no plate glass or plastic implosion guard is necessary in the receiver. Also mounted on the steel band are fixing lugs so that the tube may be very simply mounted in a cabinet. This tube will undoubtedly offer new opportunities to receiver designers and stylists, and at the same time the absence of an implosion guard reduces reflections caused by room lighting.

Looking to the future, present trends seem to indicate an increase in the e.h.t. potential applied to the tubes to increase the brightness and further improve definition. Operation at e.h.t. potentials of between 18 and 20 kV instead of the more normal 16 kV were shown by both Mullard and Thorn-A.E.I.

Colour television was noticeably absent from the Show but a new range of valves for colour deflection circuits by Mullard reminded us that technical preparation continues.
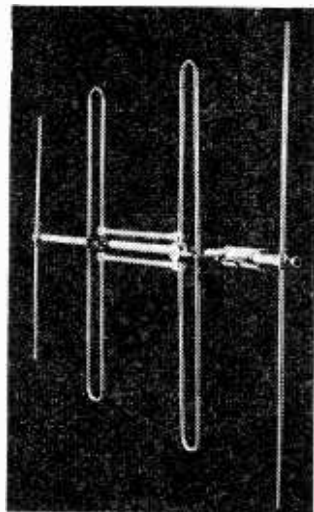
Aerials

The importance of the aerial and especially the direction of the array was emphasized in a convincing demonstration at the B.B.C. stand. Visitors were able to orientate a model array on a chimney stack and see the degradation in the television picture quality when the aerial was swung away from the transmitting aerial towards a "block of flats" diametrically opposite. Incidentally, in a recent I.T.A. "opinion survey" it was found that two-thirds of
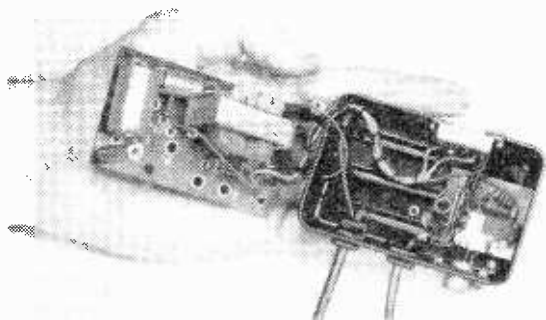
Belling-Lee broadband television aerial for Channels 6-13 showing the two folded dipoles.

viewers complaining of poor reception had inadequate aerials.

Apart from aerials there were but few components and accessories to be seen at the Show. However, one can hardly talk of trends in aerials as their design is dictated mainly by the frequency band or bands to be received. The emphasis at the Show was on u.h.f. aerials but the recent introduction of BBC-1 transmissions at the top end of Band III has called for wideband aerials to cover both the I.T.A. and B.B.C. transmissions in this band. Most of the aerial manufacturers have introduced these.

Belling-Lee have achieved the necessary broadband coverage (Channels 6-13) by using two folded dipoles, of different lengths, joined in parallel by a matching bar. A dipole reflector and single director complete the array. Labgear use a skeleton conical arrangement resembling the mathematical signs "much greater than" or "much less than" with space impedance termination to secure a uni-directional polar diagram. It is claimed to have a Band III performance equivalent to a six- or seven-element array. These "Spacematch" aerials, as they are called, also operate as a broadband half-wave dipole on all Band I channels and as a full-wave dipole on Band II.

A wide variety of u.h.f. arrays, some featuring novel arrangements of elements, were to be seen. Among the set-top types the bow-tie and "V" arrangements predominated and some of these embodied built-in amplifiers in the mounting base. Aerialite have introduced a new "Golden Gain" range of u.h.f. aerial with gradually increasing spacing of the directors (either 11 or 18). Folded, instead of multi-rod, reflectors have been introduced by J-Beam on some of their arrays. They are used on the u.h.f. section of their "Tribeam" three-band array which incorporates a Band I dipole, three elements for Band III and six-element u.h.f. section.

Incidentally, one u.h.f. aerial seen at the Show had uncropped mounting bolts of about half the length of a Band IV dipole which at first appeared to be part of the array!

The question of whether or not to use a balun to connect the unbalanced coaxial feeder to the balanced aerial is still hotly contested—the "fors" are Anti-

The mains version of Labgear's u.h.f. aerial amplifier with the cover off and the power pack removed.

ference and J-Beam and the "againsts" Aerialite, Belling-Lee and Labgear. A new type of inverse balun has been introduced by J-Beam.

Most of the aerial manufacturers, and also Perdio, were showing transistor aerial amplifiers. Some of these boosters are for mains operation but there are also several battery versions. Similarly there are models for masthead mounting and others for clipping on to the back of the receiver.

Sound Receivers and Reproducers

The transistor, having ousted the valve from all battery portables, is now making inroads into mains-operated receivers and radiogramophones—even the most expensive high-quality types. Transistors do not in themselves give lower distortion than valves, which will still be the logical choice with high-impedance loudspeakers of the electrostatic type, but with the popular low-impedance moving-coil loudspeaker the output transformer can be dispensed with if two power transistors in a half-bridge circuit are used in the output stage. These are generally directly coupled to a complementary-pair driver stage and, with overall feedback, distortion can now be reduced to 0.1% or less. But other circuit variants are capable of producing equally good results and it is safer to say that most of the circuits discussed in this journal last year by O. Greiter ("Transistor Amplifier Output Stages") will be found to have their adherents. Input stage background noise has been further reduced by the introduction of special silicon transistors such as the Mullard BC107.

Now that transistors can compete with valves on an equal footing as regards background noise and distortion, manufacturers have been quick to exploit their other advantages when used in mains-operated receivers and amplifiers. No warm-up period, with "instant" music or football results, is an obvious technical bonus which will carry weight with the customers, but the designer is more likely to dwell on the relief from hum troubles due to small size and low impedance of circuits, the greater reliability of components due to lower potentials and less heat, and the prospect of indefinitely long life in the transistors themselves. By now most servicemen have learnt to avoid damage when using a soldering iron or applying continuity test voltages.

Among sound broadcast (radio) receivers, valve
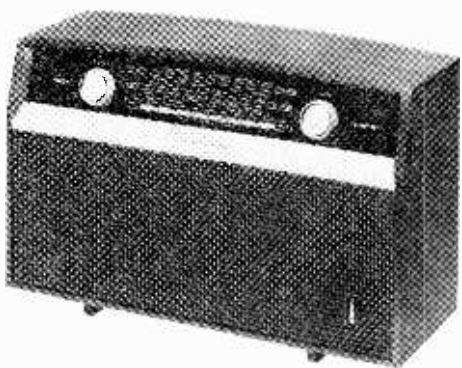
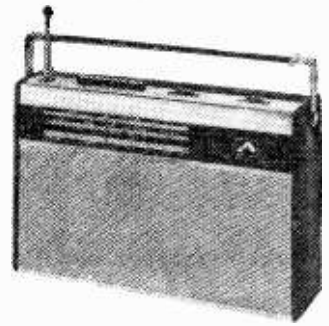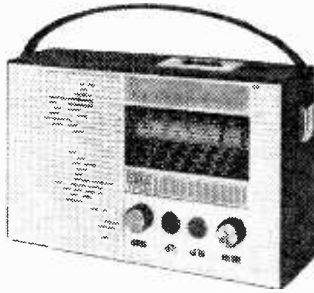*Perdio "Marco Polo" transistor receiver with 9 wavebands.*
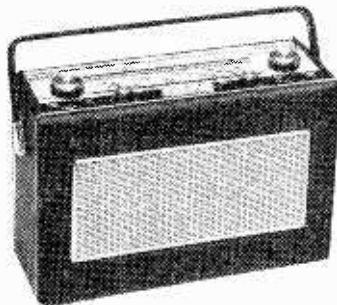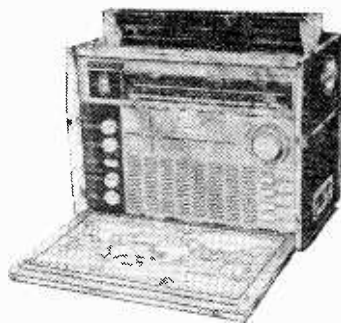
Hacker "Sovereign" portable with a sensitivity of 2 μV.

types are hard to come by, but there is still a specific demand from conservative listeners and "by special request" Bush have produced the VHF81 with f.m. and medium- and long-wave a.m. coverage, push-button wavechange, and 2 watts output. But the main trend in this country as well as on the Continent is towards the large, high-performance transistor transportable for which the vogue started some years ago in the United States. The shiny black and chromium styling is well exemplified by the Perdio "Marco Polo" which is also typical in having a world local time map inside the front cover. There are in all 9 wavebands (v.h.f./f.m., l.w., m.w. and six s.w. covering 1.6 to 30 Mc/s), and a beat frequency oscillator is included for c.w. reception. Automatic frequency control is provided for v.h.f. for which a circuit separate from the a.m. side has been incorporated. Hacker Radio in their Model RP 18 "Sovereign" receiver have also used completely separate tuners for a.m. and f.m. and can claim a sensitivity better than 2μV for 10 dB s/n ratio at 30% modulation with full limiting at 5μV on the v.h.f./f.m. band. Sensitivities on the medium and long-wave range average 6μV, but 2μV at 200 metres where the "extra-territorial" stations congregate. This set is more subdued in appearance than most, but boasts an 8 in × 5 in loudspeaker fed with up to 1.2 watts from a transformerless d.c.-coupled circuit. It has a.f.c. on f.m. and an inter-station noise suppression button.

In the smaller portables there is also a trend towards greater range and the Alba "Olympic" with its extra short-wave range has fine tuning which is also available for accurate adjustment on Luxembourg where the L/C ratio is high. The Pam Model 5222 has four bands including v.h.f. and a S.W. range, and Model TB81 T/E by the same firm has a trawler band as well as short, medium and long waves.

Among the larger radiogramophones and stereo record reproducers the witch word this year is "solid state" (which has been with us since the

Bush VHF81 table-model, representing the older generation of receiver for which there is still a steady demand.
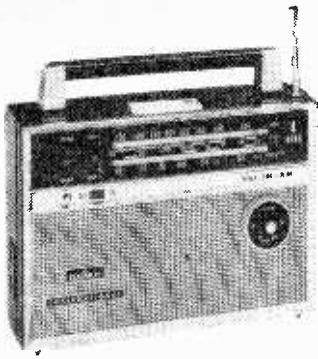
Typical of the new generation of sound broadcast receivers, R.G.D. " International ", the Decca TP99, and H.M.V. 2122.

dawn of physics and today means "semiconductors"). Every principal manufacturer has gone over to transistors in this luxury class, notable examples being the Decca 700 Mark II (with adjustable loudspeaker angles for optimum stereo effect in any given room), the C.W.S. Defiant AF 85 (which like many other stereo reproducers is adaptable for stereo broadcasting), the Pye Model 1207, the Philips 541A Model 2312. There is plenty of choice of cabinet styling, both traditional and *nouveau vague,* and in the latter category we would not hesitate to put the Pye "Achoic" stereo reproducer which provided one of the talking points for "hi-fi" visitors to the Show. Pye have always had a soft spot for "black

boxes" which produce pleasant sound in a rather mysterious way, but this latest in the line was open for all to see; indeed the "exploded" version revolving on their main stand was one of the few technical novelties to be found outside the private demonstration rooms. The somewhat amorphous title chosen for this instrument evokes among hi-fi enthusiasts the well known term "anechoic," meaning free from echoes, but the system does, in fact, depend on first reflections from the walls of a room—preferably adjacent walls in a corner. This in itself is not a new idea, having been seen on the Continent and reported in this journal four years ago. What is interesting is the use of three small-diameter moving-coil units in each channel with a special low-frequency pair with a common feed from both channels having a large-amplitude linear movement. Transistors are used throughout and the output in each channel is 5 watts from a transformerless Class B circuit. (Fig. 4.) The automatic record changer is fitted with a lightweight (2 gm) ceramic stereo pickup in a retractable tone-arm housing developed by C.B.S. Laboratories of Stamford, Connecticut.

Garrard have broken fresh ground with their LAB 80 transcription turntable, which can be converted to operate as an automatic record changer merely by the insertion of a special centre spindle. This spindle eliminates the need for an overarm and
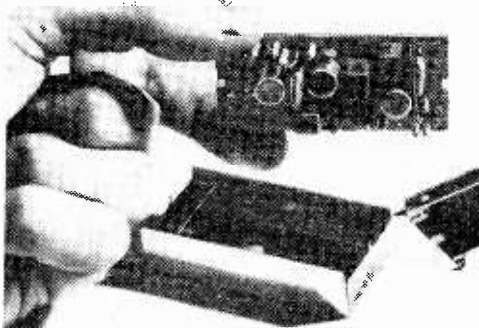
Set makers can now buy ready-made modules for assembly in transistor receivers. The example illustrated is the Mullard Type LP1156 r.f./i.f. fully screened mixer/amplifier for use with external short-wave (up to 26 Mc/s), medium-wave and long-wave coils. It measures 2.44 × 1.19 × 0.64in.

K.B."Discomatic" record player with a capacity of 40 7-in discs.
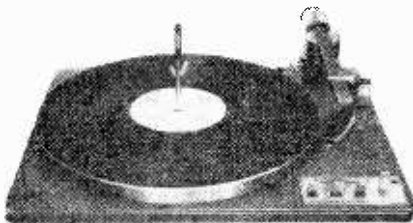
Garrard LAB 80 transcription gramophone turntable with conversion spindle for automatic record changing. The tone arm, designed for minimum torsional resonance, is of selected wood reinforced with metal.

490
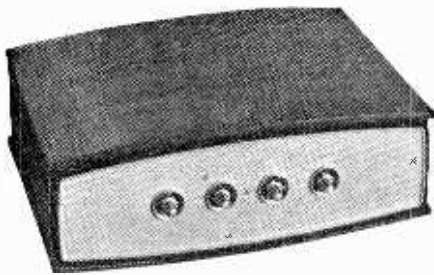
Pye " Achoic " stereo record reproducer.
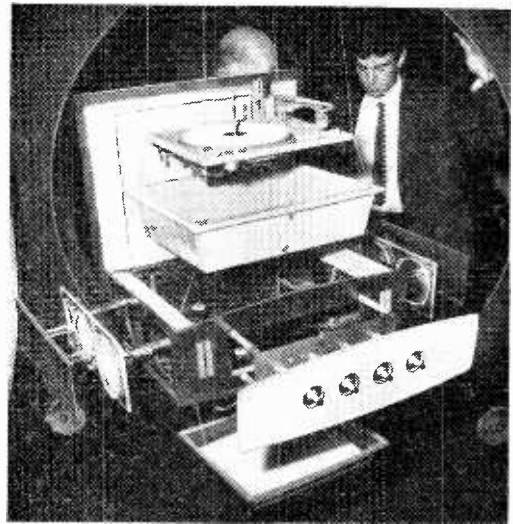
Technical details of the Pye " Achoic " box were effectively displayed in this " dissected " version.

will accommodate 8 records (two speeds only, 33⅓ and 45 r.p.m.). The pickup arm, of composite wood and metal construction, is designed to eliminate torsional resonance and is provided with a calibrated adjustment for stylus pressure. The inward force resulting from stylus friction is offset by a lever operating an auxiliary counterbalance. The conducting rubber turntable mat is held concentric at the edge as well as at the centre. Controls are by a row of tab switches and the auto-trip mechanism is operated through the repulsion of two small magnets with like poles opposed.

While on the subject of record players, and to conclude, mention may be made of the K.B. "Discomatic" portable transistor record player. This holds forty 7-in discs and enables immediate selection to be made of either side of any record. The playing mechanism travels on guides behind the record store and clamps and plays any record which is rolled out and finally returned to the store in a sequence selected by push buttons.
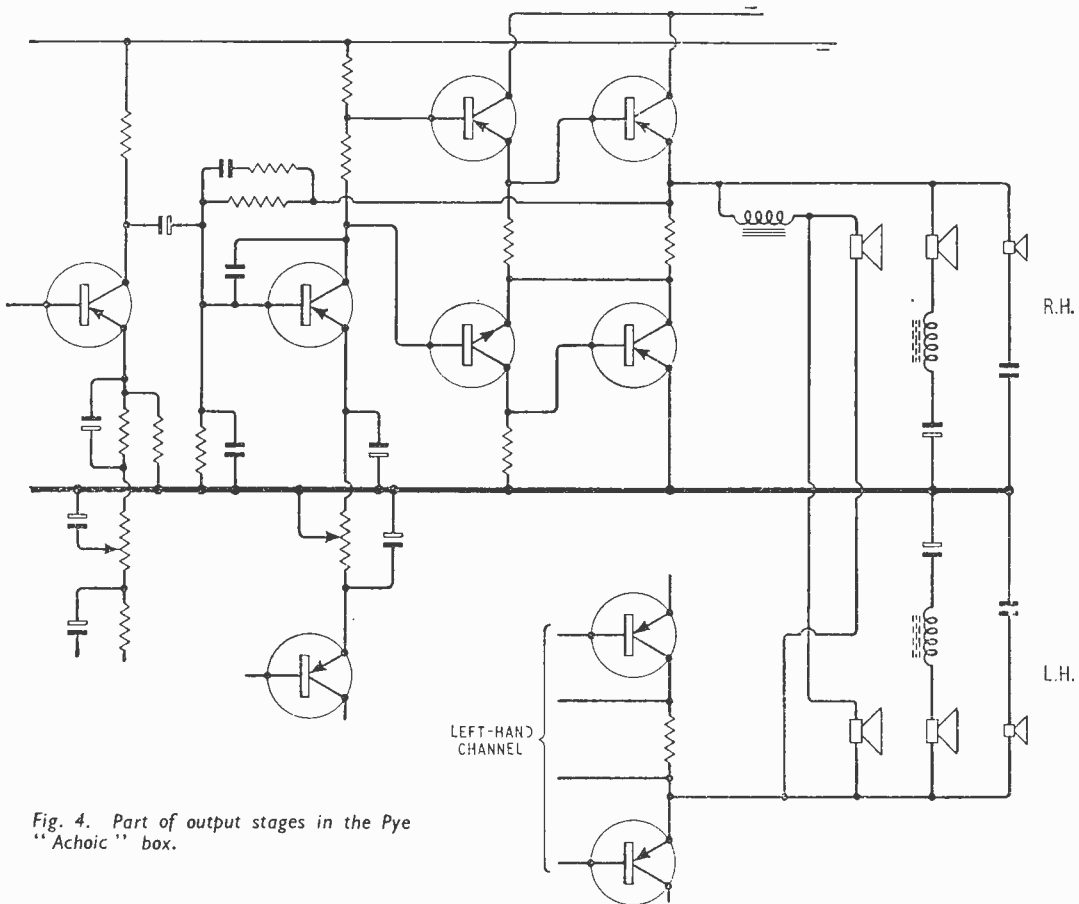
Fig. 4. Part of output stages in the Pye " Achoic " box.

Outside Earls Court

INTERNATIONAL PRODUCTS SEEN AT OTHER LONDON SHOWS

IN addition to the wide range of products displayed at this year's National Television and Radio Exhibition, some 15 independent shows, exhibiting equipment from most of the radio manufacturing countries of the world, were held in London at the end of August. (A detailed list was given on p. 461 of the previous issue.) Most of the equipment seen by *Wireless World* staff was of good quality—both in cabinet and chassis design—and it is evident that importers are finding that the public at large are becoming more selective and are now prepared to pay for quality.

Another interesting fact which came to light was that most of the exclusive distributors of foreign made equipment in this country now have good servicing organizations backing their sales. The distributors of the Sharp range of Japanese equipment (Sharp Sales and Service, 16-18 Worsley Road, Swinton, Manchester) show their faith in the lines they sell by giving a five-year guarantee in the first year of which they make no labour charge for any repairs should a unit fail through faulty workmanship or components.
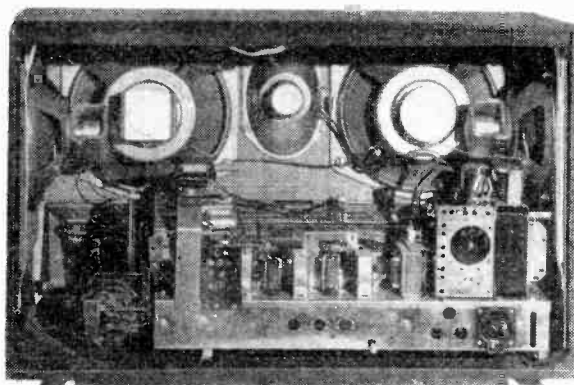
Hi-fi Equipment

Quite a number of the outside exhibitors had hi-fi equipment on show. The highlight of the German Loewe Opta display (organized by the United Kingdom

Rear view of the " Freiburg " table radio from Saba Electronics. Its a.m./f.m. chassis, which has provisions for a multiplex unit, is very similar to the " Freiburg Studio " receivers used in their hi-fi outfits.

distributors Highgate Acoustics, 71-73 Great Portland Street, London, W.1) was the Model LO 40 a.m./f.m. stereo receiver, which forms part of an integrated reproducing system. This receiver is fitted with a multiplex unit in anticipation of the introduction of an f.m. stereo service in this country. Valves are still used in the front-end, which covers the l.w., m.w., s.w. and f.m. bands, and transistors are used in both of the integral 20-watt amplifiers. Although any brand of speakers can be used, and for that matter any transcription unit, a

pair of their own speaker units and a Garrard Type A transcription unit are assembled in the Luna-Phono-Stereo outfit.

Another similar outfit from Germany was shown by Saba Electronics Ltd., of Eden Grove, London, N.7. This outfit is built around their four-waveband "Freiburg " a.m./f.m. studio receiver which features—as a number of other radios and radiograms in their range—a remote control unit. With this, one can switch the outfit on from the armchair and have full control of the radio section on the medium-wave and the f.m. band. Changing of stations is effected by means of a single hold-on switch, which when operated causes the receiver to hunt—either to the left or to the right dependent upon selection—until the next station in the selected band is reached; the station is then automatically fine-tuned. This procedure is continued until the station you require comes up. Adjustment of the level of volume and operation of the bass-cut control can also be effected through this unit, which is electrically connected to the receiver. Although a stereo decoder is not fitted to this receiver, one can be fitted when required and used in conjunction with the integral six-watt per channel stereo amplifiers.

A comprehensive range of Japanese Trio equipment was demonstrated by the U.K. importers Winter Trading Ltd., of 95-99 Ladbroke Grove, London, W.11. Combined tuner/stereo amplifiers were shown and only the senior model, the WX-400U, at 99gn was fitted with a stereo decoder, although a separate multiplex unit is available for use with their other units. The WX-400U covers 535 to 1,605 kc/s in the medium-wave band, 80 to 108 Mc/s in the f.m. band and has an output of 20 watts per channel (music). A signal level of 1.9μV (at 98 Mc/s) is required to obtain a 20 dB signal-to-noise ratio in the f.m. band and 2.0μV (at 1,000 kc/s) for a signal-to-noise ratio of 10 dB in the m.w. band. The frequency response of f.m. stereo is within $\frac{1}{2}$ dB from 50 to 15,000 c/s (amplifiers $\frac{1}{2}$ dB from 20 to 20,000 c/s) and separation is quoted to be better than 38 dB. Twenty-two valves and eight diodes are used in this receiver.

The first all-transistor a.m./f.m. stereo receiver from the Danish manufacturer Bang & Olufson was shown by their U.K. distributors, St. Aldate Warehouse Ltd., of Innsworth Lane, Gloucester. Known as the Master 610K, it covers the l.w., m.w., s.w. and the f.m. bands and has an audio output of six watts per channel. Provisions are made for acceptance of the B. & O. multiplex unit, which can be fitted should stereo broadcasting start in this country. Its long, low lines ($5\frac{3}{4} \times 29\frac{1}{4} \times 8\frac{3}{4}$in) are rather pleasing with the speakers facing forward at either end of the cabinet. An almost identical model, but with no speakers, is available in the form of the Beomaster 900.

Another continental stereo receiver with similar lines ($10 \times 25\frac{1}{2} \times 10\frac{5}{8}$in) and separate speakers ($8\frac{1}{4} \times 25\frac{1}{2} \times 10\frac{5}{8}$in) was shown by Telefunken's U.K. distributors Welmec Corporation Ltd., Lonsdale Chambers, 27 Chancery Lane, London, W.C.2. Thirteen valves, nine diodes, a

Right: Bang & Olufsen's "Master 610K" a.m./f.m. stereo receiver.
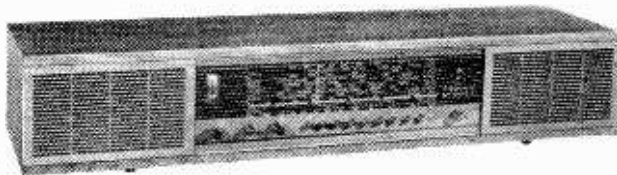
Below: Trio Model WE-85 combined tuner/stereo amplifier. Provisions are made for fitment of a stereo decoder in this three-waveband receiver.
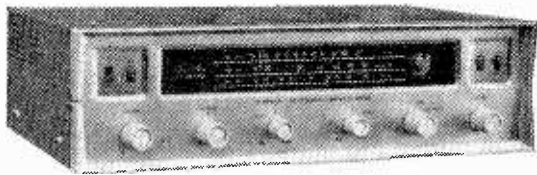
transistor and two rectifiers are used in this 155gn German outfit, which covers four wavebands and is fitted with an f.m. stereo decoder. Known as the Opus 2430 MX, the pair of push-pull output stages are each rated at eight watts and the input sensitivity of the receiver on the f.m. band is quoted at 1.0μV for a signal-to-noise ratio of 26 dB. Each of the two speaker units is fitted with a $5\frac{1}{8} \times 7\frac{1}{8}$ in medium treble speaker, a $7\frac{1}{8} \times 13\frac{1}{2}$ in woofer and a filter for treble and bass frequency separation. A stereo balance control is fitted to the receiver and has an adjustment range from +8 dB to --40 dB.

An interesting German four-waveband stereogram chassis was shown by Kuba Sales and Service Ltd., of 64 Thornton Road, Thornton Heath, Surrey. Known as the Type 664 chassis, printed circuits are used throughout with six valves, three semiconductors and a selenium rectifier to cover the l.w., m.w., s.w. and f.m. bands. A decoder can be fitted without difficulty for f.m. stereo reception if required, and sockets are provided for stereo pickup, tape recorder and external loudspeakers. This chassis, which is fitted to a number of their radios and radiograms, can be purchased for under 30gn. Incidentally, the Kuba products sold through wholesalers carry the brand name Imperial, and a number of their radiograms were displayed by Tellux Ltd., of Avenue Works, Gallows Corner, Colchester Road, Romford, Essex. Several of the models shown were fitted with the Type 664 chassis.

Most of the exhibitors of the hi-fi labelled equipment displayed a selection of radiograms the majority of which were fitted with the same chassis as that used in their hi-fi receivers.

Four new stereograms have been added to the Grundig range of equipment available in this country. Each of them incorporates a radio chassis covering the v.h.f. band as well as the l.w., m.w. and s.w. bands and a decoder for stereo broadcasts is optional. Two of them have two large elliptical speakers with two concentric tweeters, another has an additional four "treble" units and the fourth (Model KS580) has a total of ten speakers and an output of 8.5W per channel. Each of these stereograms has a four-speed record changer incorporating a precision pickup arm device which gently lowers the head on to the pre-selected section of the record. The prices of these instruments range from 119 to 275 gn.

Grundig (Great Britain) introduced television receivers for the first time at their show at the Hilton Hotel. The two receivers, which are now being made in this country, incorporate the same 405/625-line chassis with a 23in screen. The Console K230 has a front-facing elliptical speaker fitted on either side of the screen. The "Stereo Theatre," costing 365 gn, incorporates an a.m./f.m.

receiver, transcription record changer and six speakers, and has an output of 6W per channel.

Transistor Portables

Although we still have not seen an f.m. receiver in this country especially designed for car installations, a number of a.m./f.m. portables designed to double as car radios were shown this year. One of these, a three-waveband receiver from Braun, known as the T580, was shown by the United Kingdom distributors Argelane Ltd., of 251 Brompton Road, London, S.W.7. Covering the long, medium and f.m. bands, it has an output in excess of one watt and requires a signal input of 3μV for a 50mW output. A complete car installation, including a dashboard speaker and all the mounting hardware, is available for the 32gn receiver. When inserted into the car mounting, the internal battery is automatically disconnected and the receiver obtains its supplies from the car battery (6V). The internal aerial and speaker are also automatically disconnected and connected to the car aerial and speaker. Automatic frequency control circuits are featured in the f.m. section of the receiver.

Also from Germany, and having similar coverage, is the Akkord nine-transistor "Auto-Tourist," which was shown by the U.K. distributors Denham & Morley Ltd., Denmore House, 173-175 Cleveland Street, London, W.1. It costs a little more at £40 but covers one of the short-wave bands and has a theft-proof car bracket. Another such a.m./f.m. receiver, although not specifically designed to double as a car radio, is the Nordmende "Transita-Globetrotter."

Judging from the number of receivers on show having at least one short-wave band, and some many more, short-wave listening is about to become popular again. Perhaps the most impressive seen, as far as coverage is concerned, was the German all-transistor "Transita-Globemaster" from Nordmende, which was
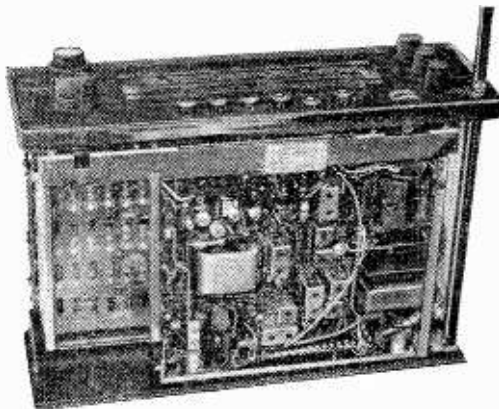
Inside view of the Nordmende "Transita-Globetrotter" fifteen-waveband a.m./f.m. transistor portable.
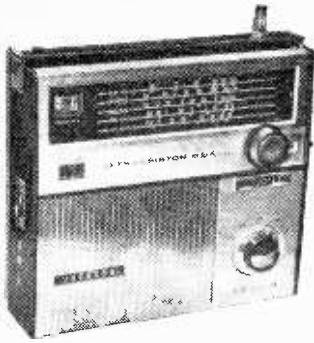
Jackson five-wave-band transistor receiver from Japan.

shown by the importers TAK Continental (Importers) Ltd., of High Street, Stone, Staffs. This 67 gn receiver has eleven widespread short-wave bands covering 11 to 80 metres and also covers the marine- (1·5 to 3·7 Mc/s), long- and medium-wave bands and 87 to 104 Mc/s in the f.m. band. An internal 9×5 in speaker is used to handle the 2·5-watt output and sockets are provided for extension speakers—or headphones—and also for external aerial, gram and tape recorder inputs. Automatic frequency control is provided for the f.m. band and the receiver can be operated from either its five internal 1·5-volt cells, a car battery or from the mains; a special connector being available which incorporates a transformer and rectifier. A ferrite-rod aerial is fitted for the medium- and long-wave bands and a telescopic aerial is provided for the rest. Car brackets are available.

Another a.m./f.m. receiver with almost as many wavebands, thirteen in actual fact, but at more than twice the price is the Braun T1000 all-purpose receiver. The short-wave section is spread over eight bands and covers 1·6 to 30 Mc/s. Sensitivity figures quoted for these bands range from 6 to 15 μV for a 10 dB signal-to-noise ratio. The long- and medium-wave bands are both split into two, the first covering 130-240 kc/s and 230-420 kc/s (5 μV/10 dB) and the other covering 0·52-0·94 Mc/s and 0·9-1·65 Mc/s (7 μV/10dB). A separate receiver—to the audio stages—is employed for f.m. reception and only requires an input of 0·8 μV for a signal-to-noise ratio of 26 dB. Automatic frequency control is provided for the f.m. section, which covers 87 to 108 Mc/s, and the a.g.c. circuits are so designed that limiting starts at 1 μV on f.m. signals. Two stages in the a.m. section of the T1000 receive a.g.c. voltages as against one in the f.m. side. A beat frequency oscillator is featured in this receiver, which employs 20 transistors, 8 semiconductor diodes and two selenium stabilizers. These receivers cost £195.

Separate a.m. and f.m. stages are also featured in the French Pygmy-Radio " Super 2001 " shown by Europa Electronics Ltd., of Howard Place, Shelton, Stoke-on-Trent, Staffs. This receiver uses transistors throughout and in addition to the l.w., m.w. and f.m. bands, it covers seven short-wave bands; four of which are bandspread.

Another interesting set, but at the lower end of the price scale of the multiple waveband receivers, was the senior model in the Jackson range of Japanese portables imported by Winter Trading. This receiver covers the l.w., m.w. and three short-wave bands and, as a number of other sets on show, is fitted with a " null " tuning indicator and a tone control. Ten transistors are used in the receiver and to assist in tuning at night a dial light is fitted to this 29½ gn set.

Tape Recorders

A number of interesting tape recorders were shown. Elizabethan, for example, had several recorders on display ranging from single-speed twin-track machines with automatic record level control at 26 gn, to their senior model, the LZ 511. This stereo machine employs transistors throughout, has a three-speed, four-track deck and detachable 8×5 in speakers. The amplifiers are both rated at three watts and the frequency response of the machine is quoted as 40 to 16,000 c/s at 7½ in/sec, 40 to 12,000 c/s at 3¾ in/sec and 40 to 7,000 c/s at 1⅞ in/ sec. Dual recording meters, bass and treble controls, and full superimpose and monitoring facilities are -features of this 65 gn machine.

Voice-operated tape transport control is featured in the National RQ-150 from Matsushita Electric. This can be adjusted to operate at any voice level and overruns for approximately 1½ seconds so as not to sut off the tape recorder with small interruptions in speech. -The frequency response of this Japanese machine is 100 to 7,000 c/s at 3¾ in/sec and 100 to 4,000 c/s at 1⅞ in/ sec. Its features include automatic film-slide and movie synchronization and remote control facilities, and it can be obtained through the sole U.K. importers (Unamec), United Africa Mechanical and Electrical Ltd., United Africa House, Blackfriars Road, London, S.E.1.

Another interesting exhibit was the Model 1650 from Roberts of America. Handled in this country by Argelane Ltd., of 251 Brompton Road, London, S.W.3, this four-track stereo machine employs a new heavy-duty motor and has a wow and flutter figure of less than 0·2% at 7½ in/sec. Frequency response at this speed is within ±3 dB from 30 to 18,000 c/s and within ±3 dB from 50 to 10,000 c/s at 3¾ in/sec. An accessory kit is available for 15 in/sec recording and playback, and at this speed the frequency response (±3 dB) is extended to 20,000. A signal-to-noise ratio of better than 45 dB is quoted for this £175 machine.
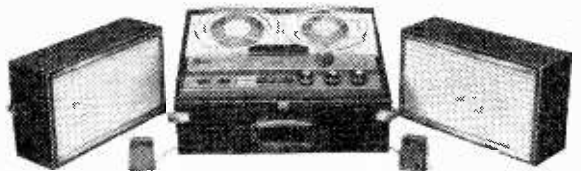
Elizabethan Model LZ 511 stereo tape recorder. Dual recording meters are featured on this four-track, three-speed machine.
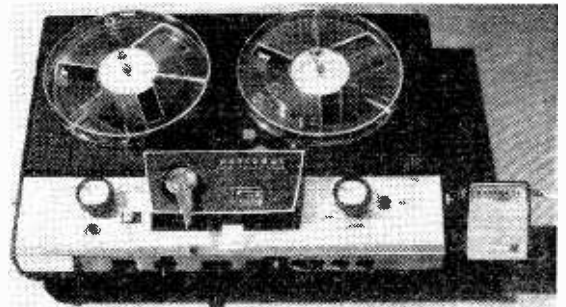
National RQ-150 voice-operated portable tape recorder from Matsushita Electric, of Japan.

Television Distribution by Wire

1.—A COMPARISON OF H.F. AND V.H.F. SYSTEMS

By R. I. KINROSS,* M.I.E.E.

THE advantages of distributing television by wire not only in blocks of flats but throughout large towns are now so well known that no further elaboration is necessary. What is surprising, however, is the number of engineers who, when a wired television distribution system is mentioned, tend to conclude that the cable used must be coaxial and the carrier frequencies must be in the v.h.f. band, i.e. the same as those normally used for broadcasting television in Band I and Band III. This is surprising because the number of subscribers receiving their signals by means of v.h.f. signals on coaxial networks at the end of 1962 were some 170,000 whereas

Fig. 1. Growth in number of television relay subscribers in the United Kingdom.

those receiving their signals in the 5-10 Mc/s band on balanced pair cable amounted to some 509,000.[1] The relative growth of h.f. and v.h.f. systems is illustrated in Figs. 1 and 2.

It will be noticed that, whereas the growth in the number of *systems* has been more rapid for v.h.f. the growth in the number of *subscribers* has been more rapid for h.f. systems. This illustrates how much larger h.f. systems are, in general, compared with v.h.f.

The purpose of this article is to explain why h.f.

(1) Hollinghurst, F., and Hawkins, C. F. W.: " A Survey of the Development of Television Broadcast Relay in the United Kingdom," International Television Conference, I.E.E., 1962.

systems on balanced pair cables have now become so much more popular than v.h.f. on coaxial and the various developments that have brought this about.

Problems of the V.H.F. Systems

The main reasons for the early popularity of v.h.f. coaxial systems were that they required comparatively little development work and were capable of feeding completely normal aerial receivers. Thus, for isolated blocks of flats where it was quite impractical for every tenant to have his own aerial the coaxial system was the natural one to use in the late forties and early fifties.

While only one television programme was being broadcast it was only necessary to introduce an amplifier between the aerial and coaxial cable, make up a few elementary resistive pads for spurs and drop-ins and you had a communal aerial system. Even in those days one had to be careful not to try to obtain too much output from the amplifier or cross-modulation occurred between sound and vision in the output valve but even so it was a relatively simple matter to obtain approximately 1 volt of r.f. signal to feed into a coaxial system and by limiting the input to each subscriber to approximately one millivolt it was not difficult to feed a block of some thirty or forty flats in this manner. When the I.T.A. started up on Band III in 1955 things became a little more complicated but
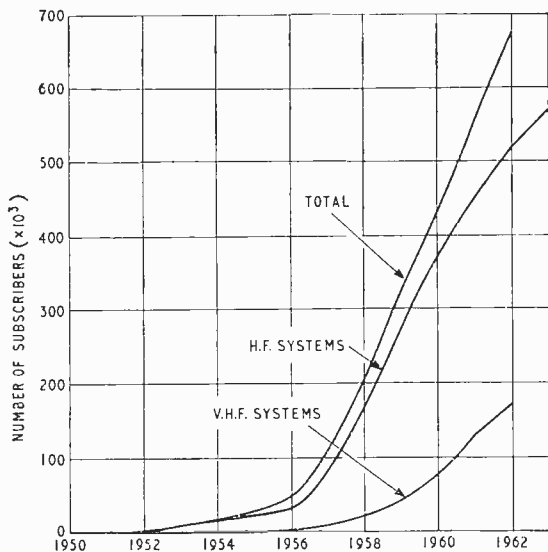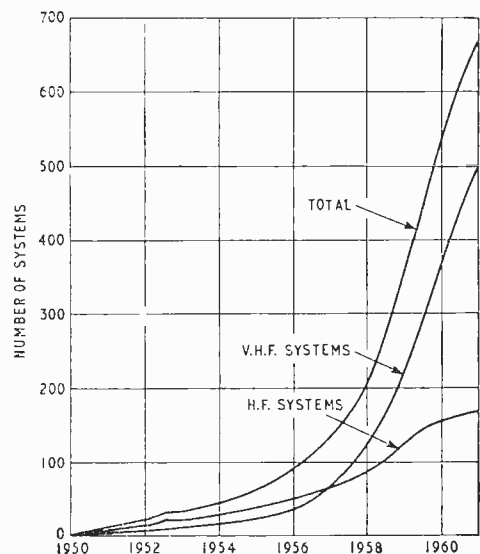
Fig. 2. Television relay systems in the U.K.

still not too difficult. One could add another aerial and another amplifier and combine the outputs from the two amplifiers into the coaxial cable. This was the simplest form of head-end equipment but it meant distributing the I.T.A. programme on Band III and the considerably higher attenuation of the cable at these frequencies made it difficult if not impossible to feed the flats previously comfortably energized on Band I. Thus, most systems (unless they were very small) used a frequency changer which converted the incoming Band III signal into a vacant channel on Band I (say Channel 3 in the London area), amplified this signal and combined the output with that on Channel 1 : the slightly higher attenuation on Channel 3 as compared with Channel 1 did not cause too much trouble. A number of other difficulties, however, soon began to make themselves felt especially as v.h.f. systems were extended in size from blocks of flats to small towns. The following is a selection : —

1. It was no longer safe to use the same carrier frequency on the cable as that of the transmission received by people with aerials in the vicinity. If the transmitter was very close its signals broke through the screening of the coaxial cable and produced ghost images. If the transmitter was some distance away radiation from the coaxial cable would produce ghost pictures on the receivers of those people trying to receive the signal with their own aerial. Thus a frequency changer at the head-end became virtually essential for all programmes.

2. If a large number of repeaters were used in tandem and these were of the " strip " type, i.e. each repeater amplified only one channel, then distortion becomes apparent due to the large number of separating and combining filters used at each repeater point.

3. If broadband repeaters were used, i.e. each repeater amplified several programmes, then care had to be taken to avoid cross-modulation between programmes. This either takes the form of unwanted pictures appearing on other programmes or alternatively of beats caused by the sum and difference frequencies of the various carriers. To minimize these effects the outputs of the repeaters must be lowered and this in turn tends to degrade the signal-
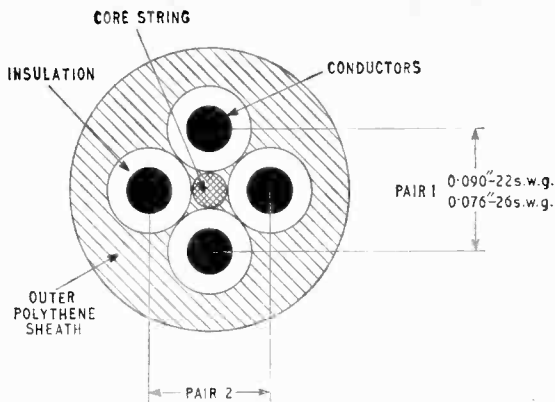
Fig. 3. Cross-section of star-quad audio distribution cable.

noise ratio with a large number of repeaters in tandem.

4. The use of adjacent channels must be avoided since the selectivity of receivers is not usually good enough. (Modern receivers are improving in this respect.)

5. With the growth in the number of programmes and the obstacles in the way of using various channels in Band I, one is forced to use channels in Band III, which means that many more repeaters have to be installed to overcome the increased attenuation of the cable.

The above are some of the main difficulties which have to be overcome by the designers of v.h.f. systems. None of them is by any means insuperable and a great deal of ingenuity and engineering skill has gone into the design of modern v.h.f. systems [2, 3, 4 and 5], but you will see that they are now very different from the simple systems used in the early 1950s.

Problems of H.F. Systems

Let us now consider the problems facing the designer of a high-frequency system and the steps taken to overcome them.

First let us consider the relative merits of coaxial cables and twisted pair cables. While it is well known that for a given size, cost and frequency the attenuation of coaxial cable is lower than it is for a *screened* twisted pair, what is not so well known is that this is no longer the case when comparing a coaxial cable with an *unscreened* twisted pair cable. Some years ago it was realized that if it were possible to design a system using a multi-pair cable in such a way that each pair could carry a different television programme in the 5-10 Mc/s band without the need for screens between the pairs such a system would show very real economic ad-

(2) Hooper-Smith, L. E.: " Wired Distribution Networks for Television at V.H.F.," *Proc Society of Relay Engineers*, Vol. V No. 5, Sept , 1961.

(3) Whitbread, C. F.: " V.H.F. Broadcast Relay Systems," *Proc. Society of Relay Engineers*, Vol. V No. 6, Dec., 1961.

(4) Hunt, G. J.: " Television Distribution by Coaxial Cable," *Proc. Society of Relay Engineers*, Vol. V No. 6, Dec., 1961.

(5) Whitbread, C. F.: " V.H.F. Broadcast Relay: Limitations to System Size," Contribution to International Television Conference, 1962.

TABLE I

Comparison Between Coaxial Cable Used at V.H.F. and Multi-pair Cable Used at H.F.

Cable Type	Conductor Size s.w.g.	Cost/1000 yds.	Attenuation dB/100ft.			Outside Diameter ins.
			220 Mc/s	80 Mc/s	5 Mc/s	
Coaxial	12	£111	1.3	0.9		0.57
Coaxial	14	£90	1.75	1.05		0.497
6 Pair Screened	22	£100			0.78	0.47
6 Pair Unscreened 70 mil. Sheath: Dirty	22	£75			0.87	0.45
6 Pair Unscreened 60 mil. Sheath: Dirty	26	£59			1.06	0.375
9 Pair	6 Pair of 26+3 Pair of 27	}£77			1.06	0.375

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vantages over those of a coaxial system operating in the v.h.f. band.

Table I illustrates the advantages of a multi-pair cable over a coaxial type as regards price, diameter and attenuation. It also illustrates that, while these particular advantages were marginal in the days when v.h.f. distribution could be limited to Band I, the advantages are now much more marked today when, with the increase in television programmes to be distributed, Band III up to 220 Mc/s must be used on a coaxial system. Furthermore, each balanced pair can carry a sound programme at audio frequencies.

In producing this table (which is factual) so early in this article we have jumped ahead of the logical exposition of the work entailed in designing a multi-pair h.f. system, but it should be realized that it was not very difficult to guess at the contents of such a table some ten years ago: what was much more difficult, however, was to transform it from guess-work to reality. Guesswork of this type is always useful when trying to decide whether the expenditure of a large amount of money and effort is going to be worth while. This table shows clearly that the multi-pair cable for an h.f. system is, in general, less expensive and bulky than coaxial for a v.h.f. system. These two points are both important. As regards the first, while it was clear that a wired receiver would be appreciably cheaper than an aerial receiver (no waveband switching, less amplification and no sound channel), the overall advantage of the h.f. system would be more difficult and complicated to argue if the multi-pair cable cost more than coaxial. As regards the size of cable, we do not wish to eliminate private aerials and replace them with bulky and ugly cables.

However, before unscreened multi-pair cable could be used, problems of radiation, interference, cross-view (transfer of signals from one pair to another), changes of attenuation, etc., all had to be investigated and solved.

The first cable investigated was a star-quad cable similar to that already in use on audio networks for distributing two audio programmes. The cross section of this cable is illustrated in Fig. 3. It was soon found that attenuation of this cable varied over very wide limits due to rain and due to the formation of a film of dirt on the outside. These variations could be completely eliminated by putting a very cheap aluminium foil spiral tape around the cable, but the long-term aim of avoiding the screen altogether was kept in mind.

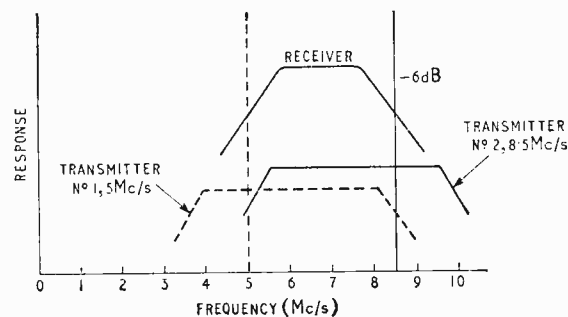The next problem was to consider methods of

Fig. 4. Illustrating the principle of the " Tête Bêche " system.

TABLE 2

Crossview Protection Required between Two Television Signals Transmitted with One Complete and One Vestigial Set of Sidebands

1.	Synchronized carriers: same standards: carriers in phase	44 dB
2.	Synchronized carriers: same standards: carriers in quadrature	32 dB
3.	Synchronized carriers: one 405- and the other 625-lines	34—40 dB[1]
4.	405-lines: one third line precision offset	38 dB[2]
5.	625-lines: one third line precision offset	34 dB[2]
6.	405-lines: half line semi-precision offset	42 dB[2]
7.	625-lines: half line semi-precision offset	38 dB[2]
8.	405-lines: " Tête-Bêche " 3½ Mc/s separation between carriers	28 dB
9.	" Tête-Bêche ": one 405-line programme interfering with one 625-line programme with a difference frequency between carriers set to an odd multiple of half line	34 dB

[1] Dependent on phase of carriers and difference between frame frequencies.
[2] Flywheel synchronization required in receiver.

distributing two 405-line television programmes on two pairs of wires close to each other without mutual interference. It was found that if both the carriers were at about 5 Mc/s, somewhere around 56 dB protection was required in order to avoid mutual interference. If the carriers were exactly synchronized, the protection required was only 32 to 44 dB (depending on the carrier phase), and one large operating company has relied on this system of protection for most of its networks. Further investigation, however, showed that the " Tête Bêche " system originally invented in France required a much lower protection ratio, the actual amount depending on the frequency separation between the two carriers. This made it possible to use cable made virtually in exactly the same way as the normal star-quad cable illustrated in Fig. 3, except for the addition of a screen and protective sheath.

The practical arrangement used is illustrated in Fig. 4. The 5 Mc/s transmission employs mostly upper sidebands, while the 8.5 Mc/s transmission employs mainly lower sidebands. Thus the sidebands overlap, but due to the virtues of the " Tête Bêche " system a crossview protection of some 28 dB is sufficient to avoid interference on 405-lines with 3.5 Mc/s separation between carriers. It will be seen that the receiver input response curve is so shaped that it is minus 6 dB both at 5 Mc/s and at 8.5 Mc/s. Thus the receiver requires no adjustment when switching from one programme to the other but is capable of receiving both, simply by switching its input either to one pair of a cable or the other pair of the same cable. The method of doing this is illustrated in Fig. 5. It will be seen that a high-frequency auto-transformer bridges the feeder and both the audio and high frequency signals are fed from the feeder to the drop-in, at the foot of which the appropriate programme is selected both as regards sound and vision by a simple double-pole multi-position switch. Each of these h.f. transformers is capable of feeding up to four subscribers. The method illustrated in Fig. 5, so far as selection of programmes is concerned, has now been in use for some eight years in the homes of several hundred thousand subscribers and has proved so satisfactory that there has been no reason to depart from the basic principle of allotting an individual pair of wires to each programme when introducing new systems for 625-lines.

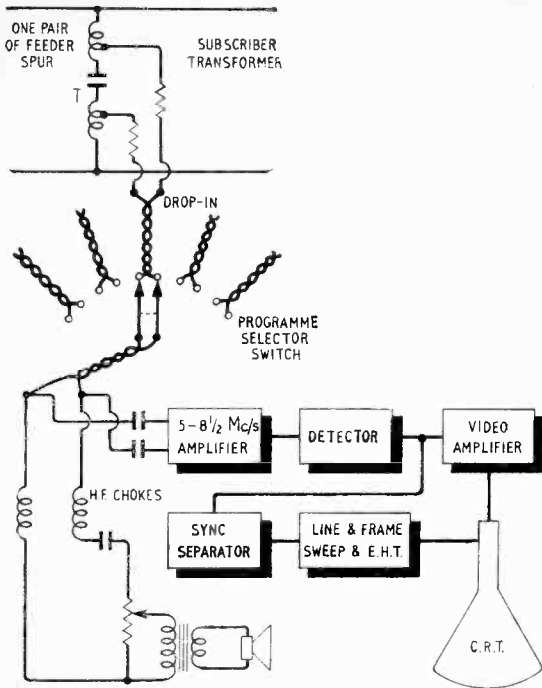Since this system was developed the most impor-

Fig. 5. Basic programme switching circuits.

tant changes that have taken place in television broadcasting are:—

1. We now know that nearly all new programmes in England will be broadcast on 625-line standards and eventually all television transmissions in England will also be on 625-lines.

2. There can now be no doubt that it will not be very long before we have colour transmissions in England even though at this moment it is still not possible to say which particular system will be adopted.

Development work on h.f. wire broadcasting systems has not only had to take account of the above factors, which meant designing systems capable of dealing with mixed standards and colour, but work has also continued in reducing the number of separate cables that need to be erected even though the number of television programmes will be greater.

Progress has also been made in eliminating the need for a screen on large sections of the network.

The question had to be decided whether the "Tête Bêche" system, which had operated so satisfactorily on 405-lines, should continue to be used for mixed standards of 405- and 625-lines or whether some different system should be relied upon. A study was, therefore, made of a large number of different methods of distributing programmes and the crossview requirements of each method was established by means of both technical and non-technical panels of viewers. Some of these results are set out in Table 2. While due acknowledgement is made here to the value of the many useful papers issued by the C.C.I.R. on protection ratios of various systems, care had to be taken in making use of this information since they are usually in the form of "tolerable interference" on the assumption

that interference is only experienced for a small percentage of the time. In the case of a wired television network, if the crossview protection is not adequate, interference would be experienced all the time on certain parts of the network and the crossview protection required for these networks is, therefore, set at a higher standard than some published figures used for broadcasting. Some curves typical of many taken to establish these figures are shown in Fig. 6. There is not space in this article to go into the full details of how a curve of this type is converted into a simple crossview performance for a coil of cable: suffice it to say that such factors as the spread in crossview measurements of individual coils at the factory, the possibility of a number of low-pass limit coils all being connected in tandem, the maximum length of networks, and so on, all have to be taken into account. In practice it is found that feeders up to 1,500 yards in length can be built, using cable whose average crossview is 55 dB at 5 Mc/s per length of 250 yards and nowhere on such a feeder will the crossview be worse than 44 dB. (This figure of 1,500 yards refers to the greatest distance between the start of a feeder and any subscriber: such a feeder could easily comprise up to 10,000 route yards of network excluding the drop-ins.)

This is good enough for preventing mutual interference between synchronized carriers, irrespective of their relationship, and this degree of crossview can be achieved between the alternate pairs of wires in the six-pair cable illustrated diagrammatically in Fig. 7. The crossview between adjacent pairs is, however, not so good and some other method must be relied upon.

From example 9 of Table 2 it will be seen that the crossview protection required between mixed standards using the "Tête Bêche" system is only some 34 dB and this is one of the methods relied upon to distribute mixed standards on adjacent pairs. (The term "adjacent pairs" in this article applies equally to the two pairs inside one screened quad cable or to two pairs adjacent to each other in a six-pair cable such as yellow and green in Fig. 9.) While the low crossview protection required by the "Tête Bêche" principle for separating two 625-line programmes is also attractive, a serious objection is that carrier frequencies of approximately 5 Mc/s and 11.5 Mc/s would have to be used as compared with the highest carrier frequency of 8.5 Mc/s that it used on 405-lines (see Fig. 4). Due to the higher attenuation at 11.5 Mc/s a higher voltage would have to be transmitted which would considerably increase the cost of repeaters and also might raise difficulties over radiation from network: or it might be necessary to move existing repeater kiosks closer together.

The above considerations prompted investigations into the possibility of distributing all 625-line programmes on carriers of approximately 5 Mc/s. Since several tens of millions of yards of multi-pair cable has already been erected in the United Kingdom with a crossview of about 34 dB between the pairs, the problem was to work out some way of distributing either one 405 and one 625-line programme on adjacent pairs of cable or alternatively two 625-line programmes. It was hoped at one time that synchronized carriers of unlike standards (method 3 of Table 2) might only require some

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Fig. 6. Subjective assessment of crossview requirements by 8 technical and 16 non-technical observers on 19-in tube in darkened room at a viewing distance X4 picture height, (a) 625 lines, half-line semi-precision offset. (b) 625 lines, one third line precision offset (c) 405 lines, "Tête Bêche," 3·5 Mc/s separation between carriers.
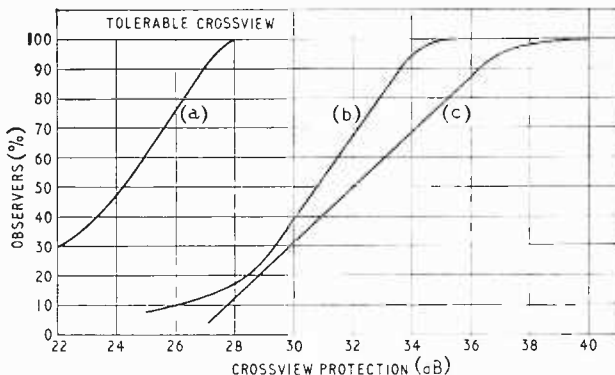
34 dB crossview and, indeed, the earliest tests that were carried out on such a system appeared very promising. The reason for entertaining these hopes was that the unwanted picture, having a difference of some 5 kc/s in timebase frequency, would speed across the cathode-ray tube so fast that it would be scarcely visible. Unfortunately, more careful tests and juggling with all the variations that can occur with frequencies of line timebase and frame timebase showed that certain combinations occurred where 40 dB was found to be necessary for acceptable crossview and this method had to be abandoned.

Fortunately the subjective effect of interference from the existing 405-line programme on 8.5 Mc/s on a 625-line programme at 5 Mc/s can be minimized by arranging the difference frequency between their carriers to be an odd multiple of half the 625-line timebase frequency (method 9 of Table 2) and this method can, therefore, be relied upon for distributing programmes of unlike standards on adjacent pairs of cable.

As regards two 625-line programmes, these can be distributed on adjacent pairs by relying on " precision offset " (method 5 of Table 2) since only 34 dB protection is required.

Thus, to summarize, with two monochrome transmissions distributed inside one screened quad cable or on adjacent pairs of a six pair cable, one can rely upon either of two methods.

Method A

Two 625-line Programmes: employing one car-
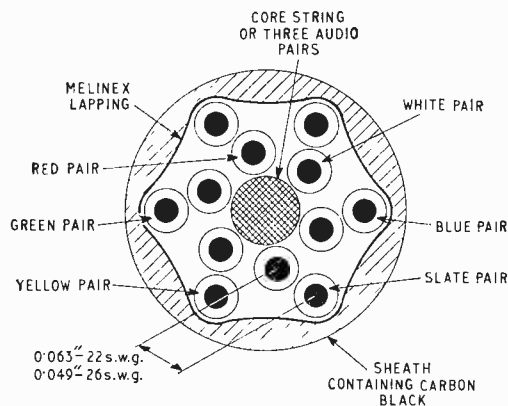
Fig. 7. Cross-section of six-pair cable.

rier of 5 Mc/s and another offset from it: both signals using mainly upper sidebands.

Method B

Mixed standards: distributing the 625-line programme at 5 Mc/s and the 405-line at approximately 8.5 Mc/s where the difference of 3.5 Mc/s is itself an odd multiple of half the line timebase frequency of the 625-line programme. In this case the 5 Mc/s carrier uses upper sidebands and the 8.5 Mc/s carrier uses lower sidebands.

Thus, if there are two screened quad cables running side by side, two 405-line programmes can be distributed by "Tête Bêche" in one cable and two 625 offset from each other in the second cable or alternatively mixed standards can be distributed by Method B in each cable with the two carriers in one cable exactly synchronized with the two carriers in the second cable. In fact, the second method is preferred since this fits in better with the use of multi-pair cable which will be described later.

In this article it is not proposed to list all the precautions that have had to be taken in choosing carrier frequencies to avoid visible effects from spurious frequencies. The choice of frequencies described in outline above are the subject of still further minor variations in order to minimize such effects as : —

(a) The second harmonic of the 625-line 5 Mc/s carrier falling amongst its own upper sidebands.

(b) The second harmonic of the 625-line 5 Mc/s carrier causing a beat with the colour sub-carrier.

(c) Crossview interference between colour sub-carriers on adjacent pairs of cable.

(d) Crossview from a 405-line signal at 8.5 Mc/s interfering with a colour sub-carrier of a 625-line signal with monochrome carrier at 5 Mc/s.

To achieve (a) and (b) a high degree of linearity is required in repeaters as well as a careful choice of carrier frequency, but so far no difficulty has been experienced in distributing three 405-line programmes plus one 625-line programme (the latter in colour) throughout a town in South East England on an existing network of two screened quad cables erected some years ago. This dealt with the immediate problem that had to be faced in April, 1964, with the start of B.B.C. 2.

The main reasons for developing multi-pair cable were, first, that it would obviously be neater to erect one multi-pair cable rather than a number of screened quad cables such as had been done in the past. Second, that the individual wires of a pair would be closer together and it was hoped therefore

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that better crossview could be achieved and also, due to the smaller coupling that these pairs would have with the outside of the cable, the effect of external dirt would be less pronounced and thus a screen could be omitted over a large proportion of the network.

All these hopes have now been realized.

The first attempt at including more than two TV programmes in one cable was to use a four pair cable (see Fig. 8) in which the best crossview was obtained between the opposite pairs of cables and second best crossview was obtained between adjacent pairs. Such a cable would have been neater than two screened quads, but while its development was in progress it became evident that future networks must cater for at least six television programmes and accordingly development work on six pair cable was started some years ago. The cross-section of this cable is shown in Fig. 7. This illustrates the point made above that the spacing between the wires of a pair is less on twisted pair than it is on screened quad (see Fig. 3). For 26 s.w.g. for example the spacing on screened quad is some 50% greater than for twisted pairs. Further-
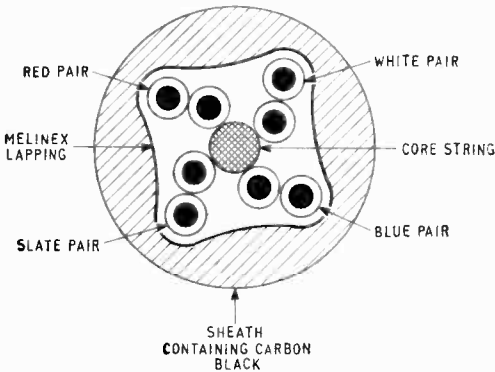

Fig. 8. Cross-section of four-pair cable.

more, the lays of the pairs have been so arranged that the best crossview exists between alternate pairs and a more modest crossview between adjacent. This is illustrated diagramatically in Fig. 9. This results in six first-class crossview combinations and fifteen second-class. The first-class are suitable for synchronized carriers: the second-class for Methods A and B referred to above.

An additional feature of this cable is that it is possible to include three pairs of slightly thinner conductors at the centre (instead of the central core string shown in Fig. 7) which have no effect whatever on the six outer pairs. These three inner pairs can then carry audio programmes. Thus, this nine-pair cable is capable of carrying up to six television programmes and their sound plus a further three sound-only programmes.

Two practical examples of using nine-pair cable will make this subject clearer and these are set out in Table 3. One example illustrates the distribution of three 405-plus three 625-line plus three sound programmes and the other six 625-line and three sound programmes.

Having considered ways of avoiding the need for screens between individual pairs let us now con-

sider whether it is possible to avoid the need for a screen round the complete cable.

The effect of rain or dirt or, in fact, anything which produces a resistive film on the outside of an unscreened quad cable is to increase the attenuation. This is illustrated in Fig. 10, which is taken from a continuously monitored record of the attenuation of quad cable and it will be seen that the attenuation almost doubles during heavy showers. A more careful exploration of this effect is illustrated in Fig. 11 where the change in attenuation is plotted against the resistivity of the outer film of quad cable at a number of different frequencies. As an example it will be seen that if the worst resistivity occurs at 10 Mc/s the attenuation increases to as much as three times the normal. A considerable reduction in this increase can be made by using twisted pair cable instead of quad and a further reduction made by using a thick outer sheath which keeps the resistive coating further away from the twisted pairs. As an example, six-pair 26 s.w.g. cable with an outer sheath of 70 mil. only increases in attenuation by some 15% at 5 Mc/s even when the resistivity is carefully chosen to have its worst possible effect. Clearly a cable of this type could not be used for long vision trunk routes going from one side of a large town to the other. No doubt the change in attenuation could be taken care of by adequate automatic gain control in the repeaters but some form of automatic change of frequency equalization would also have to be introduced. However, since vision trunk routes usually only constitute some 6% of the total network, the cost of the actual cable used for this is not of paramount importance and it is normal to use separate coaxial cables for each vision programme in this application. In the case of feeder spurs, however, the story is very different. These are the cables to which the drop-ins to subscribers are connected and these cables constitute over 90% of the complete network. Elimination of the need for a screen on these cables is well worth while, both due to the saving in cost in the cable itself but also because it saves the need to bond screens together at cable joints. Since these spurs seldom exceed a length of 500 yards the change in attenuation and the slight change in frequency response under different weather conditions does not affect the picture as seen by the subscriber, even when colour is distributed.

Before the outer screen could be entirely omitted consideration had also to be given to problems of radiation and interference. As regards the former, the General Post Office has laid down a limit of

TABLE 3
Two Examples Illustrating the Use of Nine-pair Cable

Colour of pairs (see Fig. 9)	Three 405 plus three 625-line Programmes*			Six 625-line Programmes*		
	Lines	Carrier Frequency (Mc/s)	Side-bands	Carrier Frequency (Mc/s)	Side-bands	
Blue	405	8.5	Lower	5	Upper	
Slate	625	5	Upper	5 Offset	Upper	
Yellow	405	8.5	Lower	5	Upper	
Green	625	5	Upper	5 Offset	Upper	
Red	405	8.5	Lower	5	Upper	
White	625	5	Upper	5 Offset	Upper	
3 central pairs	Three sound programmes			Three sound programmes		

*Vision and sound.

— ALTERNATES—BEST CROSSVIEW

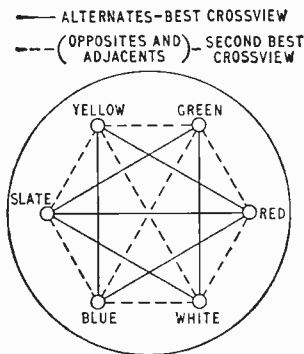--- (OPPOSITES AND ADJACENTS) — SECOND BEST CROSSVIEW

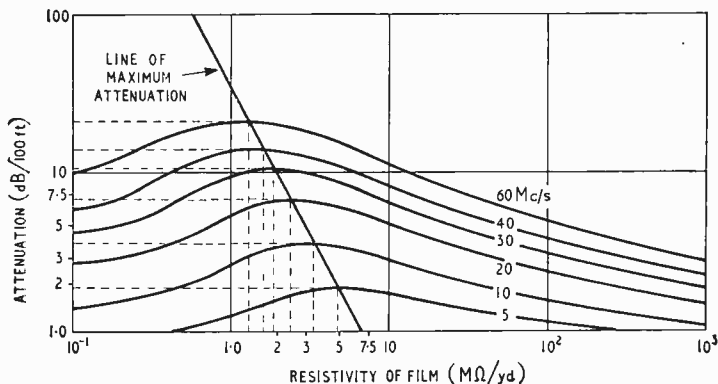Fig. 9. Two possible methods of utilizing a six-pair cable for lowest crossview.

Fig. 11. Variation of attenuation of Type CA37A cable with resistance of film on outer surface.
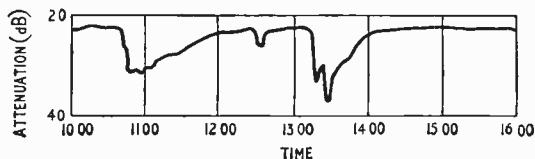

Fig. 10. Variation of attenuation of unscreened cable with time and weather.

100 microvolts per metre at 10 yards and this can be achieved by the use of a copper screen on all sections of the network where the level is above some $2\frac{1}{2}$ volts. This only represents a very small proportion of the network since the sending voltage is never more than 20 volts while levels are allowed to drop to 15 millivolts at the subscriber input. Interference is only a problem when networks run very close to a powerful transmitter. Such h.f. transmitters are very rare in the centre of a built-up area, though there has been an increase in the number of low-power medium-wave transmitters established in the centre of towns recently by the B.B.C. Fortunately the frequency response of wired receivers falls very rapidly at frequencies below 5 M/c and the only way that trouble can be caused by a medium-wave transmitter is if such large voltage reaches the grid of the first valve of the wired receiver as to cause cross-modulation. This can only happen within a matter of a few hundred yards of a transmitter and is dealt with by the inclusion of a high-pass filter between the drop-in and the receiver. Typical interference and radiation figures are given at Table 4.

The outcome of all this work made it possible to produce the table of comparison between coaxial and multi-pair cable illustrated in Table I and already referred to.

A word should perhaps be said about the factors affecting repeater coverage.

The main factors which govern the area covered by a repeater are the output level of the repeater, the attenuation of the cable, the number of spur branches, the minimum isolation between a subscriber and the feeder, and the minimum input to a subscriber.

The main factors to be taken into consideration as regards sending and receiving levels are radiation from the network, interference from external causes on to the network, noise, and economics. Interference and radiation have been dealt with briefly, and the most important point left for discussion is the question of economics. Cable attenuation is extremely important since it can be shown that the area, and thus the number of subscribers that can be covered, varies inversely as the square of the attenuation per unit length, assuming that the area is reasonably circular in shape and not just a ribbon development. The cost per watt output of an amplifier is high for small powers and falls as the power increases, as shown in Fig. 12(a). Experience of the exact figures to be used in Fig. 12(a) is only just beginning to become available for television repeaters. It is possible to draw a further series of curves as shown in Fig. 12(b) from which it is clear that the area covered by a certain transmitted power rises rapidly at first but ceases to increase so rapidly

TABLE 4
Radiation and Interference Properties of Various Cables.

Type of Cable	Type of Screen	Screen Material	Interference Unwanted Voltage Produced in 100yd. of Cable in a Field of 10mV/m between 4 and 10 Mc/s	Radiation Field Radiation from 100yd. of Cable at a Distance of 10yd. for IV Transmitted between 4 and 10 Mc/s
Quad	None	—	(μV) 80–250	(μV/m) 50–150
Quad	0.005in.-thick Tape Helically Lapped with 25%–45% Overlap	Aluminium	20–90	12–20
Quad		Copper	4–10	1–2
Multi-pair		Aluminium	10–45	6–10
Multi-pair		Copper	2–5	—
Multi-pair	None	—	87–128	20–30

The figures are only approximate, as the behaviour of cable depends on the balance of the pairs and the method of applying the screen.
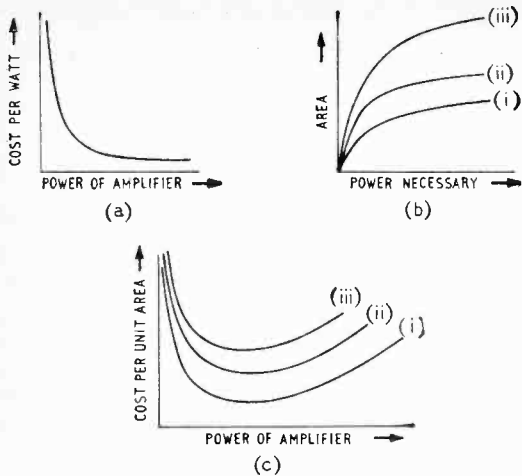
Fig. 12. Relationship between power of amplifier and cost per unit area.

with further increase in power. Curves (i), (ii) and (iii) can represent the situation for different street spacing, or different signal levels supplied to subscribers. By combining the results of Figs. 12(a) and (b), Fig. 12(c) can be produced from which the lowest capital cost per unit area, as far as repeaters are concerned, can be ascertained. The curve is usually fairly flat between 5 and 20 W with existing types of valve and equipment. It may be that this picture will change completely when it becomes possible to use transistors in repeaters. At present they can only be used with outputs of about 1 V, and their main function is to improve odd pockets just outside the reach of a valve repeaters. As regards receiving level, here again the most important factor is that of economics. If a low receiving level is chosen, more subscribers can be fed from one repeater but the down-lead to the receiver will have to be carefully screened, more valves will have to be used in the receiver and signal/noise ratio may become important. A high receiving level for a given cable attenuation means either more or higher-powered repeaters and, if the latter are used, better screening of the network at the sending end to limit radiation and larger and more expensive energy-splitting transformers on the network will be necessary. A reasonable compromise at present appears to be about 15 mV, since, at that level sufficient amplification is possible in the wired receiver using only two h.f. amplifying valves before the detector and no screen is necessary on the drop-in cable provided that care is taken in the receiver design.

(*To be concluded*)

OCTOBER CONFERENCES AND SHOWS

Further details are obtainable from the addresses in parentheses

UNITED KINGDOM
6-14   Olympia, London, W.14
  Business Efficiency Exhibition
  (Business Equipment Trade Assoc., 64 Cannon Street, London, E.C.4)
12-16   New York
  Audio Convention & Exhibition
  (Audio Eng'g Soc., Box 383, Maddison Sq. Stn., N.Y.)
14-21   King's Hall, Belfast
  Radio, TV & Electronics Exhibition
  (Northern Ireland Radio Retailers' Assoc., 12 Malone Road, Belfast 9)
28   Exhibition Centre, Sheffield
  High Speed Instrumentation
  (R. Cleathero, Society of Instrument Technology, c/o River Don Works, Sheffield, 9)
28-31   Seymour Hall, London, W.1
  R.S.G.B. Radio Communications Exhibition
  (P. A. Thorogood, 35 Gibbs Green, Edgware, Middx.)

OVERSEAS
5-7   Utica, N.Y.
  Communications Symposium
  (I.E.E.E., Box A, Lenox Hill Station, New York 21)
7-12   Genoa
  Communication Congress
  (Civico Instituto Colombiano, Palazzo Tursi, Genoa)
12-16   New York
  Instrument-Automation Conference
  (W. H. Kushnick, 212 Sixth Avenue, Pittsburgh 22, Pa.)
12-21   Milan
  World TV Progress (Congress & Show)
  (International Television Committee, Casella Postale 33, Novara, Italy)
13-16   Stockholm
  British Components Exhibition
  (Industrial Exhibitions, 9 Argyll St., London, W.1)
14-16   Santa Monica, Cal.
  Sonics & Ultrasonics Symposium
  (I.E.E.E., Box A, Lenox Hill Station, New York 21)
19-21   Chicago
  National Electronics Conference
  (I.E.E.E., Box A, Lenox Hill Station, New York 21)

19-23   Namur
  International Cybernetics Congress
  (Assoc. Internationale de Cybernétique, Palais des Expositions, Place André Rijckmans, Namur, Belgium)
21-28   Munich
  Electronica—Electronic Components Show
  (G. G. Kallman Associates, 16 Soho Sq., London, W.1)
29-31   Washington
  Electron Devices
  (I.E.E.E., Box A, Lenox Hill Station, New York 21)

Radio Communications Show

SEVERAL newcomers are listed among the exhibitors at this year's International Radio Communications Exhibition which is being held in the Seymour Hall, Seymour Place, London, W.1, from 28th-31st October. In addition to the manufacturers, suppliers of equipment, the Services, G.P.O. and organizations included in the following list of exhibitors there will also be stands devoted to demonstration amateur stations and displays of equipment by clubs affiliated to the Radio Society of Great Britain, the sponsors of the exhibition. The Show will open daily from 10 a.m.-9 p.m., admission 3s.

|	
Amateur Radio Mobile Soc.	Philpott's Metalworks
British Amateur TV Club	R.S.G.B.
Brit. National Radio School	Racal Electronics
C. & N. (Electrical)	Ralfe Radio
Codar Radio Co.	Ray Cross Electronic Co.
Courier Communications	Roding Boys Radio Society
Daystrom	Royal Air Force
Electroniques (Felixstowe)	Royal Navy
Enthoven Solders	Salford Electrical Instruments
Formica	Scouts Amateur Radio Group
General Post Office	*Short Wave Magazine*
Green & Davis	Territorial Army—65th Signals
Hammarlund Manufacturing Co.	Webbs Radio
J-Beam Aerials	*Wireless World*
K.W. Electronics	Withers Electronics
Labgear	World Assoc. Methodist Radio
Minimitter Co.	Amateur Club
National Radio Co. of America	

WORLD OF WIRELESS

Technological Awards

THE National Council for Technological Awards, which was set up in 1955 as an independent self-governing body to "create and administer technological awards," will soon cease to exist. Some of its responsibilities will be taken over by the Colleges of Advanced Technology when, under the "Robbins" scheme, they become universities and award their own degrees; others will be inherited by the new Council for National Academic Awards which will be empowered to award degrees not only in the field of technology.

Some 3,000 students have been awarded the Diploma in Technology (introduced by the N.C.T.A.) after taking the integrated industrial training and academic courses which have been a feature of the Council's awards scheme. At present there are nearly 9,000 students attending 122 courses—many of them in electrical engineering and applied physics—leading to the Dip.Tech. The N.C.T.A. has strongly recommended that if awards in a new style of title are created either by the new Council or the Colleges of Advanced Technology, they should be granted retrospectively to holders of the Dip.Tech.

B.B.C. Research Scholarships

EACH year several B.B.C. Research Scholarships are awarded to provide the opportunity for selected honours graduates to work for a higher degree at a U.K. university, the subject chosen for the study being within those fields of physics or engineering that have an application to sound or television broadcasting. The following three graduates have been chosen for this year's scholarships. G. Brown, who graduated in applied physics at Durham University this year, has been awarded a three-year scholarship at the University where his researches will be concerned with the microwave spectroscopy of maser materials. R. W. Smith, graduate of Trinity College, Cambridge, is to undertake a three-year study of photoelectronic image delay and storage tubes at Imperial College. B. J. Vieri, electrical engineering graduate from Birmingham University and for the past three years doing research on the automatic bandwidth reduction of television and facsimile channels by statistical encoding at Imperial College, has been awarded a one-year scholarship to enable him to complete this work.
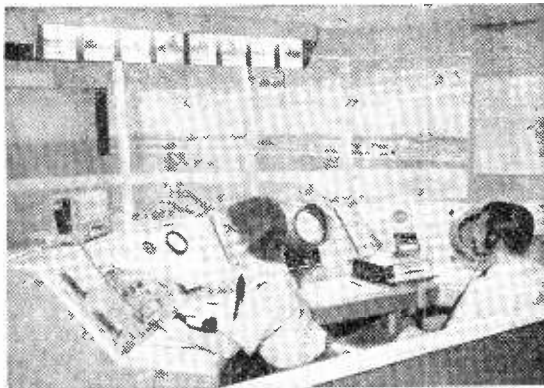
Air Traffic Control was simulated, with the aid of a specially prepared film, on the R.A.F. stand at the Radio Show. The film of aircraft taking off and landing was back-projected on to a screen inserted in the "view" of the airfield seen from the control tower

Berlin Radio Tower. To increase the communication facilities to west Berlin this 212-metre tower has been erected at Berlin-Schäferberg. The tower is the focal point for several hundred telephone channels and also houses two 20-kW transmitters and aerials to broadcast the second and third television programmes
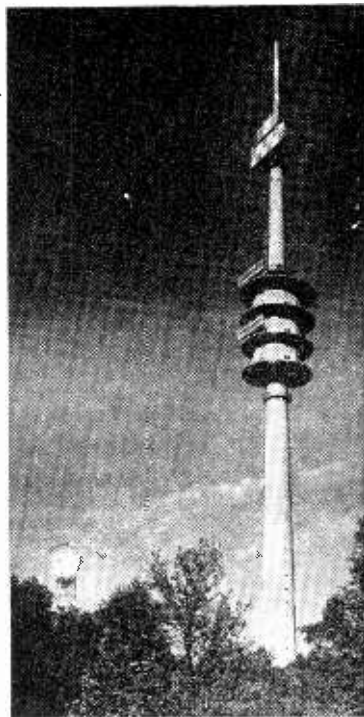
Europe's Television Stations.—Operating characteristics of nearly 2,500 television transmitters in the European Broadcasting Area are included in the latest list (No. 9) published by the European Broadcasting Union. The details given include: site co-ordinates and height above sea level, mast height, vision and sound e.r.p., carrier offset (if any), directivity, and polarization. Italy heads the list with 690 transmitters. Next comes W. Germany with 590 followed by E. Germany with 239 and France with 227. The "Area" includes Egypt and the Eastern Mediterranean countries but only the western part of the U.S.S.R. and, therefore, only 18 transmitters are listed for the Soviet Union. The "List of Television Stations," plus six bi-monthly supplements, costs 100 Belgian francs and is obtainable from the E.B.U. Technical Centre, 32 avenue Albert Lancaster, Bruxelles 18.

Radio Show Attendance.—Visitors during the twelve days of the Earls Court Radio Show, which closed on September 5th, totalled 121,907 which was just over one-third of the total attendance (350,620) at the last Show in 1962. In view of this reduction it is understood the whole question of future exhibition policy is to be looked into by B.R.E.M.A. and the exhibition organizers.

London Audio Festival.—Plans are under way for the 1965 International Audio Festival and Fair which is to be held at the Hotel Russell from 22nd-25th April. It is being organized on the same lines as previous shows by C. Rex-Hassan (42 Manchester Street, London, W.1).

Paris Shows.—Next year's Paris Radio Show is to be held from 9th-19th September under the ægis of the Fédération Nationale des Industries Electroniques and will again be international. The Federation is also organizing two other Paris shows—the Festival du Son (11th-16th March) and the Salon des Composants Electroniques (8th-13th April) both of which will also be international. Concurrently with the components exhibition a symposium on "techniques des mémoires" will be held from 5th-10th April. The new address of the F.N.I.E., is 16 rue de Presles, Paris 15.

Self-Tuning Equipment.—The *pièce de résistance* of the Telecommunications Exhibition staged by Marconi at Rivenhall, Essex, in September was the MST (Marconi Self-Tuning) h.f. point-to-point system which was demonstrated under operating conditions to the large number of guests, many from overseas, who attended the fortnight's show. The system's main features are its stability, rapid frequency changing and ease of operation. Frequency changing can be completed at both transmitting and receiving centres with a break in traffic of less than one minute.

Scout Jamboree-on-the-Air.—This annual international event will be held during the week-end 17th/18th October. The following stations are scheduled to operate throughout the 48 hours: DU1BSP, Philippines; GB3BPH, Baden Powell House, London; K2BFW, United States; VE3WSB, Canada; and XE1ASM, Mexico. The U.K. organizer is L. R. Mitchell (G3BHK), Tyneham Close, Sandford, Wareham, Dorset.

Conference of the Electronics Industry.—The secretariat of this consortium of nine associations in the radio and electronics industry has moved from 20 Peel Street, London, W.8, to 61 Green Street, W.1, (Tel.: HYDe Park 8388). Capt. R. A. Villiers relinquished the secretaryship of the Conference on his appointment on 1st August as director of the Electronic Engineering Association and G. M. Haslet is now acting secretary.

I.E.E. Council.—The new ordinary members of the Council of the Institution of Electrical Engineers for 1964/5 are Prof. P. J. B. Clarricoats (Leeds University); J. F. Coales (Cambridge University); Dr. J. M. Dodds (A.E.I. Research Lab.); Dr. E. Eastwood (English Electric & Marconi); Dr. J. S. Forrest (Central Electricity Research Labs.); Dr. F. E. Jones (Mullard); and F. C. McLean (B.B.C.). As announced earlier the new president of the Institution is O. W. Humphreys, vice-chairman of the General Electric Company.

Newly elected members of the Board of the **I.E.E. Electronics Division,** of which G. G. Gouriet is chairman, are: J. H. H. Merriman (G.P.O.) vice-chairman; H. V. Beck (Marconi Instruments); W. J. Bray (G.P.O.); F. J. Hyde (University College, Bangor); B. Marsden (Associated Television); Dr. G. H. Metson (G.P.O.); Dr. W. H. Penley (Min. of Aviation); A. J. Young (English Electric Valve); and R. E. Young (consultant).

Testing and aligning tuners was featured on the Pye stand at the Earls Court Show where there was also an assembly unit

The Paul Instrument Fund, which is administered by the Royal Society, I.E.E. and the Institute of Physics & the Physical Society, has recently made substantial grants to four research workers. Dr. D. J. E. Ingram, professor of physics at the University of Keele, has received £5,400 for the design and construction of a millimetre wavelength electron resonance spectrometer to work at zero or near zero magnetic field strengths and with as wide a frequency coverage as possible. Dr. H. Motz (University of Oxford) is to receive £2,200 per annum for two years for the construction of a pulsed millmetre-wave generator. A £3,400 supplementary grant has been given to Dr. E. E. Schneider, reader in solid state physics (University of Newcastle), to enable him to continue his work on the application of superconducting cavities to magnetic resonance spectrometers, and a supplementary grant of £1,100 has been made to Dr. P. B. Hirsch (University of Cambridge) for the continuation of his work on an electron microscope with velocity analyser.

Mullard Educational Service.—An exhibition to mark the tenth anniversary of the formation of the Mullard Educational Service is to be held in November at the Mullard headquarters in Torrington Place, London, W.C.1. Invitations have been sent out to people in the educational field for the opening day, the 11th, and thereafter it will be open from 10 a.m. to 5 p.m. (excluding weekends) until 27th November. Tickets are not required.

A flying trade fair, aboard a DC7 aircraft, is visiting eleven cities in Europe during September and early October. The "Yankee Peddler" is scheduled to be at Heathrow, London, from 9th-14th October. Hi-G Inc., manufacturers of mechanical relays and electronic modules, have advised us that they are among the 20 companies participating in this project sponsored by the Greater Hartford Chamber of Commerce, Connecticut.

International Hearing Aid Exhibition.—The tenth convention of the Society of Hearing Aid Audiologists (Gt. Britain) Ltd. is being held in London on 9th and 10th October at the Europa Hotel, Grosvenor Square, W.1. A trade exhibition is to be held at the same time and applications for tickets should be made to the secretary of the Society, 2 Greenland Place, London, N.W.1. (Tel.: GULliver 3781.)

Radar Reunion.—The Radar & Electronics Association is organizing a reunion of members of the war-time 60 Group of the R.A.F. It will be held at 7.0 on 24th October at the Victory Ex-Services Club, Marble Arch, London, W.1. Further information is obtainable from the Association, 43 Grove Park Road, London, W.4.

Special Courses.—In order to give the widest possible publication to part-time special advance courses held in colleges in London and the Home Counties, the Regional Advisory Council for Technological Education issues a bi-annual bulletin. The latest edition, for the 1964/5 Autumn term, includes brief details of well over 500 courses at some 40 colleges. Copies are available, price 5s, from the Council, Tavistock House South, Tavistock Square, London, W.C.1.

The television section of the B.B.C.'s new relay Station at **Hereford** was brought into service on 14th September on Channel 2 using horizontal polarization. The v.h.f. sound broadcasting transmitters at this relay station are scheduled to come into operation later in the year and will radiate with horizontal polarization on 89.7, 91.9 and 94.1 Mc/s.

The correct price of the **direct read-out counter** quoted in Proops' advertisement in our September issue is 10gn, not 10s.

Major-General E. S. Cole, C.B., C.B.E., a director of Granger Associates Ltd., of Weybridge, Surrey, since its formation last year, has been appointed managing director. The company, which specializes in the field of h.f. radio communication and plans to manufacture in this country,

Major-General E. S. Cole

is the wholly-owned subsidiary of Granger Associates, of Palo Alto, California. Major-General Cole, whose last appointment before retiring from the Army in 1961 was that of director of telecommunications at the War Office, was for two years manager of the Telecommunications Division of Ultra Electronics. He is continuing to act as a consultant to Ultra.

G. G. Gouriet, M.I.E.E., who recently rejoined the B.B.C. as head of the Research Department after spending five years with the Wayne Kerr Company as technical director, has been elected chairman of the Electronics Division of the I.E.E. He originally joined the B.B.C. in 1937 and was head of the television group in the Research Department when he left in 1958.

Roger Munt, a 20-year-old student technician apprentice at the M.E.L. Equipment Company, Crawley, was awarded a gold medal for gaining first place in the radio and television servicing section of the International Apprentice Competition held in Lisbon in August. He was selected to represent the U.K. in the section which was included for the first time in this year's competition. Mr. Munt is completing his third year in the M.E.L. Electronics Apprentice Scheme. In all, 27 youths from this country entered the various sections of the competition and received eight gold, five silver and two bronze medals.

Alan Burke, A.M.I.E.R.E., chief development engineer of British Relay for the past two years, has been appointed chief engineer in succession to **K. A. Russell,** B.Sc., A.M.I.E.E., who, as announced last month, has been elected to the board and is now group technical director. Mr. Burke originally joined British Relay in 1948 but after National Service spent nearly two years with the B.B.C. before rejoining B.R. in 1953. He is this year's president of the Society of Relay Engineers.

James McG. Sowerby, B.A., M.I.E.E., has joined the board of English Electric-Leo Computers as technical director and will be at the company's main office at Kidsgrove, Staffs. Mr. Sowerby, who is 48, graduated in physics at Oxford and during the war served in the Scientific Civil Service on the design and development of electronic instruments at the Chemical Defence Experimental Establishment. In

J. McG. Sowerby

1946 he joined Cinema Television (now Rank Cintel) and five years later went to the English Electric Company's navigational project division (now part of the British Aircraft Corporation). He was successively chief electronics engineer, chief development engineer and project manager for guided weapons. *Wireless World* readers may remember Mr. Sowerby's series of articles "Electronic Circuitry: Selections from a Designer's Notebook " which ran for two or three years from 1948.

B. A. Pettit, who joined the Plessey organization 10 years ago and for the past three years has been senior sales engineer in the Components Group, has been appointed to the new post of technical sales manager of the Professional Components Division.

D. J. Whittle, M.A., A.M.I.E.E., has joined Tolvision Ltd. as director of engineering. Mr. Whittle is a graduate of Queen's College, Cambridge, and was a graduate apprentice with Marconi's. Since 1956 he has been with Alpha TV Services Ltd. (who operate studios in Birmingham for A.T.V. and A.B.C.) where he was latterly chief engineer. Tolvision Ltd. hold the U.K. franchise for the American subscription television system of that name which is operated over a coaxial network and employs a central billing system. It is one of the five companies appointed by the P.M.G. to conduct subscription television tests during the next three years.

J. S. E. Riddle has been appointed to the new post of manager, service department, at the head office of the Marconi International Marine Company, Chelmsford. He started his radio career in the Post Office Engineering Department and joined Marconi's as a sea-going radio officer in 1940. He transferred to the shore staff in 1946 and became an inspector in 1956. He has since served abroad in Calcutta, Port Said and Oslo and for the past 18 months has been in charge of the company's depot at Lowestoft.

L. Rushforth, M.B.E., B.Sc., M.I.E.E., since 1956 manager of the Valve and Semiconductor Engineering Department at the Lincoln factory of Associated Electrical Industries, has been appointed to a similar position by the English Electric Valve Company who have

L. Rushforth

acquired the Lincoln plant from A.E.I. Mr. Rushforth, who is 54, and a graduate of Leeds University, was from 1933-1946 a valve research engineer with the B.T.H. Co., Rugby, and during the war was con-

cerned with the development of magnetrons and other radar tubes. He was head of pre-production and engineering at the B.T.H. research laboratories for seven years until 1953 when he became head of the Valve Engineering Department at A.E.I. Leicester. The E.E.V. Co. has transferred **R. E. Lake**, B.Sc., from Chelmsford, where he was manager of the Gas Tube Division, to Lincoln where he is deputy manager. Mr. Lake will also be in charge of the Industrial Gas Tube Department. **C. Z. Muskus**, B.Sc., is appointed assistant manager (duplexers) at Lincoln and takes charge of the manufacture of T.R. cells. He joined B.T.H. in 1950 and in 1955 resumed responsibility for valve engineering work associated with the production of T.R. cells at A.E.I. Leicester. Since 1963 he has been assistant engineering manager of A.E.I. Lincoln covering the whole field of valve manufacture there.

S. W. Thompson, M.I.E.E., head of the B.B.C's Transmitter Technical Services since 1961, has retired. He joined the Corporation in 1941 and played a significant part in the commissioning and subsequent operation of the high-power station at Ottringham, near Hull, for the B.B.C's European services. Mr. Thompson was from 1947-61 assistant to the superintendent engineer transmitters at Broadcasting House.

Air Cdre. A. G. P. Brightmore, M.I.E.R.E., director of radio (air) at the Ministry of Defence until his recent retirement from the R.A.F., has been appointed to the newly created position of consultant to the managing director of A. C. Cossor Ltd. Air Cdre. Brightmore was

Air Cdre. A. G. P. Brightmore

director of electronics research and development (air) in the Ministry of Aviation from 1958-1961 having previously served with the 2nd Tactical Air Force as chief signals officer. At one time he commanded No. 3 Radio School R.A.F. at Compton Bassett, Wilts.

A. K. Edwards, B.Sc.(Econ.), who just over a year ago joined the secretariat of the British Radio Equipment Manufacturers' Association as assistant secretary responsible for economic, statistical and export services, has been appointed secretary. He succeeds **S. E. Allchurch**, O.B.E., who was appointed secretary in 1946 and since his appointment as director four years ago has combined the duties of the two positions. Mr. Edwards, after receiving his degree from London University, joined the Colonial Service (now known as the Government Overseas Administrative Service) and spent about 10 years in Nigeria in the Ministry of Communications.

Frank Jones, A.M.I.E.R.E., who recently retired from the R.A.F. after 22 years' service, has joined Wayne Kerr as senior executive engineer. Before his retirement as squadron leader in the technical branch he was senior lecturer in basic control and missile control engineering on the Advanced Weapons Course at the R.A.F. Technical College, Henlow. During the acceptance firing trials of the Bloodhound Mk. 1 at Woomera, Mr. Jones was officer-in-charge, nical services.

In a rearrangement of the "management structure" of the Wayne Kerr company following the concentration of production at South Bersted, near Bognor Regis, Sussex, **J. A. Enwright** has been appointed general manager of Wayne Kerr Laboratories Ltd. and **G. L. Ball**, B.E., A.M.I.E.E., has become general manager of the Wayne Kerr Instrument Company.

Peter E. M. Sharp, A.C.G.I., B.Sc.(Eng.), A.M.I.E.E., recently joined Brush Clevite Company (formerly Brush Crystal) as general sales manager, in charge of all home and overseas marketing. Mr. Sharp, who is 43, joined the Westrex company in 1960 and was appointed a director of the company in the following year. For the past few months Mr. Sharp has been acting as a consultant.

Robert B. Levy, B.Sc., A.R.C.S., has joined Brush Clevite Company, of Hythe, Southampton, as general production manager. Mr. Levy, who is 35, studied at the Imperial College of Science and Technology, where he took his degree in chemistry, and was until recently with Texas Instruments at Bedford.

Centralab Limited have appointed **J. B. Hodgson** as general manager. He was formerly with Elliott-Automation as chief engineer of the Minilog Division.

J. Korndorffer, M.A., has become director of the Mullard television tube factory at Simonstone, Lancashire, in succession to **M. J. Snijders** who has retired at the age of 61 after 39 years' service with Mullard. Mr.

J. Korndorffer

Korndorffer obtained his degree in physics at Oxford University and joined the Mullard Company at Mitcham in 1946. He became works manager of the Simonstone factory in 1955 and last year was appointed deputy plant manager. Mr. Korndorffer, who is 46, operates an amateur radio station under the call G2DMR.

T. H. George is now engineer-in-charge of the B.B.C. Transcription Recording Unit, London, in succession to F. W. Chignall, Assoc.I.E.E., who, as announced in August, has retired. Mr. George joined the Corporation's Technical Recording Section in 1935 and ten years later transferred to the Midland Region headquarters, Birmingham, where he has been mobile engineering manager since 1957.

OBITUARY

Admiral Patrick W. B. Brooking, C.B., D.S.O., superintendent of the Admiralty Signal Establishment, Haslemere, from 1944 to 1946, died on 3rd September, aged 67. Admiral Brooking, who retired from the Navy in 1950 after 41 years' service, was a signals specialist and served during the early part of the last war in the Admiralty Signal Department of which he became director in 1941.

Arthur F. R. Cotton, director of international operations of the Capitol Radio Engineering Institute, died on 19th August, aged 65. He held a commission in the Royal Navy in both world wars and in 1947 went to the United States where he stayed until 1958 and was at one time chief engineer of Airtronic Research Inc. He returned to the U.K. in 1958 to set up and manage the London office of the C.R.E.I.

An Introduction to

MICROWAVE TECHNIQUES

3.—MICROWAVE POWER SOURCES

By K. E. HANCOCK*

IN the two previous articles in this series mention has been made in passing of the early difficulty of producing power at microwave frequencies, and of some of the power-producing devices, such as klystrons and magnetrons, now in use. We will now look into the subject of power sources in more detail.

Above about 1000 Mc/s normal valves and resonant circuits become very inefficient due to the following effects:

(a) The transit time of electrons between electrodes becomes a significant portion of a half period, i.e. the time taken for the wave to travel half a wavelength, and the valve becomes unstable.

(b) The inductive reactance of electrodes becomes significant.

(c) Electrodes are made very small to reduce capacitance and so have small power-handling capacity.

(d) Electrodes, wiring and components, all tend to radiate.

(e) Stray capacitances form a very high proportion of the total capacitance in the circuit.

(f) As the components themselves are in physical size a significant portion of a wavelength they no longer exhibit pure inductive, capacitive or resistive effects as the case may be, but tend to become resonant circuits in themselves.

These effects gradually become more critical as frequency is increased up to about 4000 Mc/s and are combated by various means. At about this frequency, however, they are so great that normally a complete departure from normal valve circuitry must be made. For the microwave band, which may be said to reach from about 1000 Mc/s to the lower infra-red region, five main oscillators and six main types of amplifier have been developed. Of these devices the five currently in greatest use share the common feature of modifying the velocity of an electron stream by structures of resonant length forming an integral part of the device.

The amplifiers, which will not be dealt with in detail, are the microwave triode amplifier, the amplifying klystron, the travelling-wave tube, the parametric amplifier, the maser, and the u.h.f. transistor.

The five types of oscillator in common use are the microwave triode oscillator, the reflex klystron, the magnetron, the backward wave oscillator, and the u.h.f. transistor oscillator. Although these are mentioned in chronological order of development they have not been developed from, nor do they supersede, each other, each operating on different principles and being used for varying purposes.
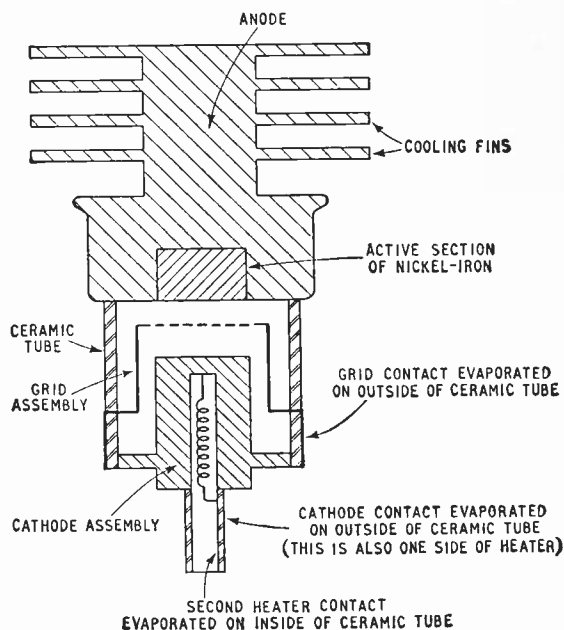
*Canadian Marconi Company.

In addition to these, the varactor multiplier, which is strictly neither an amplifier nor an oscillator, finds many applications as a power source, particularly in the communications field. This device uses special microwave diodes as the active elements in a series of circuits tuned to a harmonic of the previous stage. Using transistor oscillator drivers, operating in the region of 100 Mc/s, milliwatts of power are obtained at frequencies up to around 11,000 Mc/s.

Other power sources such as the tunnel diode oscillator and the step diode multiplier are being developed, and are at present in limited use.

Microwave Triodes

In the transitional region above 300 Mc/s and the lower microwave range up to around 4000 Mc/s it is still possible to use specially designed valves as oscillators and amplifiers. In this section we will deal only with valve oscillators, although many details will apply equally well to amplifiers. The advantages of these valves over other strictly microwave power sources are the relatively simple power supplies and the versatility of the associated circuitry.

Fig. I. Section of a typical microwave planar triode.

ANODE

COOLING FINS

ACTIVE SECTION OF NICKEL-IRON

CERAMIC TUBE

GRID ASSEMBLY

GRID CONTACT EVAPORATED ON OUTSIDE OF CERAMIC TUBE

CATHODE ASSEMBLY

CATHODE CONTACT EVAPORATED ON OUTSIDE OF CERAMIC TUBE (THIS IS ALSO ONE SIDE OF HEATER)

SECOND HEATER CONTACT EVAPORATED ON INSIDE OF CERAMIC TUBE

As mentioned in the introduction to this article, normal valves become increasingly inefficient with frequency due to such effects as the transit time of electrons between electrodes, inductance of electrodes and radiation. An adaptation of a conventional triode called a disc seal or planar triode alleviates these difficulties enabling the practical operating range of triodes to be extended up to 4000 Mc/s, while low-power experimental units operate up to 10,000 Mc/s.

The technique used to achieve this is to take the electrodes straight out of the side of the valve through metal-to-glass, or metal-to-ceramic disc seals. The flat, or planar, electrodes form ideal terminations for microwave resonators, more details of which will be given later. Radiation and lead inductance are therefore greatly reduced. The parallel plane electrode assembly permits the use of small electrode areas. This in turn allows very close spacing of electrodes to reduce transit time effects whilst still keeping inter-electrode capacities down to a reasonable level. A line drawing of a typical planar triode is shown as Fig. 1.

Some planar triodes use a glass envelope but, in general, modern practice is to use ceramic, due to its better shock characteristics, thermal conductivity, lower dielectric loss and the fact that its use makes the holding of manufacturing tolerances easier.
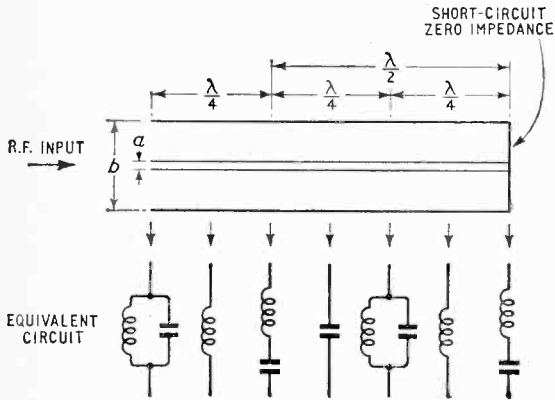

Fig. 2. Resonant lengths of line.

The use of nickel iron, having a fairly low temperature coefficient, for the active area for the anode, together with the flat anode structure helps to prevent change of grid-to-anode capacitance with temperature.

It may be noted at this point that theoretically tetrodes will be more efficient than triodes, but these are seldom used due to the difficulty of providing sufficient screen dissipation, and the fact that they are not quite so convenient to use with coaxial resonators.

Circuitry:—As with a low-frequency oscillator, tuned circuits are required in anode and grid circuits, together with a suitable form of feedback in the correct phase. The normal parallel lumped-constant tuned circuits become very "lossy," and of very small physical size at these frequencies, and distributed-constant coaxial line resonators are used almost exclusively with these values.

Resonant Lines:—First consider a short-circuited piece of coaxial line, as shown in Fig. 2. Remember-ing the theory of reflections and standing waves given in the previous article, we can say that, as a short circuit is by definition a point of zero impedance, the reflection from the short circuit will set up a standing wave. In the case of a lossless line the standing wave would give a point of infinite impedance exactly one quarter wavelength from the short circuit. The input of a shorted circuited $\lambda/4$ line therefore acts in a similar manner to a parallel tuned circuit, and can in fact be used as one.

To substantiate this theoretically, the input impedance (Z_1) looking into the terminals of an air-spaced shorted coaxial is given by—

$$Z_1 = j(138 \log_{10} b/a) \tan(2\pi l/\lambda)$$

where
- a = diameter of inner conductor (cm)
- b = diameter of outer conductor (cm)
- l = length of line conductor (cm)
- λ = wavelength in the line at frequency in question (cm)

Examining the term $\tan(2\pi l/\lambda)$; when $l = \lambda/4$, or any odd multiple thereof, the term reduces to $\tan \pi/2 = \tan 90° = $ infinity, the condition of impedance of an ideal parallel-tuned circuit. It may be easily seen that when $l = \lambda/2$ or any multiple thereof the input impedance is zero and the circuit acts as a series tuned circuit. By suitably adjusting the length of the line any susceptance, capacitive or inductive, can be obtained.

The use of resonant, inductive and capacitive lengths of line is of great importance in microwave work. The line may be coaxial as shown, or waveguide, replacing the free space wavelength factor (λ) by guide wavelength (λ_g).

Microwave Triode Oscillator Circuits:—It will be readily appreciated that quarter-wavelength coaxial lines are very suitable for use as tuned circuit elements with planar triodes. The construction of the valve is such that it can be used to form part of the centre conductor of the resonant circuit, the electrodes forming the input to the lines. Radiation is practically eliminated, and tuned circuit losses are small.

A line drawing of a typical planar triode microwave oscillator is shown as Fig. 3. It will be noted that the resonant lines are not in fact open circuits at the input ends, but are shunted by the anode-to-grid, and grid-to-cathode capacitances respectively. The effect of these capacitances is to lower the frequency of resonance and the resonators must be designed accordingly.

The frequency of the oscillator is mainly determined by the anode-to-grid resonator, the primary function of the grid-cathode tuned circuit being to give the correct phase and amplitude of feedback to maintain oscillation. Some direct feedback between the two circuits is supplied by the anode-to-cathode capacitance of the valve. However, to assure steady oscillation under load conditions, additional feedback is usually required and this is provided by feedback probes or loops between the two cavities.

The Reflex Klystron

The main features of this device are illustrated in Fig. 4. The cathode assembly is of the normal type and is surmounted by a focusing anode. The resonator is a cavity, usually doughnut shape, of dimensions to resonate at the required frequency. At a
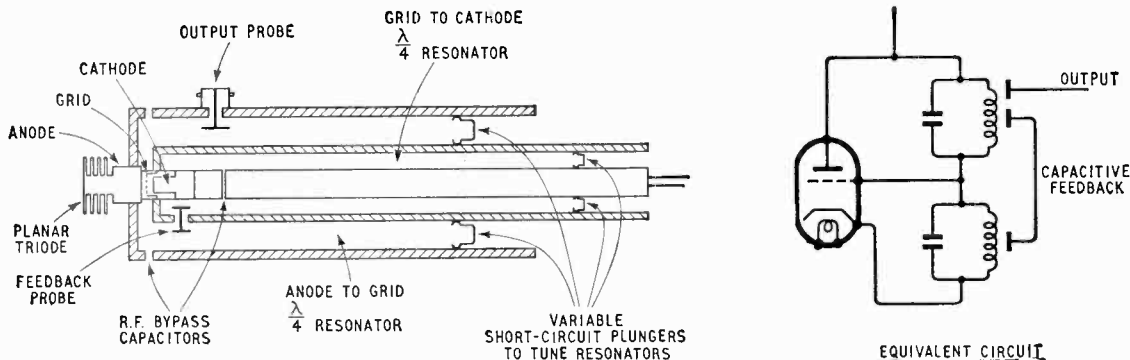
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Fig. 3. Section through a typical planar triode oscillator and (right) its equivalent circuit.

suitable distance from this is the reflector anode. The resonator is held at a high positive potential with respect to the cathode, whilst the reflector is held at a potential which is negative with respect to the cathode and, therefore, very negative with respect to the resonator. An electron beam will therefore be produced which will be focused into a circular beam by the focusing anode, and accelerate toward the resonator, passing through the hole in the centre of this electrode toward the reflector. As the potential on the reflector is well below that of the resonator, as soon as the electrons pass through the resonator they are retarded and, if the reflector voltage is low enough, will reverse their direction and return to the resonator. If this were the complete function of the valve it would merely act as a diode; however, due to random fluctuations in the resonator voltage and beam current the resonator cavity will be excited at its resonant frequency, producing a very small microwave signal which appears across it. Considering the instant at which the polarities are as shown in the diagram; electrons entering gap G_1 will tend to slow down. If the resonator voltage is correctly set, by the time the electrons have reached G_2 the polarity will have changed and will slow down the electrons still further. At the same time the electrons now passing G_1, which has changed to positive polarity, will be speeded up. These electrons will tend to catch up the previous electrons and the beam will bunch as shown, the bunching frequency being equal to the resonating frequency of the cavity. As the slowing down of electrons has added energy to the cavity and the speeding up taken away, the net increase of microwave signal is zero. However, the bunches of electrons having passed through the resonator are reversed and by adjustment of the reflector voltage a bunch maximum can be made to arrive back at G_2 at the same time as microwave field is a maximum. The bunch will then reinforce the field and increase it. This in turn will cause greater bunching of the electron beam followed by a greater addition to the microwave field. Clearly the effect will be cumulative and the cavity will oscillate with a power limited only by its own losses and the power of the electron beam. The power is extracted from the cavity by a suitable probe or loop either into a coaxial line or direct into a waveguide.

Modes:—Oscillation at approximately the same frequency will take place at a number of fixed reflector voltages, corresponding to one or more

bunches existing between resonator and reflector. By varying the reflector voltage slightly about these fixed points, the frequency can be varied by adjusting the time the returned bunches add to the microwave field this being termed electronic tuning. The tuning possible by this method is usually about 0.25% or 25 Mc/s at 10 Gc/s. The first mode, i.e. that with the least number of bunches and the highest voltage difference between resonator and reflector, usually provides the greatest power and electronic tuning range. A graph of reflector modes against reflector voltage is shown in Fig. 5.

Mechanical Tuning:—The frequency of operation of a reflex klystron can be varied over a wider range than is possible electronically by mechanically adjusting the cavity size. This is commonly done by one of three methods:

(a) *The Flexible Cavity:* One or more sides of the cavity is made of flexible metal and adjusted bellows fashion with a clamp. This type of tuning which is normally pre-set, is very common for small klystrons.
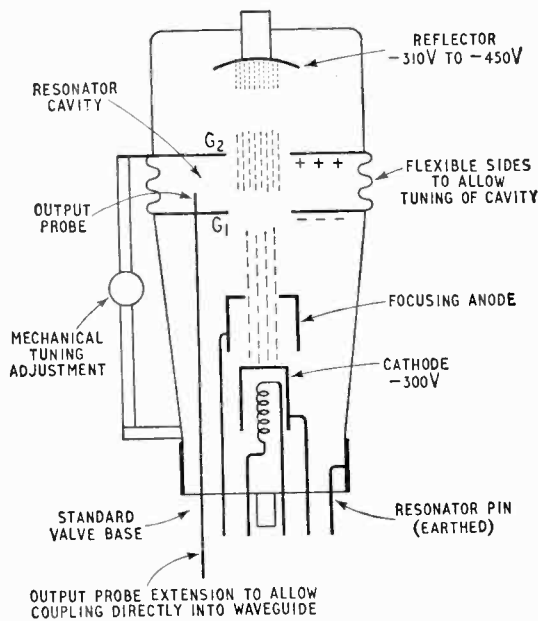

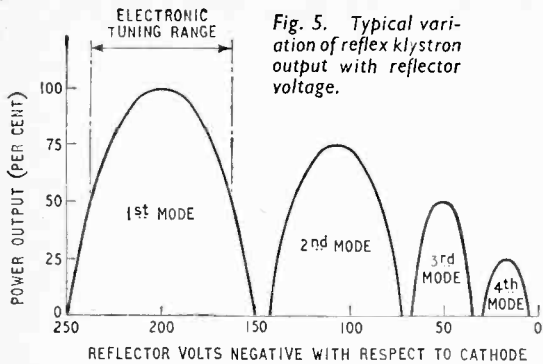Fig. 4. Schematic diagram of a reflex klystron.

Fig. 5. Typical variation of reflex klystron output with reflector voltage.

The tuning range obtainable varies greatly from type to type, but may be as high as 25%.

(b) *Slug Tuning:* As its name infers this technique adjusts the resonant frequency of a cavity by the insertion of a reactive slug or plunger.

(c) *External Cavities:* Klystrons are often manufactured so that an external cavity to meet the user's specific requirements may be used. An interesting off-shoot of this method is the use of the klystron as the inner of a coaxial cavity. The cavity dimensions are then varied by a plunger. By this method tuning ranges of 50% can be obtained.

Uses of Reflex Klystrons:—Perhaps the main use of the reflex klystron is as a local oscillator in microwave radar and radio relay receivers. Its facility of electronic tuning is widely used to provide automatic frequency control.

Medium-power reflex klystrons with outputs of a few watts are used to obtain a continuous-wave output for many radio relay equipments and for Doppler type aircraft radars, the electronic tuning facility being used to frequency-modulate the carrier. These applications and others such as are used in radar speed traps, are becoming of increasing importance. Another common use, particularly of the coaxial cavity type, is as a low-power, variable-frequency source for laboratory and test bench use.

The Magnetron

This microwave source is perhaps the least flexible of the devices under discussion. It was developed in World War II to perform one definite function, that of providing a high-power transmitter output for radar equipment operating in the microwave band. It is ideally suited for this type of high peak power pulse circuitry and still finds its main application in this field.

The theory of operation of the magnetron is extremely involved so a simplified explanation only will be given here. The valve consists of a cathode surrounded by a ring anode, on the inner face of which a number of resonant cavities have been cut. The cavities, often eight in number, are dimensioned to be resonant at the required frequency. When suitable voltages are applied an electron stream will flow from cathode to anode, the device acting as a diode. If a transverse magnetic field is now applied, it will interact with the electron stream causing the electrons to deviate in the direction shown. The angular movement is cumulative as the electrons move out from the cathode so the electrons will execute spiral orbits. When the

electrons collide with the anode the cavities will be shocked into oscillation giving the polarities shown in Fig. 6. This will cause bunching of the electron stream in a similar manner to the bunching in a klystron. In the magnetron, however, the bunched electrons will carry on in orbit and affect the next and subsequent cavities until colliding with the anode. If these cavities are at the correct polarities at the instant the bunches reach them the oscillations will be reinforced and power will be taken from the electron beam.

As in the klystron there are a number of different modes in which the magnetron can operate, corresponding to relative positions of the cavities the bunches excite in turn. Most power is obtained from the "pi mode," i.e., when the voltages across adjacent cavities are 180° out of phase. To allow this mode to propagate whilst suppressing the others, alternate cavity spacing segments are strapped together allowing large circulating currents to damp the unwanted modes. Another method of achieving the same end is shown in Fig. 7, this being known as the rising sun configuration. Mode suppression is obtained by the relationship between large and small cavities. This layout is used at high frequencies, WG-18 and WG-22 frequency ranges being examples, where the small physical size of the cavities and strapping give rise to manufacturing problems.

Output is taken by a coupling loop or probe in one of the cavities feeding into a waveguide or coaxial line.

Many magnetrons are fixed in frequency although a small tuning range can be obtained by a flexible casing.

The efficiency of the magnetron is very high, even when compared with conventional valve at audio frequencies. An efficiency of over 60% is normally obtained at S band (3 Gc/s) whilst at Q band (30 Gc/s) 30% is average.

Due to the very high efficiencies and the large electron beam power obtainable with the circular cathode, very high powers are obtainable with comparatively small units. Peak pulse power of several millions of watts are quite common with magnetrons only inches in diameter.

Heaters:—Due to the high powers generated the cathode runs hot enough to dispense with or greatly
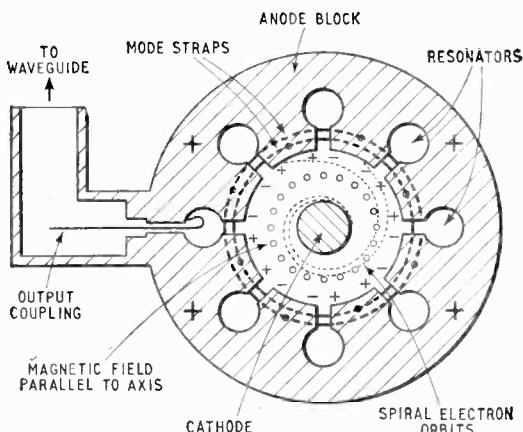

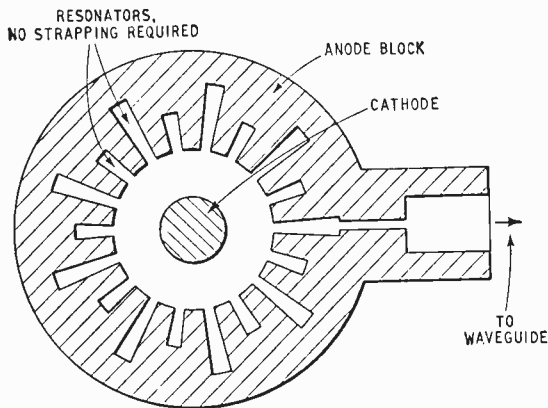Fig. 6. Action of a cavity magnetron.

Fig. 7. Rising sun type magnetron block.

reduce the heater supply after the device has warmed up. As a matter of historical interest, this phenomenon of heaters requiring to be open circuited, in contrast to the more normal failure due to this cause, resulted in many of the early magnetrons overheating and ceasing to function. This problem held back the use of the valve until the cause, and simple remedy of switching off the heaters had been found.

Cooling:—Again due to the high power developed in such a small device, cooling is normally required. In many cases finning, with or without an air blower, is adequate. However, some large units intended for static use are water cooled.

Magnets:—As a very stable magnetic field is required, permanent magnets of very high fields strengths are normally used. Much research has gone into the problem of reducing magnet size and now magnets with fields of the order of 10,000 gauss can be made reasonably small.

The Backward Wave Oscillator

This device, which has come into general use over the last five years or so, is perhaps the most versatile, being capable of a very large electronic tuning range. The action of the backward wave oscillator is as follows. First consider the relative velocities of a microwave field along a conductor and the electrons in an electron beam. The electrons will have a comparatively low velocity governed by the potential difference between the anode and cathode, whilst the velocity of the microwave field will be close to that in free space. If, however, the conductor carrying the microwave field is arranged as a helix, the velocity of the field relative to the axis will be $V\sin\phi$ where ϕ is the pitch of the helix and V the velocity of the field along the conductor. It will be seen therefore that by suitable selection of the pitch angle, the axial velocity of the microwave field can be made comparable with that of the electron beam.

Referring now to the arrangement shown in Fig. 8, the electron beam is generated in the normal manner and partially focused by the first anode. This electrode also controls the power in the beams. The helix is at a high potential, the value of which is determined by the frequency of oscillation required, as will be shown later. An intense cylindrical mag-

netic field concentric with the beam focuses it into a hollow cylindrical configuration passing very close to but not touching the helix. The beam continues to the collector electrode. The helix is terminated in a matched load at the end remote from the electron gun. If, due to noise, a small r.f. voltage is generated across the load, this voltage will propagate towards the gun. If the velocity of the electron beam is correctly adjusted the r.f. voltage will interact with the beam causing bunching in such a phase that energy is given up by the beam and will reinforce the r.f. voltage. The action is cumulative until losses and the limited power in the electron beam prevents further amplification and a stable oscillation takes place. The frequency of oscillation is determined simply by the velocity of the electron beam being such as to add to the oscillation in the correct phase. The required velocity and therefore the helix voltage increases as frequency increases. It will be seen that by merely adjusting the helix voltage the frequency can be varied. This can be done over very wide ranges, the device being ideal for swept frequency operation.

An interesting variation on the configuration just described is the use of a folded waveguide in place of the helix. This allows a greater dissipation than is possible with the helix and permits the collector to be connected directly to the helix or dispensed with altogether.

Uses of the Backward Wave Oscillator:—These components are mainly used in equipment where wide-band operation and simple frequency changing are required. Instances of these are signal generators, swept frequency test equipment such as reflectometers and spectrum analysers, radar jamming and anti-jamming equipment, and spectroscopy systems.

Normally the end of the helix acts as probe in a length of waveguide from which the output is taken. With folded waveguide type of construction the output is obviously taken direct from this. It should be noted that with many b.w.os. with this type of construction the output waveguide is often at high voltage and care should be taken to shield the output guide and provide d.c. isolation from the rest of the system.

As has been mentioned the b.w.os. can be tuned over a wide range by adjusting the helix voltage. They are normally designed to cover a full waveguide range e.g. 26.5 Gc/s to 40 Gc/s in WG-22.

At the present time b.w.os. are low power devices, giving in nearly all instances under one watt, commonly only of the order of tens of milliwatts.

Focusing:—Both solenoids and permanent magnets are in common use at the present time to provide
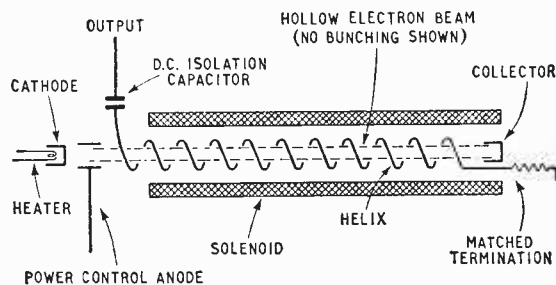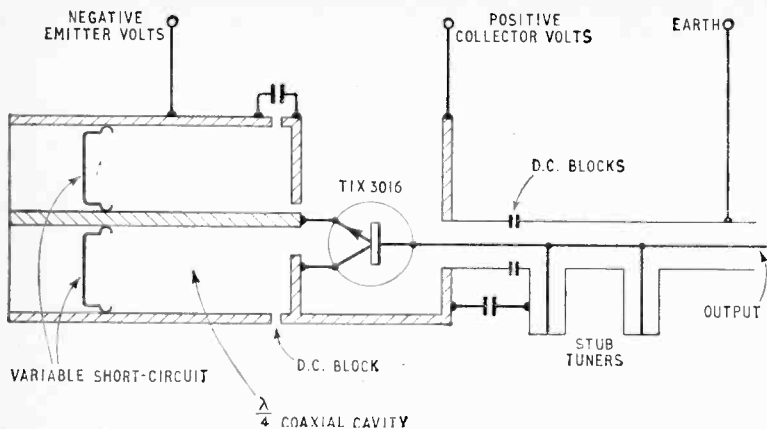

Fig. 8. Backward wave oscillator schematic diagram.

diffused transistors, and epitaxial diffused base transistors, have extremely low inter-junction capacitances and consequently high maximum frequencies of operations. Two main package configurations are at present on the market, a coaxial type suitable for $\lambda/4$ coaxial cavities, and a flat pancake shaped device designed for stripline resonators or coaxial cavities.

Both types are very recent innovations and will probably be joined by other types in the near future. Already there is large demand for these devices in applications where space and weight, both of the oscillator and its power supplies, are of prime importance.

The design of the circuitry for these units is basically very similar to that for planar triodes, and will not be dealt with in detail. A practical circuit for a 2000 Mc/s oscillator is shown as Fig. 9. The output power at these frequencies with current devices is only of the order of a few milliwatts and frequency stability is only fair. However, it seems likely that in the near future transistors will take the place of low-power klystrons in many local oscillator applications.

the required focusing field. The tendency. however, seems to be towards increasing use of permanent magnets thus obviating the need for a solenoid power supply.

In general b.w.os. using solenoids for focus require a forced air draft to cool the coil. For those oscillators using permanent magnets ambient air cooling is usually sufficient.

Transistor Oscillators

Recent advances in solid-state technology has given us transistors capable of operating as oscillators up to around 3000 Mc/s.

These transistors, variously termed micro alloy

COMMERCIAL LITERATURE

The provisional data sheets describing a range of silicon " **Field Effect Transistors** " manufactured by the recently formed company Semitron Ltd. are available from the company's works, Cricklade, Wiltshire.
13WW 325 for further details

S.T.C. Components.—The Components Group of Standard Telephones and Cables Ltd. have recently published the second edition of their "Designers' Digest". Copies of this 40-page catalogue, which contains abridged technical details on products from their quartz crystal, magnetic materials, semiconductor and valve divisions, are available from the Components Group, Standard Telephones and Cables Ltd., Footscray, Sidcup, Kent.
13WW 326 for further details.

Copies of the D.T.V. Group's " **Industrial Electronic** " catalogue are available from 126 Hamilton Road, West Norwood, London, S.E.27. It contains, in 80 pages, information on the products D.T.V. distribute in this country. This includes a wide selection of components (from plugs and sockets to transformers and valves), test gear, industrial audio equipment, motors and ultrasonic cleaners.
13WW 327 for further details

A.E.I. Semiconductors.—The range of A.E.I. semiconductors now available for industrial applications are described in publication 3320-51. Copies of this 28-page booklet, which is intended to be a general guide to the larger semiconductor devices within the A.E.I. range for use in industrial equipments, may be obtained from the Electronic Apparatus Division, Electronics Group, Associated Electrical Industries Ltd., Carholme Road, Lincoln.
13WW 328 for further details

Information on the " Etchineering " process of **photo-etching metals** is included in an eight-page booklet available from Micropanent Development Ltd., who have recently moved to 17 Newhall Hill, Birmingham 1. (Tel.: Central 6201.)
13WW 329 for further details

A 30-page catalogue describing the Variac range of **continuously variable transformers** made by the Zenith Electric Company, is available from the British distributors Claude Lyons Ltd., Valley Works, Hoddesdon, Herts. A large section of the publication is devoted to their toroidal-wound variable transformers.
13WW 330 for further details

A short form catalogue describing the products of **F. W. Bell Incorporated,** of Ohio, is available from Livingston Laboratories Ltd., 31 Camden Road, London, N.W.1. It includes details of their gaussmeters and probes, Hall effect devices, Hall multipliers, wattmeter transducers, magnetic testing instrumentation and their wideband wattmeter.
13WW 331 for further details

A data sheet describing the Leach Models FM 200A and FM 200B two-watt **telemetry transmitters,** which are designed to operate in the frequency range 215 to 265 Mc/s, is available from the controls division of the Leach Corporation, 717 North Coney Avenue, Azusa, California. These transistor units are frequency modulated and weigh less than 22 ounces.
13WW 332 for further details

Underwater Components.—" Cable-glands and Housings for under-water electronic applications " are described in a recent publication (276) from Submarine Cables Ltd., Greenwich, London, S.E.10.
13WW 333 for further details

ELECTRONICS AT FARNBOROUGH

DEVELOPMENTS IN SYSTEMS AND INSTRUMENTATION

"FARNBOROUGH—'64," coming after a two-year break, had more than its usual quota of electronic equipment on show reflecting the ever-increasing need for electronic aids, not only in the art of flight itself but also in air traffic control, meteorology, communications, test equipment and training.

In parallel with the technical developments a marked increase was noted in co-operation between manufacturing companies both at home and abroad. With the massive development costs in introducing advanced systems more advantage is being taken of cross-licensing of designs and even of joint development.

Most publicized of the exercises in joint development is, of course, the Anglo-French Concord(e) and the choice, announced on the eve of Farnborough, of Elliott-Automation to lead a three-nation team to develop the automatic flight control system for this aircraft emphasizes the new international approach. Partners with Elliott-Automation are the French Company S.F.E.N.A. and the Bendix Corporation of America with whom E-A have had a long and successful association.

Other examples are Decca Radar's HARCO system for the short-range navigation system for Eurocontrol, developed in conjunction with C.S.F. in France and Telefunken in Germany; SECAR secondary radar where Marconi are working with the French Thomson-Houston Company, and the recently announced joint Anglo-French proposal for a new air-to-surface tactical-strike guided missile.

The new Sea Dart small warship missile from Hawker Siddeley demonstrates the continued team spirit on the home front by the consortium of A.E.I., E.M.I. Electronics, Ferranti, G.E.C., Hawker Siddeley Dynamics and Sperry, all engaged on aspects of guidance, control and testing of the new weapon.

Two years ago the Farnborough electronics interest was largely on blind landing. For civil use this was
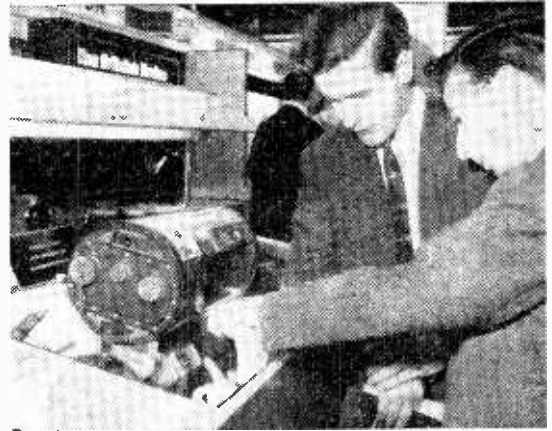

Louis Newmark repeater platform unit.

necessarily a long-term project but equipment is already in the Belfast, Trident, One-Eleven and VC-10. Over 12,000 successful landings have been made with the BLEU system and a Trident with Smiths duplex system has made a number of test landings at R.A.E. Bedford, Trident's home base at Hatfield and at London Airport. It is hoped to achieve certification for duplex auto-flare during the coming year, clearance for fair-weather triplex auto-land in 1965/66, and full blind-landing certification by 1968/69. The Belfast shown at Farnborough was equipped with the Smiths full triplex system.

With both *en route* and landing auto-control systems in being, the only flight regime not yet in an advanced stage of automation is take-off. This situation is about to be remedied by Elliott-Automation who revealed for the first time, as a first stage approach, their Take-off and Overshoot Director. This equipment provides the pilot with the optimum profile to fly under all conditions of sudden wind-shear, early or late rotation, temperature changes and so on. The system is programmed with the characteristic of the aircraft in which it is installed and further programmed for the particular condition of take-off immediately before the event. Engine failure procedures are already programmed in the computer. The equipment shown operates only in pitch but a three-axis model is under development and will have the same safety standard as automatic landing systems.

Smiths are not neglecting this new field and showed two new items, a Ground Run Indicator and their new Take-off Director System. The Ground Run Indicator is a simple device deriving distance-to-go and velocity information from a wheel pick-off. The Take-off Director provides an output suitable for any flight director or head-up display and directs the pilot when to start the rotation manœuvre, the correct rate at which to pitch the aircraft, the pitching motion to achieve best flare-up, action to be taken for thrust or drag changes and the action required for best climb-out. The system uses inputs of pitch attitude and longitudinal acceleration to compute the commands, and an airspeed sensor for detecting rotation speed. Computation is by analogue methods and programming by digital type
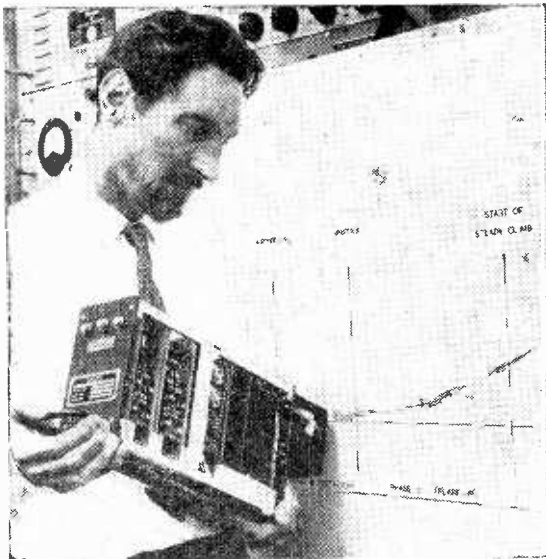
Elliott Take-off and Overshoot Director.

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logic. All circuits are solid state and the sensors, carried in the aircraft, may be duplicated if required. The system is soon to start flight testing.

Louis Newmark Ltd., a few years ago practically unknown in electronics, now report that avionics has become a major part of their business. Concentrating on the special requirements of helicopter auto-pilots and auto-stabilizers, one of their new developments on show was a repeater platform unit which has the primary objective of maintaining the sensitive axis of an accelerometer vertical with respect to the earth's surface to measure vertical acceleration. Two motor-driven gimbals, three synchros and three accelerometers are employed to provide additional control functions and repeater information. The servo amplifiers and electronic units are all in modular form and the total weight of the equipment is under 19 lb. Platform errors are claimed as 8.5 minutes of arc in the datum position and 11.5 minutes of arc at 30 degrees.

Ferranti's navigation contribution was the lightweight inertial navigator available in four variants with either the high-quality M2519 Kearfoot type beryllium-floated integrating rate gyros (manufactured under licence) for full inertial capability or the Ferranti 122 single-axis fully floated gyro for limited inertial capability and use with Doppler-mix or star-tracker systems. The outputs will match digital or analogue present-position computers. A fully transistorized system giving latitude and longitude outputs and with self-contained gyro-compassing has already been successfully flight tested.

Smiths new Series 6 Flight Control System, already specified for Fokker's F28 Fellowship turbofan transport, has been designed on the building-brick principle so that it can be extended as required from a simple auto-stabilizer or heading reference to complete automatic and instrumental control. Flight development is proceeding in Smiths' own Hawker Siddeley 748 aircraft which was present at the show.

Elliott-Automation, also, announced a new inertial navigation system which will be based on design and operational experience gained with the E-3 stable platform.

While safety of flight is always the prime consideration, the demand for positive indication of cause of failure following a mishap has created a flurry of activity in data recorders. The Royston Midas system, providing complete data acquisition and subsequent analysis for normal as well as abnormal conditions, is well enough known. Newcomers, however, included the Davall/Plessey Flight Data wire recorder, the Redifon/M.L. Aviation/R.A.E. Aircraft Accident Data Recorder and the Elliott AIR2 Flight Recording System.

The Davall unit, with mechanics by Davall and electronics by Plessey, is a 200 hours continuous recorder with cassette loading and a performance, with a wire speed of 3.5 in/sec, of 24 samples per second of an 11-bit binary coded system. In the crash role the recorder will sustain impact shocks of 100g at the attachment points, a static load of one ton applied in any direction and exposure to flames of 800°C over 50 per cent of its surface for 15 minutes. The medium itself can retain magnetic records at temperatures in excess of 500°C. Among the airlines to be supplied with this recorder are BEA, Aer Lingus, Olympic, Sudan and Pakistan International.

The Redifon unit, selected for the TSR2, has been designed in conjunction with M.L. Aviation and has a tape recorder based on reciprocating equipment developed by R.A.E. to provide storage of information of flight data for fifteen minutes. A programming patchboard gives flexibility in use and up to 70 parameters may be recorded at rates of one to six times a second up to a limit of 280 per second. Ejector and non-ejector (the latter fireproofed and armour-plated) versions are available. The ejector version is fitted with a parachute to limit terminal velocity, an 80-hour duration radio beacon, a fluorocine marker for location in water and a self-inflating stabilizing bag for extra stability in rough seas. But even without the stabilizing bag the unit is sufficiently self-buoyant to surface from 100 ft depth of water.

The Elliott unit has been specifically designed for aircraft flight trials. Using 1-inch tape and heads for 14 or 16 channels, an eight speed mechanism gives over 12 hours recording on a single reel at one end of the range and a tape speed of 60 in/sec at the other. Tape capacity is 1,800 ft.

Another airborne tape recorder shown was the miniature model design by the R.A.E. to be used in the British earth satellite UK3. Powered by solar cells it will record data during each 96 minute orbit on 140 ft of tape and, on command, will transmit by telemetry link the stored data in a time of 2 minutes. It is expected to work continuously for one year. Power consumption is 0.75 W on "record" and 1.5 W on playback.

Military airborne radar performance is, naturally enough, highly classified but Ferranti showed a film simulating radar trial flights of high-speed low-level approaches to targets over mountainous terrain. This is the role for the TSR2 for which Ferranti are responsible for the forward looking radar.

The situation is not nearly as delicate on the civil side and Ekco Electronics had no restrictions on publicizing their new high-powered E190 airborne weather radar available, if required, with a bright screen storage tube. The new unit is similar to and interchangeable with the standard unit but has twice the power ouput and a longer pulse giving a range increase of 40 per
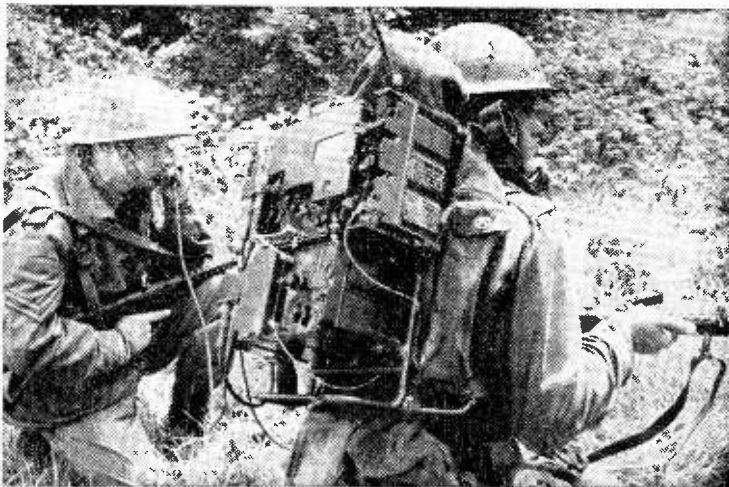
Above: Tape recorder unit for UK3, driven from solar cells (total power 1.5 W).

Left: Plessey mobile radio station AI3, demonstrated at Farnborough.

www.americanradiohistory.com

Ferranti-R.A.E. moving map display for low-level navigation.
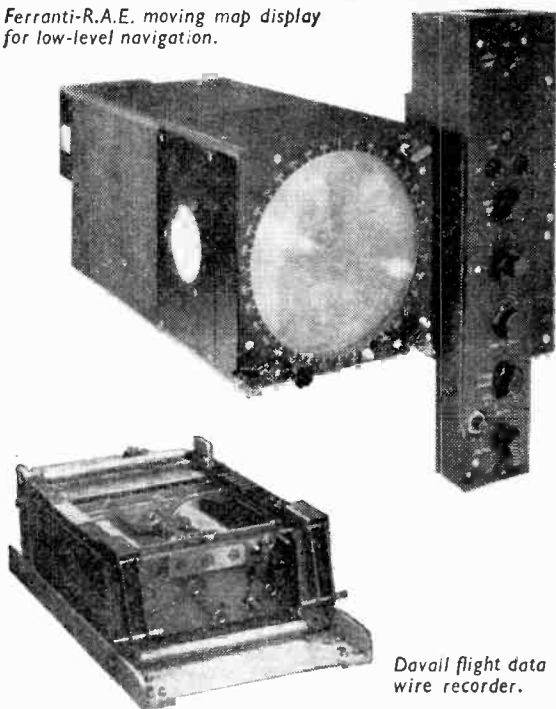
Davall flight data wire recorder.

cent. The duplicate system, as fitted to the VC-10, and a lightweight system for small aircraft were featured on the company's stand.

Air traffic control grows in importance and complexity as the traffic it controls multiplies year by year. The National Air Traffic Control Service was demonstrated by the M. of A. with a data link to their Apollo computer.

Secondary radar was demonstrated by Cossor, who are old hands at the game, and by Standard Telephones & Cables and A.E.I. who have jointly developed 2- and 3-pulse ground interrogator equipment meeting ICAO standards. S.T.C. are responsible for the transmitter/receiver system and A.E.I. for the aerial, turning gear and control equipment. The S.T.C. transmitter employs a single-grid pulsed travelling-wave tube of high gain to amplify all mode pulses before feeding to a high-power coaxial semiconductor switch. The switch feeds the individual pulses through pre-set r.f. attenuators to either the interrogate or control elements of the aerial as required. This method of deriving all pulses from one transmitter through passive networks gives consistent pulse amplitude stability and eliminates the necessity of balancing separate transmitters. Solid-state devices are used throughout with the exception of the t.w.t.

Knowledge of aircraft height is essential to efficency in air traffic control and both Smiths and Elliott-Automation announced transmitting altimeters to meet the expected mandatory requirements for civil aircraft. Decca Radar, in their live demonstration of an integrated a.t.c. system, featured height information as an additional feature on their data link from the demonstration aircraft which was transmitting Decca Navigator information and which controlled a marker symbol on the radar display. The display unit was the 12C from the versatile Decca Series-5 range of autonomous transistorized displays which comprises some 100 versions. These displays are to be used for the Eurocontrol simulator project.

A three-dimensional display for use with any data-processing radar was featured by E.M.I. Electronics. This display uses a flat-faced c.r.t. on which is generated the outline of a perspective view of a trans-parent cube to represent the airspace being examined. The aircraft appear within the cube as luminous spots. The cube can be rotated and tilted as required and the operator can introduce graticules in any of the three planes for quantitative assessment of the a.t.c. situation. Although a monochrome display was shown it is possible to produce a version to distinguish, by colour, the various kinds of information.

Among the bright-screen displays was the Marconi Distance from Threshold Indicator using a 5-in direct view storage tube. Two modes of operation give either an off-centred display showing the final 10 miles of approach or a centred display with a range of 10-20 miles radius from the site. In the prototype trials the first storage tube exceeded 8,000 hours life.

A new meteorological radar, the Marconi Rainbow, was on public view for the first time. Six display ranges are provided from 12.5 to 200 nautical miles, enabling storms and rain-producing clouds to be examined over an area of 125.000 square miles. The 12-inch high-brightness display is fitted with an electronic bearing indicator to eliminate parallax error. The 70 kW p.e.p. X-band transmitter and the receiver are housed in the scanner mounting which may be as far as 3,000 ft from the display.

Decca were able to announce at Farnborough the first order for London Airport of their new airfield surface movement indication radar, now under development. This 8-mm wavelength equipment has a scanning rate approaching 1,000 r.p.m. to provide continuous movement presentation so necessary for controllers diverting aircraft to high-speed turn-off points. The turning point can be precisely specified, thus minimizing the risk of overshoot.

In communications Marconi have added a new solid-state airborne HF transmitter/receiver equipment to their Sixty Series. Double and single sideband modes are provided over the range 2 to 29.999 Mc/s with $\frac{1}{4}$ kc/s channel spacing. Silicon transistors are used throughout with the exception of the final power output stage. Operating frequencies are generated by a synthesizer, semiconductor diodes are used for all switching functions and solid-state tuning is used. Two models are available, the AD460 rated nominally at 500W p.e.p. and the AD470 rated at 1 kW p.e.p.

Perhaps because airborne assault troops took part in the flying display the S.B.A.C. permitted exhibition of much equipment, principally for communications, not specifically connected with flight. Outstanding in this group was the Plessey transistorized HF equipment

E.M.I. three-dimensional display for radar data.
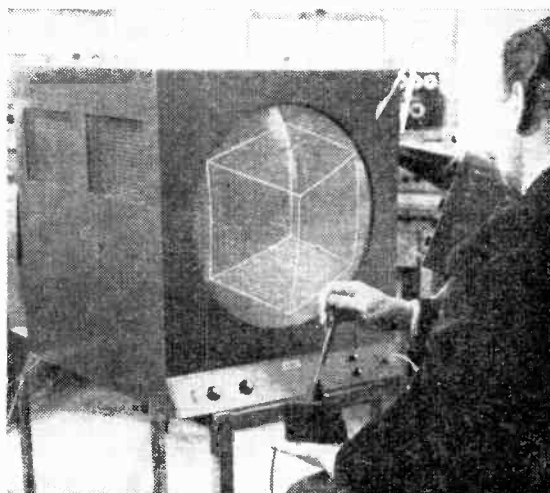
A13 making its public debut. Frequency range is 2-8 Mc/s in 2,400 channels with phase modulation as well as a.m. and c.w. facilities. Produced in conjunction with the M. of A. for the British Army, the equipment is designed for five different rôles from a low-power one-man packset to a high-power vehicle installation. British Communications Corporation showed a similar equipment but of higher power with 18 crystal-controlled channels.

Another item of great interest was the Chobham Navigator by Sperry, which was demonstrated in a Land-Rover. This device, developed in conjunction with the Fighting Vehicle Research and Development Establishment, obtains heading references from the earth's magnetic field by means of a pair of Sperry flux valves and gives the commander of the vehicle a running six- or eight-figure map reference accurate to better than one per cent of the distance travelled.

In instrumentation Bryans Ltd. showed their latest XY/T plotters, Model 22000 and variants, which are portable and low-cost. These plotters are completely transistorized and have an acceleration of 1000 in/sec² and a slewing speed of 63 in/sec. Maximum sensitivity on d.c. is 0.2 mV/in on both axes and on a.c. 0.1 mV/in and 0.1 V/in on the Y and X axes respectively. Accuracy is within 2 per cent up to 30 kc/s.

A major breakthrough by Wayne Kerr Laboratories and the R.A.E. has solved the problem of calibrating instrument landing systems for ICAO category 2 (50ft), and even category 3, which is full autoland. The new accuracy achieved, 0.01 per cent, is more than 100 times better than has been achieved on previous instruments. Fully transistorized, it measures the mean modulation depth and phase of the tone for both localizer and glide path. The new measure of accuracy achieved represents a displacement of less than 3 inches at the runway threshold.

Yet another new instrument was a variant of Marconi Instrument's TF801D/1. The modified instrument, TF801D/SMI, has an altered frequency range, continuously variable output, and improved stability and external modulation circuits providing negligible phase shift at 30 c/s to cater for VOR requirements. A crystal oscillator is fitted internally for use when an accurate 75 Mc/s signal is required for checking marker beacon receivers.

Bryans portable XY/T plotter.

Little room is left for mention of automatic check-out systems or training aids, but Solartron showed their four-target A.T.C. radar simulator and Redifon and G.P.S. were prominent with flight simulators. Redifon's four-target a.t.c. radar simulator and Redifon and an order for a Douglas DC9 flight simulator for Air Canada, the first time an initial flight simulator contract has been awarded for an American-type aircraft outside the United States.

What is the shape—and size—of things to come? Standard Telephones and Cables had three experimental sub-miniature units on view. They were a marker receiver and a single-channel v.h.f. transmitter and receiver. All use thin-film modules, silicon planar transistors and planar wiring techniques. Each unit measures 4.55 in × 1.1 in × 0.9 in and weighs under 5 oz.

J. P. W.

ANY MORE FOR THE SKY LARK?

A CONDUCTED TOUR OF FARNBOROUGH

BY "VECTOR"

DESPITE their unpromising and frigid exteriors, deep down inside them the British dearly love a party. In Elizabethan and Stuart times the urge found expression in dancing around maypoles, in wassailing and in assorted mollocking, but when O. Cromwell, Esq. arrived on the scene he soon put a stop to all that sort of nonsense.

Today finds us re-equipped with the desire to let off steam, but as the Puritan influence still lingers, we now have to find a justification for throwing a party. Some Sacred Cause, preferably. And what more Sacred Cause could there possibly be than that of making money? Hence the twentieth-century epidemic of Motor Shows, Industrial Exhibitions, Radio Shows, Instrumentation Shows, Toy Fairs—but fill in the list for yourself. Sex is probably at the root of it all; something to do with prehistoric fertility rites I shouldn't wonder, if only we could dig down deeply enough into the British character to find out.

Thus it comes about that Farnborough (Hants) which,

for fifty-one weeks of the year is as pleasant and law-abiding a little town as one would ever wish to by-pass, suddenly burgeons into the Anglicized equivalent of Dodge City. At the first signs of the imminence of the Air Show the local citizenry, according to their temperaments, either lock up their daughters or send them off post-haste for new finery at Horridges and then get themselves set up in the taxi business. Living accommodation is at a premium. Every henroost for miles around has been booked a year in advance by engineers; indeed, so appalling is the shortage that even Managing Directors have, on occasion, been forced to pig it in three-star hotels.

But this is the climax. Farnborough Air Show actually begins back in the manufactories on January 1st, when the Exhibitions and Fairs Bloke, in a mental triumph of hope over experience, calls a meeting of all the Divisional Top Brass in order to decide what is to be shown at Farnborough. This, he explains in his opening remarks, is essential in order that he may get

to work on a scheme for the stand. His homily, which is delivered in the tone in which he normally converses with his three-year-old twins, is received with applause, and the meeting gets down to brass tacks.

It continues for three days and much is accomplished. In the Deputy Managing Director's absence his new limousine is thoroughly assessed, with divers conjectures as to how he got it. The Aviation Manager, who has a touch of sciatica, is presented with sovereign remedies by one and all. Christmas experiences are freely exchanged, and the latest iniquities of sundry competitors are given frank and generous discussion, with particular reference to the scandalous distribution of New Year Honours. Only when the Exhibitions Bloke raises for the nth time the question of what is to be shown at Farnborough is there a strained silence. Exhibition Managers are among the Mental Homes' best customers.

He really should have known better than to ask. No Divisional Chief will ever make up his mind that far in advance and even if he did he would only get it changed for him at least twenty times by his Chief Sales Engineer and all points east. When the die is eventually cast (about three weeks before opening day if the Exhibitions Bloke is lucky) it will be in favour of some bit of equipment which has been in full production for six years and has sold so well that not one working version remains in the factory. As a full-scale working demonstration is envisaged, a luckless team of junior engineers is conscripted with orders to work day and night to build one by hand. This is finished in the nick of time and rushed Exhibition-wards by special road transport, only to disappear into thin air *en route*. The Exhibitions Bloke, a man of resource, fills the gap on the stand with a knitted statue of the Minister of Aviation, kept handy for just such a contingency, and the show goes on.

It is, naturally, by no means only the manufacturers who have to plan ahead. Every Chief Highways Engineer in the country, and particularly those within a hundred-mile radius of Farnborough, must be on his toes to ensure that at least one—and preferably several —main roads are scheduled for tearing up during Air Show week, thus providing a diverting manoeuvre for the benefit of the A.A. and R.A.C. The only people who report reasonable road conditions during that week are those who find that they have been diverted to Farnborough (Kent).

One might be tempted to suppose that the best possible advertisement for British aviation would be a fixed-wing and helicopter ferry service between the main cities and Farnborough airfield, but no! The nose-to-tail crawl which was good enough for our fathers is good enough for us—and what better exercise for the soul than to be stuck out miles in the country watching the snails whizz past?

There is a subversive school of thought which holds that the only people who really want an Air Show— with the possible exception of the brewers and distillers —are the Great British Public, and they are not allowed in until the last three days, anyway. This school goes on to conjecture that the vast Flutters-Maddely Aircraft Corporation only exhibits because the mammoth Staggers Aviation Group will assuredly be there, and *vice versa*. That this is manifestly a heresy is shown by the orders which hit the newspaper headlines during the first couple of days. Things like:

STAGGERS AVIATION CAPTURE £60M. CONTRACT

"We are rather pleased," says Managing Director.

Such orders, taken on the very first day, conjure up a rather charming cameo. One can imagine the Chairman of Ruritanian Airlines trotting around bright and early that morning, getting his shopping done before the rush starts. He pauses to admire a luridly coloured model of the proposed Staggers Scabrous 10-jet 300-seater. "So sweet iss" we hear him murmur approvingly. "Oh—you say nots evens ons drawings boards yit? It makes for noddings. I 'ave 'alf dozens, pliss" And a smiling salesman makes a back for the Chairman to sign his £60 million cheque on. It is, of course, pure chance that Staggers Aviation's Chief Press Officer has simultaneously arrived on the stand with five newspaper Air Correspondents and three cameramen in tow. It all goes to show the zippy way in which business is conducted at Farnborough, with none of those tiresomely protracted examinations of detailed specifications and close scrutiny of a prototype by armies of technicians, which have been known to preceded the laying down of even a token deposit by the customer.

Farnborough is primarily an airframe show into which the electronics industry first crept under the tent-flap. But as no self-respecting aircraft of today would dream of lifting a wheel off the runway unless it has at least half a million pounds' worth of electronic gubbins aboard, the tail is now tending to wag the dog. As a consequence, hordes of electronics sales engineers are kept frantically busy on the stands fending off stupid questions, like "What is the price, please?" and "What is the delivery date?" which foreign visitors in their ignorance of the British are prone to ask.

But no one can deny that technically the aviation electronics firms are right on the ball. As an instance, take microelectronics, which is still considered frightfully *avant-garde* by the industry in general. The aviation boys are too modest to say this, of course, but the fact is that they are miles ahead of the field in such matters. Indeed, so far have their techniques developed that a surreptitious opening of any of the black boxes which adorn the stands is likely to expose microcircuitry which is so minute that it is quite invisible.

During the afternoons when flying is in progress, the pace slackens in the Static Exhibition. This permits stand-to-stand fraternization or, less couthly, a snoop around to see what the others have got. Camaraderie prevails. Cigarette packets are proffered to deadly rivals with a frank, friendly smile and a "Do you smoke, old man—or do you leave that to your equipment?"

But all work and no play has notorious effects and if the exhibitors work hard, they play hard too. After 7 p.m. Farnborough is a wideopen town until at least 9.30. The girlie shows run non-stop and the gambling hells blaze with neon. At the plushiest joints, Managing Directors are staking their Company's future on the turn of a domino and in the less exalted emporiums Chief Engineers stare crazy-eyed at the snakes-and-ladders board. Saddest sight of all, away over on the other side of the tracks crouch the engineers, huddled is dismal shanties, sucking the pernicious peppermint and passing over their month's salary to the impassive croupier in charge of the snap cards. A half handful of rice is the recognized currency in this unsavoury quarter.

And suddenly, the week is over; the captains and the air marshals depart and Farnborough is itself again. But before you know where you are it will be January 1st again and the Exhibitions and Fairs Bloke will call a meeting. This time it will be Paris, which is the same thing all over again, but in French.

CLUB NEWS

Introduction to
Practical Transistor Circuit Design

2.—PARAMETERS (CONTINUED): SOME PRACTICAL CIRCUITS CONSIDERED

By G. P. HOBBS,* B.A., Grad. I.E.E.

A GENERALIZATION often heard is that transistor impedances are always complicated by input conditions being dependent on output circuitry and *vice versa*. Whilst it was shown last month that theoretically the input resistance of a grounded-emitter could vary over a 2 : 1 range as the collector load changed, in practice it was found seldom to vary much from the value $r_{b'e} + \beta R_E$. What, on the other hand, of the output resistance at the collector in this configuration—does this vary with change in the source resistance? It turns out that it does, by the 2 : 1 factor again, and the variation this time is a practical occurrence. It will be shown that the range covered is from r_{ce} to $r_{ce}/2$. This, however, assuming normal values of collector load ($R_C \ll r_{ce}$), has only minor importance. The output admittance for infinite source resistance, $2/r_{ce}$, has a corresponding h-parameter, h_{oe} (resistive part), and often appears in makers' data.

Referring to Fig. 1 (repeated here), $r_{b'c}$ is so much larger than r_{ce} that its shunting effect at the output would be thought negligible. Indeed this is so when the base terminal is a short-circuit to earth at signal frequency, but not when the base terminal is allowed to float. Consider the case of infinite source resistance and imagine injecting a small current δI_C in at the collector. Most of this finds its way to earth through r_{ce}, but a small fraction

$$\frac{r_{ce}}{r_{ce} + r_{b'c} + r_{b'e}},$$

which may be written to sufficient accuracy as $\frac{r_{ce}}{r_{b'c}}$, splits off down the high resistance path to the base. As the base is floating, the current has no choice but to flow to earth through the base-emitter junction. Now transistor action will be to produce a current β times greater in the collector circuit giving a total current flow at the collector of $\delta I_C\left(1 + \beta \dfrac{r_{ce}}{r_{be}}\right)$ $= 2\delta I_C$. Twice as much current flows into r_{ce} as had originally been envisaged or, more explicitly, the resistance seen by δI_C is $r_{ce}/2$ and not r_{ce}. As the source resistance has only to become comparable with $r_{b'e}$ for a reduction in output resistance to occur, this is quite a practical effect.

In the presence of an emitter resistance the criterion on whether the $r_{b'c}$ path contributes to a significant reduction in output resistance is the ratio of R_S, the source resistance, to $r_{b'e} + \beta R_E$. The emitter resistor on its own tends to raise the

* The Marconi Company Ltd., Chelmsford, Essex.

collector resistance. When the source resistance is infinite there can be no such increase but when the base is tied to a fixed voltage, the output resistance is raised by an amount μR_E. Just as the anode slope resistance of a valve becomes $r_a + (\mu + 1)R_K$ with an unbypassed cathode resistor R_K, the collector resistance becomes $r_{ce} + \mu R_E$ for a *voltage* drive at the base. Treating the arrangement as a compound transistor, with emitter resistance $r_e + R_E$ we have for a voltage drive on the base, an effective mutual conductance of $\dfrac{1}{r_e + R_E}$. The amplification factor, $\dfrac{dV_C}{dV_B}$, being measured at constant collector current remains as μ (the presence of R_E can have no influence when I_C remains constant). The output resistance of the compound transistor is then given by the ratio of the amplification factor to mutual conductance as $\mu(r_e + R_E)$ and this is our justification for the stated increase μR_E.

Common Base Stage:- Let us go one stage further and make R_E infinite whilst grounding the base. This is, of course, the common base configuration. The only path between the emitter terminal and ground is now the "black box" resistance $r_{b'e}$. The collector resistance is raised, according to the last paragraph, to $r_{ce} + \mu r_{b'e}$ or roughly to $r_{b'c}$. In the presence of such a high impedance one cannot ignore the other path from collector to base—through $r_{b'c}$ itself. The two paths in parallel give a total output resistance of $r_{b'c}/2$. The common base output admittance with input floating is an h-parameter h_{ob}, so that h_{ob} (resistive part) $= 2/r_{b'c}$.

By swinging the changes—varying the relative resistance paths to earth from base and emitter, the collector resistance to earth moves over the range $r_{ce}/2$ to $r_{b'c}/2$. The path to the base grounded is β times greater than the path to the emitter grounded. Another example, perhaps, of an impedance asso-

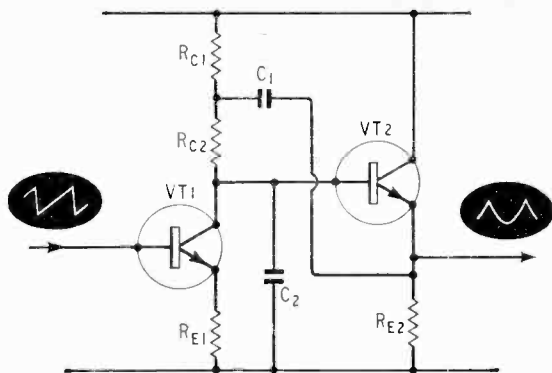*Fig. 1. Common-emitter hybrid-π equivalent circuit.*
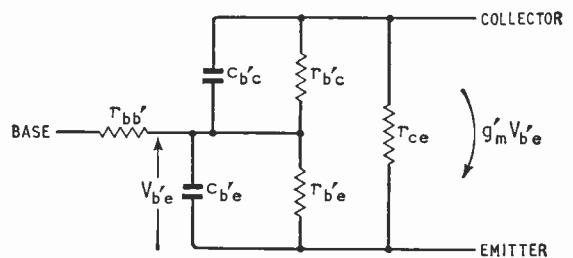
Fig. 2. Shading waveform generator.

ciated with the base being β times as large as the impedance associated with the emitter? In general the output resistance lies between the two extremes, being nearer to $r_{ce}/2$ when R_E is small compared to $r_{b'e}$ and rising towards $r_{b'c}/2$ (with zero R_S) as R_E becomes comparable to and then larger than $r_{b'e}$. In our example (Fig. 2, Pt 1) the range covered from $r_{ce}/2$ to $r_{b'e}/2$ is from $9k\Omega$ to $450k\Omega$.

The output resistance with $R_S = 0$ has been recognized as pertaining to the common base configuration, but can one be so categorical when both R_E and R_S are finite? There is no compelling reason, other than as a matter of convenience, for describing this as a common emitter stage with emitter degeneration rather than common base with series base resistor. In practice a hybrid stage of this type is more likely to be met than a pure common emitter or pure common base configuration; a rough idea of the form of derivation of the output resistance ought to be more useful in practice than the specific values $r_{ce}/2$ and $r_{b'c}/2$.

The foregoing elaboration into circuit parameters (see also Pt 1) has been made in the belief that a proper appreciation of their actions leads to a quick approach with real examples. The information should also be of assistance in evaluating makers' data. It would help if more manufacturers in quoting the h-parameters were to give them all tolerances as is generally done for the small signal current gain h_{fe}.

As intimated last month the remainder of this part will be devoted to practical examples of transistor work. The illustrations, which perhaps have a bias towards television topics, will exemplify the important circuit parameters rather than detail all the problems of the design.

In presenting rather variable impedances to its embodying circuitry, the transistor proves to be a little more difficult to handle than does a valve, but its integration into conventional circuit networks follows with greater ease once the complications have been mastered.

Let us direct our attention to an ordinary amplifying stage. Various stipulations might be made over the impedance levels it is to present. The input impedance can be made to range from the very low—using a common base stage—to the higher levels of a common emitter stage or a common emitter stage with emitter degeneration (at its simplest an emitter follower). The highest input impedances are achieved where feedback techniques are applied

over several stages. The output impedance at the collector is often set by the value of the load employed, but where this is not the limitation a cascode amplifier may be used to give an impedance level as high as $\dfrac{r_{b'c}}{2}$. In this arrangement the emitter of the second transistor, a common base stage, is fed from the collector of the first, so realizing the condition that the highest output resistance of a common base stage is dependent on the source resistance being high. All these matters were truly brought up in the previous article where in particular it was shown how all the impedance levels prove to be dependent on the magnitude of the standing current. We must now move on from the general to the particular.

Parabolic Waveform Generator: An interesting application involving an emitter follower used in a bootstrap circuit is shown in Fig. 2. When driven with a sawtooth voltage waveform, the output generated is a parabola. This waveform is widely used as shading correction for vidicon camera tubes. A signal voltage at either line or field frequency applied to the base of VT1 defines a sawtooth current waveform through R_{E1} and thence also at the collector. Here the current charges a capacitor, C_2, and produces the desired voltage waveform. Now, for an accurate rendering of the parabolic form, the drive to C_2 should be from a current source; the resistive loading across C_2 should be slight. The output resistance at the collector of VT1 presents no problems, particularly as R_{E1} serves to increase it, there being a voltage drive on the base. The collector resistor is, however, an embarrassment. Bootstrapping across from the emitter of VT2 via C_1 will raise the effective value of R_{C1} to something approaching $\beta_2\left(\dfrac{R_{C1}R_{E2}}{R_{C1} + R_{E2}}\right)$, but not to the full extent of this value because R_{C2} shunts $r_{b'e}$ of the second transistor. Given the collector current of VT2 and a rough value for the current gain, $r_{b'e}$ can be estimated and then R_{C2} chosen to be at least comparable to $r_{b'e}$ if not several times larger. Where necessary we have at our disposal sufficient information to do a full analysis for various resistor values and for a range in current gain. The expression $r_{b'e}$ $(1+g_m'R_e)$ would be employed for calculating the resistance at the collector of VT1, $r_{b'e}$ being replaced by the parallel combination of $r_{b'e}$ of VT2 and R_{C2}, and R_E replaced by the parallel combination of R_{E2} and R_{C1}. The output parabola is conveniently taken from the emitter of VT2. Although this is a low impedance point, the following circuit must not appreciably load R_{E2}; to do so would lower the impedance at VT1 collector and deteriorate the parabolic waveform.

Voltage Feedback Pair: The shading generator lent itself well to demonstrating how transistor impedances control circuit action; it will now be shown how the impedance levels of a feedback amplifier can be brought to light.

Fig. 3(a) will be recognized as a complementary pair amplifier; the voltage gain is given by $\dfrac{R_{C2} + R_{E1}}{R_{E1}}$.

This amplifier has received adequate treatment in the past but perhaps in rather mathematical terms. What at a glance are its salient features? First, there are two phase reversals involved and secondly, all the signal current from VT1 ideally flows into the base of VT2. This original current is amplified β_2 times by VT2 and passes back through R_{E1}. The current through R_{E1} is then β_1 $(\beta_2 - 1)$ or very nearly $\beta_1 \beta_2$ times greater than the input current and this accounts for the input resistance being roughly $\beta_1 \beta_2 R_{E1}$. For the most efficient operation, with highest input resistance and widest bandwidth, the path into the base of VT2 must be made a low resistance as compared to R_{C1}. Certainly R_{E2} must be by passed by a decoupling capacitor (a Zener diode may conveniently be used in place of R_{E2} if desired) and R_{C1} should be made as large as is practical, without an undue lowering of the standing current in VT1. To facilitate this latter condition, the voltage drop across R_{E2} is preferably made several volts or alternatively R_{C1} taken to a still higher supply rail.

We now come to the output resistance of this amplifier and can get at it by trying to inject a small current back into the output. The collector impedance of VT2 is large, so the current prefers the path down through R_{C2}. On reaching the junction of R_{E1} and the emitter of VT1 the current will split according to the ratio of impedances at this point. Clearly the impedance presented by the emitter of VT1 depends on the driving source; the case for zero source impedance will be considered. The emitter resistance of VT1 can then be assumed to be small compared to R_{E1}, our injected current flows down R_{C2} into the emitter of VT1, out at the collector again and into the base of VT2. In finally reaching a supply rail by flowing through the base emitter junction of VT2 and through C_1, it gives rise to a current β_2 times greater at the collector of VT2.

In the same manner as we identified h_{oe} as $\dfrac{2}{r_{ce}}$ we have, by our argument, shown that the output resistance of the complementary pair is approximately $\dfrac{R_{C2} + r_{e1}}{\beta_2}$. Moreover, we know the condition where this is applicable: when $\dfrac{R_s}{\beta_1}$ presents a lower impedance path than R_{E1}, R_s being the driving source resistance. The complementary pair therefore gives a low output impedance provided the source resistance is small compared to $\beta_1 R_{E1}$.

Suppose R_{C2} were 1.8 kΩ and the mean value of β_2 45, then the output resistance at low frequencies would be around 40 ohms. At high frequencies the magnitude and phase of the current gain deteriorate and the internal feedback lessens. The output impedance rises with frequency and so must be inductive in nature. This fact can be verified by loading the output with some capacitance; the output actually rises at the high frequency end of the pass band. Consequently, it is bad practice to load this
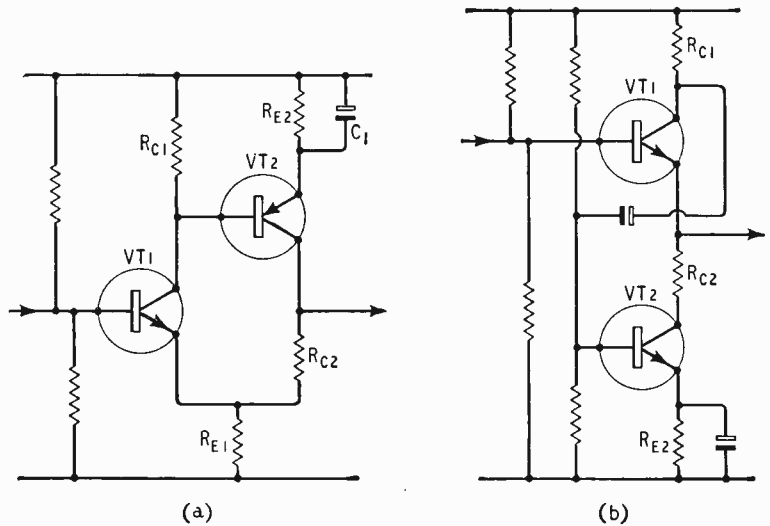

(a)   (b)

Fig. 3. Forms of voltage feedback pairs.

form of amplifier with much stray capacitance; a peak in the response at the resonant frequency formed by the output inductance with the strays can further lead into an unstable condition. On this basis one might condemn the principle of cascading feedback pairs of this type. In fact there is one simple way of overcoming the drawback and this is to insert a small series resistor of, say, 220 Ω between the stages. The resistor, which should have a value several times the size of the low-frequency output resistance, will serve to isolate VT2 collector to a sufficient extent from the input capacitance of the following stage.

Frequency response and stability margins are matters best left to experiment. For one thing, the stability of a feedback pair used as a wide band amplifier may depend to as large an extent on circuit layout as on transistor performance. The transistor contributes a number of factors determining the bandwidth: there is the collector output capacitance, the capacitance at the base behind r_{bb}', the Miller feedback capacitance and last, but not least, the fall off in current gain with frequency. Now it so happens that whereas the tolerance on the 3 dB point for β may be fairly wide, the gain frequency product for a silicon planar transistor is moderately well controlled in manufacture. This may be expressed in terms of the common base current gain 3 dB point or of the gain bandwidth product, f_t. In a feedback amplifier where the stage gain is well stabilized and planar transistors are used, the bandwidth should be found to remain reasonably constant as a variety of transistors with the same type number are substituted into the circuit.

So that having achieved a certain passband in an experimental amplifier on the bench, one can be reasonably confident of repeating the results in future models. In trying for an extended bandwidth it is naturally possible to trade in some gain. There are, as well, other means for increasing the bandwidth employing peaking inductors and capacitors; in particular a small capacitor across R_{E1} of Fig. 3(a) can be used to compensate for a falling response. It would seem most unwise, however, to make much use of such techniques, for the consequences follow

very much along the same lines as the effects of capacitive loading on the output of this amplifier. Phase shift with frequency is controlled by so many internal capacitances and particularly through β that any additional phase shift is liable to lead to instability. For this same reason many people advocate restricting feedback loops to a maximum of two transistor stages. It should be added that frequency compensating networks ought to be placed outside the feedback loops.

Before leaving the amplifier of Fig. 3(a), it should be mentioned that this basic arrangement can appear in other disguises. There is no need to follow the neat method of direct coupling which results from employing one n-p-n transistor and one p-n-p. They could well both be n-p-n (which is why the description voltage feedback pair is to be preferred to complementary pair). Fig. 3(b) for instance is dressed up to appear as something totally different, as a shunt regulated amplifier. On tracing the signal paths, however, it amounts to very much the same as Fig. 3(a) but with unity voltage gain ($R_{E1} = \infty$). Placing R_{e2} as zero in the expression for output resistance gives $\dfrac{r_{e1}}{\beta_2}$ or $\dfrac{1}{g_{m'1}\,\beta_2}$, an extremely low value. R_{e2} is included in Fig. 3(b) to remove the collector capacitance of VT2 from the output. In its new guise one would describe this as an emitter follower, VT1, with a shunt stage VT2, connected across the output to further lower the impedance. A suitable biasing arrangement for Fig. 3(b) would feature a resistor chain for establishing the base potential of VT2 and hence the current through R_{E2} and a further chain for establishing the base and emitter potential of VT1. The current taken by VT1 is the same as that passing through VT2.

Series Feedback/Shunt Feedback Stage: In mentioning the cascading of voltage feedback pairs we are touching upon a useful principle for video amplifier design—that of mismatching. Feedback gives a well defined gain and reasonably consistent bandwidth, but there must be surely some properties of the circuit involving β that are left as variable. The impedance levels are all dependent on β and as current gain can vary widely between transisistor samples, these are not at all well defined. However, the output impedance of Fig. 3(a) is low and the input impedance of a following stage of the same

type would be high. As the loading is so slight, the overall gain still remains independent of β. This degree of mismatching may be wasteful on gain-bandwidth product, but it does lead to a predictable performance. As with the problem of peaking components, our policy seems to be to avoid extracting the last ounce of performance from the fewest possible number of transistors. The philosophy here is different from valve practice because the comparative size of the circuitry makes the addition of an extra stage a minor event. The cost of additional transistors and associated components may well be offset by the saving in the cost of peaking inductances. Certainly the setting up of the response may be left to one network within the whole amplifier.

The mismatching principle has been strongly advocated in two recent papers[1, 2] which describe a further form of feedback amplifier. The bare outlines of the arrangement are given in Fig. 4. Its action may be considered as follows.

The first transistor has a series emitter feedback resistor R_E. An input signal voltage v_{in} is presented with an input resistance $r_{b'e} + \beta_1 R_E$ and a signal current $\dfrac{v_{in}}{R_E}$ is defined by the emitter resistor. The second transistor employing a shunt feedback resistor R_F from collector to base has a very low input impedance. The collector of VT1 is made a virtual earth and all but a small fraction of the signal current flows into R_F. The small fraction that does flow into the base of VT2 controls a collector current swing β_2 times as great, which in turn develops the output voltage swing across R_C. The output swing must also be developed across R_F, its lower end being virtually fixed in potential and its upper end connected to VT2 collector. Herein lies the clue for finding the voltage gain of the two stage amplifier. To a good degree of approximation the signal current into R_F is $\dfrac{v_{in}}{R_E}$ from VT1 collector, the voltage developed across R_F is $v_{out} = \dfrac{v_{in}}{R_E}\,R_F$ and the voltage gain $\dfrac{v_{out}}{v_{in}}$ is $\dfrac{R_F}{R_E}$. Just as with the voltage feedback pair the gain has been related to resistor values; β has a first order influence only on the impedance levels.

To complete our analysis of Fig. 4, we should try to find a rough value for the output resistance. Looking back at the collector we see $\dfrac{r_{ce}}{2}$, R_C and R_F. From the basis of a previous argument, this is in error; it should truly include the parallel combination of R_C, r_{ce}, $\dfrac{r_{b'e}}{\beta}$ and $\dfrac{R_F}{\beta}$ because R_F presents a path from collector to base externally across the transistor just as $r_{b'e}$ does internally. With a normal value for R_F (say comparable to R_C), the output resistance will be very close to $\dfrac{R_F}{\beta}$.

The circuit in the exact form shown in Fig. 4 can be rather neatly employed as a high level video driver stage for a cathode ray tube. With a supply
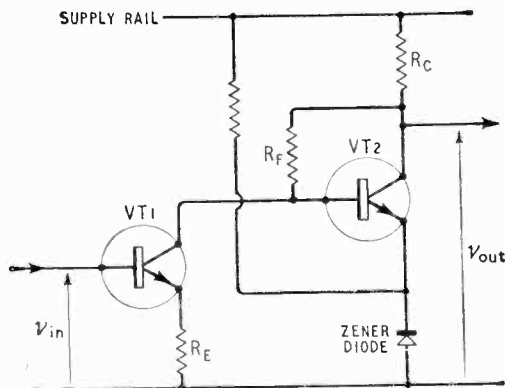

Fig. 4. Series-feedback/shunt-feedback amplifier.

[1] "The Design of Wide-band Transistor Feedback Amplifiers", E. M. Cherry and D. E. Hooper, *Proc. I.E.E.* Vol. 110, No. 2, February. 1963.
[2] "An Engineering Approach to the Design of Transistor Feedback Amplifiers". E.M. Cherry, *J. Brit. I.R.E.*, February, 1963.

rail of + 140 volts VT2 needs to be a high voltage v.h.f. transistor (e.g. R.C.A. 2N3119) and where direct coupling is employed through R_F the available output swing is determined by the potentiometer formed by R_C and R_F. 40 volts drive to the cathode ray tube can be obtained when $R_C = R_F = 3.9k\Omega$ and the output resistance would then be of the order of 80 ohms. With this low output resistance a fair degree of capacitive loading (10 to 20 pF) may be tolerated without degradation of the response, although naturally the available amplitude at the high frequency end of the band may be limited should the rise time associated with the collector load and capacitive loading be allowed to become too long. In common with emitter followers the stage drives more easily into a capacitive load in one direction of signal swing than in the other. With care the bandwidth may be extended by placing a preset variable inductor of value around $20\mu H$ in series with R_F. The inductor will compensate for the capacitive loading and can be set for a flat response from the amplifier in situ.

The black level in this application of Fig. 4 may be established before the amplifier input and the collector of VT2 coupled directly on to the cathode of the cathode ray tube. Because the output voltage with respect to the lower supply rail may be said to be solely determined by R_F, R_E and v_{in}, the 140 volt supply need not be very well regulated. There can even be considerable 50 c/s ripple on this supply without visible obtrusion on the picture. Only the tube voltages (inclusive of the brightness setting on the control grid) and the black level reference require stabilising for a high degree of black level stability.

Now that high voltage plus high frequency transistors are generally available it does seem that a high level video stage is becoming a practical reality. The example quoted is but one method of approach and was developed for the fairly simple task of driving a 7 inch monitor tube with a grid base of 35 volts. Power dissipation and voltage ratings are the main barriers limiting the possible signal amplitude and frequency response. There are also hazards, not lightly to be dismissed, of flashovers within the cathode ray tube damaging semiconductor circuitry directly attached to the tube. A reverse biased diode connected across the resistor R_C is one safeguard. It prevents the collector potential from rising above the h.t. supply voltage and, provided the current pulses in themselves do no damage, protects the transistor from excessive reverse voltages.

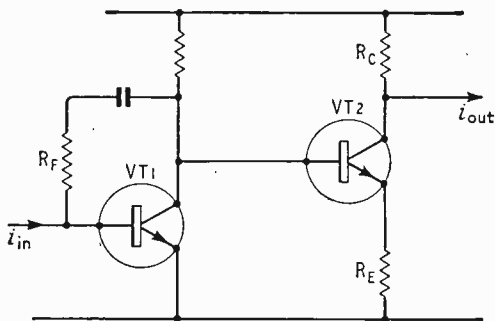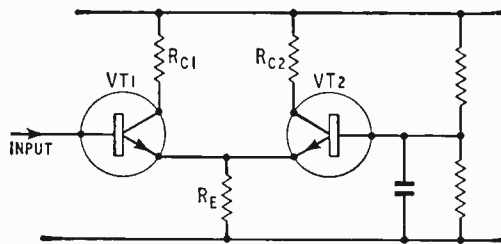The description of the series feedback/shunt feed-

Fig. 6. Long-tailed pair.

back stage has very obviously been of a voltage amplifier. A current amplifier results where the order of the operations is reversed. In Fig. 5 the input current sees a low resistance path into R_F so that the signal voltage at the collector of VT1 must be $i_{in} R_F$. Neglecting r_e of VT2 in comparison to R_E, the output current given by this signal voltage amounts to $\frac{R_F}{R_E} i_{in}$. The current gain is approximately $\frac{R_F}{R_E}$ and the whole circuit is clearly the dual of Fig. 4. Where the collector of VT2 is not loaded by a following current amplifier, there is an output voltage $\frac{R_F R_C}{R_E} i_{in}$ developed across R_C, a quantity proportional to the input current. Such a configuration finds an application wherever a signal from a current transducer requires amplification. The vidicon or image orthicon camera tubes are cases in mind.

Long-tailed Pair:- The evaluation of transistor long-tailed pairs proves to be quite straightforward when examined in terms of emitter intrinsic resistance. In Fig. 6 R_E is shunted by r_{e2} of the second transistor (the base of VT2 is decoupled at signal frequency to earth). The input signal therefore appears across r_{e1} and r_{e2} in series; the value of R_E will be an order of magnitude higher and may be neglected. If for the moment the two emitter resistances are taken as equal, half the signal voltage appears across either of them and the gain to the collector is given by $\frac{1}{2} \frac{R_C}{r_e}$ or $\frac{1}{2} g'_m R_C$ (compare the valve long-tailed pair). Otherwise, for unequal collector currents, the signal current will be $\frac{v_{in}}{r_{e1} + r_{e2}}$ As R_{E1} passes virtually no signal current, the two signal currents in VT1 and VT2 must always be equal and of opposite phase. The gain to either collector is therefore $\frac{R_C}{r_{e1} + r_{e2}}$.

As it stands the circuit is capable of giving a large voltage gain; nearly the full value of g'_m is realized and a small input voltage produces a large change in collector current. As a small change in the relative biasing of the two bases produces a large differential shift in the standing currents, it is difficult, as it stands, to set up the collector currents. Resistors inserted at the emitters will lower the effective mutual conductances, will make the biasing easier and make for better linearity. As an alternative, the long-tailed pair could be included in the feedback loop of a direct coupled amplifier and its working point established by other parts of the circuit.

Fig. 5. Current amplifier—the order of operations is the reverse of that in Fig. 4

LETTERS TO THE EDITOR

The Editor does not necessarily endorse opinions expressed by his correspondents

F.M. Tuner

IN your September issue you published a letter from Mr. P. J. Baxandall describing a Band II f.m. tuner in which the local oscillator operates on a frequency in the region of 45Mc/s, the second harmonic being used for frequency-changing.

The potentialities of such a device to generate interference with Band I television reception are considerable. If a tuner of this type were used in, for example, the London area, the local-oscillator frequencies involved, assuming the suggested intermediate frequency of 160kc/s, are as shown below.

Wrotham transmission frequencies (Mc/s)	Local-oscillator 2nd harmonic (Mc/s)	Local-oscillator fundamental (Mc/s)
89.1	88.94 or 89.26	44.47 or 44.63
91.3	91.14 or 91.46	45.57 or 45.73
93.5	93.34 or 93.66	46.67 or 46.83

Radiation at the local-oscillator fundamental frequency could therefore produce objectionable pattern interference on neighbouring television receivers that were tuned to the Crystal Palace signal on 45Mc/s.

Stating the objection to Mr. Baxandall's design is simple (destructive criticism usually is!). What is more difficult is to suggest a satisfactory alternative. There are two obvious possibilities, neither of which is wholly free from drawbacks. The first is to operate with the oscillator fundamental at the frequency required for mixing. The objections to this are that the second harmonic will then fall in Band III, with the possibility in some areas of interference with the local I.T.A. transmission, and that the power radiated in Band II will probably be increased as compared with the original design. As the frequency of the local-oscillator differs by only 160kc/s from that of the received signal, neighbouring Band II receivers, tuned to the same programme, may be disturbed by the presence of an unmodulated carrier so close to the frequency of the wanted signal. The possibility of "tuning through" interference on neighbouring Band II receivers as the interfering receiver is adjusted in frequency will also be increased.

The second possibility is to reduce the local-oscillator fundamental to about 30Mc/s and use the third harmonic for mixing (as in the *Wireless World* design published in the July issue). The fundamental will then lie outside the domestic broadcasting bands and the level of radiation in Band II and Band III will be reduced because the orders of the harmonics concerned are higher. The objection here is that the second harmonic will fall in Band I and might still interfere with reception of a signal in Channel 4 or 5. If this design were used, care could reduce the radiation of the unwanted second harmonic well below that of the fundamental.

The underlying problem is that the choice of intermediate and local-oscillator frequencies for receivers, and the allocation of broadcasting channels are interrelated. The receiver standards in current use, i.e. an intermediate frequency of 34.65Mc/s with the frequency of the local oscillator above that of the signal for v.h.f. television receivers and an i.f. of 10.7Mc/s with local oscillator low for Band II receivers, were determined partly by consideration of the frequency bands allotted for broadcasting. Similarly, the allocation of individual broadcasting channels to specific areas has to take account of receiver design standards in order to minimize the possibility of interference. In view of this, it is not

surprising that the counter-discriminator f.m. receiver with its very low i.f. does not fit easily into the established pattern.

A possible solution may lie in the use of a double-superheterodyne circuit; this would, of course, complicate the design somewhat. Furthermore, with two local oscillators to consider, great care would have to be exercised in the choice of their frequencies or the final state could well be worse than the first.

The purpose of this letter will, however, have been accomplished if the attention of prospective constructors is drawn to the difficulties, trusting that they will adjust the design to avoid the likelihood of interference to their neighbours.

Kingswood Warren,
Surrey.

J. G. SPENCER
B.B.C. Research Department

Loudspeaker Polarity

I HAVE been following with interest the correspondence resulting from the letter by A. M. Wooller *et. al.* which appeared in the June issue of *Wireless World*, and have carried out an experiment designed to investigate the theory put forward by my brother K.C.J. in his letter published in the August issue, namely that, if a pulse of pressure arrives at one ear simultaneously with an equal rarefaction at the other ear, the brain will analyse this situation by locating the source of sound as being on the side which was subjected to the pulse of pressure. My experiment also allows confirmation of the "Wooller Effect."

My set-up was as follows: not having any headphones, but happening to have available two 10-inch loudspeakers mounted similarly, and of comparable high quality, I arranged these to be fed in parallel from the output of my mono U.L. hi-fi amplifier, using a switching arrangement which enabled the polarity of each speaker to be reversed independently of the other. There was also an "off" position for each speaker, and a means whereby the slightly higher efficiency of one of the speakers could be compensated for, making their outputs subjectively equal.

The loudspeakers were placed one on either side of the author's head, and in the later stages of the experiment two truncated cones (lampshade shape) were made from thick paper so that substantially the whole of the sound from the L speaker was fed to the L ear and the whole of the sound from the R speaker fed to the R ear.

The first part of the experiment was concerned with confirming the "Wooller Effect," and the results here were extremely convincing. With the speakers used one at a time, and using both ears, the polarity was reversed, using recording of speech, and of brass and woodwind in conjunction with other orchestral instruments. In nearly every case a decision could be made with complete certainty that one polarity sounded more realistic than the other. This was sometimes the "plus" and sometimes the "minus" position, thus ruling out the possibility of the effect being due to a non-linear transducer and/or amplifier and a non-linear loudspeaker. When the material was from v.h.f. radio, the difference in quality was not always quite so definite.

I certainly intend now to incorporate a reversing switch as a permanent feature of my hi-fi outfit!

Having in this way designated the polarities of the two speakers "plus" and "minus" using a particular

recording, they were set up as if for stereo and both switched to "plus." With this arrangement the music appeared to come from the space midway between the speakers confirming that they were indeed operating in phase.

Lastly the one-speaker-to-each-ear arrangement was used, and the observation here was quite definite in every case that when the polarities were the same (plus-plus or minus-minus) the sound seemed to be inside one's head; but when the polarities were different (plus-minus or minus-plus) the sound seemed to come from two separate sources, one on either side. This phenomenon has been observed previously with binaural headphones, and is reported in the literature. ("Handbook of Experimental Psychology," Ed. S. S. Stevens, Wiley 1951.)

This last result would appear to indicate quite clearly that the human auditory apparatus does not especially favour a sound with correct pressure polarity received by one ear against a sound of equal intensity but with reversed polarity received simultaneously by the other ear. It leaves me, however, with the job of explaining the effects observed by my brothers with their capacity bridge (*Wireless World*, July and August), and I have to admit that even after much cogitation I still cannot offer a really satisfactory explanation.

The difficulty is that, if the sound appeared to be in front when the bridge was near balance, the headphones must have been connected in phase (which is the normal arrangement, incidentally). It then becomes very difficult to explain why the sound should have appeared to be on either side when the bridge was off-balance. Non-linearity cannot be the reason, since the situation on each side would have been identical in phase and amplitude. A time difference of only a few microseconds between the signals reaching each ear would have been enough to produce a sense of directivity; but, while it is true that when the bridge was unbalanced there probably was a slight delay or advance, according to the sense of unbalance, of the time of arrival of the pulse at one terminal of the headphones relative to its time of arrival at the other, it is hard to see how this could lead to pulses of pressure being produced at different times in the two ears, since the two phones were in series.

If the phones were connected in anti-phase, an explanation of the sound appearing to come from the side when the bridge was off-balance is very easily found in the inherent non-linearity of the moving-Stalloy phones, because this would have resulted in an amplitude difference between the sounds presented to the two ears. In this case it is difficult to explain why, when near balance, the sound appeared to come from in front. My experiment, and earlier independent work, indicates that it should have appeared to come from both sides.

It is clearly not worthwhile pursuing this particular question further without a detailed knowledge of the construction of the capacitor bridge, which might well provide an unforeseen clue. Private correspondence within the Johnson family is indicated!
Bournemouth.   F. B. JOHNSON

Transistor Tester

WE cannot agree with Mr. Sizmur (May 1964 issue) that his transistor-tester is foolproof. If one tries to measure β for germanium transistors on the low collector-current ranges, one either finds the range impossible to use because the meter pointer bangs over on the end stop and cannot be budged, or else one gets absurb values for β. We think this follows from Mr. Sizmur's definition of β. One may only shorten the more satisfactory expression

$$\beta = \frac{I_c}{I_b + I_{co}} \text{ to } \beta = \frac{I_c}{I_b} \text{ if } I_b >> I_{co}.$$

On the low current range the tester injects a maximum

base current—in the $\times 10$ position—of about $1\mu A$. Clearly this is not greater than I_{co}, perhaps $5\mu A$. With silicon transistors the instrument is all right. But with germanium transistors one must either avoid the low-current ranges, or modify the instrument.

We have done this by splitting the base current I_b into two components, I_{b-test} and I_{b-set}, as in the accompanying figure. We then have

$$\beta = \frac{I_c}{I_{b-test} + I_{b-set} + I_{co}}$$

I_{b-set} is made equal to $-I_{co}$ by adjusting the "set" potentiometer; then the expression reverts to the simple form

$$\beta = \frac{I_c}{I_{b-test}}$$

assumed by Mr. Sizmur. To achieve this, the push button is pressed to disconnect the test current circuit,
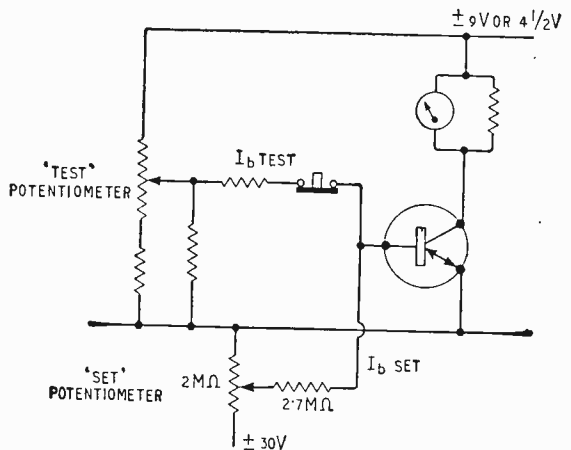
and the slider of the set potentiometer is turned away from emitter potential until the collector current falls from its initial value, about I'_{co}, to I_{co}. The button is then released and the instrument used normally.

We were able to carry out this modification without butchering the panel we had originally made. An extra 2-pole, 2-way wafer is required on the p-n-p/n-p-n switch, to control the polarity of the additional 30-volt supply. The "press to read" switch needs supplementing with an extra pair of poles for the 30-volt supply; we substituted for the toggle switch here a 4-pole, 2-way rotary switch, in which the ball-click mechanism had been removed and a biasing spring added. Room has to be found on the panel for a press-to-open button and a small linear carbon potentiometer; this is easily done. A miniature hearing-aid battery is adequate for the 30-volt supply; the current drain is never more than a few μA.
Cambridge.   P. E. K. DONALDSON
                                         D. GRIFFIN
                                         T. HOLLAND

The author replies:

I must agree with Mr. Donaldson, that my transistor tester is not completely foolproof. When designing the instrument, I did not give a great deal of thought to the measurement of germanium transistor β's at very low collector currents. Circuits operating under these conditions have a nasy habit of drifting with temperature and time, and performance tends to be unreliable. Consequently, I felt that the demand for low-current gain measurement would be small, and the complication of I_{co} "back off" would not be justified: however, for those

people who require such a facility, Mr. Donaldson's modification appears to be very suitable. I have not been able to try out the circuit he suggests, but I have found two other modifications worth incorporating.

If the meter series resistor is increased, such that the total resistance is 900Ω, the various shunt resistors can be selected from 1% standard values:—

R_{10} 33Ω
R_{11} 1800Ω
R_{12} 100Ω
R_{13} 10Ω
R_{14} 1Ω
R_{17} Not used
R_{18} 100Ω
R_{19} 10Ω in parallel with 100Ω
R_{20} 510Ω
R_{21} Not used

When making measurements on fast switching and u.h.f. amplifier transistors, trouble is usually experienced due to the inductance and capacitance of the instrument wiring causing the transistor to oscillate, giving misleading results. This can be avoided by slipping a few ferrite beads over the base and collector wires, keeping them close to the terminals, and decoupling the base and collector leads with $0.1\mu F$ ceramic capacitors to emitter, the capacitors being connected direct to the terminals, or transistor holder.

Finally, I would like to draw readers' attention to some errors in the circuit diagram and component list.

(1) The 1mA and 100mA meter shunt connections to switch Sw2d should be as shown:—
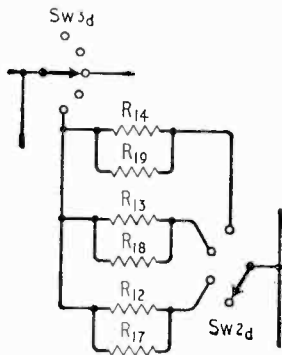
(2) The position of the Sw3 wiper is confusing as drawn originally (Fig. 2). When in the fully anticlockwise position (Battery) the wipers of Sw3b, c, d and e are at the top and Sw3a at the bottom.

(3) The R_a appearing between R_2 and R_{10} in components list should be deleted. The correct value is 100Ω, 5%, 1 watt.

(4) RV1 should appear in the component list as 5kΩ, 1 watt, wire-wound, linear.

F. M. SIZMUR

Intermodulation Distortion Measurement

THERE are two points in Mr. J. Somerset Murray's letter in the September issue which should not be allowed to pass unchallenged.

His contention that it is possible to calculate *precisely* the amount of any order of distortion from the total noise measured in the slot is based on too many assumptions. The fact that there are laws which govern the amount of noise due to each order of distortion is indisputable, but it is impossible to decide their proportional contribution from a simple noise measurement. The method of increasing the excitation level and noting the proportion of noise rating change is only useful if one distortion order predominates.

The suggestion that third-order distortion is roughly evenly spread over the land is unacceptable as this is only the case in an ideal amplifier. In practice this is seldom the case as will be seen by looking at Tables 3 and 4 in my article. Further examples may be obtained by looking at Fig. 13.54 on page 601 of the fourth edition of "The Radio Designer's Handbook" by H. Langford-Smith which shows distortion curves for a simple amplifier, or Figs. 13, 14 and 15 on pages 16 and 17 of B.B.C. Monograph Nr. 49, July, 1963. ("Apparatus for Measurement of Non-Linear Distortion as a Continuous Function of Frequency" by H. D. Harwood) which shows distortion curves for loudspeakers and a crossover network. These curves demonstrate the requirement quite clearly and it is obvious that the slotted white noise test could not resolve the undulations in the distortion/frequency characteristics or indicate any resonances.

D. E. O'N. WADDINGTON

Riposi:—
Fig. 13.54 on p.601 of "Radio Designers Handbook" is a splendid example of the uselessness of voltage measurements of harmonics by wave analyser when the pickup point has a pronounced resonance. The 2nd harmonic apparently rises above 50% at 35 c/s. The footnote which states that the bass resonance of the speaker load was 70 c/s and of unstated Q renders the whole curve meaningless. The figure of 50% must certainly be divided by the Q which could be 10 or so, giving a real figure of 5%! The effect, of say, 5% second harmonic at 35 c/s could only be assessed by measuring the intermodulation produced on a white noise test.

The point is not the extent of the limitation of slotted white noise. It is not worth splitting hairs to determine whether the author's statement that s.w.n. will *not* differentiate between even and odd, or mine that it *will* precisely between 2nd and 3rd is the greater overstatement. The fact remains that noise power ratio is what the customer gets and he should be given a chance to be told what it is, at a suitable white noise loading.

Like "Monkey Brand" it "won't wash clothes." But it will give the true figure of merit from the users end. That alone should ensure it a mention in any discussion of the problem.

J. SOMERSET MURRAY
[This correspondence is now closed.—Ed.]

Inter-carrier Interference

READING the article on rejection of inter-carrier signals in TV receivers, by P. Visontai, in the August edition of W.W., brought to mind some interference experienced at this receiving station on 3·5 Mc/s. Other amateur operators using 3·5 Mc/s have had the same trouble, which occurs on 3·5 Mc/s exactly.

As this trouble only occurs at odd periods, it is reasonable to assume that it comes from a TV receiver in which the inter-carrier signal has not been suppressed sufficiently. I must add that the receiver used in a double superhet, and that the signal is only present when an antenna, resonant or not, is connected. I wonder if any other readers of W.W. have found the same trouble, or know any reasonable cure.

Old Coulsdon   S. N. GALL (A4205)

Momentous Error

IT is rumoured that 400 of the new Garrard 407 gramophone motors with 61-lb turntables (*Wireless World*, September 1964, p. 443) have been ordered for the new "Queen" luxury liner, to be installed in all first-class cabins.

The designers believe that this will effect a considerable economy, as gyro-stabilizers will not now be necessary.

Sheffield.   B. R. BLACKFORD
[Touche! The weight is in fact 6lb—Ed.]

Logarithmic Aerial for Bands IV and V

2.—CONSTRUCTIONAL DETAILS

By M. F. RADFORD,* M.A.

THE first part of this article (in last month's issue) described the development of the logarithmic dipole aerial from a simple radiator. However, it omitted the explanation of how the aerial came to be called "logarithmic". We saw that the aerial consists essentially of a set of dipoles whose lengths and spacings increase in geometrical progression. Now most engineers dislike arithmetic, and the prospect of multiplying a number by a ratio some twenty or thirty times over is not pleasing to them, so they reach for the log. tables. If the antilogarithm table is read off at regular intervals, a set of numbers in geometrical progression is obtained, and this makes an ideal starting point for an aerial design. The taper ratio *t* of the aerial is defined as the ratio of one dipole length to that of its longer next neighbour, so that *t* is always a little less than one. Now the longest dipole must be a half wavelength long at the bottom of Band IV, 470 Mc/s, and this is about 12½ inches. The shortest dipole must be small enough to be a director at the top of Band V, 960 Mc/s, and thus is only about 4½ inches long. If *t* is too close to unity, the number of steps required to

cover the ratio of nearly three to one becomes too large, and the resulting aerial is long and unwieldy. If *t* is too small, few dipoles are needed and the aerial is short and compact, but as only one or two dipoles are sufficiently near to resonance at any one frequency the gain is low. The accompanying table is based on a medium taper ratio, *t*=0.944 (antilog (1̄).975) and yields an aerial just under four feet long with a gain of 11 dB over isotropic.

TABLE

Dipole No.	Span (inches)	Spacing (inches)	Dipole No.	Span (inches)	Spacing (inches)
1	12.59		10	7.50	
		3.98			2.37
2	11.89		11	7.08	
		3.76			2.24
3	11.22		12	6.68	
		3.55			2.11
4	10.59		13	6.31	
		3.35			1.99
5	10.00		14	5.96	
		3.16			1.88
6	9.44		15	5.62	
		2.98			1.78
7	8.91		16	5.31	
		2.82			1.68
8	8.41		17	5.01	
		2.66			1.58
9	7.94		18	4.73	
		2.51			1.50
			19	4.47	

It will be seen that the spacings are only about one third of the dipole lengths, although the elementary explanation in the first part of this article led us to expect spacings of a quarter wavelength or about half the dipole lengths. These closer spacings were found to give the best results experimentally, and were subsequently justified by Dr. Carrel's accurate theoretical work.[1] This theory takes into account the mutual inductances between the dipoles and also the Hansen-Woodyard effect,[2,3] by which a certain amount of misphasing can be made to yield an increase in forward gain.

The dipoles are connected alternately to a pair of booms which form the central feeder line of the aerial. The characteristic impedance of this line must not be too high or the gain will drop. On the other hand it must not be too low or the backlobes will increase. To see the reason for this, consider the aerial operating as a transmitter. If the impedance of the line is high, all the energy is transferred to the first one or two dipoles that are approaching resonance and thus the potential gain of the remaining near-resonant dipoles is not realized. If the line impedance is too low insufficient power is transferred to each dipole and there is still quite a lot left in the line when the resonant region has been

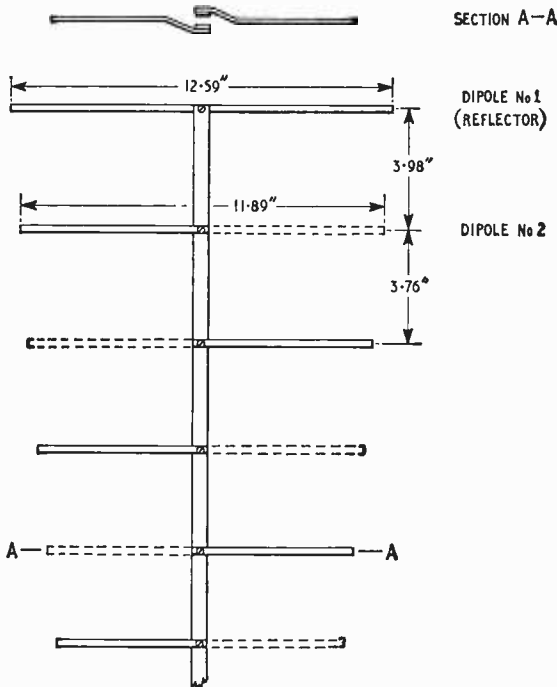SECTION A—A

DIPOLE No 1 (REFLECTOR)

12·59″

3·98″

DIPOLE No 2

11·89″

3·76″

Fig. 4. Plan view of logarithmic aerial. The elements of the lower half of the array are shown in broken lines.

* The Marconi Research Laboratories, Chelmsford, Essex.

DIELECTRIC SPACER — DIPOLE

INNER TO UPPER BOOM

OUTER TO LOWER BOOM

COAXIAL CABLE

Fig. 5. *Detail of smaller end of array showing method of connecting cable.*
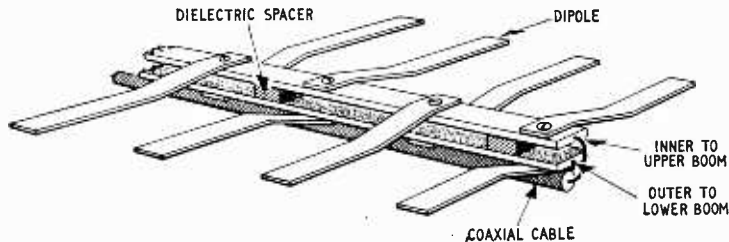
passed. This power is eventually radiated by longer dipoles resonating in higher-order modes or reflected back along the line towards the vertex, and in either case the result is a poor radiation pattern. Fortunately between these extremes there exists a range of impedances over which satisfactory results are obtained, so that the line impedance need not be accurately specified.

There are several alternative ways of terminating the line at the longest dipole, for example, short circuits, open circuits, resistive loads and quarter-wave short-circuited stubs. Of these the best overall performance at frequencies near cut-off is obtained with a short-circuit. This is also the most convenient mechanically, as we can support the booms solidly at this point. The short circuit means in practice that the longest element is never fed, but can only act as a reflector.

It is necessary to connect the feeder cable to the vertex end of the twin line. For correct operation a balanced feed is required, but a coaxial cable is inherently unbalanced. Over limited frequency ranges a balun (balance-to-unbalance transformer) may be used, but it is more satisfactory to construct a self-balancing feed. This is done by passing the cable along one of the booms, connecting the outer braid to that boom at the vertex end of the array and connecting the inner conductor across to the other boom. Since neither conductor is effectively earthed at the feed point the voltage is shared between the two booms.

The characteristic impedance of logarithmic dipole aerials usually lies in the 50-100 ohm range, and with the gradual taper suggested the self-balun will give a reasonable match to either 50-ohm or 75-ohm cable without any additional impedance transformation. It is, however, sometimes necessary to add a small reactive compensation at the feed point if a good impedance match is required, e.g. for transmitting. This is because near the vertex the dipoles are too short to radiate significantly but they nevertheless impose a capacitive loading on the line. As dipole lengths and spacings are in constant proportion, and capacitance is roughly proportional to length, this capacitive loading per unit length is approximately uniform, and lowers the impedance of the line from its natural 100-200 ohms to the characteristic impedance of the actual aerial. Additional capacitance is sometimes needed in order to maintain this capacitive loading beyond the dipoles right up to the cable termination.

The aerial should ideally be supported from the rear end so that the currents on the line and dipoles are disturbed as little as possible. This is sometimes quite convenient in practice, but if not, no serious harm is done to the gain if the aerial is supported on an insulator at its point of balance. The radiation patterns are, however, affected, and mean side-lobe and back-lobe levels are about 5 dB worse at 25 dB down. This is, of course, still ample for most situations.

Constructing a Practical Aerial

The aerial should be constructed in brass or aluminium in order to combine high conductivity with good corrosion resistance. Brass is more easily joined, and joints should be screwed and soldered or brazed for maximum durability.

It is possible to side-step the assembly problem by cutting the halves of the array from sheet metal. This leads to a very simple and effective construction.

The dipoles should be around a quarter of an inch wide. However, this is not at all critical and we can use strip, sheet, rod, tube, angle or channel for the dipoles as is most convenient. The central booms must be strong enough to support the dipoles and keep the aerial rigid, here it will be found that half-inch channel, strip or tube is convenient. The booms are connected electrically at the longest dipole only, usually by joining them to a third member which acts as spacer and also as a support for mounting the aerial on its mast or bracket. The booms are kept correctly spaced along the aerial by low-loss dielectric spacers which should be of minimum size so as to disturb the currents as little as possible.

The correct spacing for the booms is about one quarter of an inch for half-inch wide strip or channel; however, this dimension is not critical. The
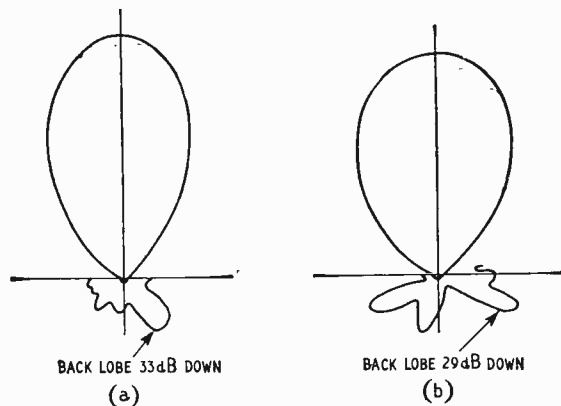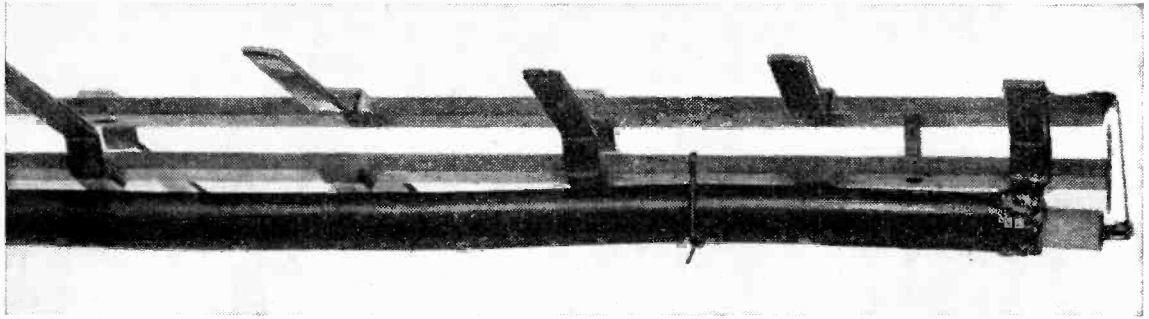

BACK LOBE 33dB DOWN

(a)

BACK LOBE 29dB DOWN

(b)

Fig. 6. *Typical radiation patterns of logarithmic aerial at 600 Mc/s. The patterns are plotted on a linear field strength scale with the back lobes magnified 20 dB. (a) is the pattern in the plane of the dipoles and (b) the pattern perpendicular to the dipoles.*

G

Close-up showing the method of connecting the cable, the capacitance plates added at the vertex to improve the impedance match and the nylon spacing screws used on the experimental model.

cable should lie below or within the lower boom so that the upper boom is not "aware" of its presence.

The joining of the cable should be carried out very carefully, and there should be some means of protecting the open end of the cable from the weather. For example, a plastic sleeve may be used, or the joint may be sealed in polythene sheet.

Performance:—A brass model was constructed in the laboratory to the dimensions given in the table. Its performance was as follows:

Beam width in plane of dipoles	48° between half-power points.
Beam width in perpendicular plane	60° between half-power points.
Directivity gain	11-12 dB over isotropic in band 470-960 Mc/s.
Back-lobe and side-lobe level (minimum)	25 dB
Back-lobe and side-lobe level (mean)	30 dB

A home-made aerial of identical design has since been constructed by a neighbour and is giving good pictures on a hill site 35 miles from the Crystal Palace transmitter. On bad sites the range will, of course, be very much less. Range may be increased by raising the aerial to a greater height or by adding a pre-amplifier.[4]

The author wishes to thank Mr. E. W. Woloszczuk who was responsible for most of the experimental work, and the Director of Enginering and Research of the Marconi Company for permission to publish this article.

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2. J. Kraus. "Antennas". (McGraw Hill, 1950.) Chapter 4, p. 81.
3. W. W. Hansen, J. R. Woodyard. "A New Principle in Directional Antenna Design." *Proc. I.R.E.* Vol. 26, March 1938, p. 333.
4. M. V. Callendar. "Transistor Aerial Pre-Amplifier." Wireless World, Vol. 69 No. 12. December 1963, p. 580.

H. F. PREDICTIONS — OCTOBER
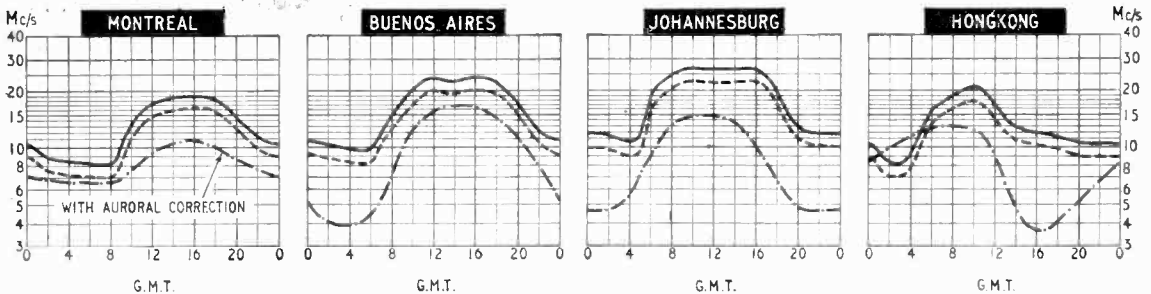
The prediction curves show the median standard MUF, optimum traffic frequency and the lowest usable frequency (LUF) for reception in this country. Unlike the standard MUF, the LUF is closely dependent upon such factors as transmitter power, aerials, and the type of modulation. The LUF curves shown are those drawn by Cable and Wireless Ltd. for commercial telegraphy and assume the use of transmitter power of several kilowatts and rhombic aerials.

The effects of sporadic-E ionization are becoming less significant as winter conditions set in; and this month it is unlikely that sporadic-E will permit operation above the predicted MUF. The seasonal change in shape of the MUF curve is becoming apparent. The very flat curve of the summer months is being slowly replaced by the slightly higher peaky curve, characteristic of the winter.

MANUFACTURERS' PRODUCTS

NEW ELECTRONIC EQUIPMENT AND ACCESSORIES

Miniature Soldering Iron

THE latest addition to the range of soldering irons made by Antex Ltd., Grosvenor House, Croydon, Surrey, is the Model C240N. In general construction it follows the principles of earlier Antex irons in having readily interchangeable bits and a wide choice of operating voltages, but the new series is fitted with a "Ferraclad" bit which is claimed to give at least five times the life of ordinary nickel-plated bits. The moulded handle is now yellow to facilitate recognition on a crowded workbench.

13WW 301 for further details

U.H.F. Planar Triode

A SIGNIFICANT increase in power over previous types manufactured by Eimac is claimed for the Type X843 u.h.f. triode. This valve, which is intended to supersede the 2C39A and the 3CX100A5, has an output of 22 watts at 2250 Mc/s and is smaller than its predecessors. The increased performance is due to improvements in the design of the grid, which now has a dissipation of 4 watts. This valve is still in development and at present only available in small quantities for prototype work, from Walmore Electronics Ltd., 11-15 Betterton Street, Drury Lane, London, W.C.2.

13WW 302 for further details

Rack Mounting Laboratory Scope

A NINETEEN-INCH rack mounting oscilloscope, which occupies only seven inches of vertical space, to a depth of 16 in, has been introduced by Telequipment Ltd., of 313 Chase Road, Southgate, London, N.14. Known as the Model D43R, it is fitted with a flat-faced four-inch PDA tube and has been designed for a wide range of industrial, laboratory and medical electronic applications. The in-built timebase unit provides 18 pre-set calibrated sweep speeds from 0.5 sec/cm to 1μ sec/cm, with a rise time of 23n sec; input impedance is 1 MΩ.

A choice of five plug-in amplifiers, two of which are new, are available

for this scope. The Type A is a general purpose, B differential, C ultra high gain, D an envelope monitor, and E is a combined wideband and differential amplifier; the last two being the new units. The envelope monitor is a tuned amplifier, with four switched ranges from 2.5 to 32 Mc/s, and when tuned to resonance has a sensitivity of 1 V/cm. A leaky-grid detector is also featured in this unit and can be used to provide a sync output for the time-base unit; to enable the modulation frequency of an a.m. carrier to be displayed. The Type E wideband and differential amplifier has a maximum input voltage of 10 volts p-to-p and the differential inputs have rejection figures of greater than 200 : 1 from zero frequency to 1 Mc/s (sine wave input), reducing to not less than 30 : 1 from 1 Mc/s to 12 Mc/s.

13WW 303 for further details

Computer Elements

ANALOGUE and simulator components suitable for experimental work on amplifying systems, transfer func-

tions, buffer stages, smoothing or averaging circuits, summing integrators, symmetrical c.r.t. deflection amplifiers, analogue computers, system simulation, etc., are available from Feedback Ltd., Crowborough, Sussex. Included in the range now available, which is continually being added to, is the Type AD1B d.c. amplifier. This unit contains two independent amplifiers with open-grid inputs and cathode-follower outputs. One of these gives a positive gain continuously variable over the range +1 to +20 (bandwidth ± 3 dB from zero frequency to 100 kc/s) and the other provides a negative gain of -1 to -150, with a bandwidth of z.f. to 100 kc/s when used for phase reversal and a bandwidth of z.f. to 40 kc/s when used as a function generator.

13WW 034 for further details

Slotted Stand-off Terminal

A SUBMINIATURE "Press-Fit" stand-off terminal has been added to the wide range of terminals produced by Sealectro Ltd., Hersham Trading Estate, Walton-on-Thames, Surrey.
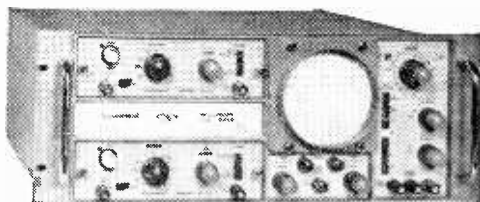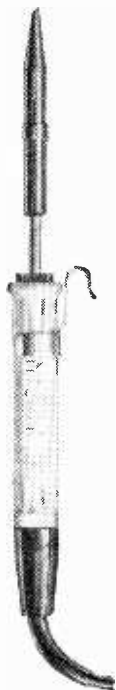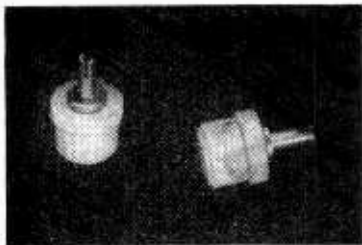
Above: Telequipment rack mounting oscilloscope.

Left: Antex Model C240N miniature soldering iron.

Below: Eimac u.h.f. planar triode.

Sealectro subminiature stand-off terminal.

Exploded view. with dust cover removed, of the B & R miniature relay.

The pin in the Type ST-SM-1SL-1L terminal is of solder-plated brass and extends 0.125 in above the Teflon bushing.

13WW 305 for further details

500 Mc/s Power Tetrodes

TWO new power tetrodes of metal-ceramic construction have been introduced by the Raytheon Company, Lexington 73, Massachusetts, U.S.A.* Known as 4CX125C and F, they have a power of 125 watts when cooled by forced-air. Including the radial cooling fins, which are designed for either liquid or forced-air cooling systems, both valves have diameters of approximately $1\frac{1}{4}$ in and require $2\frac{1}{2}$ in in height.

13WW 306 for further details

Elapsed Time Indicator and Events Indicator

A FOUR-DIGIT elapsed time indicator and a four-digit events indicator are soon to be produced in this country by Bowmar Instrument Ltd. (part of the Booker Bowmar Group),

*Correspondence from readers in the British Isles and continental Europe should be sent to Raytheon-Elsi, S.p.a., Villagrazia, Palermo, Italy.

Raytheon 500 Mc/s power tetrode.

Bowmar elapsed time indicator.

of Sutherland Road, London, E.17. Both of these indicators are housed in similar cases and have displays engraved with $\frac{1}{8}$-in high white numerals on black drums—reading up to 9999. The events indicator has a maximum counting rate of 10 per second—with pulse length of 50 milliseconds—and can operate from 24-28 volts d.c. or a 115 volt, 400 cycle supply; at 2 watts. The elapsed time indicator can only directly work off a 115 volt, 400 c/s supply (1.1 W), although inverters are available to enable the units to work from 24 volt d.c. sources. Neither of the indicators can be re-set.

13WW 307 for further details

Miniature Relays

THE latest additions to the B & R range of relays is the D05/P, a unit which is suitable for operation from voltages up to 170 volts d.c., and the D55/P, which is suitable for voltages up to 350 volts a.c. Both models are mounted on 11-pin international bases, and have no soldered wiring between the contacts and the plug-in base. The three changeover contacts are peripherally arranged and con-

tained in individual pockets to improve the insulation characteristics and prevent flash-over between the contacts. Each contact is rated at 6 amps, at 250 volts a.c. on the D05/P and at 30 volts d.c. on the D55/P. Nominal coil power required is 2 watts or 4 VA and the maximum d.c. coil resistance is 10.2 kΩ. A vacuum impregnated coil can be fitted to either model when the units are required to operate in tropical climates where high humidity conditions prevail. Weighing only $3\frac{1}{4}$ oz, both models are supplied complete with a plastic snap-on cover. A pin connection diagram is engraved on the top of the cover; connections cannot be varied. Dimensions of the two models, which are available from B & R Relays Ltd., Temple Fields, Harlow, Essex, are only $2\frac{5}{16} \times 2 \times 1\frac{9}{16}$ in.

13WW 308 for further details

Voltage Sensing and Time Delay Relays

TWO new series of Potter & Brumfield relays, one covering voltage sensing and the other time delay, are available from the electrical products division of AMF International Ltd., Whitstable, Kent. Typical of the voltage sensing relays is the CDK-22-30006, which incorporates a solid-state control circuit and a telephone type relay enclosed in a plastic dust-cover with an octal base. It has a life expectancy of 100,000 operations and operates from a 22 to 24 volt d.c. supply with a maximum current consumption of 4 mA. Other units in the series are available to operate on spot voltages within the range 12 to 50 V d.c. and a.c. versions, for operation in the range of 20 to 115 V, are currently being developed.

Units in the solid-state series of time delay relays are available with either fixed or adjustable time periods and are suitable for operation on a.c. or d.c. supplies. The maximum time delay provided by standard units is 300 seconds for both the fixed and the variable types. These units are available with any of the following types of mounting: octal base, miniature-pin plug, screw terminals, or solder tags.

13WW 309 for further details

Travelling-wave Tube for Television

A HIGH-EFFICIENCY travelling-wave tube designed by Varian for use as a driver amplifier in the video section or as an output stage in the

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sound section of a u.h.f. television transmitter is now available from this American company's British subsidiary, Varian Associates Ltd., Fox Oak, Seven Hills Road, Walton-on-Thames, Surrey. Known as the VA-651, it has a minimum c.w. output of at least 275 watts over the frequency range 450 to 900 Mc/s, with minimum efficiency of 21% and a mid-band efficiency of approximately 33%. A single forced-air supply is required to cool the tube and integral focusing electromagnet; with the air entering the focusing magnet at the cathode end of the tube and discharged through the finned collector. This tube meets the phase and amplitude linearity requirements of colour television transmitters.

13WW 310 for further details

Variable Transformer

AN ENCAPSULATED auto-wound variable transformer has been added to the Torovolt range of variable ratio units manufactured by the Cressall Manufacturing Company, of Cheston Road, Birmingham, 7. This transformer, the Model 33Y, is designed for operation off 240 volt a.c. supplies and enables smooth variations of output to be obtained from zero up to line voltage at a maximum current rating of 0.8 A; continuous current rating is 0.6 A. Units for front- or back-of-board mounting are available, price 85s complete with knob and dial.

13WW 311 for further details

Panel Mounting Voltmeters

FOLLOWING the recent acquisition of the Metronix Division of Assembly Products Inc. by Millivac Instruments Inc., their range of panel mounting voltmeters are now available through Millivac's United Kingdom distributors Claude Lyons Ltd., Instruments Division, Hoddesdon, Herts. Single and multi-range a.c. and d.c. models with accuracies up to ±1% and repeatable accuracies of at least ±0.2% are included in the range designed for building into systems and consoles. High input impedance and mirror scales are standard features of all instruments and most of the models can be provided with either a locking-coil arrangement or an optical meter relay for monitoring " go-no-go " and automatic control applications. Ruggedized versions and types suitable for operation from 400 c/s supplies are available to order.

The senior instrument in the range, the PM-311-1, is a ten position a.c. instrument with ranges from 10 mV to 300 volts f.s.d. and has an input impedance of 5 MΩ and 25 pF. Accuracy is ±1% f.s.d. over the frequency range 30 c/s to 100 kc/s and ±2% from 20 c/s to 250 kc/s. The instrument is priced at £93 15s 0d (exclusive of duty if applicable) and another version of the same instrument, the PM-311, which is rated at ±2% between 25 c/s and 150 kc/s and ±5% to 250 kc/s, is available at £63 12s 6d.

13WW 312 for further details

U.H.F. Television Klystrons

A SPECIAL range of u.h.f. television klystrons are now being produced by the valve division of Standard Telephones and Cables Ltd. at Paignton, Devon. The first completed klystron, Type 4KM100LH, is a magnetically focused power amplifier with four integral cavities and a frequency coverage of 700 to 890 Mc/s. Initial production is being concentrated upon this unit and two others, the 4KM100LA and the 4KM100LF, which together cover the 470 to 890 Mc/s frequency band. Outputs will be of the order of 25 kW to start with, and additional types—operating in the same frequency band—with higher and lower power outputs will be manufactured later.

13WW 313 for further details

Ten-watt Audio Amplifier

A POWER amplifier with an input sensitivity of 1 mV and a frequency response of better than ±1 dB from 5 c/s to 20 kc/s has been developed by Sinclair Radionics Ltd., of 22 Duncan Terrace, London, N.1. Known as the Sinclair X-10, it uses the pulse width modulation principle (described in the February,

Varian Type VA-651A u.h.f. travelling-wave tube.

Metronix panel mounting a.c. voltmeter.

Cressall Model 33Y variable transformer.

25 kW klystron from S.T.C.

1963, issue) and thus requires no heat-sink for the transformerless (15Ω) output stage and enables smaller—in size—power transistors to be used. Total harmonic distortion of less than 0.1% is quoted. Four of the eleven transistors used are employed in the output stage, in place of the usual two and are so arranged that no speaker coupling capacitor is required. The unit is designed to operate from any 12 to 15 volt d.c. source; quiescent current is quoted at 75 mA. A mains power supply unit, powerful enough to operate a pair of these amplifiers is available at £2 14s. Built and tested amplifier units, which measure $6 \times 3 \times \frac{3}{4}$ in, cost £6 19s 6d and kits of parts with instructions cost £1 less, by post.

13WW 314 for further details

Sinclair X-10 ten-watt audio amp-lifier.

Plastic cable clip from Firth Cleveland Fastenings Ltd.

Plastic Cable Clip

SIMPLE cable clips made of low density polyethylene are now available from Firth Cleveland Fastenings Ltd., Stornoway House, St. James's, London, S.W.1, or Herbert House, 71 Cornwall Street, Birmingham, 3. Known as P0001, these clips have a maximum capacity of $\frac{5}{8}$ in, that is to say a single cable of that diameter or a number of cables making up that diameter, and cost less than a penny each—on orders of about 1,000. They require two quarter-inch holes for fixing.

13WW 315 for further details

Miniature Resistors

THE style 3105M eight-watt chassis mounted resistor from the Sage Electronics Corporation, U.S.A., is now available from Lectropon Ltd., Kinbex House, Wellington Street, Slough, Bucks. Values range from 0.05 ohms to 21 kΩ, with a tolerance rating of 1%. These wire-wound resistors are housed in finned black anodised aluminium casings, whose
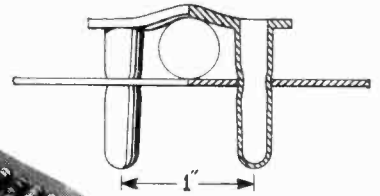

Eight-watt miniature resistor from the Sage Electronics Corporation. A three-penny piece is included to show size.

Servo repeater from the Theta Instrument Corporation.

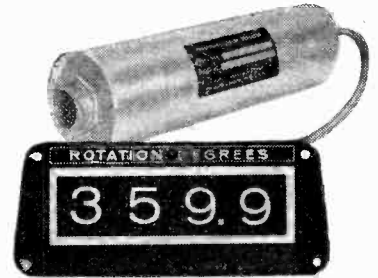overall length is 0.595 in, and are claimed to meet the MIL-R-18546C specification.

13WW 316 for further details

Replacement Transistor Kit

BY careful choice of characteristics, Newmarket Transistors Ltd., of Exning Road, Newmarket, Suffolk, have put together a kit of fourteen transistors which they claim will enable any serviceman to repair virtually any entertainment type of transistor equipment. Known as the "Servikit," it contains four alloy diffused v.h.f., five alloy r.f., three p-n-p a.f., one n.p.n. a.f. and one power transistor. To help select a suitable replacement, the makers have included an index of British, continental Europe and Japanese

types, which the range is designed to replace. The "Servikit" range of transistors are available either individually or in complete packs through Radio and Television Services Ltd., Gloucester Street, Cambridge.

13WW 317 for further details

Solid-state Servo Repeater

POSITION location of remotely located synchros and resolvers, with an accuracy of six-minutes-of-arc, is effected in the solid-state servo repeater Model PPR, which is now available from the Theta Instrument Corporation, Saddle Brook, New Jersey, U.S.A. It has a full 360-degree range and a four-digit display which requires a panel area of 1×4 in. The digits have a character height of $\frac{3}{4}$ in and are illuminated. In addition to the display, a decimal or binary code at a 24 volt d.c. level is available from the servo unit. The price in the States is $1,500.

13WW 318 for further details

Replacement Styli for Decca

NEW high-compliance diamond styli for the Decca Deram ceramic pickup head for both changer and transcription types are now available from the special products division of Decca Radio and Television, Ingate Place, Queenstown Road, London, S.W.8, price 25s. Although the output is slightly down on their predecessors at
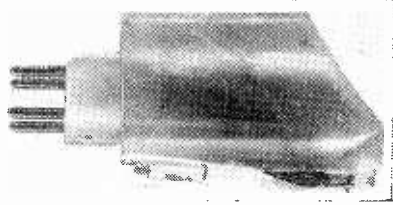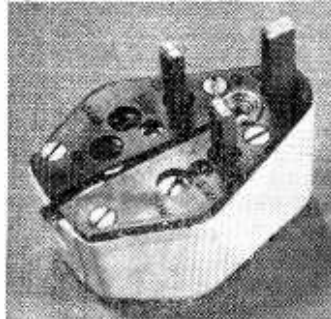
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Decca Deram head fitted with replacement stylus.
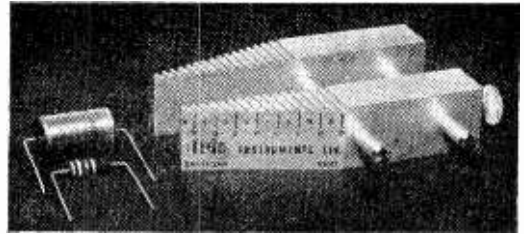
Component bending clamp from Trio Instruments Ltd.
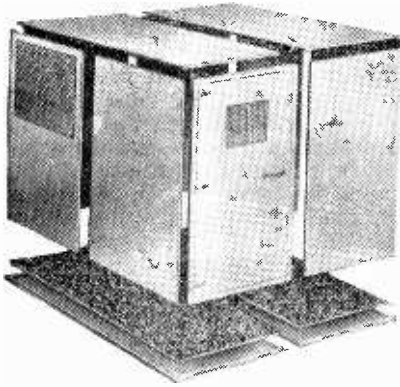
Exploded view showing the panels available in the Belling-Lee "100" series of modular enclosures.

Fittall plug from R W. Rumble (G.B.) Ltd.

Printed circuit connector from Mills and Rockleys.

50 mV/cm/sec, tip mass and tracking weight is the same and channel separation and frequency response characteristics have been improved. A figure of better than 20 dB at 1 kc/s is now given for channel separation (as against 18 dB) and a figure of ± 3dB for frequency response between 18 c/s and 18 kc/s (as against 40 c/s to 12 kc/s) and ±3½ dB for the changer type for the same frequency range.

13WW 319 for further details

Standard Bending Clamp

PRIMARILY designed for use in the assembly of printed circuit component boards, a standard bending clamp is now available, price £2 17s 6d, from Trio Instruments Ltd., Burnham Road Trading Estate, Dartford, Kent. It is suitable for use with components with body lengths of up to 1¾in and will bend their leads to within ₁⁄₁₆in of the ends and up to 3¼in centres. The overall dimensions of the clamp are ⅞ × 3½ × 4½in.

13WW 320 for further details

Modular Screened Rooms

IN addition to its wide range of screened compartments, Belling and Lee Ltd., of Great Cambridge Road, Enfield, Middx., has introduced the

"100" series of modular enclosures. This series is based on a range of interchangeable metal-framed sub-units, which can be quickly assembled to provide a shielded room with attenuation of up to 100 dB at frequencies between 1 and 500 Mc/s. Special conducting gaskets for r.f. bonding of the panels and a new design of push-fitting door, which is self-bonding and holding, are features of this series. Flexibility is another. These enclosures, which can be fitted with modular window panels in metal mesh or in honeycomb form, can easily be modified or extended. The metal-framed sub-units are 88 in high by 44 in wide.

13WW 321 for further details

Five-in-One Mains Plug

A FUSED mains plug which can be easily adjusted to fit one of the following sockets: 15 amp three-pin, 15 amp two-pin, 13 amp three-pin 5 amp three-pin and 5 amp two-pin is being produced by R. W. Rumble (G.B.) Ltd., of Coastguard Road, Larne, Northern Ireland. This plug, which retails at 12s 6d, will be found to be particularly useful to those who have to operate electrical and electronic equipment from supplies using different outlets. All five positions are served by the same fuse.

13WW 322 for further details

Printed Circuit Connector

A NEW type of printed circuit board connector which can be plugged into a printed circuit panel in any position has been developed by Mills and Rockleys (Electronics) Ltd., of Swan Lane, Coventry. The contacts of the connector are so designed that connections may be made to either or both sides of a board, as the spring contacts of the connector automatically make contact with both sides of the board. The connector can be inserted from either side of a board.

13WW 323 for further details

Audio Announcers

THE full range of transistor audio announcers manufactured in the United States by Cousino Audio Announcers, is now available from the D.T.V. Group, 126 Hamilton Road, West Norwood, London, S.E.27. The range comprises five models, all of which use Echo-Matic tape cartridges. These are available with variable tape lengths giving playing times up to 40 minutes. Four of the machines operate from 105 to 120 volt d.c. supplies and the other from 12 volts d.c. All of the machines operate at 3¾ in/sec, but can be modified, by changing one of the drive belts, to run at 1⅞ in/sec.

13WW 324 for further details

Elements of Transistor Pulse Circuits

9.—"GATES"   By T. D. TOWERS,* M.B.E.

YOU can look at electronics as simply "piping" a flow of signals through a system. Electronic "gates" are the circuits by which you steer these signals the way you want them to go. In the "old days", before the rise of the electronic computer, gating circuits were not very important in the framework of electronics and were seldom given an extended treatment in the textbooks. Nowadays, with pulse circuitry playing a very large role in electronics, gates have become an important special field with its own special jargon. The purpose of this article is to try to present a working overall picture of this field, insofar at least as it is concerned with transistors and semiconductor diodes.

Transmission v. Logical Gates

There are two basic kinds of gates, "transmission" and "logical". A transmission gate is one in which, ideally, the output is identical with the input signal when the gate is open, and there is no output when the gate is closed. The transmission gate is sometimes known as a "linear" gate for this reason—the output signal, when there is one, is the same as the input. In a logical gate on the other hand, the output may or may not be a replica of the input. What actually appears at the output is decided by the logical combination of the signals fed into the gate inputs. The output signal, when there is one, need not be the same as any of the input signals.

A commonplace illustration of a transmission gate is the on/off switch of a mains radio receiver. Here the input to the gate is the 230V mains voltage. When the switch is off, the switch output to the receiver is zero; when it is "on", the output is 230V. An illustration of a logical gate from the same receiver is the a.g.c.-controlled 1st i.f. stage. Here the 470-kc/s signal from the mixer and the a.g.c. d.c.-control voltage from the detector are fed into the controlled stage and the output is determined by the combination of these two.

Transmission Gates Using Diodes

Diodes are often used for building transmission gates, because they approximate to a short circuit when forward-biased and to an open circuit when reverse-biased. A simple illustration is the unidirectional *single-diode gate* in Fig. 83(a). Here, when the control voltage V_G applied to the gate control terminal is positive, the diode D conducts and the signal input $+V_s$ reappears as $+V_0$ at the output. When the gate control voltage V_G is negative the diode is reverse biased and no signal appears at the output. The circuit is thus equivalent to the simple on-off switch of Fig. 83(b) controlled by V_G.

The simple circuit of Fig. 83(a) has the defect that the output signal V_0 when the gate is open includes not only the input signal V_s but a d.c. "pedestal" voltage due to the forward gate current through the diode into the load R_0. Also some of the gate current is deflected through R_G into the signal source, so that the signal line and the gate-control circuit are not adequately isolated.

To deal first with the spurious pedestal voltage at the output, this can be eliminated by applying a balanced gate control as in the *two-diode gate* of Fig. 83(c). Here a push-pull gate voltage $\pm V_G$ is applied across diodes D1, D2, which are so arranged that, when V_G is positive, both diodes conduct and when V_G is negative both are cut off. So far as the gate signal goes, the diodes are in series, but, so far as the controlled signal V_s is concerned, the diodes are in parallel. The important point is that
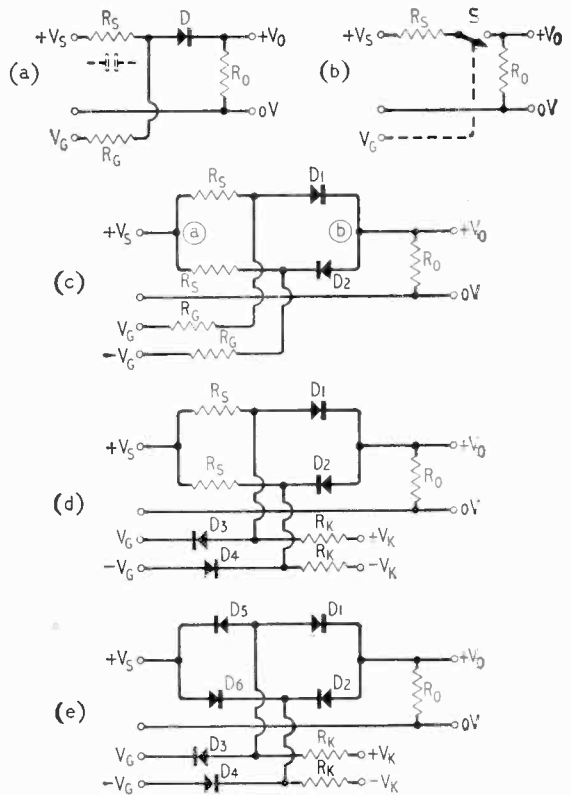

Fig. 83. Transmission gates with series diodes; (a) basic single diode circuit. (b) equivalent single-diode circuit. (c) two-diode gate, (d) four-diode gate, (e) six-diode gate.

*Newmarket Transistors Ltd.

the voltages at points (a) and (b) are not affected by the application of the push-pull gate voltages.

The circuit of Fig. 83(c) has certain defects still however. The "gain" of the gate (defined as V_0/V_G during transmission) can be shown to be

$$A = \frac{R_G}{R_G+R_S} \cdot \frac{2R_0}{2R_0+R_GR_S/(R_G+R_S)} \quad \cdots \quad (1)$$

if we ignore the forward diode resistances. This points to the major disadvantage of the two-diode gate—its low "gain" i.e. heavy attenuation of the controlled signal voltage. It is also susceptible to unbalance in the gating voltages.

Better gain can be achieved by the *four-diode circuit* of Fig. 83(d) which requires two additional fixed bias voltages V_K and $-V_K$. As these are fixed, however, they do not unduly complicate the circuit. The diodes D1 and D2, considered by themselves, would be forward-biased by the voltages $+V_K$, $-V_K$. Now if V_G is positive, diodes D3 and D4 are cut off, D1 and D2 remain conducting, and the gate transmits V_S to the output. If now the gate voltage V_G is made sufficiently negative, diodes D3 and D4 conduct, D1 and D2 cut off, and the gate ceases to transmit. It can be shown that this four-diode gate has a higher gain that the two-diode version, but it is still far from the theoretical unity gain of a perfect transmission gate. However the circuit is now much less sensitive to gate voltage unbalance.

For further improvement in gain, recourse may be had to the *six-diode transmission gate* of Fig. 83(e). Here the signal-isolating resistors R_S are replaced by diodes D5, D6 and a gain very close to unity can be achieved if R_K and R_0 are large compared with the forward diode resistances.

We have analysed these diode transmission gates in terms of d.c. voltages, but equally they can be used with pulse or a.c. voltages. The coupling capacitors, where used, will then have values governed by the usual design considerations i.e. no significant discharge between pulses and no significant charging on pulses. Also account may have to be taken of diode capacitances and leakage currents. Fuller information can be found on these aspects in J. Millman and T. H. Puckett "Accurate Linear Bidirectional Diode Gates" *Proc. I.R.E.* Vol. 43, pp. 27-37, Jan. 1955.

All the diode transmission gates of Fig. 83 work on the principle of short- or open-circuiting a diode in *series* with the signal line. A diode can similarly be used as a switch *shunting* the signal line. This gives rise to a whole family of shunt diode transmission gates which can be derived by analogy from Fig. 83.

Diode transmission gates find wide use in electronics. A typical example taken from the field of electronic organs, is given in Fig. 84 to illustrate actual circuit values used in practice. Here a series diode D1 is switched on and off by a switch S attached to the organ manual key. When the note is depressed, S closes and forward biases D1 by applying -18 V across the diode and the two series $1\,M\Omega$ resistors. At the same time diode D2 is reverse-biased and effectively open circuit. The tone signals arriving at (a) then pass through to the output (b) via a buffer emitter-follower stage Q. When the key is released, the switch S opens, and the -18 V is removed from the diode circuit. Diode D1 is now reverse-biased by the polarizing $+18$ V through $6.8\,M\Omega$, and presents an open circuit to the input signal. At the same time diode D2 becomes
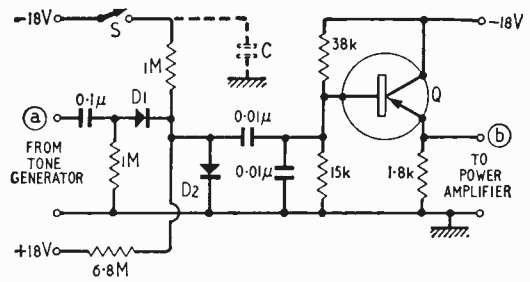

Fig. 84. Practical diode transmission gate used in electric organs.

forward biased and clamps the signal line on the output side of D1 to earth. The two $0.01\,\mu F$ capacitors and $15\,k\Omega$ resistor at the input of transistor Q form a filter network to partially suppress switching transients ("key clicks") on the signal line. The capacitor C shown dotted can be added to the circuit so that when the note is released (switch S opens) the polarizing voltage holding D1 conducting dies away only gradually (with a time constant set by the value of C and its associated $1\,M\Omega$ resistor). As a result the note does not cut off sharply, but "sustains" for a short time to simulate the gradual decay of the note from a conventional organ pipe.

Transmission Gates Using Transistors

The effectiveness of diode transmission gates is limited somewhat because, although the diode forward resistance is small, it is still far from the ideal of zero resistance. It has been found that with transistors you can get much lower forward resistances. There are two ways of using transistors in transmission gates.

First, the transistor can be substituted directly for a diode in any of the gate circuits explored earlier, if its collector and base are directly connected together in what has been called the "triode" (= triode-as-diode) arrangement shown in Fig. 85(a) for p-n-p or (b) n-p-n. This produces a diode-substitute with a forward resistance several times
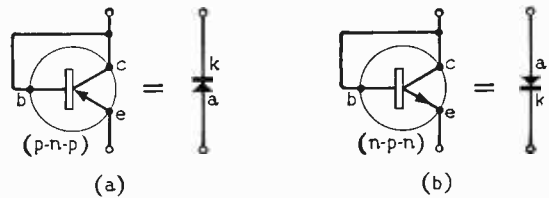

Fig. 85. Transistor "triode" substitute for diode.

lower than an equivalent conventional point contact or gold-bonded diode.

Secondly, the transistor can be operated as a triode, where the control gate voltage is applied to the base and the controlled signal voltage to the collector (or to the emitter used as a collector). A single-ended arrangement of this sort is given in Fig. 86(a). Here a positive signal $+V_S$ applied to the input is not transmitted to the output if a positive gate voltage $+V_G$ is applied to the n-p-n transistor base. The transistor is then "bottomed" and has a very

low collector output resistance which in effect short-circuits the signal line to earth. If a negative gate voltage $-V_G$ is applied to the transistor base, the transistor has both emitter and collector junctions cut off. Under these conditions the collector-emitter resistance of the transistor is high, the signal is not significantly shunted to earth and the input signal V_s is transmitted to the output as V_0 with an attenuation fixed by the ratio of R_0 to R_s.

If the switching transistor is inverted (i.e. with collector and emitter interchanged) as in Fig. 86(b), it is found that the " on " resistance may be much lower than for the non-inverted configuration, while the off resistance is much higher. The inverted configuration thus gives a closer approach to an ideal switch.

For negative-going input signals, the circuits of Fig. 86(a) and (b) can be used, but with p-n-p transistors instead of n-p-n and with a negative gate voltage V_G to close the gate and a positive one to open it.

When the input signal V_s is bidirectional (i.e. either positive or negative), a balanced arrangement of two transistors such as Fig. 86(c) may be used. Here the n-p-n transistor Q1 controls $+$ve signals while the p-n-p one, Q2, controls negative signals. Note that oppositely-phased gate sign signals V_G are used on the two transistors.

Some people will recognize in Fig. 86(a) and (b)

Fig. 86. Transistor transmission gates; (a) basic single-ended (positive unidirectional input), (b) basic inverted single-ended (positive unidirectional input), (c) basic push-pull (bidirectional input), (d) electronic organ keying gate.
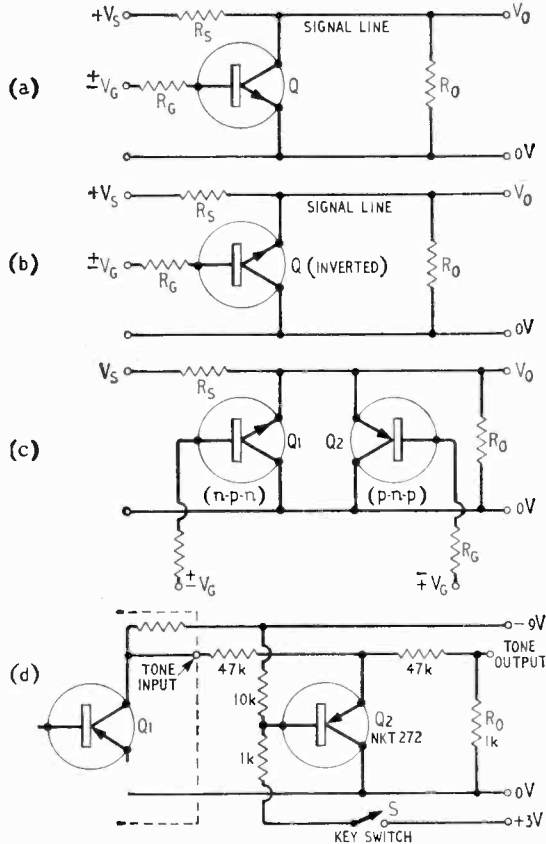
the basic circuit of the transistor " chopper " widely used in d.c. amplifier practice. In this application the gate may be controlled by a square wave with a fixed repetition rate. This converts a d.c. input into a " chopped " square wave output which can be handled by a standard a.c. amplifier and thus largely reduce the effect of drift which is so troublesome in a " straight " direct-coupled amplifier.

An interesting practical use of this type of circuit is again in electronic organs as an alternative to the diode keying system described earlier. This is illustrated in Fig. 86(d) where the output from a multivibrator tone generator Q1 is passed via a 47 kΩ isolating resistor to the top end of an inverted gating transistor Q2. The output of the tone generator is unidirectional negative so a p-n-p gating transistor is used. The switch S attached to the playing key is normally open (when the note is up), and the transistor Q2 is biased on by the 10 kΩ resistor from the base to the negative supply rail. The output resistance at the emitter of Q2 is then very low, and the signal line is effectively shorted to earth so that no tone signal appears at the output. When now the key is pressed, S closes and the base of Q2 is carried positive by the potentiometer formed by the 10 kΩ and 1 kΩ across the -9 V and $+3$ V rails. Transistor Q2 then has both its collector and emitter junctions reverse biased. Its emitter therefore presents a high impedance to the signal line. Thus when a note is pressed, its tone is no longer shunted to earth and so appears at the output. By connecting various CR networks in the base circuit of the gate transistor it is possible to shape the envelope of a note to give various forms of attack and sustain.

Digital computers use transmission gates frequently, but they also require logical gates to carry out all their operations. Before the advent of transistors, most logical gates were constructed of diode networks. By themselves, however, diodes cannot make up a complete set of gates for a computer, since they cannot perform the functions of amplification and phase inversion which must be available. With only diodes, however, we can make up at least two of the most widely used logical circuits—the " OR " and " AND " gates.

Before we examine the diode OR and AND gates, we must diverge to set the picture of logic " levels." A digital computer usually works by handling a series of pulses. When the pulse is there, the signal level can be said to be " UP " and when it is absent " DOWN." For the purpose of this discussion, we will regard a signal as UP when the voltage level is $+V$ and DOWN when it is zero. In practice the UP and DOWN levels may be arbitrarily selected voltages, neither of them zero.

The basic circuit of a *diode OR gate* is given in Fig. 87(a). When input 1 is UP (i.e. at $+V$) the diode D1 is forward biased because its anode (a) is positive with respect to its cathode (k) (which is connected via R to zero volts). Then the output, too, is at $+V$, if we assume an ideal diode which is a short circuit when forward biased. In the meantime, if input (2) is DOWN (at zero volts), diode D2 is reverse biased, and presents an effective open circuit across the output, not affecting the output voltage level. If, however, input (2) is also UP, both diodes will be conducting, so that the output is still UP. Only if input 1 *or*
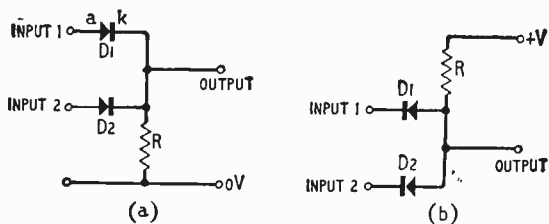
Fig. 87. Basic diode logic gates; (a) "OR", (b) "AND".

input 2 is UP, will the output be up too—hence the name OR gate. If both inputs are DOWN, the output too must be DOWN.

We have shown the basic OR gate with two inputs, but more than two inputs may be used. If we apply the same analysis as in the two-input case, we find that the output will be UP if any input is UP, and DOWN if no input is UP.

The other basic gate is the *diode AND gate* illustrated in Fig. 87(b). Here if either input is DOWN (at 0V) its corresponding diode is forward biased and the output thus clamped to 0V is also DOWN. Only if both input 1 *and* input 2 are UP, will both diodes be cut off and the output be UP too—hence the name AND gate. This gate is also known as a " COINCIDENCE " gate because its output is UP only when UP signals coincide at the inputs.

Logical Gates Using Triodes

One essential of all digital logic circuits is the " *NOT*" *gate* illustrated in basic form in Fig. 88(a). This circuit is essentially an overdriven common-emitter amplifier and is often called an INVERTER because it inverts the phase of a signal passed through it (i.e. a positive going signal at the base appears as a negative going signal at the collector). But the NOT gate does more than just phase-invert. It changes the absolute signal level. An UP input gives a DOWN output and vice versa. The basic design feature of the circuit is that $R_B < h_{FE} R_0$ where h_{FE} is a d.c. current gain of the transistor at a collector current V/R_0. Some readers may be puzzled by the description " gate " attached to this circuit, which does not appear to have any *control* over the input signal, but merely alters its character. This is simply a convention to enable this essential switching circuit block to be classified with other control circuits which are more rigorously described as gates.

With nothing more than the three logic gates so far discussed—diode OR, diode AND, transistor NOT—it is possible to fabricate the complete pulse handling logic of a computer. But this is not the most economical way to do the job. For example, to make up signal losses through the passive diode gates a non-inverting amplifier is required, and for this two inverting NOT gates must be used in series. Transistors, through the diode characteristics of their base-emitter junctions, can be used as active gates to replace the diode OR and AND gates, thus eliminating the need for separate amplifiers.

A basic *transistor OR gate* is illustrated in Fig. 88(b). For the logic levels of 0 and $+V$ selected, n-p-n transistors are used in an arrangement of two emitter-followers with a common emitter load resistor R_0. If input 1 is UP (at $+V$), then transistor Q1 conducts, its base-emitter voltage is negligible
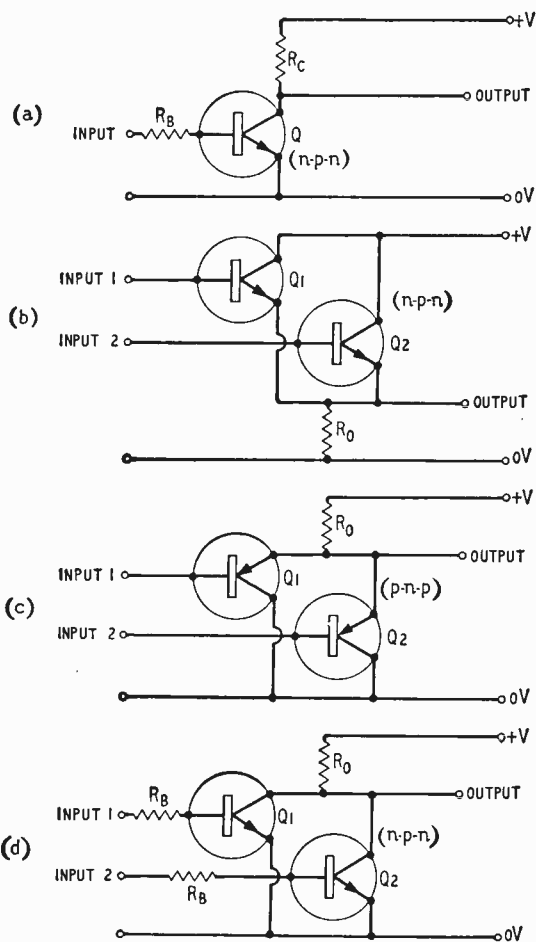
Fig. 88. Transistor basic logic gates; (a) "NOT" gate (inverter), (b) "OR" gate, (c) "AND" gate, (d) "NOR" gate.

(ideally zero) and its output at the emitter too is UP. Similarly, if input 2 is UP, the output is UP. Thus if input 1 *or* 2 is UP the output is UP, and we have an OR gate.

The basic *transistor AND gate* takes the form shown in Fig. 88(c). Here, for logic levels O and $+V$, p-n-p transistors are used in an arrangement of two emitter-followers with a common emitter load resistor R_0. If either input 1 or 2 is down (at 0V), then the related transistor Q1 or Q2 conducts and the output is clamped down to 0V through the conducting base-emitter diode. Only if *both* inputs are UP (i.e. both input 1 *and* input 2) will the output also be UP. We thus have an AND gate.

One interesting point about these transistor gates is that they use complementary transistor types— n-p-n for the NOT and AND gates and p-n-p for the OR gate. This leads to a logical simplicity that would not be possible with valves (which are equivalent to only one transistor type, the n-p-n). If you restrict your logic gates to only one transistor type, say n-p-n, you can only replicate the more complex valve circuits.

Although we have set out NOT, OR and AND gates as the basic " building block " gates of a digital computing system, in fact these are not all *necessary*

gates. There is, however, one gate which by itself is logically complete; that is, any logical expression can be achieved by combinations of this gate. A whole digital handling system could thus be built up with this single gate type—even if it would be uneconomical in practice. This is the " NOR " gate illustrated in basic form in Fig. 88(d). " NOR " stands for " NOT-OR " and implies that the output is *not* UP when either input 1 *or* input 2 is UP. This should be clear from the circuit diagram because if either input is UP the positive voltage applied to it biases the corresponding n-p-n transistor hard on and the output voltage at the collector falls virtually to zero (i.e. the output is DOWN). Conversely, when both inputs are DOWN, the transistors are cut-off (because no current flows into either base) and the output is UP. Around a NOR gate of this basic type has been produced a commercial range of logical switching blocks down as " NORBITS," which can be wired together to produce complete digital switching equipments. In the " NORBIT " system the basic NOR gate is supplemented by a small number of amplifiers, etc. but the logic is primarily designed round the primary NOR element.

Symbols for Logical Gates

Designers of logical switching systems use a system of " shorthand " rather than draw out the various gates in detail. The gate symbols used have not yet been firmly standardized but one commonly used set is given in Fig. 89 where (a) (b) (c) and (d) are the symbols for the AND, OR, NOT and NOR gates so far covered. Where a NOT gate is inserted in an input line to another gate it can be symbolised by the second simplified sign in Fig. 89(c). This can be seen used in Fig. 89(d) where the normal NOR symbol can also be represented as an OR symbol with a NOT symbol in each input line.

The symbols of Fig. 89 were selected from the many different types that have been used from time to time, not for any logical " philosophical " reason but because they are boxes with vertical and hori-

Fig. 89. Symbols for logical gates.

zontal edges which are convenient to outline on a drawing board. Other symbols using circles, or triangles are more troublesome in this respect. The inputs have been shown entering from the left hand edge but they can also enter at top or bottom. Similarly the output can emerge from any side. When it is not self evident which is input and output, appropriate arrowheads are added as in the specimen OR gate at Fig. 89(e).

Supplementary Transistor Logic Gates

A survey of logic gates would not be complete without mention of the two other commonly used special gates shown in Fig. 90 together with their
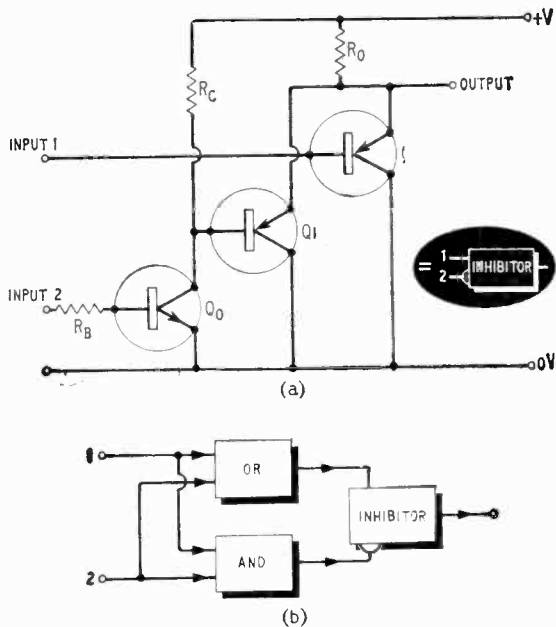
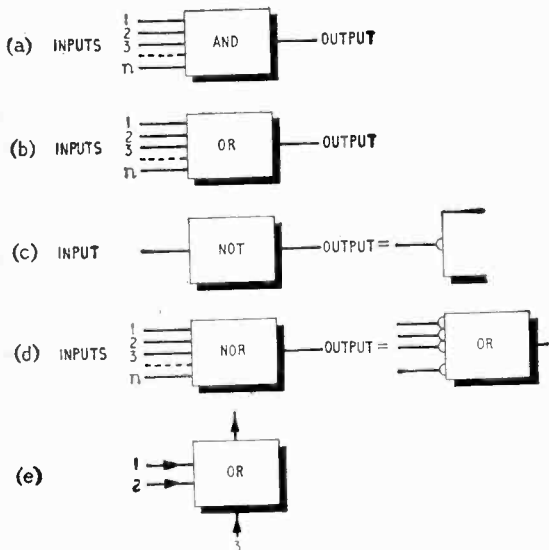Fig. 90. Supplementary transistor logic gates; (a) inhibitor (b) exclusively- OR (in symbols).

symbols—(a) " INHIBITOR " and (b) " EX-CLUSIVELY OR."

The INHIBITOR gate of Fig. 90(a) is in effect an AND gate made up of Q1 and Q2 where input 2 is pre-inverted by the NOT gate Qo. As a result, if input 1 is UP and input 2 DOWN the output will be UP. Conversely if input 2 is UP, then the output cannot be UP whatever the input 1 is. The gate is called an INHIBITOR because an UP signal at the " inhibiting terminal " 2 prevents an UP signal at input 1 from being transmitted through to the output. The gate is also known as an " ANTI-COINCIDENCE " circuit, because it gives no output when two inputs coincide. Another self-explanatory name used is " NOT-AND " or " NAND " gate.

This gate illustrated a point not made clear earlier; namely that any input terminal of a logical gate can be selected for use as a separate control gate and the logical gate then used as a simple transmission gate.

The other auxiliary logic gate illustrated in Fig. 90(b) is the EXCLUSIVELY-OR gate. In the

simple OR gate described earlier the output is UP if any one or more of the inputs is UP. Now some logic circuits require the EXCLUSIVELY-OR gate in which the output is UP if one, but not more than one, of the inputs is up. In the arrangement of three gates shown in Fig. 90(b) if inputs 1 and 2 are UP together, the output of the AND gate too is UP and closes the INHIBITOR gate, so that the final output cannot be UP. If either input 1 or input 2 is UP by itself, the output from the AND gate cannot be UP, so that the INHIBITOR gate is not closed. Meantime the output of the OR gate is up because one of its inputs is UP. Thus the final output is UP. Thus this combined EXCLU-SIVELY-OR gate gives an UP output when one or other of the inputs (but not both) is UP. This gate is also known as an " AND-NOT " gate.

Practical Aspects of Logical Gates

The field of electronics logic has many forms of gate apart from the basic circuits we have looked at above, and only a detailed study of computer circuits can show all the practical problems of their design. We have dealt only with d.c. coupled gates, but in pulse circuitry a.c. coupling is frequently used. This brings in a need for various d.c.-level-restoring circuits that are outside the scope of this approach survey. Also we have assumed ideal semiconductors with junctions assumed to be short circuits on forward bias and open circuits on reverse bias, thus avoiding such troublesome design problems as leakage current variation with temperature. Readers interested in more exact design information should look up such a treatise as J. Millman and H. Taub " Pulse and Digital Circuits " (McGraw Hill 1952).

While we have looked briefly at diode and transistor gates, it should not be overlooked that in recent years a new series of devices such as tunnel diodes, p-n-p-n " thyristors," s.c.r.s etc. are opening up new types of transmission and logic gates to supplement the basic diode and transistor triode types. As yet these are relatively new and no easily accessible complete accounts of their use as gates are available, but it is probable that they will change the face of gating practice as much as the transistor did when it " took over " from the valve.

BOOKS RECEIVED

Handbook of Microwave Measurements, edited by Max Sucher and Jerome Fox. Third edition, in three volumes, revised and enlarged, of a comprehensive treatise sponsored by the U.S. Army Signal Corps and the U.S. Army Electronics Research and Development Agency on step-by-step procedures for testing systems and components. The revision makes the work more general, and less dependent on specific pieces of commercial equipment. It also includes recent developments in ferrite materials and parametric amplifiers. Pp. 1145. John Wiley and Sons Ltd., Glen House, Stag Place, London, S.W.1. Price £15.

Electrical Who's Who compiled by *Electrical Review.* The 1964/5 edition contains potted biographies of about 8,000 leading men and women in the various branches of the electrical and electronics industries. Over 1,000 new entries are included in this eighth edition which also incorporates a list of personnel in the various companies and organizations. Pp. 528. Iliffe Books Ltd., Dorset House, Stamford Street, London, S.E.1. Price 55s.

The Propagation of Electromagnetic Waves in Multiconductor Transmission Lines, by P. I. Kuznetsov and R. L. Stratonovich. Translated from the Russian, this mathematical treatise extends the application of Maxwell's and Kirchhof's equations with special reference to finite conductivity and to non-uniform lines. Pp. 190. Pergamon Press, Headington Hill Hall, Oxford. Price 70s.

Telecommunications, General Editor Prof. H. M. Barlow, F.R.S. **Vol. 1. Principles of Telecommunications,** by J. Brown and E. V. D. Glazier. The emphasis is on the basic problems of communication rather than on circuit details—the nature of signals, noise and its limiting effect, information theory and the application of this concept to communication and position-finding systems. Extensive appendices deal with the use of transforms in circuit analysis and with Bessel functions. Pp. 370. Chapman & Hall Ltd., 11 New Fetter Lane, London, E.C.4. Price 45s.

Horizontal Sweep Servicing Handbook, by Jack Darr. An exhaustive treatment of one section of the television receiver (line timebase, e.h.t. circuits and deflection coils) from the point of view of the serviceman. Diagnosis and repair of faults is discussed with numerous photographs of picture distortion and waveform diagrams. Theory is introduced to give a basic understanding of the work done. Pp. 224. Gernsback Library Inc., 154 West 14th Street, New York 11, N.Y., U.S.A. Price $4.10.

Sensitivity Indices for Hall Generators, by Sherwin Rubin and George J. Rogers. N.B.S. Technical Note No. 233. The ratio of Hall voltage to the product of control current and magnetic induction is not a completely satisfactory method of stating sensitivity, and arguments are adduced for two additional sensitivity indices. Pp. 22. National Bureau of Standards, Washington 25, D.C., U.S.A. Price 25 cents.

Reference Data for Radio Engineers (4th edition, 9th printing). Starting as a 60-page brochure edited by W. L. Macpherson and issued in 1942 by Standard Telephones & Cables Ltd., it has since been taken up by the American I.T.T. Company and expanded into what is described as a "compact" volume containing nearly twenty times the amount of material and covering most aspects of radio and electronic engineering from the points of view both of the professional and of the novitiate in any given branch. Pp. 1136. Standard Telephones & Cables Ltd., Therese House, 29-30 Glasshouse Yard, Aldersgate Street, London, E.C.1. Price 42s.

Vacuum and Solid State Electronics, by D. J. Harris, B.Sc.(Eng.), Ph.D., A.M.I.E.E., and P. N. Robson, B.A., A.M.I.E.E. Introductory course on the basic physics of electron devices with particular reference to junction diodes and transistors Forms part of the Electrical Engineering section of the Commonwealth and International Library of Science, Technology, Engineering and Liberal Studies. Pp. 254. Pergamon Press Ltd., Headington Hill Hall, Oxford. Price 20s.

NEWS

FROM

INDUSTRY

Consortium Formed to Bid for NATO Contract.—Two British companies, Associated Electrical Indutries and Elliott Automation are members of an international consortium which has been formed to tender for a £110M contract for a new NATO defence network against air attack. The other members of the consortium are Litton Industries Inc. of America, Compagnie Générale de Télégraphie sans Fil (C.S.F.) of France and the International Telephone and Telegraph Corp.— Europe. The proposed network, to be known as NADGE (Nato Air Defence Ground Environment) has been designed to provide instant response against attack by supersonic aircraft and will comprise a chain of defence stations stretching through nine countries from Norway to Turkey. Contracts are expected to be awarded by the middle of next year.

A.E.I. Lincoln Valve Plant Sold. —The English Electric Valve Company, of Chelmsford, Essex, has purchased Associated Electrical Industries' Carholme Road factory in Lincoln, together with the valve business being carried on there. It is the intention of the English Electric Valve Co. to increase still further the production of specialized electronic valves and tubes used in television transmission and telecommunications, and eventually to build up the labour force at the Lincoln factory to some 1,000 people. E.E.V. has leased A.E.I. part of the factory to enable A.E.I. to continue to develop and manufacture semiconductors in their present premises.

Clairtone.—Following an agreement between the Ditchburn Organisation and the Clairtone Sound Corporation, of Toronto, Canada, a new company—to be known as Ditchburn Clairtone Ltd.—has been formed. Under the agreement, the new company has the sole manufacturing and distribution rights for the United Kingdom and will also be supplying continental Europe with Clairtone products. Clairtone was formed five years ago to produce high-quality radiograms and its sales

figures have risen from $311,000 to $8,910,000 in 1963. The new company will operate from Dock Road, Lytham St. Annes, Lancs.

I.T.T. Form U.K. Company.— The International Telephone and Telegraph Corporation, of New York, has formed a new company in the United Kingdom under the name I.T.T. Industries Ltd. This company will market a wide range of industrial products, manufactured in the United States and Europe. The chairman of the new company is Rex B. Grey, who is the managing director of Standard Telephones and Cables Ltd., another I.T.T. affiliate in the U.K. The formation of this company is complementary to similar companies which have been, or are in the process of being, established in Germany, France, Italy and Belgium. Robert Maclaren & Co., who make thermostats and was acquired by Standard Telephones and Cables Ltd. last year, has been transferred to the new company. Also under the wing of the new company are Thermocontrol Installatons Co. Ltd., of London, and Cooper Compressors Ltd., of Letchworth.

Pye of Cambridge Ltd. announces that its trading profit for the year ended 31st March amounted to £7,082,756 and shows an increase of £2,730,658 on the previous year's result. Group profit before taxation shows an increase of over 100% on the 1962/63 result at £4,600,256 (£2,156,313), and after-tax profit is well up at £2,410,432 (£1,014, 134).

According to comparative figures issued by the directors of the subsidiary company E. K. Cole Ltd. its contributions to the total trading profit rose from £420,206 in 1962/63 to £1,132,882, whilst the subsidiary Pye Ltd. pushed its trading profits up from £3,961,946 to £5,997,729. The Telephone Manufacturing Company Ltd., another subsidiary of the Pye organization, announces a pre-tax profit for the same period of £470,621, which represents a drop of nearly £25,000 on the previous year's result. Incidentally, this subsidiary has regrouped its components activity and has formed a components division in Roper Road, Canterbury, Kent. (Tel.: Canterbury 66577.)

Dubilier Condenser Co.—The trading profit for the year ended 31st March amounted to £441,068 and is the highest yet recorded. It represents an increase of over 100% on the previous year's result of £201,224. Taxation took £181,690 as against £106,789 in 1962/63 leaving, after other deductions, a net profit of £156,040 (£94,435).

Controls and Communications Ltd. group profit for the year ended 31st March amounted to £650,579 and shows an increase of £83,316 on the previous year's result. The charge for taxation is £315,585, as against £274,375 for 1962/1963, and the net profit amounts to £334,994 (£292,888). Airmec, British Communications Corporation, Modern Aerials and Thermionic Products (Electronics) are subsidiaries.
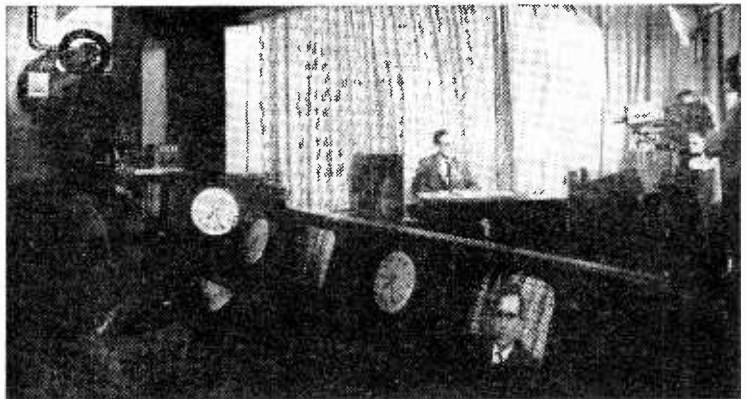
TV Studio at Shell Centre.—A closed-circuit television studio has been completed at the headquarters of the Shell International Petroleum Company. This has been designed primarilly to coach members of the staff in the techniques in speaking on the television networks. Two cameras are used in the studio with two more in the control room. One of these is used for titles and captions, and the other forms part of a simple telecine arrangement. The production team have complete control of the cameras and in addition to the camera monitors, an "off-line" receiver is installed in the control room to indicate the quality of picture and sound being distributed through the Shell Centre offices, conference rooms, lecture halls, theatre and lounges. The cameras and associated equipment was supplied by EMI Electronics Ltd.

Group trading profits of the **Rank Organisation** in the year to 27th June rose from £11,312,000 to £15,903,000. After providing £5,651,000 (£3,927,000) for depreciation, £3,194,000 (£2,751,000) for taxation and making other deductions, the net profit for the year amounted to £5,778,000 as against £3,557,000 in the previous year.

Colvern Ltd. pre-tax profits for the year ended 31st March totalled £236,906 and represent a drop of £38,454 on the previous year's result. Tax this year took £123,779 (£143,968) leaving, after other deductions, a net profit of £113,127 (£131,392).

Antiference group trading profit for the last financial year, ended 31st March, amounted to £240,790 and represents an increase of £18,894 on the previous year's result. Taxation this year took £120,126 as against £111,560 and the net profits rose from £110,336 in 1962/63 to £120,664.

Telefusion Ltd. announces a group trading profit of £2,010,554 for the 53 weeks ended 29th April, as against £1,712,542 for the previous 52 weeks. After deductions, including £1,235,943 (£1,003,333) for depreciation, £79,516 (£247,400) for taxation, the net profit rose from £438,237 in 1962/63 to £669,135.

Painton and Co. group pre-tax profits for the year ended 30th April amounted to £373,481 and represent an increase of £98,012 on the 1962/63 result. Net profit of this company, which was made public two years ago, amounted to £194,588 (£156,262). Taxation took £178,893 as against £119,207 in the previous year.

Brayhead Ltd. has acquired a controlling interest (60%) in Tape Recorders (Electronics) Ltd. for £75,000 in cash. Tape Recorders will continue to manufacture under the trade name Sound at 105-113 Lawrence Road, Tottenham, London, N.15.

The **Nottingham Electronic Valve Company,** who developed the Telcan domestic television tape recorder and hoped to put it on the market this year, has gone into voluntary liquidation. The first meeting of creditors was held at East Bridgford, Nottinghamshire, on 20th August. Prior to this meeting, the managing director, Norman Rutherford, said his Company had not been able to raise the necessary capital for the Telcan venture and that negotiations with a number of U.K. and overseas companies have not materialized.

OCTOBER MEETINGS

Tickets are required for some meetings : readers are advised, therefore, to communicate with the secretary of the society concerned.

LONDON
1st. Television Society.—"Microphones and sound effects for television" by D. J. Basinger at 7.0 at I.T.A., 70 Brompton Road, S.W.3.

1st. S.E.R.T.—"Colour television maintenance problems" by B. J. Rogers at 7.15 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

5th. I.E.E. & I.E.R.E.—Discussion on "Transistorized biological amplifiers" at 2.30 at Savoy Place, W.C.2.

7th. I.E.R.E.—"The contribution of the engineer to the economy" by Dr. A. C. Copisarow at 6.0 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

8th. I.E.E.—O. W. Humphreys' presidential address at 5.30 at Savoy Place, W.C.2.

8th. Radar & Electronics Assoc.—"Telecommunications from the new Post Office tower" by W. L. Newman at 7.0 at the Royal Society of Arts, John Adam Street, W.C.2.

12th. I.E.E.—"Application of electronic vector scanning techniques applied to height-finding landing systems" by Dr. D. E. N. Davies and "Frequency scanning aerial systems" by Miss E. Killick at 5.30 at Savoy Place, W.C.2.

13th. I.E.E.—"The design and control revolution" by Prof. M. W. Humphrey Davies, chairman Science and General Division, at 5.30 at Savoy Place, W.C.2.

14th. Society of Environmental Engineers.—"Some electronic systems applied to environmental problems" by B. E. Grant at 6.0 at Imperial College, Mechanical Engineering Dept., Exhibition Road, S.W.7.

14th. B.K.S.—"Colour perception" by K. R. Sadek at 7.30 at Central Office of Information, Hercules Road, S.E.1.

16th. Television Society.—"Transcoding from SECAM to N.T.S.C." by H. Steele at 7.0 at the I.E.E., Savoy Place, W.C.2.

21st. I.E.E.—"Through communications to electronics" by G. G. Gouriet, chairman Electronics Division, at 5.30 at Savoy Place, W.C.2.

21st. I.E.R.E.—"The effect of tolerances on automatic landing" by M. G. Henley at 6.0 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

21st. B.K.S.—"The anatomy of speech signals" by Dr. A. Sekey at 7.30 at Shell-Mex Street, Strand, W.C.2.

22nd. Society of Instrument Technology.—"The function of the National Physical Laboratory" by Sir Gordon Sutherland at 6.0 at the Royal Institution, 21 Albemarle Street, W.1.

26th. I.E.E. & I.E.R.E.—Colloquium on "Design automation"* at 2.30 at Savoy Place, W.C.2.

26th. I.E.E.—"Millimetre wave examination of gas discharges" by Prof. A. L. Cullen at 5.30 at Savoy Place, W.C.2.

28th. I.E.R.E. & I.E.E.—Symposium of short papers on "Magnetic

* All wishing to attend must register.

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circuit design applied to electro-mechanical transducers" at 6.0 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

29th. I.E.E.—Discussion on "Hollow beams" opened by A. H. W. Beck at 5.30 at Savoy Place, W.C.2.

BIRMINGHAM
26th. I.E.E.—"Television standards conversion by electronic methods" by E. R. Rout at 6.0 at the James Watt Memorial Institute.

BRADFORD
27th. I.E.E.—Discussion on "Conventions and signs" opened by M. G. Scroggie at 6.30 at the Bradford Institute of Technology.

BRIGHTON
28th. I.E.E.—"Electronic telephone exchanges" by Dr. J. E. Flood at 6.30 at the College of Technology, Mouiescombe.

BRISTOL
21st. I.E.E. & I.E.R.E.—"From morse to microwave—the story of transatlantic communications" by C. A. L. Nicholls at 6.0 at The University, Queen's Building.

CAMBRIDGE
22nd. I.E.E. — "Technology — life and leisure" by Prof. D. Gabor at 8.0 at the Engineering Laboratory, Trumpington Street.

CARDIFF
14th. I.E.R.E.—"The N.T.S.C. colour television system" by P. Lowry at 6.30 at Welsh College of Advanced Technology.

CHELMSFORD
5th. I.E.E.—"Some thoughts on technical education" by Prof. M. G. Say at 6.30 at the Lion and Lamb Hotel.

CHELTENHAM
20th. I.E.E.—"Connections in electronic circuits" by G. W. A. Dummer at 7.0 at Cheltenham Technical College.

CHRISTCHURCH
14th. I.E.E.—"Newton and Heaviside in control—the direct approach to control-system analysis and measurement" by G. G. Gouriet at 6.30 at the King's Arms Hotel.

DORKING
7th. I.E.E.—"Computers in control of processes—the coming revolution in industry" by Dr. D. N. Truscott at 7.30 at the Dorking Halls.

EDINBURGH
7th. I.E.R.E.—"Electronic control systems in coal mining" by G. M. Rendall at 7.0 at the Department of Natural Philosophy, The University, Drummond Street.

13th. I.E.E.—"The maintenance of electronic equipment" by L. Tweeddale at 6.0 at the Carlton Hotel, North Bridge.

FARNBOROUGH
27th. I.E.E.—"Colour performance of the SECAM colour television system" by G. B. Townsend at 6.15 at Technical College.

29th. I.E.R.E.—"High-frequency induction and dielectric heating" by W. D. Wilkinson at 7.0 at the Technical College.

GLASGOW
1st. S.E.R.T.—"The principles of 625-line television reception" R. T. Frost at 7.15 at the McLellan Galleries, Sauchiehall Street.

8th. I.E.R.E.—"Electronic control systems in coal mining" by G. M. Rendall at 7.0 at the Institution of Engineers and Shipbuilders, 39 Elmbank Crescent.

12th. I.E.E.—"The maintenance of electronic equipment" by L. Tweeddale at 6.0 at the University of Strathclyde, George Street.

HATFIELD
20th. I.E.E.—"The impact of modern ionospheric research on communications" by G. Millington at 7.0 at Hatfield College of Technology.

HULL
8th. I.E.E.—"Stereophonic broadcasting systems" by Dr. G. J. Phillips at 6.30 at the Y.E.B. Offices.

LEICESTER
14th. I.E.R.E.—"Transistor amplifiers" by P. J. Baxandall at 6.30 at The University.

LIVERPOOL
12th. I.E.E.—"Some recent applications of semiconductors" by Dr. F. J. Hyde at 6.30 at the Royal Institution, Colquitt Street.

21st. I.E.R.E.—"Cold cathode tubes" by D. Reaney at 7.30 at Walker Art Gallery.

MANCHESTER
3rd. Institution of Electronics.—"The vanishing electron" by Dr. R. C. Jennison (president) at 6.0 at the Renold Building, College of Science and Technology, Altrincham Street.

NEWPORT, I.o.W.
2nd. I.E.E.—"Medical electronics" by W. J. Perkins at 6.30 at the Isle of Wight Technical College.

PETERBOROUGH
21st. I.E.E.—"Satellite communications" by D. Wray at 7.30 at the Angel Hotel.

PORTSMOUTH
21st. I.E.E.—"The roles of the engineer" by E. P. Fairburn at 6.30 at the College of Technology, Anglesea Road.

RUGBY
14th. I.E.E.—"Computers and engineers" by Dr. J. R. Mortlock at 6.30 at Rugby College of Engineering Technology.

SOUTHAMPTON
13th. I.E.E.—"Compatible stereophonic broadcasting" by A. R. V. Roberts at 6.30 at Lanchester Theatre, The University.

28th. I.E.E.—"Automatic flight recording" by K. G. Dobson at 6.30 at The University.