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Wireless World

Radiation at Very Low Frequencies

IN the present state of the art there are often times when the study and practice of radio may seem to be a hard grind. "Under the sun there's nothing new" and work consists of mastering known principles and taking advantage of improved materials to refine existing designs. But our subject is never dull for long. The field is wide, the labourers are many and new finds in old workings are constantly turning up to fire the imagination and shift the centres of interest. Hertz worked with centimetre waves, and electromagnetic waves at frequencies which would be audible if air were the propagating medium were widely used in the early days.

From these extremes of frequency interest tended later to converge to the intermediate values which gave greater bandwidth and traffic-handling capacity, lower capital cost for transmitters and greater running economy. In recent years the interest, as far as frequencies are concerned, has again become divergent; to centimetric waves for narrower beams and higher discrimination in radar, and to very long waves for special navigation and communication systems and for geophysical research.

In passing, it is of interest to recall the criticism which was levelled at the Post Office for continuing in their policy of building a high-power long-wave station at Rugby, when the new short-wave beam stations were showing every promise of making it obsolete. A similar situation is now arising between the fact of the Commonwealth telecommunications project and the promise of satellite communications.

Although the bulk of the world's communication traffic took to the new short-wave bypass, we have reason to be grateful, now more than ever before, that the Post Office, and authorities in other countries, did not allow the old low-frequency roads to fall into disrepair. The services of Rugby GBR (16kc/s) and Criggion GBZ (19.6kc/s) are much in demand all over the world not only for communication but for time and frequency comparison and, because of their wide dissemination and high stability, for navigational purposes. New stations, working on similar frequencies with powers of 1MW, have been built in the U.S. for communication with submarines.

At "extremely low" frequencies[1] there is world-wide interest and much international co-operation in the investigation of electromagnetic phenomena of terrestrial and extra-terrestrial origin. Lightning flashes produce transients with e.l.f. components of considerable magnitude, and correlation has been established with perturbations of the geomagnetic field. But by far the most interesting development in the e.l.f. and v.l.f. ranges has, in our opinion, been the investigation of "whistlers," which can be heard under favourable conditions and in high latitudes by connecting an aerial directly to the input of an audio amplifier. These have been shown to have their origin in lightning flashes and to owe their peculiar sound to the different rates of propagation with frequency of the components of the original pulse waveform in following the lines of force of the earth's field through a dispersive medium. This gave the first intimation, later confirmed by rocket exploration, of the existence of belts of ionized particles extending to heights of many earth radii.

While much new knowledge has been collected by patient observation and analysis of natural phenomena, more rapid progress would be made if controlled impulses and burst of radiation at specific frequencies could be launched, particularly from the polar regions. But the resources of conventional radio engineering find themselves hard pressed in trying to emulate lightning as far as power and radiator dimensions are concerned. Many ingenious suggestions have been put forward, for example, that v.l.f. signals might be superimposed on the electricity grid system. Unfortunately, grid systems are seldom to be found where the scientists want them. An experiment, reported on page 614 of this issue, makes use of a 10,000 ft. aerial wire suspended from a helicopter in what must surely be the biggest mobile-marine transmitting station ever devised. Even so, the aerial is no longer than that used at the Marconi transatlantic receiving station at Towyn in the early 1920s.

To our way of thinking, the most ingenious suggestion put forward so far is that due to M. G. Morgan[2], of the Thayer School of Engineering, Dartmouth College, Hanover, New Hampshire, U.S.A. This is to use the whole of Deception Island in the South Shetland Islands as a slot aerial, using the surrounding sea as the ground plane conductor. The island is the rim of a submerged volcano and has one gap leading to an inner lagoon. An expedition of the Falkland Islands Dependencies Survey is now on its way with equipment to check that the rock formation is a good enough insulator and to measure the impedance of the "slot," which has a calculated resonant frequency of 5kc/s. If the answers are favourable it is hoped to try to energize the "aerial" at points opposite to the lagoon entrance by current entering the sea on each side of the saddle, and thus to launch waves upwards into space.

We wish every success to this enterprise, which has shown that the older arts of radio are still as capable of stirring the pulse as those of its younger offspring, electronics.

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[1] Designated as the range from 1c/s to 3kc/s at the January 1960 Conference on Propagation of E.L.F. Electromagnetic Waves, Boulder, Colorado, U.S.A., and reported in the National Bureau of Standards Technical News Bulletin, Vol. 44, No. 5, May 1960.

[2] *I.R.E. Trans. on Antennas and Propagation*, Sept. 1960.

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Practical Aerial Measurements

By F. C. JUDD*

INVESTIGATING PERFORMANCE OF AERIALS BY MEANS OF SCALE MODELS

CALCULATING the radiating and/or pick-up properties of any aerial is a tedious process and does not take into account its environment once *in situ*. For this reason alone many engineers and organizations who specialize in aerials use scale models operated at very high frequencies for determining performance under working conditions. Practical experiments of this nature are fascinating to say the least, and may be carried out by anyone with a few simple items of equipment plus a little knowledge of basic principles of radiation.

The aerial "table" described in this article was constructed mainly for investigating the performance of aerials used for amateur radio transmitting and for live demonstrations during lectures.

For this article the reader is asked to assume that all reference to the performance of an aerial is in the radiating sense. The characteristics and performance of an aerial during reception are for all practical purposes reciprocal and identical. It is easier to think and talk in terms of radiation.

In general the object of the aerial designer is to produce standing waves on the radiating elements of an aerial so that radiation takes place in a known manner and where required. For example, resonance may be obtained with a quarter wavelength of wire if one end is on a theoretically infinite conducting sheet (e.g. copper) placed perpendicular to the wire. The reflection from the sheet then produces an image of the quarter-wave wire, as, say, a pencil standing on a mirror appears to be carried on into the mirror. The system resonates as freely as a half-wave length of wire but with halved radiation resistance.

The diagram of Fig. 1 shows how reflection from the earth takes place and how the angle of reflection is determined by either the height or the length of the aerial above ground. As the height or length is increased the relative phase angle between the direct and reflected wave will vary, thus modifying the strength of radiation in different directions.

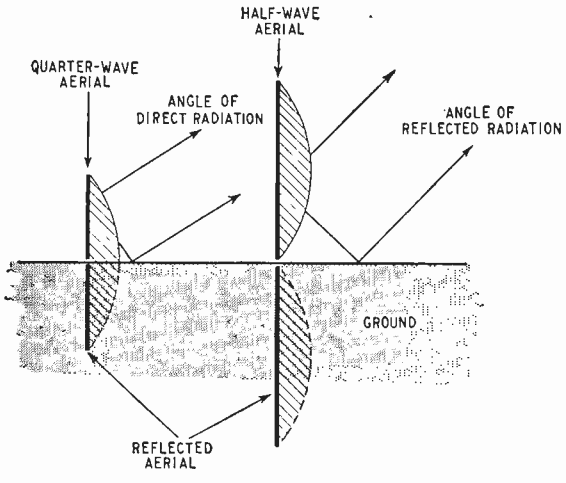

Fig. 1. Direct and reflected radiation from aerials adjacent to earth.

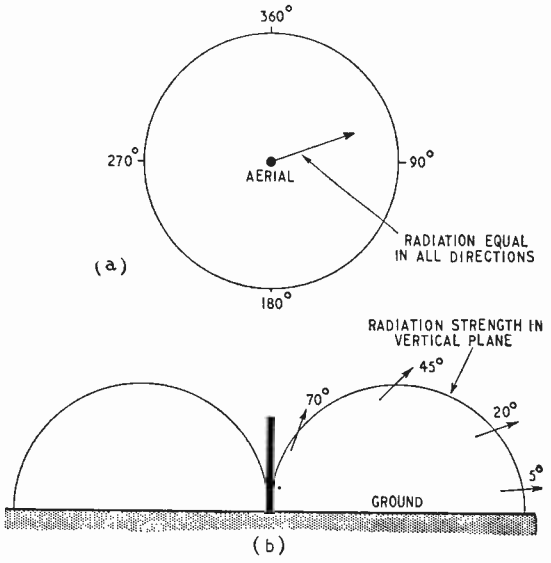

Fig. 2. Radiation field from vertical aerial; (a) in horizontal plane, (b) in vertical plane.

Radiation from any aerial system is determined by resonant length, or by the physical assembly of a number of radiating and/or reflecting and directing elements (beam aerials). For example, the radiation from a single vertical $\lambda/4$ radiating element is uniform for all directions around the aerial (horizontal plane). In the vertical plane the field strength varies as the angle from the ground increases, being maximum at ground level and zero in the true vertical direction as shown in Fig. 2.

In free space, clear of any conducting or semi-conducting obstacles, an aerial generally behaves according to accepted theories, but in the presence of other conductors and earth, the true radiation pattern may become very much modified. Since the height of an aerial above ground will never be very great (compared with an imaginery position in free space) the earth and its conductivity always play a great part in forming the actual radiation pattern. The term "earth" or "ground" applies also to aerials on aircraft since the body of an aircraft may be regarded as "earth" and usually has considerable effect on radiation.

The Theory of Similar Aerials.—The difficulties involved in plotting, other than the ground radiation

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field of aerials operating in the lower portion of the radio frequency spectrum, make it almost impracticable to attack the problem. It becomes necessary, therefore, to devise some other system, other than calculation, for investigating true radiation patterns. The use of scale models is not an entirely new idea, for the method was used before the war by the B.B.C. and others, although the scale reduction of the models was limited owing to lack of suitable sources of r.f. power for very high frequencies[1].

From a practical point of view a half-wavelength aerial resonant at say 10 centimetres (3,000Mc/s) would behave in the same way as an aerial of similar type operating at 10 metres (30Mc/s) or even at 100 metres (3Mc/s), provided all other conditions were maintained, i.e. height above ground, conductivity of ground, dielectric constants and/or conductivity of materials used for the manufacture of the aerial and the effects of surrounding objects. Most of these can be simulated in scale models and the results of small differences ignored, although at certain very high frequencies the construction of an accurate model does become more difficult.

The problem of suitable methods of feeding the aerial also arises and at frequencies above about 200Mc/s the radiation field, particularly from balanced aerials such as the dipole, may become asymmetrical owing to inaccurate matching of aerial to feed system. (Some asymmetry may be noticed in the dipole pattern of Fig. 9.)

The method does, however, provide a means of establishing the pattern of the radiation strength in both the vertical and horizontal planes, as well as the effect of surrounding buildings and similar structures. Measurement of gain in beam aerials may be carried out and the effect of physical modifications rapidly ascertained. Many commercial concerns use the scale model method for determining radiation patterns, etc., the U.S.A. Bureau of Standards for example have a "Model Antenna Testing Range"; many aircraft companies use scale model aerials in conjunction with model aircraft to the same scale[2, 3].

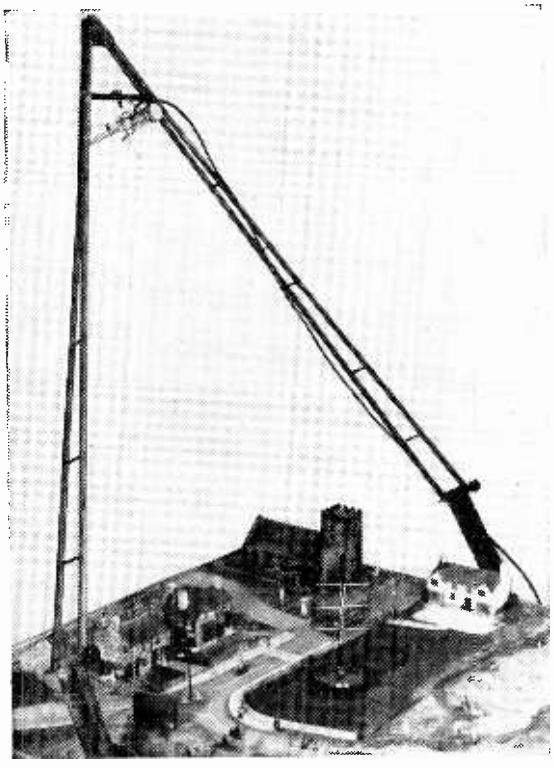

Fig. 3. The 3,000-Mc/s model aerial testing table (scale 4mm/ft) used by the author. The aerial shown in lower centre is a scaled-down 6-element, stacked array for a normal frequency of 30Mc/s.

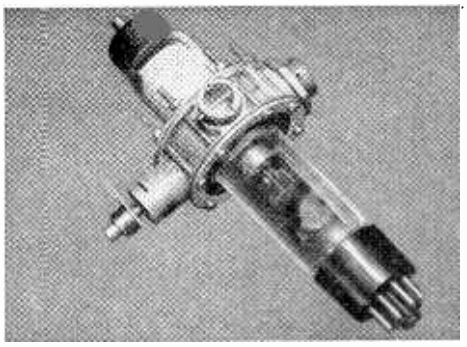

Fig. 4. Typical 3,000-Mc/s Klystron oscillator, the Type CV67.

Suitable Frequencies.—The writer's earliest experiments were carried out with an operating (model) frequency of 144Mc/s and many types of aerials commonly used for the radio amateur bands of 1.8, 3.5, 7 and 14Mc/s were scaled down for measurement of gain and radiation. More than 30 model aerials were constructed, most of the tests being carried out over normal earth. Attempts were later made to construct a "table" which could be used indoors but even at a frequency of 800Mc/s reflection from walls, etc., was found to be troublesome and imposed considerable restriction on accuracy.

A Practical 3,000-Mc/s Model Aerial Table.—To avoid inaccuracies due to unwanted reflection and to allow time for the complete formation of the electric field from a radiating aerial, the field strength meter and its aerial should be at least five wavelengths distant from a radiating aerial under test. The higher the frequency the shorter becomes the free space wavelength and at 3,000Mc/s it becomes possible to construct equipment suitable for indoor demonstration, as well as for reliable estimation of field patterns.

The aerial table shown in Fig. 3 was constructed in three sections to form a total area 4ft 6in square. Plywood, backed with thin aluminium sheet was used for this and forms an effective ground plane or artificial earth. The table contains a section of a typical residential area modelled at 4mm/ft and is constructed mainly from materials that simulate as near as possible those normally used for full-size structures.

Mounted directly under the centre of the table is a 3,000-Mc/s Klystron oscillator (CV67), complete with power supplies and modulator, which provides r.f. power for the model aerials, the r.f. output being taken to an aerial via a specially designed rotating coupling flush with the top of the table. The Klystron and its associated assembly can be turned through 360° by means of a slow-

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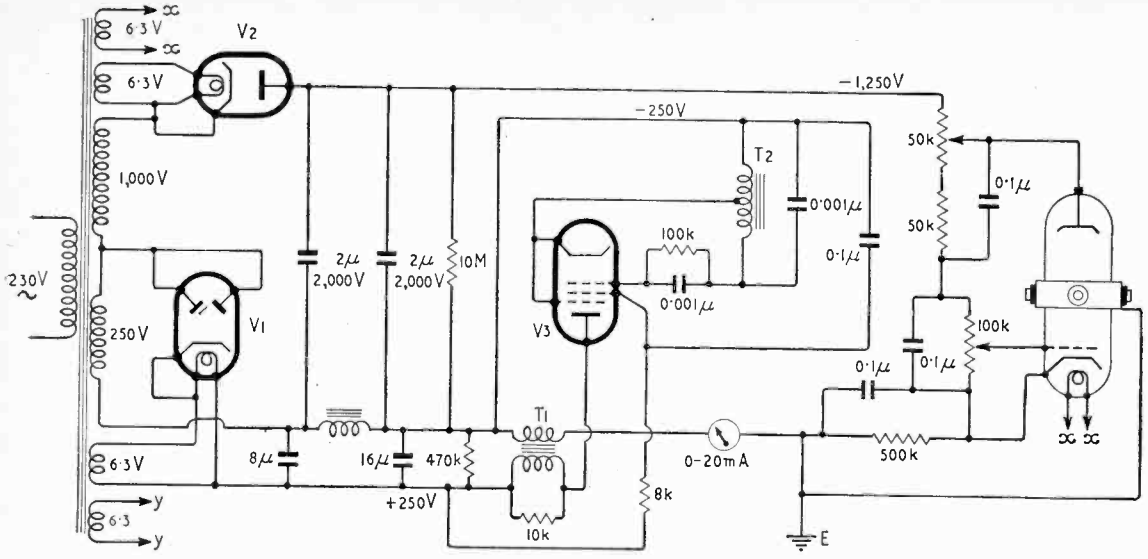

Fig. 5. Klystron oscillator, power supply and modulator used by the author. V1 = 250V rectifier; V2 = 1,250V rectifier; V3 = EF91; Klystron (see text); T1 = modulation transformer, ratio 1 to 1; T2 = tapped a.f. transformer.

motion drive and hand wheel located at the side of the table.

Klystron oscillators, such as the CV67 shown in the photograph of Fig. 4, may be obtained from Government surplus supply sources. Other Klystrons suitable for this work include the CV36 (2,850Mc/s), CV116 (3,540Mc/s), CV23 (3,300Mc/s) and the CV238 (3,050Mc/s). The latter two are low voltage types and require 250 volts between anode and cathode and 100 to 200 volts for grid bias and the target anode. The others operate with up to 1,500 volts on the target anode and take an average current of 5m/A. These Klystrons have fine and coarse tuning adjustment plugs fitted around the resonant cavity and provide an r.f. output of 100 to 150 milliwatts.

The Klystron oscillator and modulator circuit used by the writer is shown as Fig. 5. Component values may have to be modified slightly, although those given should be close enough to enable the circuit to function reasonably efficiently.

On either side of the table and on a line through the axis of the rotating coupling, two supports carry an inverted "V" frame. This is based on an arrangement used by the U.S.A. Bureau of Standards, which permits the field-strength meter and its associated receiving aerial, which are mounted at the apex of the frame, to move through an arc of 180°. This arc extends from ground level on one side of the aerial to ground level on the other.

The frame may be locked in any position so

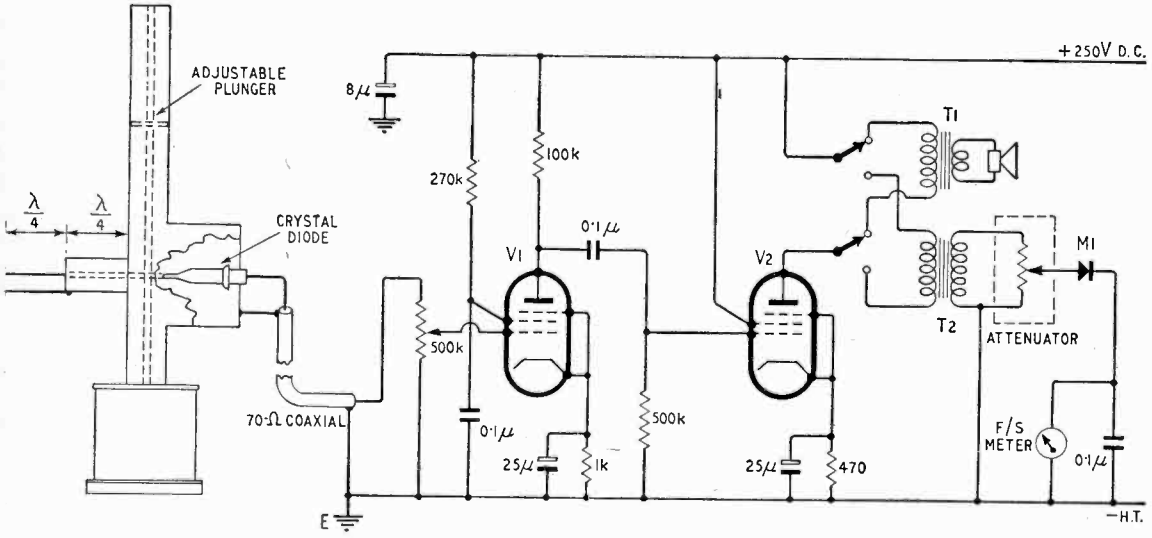

Fig. 6. Receiver and field-strength meter used for aerial measurements at 3,000Mc/s. V1 = EF91, V2 = EL91; T1 = loudspeaker transformer; T2 = 1 to 1 ratio a.f. transformer; M1 meter rectifier or diode.

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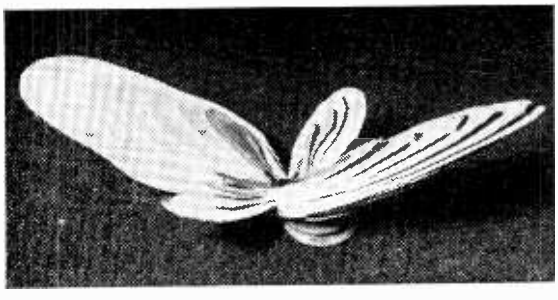
that a horizontal radiation pattern can be plotted for any vertical angle with respect to earth.

The Receiver and Field Strength Meter.—The 3,000-Mc/s receiver consists of a tunable resonant cavity and a crystal diode from which the demodulated signal is fed via an audio amplifier to a variable attenuator. Various surplus 3,000-Mc/s radar tuning units may be adapted for this purpose and used in conjunction with an amplifier circuit similar to that of Fig. 6. The audio signal level is indicated by a sensitive meter calibrated in 15 equal divisions, this being equivalent to the ruling of Chartwell Polar Co-ordinate paper, Sheet No. 4001. The attenuator is directly calibrated in decibels. The Klystron modulating signal is about 1,000c/s so that a loudspeaker may be connected in place of the meter for practical demonstration purposes.

As an alternative to the Klystron for a source of r.f. power there are many conventional valves that will oscillate at a 1,000Mc/s or more. If lower frequencies are used, however, the model aerials will be correspondingly larger but still suitable for open-air operations. Only a few milliwatts are needed to drive the aerials and ensure full-scale meter readings, so that radiation will be quickly absorbed and will not travel very far if experiments have to be made out of doors.

Plotting Radiation Patterns.—Clear surroundings are very necessary and the equipment should be carefully sited several wavelengths (at operating frequency) away from other conductors such as electrical wiring, metal window frames and pipes. Gain measurements may be made with respect to a "standard dipole," the radiated power from this being taken as a reference and regarded as 0dB. The importance of clear surroundings will be appreciated when attempts are made to simulate by means of models the conditions imposed by the presence of buildings and other structures. Two-dimensional "solid" patterns of a radiation field are more interesting than the conventional polar diagrams, especially for demonstration and from these a very clear conception of radiation directivity may be obtained. These two-dimensional shapes are produced by taking patterns from an aerial every few degrees in the vertical or horizontal plane, whichever is applicable, each pattern being drawn on thin cardboard, cut out and glued together in the correct order as shown by the example of Fig. 7. A selection of patterns taken from model aerials on the testing table described in this article are shown in Figs. 8, 9, 10 and 11. The model aerials are shown in the photograph of Fig. 12.

Fig 7. Solid radiation pattern of two vertical half-wave aerials spaced one wavelength apart and fed in phase.



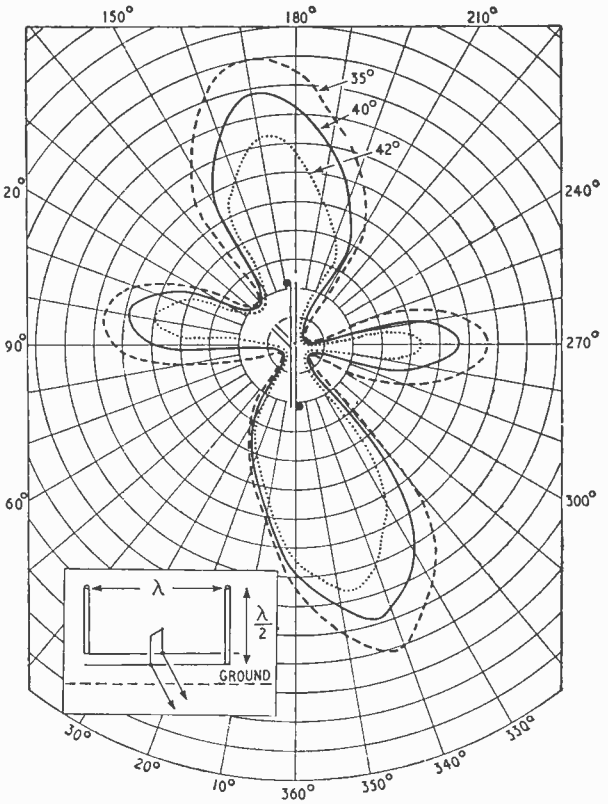


Fig. 8. Radiation patterns of two vertical half-wave aerials as described in Fig. 7 and measured at three different vertical angles.

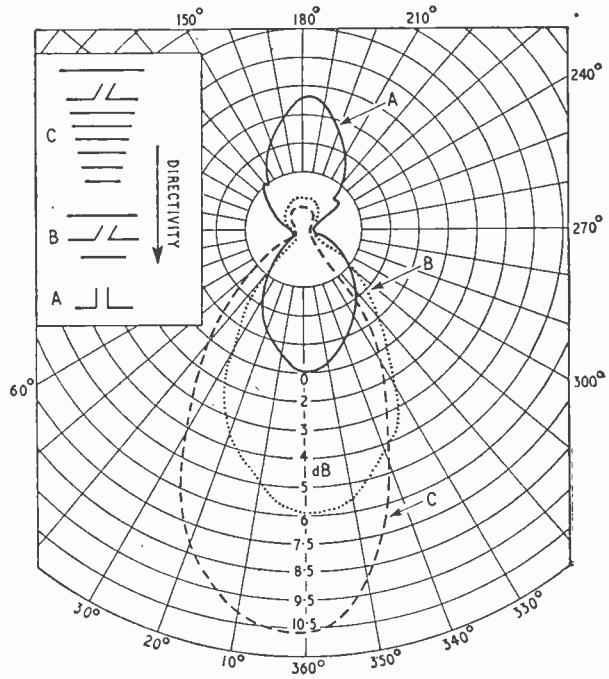


Fig. 9. Gains of 3- and 8-element Yagi aerials compared with a half-wave dipole measured at 3,000Mc/s.

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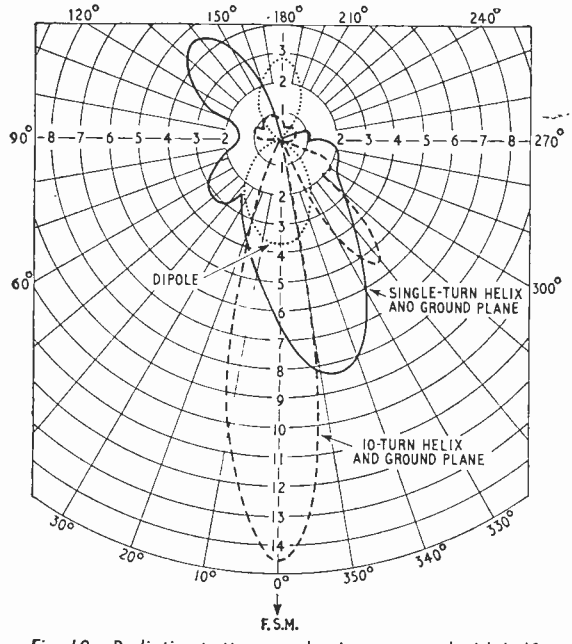

Fig. 10. Radiation patterns and gains compared with half-wave dipole of single-turn helix with ground plane and ten-turn helix with ground plane.

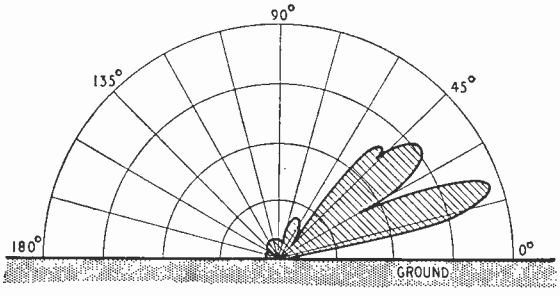

Fig. 11. Vertical radiation pattern of a scale model 2-element "Quad" aerial.

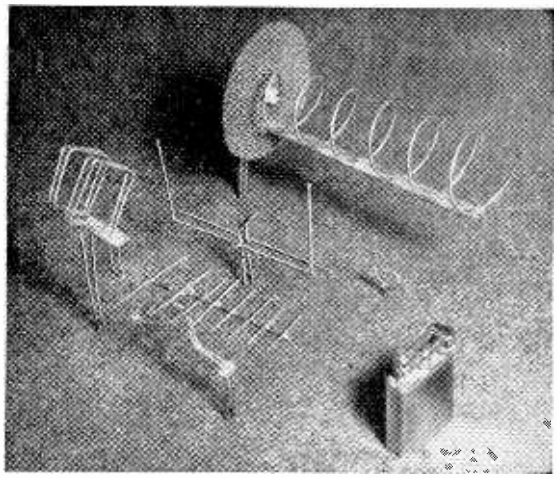

Fig. 12. Some of the scale model aerials used for the measurements described in the text.

Models provide a unique system for testing and estimating the performance of aerials for all the lower radio frequencies up to at least 30Mc/s and offer an excellent method of demonstration during lectures. The writer has used over 100 different models and several aerials suitable for amateur radio transmitting have been developed with the aid of the testing table. Using scale models, a number of enlightening experiments were recently carried out to determine the radiating properties of "loaded aerials" suitable for mobile operation on the 1.8- and 3.5-Mc/s amateur radio bands and for certain applications at frequencies around 30Mc/s.

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[2] G. H. Brown and R. King. "High Frequency Models in Antenna Investigation." *Proc.I.R.E.*—April, 1934.

[3] F. Charman, B.E.M. "High Frequency Model Aerials," *Proc.R.S.G.B.*—Spring, 1949.

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R. D. Rhodes, *Electronics*—March/49.

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BOOKS RECEIVED

The Radio Amateur's Handbook, 1960 edition, compiled by the American Radio Relay League, West Hartford, Connecticut, U.S.A. First published in 1926 and now widely recognized as the standard manual of amateur radio communication. Chapters devoted to construction of equipment have been extensively revised to include the latest s.s.b. and radio-teleprinter techniques for amateur use. Several chapters are devoted to basic principles clearly explained. Pp. 584 plus 32 pp. of tabulated data on valves and semiconductors with over 1,300 illustrations. Obtainable from leading technical booksellers, also from Radio Society of Great Britain, New Ruskin House, Little Russell Street, London, W.C.1; price 32s 6d (34s by post).

Mullard Reference Manual of Transistor Circuits. More than 60 circuits of audio amplifiers (including p.a.), hearing aids, simple radio receivers, oscillators, switching circuits, stabilized power supplies, etc., with component values, coil winding data and constructional hints. Prepared by the staffs of Mullard Research Laboratories, Applications Research Laboratory and Semiconductor Measurement and Application Laboratory. There are nine introductory chapters on transistor characteristics, equivalent circuits, bias and stabilization and limiting values. Pp. 308; Figs. 241. Mullard, Ltd., Torrington Place, London, W.C.1. Price 12s 6d (13s 6d by post).

British Semiconductor Guide—1960. Characteristics of 963 semiconductor devices including transistors, diodes and rectifiers and photosensitive devices, with introductory articles on considerations determining the use of valves and transistors, and on transistor parameters and specifications. Pp. 66. Heywood & Co., Ltd., Drury House, Russell Street, London, W.C.2.

Einführung in die Microwellen-Electronik. Teil II Lauffeld-röhren by Drs. Kerner Kleen and Klaus Pöschl. Mathematical treatise on the principles and operation of travelling-wave tubes in general and special types, including backward-wave oscillators and amplifiers. Pp. 192; Figs. 125. S. Hirzel Verlag, Birkenwaldstrasse 185, Stuttgart N.

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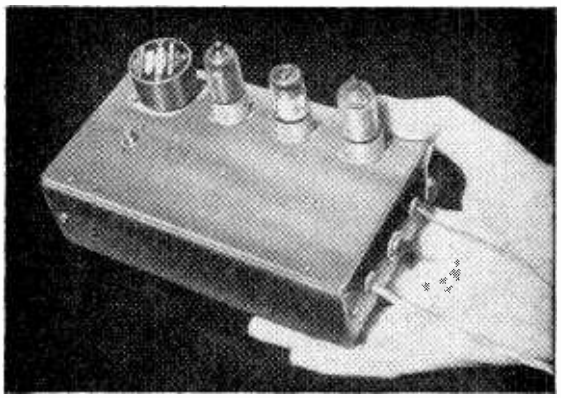
100-kc/s Crystal Marker

EMBODYING A NEON MODULATOR FOR HARMONIC RECOGNITION

By F. G. RAYER*



The completed crystal marker showing the top plate screwed to the chassis box.

THE use of a 100 kc/s crystal marker, to provide frequency checking harmonics at 100 kc/s intervals, is quite well known. Such a marker is most often employed in conjunction with a communications-type receiver to give exact calibration, or check points at 100-kc/s intervals. Amateur transmitters can employ a marker of this kind to locate the band edges, or for calibrating or adjusting a transmitter VFO. When used with a reasonably accurately calibrated receiver, this method is an acceptable one for frequency determination with amateur transmitting equipment.

The usual simple type of crystal marker has the disadvantage that it is not always possible to distinguish its signal from other signals, especially when tuning to higher harmonics. Even with the receiver aerial removed, other carriers are heard on the crowded short wave bands, so that the crystal marker's signal cannot always be located immediately and without possibility of error. To avoid this, the circuit shown in Fig. 1 is provided with a neon "modulator." This strikes two or three times a second, pulsing the 6BA6 control grid negative, so that the marker signal can always be identified at once. Such a "modulator" does not produce sidebands which would confuse tuning. In addition, the 6BA6 acts as an harmonic amplifier, so that the marker can be used up to about 30Mc/s.

The crystal oscillator stage consists of a 6AM6, with a 100-pF pre-set capacitor for frequency adjustment. The degree of adjustment is quite small, but it allows the crystal frequency to be checked against the B.B.C. 200kc/s Light Programme, or the National Physical Laboratory standard frequency transmissions on 2.5Mc/s, 5Mc/s, and 10Mc/s. Other valves, such as the CV138 or EF91, etc., may be used in this stage. The type of neon is of little importance, provided it will operate with about 150V to 250V. Various other valves could also be utilized instead of the 6BA6.

The unit illustrated was built into a universal chassis 4in × 7in × 2in, with back plate, obtainable from Home Radio (Mitcham) Ltd. The layout employed is shown in Fig. 2. To simplify work the

*Amateur Radio Station G3OGR.

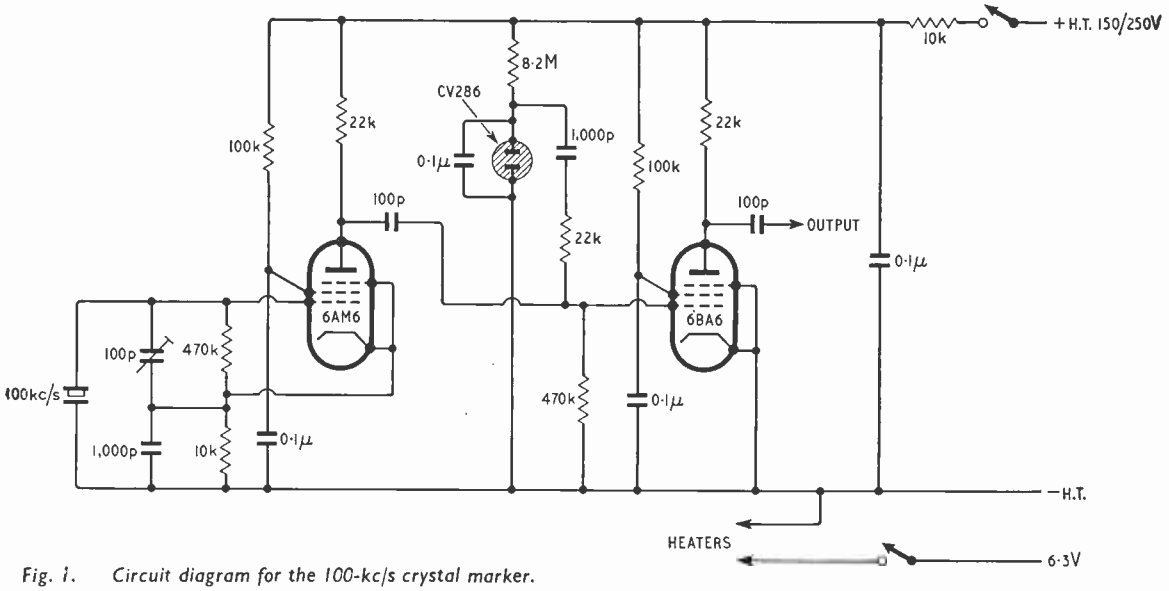


Fig. 1. Circuit diagram for the 100-kc/s crystal marker.

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marker was built on the 4in×7in back plate and when completed it was fitted on to the chassis box. For lining up with other equipment it was most convenient to have the heater switch, supply leads, and output at one end of the chassis box. If the marker is connected to its supply only when used, no switch is required, but if it is permanently connected, the h.t. circuit has to be switched, as in Fig. 1, to stop the neon striking.

It is essential that the 100-pF pre-set capacitor is isolated from the chassis. It is also necessary that the 0.1-μF capacitor, in parallel with the neon, should be without appreciable internal leakage, or the neon will not strike. For the same reason the associated 1,000-pF capacitor should be a mica type.

The crystal connections shown in Fig. 2 are for a Quartz Crystal Co's. octal-based Q5/100 crystal unit. This has so low a temperature coefficient that for normal purposes no temperature control is needed, and the crystal stage of the marker is a modified Colpitts intended for use with this crystal. With the component values given, the accuracy of the marker would usually be sufficient even without checking the frequency against the B.B.C. or MSF (Rugby) transmissions.

Power for the unit can often be drawn from the receiver; if not current may be available from a small power pack, or from some other item of equipment. Coupling between the marker and receiver will be sufficient, for lower frequencies, if the marker output lead is placed near the receiver aerial terminal. For the high harmonics, the output lead is connected directly to the receiver.

To check against the B.B.C. or MSF transmissions, tune in the signal, and adjust the marker coupling to the receiver so that its signal is of similar strength to that of the station. In some parts of the country this may mean that no aerial, or a very short length of wire, will suffice. The receiver BFO should not be used, and if the MSF transmissions are chosen they should be at those periods (of the hour) when no modulation is present.

When the 100-pF capacitor is far from its correct setting, the difference in frequency between the crystal marker and the station transmission will be audible as a low pitched flutter. As the capacitor

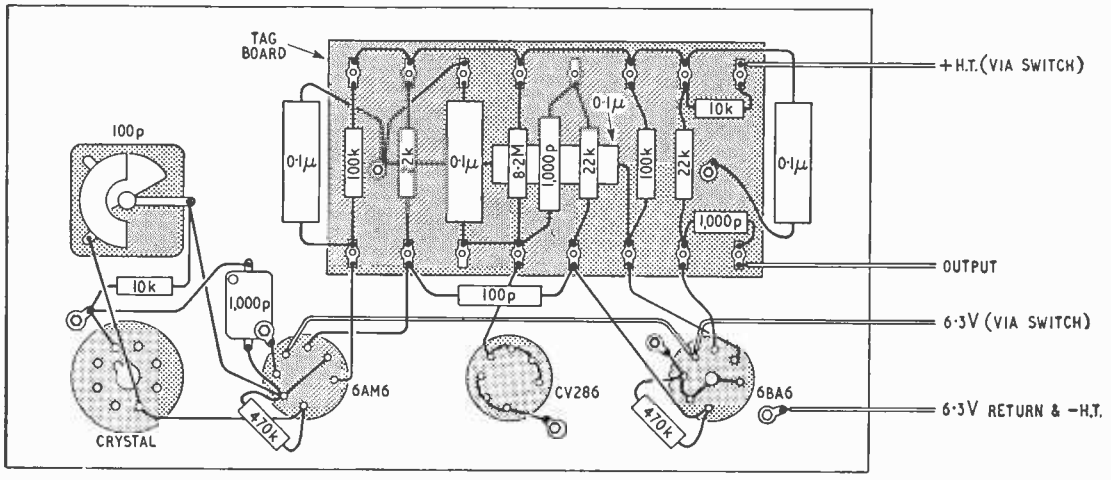
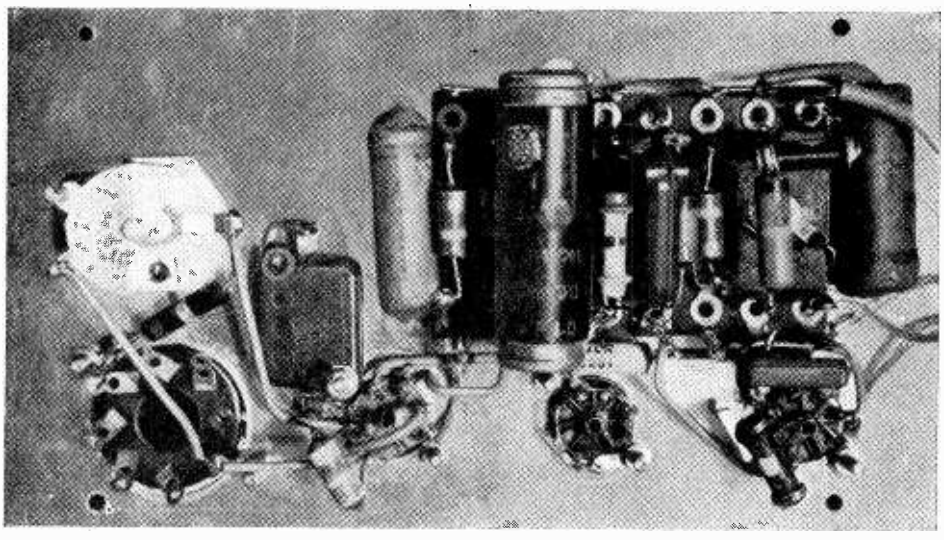


Fig. 2. Layout of components and wiring on the underside of the "top" plate of the chassis box.



This underside view of the top plate should be studied in conjunction with Fig. 2 for identification of the components.

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is adjusted towards correct capacity, the rapidity of flutter will decrease. If a tuning meter or indicator is fitted to the receiver, this will rise and fall as the marker and station signals fall in and out of step, and the best setting for the capacitor can easily be located. The B.B.C. 200-kc/s transmissions are easily received in many areas, frequency is maintained to a very high order of accuracy, and adjusting the marker against this frequency is particularly simple.

For checking receiver calibration, the receiver BFO should be switched on, and the aerial removed. The gain controls will need to be quite low for harmonics such as those used to mark the edges of the 1.8Mc/s to 2Mc/s or 3.5Mc/s to 3.8Mc/s bands. For higher harmonics, such as are required to indicate the edges of the 28Mc/s to 30Mc/s band, the receiver gain controls will need to be near maximum.

For signal generator or VFO calibration or adjusting, the BFO should be off, so that the generator or VFO signal can beat with the crystal marker's signal.

Amateurs' National Convention

VARIED R.S.G.B. PROGRAMME AT CAMBRIDGE

THE fourth post-war National Convention of the Radio Society of Great Britain—held at Cambridge from September 15th-17th and attended by some 200 members and guests—was notable for the very full programme of technical lectures and discussions, in addition to visits to places of technical interest and those social functions which are traditional at amateur radio conventions.

The links between radio amateurs and radio astronomers have always been close; indeed the first steerable radio telescope was built by an American amateur and a British amateur played an important rôle in establishing the radiation of radio signals by the sun. The Cambridge convention fittingly included talks by Prof. Martin Ryle (who holds the call G3CY) and Dr. F. G. Smith, of the Mullard Radio Astronomy Observatory. The programme also included visits to the Observatory to see the unique development of aperture synthesis and EDSAC II, the University's computer on which the observations are analysed. One of the radio telescopes now records signals automatically in digital numbers for feeding direct to EDSAC.

Prof. Ryle described the two main aerial arrays which would be capable of detecting a one milliwatt transmitter on the moon and which in June identified radio sources 4,500,000,000 light-years distant—the world's one-way DX record! Present investigations are concentrated on 38 and 178 Mc/s, though work is also being carried out on 81.5 and 408 Mc/s. By aperture synthesis, the 3,200ft, 38 Mc/s fixed array used in conjunction with the relatively small moving section gives results equivalent to a paraboloidal reflector of 1,500ft diameter.

The low-noise maser, parametric amplifier and electron beam amplifier are not exactly standard amateur practice yet (though some interesting work on parametric amplifiers has been carried out by amateurs in the United States and also, on a more limited scale, in this country) but A. H. W. Beck and Dr. F. G. Smith graphically summarised recent research in these developing fields. The Adler tube, with its remarkable ability to separate signal from noise and then to lose the noise, appears particularly promising in view of its relative simplicity of adjustment, wide bandwidth and 25dB or so gain to 3,000 Mc/s—if only prices fall to suit amateur pockets. At the other end of the radio spectrum, Dr. B. H. Briggs, of the Cavendish Laboratory (formerly G2FJD) described investigations into the strange phenomena of the "whistling atmospherics."

The rapidly increasing interest in single-sideband transmission ensured a lively audience for a survey of modern amateur practice by G. C. Bagley (G3FHL)—one of the few British amateurs who can already claim more than ten years' experience of this type of operation. Another topic attracting increasing attention stems from the results now being achieved by members of the British Amateur Radio Teleprinting Group which sprung into being after the first British amateur teleprinter contacts were made last year in the 3.5 Mc/s band.

A most effective demonstration of the present advanced state of amateur television transmission in the U.K.—which appears to lead the world in this specialized branch of amateur radio—was presented by members of the British Amateur Television Club. Two 27in receivers displayed the 405-line transmissions from G3NOX/T at Duddenhoe End, some 15 miles from Cambridge. This station, one of an active network of stations reaching well down into Essex, transmits on 436.3 Mc/s with an e.r.p. of 5.7 kW.

The pictures were of impressively high standard; so incidentally was the programme technique displayed by the team of operators who had pooled resources to provide three camera chains. Transmissions from this group of stations are made regularly on Saturday evenings and can be received over distances of up to about 30 miles on standard television receivers fitted with 70-cm converters. At the end of the demonstration, viewers at Cambridge were able to question the operator (I. M. Waters, G3KKD) at the television transmitter via a duplex radio link on 70cm and 2 metres.

Throughout the Convention transmissions were made on amateur bands from 1.8 Mc/s to 144 Mc/s under the special call-sign GB2CAM.

The convention was rounded off by a dinner at the Guildhall with guests including the Mayor of Cambridge, who had assisted the event in many ways, Dr. F. G. Smith, Brigadier E. J. H. Moppett and Major-General E. S. Cole, now Director of Telecommunications at the War Office, but formerly better known to amateurs as G2EC, SU1EC and SV1EC. General Cole spoke of the effective work of the R.S.G.B. in preserving amateur frequency allocations and of the value of radio communication in encouraging international friendships.—J. P. H.

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INTERKAMA

1960

DUSSELDORF EXHIBITION OF AUTOMATION AND INSTRUMENTS

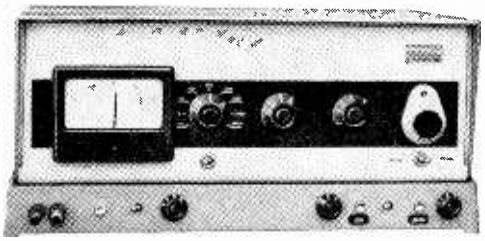
OCCUPYING thirteen exhibition halls of various sizes having a total floor area of nearly 10 acres, the Interkama exhibition and congress was held from 19 to 26 October. 470 exhibitors, 188 from countries other than Germany, displayed equipment for test, measurement, process control, data logging and the myriad other functions required by industry today. There were sections devoted to French, East German and British firms (this latter arranged by S.I.M.A.), but these were not the only displays because many "foreigners" showed their products on the stands of their German agents, or had stands of their own elsewhere in the exhibition.

Industrial Control and Automation

The simplest type of control system uses a man, who makes adjustments by reference to a continuous-reading instrument, as part of a servo loop. The next step is, naturally, the closing of the loop without the man, so that automatic control is achieved. A practical illustration of a closed-loop control system was given by Eckhardt, with a liquid-flow meter and control valve. The sensor uses the Faraday effect of the generation of a potential on a conductor moving in a magnetic field: an electromagnet energized from the mains creates a field across the pipe carrying the liquid. Two electrodes pick out the potential generated by the flow, and this potential is "bucked" or backed off by a servo-driven potentiometer whose motor is energized, via amplifiers, by the difference of potential between the potentiometer and electrodes.

For quality control of a product the recording of the many parameters of a plant must be carried out constantly. The registering, collating and working out of results from these readings can, in a complex plant, consume much time and effort, but this "watchdog" facility can be provided by a central data-processing machine, for instance, the Beckman "123" system. This can accept up to 100 electrical inputs representing plant parameters, scanning each one by a stepping switch in 60sec, processing each input as selected by the position of plugs in a peg board—a zero offset might be required for one input, say, whilst another channel may require a logarithmic amplifier characteristic. The measurements taken can be written out on an electric typewriter or punched-tape system at preset intervals or on demand, and a digital electrical output is available.

"Automation" of processes using small closed loops can have the disadvantage of inflexibility when, say, a chemical process using raw materials of variable quality or where fairly frequent changes in output are required. Each control loop must be reset to a new value each time a change is required, and all the possible combinations must have been worked out beforehand. With more than a very small number of variables it can be seen that the amount of work required could be uneconomical. However, the necessary flexibility can be achieved by opening the individual closed loops and interposing a "communal" computer. Then, by giving the computer the reaction equation and data on raw material purity and price changes the programme can be set to operate the plant automatically for maximum profit.



Macq Electronique drift meter for stabilized power supplies

A system of this type using a Ramo-Wooldridge RW 300 computer to control the manufacture of dodecylbenzene was illustrated on part of the French stand by the Compagnie Européenne d'Automatisme Electronique.

Another point noticed was the widespread use of small-package solid-state logic (such as "and," "or," "not") and instrumentation (timers, amplifiers, etc.) units. There would seem to be a good case here for the various manufacturers to standardise practical details such as mounting, connections and power supplies so that a Siemens "Simatic," say, is directly interchangeable with an Ateliers des Constructions Electronique de Charleroi "Logacec," a Telefunken "Logistat," or a Mullard "Norbit" or "Combi-element."

Instruments

A major feature of the exhibition was the display of instruments for test and measurement, as distinct from automatic control, in the laboratory or the production line. A complete floor of one exhibition hall was divided into "classrooms" in which 56 instrument manufac-

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turers gave 249 courses of instruction on their products.

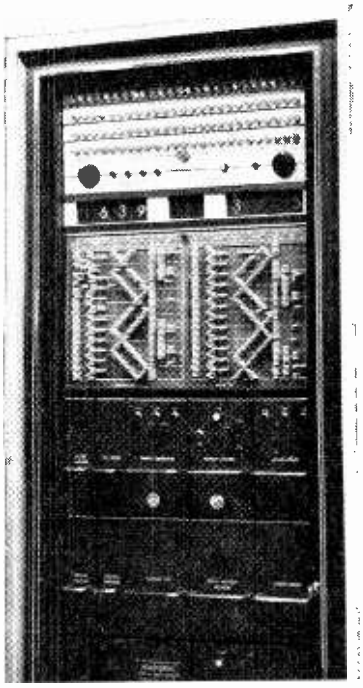
The Wandel and Goltermann WZL-181 test set is designed for the testing of transformer windings. Basically the instrument itself consists of a bridge which can be preset to check coil resistance, turns ratio, etc., a "good" coil returning a zero or "in balance" reading. In the case of unbalance an indication of direction, i.e., high or low, is given. The coil undergoing test is placed in a test jig and connected up; a standard coil induces power, and the tests (including a phase-reverse facility in case the leads have been reversed on connection) can be carried out by the use of push buttons on the jig.

On the General Radio stand small variable delay lines were found. These, having maximum delays of 0.5 and 1μsec are made rather after the fashion of a wire-wound potentiometer, but the winding is skewed on the former to enable a greater length of wire to be in close proximity to a "screen" which forms the capacitive element of the line. This type of variable line is used in the GR 1392A delay generator which can be used for measurements of time intervals as short as 1/100μsec. Another instrument seen here was a transfer-function and immittance (impedance and admittance) bridge for the range 25 to 1500Mc/s, enabling measurements to be made on two, three and "four" (one input and one output earthed) terminal networks. Two calibrated indicator heads are supplied with this bridge, one for each use, and these have small rotatable loops as variable coupling elements to the lines connected to the network under test. The loops are energized from an external generator and a null detector is connected to the junction of the output from the network, a known susceptance and a known conductance. By adjustment of the couplings from the generator to the network input and the resistive and reactive arms, a null can be achieved, when the parameters of the tested object can be read from the calibrated scales of the indicator heads.

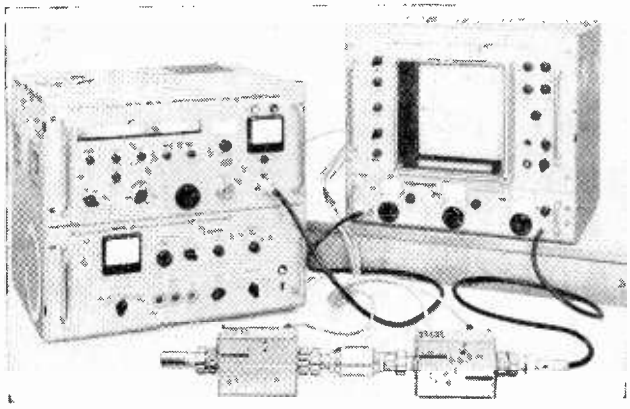
For the testing of many circuits frequency-sweep techniques have immense advantages but until the Carcinotron*, whose frequency can be varied widely electrically, was produced by the C.S.F. the widest sweep available in the s.h.f. bands was somewhat limited. Several manufacturers have produced swept signal generators using Carcinotrons, notably Ferisol (Geffroy et Cie). A generator making its debut at the exhibition was the Rhode and Schwarz Type ZWC. This has a choice of plug-in Carcinotron modules covering the range 1 to 18 Gc/s in (roughly) octave sweeps and constant output is achieved by sampling the signal at a directional coupler at the entry to the test piece so that any anomolous effects due to the cable or waveguide coupling and the three "marker-producing" wavemeters are neutralized. These wavemeters are mounted below the display unit for ease of use, and the display itself offers double-trace working on a 20-cm ($\approx 7\frac{3}{4}$-in) square cathode-ray tube.

The short-term drift, or random variations, of a stabilized power supply are usually so small that they are insignificant. However, if it is desired to know what is happening to one's "stable" supply, the difficulty of measurement has to be overcome. Macq Electronique had on display a drift-meter for this purpose; accepting inputs in the range 1V to 2.5kV, a resistive network is used to drop the applied potential to that of a standard Weston cell contained within the instrument. A mechancial chopper switches between the cell and applied potential, and the resulting a.c. is amplified, detected and applied to a centre-zero meter. The sensitivity of the amplifier can be adjusted so that variations of 1/100,000 or 1/10,000 of the input produce half-scale deflection; also sense (i.e., fall or rise) is indicated.

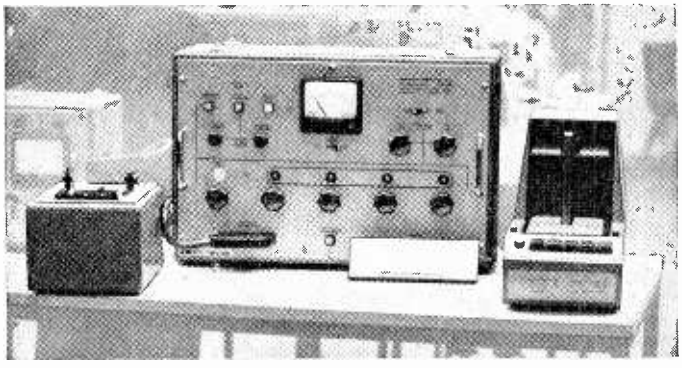
*P.476, *Wireless World*, November 1959.



Beckman Instruments "123" data-logging system. "Peg board" is used for setting up.



Swept signal generator using Carcinotron (Rhode u. Schwarz).



Wandel u. Golterman transformer test set showing the test jigs.

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WORLD OF WIRELESS

Commonwealth Telecoms

WITHIN the 62 pages of the 9th General Report of the Commonwealth Telecommunications Board, covering 1959, are reports on the activities in each of the eight partner countries which have nationalized telecommunications systems. The report as a whole is concerned mainly with traffic statistics but there are also some interesting items covering research and developments.

In this country experimental tropospheric scatter transmissions from a transmitter near Bodmin, Cornwall, to receivers near Leafield, Oxon (173 miles) and at West Beckham, Norfolk (300 miles) continued with the aim of obtaining a year's cycle of measurements for analysis of fading characteristics. The tests have included comparisons between multi-channel telephony with f.m. and narrow-band s.s.b. with a.m. and also television with f.m. Tropospheric scatter transmissions from Holland to West Beckham (150 miles) are also being conducted.

The C.T.B., of which Sir Ben Barnett is chairman, consists of a representative from each of the partner governments. Its primary function is the formulation of joint telecommunications policies.

For C.A.R.A.C. read C.C.E.C.A.

WHAT was originally known as the Civil Aviation Radio Advisory Committee has been renamed the Consultative Committee on Electronics for Civil Aviation. Broadly its terms of reference are to provide a forum for discussing U.K. policy in the field of electronics for civil aviation in relation to industrial research and development.

The representatives of the Electronic Engineering Association on the committee are Dr. B. J. O'Kane (Marconi's), K. E. Harris (Cossor) and Air Comdre. C. A. Bell (G.E.C.). The Ministry of Aviation, Admiralty, Air Ministry, B.O.A.C., B.E.A., Post Office, Society of British Aircraft Constructors and the British Independent Air Transport Association are also represented.

Student Exchange

SINCE the scheme for the international exchange of students for technical experience was introduced in 1947, over 52,000 students have participated. During the past year 6,430 took advantage of the scheme, which is operated by 24 countries. The 1960 report of the International Association for the Exchange of Students for Technical Experience records that Germany received the largest number of students (1,195) and also sent abroad the largest number (1,105), with the U.K. second, receiving 909 and sending 883.

The report issued by the U.K. branch shows the distribution by country of the students sent from and received in this country and also by the subjects which they were studying. About 20% (178) of U.K. students went to Sweden, from which the largest number of students (171) came to this country. The address of the London office is 178 Queen's Gate, S.W.7.

B.B.C. Plans

CONTRACTS have recently been placed by the B.B.C. for the building of a number of low-power transmitters to extend and improve its television and v.h.f. sound services. Combined stations are to be erected at Oxford, Llandrindod Wells (Radnor) and Redruth (Cornwall) and a TV station at Manningtree (Essex). Also the site has been chosen for a combined station near Galashiels (Selkirk).

Approval in principle has been given by the P.M.G. for a low-power station near Ballachulish (Argyll). This station is additional to those originally planned for Western Scotland. A point-to-point link was originally to be installed for this part of the route feeding two new stations. It has been decided, however, to build a small auxiliary station which will serve the dual purpose of linking the two stations and providing direct television reception for the people in the area.

Technical Writing

AUTHORS of technical articles on British electronic developments, published during 1960, who wish to compete for the six premiums of 25 guineas each awarded by the E.E.A. and R.I.C., must submit their entries by December 31st. They should be sent to the Electronic Engineering Association, 11 Green Street, London, W.1, and should consist of a copy of the journal* and the relevant pages, proof or reprint. Entries must be accompanied by a signed declaration of eligibility, showing that the entrant is not paid a salary solely for writing and not earning 25% or more of his income from articles or book royalties.

* *Wireless World* is sent by arrangement to each of the judges

Receiver Despatches.—Figures issued by B.R.E.M.A. show that manufacturers' despatches of television receivers during the first nine months of this year were 30% below the same period last year (1,257,000 compared with 1,787,000). Domestic sound receivers and car radio despatches during the same period rose by 23% (1,346,000 against 1,091,000). Radiogramophones, too, rose from 114,000 to 130,000.

Recording Studios.—The revised topographical list of members of the Association of Professional Recording Studios shows that the Association now has a membership of nearly 100 "private professional studios" in this country. It operates a scheme under licence from the Mechanical-Copyright Protection Society, permitting its members to make recordings for private customers of works controlled by the M.P.S.

CHRISTMAS PRESENTS

Why not give your technical friends a copy of the *Wireless World* Diary as a Christmas present? It has an 80-page reference section and costs 6s 9d (leather) or 4s 9d (Rexine). Friends who seem quite incapable of adjusting correctly the controls of their television sets might appreciate a copy of "Improve Your Television Reception" (5s) or "Correcting Television Picture Faults" (4s).

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Satellite Communications.—Technical discussions between American and British officials on matters associated with the possible use of communications systems *via* earth satellites are being held in the U.S.A. The U.K. team is headed by Major General L. de M. Thuillier, of the Cabinet Office, and includes Captain C. F. Booth, W. J. Bray, H. Leigh and F. J. D. Taylor, of the Post Office; J. R. U. Page, of the Office of the Minister for Science; F. E. J. Girling, A. G. Earl and C. Williams (Ministry of Aviation); F. A. Kitchen (Admiralty) and Group Captain A. Foden and C. F. Sutton (Ministry of Defence).

B.C.A.C.—When the British Conference on Automation and Computation, which is a consortium of associations and institutes interested in the field of computation, was formed in 1957 it was divided into three autonomous groups. One dealt with engineering, another control and the third sociological interests. It has now been decided to reconstitute the association with a central council. There are now about 30 societies in the reconstituted B.C.A.C. of which Sir Walter Puckey is chairman with L. T. Blakeman, J. F. Coales and H. G. Conway as vice-chairmen. The honorary secretary is W. K. Brasher, secretary of the I.E.E. which is providing secretarial services.

Local Broadcasting.—A detailed survey of their plans for 100 or more local broadcasting stations in this country has been issued as a 13-page brochure by Pye Ltd. Comparisons are drawn with the situation in the U.S.A. where extensive use is made during daylight of common medium-frequencies by a large number of stations with geographical spacing of 90 miles or less.

Fleming Memorial Lecture of the Television Society will be given by Professor D. M. MacKay on January 26th at the Royal Institution, Albemarle Street, London, W.1. His subject will be "Behind the Eye". Admission is by ticket obtainable from the society, 166 Shaftesbury Avenue, London, W.C.2. Dr. MacKay was recently appointed to the research chair in communication founded by Granada Television at the University College of North Staffordshire.

MARY E. CHAMBERS, of the E.M.I. Research Laboratories, is the first woman to be awarded the Dip.Tech. with first class honours. She has taken a four-year sandwich course at the Brunel College of Technology and E.M.I., where she has been concerned with the preparation of photo-conductors for television camera tubes and phosphors for c.r. tubes.

Publication date.—Owing to the Christmas Holidays our January issue will not be published until December 31st.

The National Radio Show, 1961, will be held at Earls Court from August 23rd to September 2nd with a preview for overseas and invited guests on August 22nd. This, the 28th National Radio Exhibition, will again be organized by Radio Industry Exhibitions Ltd., 59 Russell Square, London, W.C.1.

Aeronautical Electrics and Electronics.—A joint committee, with Professor G. A. Whitfield, of the College of Aeronautics, Cranfield, as chairman, was recently formed by the I.E.E. and the Royal Aeronautical Society to consider ways and means of stimulating discussion of problems of common interest. As a result, joint meetings of the two organizations are to be held in London and plans are being made for the formation of joint groups in the provinces. At the inaugural meeting in London on November 11th, Viscount Caldecote spoke on the future of "electrics" and "electronics" in aircraft and guided missiles.

Transducers.—The Electronic Engineering Association is seeking the help of manufacturers and users in compiling a list of transducers. It is collating information not only on current types but also on those under development. Those interested in helping the association in compiling this list, which will be available to non-members, are invited to send for the questionnaire obtainable from J. F. Richardson, Technical Secretary, E.E.A., 11 Green Street, London, W.1.

Gramophone records produced during the third quarter of the year totalled just over 16M, about 5% more than in the corresponding period last year. There were 59% fewer 78 r.p.m. records produced (688,000 compared with 1,691,000) and 2% fewer 33⅓ r.p.m. discs (3,488,000 against 3,546,000) but 18% more 45's and medium-play (11,860,000 against 10,092,000).

Vacation Courses.—"Introduction to Industry" training courses are again available at the Chippenham Works of Westinghouse Brake and Signal Co. Ltd., for boys who are taking G.C.E. "A" level scientific subjects. Two courses are arranged during the Christmas vacation, January 2nd to 6th, and 9th to 13th. Applications should be made before December 1st.

Engineering aspects of the plastics industry will be covered by a new monthly journal, *International Plastics Engineering*, to be published in association with *British Plastics*. The first issue will appear on February 1st.

INDUSTRIAL GROUPS—3

E.M.I.—Since going to press with the section of this issue in which the third of our series of surveys of industrial groups appears (p. 611), E.M.I. has supplied additional information which brings the total number of companies within the group to nearly 80. The additional companies are:—

E.M.I. (Australia) and its subsidiaries, Television Patents, Marconiphone Co., E.M.I. Finance Corp., Hayes Properties, and Castle Music; the following subsidiaries of Capitol Records Inc.: Ardmore Music Corp., Beechwood Music Corp., Capitol Record Club Inc., Capitol Records Distributing Corp., Capitol Records International Corp., Capitol Publications Inc., Electric & Musical Industries (U.S.), Electric & Musical Industries (Canada), Capitol Records of Canada, Ardmore & Beechwood (U.K.), and Capitol Royal Club of Canada; Edition Accord, Kristall Schallplatten, and Odeon Musikhaus, subsidiaries of Carl Lindstroem; and these ten additional subsidiaries of Morphy-Richards, Morphy-Richards (Cray), Morphy-Richards (Australia), Morphy-Richards (Canada), Morphy-Richards, S. Africa, Morphy-Richards Inc., U.S.A., Morphy-Richards (Nederland), M-R Salgsorganisation A/S, Denmark, Eureka Electric, Astral Equipment, and Yelsen.

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Personalities

Major-General E. S. Cole, C.B., C.B.E., has accepted the invitation to become president of the Radio Society of Great Britain for 1961. He has been a member of the society for nearly thirty years and is well known among amateurs by his call G2EC. General Cole was commissioned in the Royal Signals in 1925 and from 1941 to 1946 was Corps Chief Signal Officer. In 1952 he became Chief Signal Officer, Headquarters, Southern Command, and in 1954 was appointed Deputy Chief Signal Officer, Signals Division, S.H.A.P.E. Since 1958 he has been Director of Telecommunications, War Office. General Cole was at one time chairman of the British Joint Communications Board.

Maj. Gen. E. S. Cole

J. K. Laughton

J. K. Laughton, who joined Plessey's Telecommunications Division in 1958 as sales engineer, has been appointed manager of that division. He went to Plessey after 20 years' service in the Royal Navy. He was promoted to Commander in 1954 and was for the last year of his naval career Assistant Director of Radio Equipment (Communications) in the Admiralty.

J. H. H. Merriman, O.B.E., M.Sc., A.Inst.P., M.I.E.E., was recently appointed staff engineer of the Overseas Radio Planning and Provision Branch of the Post Office. For the past four years he has been seconded to the Treasury as the assistant secretary responsible for computer work and policy in all Government Departments. A physics graduate of King's College, London, where he later worked under Professor Appleton on non-linear oscillators for his M.Sc. degree, he joined the Research Station staff at Dollis Hill in 1936. He was closely associated with the development of MUSA—the steerable aerial system.

N. T. Atkinson, formerly head of television development in Ekco, has been appointed to the post of chief of television and radio development. He has been concerned with the development of Ekco television receivers since 1938 and in his new position he will be directly responsible to **A. J. Brunker,** executive director and chief engineer. **E. W. Maynard,** who has been in charge of export television development, succeeds Mr. Atkinson as head of television development.

Dr. J. L. Pawsey, F.R.S., assistant chief of the Division of Radiophysics of the Commonwealth Scientific and Industrial Research Organization, Australia, has been awarded the Hughes Medal of the Royal Society for his distinguished contributions to radio astronomy both in the study of solar and of cosmic radio emission.

Terence B. Tomlinson, Ph.D., B.Sc., A.M.I.E.E., A.M.Brit.I.R.E., joined Southern Instruments earlier this year as chief engineer. He is responsible for design and development for the newly formed company, Drayton-Southern, Ltd. After graduating from London University he became a laboratory demonstrator in electronics at the Cavendish Laboratory, Cambridge. He spent two years with Sobell Industries, returning to the university to take a higher degree—his research being concerned with low-frequency fluctuations of emission from oxide-coated cathodes. Dr. Tomlinson subsequently became a lecturer in electronics at Southampton University, where he stayed for six years before joining the G.E.C. Research Laboratories for work on solid-state physics. He transferred to the G.E.C./I.C.T. subsidiary, Computer Developments, Ltd., where he stayed until joining Southern Instruments.

Dudley Saward, O.B.E., who joined Texas Instruments Ltd. on its formation in 1956, has resigned from the managing directorship in order to devote more time to other activities, but will remain a director of the company. Mr. Saward was chief radar officer, Bomber Command, from 1942 to 1945 and was for some time after the war controller of navigation and telecommunications with British European Airways. He is succeeded as managing director by **A. N. Provost,** a former U.S. naval officer and an engineering graduate of Tufts and New York Universities. Mr. Provost was for some time with Sylvania Electric Products before joining the semiconductor components division of Texas Instruments, Inc., in Dallas, U.S.A.

J. D. Dale-Lace, A.M.I.E.E., D.F.H., the new sales manager of the radio components and special products department of A.E.I.'s Radio and Electronic Components Division, was a technical officer in the Royal Navy from 1940 until 1946 when he joined Pye, where he worked on the development of television transmission equipment. A year later he went to South Africa as technical representative of Sperry's South African agents. He rejoined Pye in 1951 as a telecommunications sales engineer, and since 1956 has been with de Havilland Propellers as guided weapons service manager at Hatfield.

J. D. Dale-Lace

T. J. Murphy

T. J. Murphy, A.M.I.E.E., A.M.Brit.I.R.E., of the engineering division of Radio Eireann, has been given the City and Guilds Insignia Award in Technology (C.G.I.A.) for "his competence in the field of electrical industries (broadcasting—sound and television) and in respect of a thesis on the design of modern sound broadcasting studios." Mr. Murphy had been three years in Pye's final test department before joining the Engineering Division of the B.B.C. in 1943. He left the Corporation in 1951 to join Radio Eireann, Dublin, and for the past five years has been in charge of the studio department of the engineering division.

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Colonel H. A. Lewis, O.B.E., T.D., B.Sc.(Eng.), M.I.E.E., A.C.G.I., has relinquished his appointment as managing director of E.M.I. Sales and Service, Ltd., to become managing director of Newmark (London) Distributors, Ltd., precision instrument manufacturers, of Great Portland Street, London, W.1. Col. Lewis has been with E.M.I. since 1956. For the previous six years he was in the Broadcasting Division of Marconi's. From 1933 to 1948, except for the war years when he was in R.E.M.E., Col. Lewis was in the Engineering Division of the B.B.C.

F. W. Perks, sales director of British Radio Corporation Ltd., is retiring. His career in the radio industry extends from 1914 when he joined Marconi's W/T Co. Freddie Perks, as he is affectionately known in the industry, has held many important appointments including the chairmanship of B.R.E.M.A. and B.R.V.M.A. and is at present chairman of Radio Industry Exhibitions Ltd. (organizers of the National Radio Exhibition) and president of the Radio Industries Club. He is succeeded as B.R.C. sales director by **T. B. (Jock) Henderson,** general sales manager of Philco (Great Britain) Ltd., an associate company.

P. A. M. Curry, M.A., B.Sc., has been appointed deputy to **H. St. A. Malleson,** head of Mullard's Government and Industrial Valve Division. After graduating with a first in engineering science at Oxford, Mr. Curry studied for a research degree and was awarded a Henry Fellowship providing a two-year course at Harvard where he obtained the degree of Master of Business Administration.

L. **J. M. Knotts** has joined Mullard Equipment Ltd. as technical adviser on the application of electronics to railway signalling and communication systems. He was formerly signal engineer to the Scottish Region of British Railways.

F. S. Barton, C.B.E., M.A., B.Sc., M.I.E.E., who, as announced in October, has retired from the Civil Service, has joined the board of Painton & Co., Ltd., of Northampton.

Keith Lockyer, B.Sc., A.M.I.E.E., A.M.Brit.I.R.E., has been appointed general manager of Donvin Instruments Ltd., and Dumar Optics Ltd., the instrument, camera and tape recorder repair firms which are part of the R. B. Pullin group.

Dr. T. W. Straker is deputy manager of Marconi's Radar Division and not manager as was inadvertently announced in our last issue. The manager of the division is **E. N. Elford,** O.B.E., A.M.I.E.E.

H. M. Palmer has retired from Marconi International Marine after nearly 50 years' service. He has been in charge of the company's Fleetwood service depot for the past 25 years. He is succeeded by **J. E. Dallaston** who joined the company in 1931 as a sea-going radio officer, as did Mr. Palmer.

G. H. W. Johnson, Assoc.Brit.I.R.E., for the past three years marine director of Marconi (South Africa) Ltd., has relinquished his seat on the board and has joined Norsk Marconikompani A/S in a similar capacity. Mr. Johnson joined the Marconi organization as a radio officer in 1938.

G. A. Dwyer, manager of the Marconi Marine Co.'s Bombay depot from 1952 to 1954, has been appointed the company's representative in India and Ceylon. He joined Marconi's sea-going staff in 1929. In 1941 he was appointed to the shore technical staff at Glasgow and three years later was seconded to the Naval base at Ardrossan.

Angela M. Lane has been appointed administrative secretary of the Television Society. She joined the secretariat of the Society in 1955 and has been assistant secretary for some time. **Geoffrey Parr,** the honorary secretary of the Society since 1945, who recently entered hospital for heart trouble, is now convalescing.

OUR AUTHORS

G. W. H. Larkby, author of the article describing a remotely controlled TV camera designed by the B.B.C., has been with the Corporation since 1936, except for the war period when he served with the R.A.F. in 60 Group (Radar). On his return to the B.B.C., Mr. Larkby was attached to the outside broadcast department of the Television Service. He later transferred to the Designs Department where he has been chiefly concerned with the many complex electro-mechanical and optical problems in the television field.

J. W. Bunn, joint author of the article on ceramic permanent magnets, is powder metallurgist with Swift Levick and Sons, with whom he has been associated for 13 years. In 1954 he gained the associateship in metallurgy from the University of Sheffield where he had undertaken part-time study. He is a licentiate of the Institute of Metallurgists. **J. Harrison,** his co-author, is magnet design engineer with Swift Levick. He was previously assistant metallurgist at the central research laboratory of the Permanent Magnet Association.

F. C. Judd, contributor of the article on aerial measurements, is a free-lance technical writer. Until making writing his full-time occupation, he was in the radar research laboratory of Kelvin & Hughes.

OBITUARY

Dr. G. W. O. Howe, Emeritus Professor of Electrical Engineering of Glasgow University, died on November 7th, aged 84. Professor Howe was successively technical editor of and consultant to our sister journal *Wireless Engineer* (now *Electronic Technology*) for over 30 years. In 1956 he was awarded the Faraday Medal of the I.E.E. for "his pioneering work in the study and analysis of high-frequency oscillations and on the theory of radio propagation; and for his outstanding contributions to engineering education." Dr. Howe, who was apprenticed to Siemens at Woolwich, went to Imperial College as a lecturer in 1905 and in 1921 was appointed James Watt Professor of Electrical Engineering at Glasgow University, the position he held until his retirement in 1946 when he was appointed an Emeritus Professor. Dr. Howe was a great teacher and his editorials in *Wireless Engineer* over very many years were an outstanding contribution to electrical and radio theory. In recognition of "his contributions to the advancement of radio science and in particular for his long series of notable editorial articles in *Wireless Engineer*", he was, in 1956, elected an honorary member of the Brit.I.R.E.

Professor Bernard Hague, D.Sc., Ph.D., F.C.G.I., D.I.C., M.I.E.E., who had occupied the James Watt Chair of Electrical Engineering at Glasgow University since 1946, has died aged 67. His academic career began in 1920 when he became a lecturer at the City and Guilds College, prior to which he was for four years at R.A.E., Farnborough. Dr. Hague was a lecturer at Glasgow University from 1923 until 1929 when he went to the Brooklyn Polytechnic Institute, N.Y. He returned to Glasgow as senior lecturer in 1930.

Reginald Lawler, manager of the Electronics Division of Ferguson Radio Corporation, which he joined in 1938 as a radio development engineer, died on November 2nd, aged 59. He was at one time in charge of the company's factory at Hirwaun, Glamorganshire, but returned to Enfield in 1952.

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News from Industry

Pye-Ekco Merger.—The boards of Pye Ltd. and E. K. Cole Ltd. have recommended to their shareholders a merger of the two companies through a holding company, as yet unnamed. C. O. Stanley would be chairman and E. K. Cole deputy chairman. Pye will have a 75% holding in the new company and Ekco 25%. Their combined assets are nearly £25M.

Plessey-Garrard.—Agreement has been reached in principle under which the Plessey Company would acquire all the issued share capital of the Garrard Engineering and Manufacturing Co. If the offer is accepted Garrard will continue as a separate entity under its own board of directors with Hector V. Slade as managing director.

Cossor.—Major-General Sir Miles Graham, who succeeded the Marquess of Exeter as chairman of A. C. Cossor Ltd. last March, reported at the annual general meeting that for the year 1959/60 the group trading profit was £127,699, compared with £534,260 the previous year. There was, however, a net loss of £97,977. The group includes Cossor Radar & Electronics, Sterling Cable Co., Cossor Communications, Cossor Instruments, Lea Bridge Cabinet Works and Best Products.

Baird.—Radio Rentals Ltd. have entered into an agreement to purchase Baird Television Ltd., and will market television and sound receivers bearing the name "Baird." All the company's sets are made in Bradford by its Bradford manufacturing subsidiary, Mains Radio Gramophones, and will in future carry the new trade name.

BMEWS.—R.C.A. Great Britain Ltd., the U.K. associate of the Radio Corporation of America, is "weapon system contractor" for the Fylingdales, Yorks., base for the American ballistic missile early warning system. It is estimated that the cost of the whole Fylingdales project will be $115M. Work has already begun on this, the third site for the BMEWS chain (see *Wireless World*, July, 1960, p. 335).

Eimac.—In association with the development of new Eimac klystron valves for high-power radar and communications, Eitel-McCullough are building a "superpower" supply unit drawing 12 amps at 282kV (approximately 3MW). Agents for Eimac products in the U.K. are Walmore Electronics Ltd., Phœnix House, 19/23 Oxford Street, London, W.1.

Trav-ler Tape Recorder.—This transistor battery/mains portable tape recorder introduced at the National Radio Show by Casian Ltd., is being produced by Aerialite Ltd., of Hargreaves Works, Congleton, Cheshire, who have acquired the manufacturing and distributing rights.

Balzers High Vacuum Ltd. has been formed, with offices at 1 Mornington Terrace, Regent's Park, London, N.W.1, to handle in this country the products of Balzers A.G., of Liechtenstein, including equipment for high-vacuum metallurgy and coating, vacuum pumping gear and measuring instruments.

Grundig.—To mark the sale of the 100,000th Grundig TK20 tape recorder in the U.K., G. S. Taylor, managing director, presented the 100,001st model to the Royal National Institute for the Blind at a recent ceremony in London. It is understood that it has already been assigned to the Chorley Wood College for Girls.

Air-to-Ground Telemetry.—A consortium of five British manufacturers has been formed on the recommendation of the Ministry of Aviation to exploit the overseas and U.K. markets for a major air-to-ground multi-channel telemetry system. This has been developed by the member companies in collaboration with the Royal Aircraft Establishment, Farnborough. The members are: Elliot Brothers (London) Ltd., McMichael Radio Ltd., Rank Cintel Ltd., Southern Instruments (Contracts) Ltd., and W. S. Electronics Ltd., who have been appointed to act on behalf of the consortium.

Thermionic Products (Electronics) Ltd., of Hythe, Southampton, have ceased manufacturing domestic tape recorders and dictating machines. A limited supply of spares will be available until the end of next year. The company is concentrating on the production of multi-channel recorders for airport communications logging and other fields of data logging.

Marconi's have received a further order valued at over £93,000 for the supply of translators, amplifiers and associated equipment for the B.B.C. The equipment will be used in the first stage of the Corporation's programme for the extension of its television and v.h.f. sound services by satellite stations.

Vactric (Precision Tools) Ltd., and Vactric (Control Equipment) Ltd., subsidiary companies of Vactric Ltd., which was recently put in the hands of a receiver, are continuing to operate as separate entities.

Texas Instruments France, with headquarters in Nice, has been set up by the Dallas company to manufacture semiconductor devices and components for the European Common Market.

EXPORTS

I.L.S.—Through their Canadian associates, Pye Telecommunications Ltd. have received a contract from the Royal Canadian Air Force for the supply of an instrument landing system for installation at the R.C.A.F. Airfield, Trenton, Ontario. This is said to be the first installation of British I.L.S. in the western hemisphere.

Montreal's two new commercial television stations are to be equipped by Marconi's with duplicate 18-kW vision and 9-kW sound transmitters. Each station will transmit a bilingual service (English and French).

Broadcasting Transmitters.—British Sarozal, of 22 Berners Street, London, W.1, have recently supplied a number of short-wave and medium-wave broadcasting transmitters to Africa. They include a 5-kW transmitter for Radio Pax, in Beira, Mozambique, which will radiate on 3.952 and 7.205Mc/s and another for Praia, Cape Verde Islands, for operation on 3.960Mc/s.

Communications Equipment.—Racal, of Bracknell, Berks., have received through their agents, Instronics Ltd., of Stittsville, Ontario, three major orders for communications equipment from the Canadian Department of Defence Production. They have a total value of £560,000.

Multi-lingual Catalogue.—Alfred Imhof Ltd., of 112/116 New Oxford Street, London, W.C.1, have produced an international version of their catalogue of racks, cases, consoles and accessories, every item being described in ten languages (English, French, German, Spanish, Italian, Portuguese, Dutch, Swedish, Norwegian and Danish).

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Ceram'c Permanent Magnets

By J. W. BUNN*, A.Met., L.I.M., and J. HARRISON*

A relatively recent addition to the range of magnetic materials is the barium ferrite ceramic permanent magnet[1]. This material, commercially available under a variety of trade names, e.g. Feroba, Magnadur, Caslox, Indox, Oxit, etc., is basically an oxide compound having the formula $BaFe_{12}O_{19}$. It is non-metallic and, in common with other ceramics, is hard, brittle, a non-conductor, and relatively light in weight when compared with alloy magnets. These properties together with its unique magnetic characteristics have opened up a new field in magnet applications.

Barium ferrite, although of similar appearance to the more commonly known "soft" magnetic

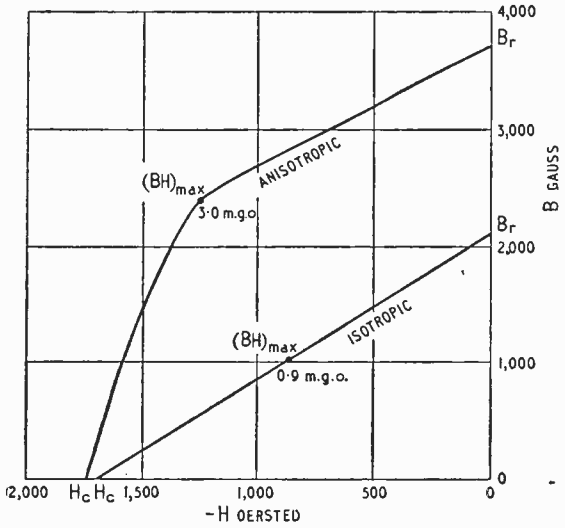

Fig. 1. Demagnetization curves for barium ferrite.

core materials, is distinct from this class inasmuch as magnetically soft materials are characterized by high permeability and low losses when used in an a.c. circuit, whereas barium ferrite is a magnetically hard material possessing a high coercivity, remanence and energy product $(BH)_{max}$. The compound $BaFe_{12}O_{19}$ has a hexagonal crystal structure with one axis of easy magnetization parallel to the hexagonal axis. This uniaxial crystal anisotropy together with a small crystal size (approximately 1 micron) is largely responsible for the high coercivity of this material compared with a "soft" magnetic ferrite which has a cubic crystal structure, i.e. three easy directions of magnetization, resulting in low coercivity.

Magnetic Properties.—An essential feature of a permanent magnet is its ability to withstand demagnetization, and this is directly related to the coercivity of the material. Barium ferrite has an exceptionally high coercivity of the order of 1600 oersted, compared with 600-650 oersted for Alcomax alloys, which is responsible for its ability to withstand high demagnetization effects such as a.c. fields, repulsion by other magnets, and excessive mishandling. Its high coercivity coupled with low permeability makes it possible to use ceramic magnets to minimize magnetic leakage fields of magnetic circuits and so increase the overall efficiency of the assembly.

Of the two further properties, remanence B_r and energy product $(BH)_{max}$ the former is a measure of the magnetization remaining in a material when the applied field is reduced to zero, and the latter is the maximum product of B × H on the demagnetization curve, shown in Fig. 1.

The low saturation magnetization[2] of barium ferrite leads to comparatively low B_r and $(BH)_{max}$, typical values for the isotropic variety being shown in Table 1.

Additional properties of permanent magnets which are sometimes required are the incremental or reversible permeability, and the maximum useful recoil energy[3]. In isotropic barium ferrite these values are 1.2 and 0.7 m.g.o. (mega gauss-oersted) respectively, from which it is seen that the recoil

TABLE 1

PROPERTIES OF BARIUM FERRITE COMPARED WITH ALCOMAX III

	Isotropic $BaFe_{12}O_{19}$	Anisotropic $BaFe_{12}O_{19}$	Alcomax III
Remanence B_r (gauss) ..	2100	3700	12,800
Coercivity H_c (oersted) ..	1700	1750	675
Maximum energy product $(BH)_{max}$(m.g.o.)	0.9	3.0	5.5
B_w at $(BH)_{max}$(gauss)	1000	2400	10,200
H_w at $(BH)_{max}$(oersted)	900	1250	540
Recoil permeability	1.25	1.15	3.5
Maximum useful recoil energy (m.g.o.) ..	0.7	1.0	1.5
Temperature coefficient of magnetization (%/°C) ..	−0.2	−0.19	−0.02
Curie temperature (°C) ..	450	450	860
Resistivity (ohm-cm)	1×10^6	1×10^6	55×10^{-6}
Density (gm/cc)	4.8	5.0	7.35
Magnetizing field for saturation (oersted) ..	10,000	8,000	3,000

*Swift, Levick & Sons, Ltd.

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energy is 47% of that of Alcomax III alloy magnet material, whereas the total energy $(BH)_{max}$ is only 18% of that of Alcomax III. In view of the comparatively low cost of barium ferrite a definite economic advantage is gained by using this material under recoil conditions. Other features of the recoil properties are dealt with in the section on design and applications.

The Curie point of this material, i.e. the temperature at which for practical purposes the material ceases to be magnetic, is 450°C, so that all traces of magnetism can be removed by heating to above this temperature. For barium ferrite, this is the best method of demagnetizing, but this method cannot be used for normal alloy magnet materials.

A serious disadvantage of barium ferrite is its high temperature coefficient of magnetization which

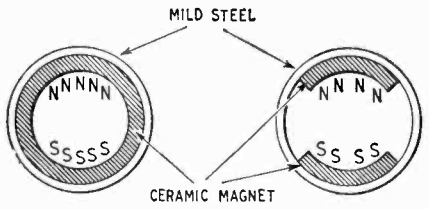

Fig. 2. Isotropic ceramic magnets for d.c. motor stators. Continuous cylinder (left) segments (right).

at $-0.2\%/°C$ is some ten times greater than that of normal alloy magnets. This excludes the use of barium ferrite for, say, measuring instruments, unless elaborate temperature compensating devices are included.

The resistivity of barium ferrite is of the order of 10^6 ohm-cm, and this is of great importance in h.f. applications.

A density of 4.8 gm/cc is usual, which can be advantageous where weight considerations are paramount.

In 1952, Rathenau and others[4] found that by aligning the crystallites of this material when in powder form by means of a strong magnetic field, an anisotropic effect was observed in the direction of the aligning field. Following this, intensive work by different workers[5] in various parts of the world has led to the anisotropic variety which has a higher remanence and a $(BH)_{max}$ some three times greater than isotropic barium ferrite.

At the time of writing, only the isotropic form is commercially available in large quantities in this country. Table 1 gives typical properties of both isotropic and anisotropic barium ferrite, together with the more commonly known alloy material Alcomax III. Demagnetization curves for both varieties of barium ferrite are shown in Fig. 1.

Manufacture.—The basic ingredients are iron oxide Fe_2O_3 and barium carbonate $BaCO_3$ which are mixed in the correct proportions and then heated in air at 1000°C approximately to form the required compound $BaFe_{12}O_{19}$. This is followed by ball-milling to a very small particle size, after which a binder is added and the powder pressed to the required shape by normal powder metallurgy techniques. The compacts so formed are then fired by heating to approximately 1200°C in an oxidizing atmosphere. The density of the fired compact is about 90% of its solid density, and volume shrinkage occurs, the final compact being approximately five-eighths by volume of the pressed compact.

The anisotropic differs mainly from the above isotropic variety in that the ball-milled powder is magnetically aligned in the required direction during the pressing process. This alignment is achieved by applying a high magnetic field to the powder, which can be either dry or in the form of a slurry, whilst the powder is in the die. To obtain precise dimensions, the finished magnet may be ground, but normal drilling and machining methods are impracticable due to the brittle nature of the ceramic material.

After mechanical inspection and magnetic testing for quality, final magnetizing is carried out, when a force of 7000 ampere-turns per centimetre length of material must be applied to achieve saturation.

Design.—In the design of permanent magnets or magnetic circuits incorporating permanent magnets, the aim is to produce the required performance in the most economical manner. In other words, the most efficient use of the magnetic material must be obtained.

Reference has already been made to the demagnetization curve and the three properties B_r, H_c, and $(BH)_{max}$ of a magnetic material, and these are the main features of the material used by the design engineer.

In the majority of permanent magnet applications it is desired to achieve a given magnetic field strength within the confines of a finite gap. In a gap of length l_g and area a_g, where H_g is the field required in the gap,

$$H_g l_g k = H_w L_m \quad \ldots\ldots\ldots\ldots (1)$$

where L_m = length of magnet material
H_w = demagnetizing force
k = reluctance factor.

The demagnetizing force H_w is the value at the particular operating point selected for the design on the demagnetization curve, and k is a factor to allow for the total reluctance of the magnetic circuit and usually has a value of between 1.1 and 1.3.

If B_w is the simultaneous induction value at point H_w on the demagnetization curve, then the total flux required in the gap is:—

$$H_g a_g K = B_w A_m \quad \ldots\ldots\ldots\ldots (2)$$

where A_m = magnet cross-sectional area
K = leakage factor

Combining (1) and (2) we have:—

$$V_m = \frac{H_g^2 v_g K k}{B_w H_w} \quad \ldots\ldots\ldots\ldots (3)$$

where V_m = volume of magnet material
v_g = gap volume

from which it is seen that the minimum volume of magnet material required to produce a given gap energy is obtained when the product $B_w H_w$ is a maximum. Hence it follows that the most efficient design will be obtained when the magnet geometry is constructed so that the point $B_w H_w$ coincides with the $(BH)_{max}$ point of the particular magnet material used in the design. For isotropic barium ferrite operating at $(BH)_{max}$ the value of B_w is 1000 gauss and H_w is 900 oersted.

The above holds for all designs and magnet materials used, but in the use of ceramic barium ferrite the high value of H_w makes practical much shorter lengths than is normal for other materials,

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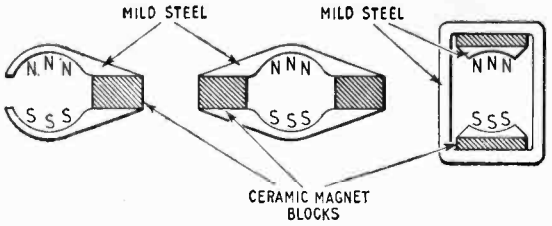

Fig. 3. Three typical methods of using anisotropic ceramic magnets as d.c. motor stators.

although greater magnet areas are required due to the lower value of B_w.

Dynamic Applications — Generators and Motors.—Despite the low value of B_w, the high coercivity of barium ferrite makes it greatly superior to other commercial permanent magnet materials in its ability to reproduce substantially the same flux after being subjected to adverse conditions. Demagnetizing fields of the order of the coercive force of the material may be applied and, upon removal, approximately 97% of the flux is recovered. Subsequently applied demagnetizing fields equal to or less than the coercive force will have no further effect on the resultant flux after removal of the demagnetizing field. From this it is seen that a magnet working at any point on the demagnetization curve after having been subjected to a demagnetizing force will return to its original working point. This unique recoil property opens up new fields in permanent magnet applications.

As outlined above, the most efficient design is achieved by operating the magnet at $(BH)_{max}$. With conventional alloys this is in the main achieved by incorporating the magnet in a flux carrying or mild steel assembly and to obtain optimum efficiency magnetization must be carried out after assembly. Owing to the favourable recoil properties of isotropic barium ferrite, magnetization may be carried out prior to assembly. This obviates the necessity for complicated and often costly magnetizing jigs and fixtures.

In bicycle dynamos and generators using a permanent magnet rotor, it is common practice to magnetize an alloy magnet before assembly in a jig, from which it is pushed directly into a mild steel ring to act as a keeper to maintain a closed magnetic circuit. It has then to be transferred in a similar manner into the stator. When barium ferrite is used, none of these precautions is necessary as the rotor may be open-circuited after magnetization without impairing the performance of the generator. Furthermore, the rotor of such a generator or any barium ferrite magnet in any assembly may be totally removed from the circuit and replaced without the necessity to remagnetize the magnet to maintain the performance after reassembly. This allows for the assembly to be dismantled and reassembled if required.

A further property of barium ferrite arises from the combination of high coercivity and low permeability which makes it possible to place poles of opposite polarity in close proximity without progressive self-demagnetization effects occurring. As many as 24 poles can be impressed on the outer surfaces of a plain cylinder of 1in diameter. The limiting factor to the number of possible poles is the difficulty of producing a magnetizing fixture to provide sufficient field to obtain magnetic saturation.

Ceramic permanent magnets may also be used in the construction of d.c. motors to provide direct current fields. Here again the high coercivity and low recoil permeability play an important part. Owing to the low flux density of this material it is necessary to provide the maximum possible magnet area in the stator, and at the same time the high coercivity enables short radial lengths to be employed. In all magnetic circuits greater efficiency is obtained by placing the magnet material as close as possible to the gap. With these considerations in mind, the simplest and most efficient method of using isotropic barium ferrite for d.c. motor fields is to have the magnet in the form of plain cylinders or segments which in themselves constitute the pole pieces (Fig. 2). In view of the low permeability of this material it is necessary to provide a low reluctance return path to complete the magnetic circuit, conveniently in the form of a mild steel ring which also serves as the motor housing. The magnetic characteristics of the material allow air gaps between three and four times those used in normal motor construction, and also allow for variations in air gap. This means that magnets in the "as fired" condition may be used, so obviating a costly internal grinding operation. For larger motors where the flux provided by isotropic barium ferrite would be insufficient, the anisotropic variety can be employed, but in this case pole pieces would normally be required in order to provide a radial field. Three typical constructions are shown in Fig. 3 using anisotropic magnet b ocks. Similarly, isotropic and anisotropic ceramic magnets can be

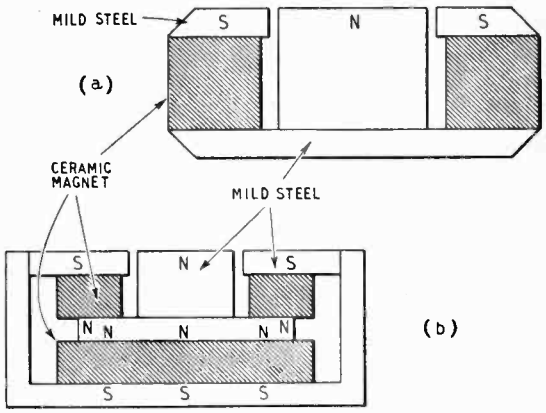

Fig. 4. (a) Ring type loudspeaker assembly (b) Pot type assembly.

used to provide the field energy for flywheel magnetos such as are commonly used in small two-stroke engines.

Radio and Television Applications.—In the domestic radio and TV receiver field, the main use of permanent magnet is in moving coil loudspeaker assemblies. The main advantage of the ceramic magnet over the alloy magnet in this field is an economic one due to the very low cost of the raw materials used. In loudspeaker design, only the anisotropic variety is considered because the

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lower B_w of the isotropic material leads to designs having unwieldy and bulky dimensions.

The magnetic properties of anisotropic ceramic material lead to designs which, although having large magnet area, have exceptionally short axial length (Fig. 4(a)). This is important where space considerations are vital, as in midget portable receivers, tape recorders, etc. Two main constructions are used for loudspeaker magnet assemblies incorporating anisotropic barium ferrite, namely ring type and pot type, as shown in Fig. 4. The latter may only be used for low gap field strength assemblies, but has the advantage of having little or no external field. This factor assumes importance in television receivers where stray magnetic fields adversely affect the c.r.t. performance. This pot assembly requires a dual magnet construction in order to utilize barium ferrite to its best advantage dimensionally[6]. A similar magnet construction to loudspeaker assemblies is used for vibrators, moving-coil microphones, and for punch card actuators.

Extensive use has been made of ceramic magnets for television tube focusing units, the high coercivity enabling two isotropic rings axially magnetized to be used in opposition. Changing the

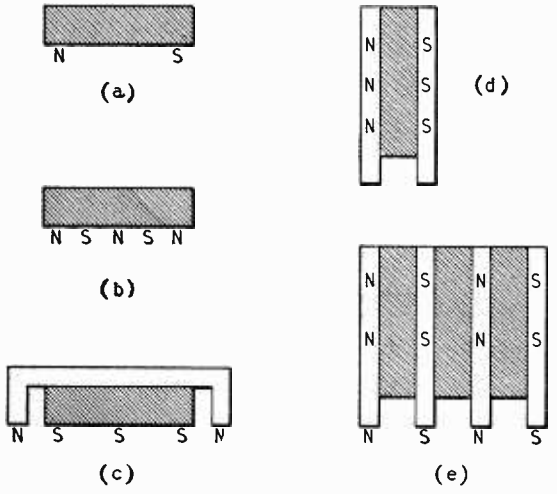

Fig. 5. Holding assemblies using ceramic magnets.

axial distance between the two rings alters the axial field strength distribution and also the working points of the two magnets, thereby changing the field strength of the magnetic lens.

Ceramic magnets are also used in conjunction with television picture tubes as ion trap and picture shift devices and as correction magnets for wide angle tubes.

Holding Applications.—Magnetic holding force is proportional to B^2A, where B is the flux density at the contact faces, and A is the contact area. Taking for example a thin rectangular block of isotropic barium ferrite, there are several methods of utilizing this as a holding device, as shown in Fig. 5. The simplest method of magnetizing is shown in Fig. 5(a), where two poles are impressed on one contact face. Since the pull of a magnetic device is proportional to the product B^2A, a greater pull is obtained by impressing a number of poles on one face, as in Fig. 5(b). This is possible with barium ferrite due to the high coercivity which reduces the effects of self-demagnetization. In order to achieve a higher B, advantage can be taken of the possible high magnetic saturation values of soft iron or mild steel. Typical arrangements are shown in Fig. 5(c), (d), and (e). Here it is seen that the mild steel is suitably proportioned to collect and concentrate the low density flux from a large area of magnet to provide a high flux density at the contact areas. Using a construction similar to Fig. 5(c), with an isotropic disc magnet inside a mild steel cup, an assembly 3in diameter and 7/16in deep would lift approximately 70lb, i.e. over one hundred times the assembly weight. Using an anisotropic magnet, the assembly would be 3in diameter and 3/4in deep, and should lift over 100lb. Construction Fig. 5(d) is widely used for applications like magnetic door catches as it has the advantage of occupying very little space. When used for such applications as magnetic separators, chucks and jigs, multi-assemblies as in Fig. 5(e) have the advantage of providing a greater number of poles in any given area than can be obtained using any other magnet material.

Magnets in the Presence of A.C. Fields.—The high resistance to demagnetization combined with a high resistivity allow ceramic magnets to be used in conjunction with fairly strong a.c. fields. Typical applications are vibrating armatures where the armature consists solely of ceramic magnet material. Alternatively, a mild steel armature inside an a.c. actuated coil may be used. This is made a close fit inside a ceramic magnet ring having mild steel pole pieces which polarize the central armature, so imparting a vibrationary motion. This principle is made use of in bells, small pumps, etc.

A similar principle applies to polarized relays.

Other Applications.—There are many other uses for which ceramic magnets may be used with advantage due to their unusual magnetic characteristics, low weight, or for economic considerations. Amongst these may be cited: remote control services, magneto-mechanical coupling possibly operating through gas-tight seals, arc blowouts, snap contact switches, travelling wave tubes, synchronized artificial eyes, toys and novelties. Barium ferrite may be embodied in plastic or rubber to form a flexible magnet material for such purposes as magnetic seals, etc.

Conclusion.—From the foregoing, it is seen that the advent of barium ferrite magnets has broadened the field of applications of permanent magnets in addition to providing an economically advantageous alternative, in some cases, to conventional alloy magnets. The unique properties of this material provide a stimulus for further investigation of its many and varied possibilities.

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NODAL ANALYSIS

By F. R. B. JONES*, A.M.Brit.I.R.E.

2.—ACTIVE NETWORKS : VALVES AND TRANSISTORS

IN the first part of this article we introduced nodal analysis to new students, showing how it is complementary to mesh analysis. In mesh analysis we use constant-voltage generators and equate known voltages to find unknown current magnitudes. In nodal analysis we employ constant-current generators and equate known currents to find unknown voltage magnitudes.

In this second part we propose to indicate a method by which "active" networks (i.e. those which contain a generator such as a thermionic valve or transistor) may be solved. The method will be identical with that used for passive networks, except for one additional convention.

Network Theory with Valves.—Every student knows that although the anode characteristics of a valve are far from straight, it is still possible to work the valve in a linear mode by avoiding the lowest parts of these curves, where the curvature is worst, and by carefully selecting the position of the load line, so as to work in Class A1. If, in addition, the part of the characteristic worked over is small, we can almost certainly assume linearity with negligible error. Idealized triode and pentode characteristics are shown in Fig. 1(a) and (b).

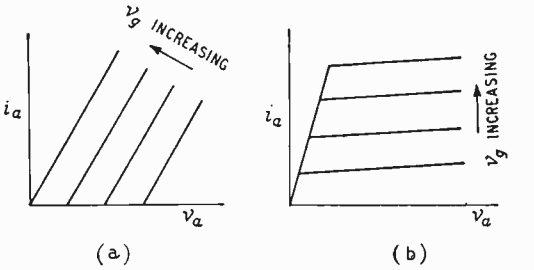

Fig. 1. Idealized triode (a) and pentode (b) characteristics.

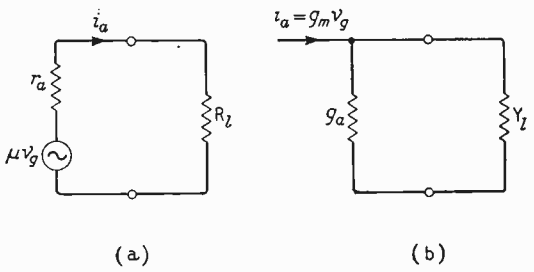

Fig. 2. Voltage (a) and current (b) generator equivalent circuits of the valve amplifier.

Valve Admittance Parameters.—The primal equation for a valve is

$$i_a = f(v_g, v_a)$$

This may be immediately developed into

$$\delta i_a = \frac{\partial i_a}{\partial v_g}\,\delta v_g + \frac{\partial i_a}{\partial v_a}\,\delta v_a$$

Both the partial differential coefficients have the dimensions of an admittance, hence the equation may be written

$$g_m v_g + g_a v_a = i_a$$

where the currents and voltages are all incremental: for our case we may say they represent the instantaneous values of the sinusoidal currents and voltages.

Conventional Development.—It is usual to develop the primal equation by specifying that a signal voltage be applied between the grid and cathode only, and that a load be placed in the anode circuit. The equation then becomes

$$g_m v_g - g_a (i_a R_l) = i_a$$

where $-i_a R_l$ is the back e.m.f. across the load. g_a is then inverted and expressed as a resistance ($r_a = 1/g_a$) and the equation easily resolves to

$$i_a = \frac{e_g g_m r_a}{r_a + R_l} = \frac{\mu e_g}{r_a + R_l}$$

where μ may or may not have a positive sign, according to the convention adopted.

The next step shows how this equation may be represented by the circuit shown in Fig. 2(a), where i_a is obviously the current flowing through the generator and load.

This, however, is only one way of interpreting the equation. Suppose we apply Norton's Theorem, as we did in the first half of this article, and transform the valve from a "constant-voltage generator" to a constant-current generator. We obtain the circuit shown in Fig. 2 (b).

In *this* circuit i_a is the current flowing in from the generator; it has a constant value for all loads from short circuit to open circuit; in the latter case it all flows out through g_a.

Nodal Development.—Returning now to the primal valve equation, we see that it has a nodal form since it gives current in terms of voltage multiplied by admittance. Since there are two voltages there must be two significant nodes and hence two equations, one for the input and one for the output. We may immediately write down the general set of nodal equations:—

$$Y_{11} V_1 + Y_{12} V_2 = I_1 \text{ (node 1, input)}$$
$$Y_{21} V_1 + Y_{22} V_2 = I_2 \text{ (node 2, output)}$$

Now a valve is an active network: it extracts unidirectional energy from the power supply unit and transforms it into alternating energy. Thus we would hardly expect its nodal equations to fall out exactly as for a passive network. The differences, however, are not large.

Fig. 3 shows the basic ideal valve amplifier (no load resistor and no grid resistor) with the input and output nodes N_1 and N_2 marked in. A cursory glance at this figure will show us that $V_1 = v_g$ and $V_2 = v_a$, but I hope we will not now fall into the trap of writing $I_2 = i_a$. I_2 is the current supplied from an external generator to node 2. In this case

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there is no such generator since we have specified one generator only, feeding a signal to the grid. I_2 is therefore zero. However, it is important to note that although I_2 is zero, this does *not* mean that no current flows into node 2 at all. Actually the anode current, i_a, flows from node 1 (the grid) to node 2 (the anode) and then to earth again, via g_a.

Now what of the coefficients Y_{21} and Y_{22} in the second nodal equation? Y_{21} corresponds to current flowing into node 2 (the anode) due to a voltage at node 1 (the grid). This, by definition, is g_m. Y_{22} is the admittance in the output circuit. For the case we are considering this, by definition, is g_a. In a practical amplifier Y_{22} would include all the admittances in the output circuit, i.e. the load resistor, stray capacities etc. The second nodal equation for a valve is thus

$$g_m V_1 + g_a V_2 = 0 \text{ (node 2)}$$

This is our primal equation in nodal form. We might have expected the current flowing into node 2, $g_m V_1$, to have a negative sign, so as to agree with our selected conventions. It must be remembered, however, that this current is itself negative, since increasing V_1 positively increases the flow of electrons or negative current, and a negative current flowing in a negative direction will have a positive sign.

What of the equation for node 1? The derivation of this will be quite straightforward. For the case where we have no grid resistor, and when we work in Class A1 (no grid current), I_1 must be zero. Hence, if I_1 is to be expressed in terms of V_1 and V_2, these must both be prefixed with a nought, which gives us

$$0V_1 + 0V_2 = I_1$$

This just means that the valve itself draws no current from the generator driving it. Looking in detail at the coefficients Y_{11} and Y_{12} in this equation, Y_{11} is the admittance in the input circuit. With no grid resistor this will be zero. In a practical amplifier, however, the grid admittance Y_g will appear in Y_{11} and then I_1 will have a definite value. Y_{12} corresponds to current flowing into node 1 (the grid) due to a voltage at node 2 (the anode). For the perfect valve we are considering Y_{12} must thus also be zero. (We will consider the practical case—"Miller Effect"—later.)

If we assemble our results for the ideal valve we obtain

$$0V_1 + 0V_2 = I_1 \text{ (node 1)}$$
$$g_m V_1 + g_a V_2 = 0 \text{ (node 2)}$$

These equations show clearly the differences between active and passive networks.

(1) In a passive network Y_{12} always has the same magnitude and sign as Y_{21}. In an active network this is not so. (Here $Y_{12} = 0$ and $Y_{21} = g_m$.)

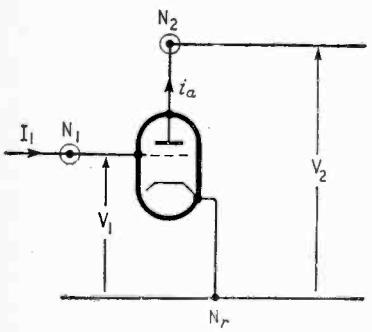
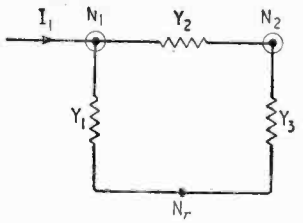


Fig. 3. Basic ideal valve amplifier.



$$(Y_1 + Y_2) V_1 - Y_2 V_2 = I_1$$
$$-Y_2 V_1 + (Y_2 + Y_3) V_2 = 0$$

Fig. 4. Simple two-node passive network with its associated nodal equations.

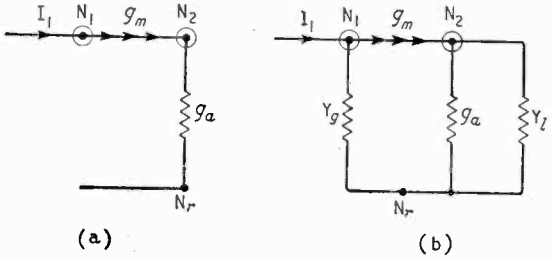


Fig. 5. Equivalent nodal circuits of a valve amplifier (a) in the ideal form of Fig. 3 and (b) with the addition of a grid admittance Y_g and load admittance Y_l.

(2) In a passive network the linking admittance joining nodes 1 and 2 appears in Y_{12} and Y_{21} prefixed with a negative sign, and also in Y_{11} and Y_{22} with its normal sign. (An easy example of this is shown in Fig. 4, together with its set of equations.) In the active network this is not so. (g_m appears in Y_{21} only, and is not included in the other three parameters.)

Hence a separate sign is necessary to indicate the unilateral admittances of an active network. We could make use of the appropriate arrow symbol for a one-way street, pointing from N_1 to N_2 say for Y_{21} and from N_2 to N_1 for Y_{12} in cases where it has a value other than zero (as in a transistor). The convention would be that where a unilateral admittance appears it is only shown once, in either Y_{12} or Y_{21}, according to the arrows, and with the sign shown. For example, the equivalent diagram of a valve only, in the ideal condition, would be as shown in Fig. 5(a). The valve with a grid admittance Y_g and a load admittance Y_l would have an equivalent circuit as in Fig. 5(b).

It only remains to state that any passive elements added to an active network behave as they normally do in a passive network, even if connected across nodes one and two, when they appear in all four parameters.

We can now proceed to apply these equations, and I think you will find this much easier than the derivation of the equations!

General Case of an Active Network.—We can now obtain some standard formulae for gain, input admittance and output admittance, which will apply to all such networks, passive or active, valve or transistor.

The general nodal equations for the case when there is no external generator connected to the output (node 2), i.e. with $I_2 = 0$, are

$$Y_{11} V_1 + Y_{12} V_2 = I_1$$
$$Y_{21} V_1 + Y_{22} V_2 = 0$$

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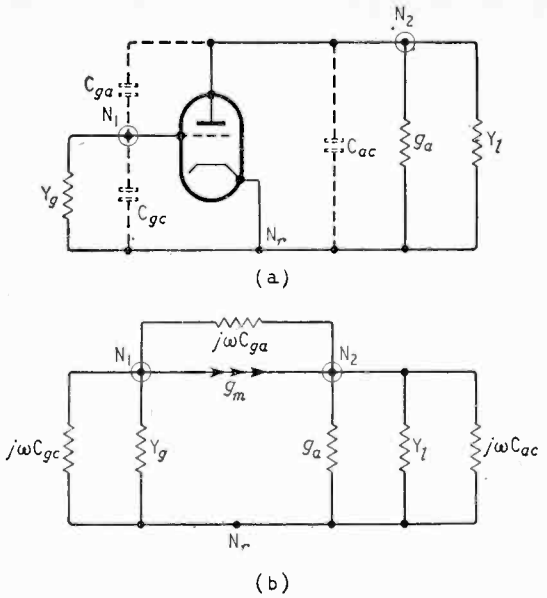

Fig. 6. Valve with interelectrode capacities (a) and its nodal equivalent circuit (b).

It can immediately be seen from the second equation that the voltage gain

$$\frac{V_2}{V_1} = -\frac{Y_{21}}{Y_{22}} = M_v$$

Similarly the short-circuited (output) current gain will be

$$\frac{I_2}{V_1} \times \frac{V_1}{I_1} = \frac{Y_{21}}{Y_{11}} = M_i$$

The input admittance of the network, which can include the load, may be found from the equations as follows. From the second equation $V_2 = -Y_{21} V_1 / Y_{22}$ and substituting this into the first equation gives

$$Y_{11} V_1 - \frac{Y_{12} Y_{21}}{Y_{22}} V_1 = I_1$$

Thus $Y_{in} = \frac{I_1}{V_1} = Y_{11} - \frac{Y_{12} Y_{21}}{Y_{22}} = Y_{11} + M_v Y_{12}$

Conversely, the " looking-back " admittance at the output will be

$$Y_o = Y_{22} - \frac{Y_{12} Y_{21}}{Y_{11}} = Y_{22} - M_i Y_{12}$$

From these equations we can see that the load only affects the source admittance, and vice versa, if both Y_{12} and Y_{21} have values (i.e. neither are zero).

Simple Valve Amplifier.—The nodal equations for the valve under ideal conditions are

$$0 V_1 + 0 V_2 = I_1$$
$$g_m V_1 + g_a V_2 = 0$$

The voltage gain $= -g_m/g_a = -g_m r_a = -\mu$.

The nodal equation brings out clearly to the new student the fact that the valve amplification factor is merely the ratio of two admittances.

Now take a simple amplifier, with anode load Y_l. Since the valve is being treated as a current generator the load will appear in parallel with the generator admittance. If we include the grid resistor $(1/Y_g)$ our equivalent diagram will be as in Fig. 5(b), and our equations will become

$$Y_g V_1 + 0 V_2 = I_1$$
$$g_m V_1 + (g_a + Y_l) V_2 = 0$$

The voltage gain

$$M_v = -\frac{Y_{21}}{Y_{22}} = \frac{-g_m}{g_a + Y_l}$$

Unfamiliar? Change the admittances to impedances and

$$M_v = \frac{-g_m}{\frac{1}{r_a} + \frac{1}{R_l}} = \frac{-g_m}{\frac{R_l + r_a}{R_l\ r_a}}$$
$$= \frac{-g_m r_a R_l}{R_l + r_a} = \frac{-\mu R_l}{R_l + r_a}$$

which is familiar to everyone—yet not as simple. If Y_l should be complex, say $g_l + jB_l$, then

$$M_v = \left|\frac{g_m}{\sqrt{(g_a + g_l)^2 + B_l^2}}\right| \underline{/180° - \theta}$$

where $\theta = \arctan \frac{B_l}{g_a + g_l}$

Calculation of Miller Effect.—Due to interelectrode capacitance a valve, particularly a triode, is not truly unilateral at high frequencies, but does transfer some energy from the output to the input, and so modify the input admittance of the valve. The basic circuit and its equivalent are shown in Fig. 6(a) and (b) and the pair of nodal equations will be

$$[Y_g + j\omega (C_{gc} + C_{ga})] V_1 - j\omega C_{ga} V_2 = I_1$$
$$[g_m - j\omega C_{ga}] V_1 +$$
$$[g_a + Y_l + j\omega(C_{ac} + C_{ga})] V_2 = 0$$

The voltage gain

$$M_v = -\frac{Y_{21}}{Y_{22}} = -\frac{g_m - j\omega C_{ga}}{g_a + Y_l + j\omega (C_{ac} + C_{ga})}$$

The input admittance

$$Y_{in} = Y_{11} + M_v Y_{12}$$
$$= Y_g + j\omega(C_{gc} + C_{ga}) - j\omega C_{ga}|M_v| \underline{/180° + \phi}$$
$$= Y_g + j\omega C_{gc} + \omega C_{ga}(1\underline{/90°} + |M_v| \underline{/90° + \phi})$$

This is the normal equation for the input admittance of a triode amplifier at radio frequencies; we have found it, together with the gain, in a few lines of working. Other examples of valves working with grounded cathode can be solved in the same manner.

Grounded-Anode Stage (Cathode Follower).—Let us now examine the grounded-anode stage. Here, due to the valve being inverted, the nodal equations must be modified. The primal equation, $i_a = g_m v_g + g_a v_a$ always applies, whatever the configuration. Referring to Fig. 7 we see that $v_a = -V_2$, and since $v_{ac} = v_{ag} + v_{gc}$, then $v_{gc} = v_{ac} - v_{ag} = -V_2 - (-V_1)$. Hence $i_a = -g_m(V_2 - V_1) - g_a V_2$. Allowing for the reversed direction of i_a, the nodal equations then become

$$0 V_1 + 0 V_2 = I_1$$
$$-g_m V_1 + (g_m + g_a) V_2 = 0$$

These equations are easily remembered, whilst the procedure for finding the gain etc., is exactly as before. Let us draw the circuit of a typical cathode follower and its equivalent, and then write down the nodal equations. The circuits are shown in Fig. 8(a) and (b) and the nodal equations are

$$Y_g V_1 + 0 V_2 = I_1$$
$$-g_m V_1 + (g_m + g_a + Y_k) V_2 = 0$$

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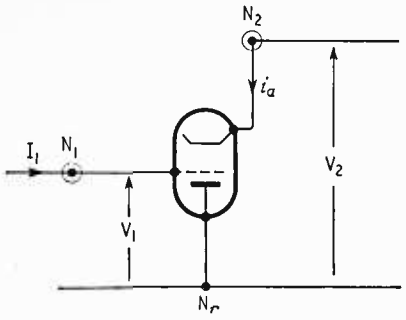

Fig. 7. Basic ideal grounded-anode valve (cathode follower).

The voltage gain

$$M_v = -\frac{Y_{21}}{Y_{22}} = \frac{g_m}{g_m + g_a + Y_k}$$

This is obviously less than one. Typical values may be, $g_m = 2.5$ milliamps per volt, $g_a = 100$ micromhos and $Y_k = 100$ micromhos. The gain is then 0.925.

If the gain equation is transformed into impedances we obtain for the voltage gain

$$M_v = \frac{\left(\frac{\mu}{1+\mu}\right) R_k}{\left(\frac{r_a}{1+\mu}\right) + R_k}$$

This is the familiar equation, which shows voltage negative feedback.

Since Y_{12} is zero, the input admittance is just Y_g and the output admittance $g_m + g_a + Y_k$. However, things become quite different if Y_g is connected between grid and cathode (i.e. between nodes 1 and 2). The input admittance then falls to about one-tenth of Y_g and the output admittance is now no longer independent of the input admittance. Why not work it out for yourself? There are some good notes by J. McG. Sowerby in the *Wireless World* for September, 1948.

The behaviour of the cathode follower at high frequencies can be studied by including the inter-electrode and other capacitances.

Grounded-Grid Amplifier.—Since the procedure followed is identical with that for the cathode follower, the explanation will be curtailed. Referring to Fig. 9 we see that $v_g = -V_1$ and $v_a = V_2 - V_1$. Substituting we find that $i_a = -(g_m + g_a)V_1 + g_a V_2$. Now I_1 must have the same magnitude as i_a (there being no grid current). Therefore it should have the same coefficients as i_a, but with the signs changed, since current flowing out of node 1 is positive, whereas the same current flowing into node 2 is negative. Hence our nodal equations are

$$(g_m + g_a)V_1 - g_a V_2 = I_1$$
$$-(g_m + g_a)V_1 + g_a V_2 = 0$$

A simple circuit and its equivalent are shown in Fig. 10(a) and (b). Its equations are

$$(Y_k + g_m + g_a)V_1 - g_a V_2 = I_1$$
$$-(g_m + g_a)V_1 + (g_a + Y_l)V_2 = 0$$

The voltage gain $= -\frac{Y_{21}}{Y_{22}} = \frac{g_m + g_a}{g_a + Y_l}$

If Y_l and g_m are much larger than g_a, this gain approximates to g_m/Y_l or $g_m Z_l$.

The input admittance will be $Y_{11} + M_v Y_{12}$ or approximately $Y_k + g_m$, for the same conditions as the gain.

Indefinite Admittance Matrix.—All the basic valve configurations have now been dealt with. We will conclude this section by giving a mnemonic to enable you to remember the three sets of equations.

First write down the admittance parameters of the common-cathode valve configuration in the position they normally occupy in the equations. We get

$$\begin{matrix} 0 & 0 \\ g_m & g_a \end{matrix}$$

Now add a third column (on the right) and a third row (underneath) in such a way as to make the sum of every column or row zero. Lastly mark the rows and columns G, A and C, as shown.

	G	A	C
G	0	0	0
A	g_m	g_a	$-(g_m + g_a)$
C	$-g_m$	$-g_a$	$(g_m + g_a)$

For grounded-cathode working strike out the third (C) row and column. This brings us back to where we started, viz.

$$\begin{matrix} 0 & 0 \\ g_m & g_a \end{matrix}$$

For grounded-anode working strike out the second (A) column and row, which gives

$$\begin{matrix} 0 & 0 \\ -g_m & (g_m + g_a) \end{matrix}$$

This agrees with the values already found.

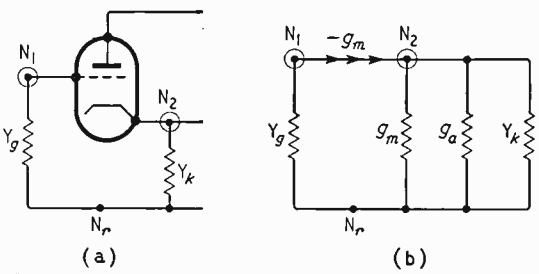

Fig. 8. Typical cathode-follower (a) and its nodal equivalent circuit (b).

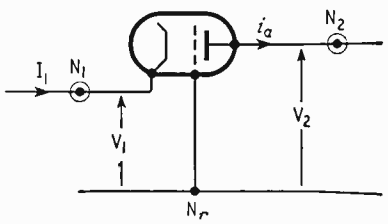

Fig. 9. Basic ideal grounded-grid valve.

Lastly, for grounded grid, we cross out the first (G) row and column to obtain

	A	C
A	g_a	$-(g_m + g_a)$
C	$-g_a$	$(g_m + g_a)$

This places the anode in the top left-hand corner, which is input, and the cathode in the bottom right-hand corner, or output. We therefore make a diagonal changeover of all four parameters to get

$$\begin{matrix} (g_m + g_a) & -g_a \\ -(g_m + g_a) & g_a \end{matrix}$$

This again agrees with the values previously found.

You may protest that these equations are easy enough to remember without this mnemonic; if so I would agree. The real reason they were brought in here was to show that the method gave the right

(*Continued on page 603*)

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answers with a valve. We will soon use the same method to convert a common-emitter configuration transistor to common collector or common base. The real justification for this method lies in matrix theory, and is due to J. Shekel[1]. This subject, however, is outside the scope of the present article.

Transistor as an Active Network.—The transistor, like the thermionic valve, is an active two-node network and as such its manipulation and basic equations for gain and input and output admittance are the same as the valve. Once we have obtained the nodal equations for the transistor the rest is merely a repetition of what we did with the valve.

Derivation of Transistor Parameters.—Following common practice, we will first consider the transistor in common base. The transistor collector curves, shown in Fig. 11(a) strongly resemble the pentode anode characteristics shown in Fig. 1(b), with one subtle difference. Whereas each separate curve on the valve characteristic represents a certain grid *voltage*, on the transistor collector characteristic each curve represents a certain emitter *current*. This makes quite a difference to the resulting equations. We must now say

$$i_c = f(i_e, v_c)$$

Our other parameter, the emitter voltage, must then also be expressed in terms of the same variables.

Once again we get equations of the form

$$\delta v_e = \frac{\partial v_e}{\partial i_e}\,\delta i_e + \frac{\partial v_e}{\partial v_c}\,\delta v_c$$

$$\delta i_c = \frac{\partial i_c}{\partial i_e}\,\delta i_e + \frac{\partial i_c}{\partial v_c}\,\delta v_c$$

$\partial v_e/\partial i_e$ is dimensionally an impedance and we may replace it with r_{11}. Similarly $\partial i_c/\partial v_c$ is dimensionally a conductance and may be replaced by g_{22}. On the other hand $\partial v_e/\partial v_c$ is a mere ratio between two voltages, let us use μ_r for this, where the subscript means "reverse" (voltage fed back to input). In the same way $\partial i_c/\partial i_e$ is the forward current gain and its symbol is usually α.

Our set of equations thus becomes

$$r_{11} i_e + \mu_r v_c = v_e$$
$$\alpha i_e + g_{22} v_c = i_c$$

with the signs depending on the convention employed.

By the reasoning employed in the first article, r_{11} and α are measured with the output short circuited to a.c. whereas μ_r and g_{22} are measured with the input open circuited to a.c.

Now it happens that in matrix theory there is a set of equations of the form

$$H_{11} I_1 + H_{12} V_2 = V_1$$
$$H_{21} I_1 + H_{22} V_2 = I_2$$

which is of the same basic form as those we have just derived. Thus the next step was to substitute H_{11} for r_{11}, H_{12} for μ_r, H_{21} for α and H_{22} for g_{22}. It wasn't really necessary, but you must admit it looks good and is calculated to baffle the most pertinacious student. Indeed we have now reached a dead end and will have to transform these "hybrid" parameters (from the H and the mixed dimensions) into admittances, similar to the valve, if we wish to attack transistor problems without the aid of a course in memory training.

We can easily transform the H parameters into Y by the aid of simple algebra, but if the transistor manufacturers would quote these values it would save us the trouble.

[1] *Wireless Engineer*, Jan. 1954, p. 6.

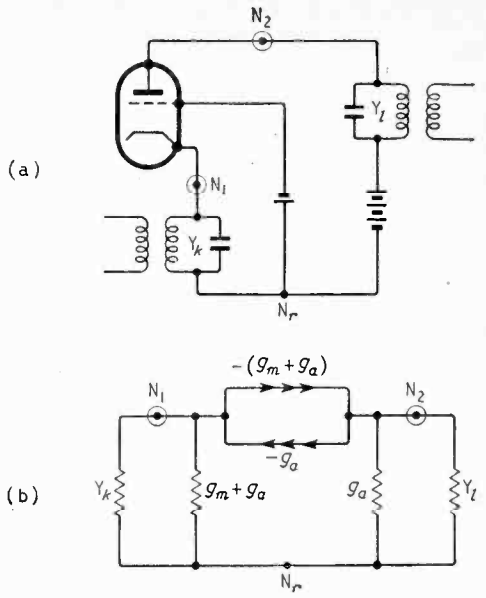

Fig. 10. Simple grounded-grid amplifier (a) and its nodal equivalent circuit (b).

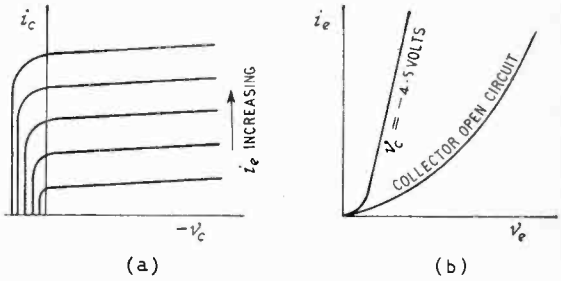

Fig. 11. Common-base characteristics of the transistor (a) at its output and (b) at its input.

From the first equation we can quickly obtain

$$I_1 = \frac{1}{H_{11}} V_1 - \frac{H_{12}}{H_{11}} V_2$$

Substituting this into the second equation we get

$$I_2 = \frac{H_{21}}{H_{11}} V_1 + \frac{|H|}{H_{11}} V_2$$

Where $|H| = H_{11} H_{22} - H_{12} H_{21}$

Hence

$$Y_{11} = \frac{I}{H_{11}}, Y_{12} = -\frac{H_{12}}{H_{11}}, Y_{21} = \frac{H_{21}}{H_{11}}, Y_{22} = \frac{|H|}{H_{11}}$$

Transistor manufacturers usually publish a set of H parameters for common-emitter, common-collector and common-base working—three sets—for each transistor.

It is common for teachers and lecturers to approach transistors from the common-base viewpoint, but in practice the common-emitter configuration is far more common. We will therefore give our example on the common-emitter configuration. Common-emitter parameters may be found in the same way as common base, and they are always given by transistor manufacturers. In any case it is always possible to transform from one configuration to another.

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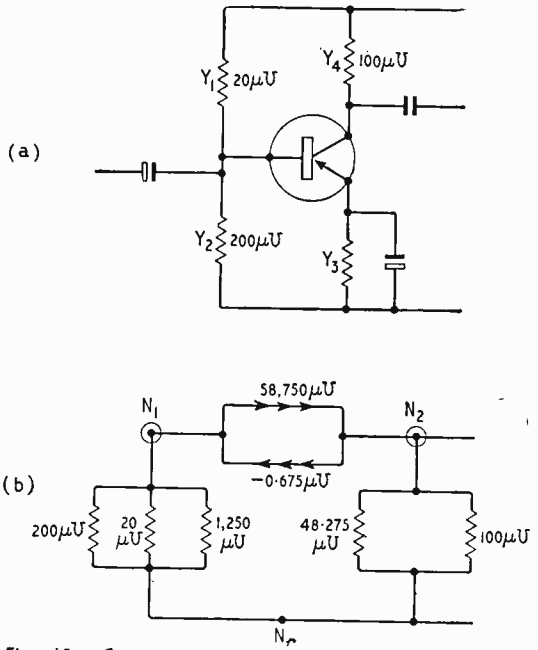

Fig. 12. Common-emitter transistor current amplifier (a) and its nodal equivalent circuit (b) (℧ ≡ mho).

Common-Emitter Transistor Amplifier.—Mullards give the hybrid parameters of their OC 71 transistor in common emitter as

$H_{11} = 800$ ohms, $H_{12} = 5.4 \times 10^{-4}$
$H_{21} = 47$, $H_{22} = 80 \times 10^{-6}$ mhos

The admittance parameters work out to

$Y_{11} = 1{,}250$, $Y_{12} = -0.675$ } all figures in
$Y_{21} = 58{,}750$, $Y_{22} = 48.275$ } micromhos

Consider the amplifier shown in Fig. 12(a).

A little consideration will show that both Y_1 and Y_2 are in parallel across the input, whilst Y_4 is obviously across the output. The equivalent circuit is then as in Fig. 12(b).

The voltage gain is still

$$M_v = -\frac{Y_{21}}{Y_{22}} = -\frac{58{,}750}{148.275} = -396$$

The current gain, with output short circuited to a.c.

$$M_i = \frac{Y_{21}}{Y_{11}} = \frac{58{,}750}{1{,}470} = 40$$

The input admittance

$$Y_{in} = Y_{11} - \frac{Y_{12}Y_{21}}{Y_{22}} = Y_{11} + M_v Y_{12} = 1{,}737\ \mu\text{mhos}$$

The "looking-back" admittance at the output

$$Y_o = Y_{22} - \frac{Y_{12}Y_{21}}{Y_{11}} = Y_{22} - M_i Y_{12} = 175.3\ \mu\text{mhos}$$

Perhaps you will agree that once the admittance parameters have been worked out, or obtained from manufacturer's data, the actual work involved in finding the gain, etc., is small.

Transistor in Common Collector and Common Base.—If one wishes to obtain the performance of a transistor in common collector (near equivalent to the cathode follower) or common base (equivalent of grounded grid), the admittance parameters for these configurations can easily be obtained from those of the grounded-emitter admittances, without recourse to the hybrid parameters again. We employ the indefinite admittance matrix, as we did for the valve, using a modification of the method devised by Shekel[2].

First write down the admittance parameters of the common-emitter configuration, in the positions which they normally occupy in the equations. Now add a third column (on the right) and a third row (underneath) in such a way as to make the sum of every column or row zero. Lastly mark the rows and columns, B, C and E. I have done it for the OC 71.

	B	C	E	
B	1,250	− 0.675	− 1,249.325	} all in
C	58,750	48.275	−58,798.275	} micromhos
E	−60,000	−47.600	60,047.6	

To obtain common-emitter parameters strike out the E row and column. (This brings us back to our starting point, of course.)

To obtain the common-collector parameters strike out the C row and column. This leaves

1,250 −1,249.325 } all in
−60,000 60,047.6 } micromhos

which are the admittance parameters for the OC 71 when used in grounded collector. They are used exactly as were the valve admittance parameters in the cathode follower.

For the common-base configuration we strike out the first (B) row and column. This gives the collector in the top left-hand corner, which is input, and the emitter in the bottom right corner, or output: our transistor is connected the wrong way round. It is therefore necessary to make a diagonal switch of all four parameters which gives

60,047.6 −47.600 } all in
−58,798.275 48.275 } micromhos

Again, these common-base parameters may be used to find gain, input admittance and output admittance exactly as shown for the common emitter, or for that matter, the valve.

Conclusion and the Shape of Things to Come.—This then is nodal analysis as applied to passive and active networks. The basic procedure is the same for passive, valve or transistor circuits, which should be of considerable help to students. Only a few examples of its use are shown, it really is a powerful method: however, it does not supersede mesh analysis, but is complementary to it.

And where do we go from here? The next step would be a study of four-terminal networks, using matrices, assisted by determinants. If you should be interested in the transient case, nodal analysis may still be very helpful, in conjunction with Laplace transforms, and will tell you whether a network is stable or unstable, and what sort of response (current) will occur as a result of an externally applied stimulus (which is commonly non-sinusoidal)[3].

However, leave these latest methods until you are quite familiar with mesh and nodal analysis: between them they will take you a long way, especially the latter!

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[2] *Proc. I.R.E.*, Nov. 1952, p. 1493.
[3] See, for example, "Linear Feedback Analysis", by J. G. Thomason (Pergamon Press).

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Camera Remote Control

USED IN B.B.C. REPORTING STUDIOS

By G. W. H. LARKBY*

IN recent years the stability of vidicon cameras has improved to the degree that it is now possible to use them without the attention of technical operators. The first example of the use of an unattended camera in this fashion was, in fact, in the B.B.C.'s Parliamentary Reporting Studio at Westminster which was put into service about a year ago.

This studio is as simple as it is possible to conceive a television studio to be, consisting of a small room furnished with a table and chair, lights, microphone and a single television camera in a fixed position. The studio is brought into action by remote control from the Television News Studio at Alexandra Palace where the received signal is "mixed" into the programme. The operational success of this facility, simple as it is, stimulated a demand to be able to control the main positional functions of the remote camera in order to give variety to the presentation. In turn, the development of the apparatus for this positional control has led to the provision of a facility whereby the camera can be made to take up any one of a number of pre-set "shots" by the operation of a push-button switch, which may, if desired, be operated by the "subject" himself.

The camera functions which require to be controlled are horizontal angle (pan), vertical angle (tilt), angle of view (focal length of lens), camera focus and lens aperture. In order to avoid a hiatus in the picture while changing the focal length of the lens, advantage can be taken of a zoom lens.

As a field experiment, a vidicon camera has been fitted with a zoom lens and is installed in the B.B.C.'s studio in All Souls Hall, near Broadcasting House, and the camera can be controlled in all its main functions, either from the local control room or from the control room at Alexandra Palace, some seven miles away.

The camera is a standard vidicon, of a type in general use in interview studios where it is normally fitted with a four-lens turret. For the purpose of this experiment, the turret was removed and replaced by a cast plate on which is mounted the zoom lens together with the motor mechanisms for the zoom, focus and iris movements.

The servo system employed is shown in Fig. 1. The two potentiometers, A and B, form a bridge circuit of which the potential difference, at d.c., between points A and B, is fed to a modulator, which detects the potential difference between these two points and provides a correcting signal which, in turn, operates a motor so that the two points are brought as nearly as possible to the same potential. The modulator circuit employed is the well-known "ring" connection of four diodes to which, in addition to the d.c. control voltage, a constant 50 c/s e.m.f. is also connected. In order to keep harmonics in the output voltage to a reasonably low level the amplitude of the 50 c/s applied to the modulator is relatively low. It can be seen from the symmetry of the circuit that at balance, i.e., when A and B are at the same potential, there will be no 50 c/s output from the bridge into the control amplifier. On the other hand, when potentiometer A is moved, say to give a current flowing in the direction from B to A, diodes M1 and M3 conduct, causing the 50 c/s e.m.f. in transformer T1 to send a current through the centre-tapped winding of the transformer T2, producing an output in a particular phase. Movement of potentiometer A in the other direction, so as to cause a current to flow from A to B, makes diodes M2 and M4 conduct and, as compared with the previous condition, reverses the connection of the e.m.f. in transformer T1 to the terminals of transformer T2. Thus the phase of the output of the voltage from T2 changes by 180° as the direction of current between A and B reverses. Accordingly, the motor can run in either direction, depending upon the position of potentiometer B relative to potentiometer A. The a.c. output from the bridge is amplified and drives the servo control motor, which will always attempt to keep the bridge

* B.B.C. Designs Department.

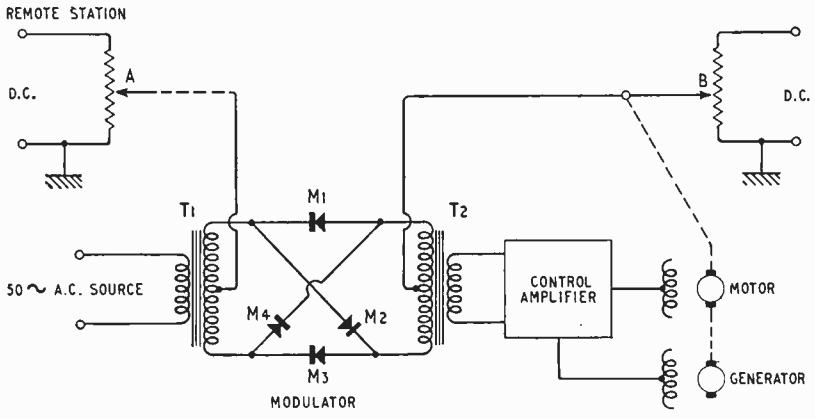

Fig. 1. Servo system schematic used for the remote control of a television camera.

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Fig. 2. Servo motors, zoom lens, etc., mounted in place of the normal four-lens turret. These are enclosed in a cover which also forms a lens hood.

in balance. Thus, any movement of the control knob results in an equal movement of the controlled potentiometers as the motor drives the bridge into balance. Coupled to the motor shaft is a generator which produces an output of voltage proportional to the speed which is fed into the servo amplifier and so adjusted as to make the whole system critically damped. The action is very nearly dead beat giving the operator the impression that the knob is directly coupled to the mechanism which it operates and he has little or no feeling that it may well be many miles away.

The use of d.c. for the control current has the advantage that for short distances, say of the order of 10 miles, low quality circuits may be used. The system as installed between Alexandra Palace and All Souls Studio makes use of phantom circuits superimposed on existing speech and music circuits. For longer distances on which a d.c. loop is not available, it would be necessary to translate the control signals to audio frequencies, at which they can be conveniently transmitted.

The control amplifiers are four identical transistorized units capable of giving a continuous output of 20 watts each. They are driven from a stabilized 24-volt power supply. The amplifiers are straightforward audio amplifiers with emitter follower driven Class B output stages, the transistors being OC71, OC71, OC72+OC72 driving 2N268+2N268. There are two controls, i.e., gain and velocity feedback, thus allowing the performance of any function to be varied at will.

The lens fitted has a minimum focus of 4 feet with a maximum aperture of f/2.8. The movement of the knurled operating rings required to go from minimum to maximum of all three functions of the lens is approximately 180°, and the preliminary design called for an operational time of 5 seconds end to end. This sets the reduction gear ratio for the servo motor, the stalled torque necessary at motor shaft being sufficient to overcome the friction of the mechanism. In view of the experimental nature of this camera only two positional servos were used on the lens, i.e., focus and zoom. The iris is controlled by a non-servo type of small reversible motor of low torque, end stops being used to limit travel. The servo balance potentiometers are mounted on the penultimate drive shaft; the final drive to the lens is by neoprene toothed timing belts. These belts have built-in flexible steel wires which prevent stretch, the teeth giving positive drive so that a minimum of side loading is required and they are silent in operation.

All the connections to the motors, etc., are brought out to a multi-way plug on the side of the plate. A cover with acoustic damping fits over the whole assembly and also operates as a lens hood.

The camera and lens assembly is mounted on a panning tilt head which has a tilting centre above the camera mounting platform so that the centre of gravity of the camera can be placed at this point, thereby making the whole assembly inherently balanced. The camera tilt mechanism consists of a sector of a circle whose centre is above the camera mounting surface. Gear teeth are cut in the curved underside of this sector and mesh with a transverse driving shaft. This mechanism can be seen in Fig. 2.

A servo motor is fitted to both pan and tilt mechanisms. The error detector in the tilt servo is a carbon track potentiometer geared to the transverse shaft, but that in the pan is a three-turn potentiometer to give adequate resolution. Velocity feedback is achieved by using a generator on the same shaft as the motor, as in the focus and zoom unit.

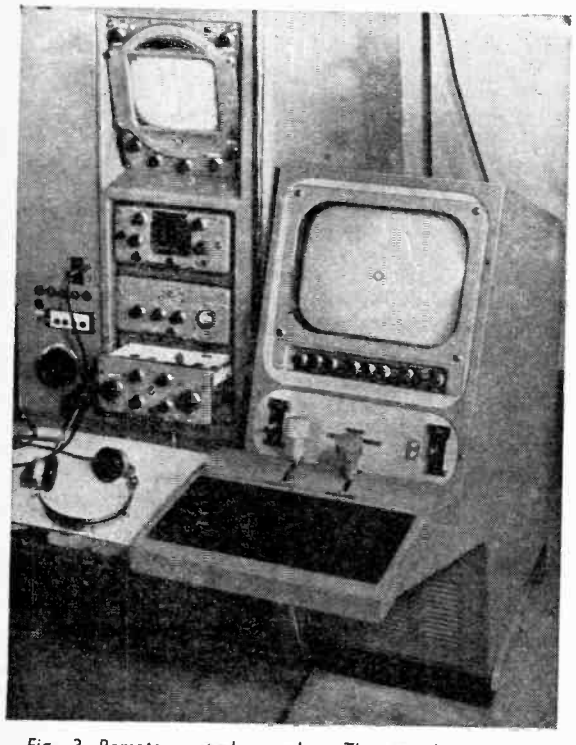

Fig. 3. Remote control console. The two large knobs control focus and zoom (left) and tilt and pan (right).

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The pan motion uses an 8mm roller chain with a spring-loaded jockey pulley. In this case the driven chain wheel is fixed to the tripod head and the motor and driving pulley drive themselves round the head carrying the camera with them. The use of this method permits a change of gear ratio to be used without the use of large, expensive, special gears.

For continuous operation of the camera controls at the remote point, the operator sits at a console on the front of which are two knobs; each of these is moved in two modes: (a) rotation, (b) fore and aft like a lever. On the right-hand knob the rotation corresponds to pan and the fore and aft motion to tilt; on the left-hand knob the rotation corresponds to focus and the fore and aft to zoom (see Fig. 3). With a little practice, by the use of both hands the operator can control all four functions of the camera smoothly and comfortably.

It was soon apparent that to give smooth control, some form of damping on the motion is required, and this is provided by discs immersed in a silicone fluid rotating in a close-fitting chamber. The physical operation of each of these controls turns a potentiometer which forms part of the bridge of the appropriate servo mechanism.

Because the setting of any of the camera functions can be represented by the position of a potentiometer, by arranging to switch to groups of potentiometers, it is possible to give the camera a number of pre-set "shots." For example, Shot No. 1 might consist of a general view showing two people in conversation, Shot No. 2 would then be a close-up of the interviewer and Shot No. 3, perhaps, a close-up of the person being interviewed. On the operation of a push button, the camera can

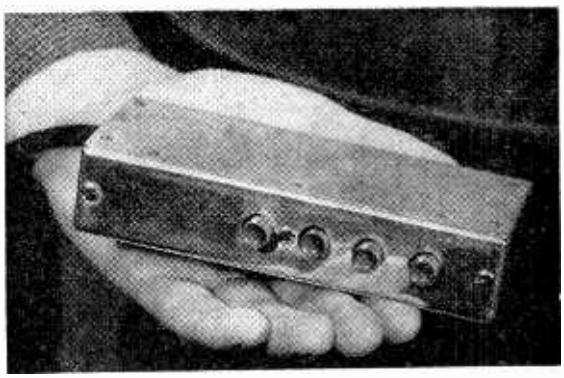


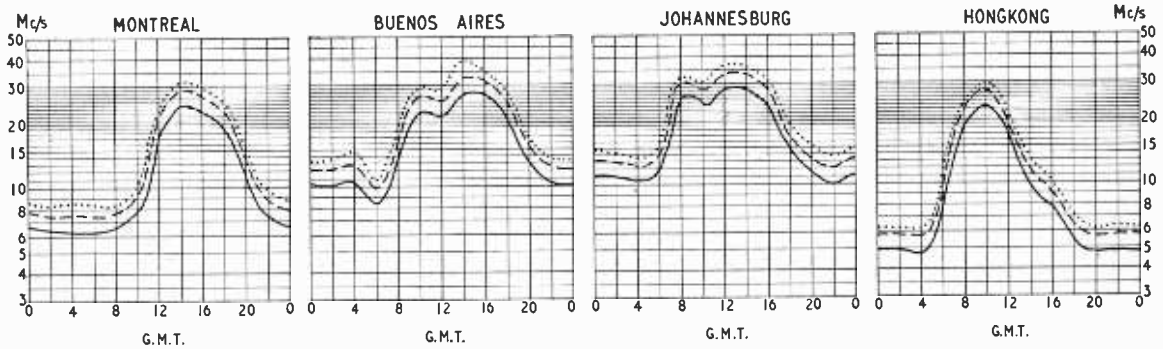
Fig. 4. "Shot-box" for the control of a camera by an interviewer.

be made to take up any of these shots at will. This leads to the possibility in studios where the programme is of a pre-set nature of using say, two remotely controlled cameras which look in turn at the appropriate "shots" under the control of the vision operators in the control room without having to have studio cameramen at all.

To pre-set any particular shot, it is only necessary to adjust the corresponding potentiometers for pan, tilt, focus and zoom, there being a group of four such potentiometers for each shot required. On the experimental camera the four positions on the "shot-box" control have proved adequate and useful. Visitors to one of the B.B.C. stands at the Earls Court Radio Show had the opportunity of manipulating a camera in this manner.

SHORT-WAVE CONDITIONS

Prediction for December



THE full-line curves indicate the highest frequencies likely to be usable at any time of the day or night for reliable communications over four long-distance paths from this country during December.

Broken-line curves give the highest frequencies that will sustain a partial service throughout the same period.

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LETTERS TO THE EDITOR

The Editor does not necessarily endorse the opinions expressed by his correspondents

Transistorized Wien Bridge Oscillator

ON PAGE 390 of the August issue Mr. Butler says, "There is little point in using RC oscillators at frequencies much higher than 100kc/s, since it is simpler and cheaper to use switched tuned circuits."

Perhaps Mr. Butler would care to expand on this statement, since (1) there is some merit in being able to have sweep or continuous tuning. The usual Wien network oscillator has a continuous 10:1 frequency sweep, and this is not normally achieved in an LC tuned system and, (2) there are several RC oscillators commercially available extending beyond 100 kc/s.

Dorking, Surrey. D. J. COLLINS

The author replies:

I AGREE with Mr. D. J. Collins that a normal LC oscillator will not cover the 10:1 frequency range of an RC oscillator and that there are occasions when this wide coverage is of value in experimental work. Nevertheless the chief merit of the RC oscillator lies in the lower frequency part of the spectrum where LC oscillators require large and inconvenient tuning elements. At higher frequencies LC oscillators with continuously variable tuning elements have these advantages:—

(a) Low distortion due to the use of high Q components.

(b) High efficiency as compared with RC oscillators.

(c) Satisfactory operation from low voltage unregulated power supplies.

(d) High stability of frequency can be obtained in a simple way, e.g., by the use of capacitors having a negative temperature coefficient to offset the positive coefficient of the associated inductance.

(e) Distortionless amplitude control is easy to apply.

(f) Pulsed or modulated operation is possible.

(g) For a given scale length, the frequency of an LC oscillator covering a 3:1 range can be read more accurately than that of an RC oscillator covering a 10:1 range.

As stated in my paper, there is no difficulty in adding an extra range covering up to 200 kc/s if this is required. For distortionless operation at such high frequencies it is desirable to use v.h.f. transistors. This is because of difficulties due to hole-storage effects in transistors which have relatively low alpha cut-off frequencies. Moreover, v.h.f. transistors have a much lower collector capacitance. This parameter is dependent on temperature and on the collector voltage and is responsible for a variable amplifier phase shift which affects the frequency.

Mr. Alan Carpenter's fixed frequency 100 c/s oscillator (October issue) embodies some interesting design features and is outstandingly good in respect of frequency stability. At this low frequency, variation of transistor characteristics (like input and output capacitance) can be swamped by the much larger capacitances in the bridge elements. Even so, to achieve a stability better than 1 part in 1,000 is an excellent result.

My only criticism of the circuit is perhaps a trivial one. It concerns the method used for amplitude stabilization. As Mr. Carpenter states, the low heater resistance of the indirectly-heated thermistor shunts the emitter load of V3 and absorbs considerable signal power, at the same time introducing a rather long time constant into the control circuit operation. Although a 100μF capacitor is used in the feedback circuit there is a phase shift of about 10 degrees in the feedback voltage due to the associated 100-ohm heater element. In my experience, the actual capacitance of large electrolytics is sometimes well below the nominal value and it tends to vary with time and temperature. This would cause minor frequency fluctuations in the oscillator output of the kind Mr. Carpenter has mentioned. I am almost certain that the use of an R_{53} or, perhaps, better, an R_{14}, directly heated thermistor would cure this trouble and also give a more effective control of amplitude.

There is, however, an entirely different way of using an indirectly heated thermistor for control purposes if the long time constant is acceptable. It involves the use of an extra transistor stage as a Class B amplifier in which the thermistor heater forms the collector load. A suggested circuit is shown in Fig. 1 in which V3 is the last stage of Mr. Carpenter's amplifier and V4 is the power amplifier stage used to energize the thermistor heater. The virtue of this arrangement is that V4 is completely outside the main amplifier and feedback loop.

The function of V4 is merely to supply heater power proportional to the main oscillator output power. A Class B amplifier is suggested because in this case there is no initial heating of the thermistor by a standing collector current in V4. Use of a Class C connection might be still better, for then there would be no thermistor heating until the oscillator output reached a definite threshold level sufficient to overcome the initial reverse base bias of V4. Where low distortion is important it is just possible that the non-linear input impedance of V4 might prove objectionable but this effect could be minimized by including a moderately high series resistance in the base circuit of V4.

When fixed frequency operation of an oscillator is required there is a great deal to be said in favour of

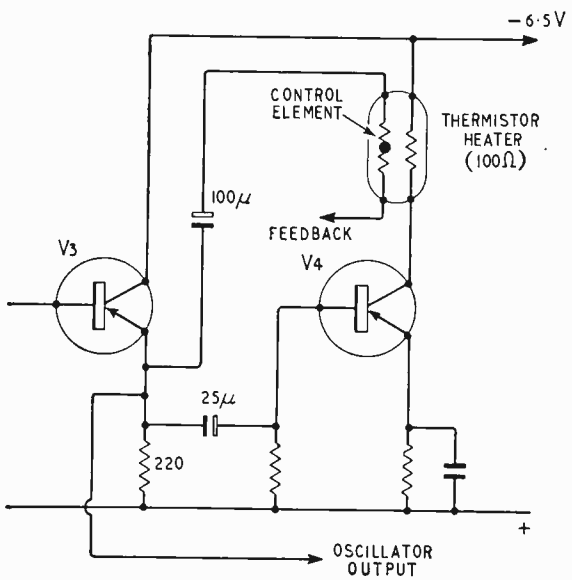

Fig. 1. Use of separate power amplifier for thermistor heater.

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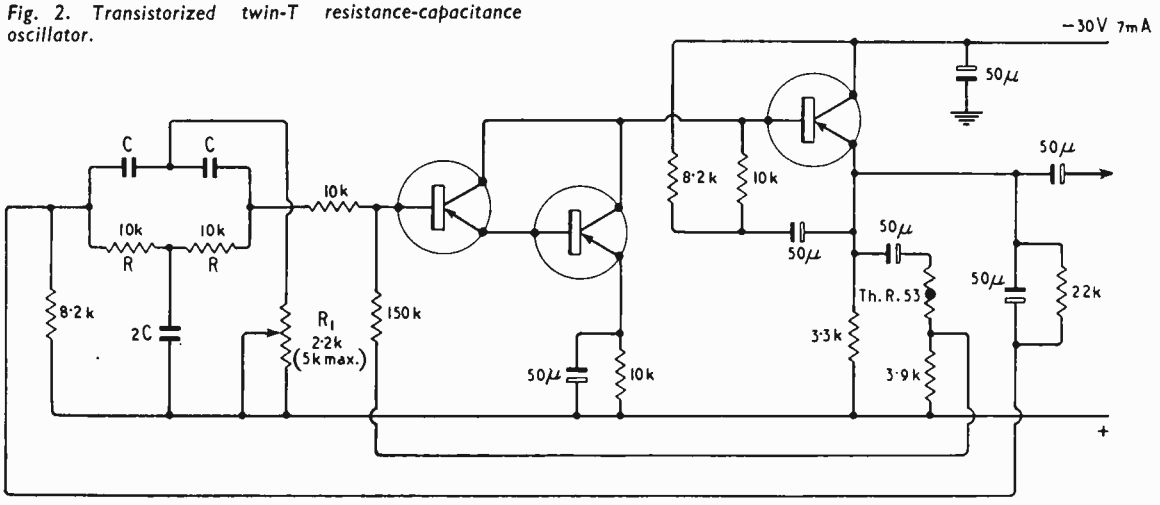
Fig. 2. Transistorized twin-T resistance-capacitance oscillator.



the twin-T RC circuit. This is in effect an equivalent of the Wien bridge which has a common input and output terminal. Reference (2) of my original article concerns a valve oscillator of this type, described by A. R. Bailey. The writer has developed a transistor version of Bailey's circuit, shown in Fig. 2. Space limitations preclude a full description of this arrangement but its salient features are the same as for the valve-operated version. Due to the use of high amplifier gain and a large amount of negative feedback the performance is outstanding in respect of low distortion and high frequency stability. For variable frequency operation the circuit is less attractive since it calls for the use of three ganged variable resistances one of which differs in value from the other two. Coarse changes of frequency are made by changing the capacitors C, C and 2C shown on the diagram. Mr. Carpenter may find the circuit useful for his timing standard. Regarding the super-alpha circuit used in my two designs, readers may care to note a brief reference to this compound-connected pair in the book "Transistor Circuit Engineering," (pp. 131-133), edited by R. F. Shea and published by Wiley.

In conclusion it may be of interest to mention a few points concerning the performance of the original Wien bridge oscillator. As regards its output level, measurements made on a version using a Standard Telephones Type R_{14} thermistor as TH.2 and a Type A as TH.1 show that the output is exactly the same over the two low-frequency ranges. On the highest frequency range this remains so up to a frequency of 13 kc/s. Between 13 and 20 kc/s the output falls slowly, dropping by 4 per cent (about one third of a decibel) at the highest frequency. Harmonic distortion is 1.2 per cent for 1 volt output at 1000 c/s.

There is a small change of frequency if a reactive load is connected across the output terminals. To remove this it would be necessary to use an emitter follower as a final output stage. Another OC 72 would be suitable for use in this position.

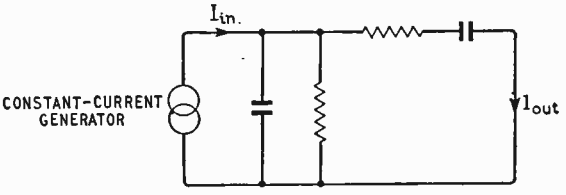
Finally, an earlier letter from Messrs. Evans and Williams, to which I replied in the October issue of *Wireless World*, cast some doubt on the performance of the super-alpha circuit at temperatures in excess of 30°C. This point has been checked by the crude expedient of holding a hot soldering iron near the casing of the first transistor V1 until it became uncomfortably hot to touch. Under these circumstances the total supply current dropped by about 10 per cent (due to the use of three d.c. coupled stages) but there was no noticeable change in the output level of waveform and only an insignificant change in frequency. No trouble from this source need be anticipated, using germanium transistors, at normal room temperatures. For use at very high temperatures it might be desirable to use silicon devices in this or any other comparable circuit.

Cheltenham. F. BUTLER

THERE is an alternative method of using RC tuning networks which avoids the difficulties arising from the low input impedance of a transistor which were pointed out by Mr. Butler in the August issue. It is to connect the networks as current attenuators rather than voltage attenuators. (See D. E. Hooper and H. E. Jackets, "Current Derived Resistance Capacitance Oscillators using Junction Transistors," *Electronic Engineering*, August 1956.)

To operate a Wien type network in this way, an input *current* is applied to what are normally the output terminals, and an output current is taken from what are normally the input terminals. The frequency at which there is no phase shift is unaltered, and the current attenuation is the same as the voltage attenuation of the usual connection.

When the network is used in this way, the input



current must be supplied by a high-impedance source, such as a common-base transistor, and the output current must be supplied to a low-impedance load: again, a common-base transistor is indicated, though a common-emitter stage can be made to serve. Under these conditions, the effect of the maintaining amplifier on the frequency of oscillation is small, just as it is in voltage-operated circuits when the input voltage source has a low impedance and the output voltage is supplied to a high-impedance load.

A difficulty of current operation is that the resistance element of the parallel arm forms the d.c. collector load of a transistor. The value of resistance which can be used is then limited by considerations of supply voltage. This problem can, however, be avoided by using an RL network instead of an RC network. The collector current then flows through an inductor, as shown in the diagram, and there is only a small voltage drop. With resistances and inductances of equal value the frequency of oscillation is $R/2\pi L$. A danger in RL circuits is that the self-resonance of the chokes might provoke oscilla-

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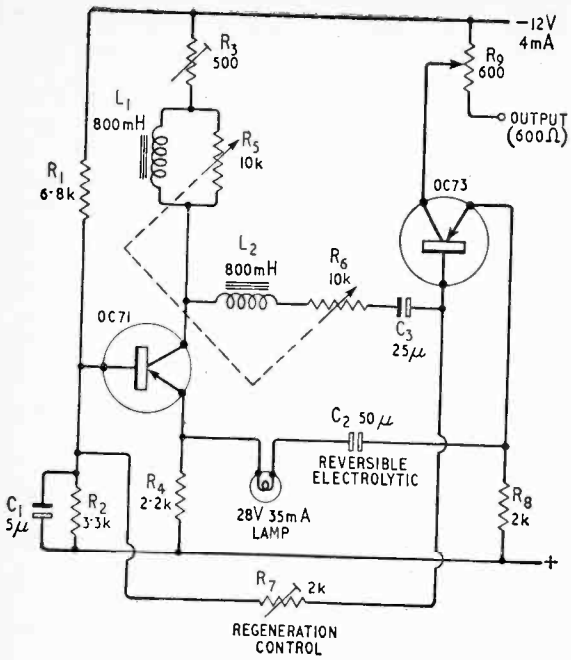


tion at the wrong frequency. In general, the risk can be reduced by making R as small as possible. When this is done, the resistance of the load, which comes in series with one of the R's, may not be negligible at the low-frequency end of a tuning range. It will affect both the frequency and the attenuation. One method of compensation is to add an extra resistance to the parallel arm (R_3 in the diagram). This trick is particularly useful in lamp-stabilized circuits, where variations in network attenuation are apt to have a bigger effect on the amplitude of oscillation than in thermistor-stabilized circuits.

The circuit shown is that of a "lash-up" constructed to see how and RL oscillator behaves in practice. It is not put forward as a proper design though, in fact, it exhibited reasonably good waveform and amplitude stability over the tuning range 100c/s—2kc/s.

Croydon. G. W. SHORT

FURTHER to the recent correspondence on transistorized Wien bridge oscillators, the accompanying circuit may be of interest.

By the use of n-p-n and p-n-p transistors in the amplifier it is possible to maintain correct bias conditions very easily, merely by biasing the first stage directly and the last stage by means of negative feedback.

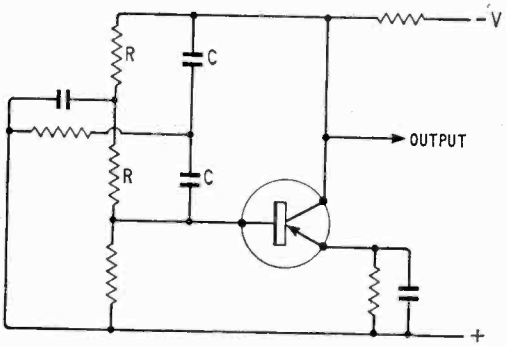
The optimum bias voltage at the point A is clearly half the supply potential and that at point B one-sixth, since the attenuation through the bridge is three times. R_7 and R_8 bias point B; R_1 and R_2 supply one-third of the amplifier output d.c. potential (i.e., one-sixth of the supply potential) as negative feedback to the emitter of the first transistor. The small potentials developed across R_4 and R_5 do not materially affect the biasing arrangements. With this arrangement R_5 and R_6 can be 100kΩ if desired

The association of a p-n-p and a n-p-n transistor for the second pair provides for handling a wide variation in load impedance without output amplitude variation.

As shown the circuit will oscillate from 2 to 20kc/s. For supply potential variation from 13 to 22 volts, or with the load impedance varying from ∞ to 100 ohms, there is negligible waveform distortion, or variation in output amplitude and frequency.

W. R. NAYLAND,
Chertsey. A. V. Roe and Co., Ltd.

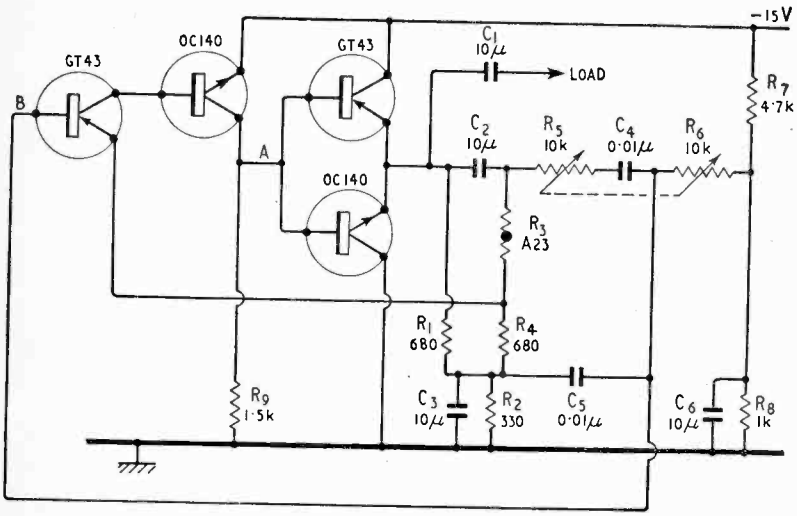
I FEEL that Mr. Carpenter (October issue) has chosen a circuit which is not really suitable for a time standard. In the first place three active elements are used to pro-



duce the necessary loop gain and phase shift to maintain oscillation; these are three items of variation and trouble. Secondly, the symmetrical case of the Wien bridge has poor selectivity and a strong dislike to a shunt impedance across the parallel RC in the network. However, the effect of this shunt impedance and the changing circuit parameters may be considerably offset by the introduction of the virtual earth system shown in the block diagram.

This refinement is still insufficient if a constant amplitude of output is required. Of course, this is due in the main to the thermistor.

With the preceding arguments I have been endeavouring to pave the way for a simple oscillating circuit briefly outlined in a paper in the section of the Proceedings of the I.E.E., at the Convention held on 25th May, 1959, and entitled "Discussion on Application: Linear Amplification and Oscillators." This oscillator consists of only one transistor and a selective network taking the form of the well-known parallel-T network.



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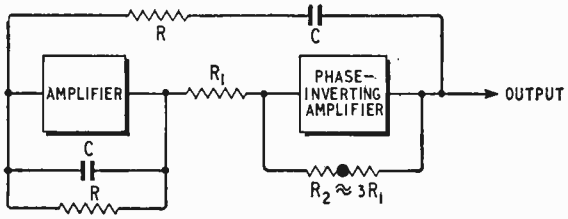


When this oscillator was subjected to temperature variation of 20°-80°C., it is stated that the frequency shifted by less than 0.1% and the output change was less than 1%.

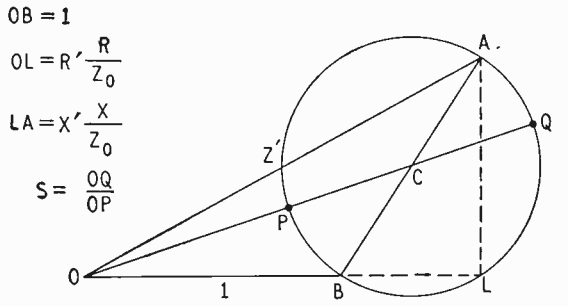
From these details it will be realized that the circuit has at least equalled the performance of the Wien bridge oscillator with considerable saving in component cost and greater reliability.

W. WOODMAN,
Nash & Thompson, Ltd.

Tolworth, Surrey.

Standing Wave Ratio

IN your June issue Mr. J. E. Robson describes a method of calculating the s.w.r. with the help of a quadratic



equation which on the face of it, appears to be frightening. Technicians possessing a pair of compass and a foot rule may find the following geometrical method much more instructional and useful in practical problems.

After normalizing the terminating impedance to $Z' = (R + jX)/Z_0$ a line OB equal to a unity is drawn to represent the normalized characteristic impedance. The line OA is then drawn to represent the normalized terminating impedance Z' with OB as the unity of scale. With AB as diameter the "reflection" circle is drawn as shown. Finally, O is joined to the centre of C of this circle, cutting the latter at P and Q. The s.w.r. is then given by

$$S = \frac{OQ}{OP}$$

This can easily be proved and, if required, Mr. Robson's equation for S obtained from the above construction without resort to complex variables and co-ordinate geometry.

Calcutta.

Q. C. GUPTA

Signal-flow Diagrams

IN the November issue S. R. Deards asks Thomas Roddam to try to justify the use of "signal-flow method" diagrams as superior to other methods. Thomas Roddam gracefully declines.

I would like to draw their attention to a book called "Introduction to Electronic Analog Computers" (Prentice Hall), signal-flow methods are described in application to computers, but it states that this method is useful not so much for *analysis*, as S. R. Deards thinks is its prime function, but for *synthesis*. It goes on to state that usually there is just not one good way, but several and this method allows one to decide which will suit the requirements. Where in the previous sentence I have used the word way, this applies to design, not s.f. methods.

Liverpool.

H. BAYLISS

PLEASE get it in your noddle
That matrix was *nodal*, not model.

THOMAS RODDAM

[We apologize to Thomas Roddam for the unlucky misspelling in line 13, right-hand column of page 562 of the previous issue. —ED.]

INDUSTRIAL GROUPS—3

TWO or three times within the last few months the initials E.M.I. have been in the news because of take-overs or rumours of takeovers by the Group, whose latest acquisition is Ardente and its subsidiary Ardente Acoustic Laboratories for the sum of over £600,000.

Electric and Musical Industries, Ltd., was formed in 1931 to merge the interests of the Gramophone Co. and Columbia Graphophone Co., and today the Group embraces nearly 50 companies in this country and abroad. Among the trade names used by the Group are His Master's Voice and Marconiphone (both also used under licence for certain products by the Thorn Group), Capitol, Columbia, Parlophone, M.G.M., Mercury, Emarcy and, of course, many beginning with "Emi."

The Group's interests in the radio and electronics field range from sound and television broadcasting transmitters and ancillary equipment and electronic computers to domestic receivers and sound-reproducing equipment. In the latter field the Group markets the Emisonic Orthotone products jointly with Clarke & Smith, of Wallington, Surrey.

The following companies are within the group which during the last financial year made a profit of £5,348,000 —some £400,000 more than the previous year's figure:—

Alpha Accessories
Ardente
Ardente Acoustic Laboratories
Capitol Records Inc.
Columbia Graphophone Co.
Columbia Graphophone Co. of Greece
Comercial del Gramofono Odeon, S.A., Spain
Compania del Gramofono Odeon, S.A.E., Spain
Davey & Moore
Electric & Musical Industries
Electric & Musical Industries (China)
Electric & Musical Industries (Ireland)
Electrola G.m.b.H., Germany
E.M.I.-Cossor Electronics
E.M.I. Electronics
E.M.I. Records
E.M.I. Sales & Service
E.M.I. (South Africa)
E.M.I. Suppliers (Sud America)
EMIAG. Verkaufs A.G. der E.M.I., Switzerland
Gramofon Limitet Sirketi, Turkey
Gramophone Co.
Gramophone Co., Pakistan
His Master's Voice (N.Z.)
Home Maintenance
Imudico A/S, Denmark
Industrias Electricas y Musicales Odeon, S.A., Argentine
Industrias Electricas y Musicales Odeon, S.A., Chile
Industrias Electricas e Musicais Fabrica Odeon, S.A., Brazil
La Voce del Padrone-Columbia-Marconiphone S.p.A., Italy
Les Editions et Productions Musicales Pathe-Marconi, S.A., France
Lindstroem, Carl, G.m.b.H., Germany
Marconiphone Co.
Morphy-Richards
Morphy-Richards (Astral)
Morphy-Richards (Sales & Services)
Musica Argentina e Internacional, S.R.L.
Nordisk Beka Record A/S, Denmark
Oesterreichische Columbia Graphophone G.m.b.H., Austria
Parlophone Co.
S.A. Gramophone N.V., Belgium
Skandinavisk Grammophon A/S, Denmark
Skandinaviska Grammophon A/B, Sweden
Skandinavisk Odeon A/S, Denmark
Skandinaviska Odeon A/B, Sweden
Ardmore & Beechwood (Belgique) S.A.
Ardmore & Beechwood (S. Africa)
Les Industries Musicales et Electriques Pathe-Marconi, France

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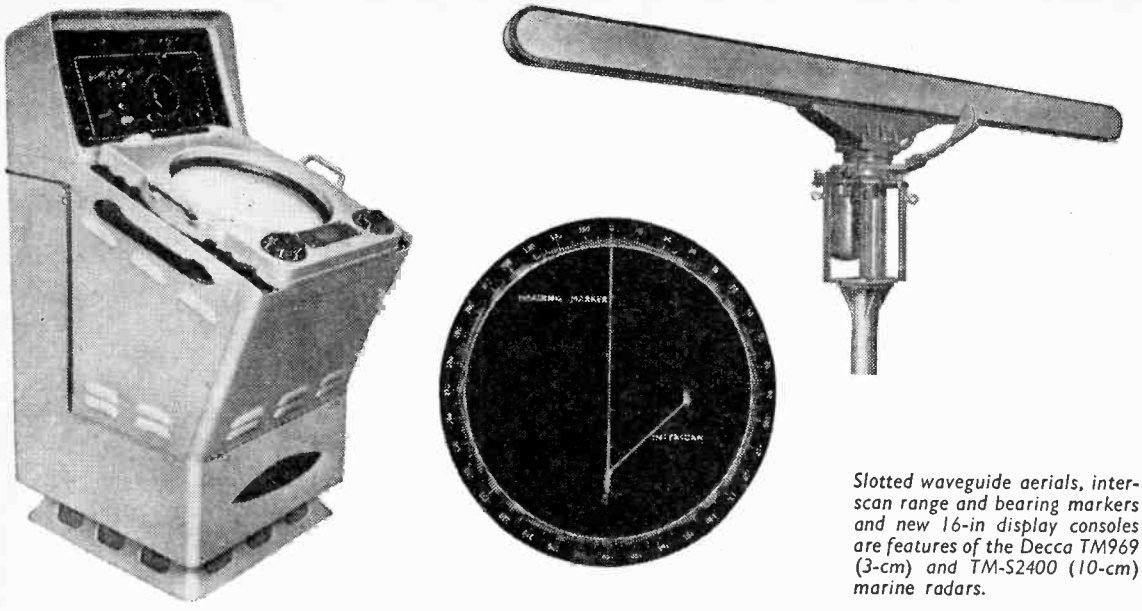


Slotted waveguide aerials, interscan range and bearing markers and new 16-in display consoles are features of the Decca TM969 (3-cm) and TM-S2400 (10-cm) marine radars.

NEW DECCA RADARS

ANALYSIS by Decca of more than 350 cases of collision at sea during the past five years has shown that more than 95% occur in congested shipping lanes and in pilotage waters, and the conclusion is drawn that the possession of radar is not in itself a guarantee of safety. Simple radar systems must be supplemented by facilities which will reduce the time and effort necessary for the interpretation of target movements on the p.p.i. display. A major step forward was taken with the introduction by Decca in 1956 of True Motion displays in which returns from buoys and coastlines remained stationary while "own ship" and other vessels under way were shown by moving spots leaving persistence trails to show their true motion. Even so the officers of the watch are often hard pressed in keeping under observation the changes of range and bearing of all the vessels in the vicinity which at any time might change to potential collision courses.

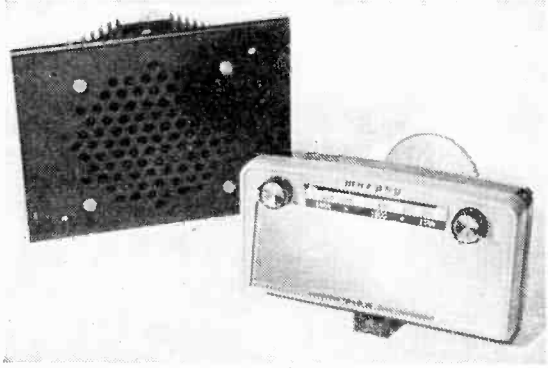
A most useful additional feature is now incorporated in the new Decca TM969 and TM-S2400 in the form of an interscan marker originating from "own ship" and variable in length and inclination, with direct reading of range and bearing from scales coupled to the controls. Any number of targets can be checked in rapid succession, and the use of a longer-persistence screen helps in showing change or—more important—lack of change of bearing with the minimum of effort.

In all, four new models have been added to the Decca range giving a choice of 12 types for varying requirements. One of these operates on 10cm (S-band) giving a high target/clutter ratio and better performance in the presence of precipitation. Two models have 16-in displays, and in all the new consoles particular attention has been given to the grouping of controls according to function and frequency of use. The display units hinge forward, giving instant access to circuits for ease of maintenance.

All the sets make use of narrow-beam slotted waveguide scanners with lower top weight and windage. The rotation rate has been increased to 20 r.p.m.

All-Transistor Car Radio

The new Murphy "Voxson" fully-transitorized, long- and medium-wave, twelve-volt car radio is made up of two separate units. One of these consists of a small cabinet *cum* rear-view car mirror (see illustration) which is attached via an adjustable ball and socket joint and suction cup to the car windscreen. This unit contains the volume, tuning and wave-change controls, the internal ferrite aerial, and the mixer, two i.f. and audio driver transistors. The 2½-watt audio output transistor, together with its associated heat sink, input and output transformers and 5-in loudspeaker form the other unit. This may be sited in any convenient position in the car, for example, under the dashboard. The total cost of both units is 20 guineas (including purchase tax).



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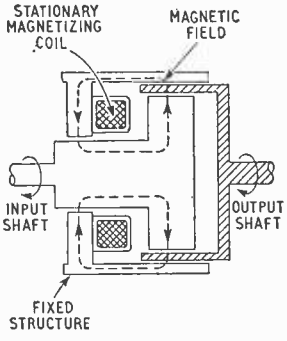
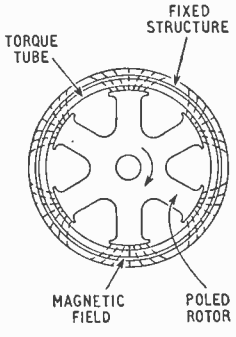
Technical Notebook

Transformer with a number of secondaries wound on separate parallel limbs is being developed by the G.P.O. With this arrangement, which is electrically equivalent to a number of ordinary two-winding transformers with their primaries connected in series, the parallel magnetomotive forces across each secondary are equal. The ampere turns are thus equal for each secondary so that the number of winding turns determines the secondary current rather than, as in a normal transformer, the secondary voltage. This new type of transformer is thus useful for feeding a number of current-operated devices such as transistors.

Peak Voltmeter in which the peak voltage storage capacitor is not, as is usual, charged directly from the input but rather from a flip-flop which is triggered from the input is described by R. P. MacKenzie in the June 17, 1960, issue of *Electronics*. In conventional peak voltmeters the indicated voltage may be too low at low input duty cycles because insufficient input current is available to charge up the storage capacitor to the full input voltage. In the circuit described by MacKenzie, as long as the voltage on the storage capacitor is less than the input voltage, their difference triggers a flip-flop which then for its unstable period charges the storage capacitor. Input voltage peaks thus continue to trigger the flip-flop to charge up the storage capacitor until the voltage on this capacitor reaches the input voltage and their difference is no longer capable of triggering the flip-flop.

Torque and Speed Control (TASC) units introduced by the Lowestoft Division of Pye Electric, Ltd., utilize inductive coupling to produce the control torque. The two cross-sectional diagrams show the construction of a typical unit. This consists of two independently rotating shafts and a stationary magnetizing control coil. The control input shaft is driven at a fixed speed and carries a poled rotor. This rotor is surrounded by an aluminium or copper torque tube attached to the control output shaft. (The larger units are driven in reverse, i.e. the input shaft carries the torque tube and the output shaft the rotor.) A fixed magnetizing coil concentric with the rotor is energized from a d.c. supply. This sets up a d.c. magnetic field (see diagrams) which streams out from the pole faces of the rotor and rotates with these poles. This induces currents in the torque tube and thus a magnetic field. The torque-tube and magnetizing-coil magnetic fields interact to produce a torque on the output shaft in the direction of rotation of the poled rotor. The magnitude of this torque is directly proportional to the value of the magnetizing coil current and is thus easily controllable. This torque is almost completely independent of the shaft speed. Three other advantages of this system of torque control are that no slip rings or brushes are used, that there is no physical contact between the input and output shafts except via the shaft bearings, and that the units may be stalled down without overheating. Applications of such units range over almost as wide a field as for electric motors.





"Change-of-State" Crystal Oven was described by D. J. Fewings (of Marconi's Wireless Telegraph Co., Ltd.) at the Brit.I.R.E. symposium on "Stable Frequency Generation" held last May. This type of oven utilizes the constancy of the melting point temperature of a substance to produce the required constant crystal temperature. Ideally such an oven would consist of the crystal imbedded at the centre of a sphere of a suitable solid substance which is in turn surrounded by a uniformly thick layer of the same substance in liquid form. The crystal and inner solid portion of the sphere will then eventually take up the melting-point temperature of the substance, and external temperature changes will then merely increase or decrease the amount of melted material, leaving the temperature nearly unchanged. The action of the oven depends on there being both solid and liquid layers of material present. The simplest practical way of ensuring this is to use a substance whose volume changes substantially on melting, together with an expansible closed container for the whole oven. The change in the volume of the container as the substance melts can then be used to operate the on/off switch for the oven heater, and this must uniformly heat the whole outer surface of the sphere. In practice the temperature control cannot be perfect because the necessary supports and connections to the crystal through the sphere provide paths along which heat can flow. However, a similar limitation applies to any type of temperature control. A suitable material to use is naphthalene, which has a melting point of 79.5°C and expands by rather more than 10% in volume on melting. In a practical case using such an oven an external temperature change of 14.5°C produced a crystal temperature change of only 0.084°C. For maximum crystal frequency stability it may be desirable to operate the crystal at the temperature at which its rate of change of frequency with temperature is zero. Crystals can be cut so that this temperature is within ±3°C of the melting point temperature of the substance used. Any remaining temperature difference could then be taken up by altering the melting point temperature by adding a suitable impurity to the substance. In the case of naphthalene anthracene is a suitable impurity: by adding up to 10% by weight of anthracene to naphthalene the melting point of the resultant mixture can be varied from 79.5°C to 76.4°C.

Low-frequency Noise can be obtained from high-frequency noise by sampling it at regular intervals and storing each sample until the next is obtained so as to produce a stepped noise output in which the step heights are equal to the sample amplitudes and in which steps occur whenever a sample is made. It can be shown that, if T is the time interval between successive samples, then 90% of the total power in the stepped noise output lies in the frequency range from 0 to 1/T. Although in this frequency range the

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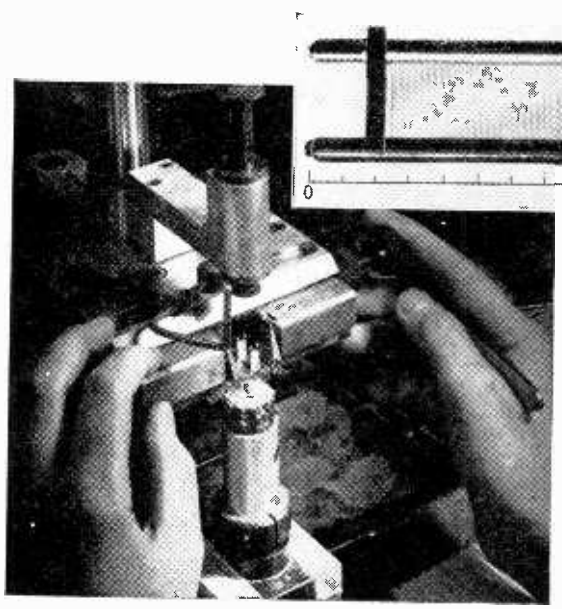
noise output decreases as the frequency increases from zero, the noise spectrum shape can be calculated and allowed for. A description of a low-frequency noise generator based on these principles is given by N. T. Slater in the August 1960 issue of *Electronic Engineering*.

Very-Low Frequency Propagation over long distances is being studied with the aid of a ship-borne 30MW (peak) pulse generator and 3,000-metre long helicopter-supported aerial according to an article by M. M. Newman *et al* in the July 22 issue of the American journal *Electronics*. With a transmission frequency of 20kc/s a signal strength of the order of 100μV/metre can be produced at a distance of 10,000km (6,200 miles) by means of this generator and aerial.

Optical Maser oscillator utilizing the fluorescence of synthetic ruby has been developed by the Bell Telephone Laboratories. The ruby is "pumped" with green light to produce "stimulated emission" at the frequency of the fluorescent colour (red). The ruby, which is the form of a rod 1½in long with a diameter of ⅛in, is held in the centre of a spiral photoflash lamp. The green component of the light from this lamp excites the chromium impurity atoms in the ruby. The excited chromium atoms at first rapidly relax from the excited quantum energy level to a metastable intermediate quantum energy level without emitting any radiation. The chromium atoms then rather more slowly relax from this metastable level to their original level, emitting red fluorescent light in the process. The fluorescent light first emitted stimulates the chromium atoms still in the metastable state to radiate at the fluorescent frequency, provided that the fluorescent light stays long enough in the ruby rod to provide sufficient stimulation. This proviso is satisfied by polishing the ends of the rod until they are exactly flat and parallel, and then partially silvering them. Some of the fluorescent light which is emitted within a small angle about the rod's axis is then reflected back and forth between the silvered rod ends for long enough to stimulate emission. It is this stimulated emission which distinguishes the action of this maser from ordinary spontaneous fluorescence. This stimulation process ensures both that the stimulated radiation is all emitted within a small angle about the rod's axis (an angle of about one-tenth of a degree was actually measured), and that the stimulated radiation is coherent (i.e. has the same phase at all points on either end of the rod). Coherence was proved by observing interference between the light from two fine parallel slits in the silver. Coherence has not hitherto been achievable with a light source. As with radio waves, it makes possible the communication processes of modulation, amplification and detection. Another property of the emitted light resulting from stimulation is that its bandwidth is only about one-sixtieth of that of normal fluorescent light, and it is hoped to achieve an even narrower bandwidth. This narrow-bandwidth property, as well as the fact that the light is all emitted within a very narrow angle, gives rise to a very bright source, in fact more than a million times brighter than the sun. This brightness should also be useful for communication purposes. The light from this maser has in fact been seen twenty-five miles away. With the present device, maser action can be sustained for about a millisecond at a time. During this time several hundred bursts of radiation spaced a few microseconds apart are produced, each lasting for about a microsecond. The stimulated emission is produced in pulses probably because, when stimulated emission occurs, it decreases the number of atoms in the metastable state so rapidly that the flash lamp is not bright enough to maintain a sufficient number of atoms in the metastable state to allow maser action to continue. Maser action then ceases, but commences again when the flash lamp has had time to produce a sufficient number of atoms in the metastable state. This alternate decrease and increase in the number of atoms in the metastable state then produces pulses of light.

Crystal-Frequency Variation with temperature can be compensated for (according to a letter from E. A. Gerber in the February, 1960 issue of *Proc. I.R.E.*) by applying a temperature-dependent force to the crystal so as to produce an opposite frequency change. A bimetal strip bearing on the crystal can be made to provide a suitable temperature-dependent force and, according to the direction of this force, a positive or negative compensating change in the crystal frequency can be produced.



Frame Grid Valve Manufacture

THE mechanical precision necessary for the handling of the fine wires (10 microns in diameter) and the assembly of frame grids with grid-cathode spacings of the order of 50 microns has called for the development of a completely new range of electrode winding and welding machines, and of assembly methods comparable with those in the watch-making industry. The accompanying photographs show a typical frame grid, and the assembly jig for the two grids of the PCC89 cascode r.f. amplifier, one of the four new high-slope television valves now in quantity production at the Mitcham Works of Mullard Ltd.

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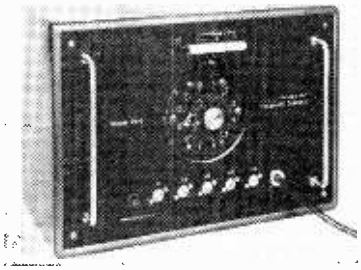
Manufacturers' Products

NEW ELECTRONIC EQUIPMENT AND ACCESSORIES

Precision V.H.F. Frequency Standard

A COMPACT and portable (but mains-operated) frequency standard for accurately checking the operating frequencies of mobile, as well as of fixed, v.h.f. radio transmitters has been introduced by Wayne Kerr Laboratories, Ltd., Chessington, Surrey. Known as Model FS100 it consists of a crystal-controlled oscillator, three



Wayne Kerr Model FS100 crystal-controlled frequency standard for testing mobile v.h.f. transmitters.

frequency multiplier units, wide-band detector and a.c. mains power unit for 110-130V or 190-240V, 40-60c/s.

The oscillator can be switched to operate with any one of 12 quartz crystals mounted in thermostatically controlled, plug-in ovens, two crystals being mounted in a single oven. Crystals for operation on fundamental frequencies within the range 7.5 to 9.7Mc/s can be used and each multiplier unit covers a specific part only of the total frequency coverage. For example, the Band I multiplier covers crystal frequencies of 7.5 to 8.17Mc/s giving final outputs on 3, 9 and 18 times as required of the frequency of the crystal selected. Between them the 3 multipliers will provide spot output frequencies of from 22.5 to 175Mc/s with an accuracy of 3 parts in 10^6.

Crystals are selected by a rotary switch mounted in the centre of the instrument panel, while multipliers are selected by means of push-buttons.

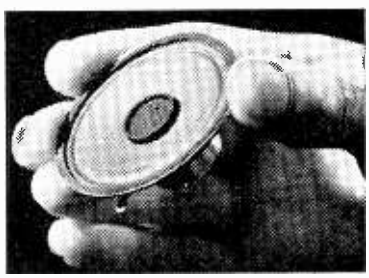
Signals from the transmitter to be tested are fed into the test set and the crystal and multiplier switches set to the transmitter's operating frequency and the output then checked for zero beat. The test set measures 13¼in wide, 9in high and 8¼in deep and weighs 16lb complete.

New Plessey 2¼in Loudspeaker

A NEW 2¼in diameter loudspeaker for use in modern miniature transistorized receivers has been introduced by The Plessey Company Ltd., Ilford, Essex.

The magnetic circuit uses a new constructional technique to enable the overall depth to be reduced to a minimum—a rod magnet being inserted into a split aluminium ring which is fitted into an accurately machined yoke. This design arrangement gives a compact, robust motor unit without the use of magnet assembly bolts.

The 2¼in diameter loudspeaker is available with a low impedance voice coil (8/10 ohms) for use with a matching transformer or alternatively with high impedance coils for direct connection into transistor circuits.



Plessey 2¼in loudspeaker has a depth of only 0.83in.

20W Transistor Amplifier

THE Type TR/2 transistor amplifier is a compact unit measuring 8in × 6in × 3in (high) and capable of delivering 20W peak a.f. output to 3.5-Ω or 15-Ω loudspeakers. It is intended primarily for portable and mobile PA applications and operates from a 12V d.c. supply, imposing a no-speech load of 0.25A and a mean working load of 1A.

It employs 5 transistors, one protective diode and a lightweight moving-coil microphone fitted with a press-to-talk switch, thereby ensuring maximum economy in l.t. consumption during intervals in operation. The price is £31 10s 0d including microphone.

Although a non-reversible l.t. input socket is fitted, a safety circuit to prevent damage to the transistors,

R.E.E. 20W transistor PA amplifier. The key gives a good indication of its size

should the battery polarity be reversed, can be included at a small extra charge.

Further details can be obtained from R.E.E. Telecommunications Ltd., Telecomm Works, Market Square, Crewkerne, Somerset.

V.H.F. Marine Radio-telephone

SHOWN in the illustration is the latest Pye marine v.h.f. radio-telephone for shipborne use. It is suitable for use in large or small vessels having 100-150V or 190-240V, 40-60c/s a.c. supplies and operates on the frequencies allocated for inter-ship, ship-to-shore, harbour and docking telephone communications.

The equipment allows for operation on 28 channels in the international marine v.h.f. band, 9 channels being for single frequency simplex and 17 for duplex working. The 28 channels are provided by 18 crystals.

Frequency modulation is employed and the transmitter power output is 20W. The Type PTC8306 equipment complies with the Hague and British G.P.O.

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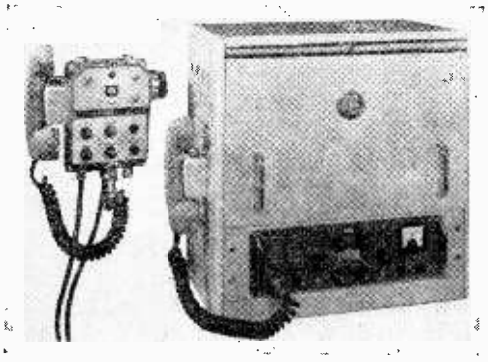


Pye marine V.H.F./F.M. radio-telephone Type PTC8306. The remote control unit is on the left.

specifications for this type of equipment so it is suitable for international use as well as for use in home waters. Provision is made for full remote control over lines up to 200ft in length.

The makers are Pye Telecommunications Ltd., Newmarket Road, Cambridge, from whom further details can be obtained.

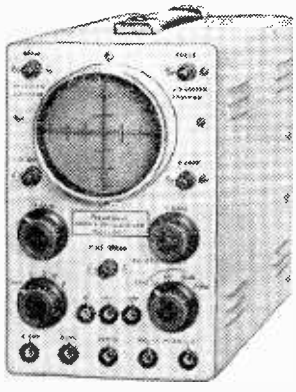
Oscilloscope Kit

THE Heathkit Model OS-1 enables an oscilloscope to be built with a Y-amplifier sensitivity of 14mV/cm and a response within ±3dB from 10c/s to 2.5Mc/s. The X-amplifier sensitivity is 1.4V/cm and its response within ±3dB from 15c/s to 500kc/s: the time-base range is from 15c/s to 150kc/s approximately. A 50c/s calibration source provides a peak-to-peak potential of 1, 10 or 50V to an accuracy of ±10%. A printed circuit board helps to ensure that all kits are wired exactly as required. The manual provided includes step-by-step wiring instructions, pictorial diagrams, and a circuit description and diagram. Operating voltages are also given. The Kit costs £18 19s 6d and is available from Daystrom Ltd., of Gloucester.

Transistor Oscillators

WITH the new Levell Electronics Types TG150 and TG150M battery oscillators sine waves can be produced at any frequency between 1.5c/s and 150kc/s and with any amplitude up to 2.5V into 600Ω. The harmonic distortion is <0.3% between 50c/s and 15kc/s and <1.5% below 50c/s and above 15kc/s. The frequency changes by <0.3% at 1kc/s for a 30% fall in the supply voltage and by <0.05% per °C temperature change. The output level varies by <0.1dB over the whole frequency range, by <0.05dB for a 30% fall in the supply voltage, and by about −0.02dB per °C temperature change. A thermistor stabilized Wien bridge circuit is used in these oscillators. The Type TG150M is fitted with a calibrated output meter and costs £36, a version of this oscillator without the output meter—the TG150—costs £27. These instruments are manufactured by Levell Electronics Ltd., of 10-12 St. Albans Road, Barnet, Herts.

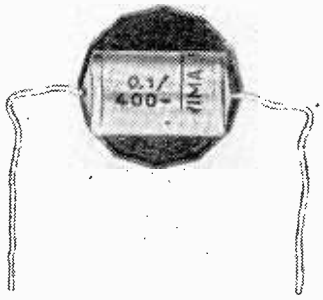
Right.—Levell Electronics Transistor Battery Oscillator. Type TG15M.



Left. Assembled Heathkit Model OS-1 oscilloscope

New Plastic Foil Capacitors

TROPYFOL capacitor is the name given to a new type of miniature capacitor which utilizes an aluminium-coated polyester foil dielectric rolled and impregnated in a plastic resin with axial end wires. They are available in 125V and in 400V types, the former with capacitance ranging from 0.01μF to 1μF and the latter from 0.001μF to 1μF. A 0.001μF capacitor in the 125V type measures 4.5mm in diameter and 12mm long and a 1μF size for 400V working is 13mm in diameter and 24mm long (0.5in × 0.9in approx.).



Tropyfol 0.1μF, 400V miniature capacitor.

Insulation resistance is said to be not less than 2,500 sec (MΩxμF) while in some cases it may reach 50,000 sec.

Supplies are available to the radio and electronics industries and further details can be obtained from Waycom Ltd., Empire Buildings, Duke Street Hill, London, S.E.1.

Very Low Temperature Coefficient Resistors

BY combining two wires of different temperature characteristics Alma Components have produced a range of precision wire-wound resistors with the remarkably low temperature coefficient of less than 4 parts per million per degree C. The wires are wound on non-hygroscopic ceramic formers encapsulated in a sealing resin. Three sizes are available rated at 1w (Type C), ½w (Type C2) and ¼w (Type C4) with resistance values of 100Ω to 300kΩ, 100Ω to 120kΩ and 100Ω to 80kΩ respectively. The winding is sectionalized with adjacent sections wound in opposite directions. Standard tolerances are 0.1%, 0.25%, 0.5% and 1%.

Further details can be obtained from Alma Components Ltd., 551, Holloway Road, London, N.19.

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Principles of

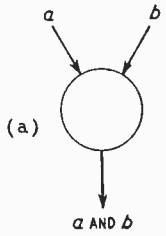
Digital Computers

By D. S. WILDE,
B.Sc., A.M.I.E.E., Grad. Inst. P.

2.—ARITHMETIC AND CONTROL CIRCUITS

IN the previous article methods of storing binary information in a digital computer were outlined. These digit patterns represent numbers and instructions and the function of the arithmetic unit (sometimes called the accumulator—Babbage called it the "mill") is to perform additions, subtractions etc. with these numbers, as dictated by the instructions.

A group of digits may be delivered from a store one after the other on a single channel (serially) or simultaneously with a separate channel for each digit (in parallel) and the choice must be made in the design of the computer between increased speed and economy of equipment. For example, a serial adder will take $nt + t$ periods to add two n-digit binary numbers occurring as pulse trains of period t (the final t is for the last carry). Parallel addition will only take $2t$ periods but there must be one adder per channel i.e. n adders.



a	b	a AND b
0	0	0
1	0	0
0	1	0
1	1	1

(b)

Fig. 3 (a) Symbolic AND gate. (b) Truth table for the AND gate.

It is possible to effect a compromise between both extremes and the Ferranti Mercury computer is an example of this. Access to the storage elements is parallel, the parallel digits are turned into serial form and dealt with by fast serial circuits.

Whilst the present tendency is for fully parallel machines, it is possible that with new types of storage operating extremely rapidly—perhaps up to 100 Mc/s—we may see a return to serial techniques and consequently smaller computers.

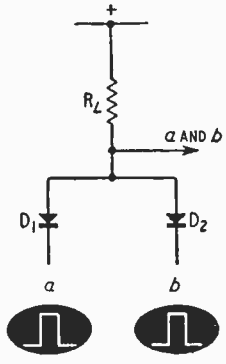
It has already been shown that the fundamental arithmetic operation is subtraction and that all the other common functions can be derived from it. Subtractions only occur about one-third as frequently as addition in most programmes, and since an addition operation performed in a subtracter would require two stages [$0-b$, $a-(0-b)$] a subtracter is an uneconomical component. An adder is always provided and a complementer then enables subtractions to be performed by complement addition.

Binary addition can be reduced to a set of logical (or Boolean) operations and these operations are performed by extremely simple electronic circuits. Given the necessary reduction details a binary adder can be easily synthesized, so can other functional units.

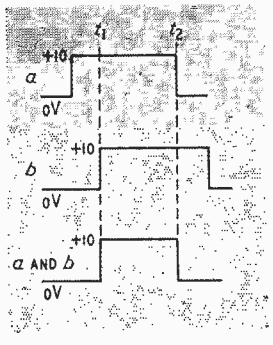
There are a variety of logical operations although only two are essential and the others can be derived from them. It is much more convenient however to use three basic logical functions, these are AND, OR, and NOT, and they are almost self explanatory.

The AND gate is shown symbolically in Fig. 3(a) and both input a AND input b must be present[9] to cause an output from the gate. There are four possible combinations for the conditions of a and b and these are shown in the "truth table" of Fig. 3(b) (1 signifies presence, 0 signifies absence). Only when $a = b = 1$ do a and $b = 1$ and hence the AND operation is equivalent to the algebraic product ab.

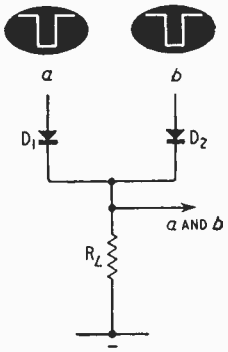
The circuit for such an AND gate is shown in Fig. 4(a) and in this case the inputs must be positive going and the supply rail is a positive rail. Suppose, in a practical case, that the supply is 100 volts and a and b



(a)



(b)



(c)

Fig. 4 (a) Circuit of an AND gate for positive-going inputs. (b) Input and output pulses for the AND gate for positive-going inputs of Fig. 4(a). (c) Circuit of an AND gate for negative-going inputs.

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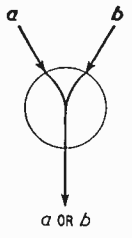
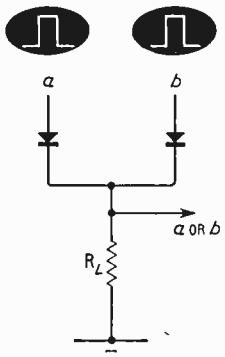


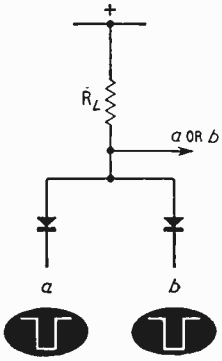
(a)

a	b	a OR b
0	0	0
1	0	1
0	1	1
1	1	1

(b)



(c)



(d)

Fig. 5 (a) Symbolic OR gate. (b) Truth table for the OR gate. (c) Circuit of an OR gate for positive-going inputs. (d) Circuit of an OR gate for negative-going inputs.

inputs are normally at earth potential. Both diodes will be conducting and if R_L is considerably higher than the forward resistance of the diode then the voltage drop across the diode will be negligible compared with that across the resistor. The output is therefore also at earth potential. If input *a* moves 10 volts positively then diode D_1 will become cut off. The diode D_2 remains conducting and hence its anode (and thus the anode of D_1) stays at earth potential. Thus although input *a* moves positively the output remains at earth. Only when *a* and *b* inputs move 10 volts positively together will the output rise by 10 volts. Fig. 4(b) makes this clear. For $t < t_1$ only input *a* moves positive and the output does not change. For $t_1 < t < t_2$ both *a* and *b* are positive and there is an output. After t_2 only *b* is now positive and there is no output.

A second type of AND gate is shown in Fig. 4(c) and this gate operates when inputs *a* and *b* are negative-going pulses, and the supply rail is negative. Only when both inputs move negatively together will the output move negatively.

Fig. 5(a) shows an OR gate symbolically. Its name suggests that input *a* OR input *b* being present will operate the gate and cause an output. The "truth table" is in Fig. 5(b) and the algebraic equivalent of *a* OR *b* is $a + b - ab$ and this can be checked by substitution of possible values from the "truth table". The OR operation is inclusive since both *a* and *b* being present together operate the gate.

The electronic OR gate for positive-going pulses is shown in Fig. 5(c) but in this case R_L is taken to a negative rail. Either input moving positive will cause the output to move positive. An OR gate circuit for negative-going pulses is shown in Fig.5 (d). An OR gate for positive-going pulses is identical to an AND gate for negative-going pulses; similarly an AND gate for positive pulses is the same as an OR gate for negative-going pulses.

NOT *a* is a very simple logical function and is algebraically equivalent to $1 - a$ since if $a = 1$, NOT $a = 0$ and if $a = 0$, NOT $a = 1$.

Electronically this corresponds to a voltage inversion and a simple valve circuit is shown in Fig. 6.

If *a* is a negative-going pulse from earth potential then the pentode will be bottomed when its grid is at earth and will be cut-off when the grid goes negative. The anode potential will be low when the valve is bottomed and high when cut off. The anode excursions are applied to the potentiometer chain R_1 and R_2 which can be chosen in conjunction with V_2 to ensure that as the input *a* moves from earth negatively the output NOT *a* moves from a negative potential to earth. D_1 merely serves to prevent the output going above earth potential.

In early computers the diodes in AND or OR gates were thermionic and valves were used for inversion circuits. The diodes are now semi-conductor types and the inversion circuits are transistors.

Using only these three circuits, AND, OR and NOT, it is possible to construct a binary adder. There is an additional circuit required for a serial adder however, this is a delay.

First it is necessary to establish the "truth table"

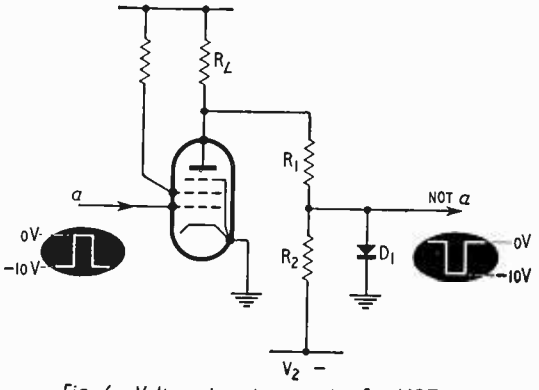


Fig. 6 Voltage inverter circuit of a NOT gate.

a	0	0	0	0	1	1	1	1
b	0	0	1	1	0	0	1	1
c	0	1	0	1	0	1	0	1
ANSWER	0	1	1	0	1	0	0	1
CARRY	0	0	0	1	0	1	1	1
a OR *b* OR *c*	0	1	1	1	1	1	1	1

Fig. 7 Truth table for binary addition.

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for binary addition (Fig. 7). There will be three digits to add; these will be from the addend, the augend and the carry digit resulting from the addition of the previous digits. With three inputs, each of which can be either 1 or 0, there are eight possible combinations of inputs to the adder. These are shown in the "truth table" together with the answer (1 or 0) and carry (1 or 0) which must result.

Suppose that the three inputs are applied to an OR gate. Whenever there is a 1 among the inputs there must be a 1 in the output. If all eight combinations are tried the output agrees with the required answer except when two of the inputs are 1's together. (The output will be 1, the correct answer should be 0.) There must be an additional set of circuits to inhibit the output of the OR gates under these conditions. In other words the required answer is (a OR b OR c) AND NOT [(a AND b) OR (b AND c) OR (a AND c)]. The logical diagram now looks like Fig. 8.

The circuit combination responsible for inhibiting the output when only two 1's occur can also be used to generate the carry pulse since there must be a carry developed when two (or three) ones are present. Unfortunately the inhibit gates will inhibit the output when three 1's are present at the input and no answer digit will appear though one is required. A three-input AND gate is included therefore and its output is applied to a two-input OR gate whose second input is the previous output.

This logical configuration now satisfies all eight conditions of input giving the correct answer digit and the correct carry (Fig. 9). The carry digit is applied to a delay of one digit period and is fed back to the input, arriving in the next most significant place.

The same logical considerations apply to adders for a computer working in the parallel mode. The carry digits in this case are not delayed to a more significant time period but are applied as third inputs to a more significant adder.

There are other forms of binary adders and a binary subtracter can be developed in a similar way. The final step in the design is the substitution of circuit elements for logical symbols, and these have already been shown.

Whatever alternative solutions are found to the design of a specific logical circuit, Boolean algebra can provide a simple check that the circuit performs the function required. In the example chosen of the adder circuit the logical function is written as

$$\text{Answer} = (a \text{ OR } b \text{ OR } c) \text{ AND NOT } [(a \text{ AND } b) \text{ OR } (a \text{ AND } c) \text{ OR } (b \text{ AND } c)] \text{ OR } (a \text{ AND } b \text{ AND } c)$$

$$\text{Carry} = (a \text{ AND } b) \text{ OR } (b \text{ AND } c) \text{ OR } (a \text{ AND } c)$$

Previously it has been shown that a AND $b = ab$, a OR $b = a + b - ab$ and NOT $a = 1 - a$. Algebraic substitutions can thus be made. Working the final expressions is rather tedious but a glorious simplification is available because $a^n = a$ (since $a = 1$ or $a = 0$). If the above substitutions are made then

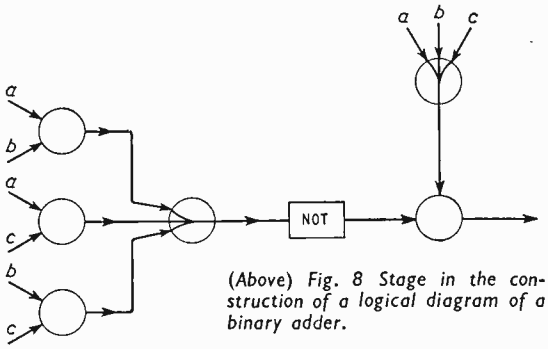
$$\text{Answer} = (a + b + c) - 2(ab + ac + bc) + 4abc$$

$$\text{Carry} = ab + ac + bc - 2abc$$

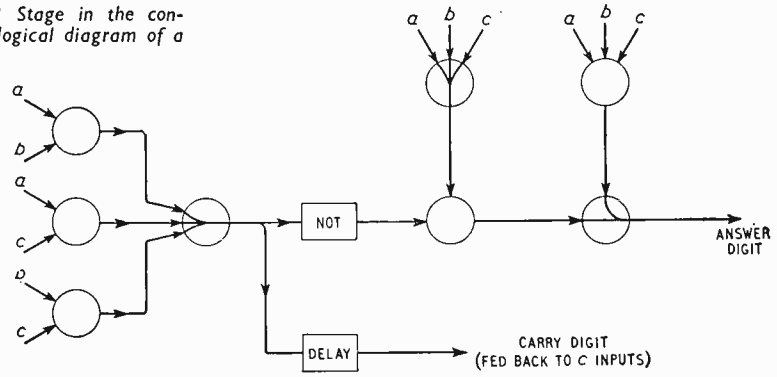
and any binary adder must satisfy these conditions.

Control Unit.—The control part of the computer is responsible for reading and sequentially obeying instructions which are held in the stores. Generally an instruction is divided into two parts, a function section (add, subtract, multiply, input, output, etc.) and address section (locating in the store the number that the function is to be performed on).

In the case of a serial computer the instruction will emerge from the storage as a series of pulses. The pulse pattern is a code and must be decoded to operate various gates in the computer which allow numbers to be routed to the various parts of the computer (the arithmetic units, the output units, another store location, etc.). Since only one pulse occurs at a time a pulse pattern can only be decoded if the individual pulses are staticised ("remembered") and all compared together after the last one has occurred. The staticisor most commonly used is the well-known bi-stable element (other names used are Kipp Relay, flip-flop, multivibrator, Eccles-Jordan circuit, and toggle). The circuit consists of a pair of valves (or transistors) cross connected from anode to grid (or collector to base). A pulse input applied to one grid causes one of the valves to conduct, the second to cut



(Above) Fig. 8 Stage in the construction of a logical diagram of a binary adder.



(Right) Fig. 9 Logical diagram of a binary adder giving both answer and carry digits.

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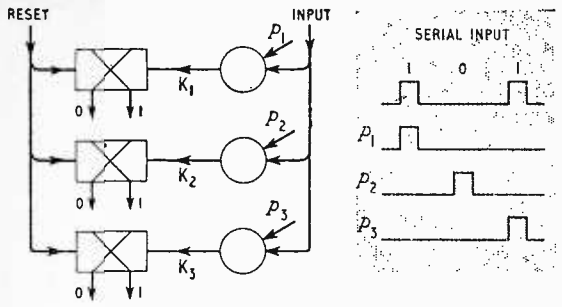

(a) (b)

Fig. 10 (a) Staticisor (store) for serial input train of three binary pulses. (b) Serial input train and clock pulses for storing 101 in the staticisor of Fig. 10 (a).

off and this state is maintained until a trigger pulse is applied to the other grid when the circuit changes state.

A set of three bistable elements is shown symbolically in Fig. 10 and the serial pulse train is applied to them via two-input AND gates. The second inputs to the gates are single clock pulses; they behave in the manner of a strobe pulse and p_1 is coincident in time with the first pulse of the pulse train, p_2 with the second, and p_3 with the third[10]. In the case of a pulse train of 101 the first bi-stable element will receive a trigger since p_1 and the first 1 of the pulse train coincide and there will be an output from the AND gate. p_2 coincides with a 0 (no pulse) and there is no output from the gate, hence the second bi-stable element is not triggered. The third one is triggered, p_3 coinciding with the third place. The pulse pattern 101 has now been stored (or staticised) and the bi-stable elements are said to be in the 1, 0, and 1 state respectively.

With three bi-stable elements there are eight possible combinations in which they can be set. These are, of course, determined by the input pulse train and could represent eight possible functions.

It is necessary to decode these eight possible states to uniquely define each of them. Fortunately this is an easy matter for a decoder is merely an AND gate; eight three-input AND gates are necessary to decode three binary digits. These are shown in Fig. 11. The first digit has its inputs connected to the 0 side of the bi-stable elements. For this type of AND gate, positive inputs are required and the 0 side of a bi-stable element is defined as that side being at a positive potential when no input trigger has been received. The 1 output must therefore be at a negative potential under these conditions. Thus if the 0 side of the three bi-stable elements are connected to the first decoding AND gate and no input triggers have been received the output of the decoder will be positive. For the second gate the 0 sides of two of the bi-stables are inputs and the 1 side of the third bi-stable is the third input. If the pulse pattern 001 is now staticised the second decoder has an output, since both 0 inputs are positive (the bi-stables have not been triggered) and the 1 input is positive (the third bi-stable has been triggered and now the 1 output is positive, the 0 output negative). This method of decoding can be extended to the remaining six combinations of digits and whatever the input pulse train may be one, and only one, of the eight decoders will register an output.

Simple Computer.—With storage, an arithmetic unit, and a control unit we have enough components to construct a simple digital computer. In addition to its logical circuits there must be a timing cycle generated to ensure sequential operation.

Associated with the store are its address decoders. These behave exactly in the manner of function decoders but select the location of a number or instruction in the store, and in this example the store may be of the electrostatic or magnetic core type, not the delay-line type.

The control unit has a two-line store and an adder in its read/write loop. Associated with it are function and address staticisors.

The arithmetic unit consists of a store acting in conjunction with adders and subtracters.

There are six instructions in the simple programme to be performed and the computer can perform four functions. These are defined by 00 (ADD), 01 (SUBTRACT), 10 (RETURN TO STORE), and 11 (STOP). The store has eight lines in it and the eight addresses require three digits to specify them.

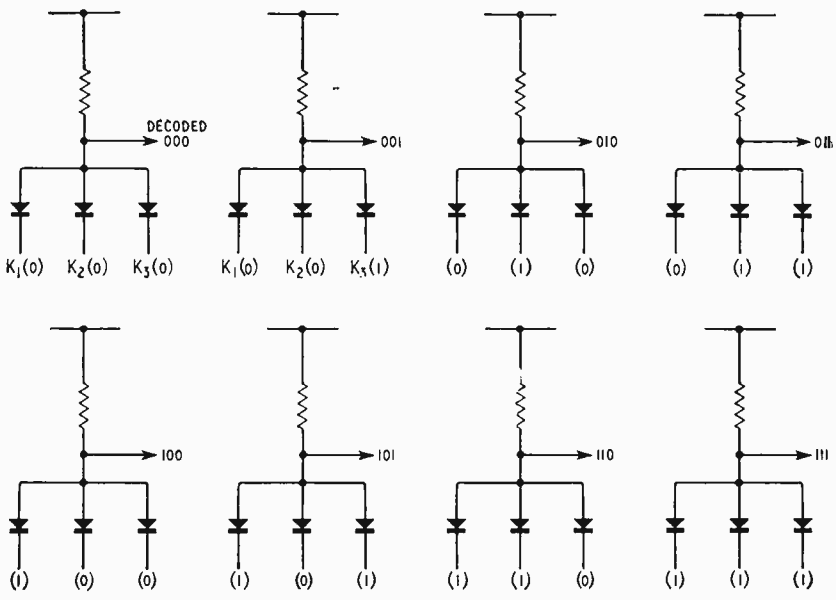

Fig. 11 Set of eight AND gate decoders for the eight possible states of three bi-stable elements.

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Instructions are therefore five digits long.

The cycle of operations can be defined by four time periods T_1, T_2, T_3, T_4 and one instruction is selected and obeyed during each cycle of four periods. What happens in each time period is detailed below.

T_1: add unity to the top line of the control store. This control address initially has zero stored in it and its job is to read instructions from the main store one by one. During T_1 the top line is read from the control store into the control adder through the STOP gate, which is open unless a STOP instruction is being obeyed. The number which emerges from the adder is used to set up the address and function staticisors and it also replaces the old number in the control store top line.

T_2: in this period the contents of the store address specified by the control unit in T_1 will be read out and transferred to the second line in the control store. This is the instruction which is to be obeyed.

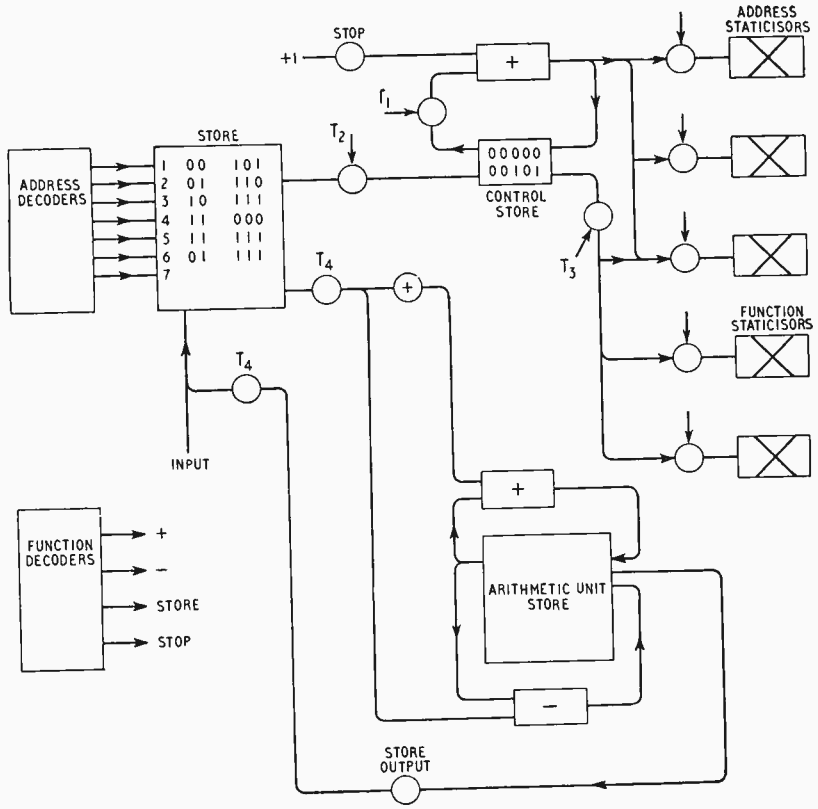

Fig. 12 Simple computer.

T_3: the instruction in the second line of control is now read out to the function and address staticisors which are set up.

T_4: the number specified by the setting of the address staticisors is read out of the main store and is operated on in the manner determined by the function staticisors.

To show how this sequence of operations works in practice the simple programme shown in Fig. 12 will be followed through. The computer, which has four functions and an 8-address store, initially starts with the programme in the main store and the control store and arithmetic unit store empty. In the first T_1 period 00000 is read from the control store, 1 is added to it, and the address staticisors are set to 001. The first two (function) digits (00) are not set up since the function staticisors are only set in period T_3. During T_2 line 001 is read from the store; its contents (00,101) pass through the gate marked T_2 into the control store. This is the first instruction and the code 00,101 is interpreted by the computer as "take the number stored in line 5 (101) and add it (00) to the arithmetic store contents".

This instruction is staticised on the function and address staticisors in T_3 and the function staticisor decoders open the gate marked + and the address staticisor decoders select line 5.

The contents of line 5 (the number 11111)* is routed to the arithmetic unit adder and arrives simultaneously with the read-out contents of the store. Addition is performed and the answer is stored. The first instruction has now been completed and the cycle repeats for the second instruction (01, 110). This can be interpreted as "subtract from the arithmetic unit total (01) the number stored on line 6 (110)". In T_4 of the second cycle the number on line 6 (01111) is fed to one input of the subtracter through the gate marked —. The number in the arithmetic store (11111) is read into the subtracter at the same time and the answer (10000) is returned to the arithmetic store.

The third instruction (10111) reads "transfer the number in the arithmetic store (10) to line 7 (111) of the store".

The fourth instruction merely says STOP. The decoded stop instruction closes the stop gate and no further adding of unity takes place in the top control line. Hence no subsequent instructions can be read and the programme has been finished with the final answer (10000) now in the main store in line 7.

This programme is an extremely simple one but it does show the way in which the basic elements work in conjunction with one another in doing a simple calculation. It illustrates also an important point from von Neumann's researches. This is that numbers and instructions were of exactly the same form. They both had five binary digits and were differentiated by the layout in the store which would be decided by the programmer. There is considerable flexibility to be gained since some programmes use few instructions but have a very large amount of numbers stored, whilst others use few numbers but a considerable number of instructions. The computer is therefore much more compact than if sepa-

* This is not intended to be a negative number in this example.

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rate stores were provided for numbers and instructions.

An additional and extremely important consequence is that instructions can be modified in the course of the programme by using them as if they were numbers and processing them in the arithmetic units to give new instructions.

The simple programme did not exploit the "decision facility" which was recognized by Babbage as essential to an automatic computer. A short series of instructions will illustrate the importance of this "decision facility". Suppose it is required to divide 9 by 3. This can be done by simple subtraction, counting the number of subtractions performed before the answer goes negative, and this is the required quotient. The programme would read

(1) Subtract 3 from the number in the arithmetic store (9).

(2) Test the answer to see if it is positive. If it is, proceed to instruction (3), if it is not, STOP. (For this purpose 0 is a positive number.)

(3) Count 1 and store it.

(4) Repeat from instruction (1).

The test facility is not difficult to achieve in practice since it has been shown that negative binary numbers are recognized by having a 1 in the most significant place. Detection of this 1 is the deciding factor in whether the computer carries on its programme or whether it stops. Far more sophisticated uses are made of this property but they cannot be dealt with here.

The principles of digital computers are simple, but a full scale computer is obviously a much larger collection of elements than those discussed in this article. There are many additional circuits necessary which are concentrated on connecting the computer to the outside world, but the aim of these articles has been to emphasise the basic simplicity at the heart of even the most mighty machines.

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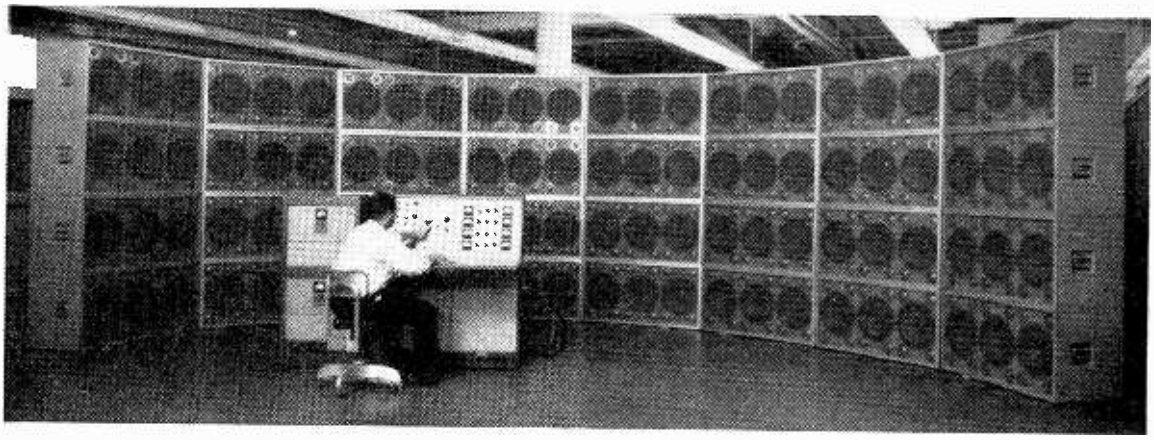

High-power Loudspeaker System

By MICHAEL LORANT

FOR STUDYING THE PHYSIOLOGICAL EFFECTS OF HIGH-INTENSITY SOUND

RESEARCH technicians of the Acoustical Engineering section of Stromberg-Carlson have recently developed for the Aerospace Medical Division of the Wright Air Development Centre, Ohio, a new high-intensity acoustic system for studies of the physiological effects of high-intensity sound.

The most unusual feature of the new system is the "high-fidelity" quality of its performance—the generation of undistorted sound throughout the full 10-octave range of normal audibility.

The "business end" of this system is a huge assembly of loudspeakers—480 in all. These are mounted in 32 separate baffles for maximum flexibility in arrangement and control. Each baffle contains three low-frequency "woofers" and twelve high-frequency "tweeters". All the loudspeakers are especially designed to deliver "high-fidelity" sound at high acoustic powers for sustained periods.

The system is controlled from a console providing four possible inputs—sine wave, electronic "white noise", tape recordings (of jet engine, missile, etc.), or an external source.

The main audio power equipment consists of two pairs of audio amplifiers. One pair of these is for "low-power" use only, with each amplifier providing an output of 200 watts. Each of the pair of high-power amplifiers has an output of 7,000 watts. The frequency response of the system is "flat" over the entire audible range, from 20 to 20,000 c/s.

To avoid unintentional exposure of subjects to high-intensity sound, a safety precaution makes it necessary for the operator to put the controls first into the low-power position before energy can be supplied to the high-power amplifiers.

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VALVE NOISE

By "CATHODE RAY"

A MAIN ambition of power engineers is to generate electricity direct from heat, instead of going through the tiresome sequence of using the heat to boil water and making the steam impinge against blades in a turbine, causing it to move an array of conductors in a strong magnetic field. They may or may not be encouraged by the fact that direct conversion of heat into electrical energy does take place in absolutely every circuit. The evidence is before our very eyes—and ears—in every TV screen and loudspeaker receiving weak transmissions. The annoying thing is that this electricity is random, and therefore not only useless but detrimental.

Last month we considered the constant factor connecting temperature with random electrical power ("noise"): Boltzmann's constant, denoted by k. Since this form of electrical power is worse than useless, the fact that we get a very poor rate of exchange is a point in favour rather than otherwise. In our ordinary units, k is only 1.38×10^{-23} joule per °K. The resulting noise voltage across a resistor or tuned circuit is of the order of one or two microvolts. But of course that is enough to be a serious nuisance if the signal we are trying to receive is of the same order. When amplified 120dB, microvolts become volts. The most significant source of this universal circuit noise (called thermal or Johnson noise) is obviously the circuit followed by the greatest amplification. In fact, if the first stage of amplification is doing well, the contributions from circuits other than its input circuit may be neglected. But Johnson noise is not the only kind that causes the escaping-steam sound in the loudspeaker and the animated graininess on the screen.

If the subject of valves is not too *passé*, *démodé*, *suranné*, *vieux jeu*, *radio à la vapeur*, or any of the other contemptuous French epithets we may choose to bestow on it in these transistorizing days, let us consider how they too contribute their quota of noise. Even the transistor hounds may find it worth their valuable time to do so, for at bottom the principles of transistor noise are similar.

One thing had probably better be made clear at the start: so far as the end product is concerned, valve noise is the same as Johnson noise. There is nothing to give a clue as to how much is due to valves and how much to circuits. (To cover myself against argumentative readers I had better declare a possible exception: two ingredients of valve noise to be mentioned might be recognizable by their tendency to occur increasingly at one end or other of the frequency scale.)

As has just been hinted, valve noise can be subdivided. The basic ingredient is what is usually called shot noise or shot effect. Sometimes writers (for the sake of effect?) name it in German, as Schroteffekt, which sounds even more penetrating. The air of mystery and confusion is further heightened by others who call it (wrongly, as it happens) Schottky effect, because it was first described by one Schottky. All these names are even more than usually subject to individual variations in spelling.

The thing was called shot noise (to come back to plain English), so we are told, because of its supposed resemblance to the sound of shot peppering a target. Since the sound in question, even after enormous amplification, is much more like a gentle hiss of steam, I prefer to think that the reference to shot is more to remind us (or even inform us, if we are beginners) that the flow of electric current through a valve is not perfectly smooth like the flow of treacle from spoon to plate, but more like the flow of water from cloud to earth, as rain.

The merit of likening it to shot or even rain is, I think, confined to the simple idea of current being made up of discrete particles and therefore subject to random variations from an average rate of flow. In other ways it is misleading. A fairly obvious discrepancy is that what we get is not the magnified sound of electrons striking the anode, but a result due to random fluctuations of current in the anode circuit. A less obvious but most important difference is that shot has no effect on the target before actual impact. To be quite correct I suppose we must say that the first effect is produced by the extra pressure of air pushed against the target by the shot, but by that time the shot is virtually home. With electrons in a valve it is quite different. Electrically, they affect the anode circuit all the time they are travelling there from the cathode, and arrival marks the end of this influence, not the beginning. The fact that the movement of an electric charge near a conductor induces a current in the conductor used to be demonstrated by one of the stock gold-leaf-electroscope experiments of the nineteenth century. Nowadays I suppose one relies on Conservation of Energy. Q in Fig. 1 is the negative charge on a particle moving in response to the constant electric field between a pair of electrodes having a difference of potential V. (The field strength is V divided by the distance between the electrodes.) As its potential is being raised, work is being done on it, and the requisite energy can come only from the battery, through which a corresponding charge must therefore pass. The faster Q moves, the greater the rate of charge flow through the circuit; i.e., the greater the current. Assuming an electron starts from rest at the cathode, and the field is uniform, its acceleration is constant, so its velocity steadily increases, and the current waveform is as in Fig. 2.

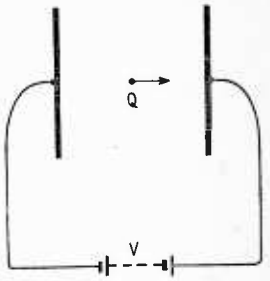

Fig. 1. A negative charge Q is moving towards the positive plate under the influence of the electric field between the plates. The work thus done on it by the battery necessitates a current through the battery.

For the sake of a nice round number, let us suppose

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the anode current in a valve is 16mA. The rate at which electrons cross the vacuum must then be 10^{17} per second. If they were released at exactly equal intervals the anode current would therefore be modulated at a fundamental frequency of 10^{17} c/s. That is in the X-ray band, so we are safe in assuming that it would be smoothed out into imperceptibility in any practical anode circuit. But although the average rate of flight is 10^{17} per second, owing to the nature of thermionic emission this rate fluctuates in a random manner around its average, rather like the day-to-day fluctuation in actual births compared with a steady long-term average. At the foot of Fig. 3 the ideal waveform of Fig. 2 is repeated at intervals representing an average of eight electrons in flight at any one instant, but varying irregularly. Above is the result of adding all these pulses, and we see that it is mostly d.c., with a very high-frequency ripple—the one we are assuming is smoothed out, like the residual r.f. in a detector circuit—and a comparatively slow and quite irregular variation of the d.c. from its average. This last is the shot noise current.

It should be clear by now that the name " shot noise " is misleading in another respect: any idea that we are hearing even an indirect effect of the separate electrons pattering on the anode is completely unfounded; their frequency is far too high.

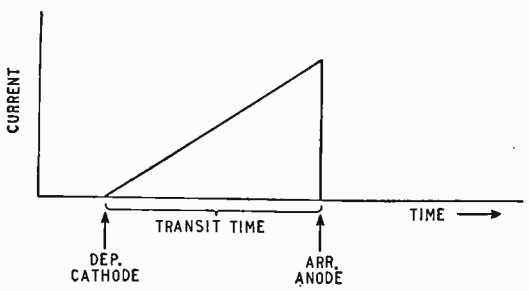

Fig. 2. Assuming a uniform field in Fig. 1, the charge is accelerated uniformly, and since the current in the circuit is proportional to the charge's velocity it increases steadily throughout the flight.

Just to make sure, and for the fun of the thing, I calculated what sort of a current Fig. 3 really represented, assuming the fairly typical transit time of 10^{-9} sec. The average rate of arrival of electrons is than 8×10^9 per sec., and as the frequency of the sawtooth ripple is the same—8×10^9 c/s or 8 Gc/s—it is actually a microwave frequency, with a wavelength of $3\frac{3}{4}$ cm. We may perhaps be surprised to find the electron frequency inside a commercially used radio waveband. But lest we imagine a great peak of noise at this particular frequency, let us remember two things. The first is that in this case one cycle is only one-eighth of the transit time, so is right outside the working frequency of the kind of valves we are considering. The second is that the anode current is only 0.001μA, which wouldn't do much anyway. But it is easily measurable, even though as few as eight electrons at a time are in transit between cathode and anode; which makes one think.

In practical valves the anode current is millions of times larger, and the sawtooth ripple (which is " shot noise " in the most literal sense) is correspondingly higher in frequency and can be left right out of account. But the slower ups and downs, due entirely to the fact that electrons are not emitted at regular intervals, are only too evident in high-gain amplifiers. Their power is distributed evenly over the frequency band. While this fact may seem natural for a purely random effect, so that we might have guessed it, it does need to be proved. Anyone sufficiently interested can wade through (e.g.) 15 pages of difficult mathematics in Davenport and Roots " Random Signals and Noise." Don't ask me to put it into a few lines of elementary algebra. I have to be content that the authorities agree on

$$I_N^2 = 2eI_aB$$

where I_N is the r.m.s. shot noise current, I_a the anode current, e the electric charge of one electron (1.6×10^{-19} coulomb), and B the frequency bandwidth. We may note in passing that I_N is proportional to the square root of I_a, so it doesn't do to starve the first valve in a high-gain amplifier. When the anode current is on the small side the gain is almost directly proportional to I_a, so signal/noise ratio would get worse if I_a were reduced too much.

Actually it is rather too soon to start drawing such conclusions, for the formula just quoted is limited to such exceptional cases that we are unlikely to find any use for it. One of the rare exceptions is a bright-emitter diode run with such low filament voltage and such high anode voltage that every electron emitted is immediately pulled across the vacuum. In other words, the anode current depends entirely on cathode temperature, not anode voltage. Its technical description is a temperature-limited diode. Another exception is a photoemissive cell.

Valves as normally used are run at a cathode temperature that emits more electrons than are required. Imagine a great crowd of delegates to a conference moving out after the first session into a room with a buffet at the far end. The first arrivals spot it and stream across, but the main body can't even see it for the crush, and mill around just inside the entrance. They form a " space charge " screening the attractions of the buffet from the late entrants. This is roughly what happens in a valve (Fig. 4). Suppose the emission is at the rate of 1 amp. That is 6.4 billion (American trillion) electrons per microsecond. Even before the cathode is fully hot after switching on, enough electrons have emerged to build up a negative charge near the cathode that more than counterbalances the positive attraction of the comparatively distant anode. So nearly all the electrons emitted from then on are repelled back to the cathode. Only the few within sight, as it were, of the anode feel its attraction and stream across, forming a current of perhaps a few milliamps. If none at all left the cathode permanently, the space charge would soon be used up, but of course the slightest reduction in its numbers reduces its repelling power and allows some of the emitted electrons to join. And so a balance is reached between the attraction of the anode and the repulsion of the space charge, resulting in a certain rate of anode current, depending on the anode voltage.

A space-charge-limited diode (for that is what we are talking about) is therefore like a triode in which the part of the negative grid, controlling the flow of electrons to the anode, is played by the space charge. It is really like automatic grid bias, as produced by a cathode resistor. Any increase in cathode current

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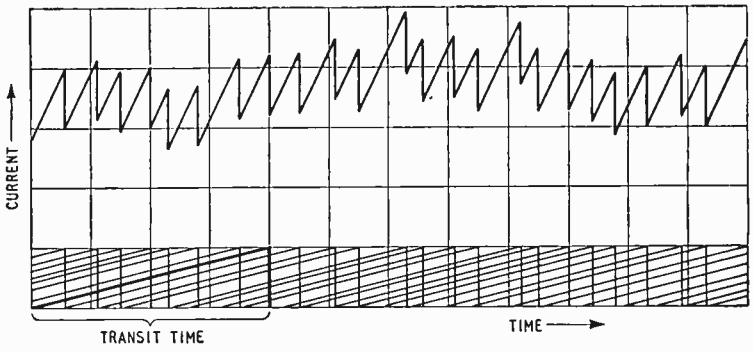

Fig. 3. Here there are, on the average, 8 electrons in flight all the time, but they start at irregular intervals. The resulting total current therefore has a slow irregular fluctuation as well as the fast saw-tooth ripple.

increases such bias and checks the increase in current. Similarly an increase in emission, due perhaps to mains voltage rising, increases the space charge and repels more electrons back to the cathode, so the current remains fairly constant.

The purpose of the negative grid in a triode is to supplement the space charge, reducing the anode current as required, even down to cutting it off altogether. So long as the potential of the grid is not allowed to rise high enough to attract electrons to itself, a triode behaves similarly to a diode as regards noise.

And how is that? Well, suppose the delegates were released from the conference room at short irregular intervals at such a rate that no crowd could form; the rate of flow across to the buffet would be equally irregular, as in a temperature-limited valve. A crowd, on the other hand, would tend to even out such irregularities and ensure a relatively steady flow. This is much more certain with electrons, which, being free from individualities such as varying degrees of hunger, politeness or sociability, work according to simple and predictable laws. That is not to say that the quantitative working out is not even more difficult than in the temperature-limited case. But having just seen that the space charge works rather like automatic grid bias, counteracting changes in anode current, we should not find it hard to understand that it has a cushioning effect on irregular emission, as indeed experience confirms.

In our ignorance of the extent of this noise-reducing or smoothing effect it can be brought into the formula for the temperature-limited valve as a factor, say S:

$$I_N^2 = 2\,SeI_aB$$

It is found that S can be as small as 1/50, signifying a 50-fold reduction in noise, but something like 1/5 is more usual. Note that this is in a formula for I_N squared, which is proportional to noise power; don't confuse it with an equivalent factor ($=\sqrt{S}$) that is sometimes used in the formula for I_N.

The question of noise in diodes seldom arises—except when they are used as frequency changers in microwave receivers—so we pass on to amplifying valves, especially those that might be considered for first-stage positions. One of the things designers want to do is compare valve noise with circuit noise. As we have seen, the only circuit that matters very much, usually, is the grid circuit of the first stage. The amount of effort worth expending on reducing this depends on how much noise the valve contributes. If circuit noise is given in microvolts at the grid, and valve noise in microamps in the anode circuit, one has to do calculations to find out which is greater, and by how much. It is of course possible to find how many microvolts at the grid would cause that number of microamps of noise, but direct comparison with circuit noise microamps would be vitiated by the fact that both figures depend on the respective frequency bandwidths, and it would be a coincidence if they were equal.

So the convenient custom is to express valve noise in terms of the resistance which, if included in the grid circuit of a noiseless but otherwise similar valve, would cause the same amount of noise. Let us call this imaginary resistance R_N. According to the formula we already have for the noise voltage at the terminals of a resistor,

$$V_N^2 = 4kTBR_N$$

I_N is related to V_N by the mutual conductance, g_m:

$$I_N = g_m V_N$$

So substituting $2SeI_aB/g_m^2$ for V_N^2 in the previous equation we get

$$\frac{2SeI_aB}{g_m^2} = 4kTBR_N$$

$$\therefore R_N = \frac{SeI_a}{2g_m^2kT}$$

This doesn't get us where we want, unless we know S. The rather difficult working-out I mentioned gives

$$S = \frac{1.28\,k\,T_c\,g_m}{e\,I_a}$$

where T_c is the temperature of the cathode. Substituting this in the equation for R_N we get

$$R_N = \frac{0.64\,T_c}{g_m\,T}$$

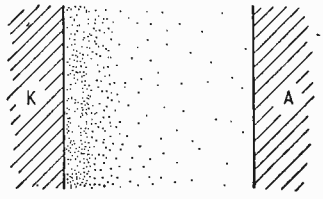

Fig. 4. The many electrons emerging from the cathode, on the left, form a negative space charge that neutralizes the distant positive charge on the anode and restricts further movement towards it. The surplus electrons are forced back to the cathode.

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The cathode temperature T_c is usually about 1130°K and the room temperature T about 290°K, so

$$R_N = \frac{2.5}{g_m}$$

Because of the various assumptions in the smoothing theory, as well as the temperatures, this conveniently simple formula is far from precise, but it does at least give a rough idea. A moderate g_m for a triode is 2.5 mA, which makes $R_N = 1k\Omega$.

At frequencies less than say 30 Mc/s, noise resistance of this order is hardly worth bothering about as a noise source, compared with the usual grid-circuit resistance, to say nothing of man-made noise and atmospherics, both of which are worse at the lower frequencies. At very high frequencies, however, all these other noises are so much reduced that shot noise is appreciable and choice of first valve is correspondingly important. And at these same frequencies another effect adds to random noise. It concerns the electrons streaming through the grid.

We are still assuming that the grid is kept sufficiently negative to prevent any electrons landing on

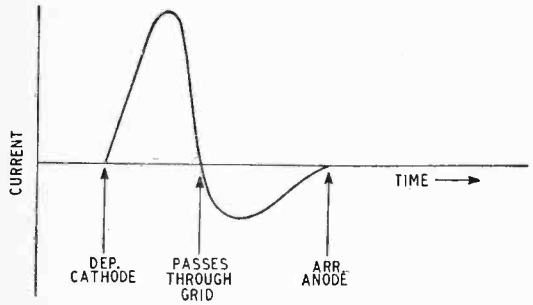

Fig. 5. An electron flying from cathode to anode through a control grid induces a grid current as shown.

it. But during the first step of an electron's journey to the anode it is moving towards the grid, so it induces a small current in the grid circuit, just as was explained in connection with Fig. 2 for the anode circuit—though the waveform is unlikely to be quite the same. After it has passed through the grid it induces a current of opposite polarity; see Fig. 5. The duration of this cycle is of course the transit time, which we have already noted is usually of the order of 10^{-9} sec. At moderate signal frequencies this is too quick for the grid potential to change appreciably, so the positive and negative portions of Fig. 5 represent equal amounts of work, and cancel out. But at very high signal frequencies the grid potential changes appreciably during the transit time and the resulting inequality of positive and negative work causes a loss in the grid circuit. This loss can be represented by a resistance. Being in parallel with the grid circuit, it is one of the things that make the net resistance low at very high frequencies. At the moment, we are not directly concerned with that; what does concern us is that this resistance depends on the rate at which electrons pass the grid, and as that varies randomly the resistance varies and causes noise.

Even at low radio frequencies one naturally uses a pentode rather than a triode, mainly for the sake of the screening it provides between grid and anode. The need for this is even greater at v.h.f. But it was soon found that at v.h.f., where noise is the limiting factor, a pentode is much noisier than a triode. This was traced to the fact that the second grid intercepts a fraction of the anode current. A row of waitresses with trays, widely spaced across the conference refreshment room, would waylay some of the delegates; each one thus intercepted would reduce the number arriving at the buffet, and thereby modulate that stream in a random manner.

It is easy to see that any current-taking grid introduces an additional random element and hence noise; but since the grid current is seldom as much as one-fifth of the whole, we might expect its noise contribution to be in that proportion and therefore not enough to worry about. But whereas the shot noise due to random emission, common to triodes and pentodes, is reduced by space charge to perhaps a tenth, there is no such luck with partition noise (as it is called). So it is usually at least double the emission noise.

I haven't left myself space to go into details about its derivation, but the rough formula for pentodes, corresponding to $2.5/g_m$ for triodes, is

$$R_N = \frac{I_a}{I_a + I_{g2}} \left(\frac{2.5}{g_m} + \frac{20\, I_{g2}}{g_m^2} \right)$$

Here the first term in the bracket is obviously the emission noise—the triode term reduced to the extent that the space current is diverted from the anode—and the second is the partition noise. Filling in values taken from data for a pentode designed for v.h.f. amplification:

$$R_N = \frac{10}{10 + 2.5} \left(\frac{2.5}{7.4} + \frac{20 \times 2.5}{7.4^2} \right)$$

$$= 0.8\ (0.34 + 0.92)\ k\Omega$$

$$= 270\Omega + 730\Omega = 1000\Omega$$

So the total is about 3 times what it would be as a triode (340Ω). That accounts for the urge to use triodes for the first stages of sensitive v.h.f. receivers, however unsuitable they appeared for the task. The first expedient to make them work there was to arrange them with earthed grid as a screen between input and output. This method has now been generally superseded by the cascode arrangement, in which a double triode secures the advantages of a pentode without its disadvantages.

At the lower frequencies it is common practice to make the first valve the frequency changer. The higher the frequency, the greater the temptation to do so, since it becomes difficult to coax amplification at the original frequency. But the signal/noise ratio of frequency changers is several times worse than that of amplifiers, so even a little r.f. amplification is not to be despised. The reason is that the effective amplification of a frequency changer is related to g_c, the conversion conductance, which is only about $\frac{1}{3}$ of g_m, whereas the noise is at least

(*Continued on page 627*)

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as great; in fact, slightly greater, owing to the oscillator. The rough formula for a triode is

$$R_N = \frac{4}{g_c}$$

and for a pentode

$$R_N = \frac{I_a}{I_a + I_{g2}} \left(\frac{4}{g_c} + \frac{20\ I_{g2}}{g_c^2}\right)$$

These speak for themselves, which is just as well, for the closing bell may sound any minute.

Lastly, there are the heptodes, hexodes, etc., which can be lumped together as multi-grid frequency changers. The more current-carrying electrodes, the more noise is introduced by random partition; so valves in this class are the worst of all, and would never be chosen for the first stage of a sensitive v.h.f. receiver. The formula is

$$R_N = \frac{20\ I_a\ (Ik - I_a)}{Ik\ g_c^2}$$

where Ik is the cathode current. I suggest you look up a valve data list and work out a few values of R_N in the various classes. Remember, of course, to use consistent units—mA and kΩ, *or* A and Ω.

We have been concentrating rather heavily on the high end of the frequency scale, because that is where random noise is the thing that limits reception, and also the transit-time ingredient increases with frequency. For the sake of completeness mention should be made of flicker effect, which seems to be due to comparatively slow changes at the cathode surface causing random variations in emission. At any rate, it is important only at low a.f. and below, where it increases steeply. In badly made valves there is yet another cause of random noise: ionization, due to inadequate vacuum. Of course it inevitably occurs in gas-filled valves even when (in fact, because) they are properly made, and such valves are sometimes used as sources of random noise for testing. In case any reader is not up in the jargon, perhaps I had better mention that random noise, in so far as it is distributed equally over the whole frequency spectrum, like white light in the visible band, is often called white noise.

In brief: all valves are subject to shot noise because of random emission. In nearly all, this effect is considerably muffled by the space charge. So diodes and triodes on the whole are relatively quiet. Current carrying grids introduce further noise (partition), which is not muffled. So pentodes are usually several times worse than triodes. Valves used as frequency changers are relatively noisier than as amplifiers, because they amplify the signal about $\frac{2}{3}$ less. The order of preference of the different classes of valve in this role is the same as in the straight amplifying role. Beside shot and partition noise, which are very "white," there are grid-admittance noise which increases steeply at the v.h.f. end, and flicker noise which increases steeply at the a.f. end.

Elements of Electronic Circuits

20.—ADDITION AND SUBTRACTION CIRCUITS.

By J. M. PETERS, B.Sc. (Eng.), A.M.I.E.E., A.M.Brit.I.R.E.

MATHEMATICAL operations can be performed on waveforms, especially the square wave, with reasonably accurate results and use is made of this in the field of computation.

It is possible to carry out the operations of addition, subtraction, differentiation and integration without having to resort to valves or other non-linear devices, but accuracy is increased with the aid of the feedback amplifier. The operations of multiplication, division, squaring and the extraction of square roots (which will be dealt with later) are very difficult to perform using only linear elements such as resistor networks. Depending on whether accuracy or speed is the governing factor a choice can be made from several different methods. For example, in multiplication, electromechanical methods may give a high degree of accuracy, but if speed is desired it will be necessary to use circuits with multi-electrode valves.

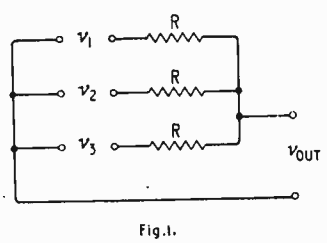

Fig.1.

Addition and Subtraction

Addition can take a number of forms and the process is met for example in (i) heterodyning in radio receivers, (ii) feedback, where a portion of the output of an amplifier is "added" to the input, (iii) a.g.c. in radio receivers, where the a.g.c. voltage is added to the bias of the earlier variable-μ stages. The simplest form of adding circuit involves linear passive elements such as the parallel-resistor adding circuit of Fig. 1.

$$v_{out} = (v_1/R + v_2/R + v_3/R)\ (R/3)$$

$$\therefore v_{out} = (v_1 + v_2 + v_3)/3$$

Inductors and capacitors can also be used in simple adding networks of this sort.

The simplest form of subtraction circuit involves a phase-reversing device such as a valve or a transformer. One of the principal drawbacks to the simple addition circuit of Fig. 1 is that at high frequencies stray capacitance effects may distort

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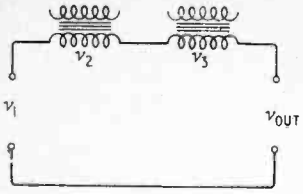

Fig.2.

the waveforms. This is overcome by inserting a small capacitor in parallel with each resistive branch and a resistor in parallel with the stray capacitances. The time constants (CR) are arranged to be the same. Series addition circuits are also used for the addition of voltage, e.g. Fig. 2 where transformers are used.

$$v_{out} = v_1 + v_2 + v_3$$

A balanced equal-arm bridge is a useful method of eliminating mutual coupling between the inputs. An example is shown in Fig. 3. Solving the mesh equations by Kirchhoff's laws it can be shown that

$$v_{out} = (Z/2)\,[v_1/(Z + Z_1) + v_2/(Z + Z_2)]$$

Difficulties are often encountered when it is desired to add voltages with short rise times such as rectangular pulses; but the method of overcoming the stray-capacitance effect described above is usually successful. Transients which produce overshooting and shock-excited oscillations can be minimized by damping and compensating networks. Waveform

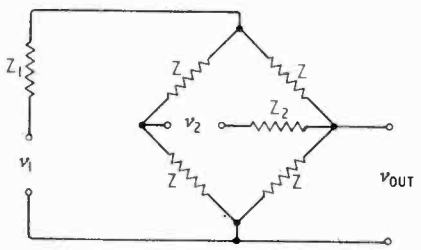

Fig.3.

shaping (described in an earlier instalment) can also be performed at the same time as addition and helps in compensating for waveform slow rise times.

Use of Valves

The use of valves in addition and subtraction circuits provides a means of isolating the network from the source voltages and for changing the impedance levels between network and source. Reasonable accuracy can be obtained by using multi-grid valves as shown in the subtraction circuit of Fig. 4.

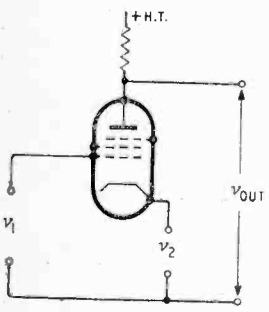

Fig.4.

$$v_{out} = v_1 - v_2$$

Note that the low input impedance at the cathode ($\approx 1/g_m$) makes it necessary to supply the cathode from a low-impedance waveform source.

Alternatively the application of signals to control and screen grids results in the output being the sum of these voltages. Sum and difference voltages

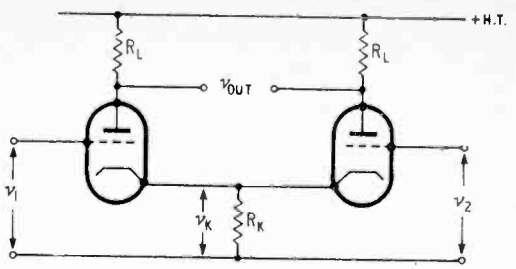

Fig.5.

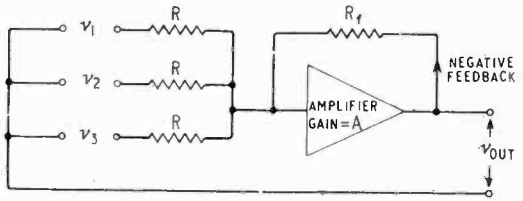

Fig.6.

may be obtained from the cathode-coupled paraphase amplifier or long-tailed pair (described in No. 5, September, 1959) (Fig. 5). The difference in voltages appearing at the anodes (v_{out}) is proportional to the difference between the inputs at the grids ($v_2 - v_1$). On the other hand, the cathode voltage, v_K, is proportional to the sum of the inputs to the grids ($v_2 + v_1$).

One of the most useful addition circuits is perhaps the parallel-addition circuit of Fig. 1 followed by stages of amplification with negative feedback (Fig. 6). This gives an output of inverted polarity, compared with the passive network. The advantages are that the amplitude of the output can exceed the input, also that with this circuit only one amplifier is necessary regardless of the number of inputs to be added.

$$v_{out} = (R_f/R)\,(v_1 + v_2 + v_3),$$

as long as the gain within the feedback loop is high. This presupposes a high value for A, the amplifier gain, and a fairly low numerical value for R_f/R, which is the overall gain of the circuit with feedback.

Commercial Literature

Thirty Transistor Circuits, covering a range of functions including a.f. amplifiers, regulated power supplies, d.c. to d.c. and d.c. to a.c. converters, oscillators and a photographic electronic-flash unit are contained in "Newmarket Transistors—Application Notes" from Newmarket Transistors Ltd., Exning Road, Newmarket, Suffolk.

Molybdenum Disulphide as a lubricant and additive to lubricating solutions can bring about reductions in wear. Booklet on molybdenum disulphide, giving data on applications, from Rocol, Ltd., Rocol House, Swillington, near Leeds.

Silvered-Mica Capacitors made by Johnson Matthey have the electrodes screen-printed, instead of sprayed, on to the mica. The makers call these "Silver Star" and claim that the sharply defined edges of the electrodes aid stability. Booklet describing the process and listing the capacitors from the manufacturers at 73-83, Hatton Garden, London, E.C.1.

Radio and Television Interference. Advice on the tracing and suppression of interference is given in a booklet called "Everyman's Guide to Electrical Interference" published by Belling and Lee, Ltd., Gt. Cambridge Road, Enfield, Middlesex.

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DECEMBER MEETINGS

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

LONDON

2nd. I.E.E.—Discussion on "Telemetering biological data" opened by Dr. G. H. Byford and Dr. K. G. Williams at 6.0 at Savoy Place, W.C.2.

2nd. Brit.I.R.E.—"Progress in microminiature circuit techniques for digital computers" by D. Roberts, Dr. D. S. Campbell and P. M. Thompson at 6.30 at the London School of Hygiene, Keppel Street, W.C.1.

7th. Institute of Physics and Physical Society.—"The international conference on physics education" by N. Clarke at 6.0 at 47 Belgrave Square, S.W.1.

7th. Brit.I.R.E.—"Flight evaluation of airborne electronic equipment" by H. G. Hinckley at 6.30 at the London School of Hygiene, Keppel Street, W.C.1.

8th. Television Society.—"The all transistor receiver: where do we stand?" by A. Landman (Plessey) at 7.0 at the Cinematograph Exhibitors' Association, 164 Shaftesbury Avenue, W.C.2.

8th. Radar & Electronics Association.—"True motion radar" by J. H. Beattie at 7.30 at the Royal Society of Arts, John Adam Street, W.C.2.

12th. I.E.E.—"Topology concepts in network theory" by Dr. P. R. Bryant at 5.30 at Savoy Place, W.C.2.

13th. Brit.I.R.E.—"Objective and subjective requirements for loudspeakers" by F. H. Brittain at 6.30 at the London School of Hygiene, Keppel Street, W.C.1.

13th. I.E.E. Graduate and Student Section.—"Electrical engineering in the Naval Service" by Sir Hamish MacLaren at 6.30 at Savoy Place, W.C.2.

16th. B.S.R.A.—"Magnetic recording in the home cinema" by D. O'C. Roe at 7.15 at the Royal Society of Arts, John Adam Street, W.C.2.

20th. I.E.E.—Discussion on "Digital transducers" opened by L. Airey at 5.30 at Savoy Place, W.C.2.

21st. I.E.E. — "Microminiaturization" by L. J. Ward at 5.30 at Savoy Place, W.C.2.

BELFAST

13th. I.E.E.—"Wave guides" by Dr. P. J. B. Clarricoats at 6.30 at the Civil Engineering Department, Queen's University, Stranmillis Road.

BIRMINGHAM

5th. I.E.E.—"Radiocommunication in the power industry" by E. H. Cox and R. E. Martin at 6.30 at the College of Technology.

BRADFORD

6th. I.E.E.—"Thermistors—their theory, manufacture and application" by Dr. R. W. A. Scarr and R. A. Setterington at 6.30 at the College of Technology.

BRISTOL

13th. Television Society.—"Ferrites in television receivers and aerials" by E. C. Snelling at 7.30 at the Hawthorns Hotel, Woodland Road, Clifton.

CHESTER

12th. I.E.E.—"The potentialities of artificial earth satellites for radiocommunication" by W. J. Bray at 6.30 at the Town Hall.

EDINBURGH

5th. Institute of Physics and Physical Society.—"Low noise amplifiers" by Dr. R. A. Smith at 7.15 at the University.

GLASGOW

6th. Institute of Physics and Physical Society.—"Low noise amplifiers" by Dr. R. A. Smith at 7.15 at the University.

HOVE

7th. I.E.E.—"Radiocommunication in the power industry" by E. H. Cox and R. E. Martin at 6.30 at 10 Queens Gardens.

LIVERPOOL

14th. Brit.I.R.E.—"V.H.F. sound broadcasting" by L. G. Dive at 7.0 at the Adelphi Hotel.

MALVERN

5th. I.E.E.—"Parametric amplifiers" by R. V. R. Carter and I. A. Bagnall at 7.30 at the Winter Gardens.

MANCHESTER

1st. Brit.I.R.E.—"Industrial television" by I. M. Waters at 7.0 at the Reynolds Hall, College of Technology.

7th. I.E.E.—Discussion on "New semiconductor devices" opened by A. A. Shepherd at 6.15 at the Engineers' Club.

21st. I.P.R.E.—"Control systems" by J. Pyke at 7.30 at Central Hall, Oldham Street.

NEWCASTLE-UPON-TYNE

5th. I.E.E.—"Radar observations of birds and 'angels'" by Dr. E. Eastwood at 6.15 at the Rutherford College of Technology, Northumberland Road.

7th. Brit.I.R.E.—"Human engineering" by S. G. Ramsay at 6.0 at the Institution of Mining and Mechanical Engineers, Neville Hall, Westgate Road.

NEWPORT, I.O.W.

9th. I.E.E.—Discussion and demonstration of stereophonic sound at 6.30 at S.E.B. Showrooms.

NORWICH

6th. I.E.E.—"Engineering aspects of commercial television programme presentation" by T. C. Macnamara at 7.30 at the Assembly House.

READING

15th. Institution of Production Engineers.—"Electronic data processing allied to production engineering" by F. W. Purchall at 7.30 at the George Hotel, King Street.

SOUTHAMPTON

6th. I.E.E.—"F.M./A.M. v.h.f. portable transistor receivers" by L. E. Jansson at 6.30 at the University.

14th. Brit.I.R.E.—"Some new piezoelectric devices" by A. E. Crawford at 7.0 at the University.

STONE

12th. I.E.E.—"Recent developments in colour television" by I. J. P. James at 7.0 at Duncan Hall.

SWANSEA

13th. I.E.E.—Faraday Lecture on "Transistors and all that" by L. J. Davies at 6.30 at the Brangwyn Hall.

WORKINGTON

13th. I.E.E.—"The transmission of news film over the transatlantic cable" by C. B. B. Wood and I. J. Shelley at 7.0 at the College of Further Education.

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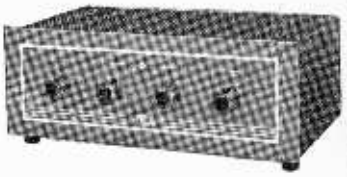

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RANDOM RADIATIONS

By "DIALLIST"

Far-East Colour TV

SO Japan, or at least Tokyo and Osaka, has a colour television service. The man who after a three-year struggle forced a reluctant government to make up its mind on the subject is said to be Mr. Matsutaro Shoriki, president of Nippon Television (NTV), who got the country's 525-line black-and-white service started in 1953. Ordinary television has become so popular in Japan that all but the very poorest now have receivers and the total is over six million. Mr. Shoriki is firmly convinced that there will be a similar boom in colour TV. To get things going he put up colour receivers in various public places. The system used is the N.T.S.C. and it is reported that the Japanese have improved upon the results obtained in the United States. They have apparently not succeeded in developing low-priced domestic receivers; but even though the earnings of factory and other workers are much less than they are in America, Mr. Shoriki is convinced that colour sets will sell. Japan, it appears, is well provided with "never-never" facilities.

What About Us?

After five years of experimental colour transmissions the B.B.C. has announced that, technically at any rate, it is ready to start a regular service, if and when permission is given. The radio industry doesn't feel that the time is yet ripe, for no manufacturer in his senses—and ours are very much in theirs—wants to go into the production of colour receivers unless there is likely to be a good demand for his wares. The big snag is the cost of the receiver, governed largely by the cost of the three-colour tube, and, frankly, I don't think that our people would go for them in a big way unless this can be greatly reduced.

DX Printing

THE setting of the type of the New York and Paris editions of the *New York Times* simultaneously is a very remarkable feat. The Paris edition now goes to press at the same time as the early edition in New York. The setting is done by a tape perforated by means of wireless signals—the transatlantic cable will be used if radio conditions are bad—which is fed into linotype machines. Naturally some of the type-setting will be done in the ordinary way in Paris, for purely local American news won't be carried in the French edition, the space being devoted to happenings on this side of the Atlantic. Many of the advertisements will be different. Owing to the time difference—Paris is six hours ahead of New York—the Paris issue must derive from a very early American edition. But, of course, the U.S.A. is a large country and very early editions are needed if the paper is to appear on distant breakfast tables.

Anti-mortar Radar

IN collaboration with the Royal Radar Establishment, E.M.I. have developed a new type of radar equipment for which substantial contracts have been placed by the War Office and by the Swedish army. This equipment enables mortar shells or bombs to be tracked in flight and makes it possible to calculate accurately and quickly the exact position from which they were fired. It is small and highly mobile and is said to be very easy to operate. Something of the kind was done towards the end of the last war with ordinary radar sets. They were used to spot shells as they left an enemy battery and proved very useful in Italy for pin-pointing hostile battery positions with considerable accuracy.

I.G.Y. No. 2

THERE are plans afoot, I see, for holding a second International Geophysical Year on a smaller scale at the time of the next sunspot minimum, which is due to come along in about four years' time. The idea is that we can get to know a good deal more if we compare the happenings recorded during a period of maximum solar activity with those which occur when such activity is at a minimum. An excellent scheme and may it have the success it deserves. Completely satisfactory explanations of some of the phenomena of I.G.Y. No. 1 haven't so far been found and the second series of observations may help to clear things up.

TV Progress in France

AT long last television seems to be really getting into its stride in France. At the end of June this year the total of "declared" sets had risen to 1,700,000. And there's pretty sure to be a largish number of undeclared, or pirate receivers, as undoubtedly there is in this country. The French transmitter, booster and relay net-

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work is not yet complete and where transmissions have only recently begun the increase in the number of viewers has so far proved surprisingly slow. And that is unfortunately true of certain other regions which have had a service for some time. Alsace, for instance, can boast only 28,900 receivers, though the Strasbourg transmitter has been at work ever since TV began in France.

Bigger and Bigger

THEY like big things in the U.S.A. and whatever sized TV screen comes along there's always a demand for something a bit larger. Having introduced 27-inch sets comparatively recently some of the manufacturers now have plans for 29-inch sets. I'd have thought that the best way of getting a really big picture would be to make use of projection techniques. But that doesn't seem to have caught on over there any better than it has done here. Talking of screen sizes reminds me of a conversation between two fishermen that I overheard on a boat not long ago:

"How big's your TV set?"

"Fourteen inches."

"Oh, you want something bigger than that."

"Does me all right."

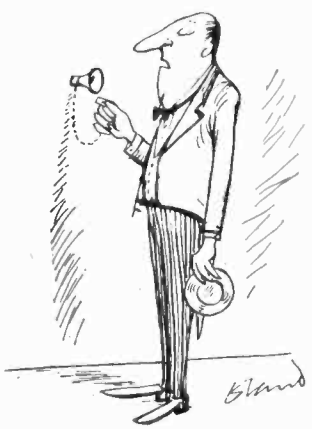
"But don't you see you're missing a lot of the picture."

"How do you mean?"

"Stands to reason. A screen of that size isn't big enough to take the whole picture that's sent out. The same sized picture is sent to everyone; but if your screen is small, some of it laps over the edges and you can't see those bits."

"Oh, I hadn't thought of that."

Frankly, I hadn't either!



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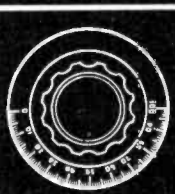

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UNBIASED

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Unlicensed Sets

HOW many unlicensed sets are there in this country? I am told that a recent industrial survey covering car radio showed that only about 50% of the sets were licensed. It does not surprise me in the least to hear this opinion, and I think the proportion in the case of domestic sets is fully as bad.

Look for example, at the numerous houses which are let out in what are euphemistically called one-room flats. In these days of miniaturized transistor sets, I wonder how many of the tenants—some of whom are very transient—bother about a licence? I would go even further and say that in a great many cases the owners of these sets think that the licence—if any—of the landlord covers them.

When a householder changes his address he can fill in a form for letters to be redirected and one of the questions asked on the form is for particulars of his wireless licence, if any. If he has no licence he is asked to write "None." The non-licence holder can write "None" with a perfectly clear conscience; at any rate that part of his conscience which deals with truth-telling will be clear, if, indeed, a conscience can be compartmented, as so many people obviously think, judging by their behaviour. It would seem to be more useful to ask if the form-filler had a receiver, but there would, of course, be little point in it unless it were made an offence to give a false answer.

But all the same, the very fact of a person having to fill in particulars of his licence or else write "None" might have the same psychological effect on a guilty conscience as does the presence of a G.P.O. wireless detector van in the neighbourhood.

Even so, only the householder is affected because it is clearly stated in the Post Office Guide (July, 1960 edition, page 67) that the P.M.G. will not undertake to re-direct the correspondence of those in lodgings, etc., and therefore, the people whom I regard as the real offenders, namely sub-tenants or lodgers, do not receive even the psychological stimulus of answering the questions about licences on the mail redirection form.

I am quite aware a G.P.O. inspector has authority to call at any time and inspect the wireless installation *of a licence holder*. But he certainly can't demand entrance to the home of a non-licence holder but must apply to a Justice of the Peace for a search warrant, after first satisfying the J.P. that he has reasonable grounds for suspicion. But Section 15 of the Wireless Telegraphy Act of 1959 only mentions a search warrant for premises. It makes no mention of a search of the person of a suspect which would, therefore, be *ultra vires*. In these days of tiny transistor sets, a radio receiver can easily be concealed in a man's pocket, or even in the corsage of a lady's dress. If an over-zealous Post Office official dared to search in the latter place, he would find himself on very dangerous ground indeed. Supposing the lady in her haste to conceal the set had inadvertently knocked the switch to the "on" position, it would be very galling but singularly apt if, as the perspiring official searched the room, the strains of "Music While you Work" burst forth from the depths of her person. He could only gaze at her in baffled impotence, knowing full well that he dared not search her. It would be truly an apoplectogenic situation.

At one time the outdoor aerial made it obvious when a TV set was installed but in these days more and more indoor aerials are in use, and before many years have gone by, we shall all be using sets with built-in aerials.

Could not a question about wireless licences be included in the census form which we shall all have to fill in on April 23rd next, or better still, could not such a question be put in the form which we all receive annually for the compilation of the electoral roll.

In my opinion, if every person who *ought* to have a licence did, in fact, have one, the B.B.C.'s revenue would be increased considerably.

Cymatology

RECENTLY, when reading an interesting article by a learned professor who is also a Fellow of the Royal Society, I was a little surprised to find that when he mentioned electromagnetic waves, he appended in parentheses the explanatory words, "light waves or radar waves." It was at once clear to me that he was not writing for his peers, who would naturally not need to be told what electromagnetic waves do for a living; nor, I realized, could he be writing for people having a slightly lesser standard of knowledge, possessed, for instance, by those who have only just matriculated in *Wireless World* readership.

It was only after further thought that it suddenly dawned on me that the writer (Professor J. L. Synge) had chosen the words "radar waves" with that careful and precise thought which one associates with an F.R.S., and that he may have intended it as an indirect rebuke to all those of us who use the vague and unsatisfactory word "radio" in such phrases as "radio receiver" and "r.f. amplifier."

When all is said and done, the true definition of a radio wave is one which is radiated *in any medium*. There is nothing to restrict the word radiation (and, therefore, radio) to the electromagnetic spectrum except customary usage or, more correctly, misusage; if that be allowed to influence us we cannot cavil at the great majority of our fellow citizens who misuse the lovely old English abbreviation "ain't," and pervert it from its true meaning.

It is clear that electromagnetic waves are merely a subdivision of radiated waves (or, in other words, of radio waves). Sound waves also are undoubtedly radiated and, in like manner, if we drop a stone into a pond, do we not bring about the radiation of surface waves in the water in ever-widening circles? The O.E.D. lends support to my views as it tells me, *inter alia*, that radiation is "the manner in which the energy of a vibrating body is transmitted in all directions by a surrounding medium"; it does not define the medium.

The word "radar" which the professor uses has a very clear and precise meaning, for it was synthesized

Searching for my stud with e.m. waves.

from the initial letters of words defining a particular application of e.m. waves, and has nothing to do with the altosonic or supersonic waves which bats use for a similar purpose.

We ought, therefore, to rename our radio receivers, and also cease to talk of an r.f. amplifier. But we must be careful not to adopt the name e.m.w. receivers for, obviously, that could equally well mean a camera, and it would certainly lead to confusion if we spoke of an e.m.f. amplifier even though the set-up which we call an r.f. amplifier is, in fact, a voltage amplifier. I do feel that only a person with the precise mind of an F.R.S. could help us straighten out our nomenclature; but probably some of you may have some good ideas?

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