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Wireless World

Reliability

THE emergence of electronics from the physics laboratory and its acceptance as an essential part of industrial and indeed of everyday life was amply confirmed by the scale of the recent I.E.A. Exhibition at Olympia and by the range of topics and lively discussion at the concurrent E.F.F.I. conference under the title "User Experience of Electronics in Industry."

The versatility and flexibility of electronics have through long familiarity ceased to be a source of wonder. It was no surprise to find at this conference papers on stock control and insurance computation followed by machine control and heat treatment, or a lecture on process control in petroleum refining between discussion of biscuit-making and steel production; but we hope that the many young electronics engineers in the audience were as impressed as we were by the revelation of the conditions under which some of their pet designs are expected to work—the high temperature and humidity of paper works, where in one instance an air-conditioned room had to be built to house the control equipment, and the radiant heat from steel strip which has called for the use of water cooling for phototransistors in equipment designed for the control of strip width by optical methods. Even in the equable atmosphere of an insurance office there may be hidden environmental hazards in the form of electrical interference. One case was reported of the mutilation of the contents of a computer store by spurious pulses arising from a radio-frequency ripple on the neutral line of the power supply.

The possible consequences of even the slightest malfunction of electronic equipment are often frightening. If a width gauge is faulty a whole coil length of steel strip may be considered as scrap and it would then be necessary to roll 100 coils accurately to make up the loss. In the three-dimensional profile milling of steel wing sections for high speed aircraft a 3in-thick billet of anything up to 40ft in length may have to be reduced to a skin thickness of 0.064in, and here again scrap can be very expensive. Petroleum refineries, where electronic controls in conjunction with digital computers are tending to take the place of analogue and pneumatic-hydraulic control, are expected to work continuously throughout the "on stream" period of 9 to 18 months with not more than 2% shut-down time for instrument maintenance.

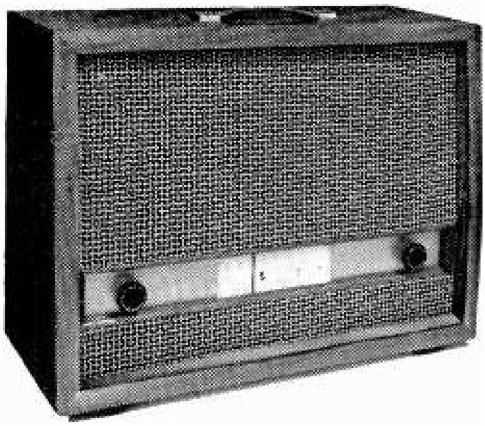
Not only in industry, but also in the civil and military services the question of reliability is never far from the thoughts of those who must put their trust in electronic devices. Problems of maintenance have been thrown into relief by the phenomenal reliability of the gas turbine engine which has greatly reduced the turn-round time for short-haul airline services. The demand is now for radio aids which will go for 3,000 flying hours between major overhauls. These and other matters such as the storage reliability of guided weapons were discussed in detail at the Symposium on Electronic Equipment Reliability organized by the Institution of Electrical Engineers. This was concerned with field experience and methods of assessing and predicting reliability and showed that the best way of coming to terms with the problem is to accept the fact of unreliability, to circumscribe it by routine maintenance or built-in self-checking facilities and by statistical analysis of case histories to trace the root causes of failure. It is interesting to note that routine testing can itself be the cause of unreliability. A case reported to the Symposium showed how failure of diodes in a large computer was traced to momentary short circuits when applying test probes. Insulation of adjacent conductors resulted in a reduction of the failure rate from as much as 4.4% to 0.03% per 1,000 hours.

The study and improvement of reliability is now a technology in its own right with its own specialized vocabulary; it may even be said in some respects to have attained the status of a science. Looking to the future we can safely build on the reliability of the electron itself, but there is still much to be learned of its behaviour in association with other elementary particles. In short, solid state physics and the properties of materials open a wide field for investigations into the long-term stability of the basic ingredients of electronic circuits. Meanwhile there is plenty of scope for simplification of some of the electronic "technicians rackets" we see employed for simple menial tasks; other things being equal, the chances of failure must increase with complexity and the number of elements involved. Ultimately, the best methods of achieving reliability are learnt from experience, but, as has so often been said, the fees are high.

Floreat Regalis Societas

ON the occasion of the tercentenary of the Royal Society we tender our respects and felicitations and wish the Society continued strength and wisdom in the future in fulfilling its functions as a touchstone of truth and a symbol of goodwill in the international relations of science.

Although the interests of the Society are wide (scientific disciplines have increased exponentially in recent years) it has not neglected to support research which is fundamental to radio astronomy and communications. In particular we have in mind the work of the Halley Bay station organized by the Royal Society during the International Geophysical Year.



In the three parts of this article a v.h.f./f.m. receiver of straightforward design is described: transistors of moderate cost are used and one watt output at low distortion is achieved. The receiver incorporates a recently described limiter and discriminator circuit giving good a.m. suppression. Some constructional and alignment details will be given in Part 2, and Part 3 contains the results of performance tests made on a prototype model.

Transistor V.H.F./F.M. Receiver

1. DESIGN CONSIDERATIONS AND CIRCUIT

By R. V. HARVEY*, B.Sc. A.M.I.E.E.

IN designing a transistor broadcast receiver, there may be a tendency to make undue concessions to the small size and low power consumption of transistors which might result in a sacrifice of performance. In applying transistor techniques to the design of a v.h.f. receiver for f.m. broadcasts, it was considered desirable to avoid this approach and to produce a receiver which without resorting to excessive expense or complexity had a performance equal, in the more important respects, to that of the better-quality domestic valve receiver. In particular, adequate suppression of amplitude modulation, adequate sensitivity and reasonable fidelity of sound reproduction were regarded as essential requirements for such a receiver.

General Design

The receiver is continuously tunable from 87 to 100 Mc/s. In the initial design, consideration of the availability and cost of transistors having a useful gain at 100 Mc/s led to the decision not to use an r.f. amplifier. However, the RCA Type 2N247 drift transistor was readily available and has sufficient gain to be used as an oscillator at frequencies

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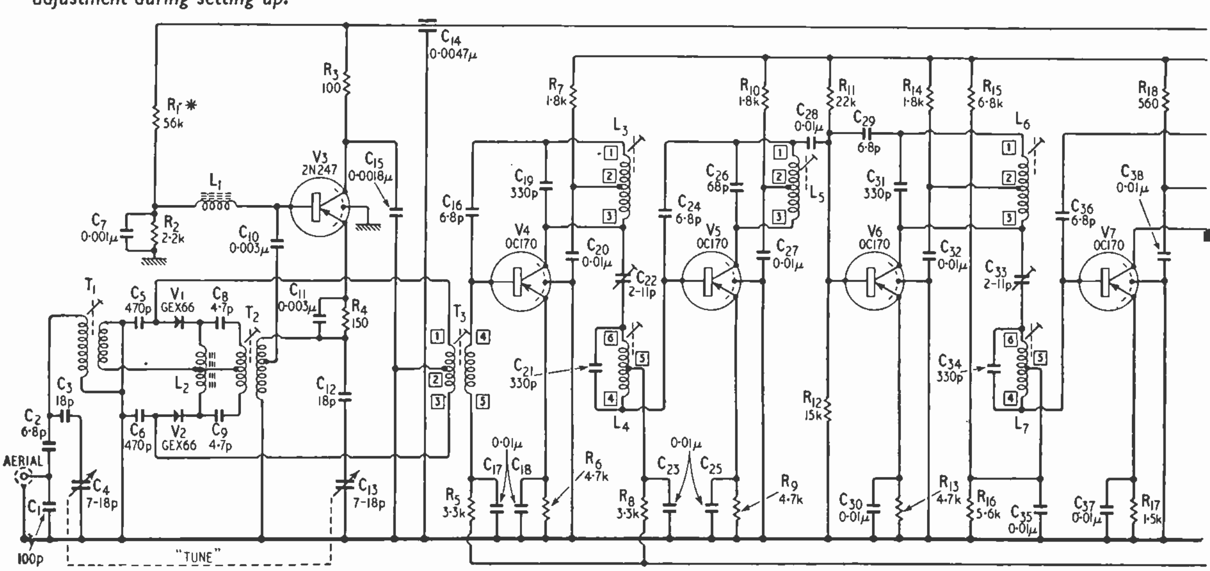
Fig. 1. Theoretical circuit diagram. Centre-tapped choke, L_2, and capacitors C_8 and C_9 may not be needed—T_2 is then joined directly to V1 and V2, the mixer diodes. Shown dotted are components for boosting bass for loudspeaker equalization: other component changes are C_{52}, reduce to 0.5µF, and C_{49}, reduce to 1,200pF. Asterisk against component value indicates adjustment during setting up.



from 77 to 90 Mc/s and to drive a diode mixer adequately for efficient conversion of the signal to the standard i.f. of 10.7 Mc/s. Radiation of oscillator power from the aerial is minimized by using a balanced mixer circuit. The effect of supply-voltage changes on the oscillator frequency is almost completely removed by shunting the oscillator supply by a Zener stabilizing diode. The remaining frequency drift is then quite small and is mainly caused by changes in room temperature as the "warming-up" effects due to internal heat production are negligible.

The i.f. amplifier must have a maximum gain of about 90 dB to make up for the conversion loss of the mixer and to supply sufficient power to the limiter; the latter can then operate satisfactorily at signal input levels down to about 30 μV. A stage gain of 22 dB could be achieved with adequate stability using the Mullard Type OC170 transistor and the required overall gain and bandwidth was finally obtained by cascading four such stages, using alternate single- and double-tuned coupling circuits. As miniaturization was not proposed, the i.f. amplifier could extend over some ten inches of chassis to avoid unwanted feedback.

It has been emphasized elsewhere that efficient suppression of amplitude modulation is essential to reduce the effects of co-channel interference[1] and multipath propagation[2, 3]. A simple valve receiver has been described[4] which achieves a good performance in this respect by incorporating a discriminator combined with a "dynamic diode" limiter. The limiter operates with a self-generated bias proportional to the mean level of the applied signal and suppresses rapid changes in level. The bias is also used for a.g.c. so that for slower changes in level, the variation of a.f. output is kept small but is not completely suppressed so enabling strong and weak transmissions to be distinguished from one another when tuning. As this combined limiter and discriminator is a passive circuit, it was adopted with little change in the transistor receiver.

A maximum a.f. output power of one watt, delivered to an 8-in high-flux-density loudspeaker, was considered sufficient for domestic reception. A transformerless Class-AB push-pull output stage, using G.E.C. Type GET115 transistors operating from a 12-volt supply, gives the required output into a loudspeaker impedance of 15 ohms. The phase-shift in these transistors at high frequencies is sufficiently small to allow about 20 dB of negative feedback to be applied to the input of the driver stage whilst maintaining adequate stability. Three additional stages, one incorporating the gain control, provide the necessary a.f. gain.

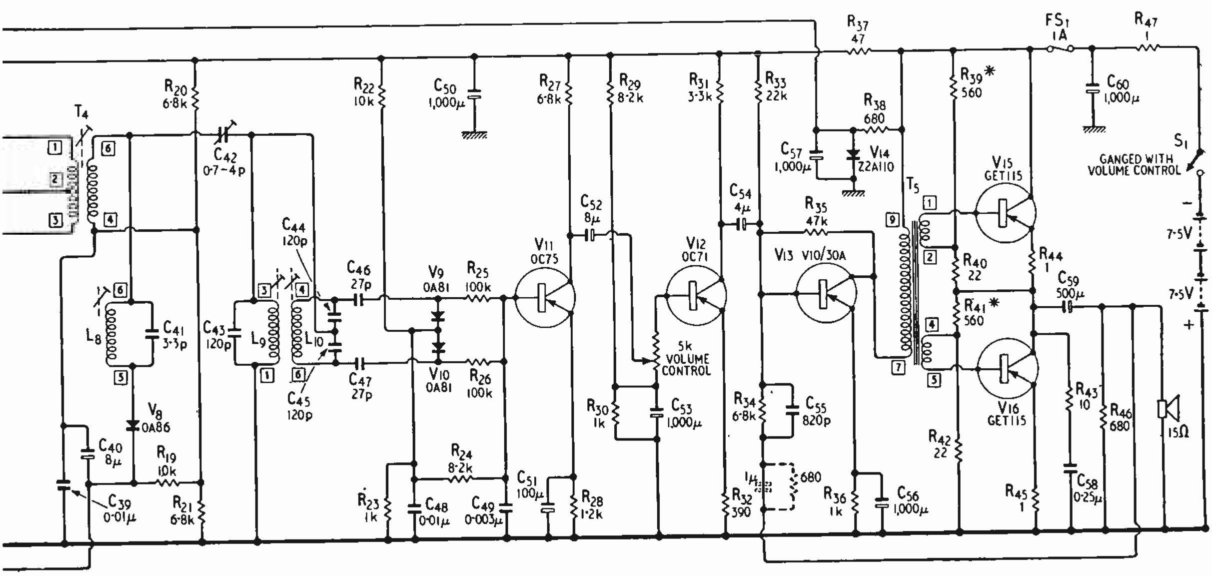
For acceptable fidelity of sound reproduction, a fairly large "table-model" size of cabinet measuring $22 \times 16 \times 10$ in was chosen. As the mean power consumption of the receiver is less than one watt, there is no need for internal ventilation. The cabinet was therefore constructed as a vented enclosure with a rigid back and with internal acoustic damping. Fixed bass- and treble-lift circuits were subsequently added to the a.f. amplifier to preserve a fairly uniform axial response.

Description of Circuits

The circuit diagram is shown in Fig. 1. Lists of suitable components and coil- and transformer-winding data will be given in Part 2.

R.F., Oscillator and Mixer.—The r.f. and oscillator circuits are each tuned by one section of a two-gang capacitor. The effective capacitance range is reduced to a variation from 5 to 7 pF by adding series 18 pF capacitors and restricting the angular swing of the tuning capacitor to 150°. To assist in the tracking of the two circuits, the r.f. coil is of slightly lower inductance (0.5 μH) than the oscillator coil and is loaded by an additional capacitive network which transforms the aerial impedance of 75 ohms to about 20 kΩ. The load imposed by the mixer and the coil loss is of the same order, resulting in an effective Q-value of about 50 for the r.f. tuned circuit.

The oscillator coil is connected between the emitter and collector of a 2N247 drift transistor, its base being tapped in close to the emitter end of the coil. This gives the required positive feedback, bearing in mind that the phase angle between collector and emitter currents approaches 180° at 90 Mc/s. As the oscillator frequency is dependent on collector



capacitance, part of which depends on the collector potential, the supply is stabilized at 10.5 volts by a Zener diode, S.T.C. Type Z2A110. The collector current is held stable at 1 mA by an emitter resistor of 150 ohms, the base being fed through a small choke from a potential divider across the battery supply.

The mixer consists of two GEX66 point-contact diodes driven in push-pull by the oscillator; the r.f. coupling is connected between the mid-point of the oscillator coil and the earth. The balanced circuit reduces the oscillator voltage appearing at the input to less than 1mV and direct i.f. pick-up through the mixer is minimized by the use of inductive coupling. To prevent spurious f.m. of the oscillator by input signals of 100 mV and greater, it may be necessary to insert capacitance (C_8 and C_9) in series with the mixer diodes and the oscillator couping, as shown in the circuit diagram; the centre-tapped choke, L_2, then provides a d.c. path for direct current in the mixer, which is about 200 μA. If C_8, C_9 and L_2 are omitted, V1 and V2 should be connected directly to T_2 primary. The output impedance of the mixer is about 600 ohms and the conversion loss of the unit at 90 Mc/s is approximately 12 dB.

I.F. Amplifier.—The balanced output from the mixer is transformed to an unbalanced impedance of 300 ohms by the first i.f. tuned circuit and applied to the base of the first i.f. stage. The amplifier consists of four OC170 transistors in common-emitter connection. The maximum-possible unilaterilized power gain is about 120 dB, of which, in the interests of stability, about 30 dB is deliberately lost. This is achieved by choosing the L/C ratios of three interstage-coupling circuits to obtain a loss of about 10 dB in each coupling with unloaded Q-values of 100. The overall response is largely determined by these three circuits, one single-tuned and two coupled pairs, and is 3 dB below the maximum at about $\pm$90 kc/s from the centre frequency. Non-critical neutralization is effected by 6.8-pF fixed capacitors.

The first two OC170 stages operate at a maximum collector current of 1 mA, developing a potential drop of five volts across their emitter resistors. The gain of the receiver may be reduced by up to 50 dB by applying a.g.c. voltage to the bases of these two stages The third and fourth stages operate with fixed bias and the last stage has a collector current of 3 mA in order to deliver a maximum i.f. power of about 5 mW to the limiter and discriminator circuits.

Limiter, A.G.C. and Discriminator.—The action of the limiter and discriminator circuits is described only briefly here; a more detailed explanation has been given elsewhere[4].

The collector of the last i.f. stage is connected to the primary of a tightly coupled step-up transformer. The secondary winding is shunted by an amplitude-modulation limiter in the form of a peak detector with a long-time constant load. As the mean load resistance imposed by the limiter is approximately one-seventh of the remaining shunt resistance across the secondary winding, the limiter will function with modulation depths of up to 87%; at greater depths the limiter will not operate at troughs of modulation. The limiting efficiency is improved by the addition of a third-harmonic filter (L_8, C_{11}) in series with the diode[5].

An a.g.c. voltage is applied to the bases of the first two i.f. transistors from one end of the limiter load resistor. The other end of the load is returned to a point on a potential divider across the d.c. supply; thus the a.g.c. bias is maintained at -5 V in the absence of a signal, decreasing to -0.5 V for large signal inputs. The a.g.c. is applied to the i.f. stages without any more long-time-constant filtering so that amplitude modulation such as aircraft flutter is effectively controlled when its frequency is too low for the limiter to operate.

A Foster-Seeley type of phase discriminator is coupled to the limiter by a small series capacitor which, with some of the primary reactance of the discriminator transformer, forms an impedance-inverting network. The discriminator is thus fed from a high-impedance source (as is essential for its correct operation) derived from the very low impedance presented by the limiter.

A capacitive centre-tap is used on the secondary of the discriminator transformer and the inductive coupling between primary and secondary is 1.5 times the critical value. The combined primary and secondary voltages are applied to two shunt diodes with load resistors returned through a relatively small common resistor. This resistor forms the source impedance for the first a.f. stage, carries the base bias for the transistor and, with the input impedance of the transistor and a shunt capacitance, forms the de-emphasis network. By connecting the diodes and their load resistors so that the difference-current flows in a small common resistor, the "dual" of the conventional Foster-Seeley circuit, which applies the difference voltage to a high-value shunt resistor, is formed. The lower output impedance of the former circuit is clearly more suited to supplying a transistor amplifier.

A.F. Amplifier and Output Stage.—The output of the first a.f. stage following the discriminator is passed to the a.f. unit, in which an output power of 1 watt is obtained from a minimum signal of 0.5 V across the 5-kΩ a.f. gain control. There are two intermediate common-emitter stages, a coupling transformer and a pair of output transistors operating in Class AB for power economy. There is no output transformer as the 15-ohm loudspeaker forms an optimum load connected (via a capacitor) between the junction of the output transistors and the chassis. The quiescent current in the output transistors is about 7 mA and, to give minimum cross-over distortion adjustment of the bias is required. About 17 dB of negative feedback is applied to the preceding stage from the loudspeaker through a correcting network and 9 dB feedback from the collector to the base of that stage. By choosing output transistors having moderate power-handling capacity and relatively high cut-off frequency, negative feedback is easy to apply and the design of a very efficient output stage has been possible.

Loudspeaker Compensation.—The 8-in diameter loudspeaker, when mounted in an open cabinet, gave a somewhat irregular response. By making the back of the cabinet of rigid board, treating the inside surfaces with layers of fibre-board and wood-wool, and cutting a 2-in diameter vent in the front panel, the gross irregularities were removed. The smoothed axial response has a progressive loss above and below 2 kc/s, amounting to 8 dB at 100 c/s and 6 dB at 10 kc/s. The circuit shown in Fig. 1 gives a substantially uniform audio-frequency response; to compensate for the response of the particular loudspeaker and cabinet used here, the circuit can be modified slightly. Partial electrical compensation at high frequencies can be provided by simply reducing the de-emphasis time-constant to $30\mu s$ (C_{49} is reduced to 1,200 pF). Partial bass-compensation is effected by inserting a 680-ohm resistor shunted by a $1\text{-}\mu F$ capacitor in the a.f. feedback loop, between C_{59} and C_{55} (shown dotted). To prevent the gain rising to excessively high levels at very low frequencies, the coupling capacitor between the first two a.f. stages (C_{52}) is reduced to $0.5\mu F$.

Power Supply

The receiver will operate satisfactorily at supply voltages of between 11 and 15 volts; the upper limit is set by the rating of the output transistors and the lower limit by the Zener diode stabilizing the oscillator supply. The current consumption is about 22 mA with no signal and about 30 mA at normal listening level. A convenient supply for the table model receiver is provided by two 7.5-volt dry batteries, each measuring $5\frac{1}{8}\times2\frac{1}{4}\times3\frac{3}{4}$in. Using this supply, costing 6s. 6d., the estimated life of the batteries is about forty days if the receiver is used for four hours every day.

(To be continued)

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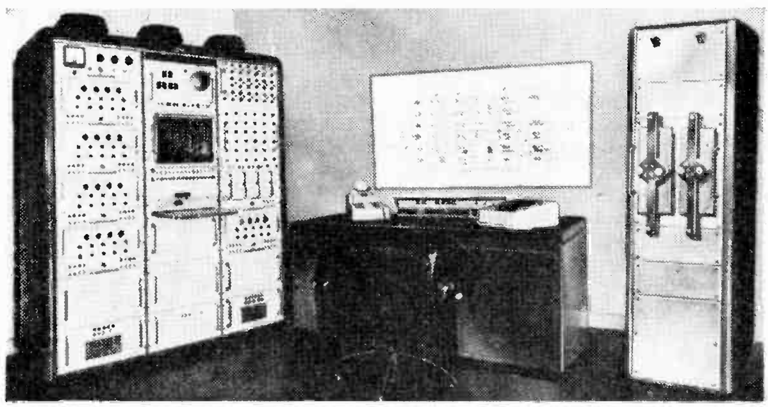
HYBRID COMPUTING SYSTEM

Analogue and Digital Methods Combined in New Equipment



IT has been recognized for some time that the ideal electronic computing system is one which combines the advantages of both analogue and digital techniques. On the analogue side there are the advantages of high speed of operation, ease of programming even with very complex calculations, ability to alter the input information during computation, relatively small size and low cost. On the digital side the principal advantages are high accuracy, convenience of input and output facilities, extensive storage and stability with time.

Unfortunately, in practice one cannot get the advantages without the disadvantages, and any combination of the two techniques must take into account such things as the limited accuracy and lack of storage of the analogue computer and the relatively slow speed and high cost of the digital machine. In short a particular pattern of advantages and disadvantages has to be selected, depending on what sort of work the hybrid computer is required for. This pattern will, of course, determine the particular way in which the analogue and digital electronic circuits are combined.

An extremely versatile combination of techniques has been adopted in the new hybrid computing system developed by Redifon (who are perhaps better known at present for their flight simulators and communications equipment). It is called RADIC, which stands for Redifon Analogue Digital Computing system. Basically it is an analogue computing system with digital input, output and storage facilities—the storage equipment being an unusual design giving quantization in the time scale. It is, above all a *system*, from which groups of computing elements can be selected for particular types of calculation—not a fixed-size computer. A major field of application which depends largely on the analogue facilities is the analysis and simulation of industrial and other control systems. Other applications, such as statistical analysis, linear programming and analysis of the transfer functions of commercial and other operations, depend more on the digital facilities.

Since the RADIC is basically analogue in its mode of calculation it is not intended for commercial and accountancy work, where 100 per cent accuracy is essential (for example, in calculating payrolls!) There are, however, a good many commercial calculations that do not require exact figures since the input information is not 100 per cent accurate, but where an answer of 99.9 per cent accuracy is most valuable if it can be produced quickly—as it can by analogue methods.

The electronics of the RADIC system, then, comprises an assembly of drift-corrected d.c. amplifiers, electronic multipliers and diode-network function generators operating on well-known principles.* These electronic computing elements, backed up by electro-mechanical servo-operated integrators and multipliers, perform the operations of addition and subtraction, multiplication and division, integration and differentiation with respect to time and the generation of mathematical functions (e.g., sines, squares, logarithms). The elements can be interconnected in various ways, depending on what type of computation is to be performed, by means of a central "patchboard."

As already mentioned, digital devices are used for feeding numerical data into and out of the analogue computing elements, and also for storage purposes. There are two keyboards for input information. One, on a modified "Addo X" digital printer, is for feeding numerical data into the storage system. The other keyboard is for the automatic setting of coefficients in the analogue computing elements. There are also two devices for digital output information, an illuminated number display (on both the main computer and the central desk) and a print-out mechanism (on the "Addo X" unit). Digital storage is provided by a magnetic tape equipment, which can also be used for the simulation of time delays in control systems and for other special purposes.

All these digital input, output and storage devices operate in the "parallel," as distinct from the "serial," mode—that is, all the pulses representing a number occur simultaneously on separate wires, not in sequence on a single wire. This method, using the binary-coded decimal system of representing numbers, enables the digital units to match the high speed of the analogue computing elements. The translation of data from digital to analogue form and vice versa is done by analogue-to-digital and digital-to-analogue converters.

Magnetic Storage

The feature of the RADIC system which, perhaps more than any other, distinguishes it from conventional analogue computers is the magnetic-tape digital storage system. This extends the field of use of the system to complex types of input data which the normal type of analogue computer is unable to handle. Physically this storage system takes the form of a separate transportable cabinet —the reason being that it can be used on its own for certain types of calculation or taken to a remote site to record characteristics of, say, an industrial plant. It contains two tape decks, a digital encoder for translating input data into a form suitable for storage, and a digital-to-analogue converter for translating digital data from the tape into a form suitable for the analogue computing elements. The magnetic tape is 35mm wide and has sprocket holes like cinematograph film. It will record 16 channels simultaneously.

As mentioned earlier a new principle is used for the storage of digital information on the tape. This is the process of quantizing the time scale as well as the data recorded. Using a sprocket drive system, the tape is moved in separate small steps, and digits are recorded and read-out while the movements are taking place.

By this means the stored information is put under more precise control than it would be on a continuously moving tape, and, in fact, the small steps are accurately synchronized to the read-in/read-out circuitry. Although the tape always moves at constant speed over the magetic heads, the intervals of time between successive movements can be extended at will. As a result the average tape speed can be precisely varied over an extremely wide range of speed. The pulse which controls the stepping action can be set at a constant rate or made to vary in accordance with some other quantity involved in a computation. Incidentally this new time-quantizing method of operation dispenses with the cumbersome and costly circuitry normally required for slow-moving tapes and flux-sensitive magnetic heads.

Time-delay Applications

One special use of this storage system is that it can be used to simulate time delays which may occur in process control systems. Data is recorded on the tape and then read out by a reading head which is physically displaced from the recording head—the time taken for a point on the tape to pass from the recording head to the reading head being determined by an accurately controlled number of steps, each of which takes an accurately controlled interval of time.

In addition this time delay facility is used for correlation computing, in which data stored on the tape is continuously compared with data on other parts of the tape (displaced by known intervals of time) in order to detect periodicities. For this work it is necessary to be able to automatically alter the spacing between the two heads by an electrical signal to give a series of different time delays as the computation proceeds. This is done by an ingenious mechanism in the tape deck based on differential movement between two tape driving sprockets.

Correlation computing (which is explained at some length in "Electronic Computers"*) can be performed on either analogue or digital input data. In the RADIC system it is intended to be applied mostly to digital information for statistical analyses —particularly the analysis of systems, whether industrial plant or commercial operations, which defy normal mathematical treatment. For this field of applications the digital storage unit, combined with built-in integrators and multipliers (required in computing correlation coefficients), is supplied as a separate equipment which is small enough to be transported to remote sites where recordings may have to be made *in situ*.

Overall control of the RADIC computing system is given by a bank of press-buttons situated on the control desk near the digital input and output equipment. Some of these buttons, for example, provide an elaborate selection system which enables the voltages at the outputs of any of the analogue computing amplifiers to be indicated as numerical values on the digital number display (actually a digital voltmeter).

The equipment shown in the photograph is a medium-sized assembly incorporating the maximum variety of analogue and digital units.

* The basic principles of analogue computing techniques were outlined recently by G. B. Clayton in "Simple Analogue Computer" in *Wireless World* for May, 1960. For additional information, see "Electronic Computers," 2nd edition, by T. E. Ivall, Iliffe, 1960.

CORNER BAFFLE LOUDSPEAKER MOUNTING

METHOD OF DOUBLING THE EFFECTIVE BAFFLE SIZE

By H. C. PINFOLD

THE recent revival of baffle mounting of loudspeakers initiated by G. A. Briggs led the writer to do some experimenting with this form.

It is known that, given a large and rigid enough sheet of wood, preferably about seven feet square and several inches thick, and a speaker of really low free-air resonance, then plain baffle mounting gives remarkably clean bass free from the boom which is often associated with the various types of enclosure mounting.

However, few people have the space for such large baffles as are necessary for reproduction right down to 40c/s.

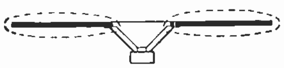


Fig. 1. Conventional baffle mounting of a loudspeaker. The dotted lines show the shortest paths connecting the front and back of the cone.

The purpose of the baffle is to keep the front and back radiations separate from one another for as great a distance as possible. The speaker is usually mounted near the centre of a square or rectangular board and thus effective separation of the front and back waves is achieved for a distance of only twice one half of the size of the board (see Fig. 1).

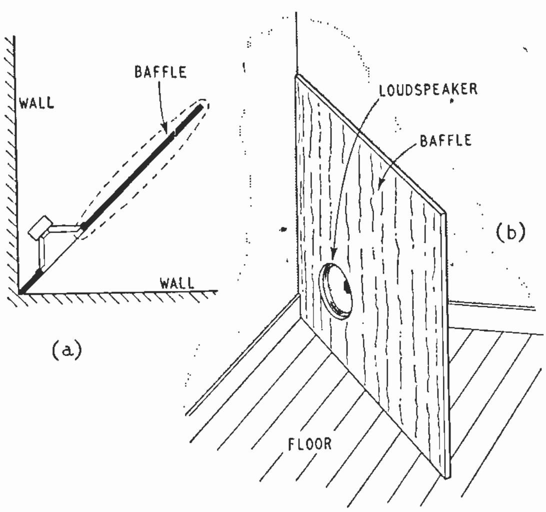


Fig. 2. Plan (a) and perspective (b) views of corner baffle-mounted loudspeaker.

However, if the speaker is mounted near a corner of the board, as near to the edges as the depth of the frame and magnet will allow, and the board is placed diagonally into the corner of a room as in Figs. 2(a) and 2(b), then, assuming the board to be the same size in both cases, it will be seen that the shortest path between the back and front of the speaker in Fig. 2 is nearly twice that in Fig. 1. Alternatively, the arrangement of Fig. 2 will give, for a board of half the size, at least as good results as that of Fig. 1.

Loading of the speaker cone is much improved in the corner arrangement, as both sides of the speaker face into spaces which are horn-like in shape. Furthermore, when a speaker is mounted on a conventional baffle and placed as is usual near to a wall, there is an inevitable interaction between the cone and the wall so that a standing wave is built up. This effect is avoided in the corner arrangement.

There is no critical tuning to be done with this sort of mounting, which works well with a variety of speakers. The only factor that governs the choice of speaker for this mounting, as for all baffle arrangements, is the bass resonance of the unit, which should be as low as possible. The Wharfedale 10-in Bronze FSB unit (bass resonance about 35c/s) sounds remarkably good and is not costly, but no doubt a high-flux 12-in unit would be more beefy.

As for the baffle board itself, 3 feet square of 1-in block board gives very fine bass and exhibits no tendency to panel resonance. Two 1-in boards screwed together would be better, or a sand-filled sandwich would be better still. A rectangular board might also be preferable. Sealing to the floor and walls is not critical, but some shaping is necessary around skirtings, etc. The board is self-supporting.

CLUB NEWS

Essex.—The Silverthorn Radio Club is holding its annual field event over the August Bank Holiday weekend at Carroll's Farm, Sewardstonebury, near Chingford. Station GB3SRC will operate in the 160-m band. The club meets on alternate Fridays at the South Chingford Community Centre, Hall Lane, London, E.4.

London.—The secretary of the International Short Wave Club (Arthur E. Bear, 100 Adams Gardens Estate, London, S.E.16) offers to send a specimen copy of the club's news bulletin "International Short Wave Radio" to any reader of *Wireless World*. The duplicated four-page monthly bulletin gives up-to-date news of short-wave broadcasting stations, including schedules and operating frequencies.

Middlesex.—At the meeting of the West Middlesex Tape Recording Club on July 28th Angus McKenzie, of Olympic Sound Studios, will speak on stereophonic recording and reproduction. The meeting will be held at 8.0 at the St. George's Hall, Lancaster Road, Southall Broadway.

Monmouth.—Preparatory to forming an amateur radio club in Blackwood, Mon., meetings are being held each Friday at 7.0 at the Blackwood Miners' Welfare Institute. Further details are obtainable from P. M. Fulton, 36, Sunnybank Road, Blackwood.

OPTICAL LINE ELIMINATOR

DISPERSIVE SCREEN UNDER DEVELOPMENT BY THE GERMAN FIRM SABA

ONE of the arguments put forward in favour of changing British television line standards from 405 to 625 is that on the larger screens (21-inch and upwards) the line structure is disturbing. It is interesting to find that the same criticism is made of high-quality pictures on the 625-line standard in Germany, according to a recent survey by SABA, the Black Forest firm of receiver manufacturers. At a recent international press conference, on the occasion of the 125th anniversary of the foundation of the firm, it was stated that, with all possible improvements in the matter of optimum phase and amplitude characteristics, fully automatic tuning and contrast control, etc., already incorporated in their sets, line structure, according to some of their customers, was the only performance factor requiring improvement. The spot-wobble technique is, of course, expensive and the production of an elliptical spot is difficult with the short necks and complicated deflection coils now necessary with wide-angle tubes.

The solution being developed by SABA is purely optical and consists of a transparent plastic sheet, with horizontal parabolic corrugations embossed on one side. This screen is mounted a short distance in front of the cathode ray tube and light from the screen is dispersed vertically (Fig. 1) but not horizontally, so that the resolution along the line is unaffected. An essential feature of the method is that the pitch of the corrugations should be small compared with the picture line spacing. In a specimen examined by this journal the rulings are 125μ (0.125mm) wide, i.e., about 200 per inch, and the height of the parabolic arc is 8.5μ. There are thus about 8 lenses to every line of a 405 picture on a 21-inch tube (line spacing 1mm).

To test the efficacy of the device a photographic plate was made of two lines each $\frac{1}{2}$mm wide and separated by a dark space of the same width (very approximately 405-line 21-inch conditions). This was illuminated from behind and photographed through the screen, the left-hand edge of which was resting on the plate and the right-hand edge raised about $\frac{3}{8}$-inch. The result is shown in Fig. 2 from which it will be seen that the lines merge when the spacing is about $\frac{1}{4}$ inch (6mm); when the distance is increased, multiple lines reappear. In practice optimum spacing would, of course, depend also on the thickness of the glass of the c.r. tube. Fig. 3(a) is a test plate also ruled to simulate 405 lines on a 21-inch tube and is reproduced full size, so that it can be judged at any desired viewing distance. Fig. 3(b) is an untouched photograph of the plate taken through the SABA screen.

Research is proceeding and in particular is directed to producing a clearer screen—the specimen we tested was translucent, due to minute score marks made by the tool used in cutting the master plate.

The beauty of the scheme, which gives the same result as spot wobble, is its cheapness; replicas are easily cast in thermoplastic material. And those who like to see the lines can always remove the screen!

Lenticular screens are not in themselves new—they have been suggested for modification of picture aspect ratio (*Wireless World*, December 1952, p. 502) and for stereoscopic television (*Wireless World*, July 1953, p. 298)—but this latest application to the removal of lininess promises more immediate benefits. It is certainly cheaper than changing our transmission system to 625 lines, or should we now say, in view of Continental experience, to 4,050 lines?

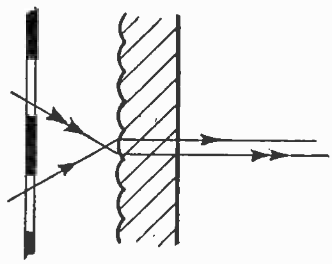


Fig. 1. Vertical section illustrating the principle of the dispersive screen under development by SABA.

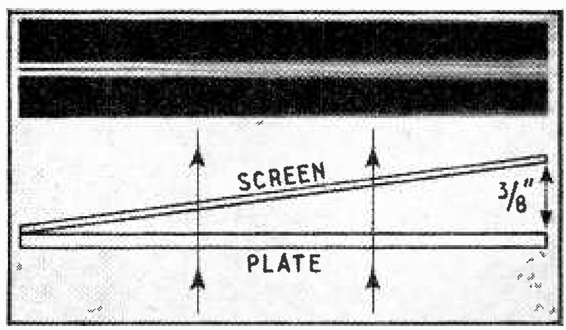


Fig. 2. Variation of visible line structure with distance between tube and screen.

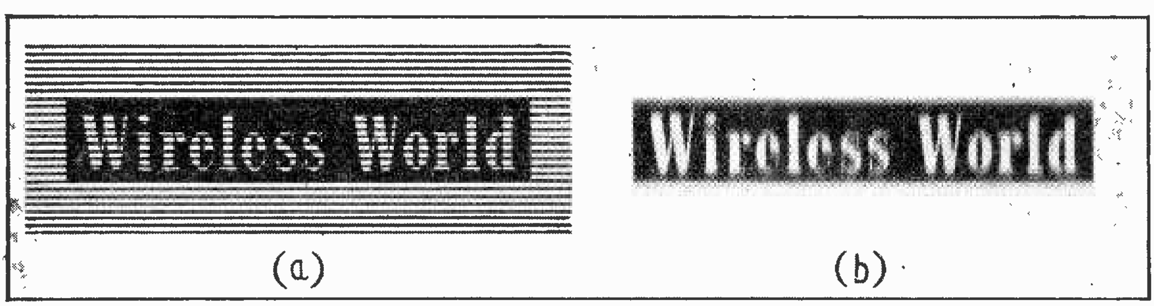
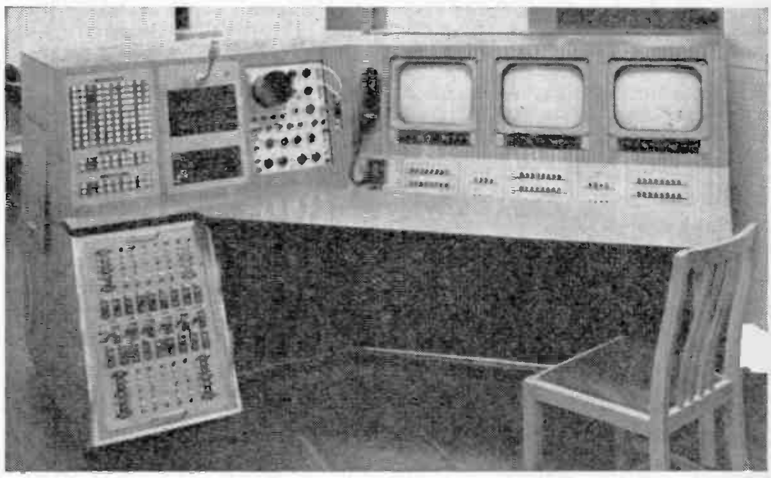


Fig. 3. Test specimen (a), reproduced full size to represent 405 lines on 21-inch tube, and (b) viewed through the SABA dispersive screen.

B.B.C. Television Centre



A WHOLE issue of this journal would be quite inadequate to cover all the interesting features of the new B.B.C. Television Centre in West London. We shall, therefore, describe and illustrate from time to time points of special interest in the installation.

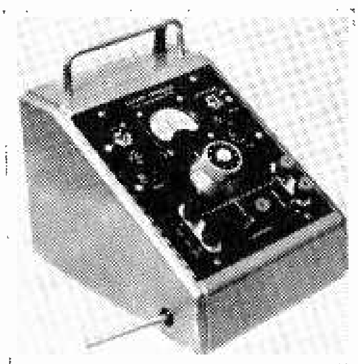
Co-ordination and ease of control have been key words in the planning of the operational control areas associated with each of the seven studios grouped around the central ring building. The first transmission from the Centre was on June 29th. Only one studio, of 8,000 sq ft, is so far in use.

Eleven flying-spot film scanners for both 35-mm and 16-mm films are being installed in the Telecine Suite. At the central control desk illustrated above the outputs from all the machines, which are housed in adjacent bays, are monitored and distributed. Facilities are provided for remote starting and stopping of the film scanners from several points in the control system.

Control consoles for studio lighting (left) and vision (right) are adjacent so that each controller sees the same set of monitors. By the use of six joystick-type controls (ringed in the photograph) one operator can remotely control the iris and the picture black level of each of up to six cameras in the studio. Each of the joystick controls has three functions. Moving over a quadrant varies the camera lens aperture; a knob on the control is rotated to adjust the picture black level and pressure on this knob switches the camera output from one picture monitor to another. This last facility enables the output from each camera to be displayed in turn on a single monitor for matching, thus eliminating possible differences in individual monitors. Alongside each monitor is a miniature waveform display. The waveform is about 5-in high but the time scale is compressed to about $1\frac{3}{4}$-in as the controller is mainly concerned with checking voltage levels.

Technical Notebook

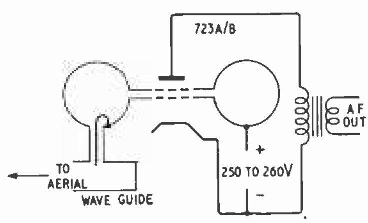
Field Plotting using a resistive sheet rather than an electrolytic tank was first described as long ago as 1845 by Kirchhoff, who used thin sheets of copper. However, this technique has been lying in abeyance pending the discovery of a more suitable sheet material. Creed's "Teledeltos" paper is used in a relatively inexpensive plotter recently introduced by Servomex (Type FP92). To plot a field, the paper is painted with silver electrodes which are then



connected to the internal supply voltage on the Servomex plotter. This voltage is divided down to an accuracy of 0.1% by means of a calibrated potentiometer, and then fed via a balance-indicating meter to a probe. By searching the resistive paper with the probe for balance points, a field line corresponding to the chosen dividing ratio can be built up. Non-uniformities in the resistivity of the sheet normally limit the accuracy of field measurements to about 7%. This accuracy is, however, not much worse than what is normally achieved with an electrolytic tank. In any case, in practice, fields are usually plotted only in order to determine correction factors to theoretical formulæ; so that errors, being only corrections to corrections, need not be kept very small.

Prefabricated Electronic Bricks—ready-assembled circuit modules—can cut down development time spent on a control-engineering or data processing problem by eliminating the work of designing individual circuits. A particular range made by Mullard are slim, colour-coded plastics "boxes" of guaranteed performance specifications covering the commonly used circuit functions. Typical units are AND/OR gates, timing and relay-operating circuits called "Norbits" (for control purposes) and flip-flop, pulse shaper and inverter-amplifier stages called Combi elements (for digital circuits). By giving only a performance specification the manufacturers can take advantage of advances in techniques (for instance, complete solid-state circuits) without, at the same time, rendering obsolete existing apparatus. Transistors are used throughout, so that battery operation is reasonably economical, and the modules are designed to connect together compatibly in a manner suited to their functions. Norbits have long, flexible flying leads for use with terminal blocks while Combi-elements have short, stiff tinned wires suitable for fitting into printed wiring boards.

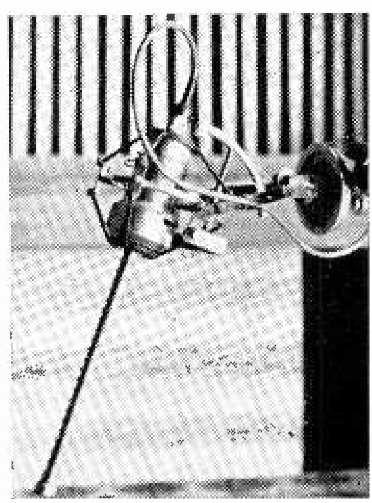
Klystron Detector for Microwaves is the subject of an article by Dr. Koryu Ishii on p. 77 of *Electronic Industries* for November 1959. Dr. Ishii made the widely available 723A/B 3-cm reflex klystron act as an a.m. detector with a 3-dB bandwidth of 50Mc/s at 9.2Gc/s and a gain (for weak signals) of between 10 and 30dB. As can be seen from the diagram, the repeller is connected, via the load, to the cathode and an h.t.



of about 250V is applied between the cavity structure and cathode. Electrons accelerated by the field between cathode and cavity can pass through the modulating electrodes (lips) of the cavity and reach the reflector. When, however, the cavity is excited by signals at its resonant frequency the lips will modulate or bunch the electron flow, retarding and accelerating on alternate half cycles of the 9.2Gc/s signal. The accelerated groups will reach the reflector, where they constitute the signal current. The retarded groups, on the other hand, will not possess sufficient speed to reach the reflector and will return, under the influence of the potential gradient between the reflector and cavity, to the cavity lips. If the relative phase of the signal on the cavity and the returned bunches is correct, then the returned bunches will give up the energy gained from the reflector-to-cavity field, so reinforcing the signal. The reinforced signal exerts a greater effect on the electron beam, in the same way that the klystron normally goes into oscillation. Cavity potential is fairly critical: results given show that a 3dB gain loss is caused by a ±0.25-V change in h.t.; however, for the same loss of gain a 1.3-V variation in heater potential is permissible.

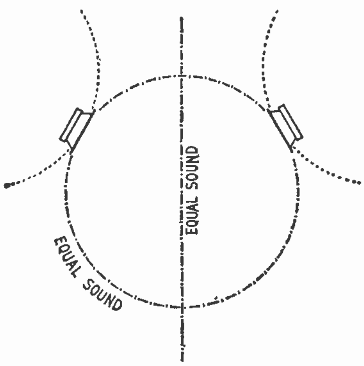
Peak Pulse Power Increase could be obtained by means of pulse shortening according to an article by C. E. Cook in *Proc.I.R.E.* for March 1960. The method of shortening suggested depends on providing a pulse in which the frequency changes linearly with time. This pulse is then passed through a filter which produces a delay which also changes linearly with time but in the opposite sense to that in which the frequency changes linearly with time in the pulse. The beginning of the pulse is then delayed more than the end and the pulse duration is decreased. If a passive delay network is used, the total energy in the pulse must remain constant so that the peak pulse power must increase in proportion to the decrease in the pulse period.

New Microphone brought into television studio service by Tyne Tees Television and manufactured by the American firm Electrovoice (Model 642) has a normal dynamic cardioid response characteristic up to 500c/s,



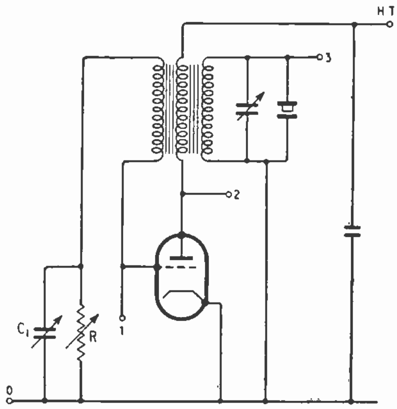
but above this frequency distributed openings at the front of the diaphragm make the response much more directional.

Stereo Listening-area Enlargement can be obtained by using loudspeakers having a figure-of-eight rather than an omni-directional polar response, according to an article by B. B. Bauer in the April 1960 issue of the American *Journal of the Audio Engineering Society.* When two loudspeakers are used to reproduce stereo, satisfactory results are obtained near places where the two loudspeakers produce equal sound outputs when fed with equal in-phase signals. In most cases such equal sound outputs are produced along the line of symmetry between the loudspeakers, and satisfactory stereo is produced in an area around this line. With figure-of-eight polar response loudspeakers, however, such equal sound outputs are produced not only along the line of symmetry between the loudspeakers, but also along the circle common to the polar responses of both loudspeakers (see diagram), so that satis-

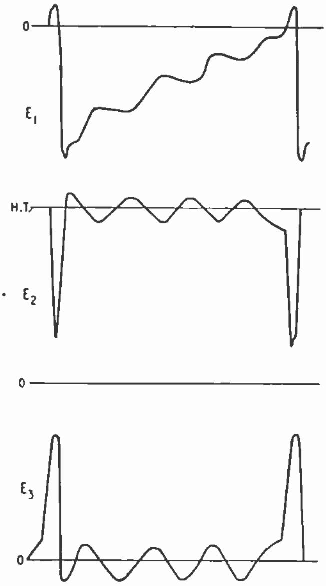


factory stereo is produced in an additional area around this circle. One way of obtaining a figure-of-eight response is to mount a loudspeaker on a baffle smaller than the sound wavelength of the highest frequency of interest, although unfortunately at low frequencies such baffle mounting results in a sound output which falls as the frequency decreases.

A Sub-harmonic Crystal Oscillator requiring only a single triode valve in a blocking oscillator circuit has been constructed at the U.S. National Bureau of Standards. As shown in the illustration at (*a*) the crystal is coupled to the blocking oscillator by means of a tertiary winding on the transformer. Alternatively the crystal could be connected across either the grid or anode windings, but the third-winding arrangement was found to be preferable. Typical waveforms at differ-



(a)



(b)

ent points on the circuit are shown at (*b*) in the illustration.

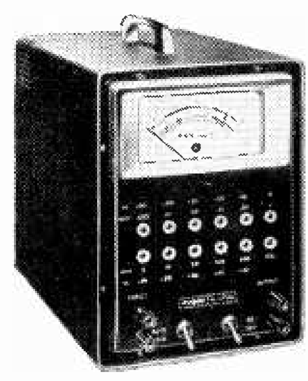
The fundamental frequency of the blocking oscillator is determined primarily by the time constant of C_1 and R in the grid circuit, so with C_1 or R or both variable a wide range of output frequencies can be generated. Each output pulse of the blocking oscillator "shock excites" the crystal, and the voltage so generated is used to synchronize the oscillator at a sub-harmonic of the crystal frequency.

Frequency division ratios as high as 10,000 to 1 have been obtained with a few crystals, but such extreme ratios would seldom be of practical value, since a small change in circuit constants could cause the output frequency to change from, say, 1/10,000 to 1/10,001 of the crystal's fundamental frequency. More realistic are divison ratios of several hundred to one.

The potentially wide range of division ratios obtainable means that a desired output frequency can be produced from any of several available crystals, or conversely, a single crystal can be used to produce a large number of crystal-controlled sub-harmonic outputs.

Interference with Television can occur in many ways—some difficult, some easy, to track down. Usually television interference by amateur transmitters falls into two categories—either pick-up by the i.f. circuits of the set, or the radiation of harmonics in the television bands. However, it can be more complicated, as N. Ashton notes in a letter on p. 424 of the March 1960 *R.S.G.B. Bulletin.* From the description given it seems that the process is like this: if a strong signal enters a television receiver it may cause cross modulation between sound and vision, so giving a 3.5Mc/s beat. When the interfering signal is near 3.5Mc/s, or a sub-harmonic, it can beat with the cross modulation, this beat being modulated back on to the sound and/or vision signals! The obvious cure is a high-pass filter of cut-off point 40Mc/s or so, placed in the aerial lead; but this does not always work, due to the use of small isolating capacitors at the chassis end of the aerial socket-to-tuner cable. These capacitors may have a high impedance to a signal as low in frequency as 3.5Mc/s, thus pick-up on the cable "outer" is transferred to the receiver. Consequently the filter has to be fitted inside the receiver, as close to the tuner as possible.

Motor-driven Automatic Correct-range Selection is an unusual feature of the new American Knight a.c. valve voltmeter kit shown assembled in the photograph: all the 11 ranges can be driven through in 2½sec. Full scale deflections can be produced by potentials ranging from 3mV to 300V, and the response is within ±1dB from 20c/s to 2.5Mc/s. As many as 10 valves are used in the circuit. Further particulars may be obtained from Ad. Auriema Inc. of 85 Broad Street, New York 4, U.S.A. or from Auriema—Europe S.A. of 27 Rue du Berger, Brussels, Belgium.



WORLD OF WIRELESS

Broadcasting Inquiry

ON July 13th the P.M.G. announced in the House the setting-up of a committee of inquiry into the future of sound and television broadcasting in this country. He also announced that the Government proposes to extend the B.B.C.'s Charter for two years so that it terminates on the same date as the I.T.A.'s—July 29th, 1964.

The Committee's terms of reference are:—

"To consider the future of the broadcasting services in the United Kingdom, the dissemination by wire of broadcasting and other programmes, and the possibility of television for public showing;

"To advise on the services which should in future be provided in the United Kingdom by the B.B.C. and the I.T.A.;

"To recommend whether additional services should be provided by any other organization; and

"To propose what financial and other conditions should apply to the conduct of all these services."

It is also being asked to consider the recent T.A.C. report. The chairman is Sir Harry Pilkington. The last Government committee of inquiry into broadcasting as a whole was set up in 1949 under the chairmanship of Lord Beveridge.

Technical Writing Awards

NEW details have been issued of the scheme introduced ten years ago by the Radio Industry Council for awards to writers of technical articles making known British achievements. The scheme is now sponsored jointly by the Council and the Electronic Engineering Association who award up to six premiums of 25 gn each for what are adjudged the best articles published each year.

The panel of judges now includes:— Air Marshal Sir Raymund Hart (director, R.I.C.), Professor H. E. M. Barlow (University College, London), B. C. Brookes (University College, London), A. H. Cooper (E.M.I.), F. Jeffery (Murphy), G. Reeves (A.E.I.) and Dr. R. C. G. Williams (Philips).

Copies of the leaflet outlining the scheme are obtainable from the secretary, E.E.A., 11 Green Street, London, W.1.

Progress in Medical Electronics

THE publication* of the Proceedings of the Second International Conference on Medical Electronics, Paris, June, 1959, adds a valuable source book to the literature of a rapidly expanding subject. In 614 pages with 400 diagrams and photographs it records more than 80 full papers and 70 abstracts ranging over a wide field and grouped under the several headings of electrophysiological techniques, electroencephalography, cardiology, manometry and flow measurement, acoustic techniques, automation in medicine, radiology and isotopes, and chemical instrumentation.

The editor is C. N. Smyth, M.A., B.Sc(Eng.), B.M., B.Ch., M.I.E.E.

* "Medical Electronics," Iliffe & Sons, Ltd., 145s.

Radio Show

THIS year's National Radio and Television Show which opens at Earls Court on August 24th, will follow very much the lines of previous exhibitions and the 130 exhibitors will be showing exclusively British equipment. Audio equipment will again be concentrated in the Audio Hall, which will occupy a large part of the first floor. The Services, Metropolitan Police, G.P.O., B.B.C. and I.T.A. will all have displays, and the organizers are re-introducing in a new form the Television Avenue to show the advantages of the larger screen receivers.

A radio servicing exhibit will serve the treble purpose of showing the public the kind of servicing they should expect, the dealer the latest test equipment available and the would-be apprentice a glimpse of the work of a serviceman.

International Scientific Studies

THE General Assembly of the International Scientific Radio Union (U.R.S.I.), which is held every three years, meets at University College, London, on September 5th. The chief aim of the Union, which was formed in 1919, is "to develop on an international basis scientific studies relating to radio."

The work of the Union is maintained through seven commissions and their "national committee" counterparts in each member country. The commissions are:— I, standards and measurements; II, troposphere; III, ionosphere; IV, radio noise of terrestial origin; V, radio astronomy; VI, radio waves and circuits; VII, radio electronics.

J. A. Ratcliffe, who is to succeed Dr. R. L. Smith-Rose as director of the D.S.I.R. Radio Research Station, is president of the British National Committee. The secretary-general of the Union is E. Herbays, 7, Place Emile Danco, Brussels 18, Belgium.

Hearing-Aid Code of Practice.—Reference was made in our May issue to the proposal of the Joint Advisory Co-ordinating Committee of the National Institute for the Deaf to draw up a code of commercial practice for the hearing-aid industry. This code of practice, which "is designed principally to protect the public against exaggerated or false claims for the efficacy of hearing-aids," has now been approved by the N.I.D. Well over 100 manufacturers and suppliers of hearing-aids are signatories to the code.

Schools TV.—Announcing plans for the extension of its television service for schools for 1960/61, the B.B.C. states that there are now 2,000 schools registered for the transmissions. This number is double that of a year ago.

I.P.R.E.—Founded in 1936 as the Institute of Practical Radio Engineers and in 1951 granted incorporation under the name Incorporated Practical Radio Engineers (I.P.R.E.) Ltd., the association has now changed its title to Incorporated Practitioners in Radio and Electronics (I.P.R.E.) Ltd. The secretary is W. Edwardes, Fairfield House, 20 Fairfield Road, London, N.8.

Receiving Licences.—The number of combined television and sound licences in the U.K. increased during May by 78,253 bringing the total to 10,646,938. Sound-only licences totalled 4,438,085, including 439,649 for sets fitted in cars. According to a report from Moscow quoted by a German correspondent, there are now 25 million sound receivers in use in the Soviet Union where there also some 28 million loudspeakers connected to local community radio centres and relay networks. The number of television receivers in the Union is given as about four million.

Poldhu.—The site of the first radio station to span the Atlantic (on December 12th, 1901) has been presented by Marconi's W/T Co. to the National Trust. A granite column marks the site of the station, built by Guglielmo Marconi, overlooking Mounts Bay, Poldhu, Cornwall. Among those present at the presentation of the title deeds by Lord Nelson of Stafford was C. S. Franklin, who joined the company in 1899 and whose pioneering work on the Marconi-Franklin beam system was undertaken at the station.

Japan, which employs the 525-line television standard, has officially announced the adoption of the American N.T.S.C. colour system.

Paris Components Show.—The French Fédération Nationale des Industries Électroniques (F.N.I.E.) is to hold the fourth international components show in Paris from February 17th to 21st, 1961.

Semiconductors.—An international symposium on semiconductor devices is being organized by the Société Francaise des Électroniciens et des Radioélectriciens in connection with the components exhibition mentioned above. It will be held in Paris from February 20th to 25th, 1961. Details and registration forms are obtainable from the Société, 10 avenue Pierre-Larousse, Malakoff, Seine, France.

A new aerial system is in course of construction at the Post Office receiving station at Somerton, near Yeovil, Som. When completed 93 new 180-foot masts will be used to support the 65 directional aerial arrays. Work began in May on dismantling 27 of the existing steel lattice masts, many of them 280-feet tall.

T.E.M.A.—At the recent annual general meeting of the Telecommunication Engineering and Manufacturing Association, R. A. Moir, O.B.E., M.C., director of Standard Telephones and Cables, was elected chairman and W. F. Oakley, director of Automatic Telephone and Electric Co., vice-chairman.

Biomedical Electronics.—The 13th annual conference on electrical techniques in medicine and biology, organized by the I.R.E., will be held in Washington, D.C., from October 31st to November 2nd. Further details are obtainable from the Institute of Radio Engineers, 1 East 79th Street, New York 21, N.Y., U.S.A.

Solid-State Circuits.—The 1961 International Solid-State Circuits Conference, sponsored jointly by the I.R.E., the American I.E.E. and the University of Pennsylvania, will be held on February 15th, 16th and 17th in Philadelphia, Pa. The secretary of the organizing committee is F. H. Blecher, Bell Telephone Laboratories, Murray Hill, N.J.

Cybernetics.—The third international congress on cybernetics is being organized by the International Association of Cybernetics (A.I.C.) for September 11th to 15th next year. It will be held in Namur, Belgium. It is planned to have sessions covering semantic machines; technical as well as economic and social aspects of automation; and cybernetics and biology. Further information is obtainable from the A.I.C., 13 Rue Basse-Marcelle, Namur, Belgium.

Electronic Organ Constructors' Society, which now has a membership of some 120, is holding its next meeting at 7.0 on July 28th at the Arsenal Tavern, Blackstock Road, Highbury, London, N.4. Alec Garton, of Nottingham, will be demonstrating his divider organ.

Royal Society Tercentenary celebrations include an exhibition of outstanding achievements in British science during the last ten years. Calculating machines, exploration by radio and electro-physiology are among the many aspects covered. The exhibition is being staged in the Diploma Galleries of the Royal Academy of Arts, Burlington House, Piccadilly, London, W.1, from July 25th to 29th (10.30-6). On the first three days admission is by invitation, but on the last two days the general public will be admitted without tickets.

Automatic Control.—British contributions to the first congress of the International Federation of Automatic Control, recently held in Moscow, will be discussed at a two-day symposium being organized by the Institution of Mechanical Engineers. It will be held on September 27th and 28th at the Institution, 1, Birdcage Walk, London, S.W.1.

Aviation Electronics.—A one-and-a-half-day convention on "Aviation Electronics and its Industrial Applications" is being organized by the South-Western Section of the Brit.I.R.E. for October 7th and 8th. Registration forms and further details of the convention, which will be held in the Bristol College of Science and Technology, are obtainable from the Hon. Sec., South-Western Section, Brit.I.R.E., c/o The School of Management Studies, Unity Street, Bristol, 1.

An Electro-Acoustics Group has been formed by the Brit.I.R.E., and its inaugural meeting will be held on October 12th, when Professor Colin Cherry, of Imperial College, will be the speaker.

Northern Polytechnic.—An evening course of 24 lectures on colour television is again included in the 1960/61 prospectus of the Northern Polytechnic, Holloway, London, N.7. The scope of the Department of Telecommunications, of which John C. Gilbert is head, has been broadened considerably and includes full-time, part-time and evening courses in industrial and applied electronics, computers, microwaves and navigational systems.

Printed Circuit Techniques.—A course of thirteen weekly lectures covering the preparation and production of printed circuits begins at the Twickenham Technical College, Egerton Road, Twickenham, Middx., on Tuesday evening, September 20th. Fee 30s.

Brentford Evening Institute, Clifden Road, Brentford, Middx., is again holding courses during the coming session in radio servicing (on Tuesdays and Thursdays) and on Wednesdays a course in preparation for the Radio Amateur Examination. Classes commence on September 20th (fee 10s per term).

Transistor Techniques.—The Medway College of Technology, Chatham, Kent, is again providing a course of lectures and experimental work on transistor techniques on successive Tuesdays, commencing October 4th.

Northwood Evening Institute, Potter Street, Northwood, Middx., is organizing classes in radio theory and also for the Radio Amateur Examination for the coming session which begins on September 19th.

WHAT THEY SAY

Now We Know Why!—"The decision to build your own high-fidelity instrument is the beginning of an emotional adventure. . . . Every time a man turns a knob or plays a record, there is an unparalled intimacy between himself and the instrument . . . and the sound." —Sidney Harman, of Harman-Kardon, New York.

Stimulating.—" . . . and it may be the reason that some hi-fi fans like to play their systems at loud volumes —for body stimulation." From "Perception of the stereophonic effect as a function of frequency," by W. B. Beambien and H. B. Moore, *Journal of the Audio Engineering Society*, April, 1960.

Personalities

Earl Mountbatten of Burma has been appointed honorary member of the Armed Forces Communications and Electronics Association. The certificate of membership "in recognition of his long-standing personal interest in defence communications" was presented to him at the Ministry of Defence by Major-General Harold Grant, a vice-president of the Association. The A.F.C.E.A. is an American organization (of which there is a chapter in London) and Lord Mountbatten is only the second Englishman to receive honorary membership, the first being **Brigadier W. T. Howe**, O.B.E., secretary of the Royal Signals Institute.

N. A. de Bruyne, M.A., Ph.D., F.Inst.P., is resigning from the managing directorship of CIBA (A.R.L.), Ltd., at the end of the year to give more time to research. He remains on the board and **R. F. G. Lea**, O.B.E., M.A., and **D. A. Hubbard** will become joint managing directors. Dr. de Bruyne founded in 1934 the original company (Aero Research Ltd., of Duxford) which was acquired in 1947 by CIBA, of Basle, and the name changed to its present title two years ago. Dr. de Bruyne was formerly fellow and lecturer of Trinity College, Cambridge. In 1952 he contributed an article to *Wireless World* on the uses of a Fresnel lens for the magnification of television pictures.

Eric D. Daniel, M.A. (Oxon.), A.M.I.E.E., has been appointed head of the new research unit set up by Ampex Electronics Ltd. at Reading, Berks. He did two years' research work in audiometers and general electro-acoustics at the Post Office Research Station before joining the B.B.C.'s Research Department in 1946 where, in association with **Dr. Peter Axon**, now managing director of Ampex, he specialized in magnetic tape recording. Mr. Daniel left the B.B.C. in 1956 and has spent the last four years in America.

E. D. Daniel

P. E. M. Sharp

Peter E. M. Sharp, B.Sc.(Eng.), A.C.G.I., A.M.I.E.E., has joined Westrex Co. as general manager. For the past two or three years he has been personal assistant to the managing director of the Troughton and Young group of companies. Previously he was with the Telegraph Construction and Maintenance Co. and was for some time with their agents in the Far East. In 1959 Mr. Sharp was awarded a Ford Foundation Grant by the English-Speaking Union for a two months' tour of the United States.

L. J. Kennard, A.M.I.E.E., has joined the Microcell group of companies as head of the data handling and process control section of the group's Electronics Division. Immediately prior to joining Microcell he was with Solartron where he was concerned with radar simulators and industrial controls.

Sir Gordon Radley, K.C.B., C.B.E., Ph.D., M.I.E.E., who retired from the director-generalship of the Post Office in May, is to devote part of his time to the work of the English Electric group of companies, particularly the development of telecommunication equipment. He has also been elected a director of Marconi's W/T, Marconi Instruments and English Electric Valve Co. and has been elected to the board of Marconi Marine.

J. M. Westhead, B.A., Ph.D., has been appointed manager of the valve and semiconductor sales department of the A.E.I. Electronic Apparatus Division at Lincoln. He has been deputy manager of the department since April, and succeeds **F. Baxendale** who is continuing as consultant. Dr. Westhead studied at Oxford University where in 1950 he graduated with first class honours in physics. Two years later, while a University demonstrator in electronics, he gained his doctorate in nuclear physics. In 1956 he joined B.T.H. now part of A.E.I.

Dr. J. D. McGee, O.B.E., M.Sc., M.I.E.E., professor of instrument technology, Imperial College of Science and Technology, London, has been awarded a grant of £1,000 by the Paul Instrument Fund Committee for the construction of a television system for X-ray image intensification. This award is supplementary to a previous grant of £2,000.

OUR AUTHORS

L. H. Dawson, B.Sc., author of the article on page 381, has been with Marconi's W/T Co. for nearly 22 years, and is at present in the mobile navigational aids research division at the company's laboratories at Great Baddow. In 1957 he headed the development team working on the "Consort" marine radar, and more recently was associated with the development of the company's traffic analyser, colloquially known as "Police Radar."

R. V. Harvey, B.Sc., A.M.I.E.E., the first part of whose article describing a transistor v.h.f./f.m. receiver appears in this issue, studied electrical engineering at Faraday House, where he obtained the diploma. In 1943 he joined the receiver group of the Telecommunications Research Establishment (now R.R.E.), Malvern, leaving there in 1947 to study physics at King's College, London. Since graduating in 1950 he has been in the B.B.C. Research Department.

R. B. Rowson, B.Sc., A.M.I.E.E., joint author of the article on an inverted triode voltmeter, is assistant chief commercial engineer (research and statistics) with the South Wales Electricity Board, and was previously personal assistant to the chief engineer, British Power and Light Corporation. **A. P. Williams**, A.M.I.E.E., his co-author, is senior assistant engineer in the system operation department at the Board's headquarters, where he is responsible for line telephony, remote control and v.h.f. radio equipment.

OBITUARY

Horace de Aula Donisthorpe, affectionately known throughout the radio industry as "Donny," died suddenly on June 15th. Born in 1893 and educated at the City and Guilds College, he joined Marconi's as a marine radio operator and was later engaged under H. J. Round on the development of valves. After service in the Intelligence Corps during the First World War he rejoined Marconi's and in 1922 was appointed assistant to the general manager. From 1926 until his retirement last year he was with the G.E.C., latterly as deputy manager of the Valve and Electronics Department. For the past year he had been sales consultant to Whiteley Electrical Radio Co. Donisthorpe was a prime mover in the formation of the Radio Industries Club, of which he was chairman for eleven years prior to being elected president for the year 1948/49.

News from the Industry

Choiceview is the name under which the Rank Organisation and Rediffusion will operate a partnership "for the development and promotion of subscription television . . . and for providing relevant programme and technical services." The two companies entered into a long-term agreement some months ago whereby the Rank Organisation acquired the right to use the Rediffusion system of wired television in relay operations. It is announced that the Choiceview system of "Pay TV" will be available in due course for general licensing to intending operators.

Instruments Merger.—The Cambridge Instrument Company has acquired the whole of the ordinary share capital of Electronic Instruments Ltd., of Richmond, Surrey. The merger was announced on June 29th by Dr. P. Dunsheath, chairman of Cambridge Instruments which, with its overseas subsidiaries employs over 1,500 people. Electronic Instruments, which employs some 330 people, will operate under its own name and A. C. W. Norman will continue as chairman, P. Goudime as managing director and D. A. Pitman as sales director together with three directors of the Cambridge Instrument Co. Mr. Goudime has been invited to join the board of the Cambridge Instrument Co.

Dawe Instruments Ltd. and its associated company, L.M.K. Manufacturing, have been acquired by Simms Motor and Electronics Corporation. The acquisition "for a sum in the region of £250,000" extends still further the electronics side of the Simms Group which was recently augmented by the acquisition of Cawkell Research and Electronics. The reconstituted board of Dawe Instruments now consists of G. E. Liardet, chairman (chairman and managing director of the group), and F. W. Dawe, managing director, together with J. Ayres, M. A. Hassid and K. G. Smith, members of the boards of Cawkell and N.S.F.

Greencoat Electronics Ltd. is the new title of Staar Electronics Ltd., of 2 Princes Row, Buckingham Palace Road, London, S.W.1 (Tel.: Tate Gallery 9393). The company, which is a member of the Gas Purification Group, will continue to market the "Little Staar" 45 r.p.m. battery-operated motor and the range of Kinder d.c. motors. Very substantial quantities of these miniature motors are being exported to Germany. The company's sales director is Harry Read.

Harry Read

Derritron Group, of which V. G. P. Weake is chairman and managing director, announces that C. T. Chapman (Reproducers) Ltd., of High Wycombe, Bucks., has joined the group. The company will in future be known as Chapman Ultrasonics Ltd. C. T. Chapman remains managing director and is joined on the board by V. G. P. Weake and R. A. W. Rudd. Doran Instrument Co., of Stroud, has also joined the group. W. E. Doran remains managing director with Mr. Weake (chairman) and Capt. J. D. Mansfield-Robinson also on the board.

Elizabethan (Tape Recorders) Ltd., is the new name adopted by E.A.P. (Tape Recorders) Ltd. of Bridge Close, Oldchurch Road, Romford, Essex (Tel.: Romford 62366).

L.C.E. Ltd. is the name of a recently formed company jointly owned by Joseph Lucas (Industries), Ltd. (through its subsidiary G. & E. Bradley, Ltd.) and the Collins Radio Co., of America. Lord Halsbury, the chairman of L.C.E., stated that although this is an Anglo-American partnership, the company is a completely autonomous body. It is not tied to a sole policy of manufacturing Collins equipment. Collins Radio have a marketing company in this country but until now had no manufacturing facilities in Europe. L.C.E., Ltd., is operating from Electral House, Neasden Lane, London, N.W.10, and it is planned to have a factory in operation by September.

T.C.C.-Sprague Agreement.—Under an agreement between the Telegraph Condenser Co. of this country and Sprague Electric Co. of the U.S.A., T.C.C. acquire the right to all Sprague U.K. patents and applications, together with the technical and engineering information necessary to exploit them, and Sprague will make available to T.C.C. all its present research and technical information and engineering knowledge. Also "for the next 21 years the two companies will exchange research, development and manufacturing knowledge, extending beyond the field of capacitors and embracing all the products of the two companies."

Standard Telephones and Cables have supplied all the submarine cable and 29 submerged repeaters for the 530-nautical-mile route across the North Sea for the first direct telephone cable link between the U.K. and Sweden. It is the longest submarine telephone cable system in Europe and is also the longest in the world using a single cable for both directions of transmission. The repeaters are designed to carry 60 telephone circuits of 4kc/s spacing. The cable is now being laid between Middlesbrough and Gothenburg by the G.P.O. cable ships *Monarch* and *Ariel.*

Anglo-French Agreement.—Steatite and Porcelain Products, of Stourport-on-Severn, have concluded an agreement with Compagnie Générale d'Electro-Céramique "for full technical collaboration including exchange of patent rights." Each company will act as agents in its own country for the other manufacturer.

Eimac Agents.—Walmore Electronics Ltd., of Phœnix House, 19-23 Oxford Street, London, W.1, have been appointed exclusive representatives in the U.K. for all products of Eitel-McCullough, Inc., of San Carlos, California.

Eitel-McCullough, S.A., has been set up in Geneva, Switzerland, as a European marketing organization by Eitel-McCullough.

Ether Langham Thompson (Italiana) Ltd., with offices and factory at Via Bisleri 19, Milan, has been formed by Ether Langham Thompson Ltd. to market and manufacture products of the group. The board of directors of the new Italian company includes J. Langham Thompson (chairman), F. W. Coulling and F. B. Duncan, who are directors of the parent company.

Campbell-Bruce Electronics Ltd. has been formed for the development of small transistor communications equipment. Offices and laboratories are at 22 Berners Street, London, W.1. (Tel.: Langham 7878.) The directors are I. Campbell-Bruce (managing), who was sales director of Cossor Communications Co.; M. D. S. Becher and R. Howard.

Teppaz record players, which are manufactured in Lyons, France, are now being handled in this country by Selecta Gramophones Ltd., of which E. R. Lewis (chairman of the Decca Record Co.) is chairman.

Westward Television Ltd., programme contractors for the I.T.A. south-west England transmitters to be built in Devon and Cornwall, have placed the main contract for the electronic equipment for their Plymouth studios with Marconi's. They will supply five Mark IV image Orthicon camera channels, master control and monitoring equipment and associated sound channels. E.M.I. are supplying two Vidicon film scanners, Rank-Cintel one film scanner and Pye a caption scanner.

An Emidec 1100 all-transistor computer has been ordered from E.M.I. Electronics for the Royal Naval Store Depot, at Copenacre, Wilts. It will handle the stock control of some 90,000 separate items covering the electrical, radio and asdic stores for H.M. ships.

An Orion electronic digital computer has been ordered from Ferranti Ltd. by the National Institute for Research in Nuclear Science. The computer will be installed at the Institute's Rutherford High Energy Laboratory at Harwell, Berkshire. Equipped with magnetic tape units and high-speed printers, Orion will be used by the laboratory for analysis and computation of data obtained from NIMROD, the 7GeV proton synchroton now under construction at Harwell.

Murphy.—The 1959 profit of the Murphy group before taxation was £668,085, an increase of almost 50% on the previous year. The net profit after taxation was £358,442 compared with £207,724 the year before.

Ever Ready Co. (G.B.) record a profit before taxation of £2,735,128 for the year ended in February, compared with £2,430,553 the previous year. Taxation for the period is estimated at £1,184,146.

Elliott-Automation Group.—The group profit before taxation of £1,015,630 for 1959 represented an increase of about 25% over the previous year. Taxation absorbed £466,755.

Ferranti accounts for the year ended March 31st show a group profit of £2,123,390, which was almost twice the previous year's figure. This was after deducting all charges, including £1,854,000 for taxation.

S.T.C. installed the sound reinforcement system in the new Royalty Theatre built on the site of the Stoll Theatre, Kingsway, London. The installation includes 19 amplifiers, 12 microphones and 41 loudspeakers. S.T.C. have also supplied the sound equipment for the *son et lumière* installation for H.M.S. *Victory* at Portsmouth.

"Hi-Fi" Catalogue.—An unusually well-prepared catalogue of "hi-fi" recording and reproducing equipment has been issued by Lasky's (Harrow Road) Ltd., 207 Edgware Road, London, W.2. Printed on art paper and profusely illustrated it gives manufacturers' particulars of all the leading makes retailed by the firm, with the object of facilitating the choice of equipment. It comprises 72 pages and costs 3s 6d to callers or 4s by post.

Temporary Address.—Wright & Weaire, the Ferrograph Co. and British Ferrograph Recorder Co. have temporarily moved to 88 Horseferry Road, London, S.W.1 (Tel.: Sullivan 5426), pending completion of new offices in Cromwell Road, Kensington, next year.

Teleng Ltd., manufacturers of communal aerial systems and relay equipment, are building a two-storey extension to their factory at Harold Wood, Essex. It will increase the available floor space from 6,000 to 17,000 sq. ft.

G.E.C. Applied Electronics Laboratories have been transferred from Brown's Lane, Coventry, to The Airport, Portsmouth, Hants. (Tel.: Portsmouth 62271.)

Oryx Electrical Laboratories Ltd., manufacturers of Oryx soldering irons, have moved to Industrial Estate, Meadow Road, Worthing, Sussex (Tel.: Worthing 30066).

EXPORT NEWS

Travelling wave tubes manufactured by the English Electric Valve Co. have been supplied to the Bonn University for its radiotelescope which is to be used for investigating the temperature of interstellar gas. Special dual channel amplifying equipment, using two tubes in cascade in each channel, has been supplied to the University by Marconi's. The telescope's parabola is 83-ft in diameter.

Aeronautical Communications.—International Aeradio Ltd., in conjunction with Pye Telecommunications, Ericsson Telephones and Creed & Co., installed the equipment for the inter-island multi-channel aeronautical radio communications system which links the eastern islands of the West Indies. It provides a 24-hour automatic telephone and teleprinter service for aircraft operating in the Caribbean. Twelve separate and simultaneous voice channels together with 12 to 18 teleprinter channels have been provided.

Surveillance Radar.—Two 50-kW, 50-cm radars, together with three display consoles and ancillary equipment, have been ordered from Marconi's for Momona Airport, Dunedin, New Zealand.

Airfield Radar.—A contract has been awarded to Decca Radar by the Crown Agents for the supply to the Royal Ceylon Air Force of a Decca 424 Mark II airfield control radar. It is to be installed at Katunayake, an Air Force Base which is also used by civil airlines operating scheduled flights.

Radar Weather Stations.—Cossor Radar & Electronics are to supply "windfinding radars" (Type CR353) for the network of eight radar weather stations to be set up in the South Pacific. Six stations will be in New Zealand, one in Fiji and another on Funafuti Island.

Electronic Development in Great Britain is the theme suggested for the prestige trade exhibition to be staged in the British Pavilion at the German Industrial Exhibition in Berlin from September 10th to 25th. Information is obtainable from the Central Office of Information, Hercules Road, London, S.E.1.

Mobile demonstration unit of E.M.I. which undertook a 4,000-mile tour of Western Europe last autumn, is now visiting Eastern Europe. The 35-ft trailer is fitted with machine tool control systems, closed-circuit television and other industrial electronic equipment.

SEPTEMBER ISSUE

Show Guide

The next issue of *Wireless World*, appearing a day or two before the opening of the 27th National Radio and Television Exhibition at Earls Court (Aug. 24th-Sept. 3rd), will contain a stand-to-stand guide to the show together with a plan and list of exhibitors.

The September issue will also include constructional details of the v.h.f./f.m. transistor receiver outlined by R. V. Harvey on p. 366 of this issue. The enlarged September number will also contain the usual quota of articles and regular features.

OCTOBER ISSUE

Show Review

The year's trends in vision and sound broadcasting receivers as exemplified by the equipment seen at Earls Court will be reviewed in the October issue. It will also include a survey of aviation radio gear seen at the Farnborough Air Show (Sept. 5th-11th).

Battery-Powered Marine Radar

DESIGN OF TRANSISTOR POWER SUPPLY FOR SMALL-CRAFT EQUIPMENT

By L. H. DAWSON, B.Sc. (Eng.)*

MARINE radars have, in the past, been developed mainly for use on the larger passenger and cargo ships where size, weight and power consumption are not of primary concern. However, the "Consort"† radar has been designed to be suitable for shipping such as tugs, fishing boats, pilot cutters, police and customs launches and private yachts.

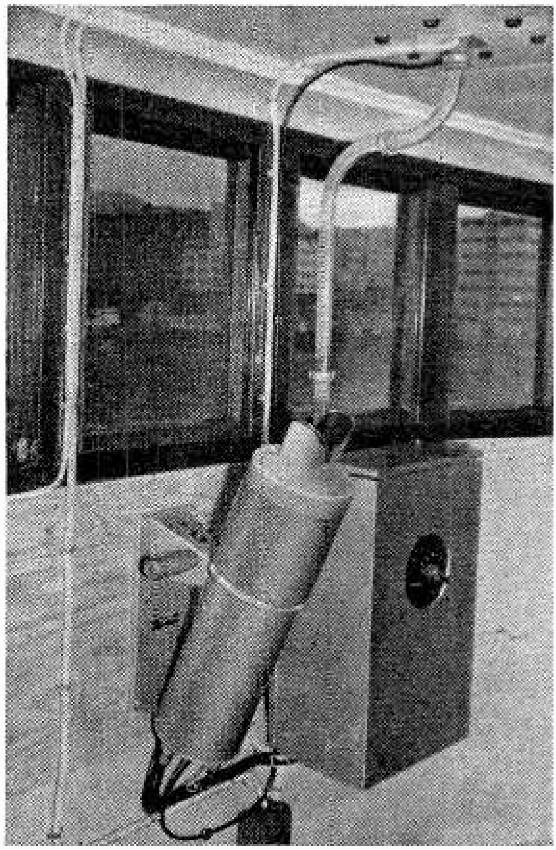
In these smaller vessels the main, and usually the only, source of electrical power is a 24-volt battery which is used to supply the ship's lighting and radio equipment. It is recharged by an engine-driven dynamo and may also serve as the starter battery for the ship's engines. Standard radars may require upwards of one kilowatt of power; but the "Consort" requires much less than this, taking only nine amps from the 24-volt battery in full operation and four amps on "standby." A "press-to-view" switch is fitted to the "Consort." The equipment automatically reverts to the "standby" condition at the end of the two-minute viewing period, but is immediately ready for a further period of operation.

To achieve consumption as low as 220W some special techniques have been used in the design and only the essentials of a radar have been included. The consumption might have been reduced even further by extensive use of transistors instead of valves; but this would have been contrary to another main aim of the design, which was to keep the cost low. Thus transistors were used in the power supply, where they offer the greatest advantage over more conventional equipment, both in cost and efficiency.

Transistor Stabilizer

As is well known, the e.m.f. of a lead-acid battery varies with its state of charge. A single cell terminates its charge at 2.66 volts and is considered to be fully discharged at 1.8 volts. Thus the e.m.f. of a nominal 24-volt battery can vary over the range of 32 to 21.6 volts. Electronic equipment cannot normally tolerate such a large variation in its supply, so some form of automatic stabilization is necessary.

Until quite recently there have been only two practical methods of doing this. One was to use a "carbon-pile regulator" and the other was to employ a motor-driven rheostat controlled by some form of error-sensing circuit. There are disadvantages in both these methods. The carbon-pile regulator can need frequent attention due to gradual softening of the carbon discs during use. A regulator large enough for the "Consort" equipment would consume about 10 watts in its control circuit and could not follow input variations faster than a few cycles per second. The motor-driven rheostat is even slower in operation and if sudden changes of load current are to be accommodated, some auxiliary switching is necessary.



"Consort" radar in wheel-house of the Norwegian ferry "Sunnmore." Display on left, transmitter-receiver, timebase and power-supply unit on right.

Within the last two or three years, high-power transistors have become available and these can be used as the series element of a stabilizer which, in general principle, is similar to a conventional h.t. stabilizer using valves. This is possible because power transistors can pass several amperes with only a fraction of a volt between collector and emitter.

In the "Consort" radar, the maximum load current that has to be stabilized is eight amps and transistors exist that can handle this and even greater currents. However, the choice does not rest on current-carrying capabilities alone: cooling is necessary, as the maximum junction temperature must be limited to, say, 85 to 90°C.

The level at which the output of the stabilizer is controlled should be as high as possible (con-

* Marconi's W.T. Co., Ltd.
† Marconi International Marine Communication Co., Ltd.

sistent with being lower than the lowest battery p.d.) in order to keep down the power dissipation in the series transistors. The level should also be suitable for direct connection to a valve-heater chain so that inefficiencies of conversion may be avoided. To satisfy these two requirements 19 volts has been chosen as being nearly equal to 3×6.3 volts, i.e., three times the standard heater p.d. In the "Consort" power supply the stabilizer must operate over a range of load currents from four amps minimum to eight amps maximum, while the voltage drop may be as much as $32-19=13$ volts. The definite minimum current allows the use of a by-pass resistor to reduce dissipation in the series transistors and this resistor can have a value as low as 13/4 ohms. The standard value of 3.3 ohms is suitable.

It can be shown that the maximum dissipation in the series transistor occurs when the load current is shared equally between the transistor and the by-pass resistor, provided other design limits are not exceeded. In this case, with eight amps load current, the maximum transistor dissipation is $(8/2)^2 \times 3.3 = 53$ watts approximately, corresponding to a battery p.d. of 32 volts. If the equipment is to work in ambient temperatures up to 55°C and the maximum junction temperature is, say, 90°C, the permissible temperature rise is only 35°C. This means that the effective overall thermal resistance between the junction and surrounding air must not be greater than 35/53, i.e., 0.66°C/W. No transistors are as yet available with such a low thermal resistance, even between the junction and mounting base; therefore more than one transistor must be used to share the power loss.

Cooling Methods

The next consideration is, how should the heat be removed from the transistor-mounting bases? The almost obvious answer for a marine radar is to use the sea water for cooling. This, however, means a pump, long pipes and a filter. If any of these failed to work satisfactorily, the transistors would soon be irreparably damaged, with a possibility of further damage to the rest of the equipment. A second method would be to blow air over them but, here again, a filter would be needed. Furthermore, a small d.c.-operated blower is not normally a very quiet device and does not have a very long life.

The most reliable method is to use large-area cooling fins, and to provide adequate ventilation. The fins will dissipate the heat by a combination of convection and radiation; but to do this efficiently they must make good thermal contact with the transistors and be of high thermal conductivity with short paths from the transistors to the edges of the fins.

The cooling fins used in the "Consort" consist of seven plates per transistor, each plate being 6-in square of 16 s.w.g. aluminium sheet. The plates are bent so that, although they are all in contact with one another at their centres where the transistor is bolted, a large proportion of the total surface area is exposed to the air. Blackening of the surfaces increases the heat-loss by radiation, and the resulting thermal resistance of each set of fins is 1.5°C/W.

Power transistors have internal thermal resistances ranging from approximately 0.8°C/W upwards. The type chosen for use in this stabilizer is the Mullard OC29 which has an internal thermal resistance of 1.2°C/W—nearly as good as and considerably cheaper than the best available. This makes the overall resistance 2.7°C/W so that four units in parallel give an effective value of 0.675 °C/W—very close to the required value—and an estimated temperature rise of 35.8°C at maximum dissipation. This is considered a sufficiently conservative design for three reasons:—

1. Although the recommended maximum temperature for the OC29 is 90°C, temperatures up to 100°C are permissible for short periods (provided total time at this temperature does not exceed 200 hours).

2. The maximum dissipation requires a battery at 32V or 2.66V/cell.

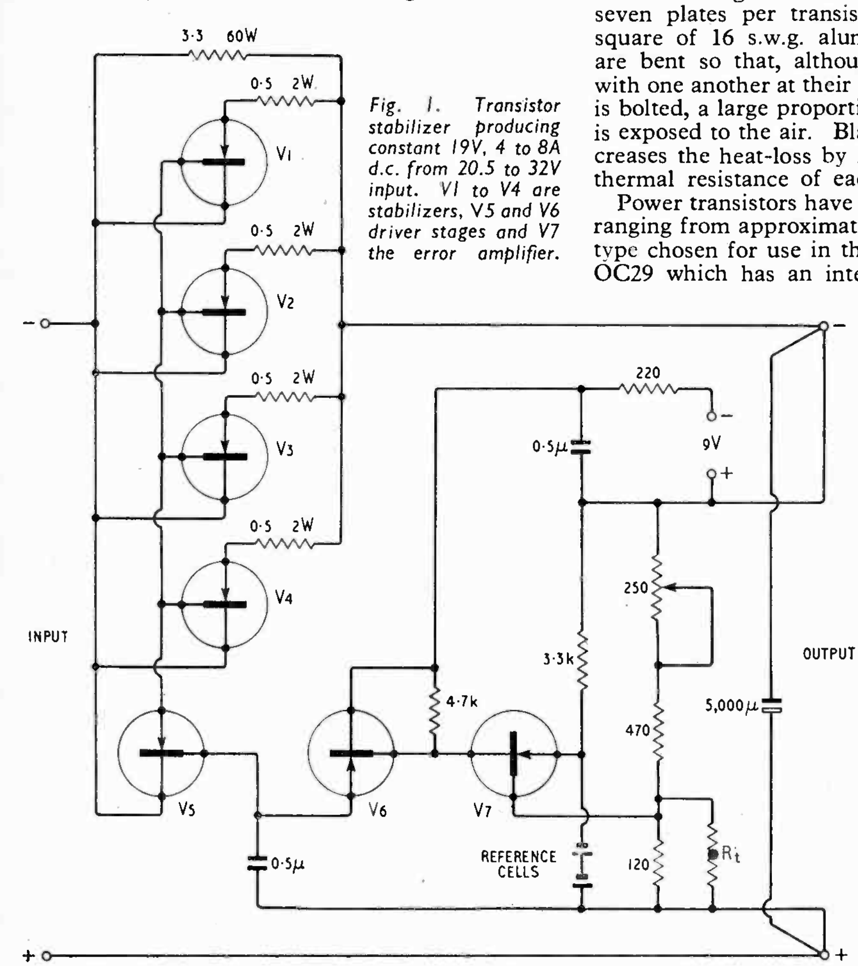
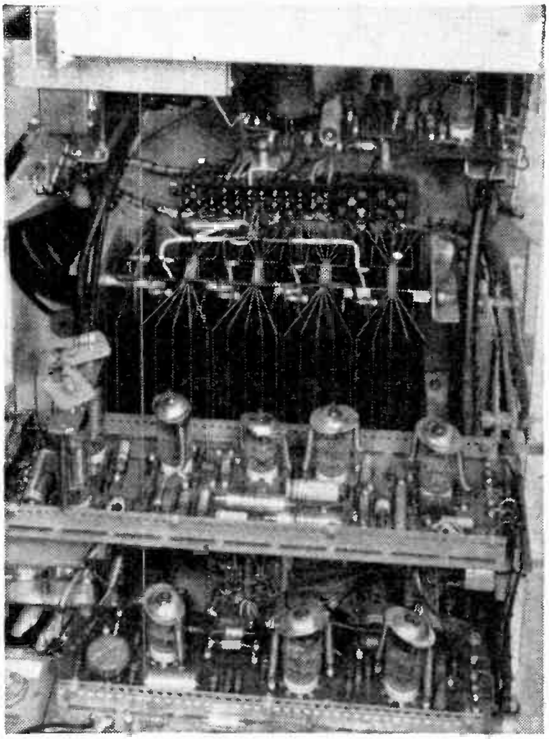


Fig. 1. Transistor stabilizer producing constant 19V, 4 to 8A d.c. from 20.5 to 32V input. V1 to V4 are stabilizers, V5 and V6 driver stages and V7 the error amplifier.



View of stabilizer power transistors, showing way in which cooling fins are splayed outwards from centre, where transistor is fitted to increase surface area.

This is very high and unlikely to be maintained for more than a few minutes or even reached in hot weather.

3. The stabilizer heat sink (cooling fins) has a fairly high thermal capacity and takes about one hour to reach a steady temperature.

This last factor is of great importance when considered in conjunction with the "two-minute viewing" feature of the equipment.

Circuit Design

Having obtained a satisfactory design for a heat sink, the electrical design can be proceeded with (Fig. 1). A small resistor is connected in each power-transistor (V1 to V4) emitter lead to provide a degree of current feedback which equalizes the emitter-current base-potential characteristics and causes the four transistors to carry similar currents. The 3.3Ω, 60-W resistor is the by-pass. With this combination of four transistors carrying a total of eight amps maximum, the base current requirements are quite large. To reduce the control current to a low level a tandem pair of emitter-followers, V5 and V6, are used. The dissipation in V5 can amount to as much as 2W, so a power transistor is necessary. To keep the number of different types to a minimum (and therefore the spares requirements low) V5 is another OC29. The heat sink requirements for this transistor are very modest and a single cooling fin of the same size as those in the main assembly is more than sufficient. The overall current gain is approximately the product of the three current amplification factors of V1, V5 and V6, amounting to some 75,000 times. This makes the normal base-current requirements of V6 only about 0.2mA, supplied via the 4.7kΩ collector load of V7, the error amplifier.

This collector load resistor and the collector of V6 are connected to an auxiliary nine-volt supply to avoid increasing the minimum potential drop in the stabilizer. Without this auxiliary supply the minimum working potential would have been increased by the base-to-emitter p.d. of both V5 and V6 as well as the potential drop in V7 collector load. In the system as shown, the minimum potential drop in the stabilizer is the sum of the p.d. across one 0.5-Ω sharing resistor, the base-to-emitter p.d. of V1 2, 3 or 4 and the collector-to-emitter potential of V5, amounting to about 1.5V total. The lowest input potential at which the output can be stabilized to 19 volts is therefore 20.5 volts, so allowing for one volt drop on the battery leads.

The error amplifier V7 has its emitter potential fixed by a pair of reference cells. These are small hermetically-sealed units designed to provide a constant 1.5-V p.d. with a low dynamic impedance. They have very little storage capacity and must be supplied with a charging current; they are therefore similar in operation to neon stabilizer tubes and Zener diodes. Neon tubes are, naturally, not suitable and Zener diodes are many times more costly.

A divider chain of low resistance compared with the input impedance of V7 applies a fraction of the output voltage to the base of V7. A thermistor R_t is arranged so as to compensate for the temperature characteristics of both V7 and the reference cells. The 5000-μF capacitor connected across the output provides a low impedance at a.c. and the 0.5-μF capacitor connected from the base of V5 to the common positive line suppresses any tendency to oscillation.

The output impedance of the stabilizer at d.c. and very low frequencies can be calculated as $1/ABg_m$ where A is the current gain from V6 base to V1-4 emitters, B is the voltage ratio of the divider chain and g_m is the slope of V7 expressed in collector current (A)/base potential change (V). This comes to $1/75{,}000 \times 0.17 \times 0.05 \approx 0.002\Omega$. At higher frequencies the current amplification factors of all the transistors fall off and the output impedance increases to a value set mainly by the series resistance of the 5000-μF electrolytic capacitor, which is of the order of 0.05Ω. To achieve these low values of resistance care has to be taken with the lengths and disposition of connecting leads. For instance, it is necessary to take separate leads direct from the

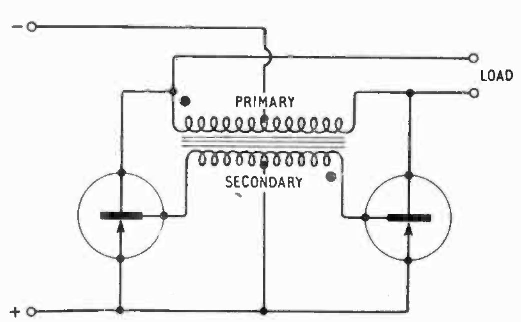


Fig. 2. Basic oscillator for "chopping" d.c. to produce a.c. Dots on transformer denote start of windings.

error amplifier to the output terminals, as in Fig. 1.

The collector impedance of the series transistors is high (hundreds of ohms) so that the stabilization ratio of the circuit is simply the ratio of the by-pass resistance to the output impedance and is in the order of 1,000 times. This is a very satisfactory figure and means that the "Consort" radar can be operated from nominal 24-volt d.c. supplies having a large amount of ripple superimposed, so long as that ripple does not take the input voltage outside the design limits of the stabilizer, i.e., 20.5 to 32 volts.

D.C. to A.C. Converter

Several different h.t. potentials are required in the "Consort" radar equipment, as well as separate supplies for both the magnetron and klystron heaters and the nine-volt auxiliary supply for the stabilizer. To obtain these it is necessary to convert the stabilized 19-volt d.c. to some form of a.c. The traditional methods have been to use either a rotary machine or a vibrator. The former is expensive and heavy, while the latter has a very short life. Now that power transistors are available, a third method is possible.

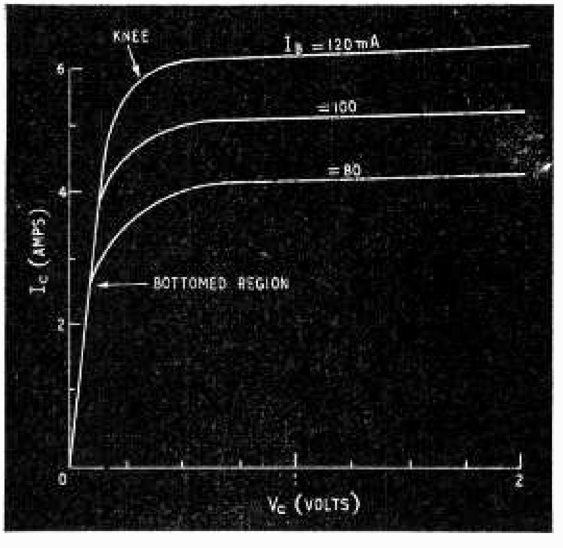


Fig. 3. Typical collector potential/collector current characteristics of power transistor.

Again the ability of transistors, when "bottomed", to pass large current with a very low potential drop between collector and emitter is used: the "saturation resistance" is measured in hundredths of an ohm. They can thus replace the mechanical contacts of a vibrator, the switching action being controlled by a drive waveform applied to the bases. The base drive is conveniently obtained by transformer action from the output so that the circuit resembles a push-pull oscillator, as shown in Fig. 2.

Mode of Operation.—The characteristics of the transformer have a major controlling influence on the oscillation frequency. During one half cycle practically the whole of the supply potential is applied to one half of the primary winding. The potential is opposed by the induced e.m.f. in the transformer winding so that the rate of change of flux is substantially constant. A magnetizing current is necessary to produce the flux and when the transformer core begins to be saturated, this magnetizing current increases rapidly.

The conducting transistor has been maintained bottomed by the drive applied to its base via the secondary winding on the transformer. This drive potential can produce only a limited base current which in turn sets the maximum collector current the transistor will pass. When the sum of the load current and the magnetizing current approaches this value (and it does so rapidly as the core saturates) the operating point on the current collector potential characteristic moves from the bottomed region round the knee (see Fig. 3). The collector potential increases: as a consequence the transformer primary potential must decrease and this in turn reduces the drive to the base. The available collector current is thereby reduced causing the operating point to move even farther round the knee. The whole effect is cumulative, causing a rapid switch-off of the transistor. The stored energy in the magnetic circuit causes the transformer output to "overswing" sufficiently to switch on the other transistor and start the next half cycle.

During each half cycle the core swings from saturation in one direction to saturation in the other direction and hence it can be shown that the frequency of oscillation is given by:—

$$f \approx V.10^4/4NAB_{sat}$$

where V is the supply potential in volts, N is the number of turns on each half of the primary, A is the effective cross-sectional area of the core and B_{sat} is the maximum flux density achievable in the core.

The simple circuit shown in Fig. 2 has one defect —it will not start under load. It may not even start without a load unless the transformer losses are very low. This is because the transistors pass only very small currents if the bases are at emitter potential. To make the oscillator start under all normal-load conditions a sufficient forward bias must be provided and this can be done conveniently by a potentiometer network across the supply, as in Fig. 4. The transformer secondary potential must be increased to compensate for the potential drop due to the base current flowing in R_2.

This explanation of the mechanism of switch-over between the two transistors is rather over-simplified, although convenient. A more accurate explanation is that as the transistor operating point moves up the I_c-V_c curve, such as shown in Fig. 3, the slope of the curve decreases, i.e., the dynamic impedance of the collector increases. This means that the instantaneous loop gain increases until, at unity loop gain, a point of unstable equilibrium is reached. The switch-over action then takes place rapidly.

Looking at the simple arrangement of Fig. 2 in this light it can be seen that switch-over may well occur at collector-current levels which are much less than those allowed by the base currents. This is especially true with high impedance loads, i.e., light loads on an oscillator fed from a high-p.d. d.c. source. To correct this condition the loop gain must be reduced and, strange though it may seem, this can be done by increasing the amplitude of the drive waveform from the transformer secondary and absorbing the excess in a series base resistance.

That this is so can be seen by taking extreme cases, as in Fig. 5. The curve represents a typical V_b-I_b characteristic with the required operating point marked A. With a zero-impedance base circuit a 10% reduction of base potential brings the operating point to B, while if an infinite impedance could be used, the operating point would be moved only to C, a considerably smaller change of base current.

The resistance obviously cannot be infinite, and indeed cannot be very large if excessive waste of power is not to occur. It need, however, only be high compared with the input impedance of the base itself, which, in transistors of this class, is only one or two ohms. A satisfactory value is 10 ohms and this is the value chosen for R_2 in Fig. 4. A separate resistor for each base is not necessary, as R_2 serves for each alternately.

Transformer Details

These principles of design have been used for the d.c.-to-a.c. converter of the "Consort" radar. A pair of OC29s switching at 6 amps handle an input current of 4.75 amps from the stabilized 19-volt supply. The frequency of oscillation is 2 kc/s and a Ferroxcube-cored transformer supplies the drive to the bases as in Fig. 4. On light loads most of the stored energy in this core is returned to the supply via the collector-emitter path of the transistor. While this energy is being removed the collector and emitter interchange roles. The transistor resistance this way round is relatively high so that excessive stored energy would cause a large "spike" on the leading edge of the square-wave output waveform. For this reason the core is chosen to be as small as possible. Leakage inductance between the two half-primaries is also a cause of spikes on the waveform, and this, too, must be kept as small as possible in any load-coupling transformers as well as in the maintaining transformer. This is accomplished by winding the primary in bifilar fashion, i.e., two wires are laid side by side and wound together to form the two half-primaries.

One of the advantages of a high oscillator frequency is that the load transformers can be small. In the h.t. systems the smoothing components may also be reduced in size. As the output waveform is essentially a flat-topped square wave, a full-wave rectifier system can supply the load directly—a reservoir capacitor is needed only to supply the load during the transitions of the square wave and no further smoothing is required.

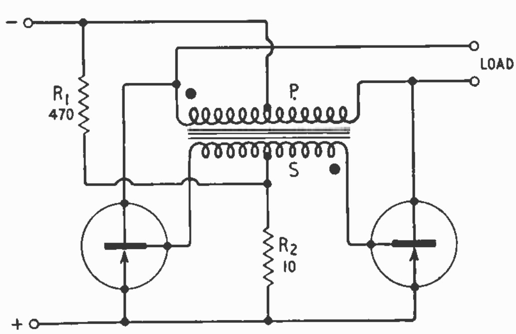


Fig. 4. Final oscillator for production of h.t. and special l.t. Resistors R1 and R2 aid starting.

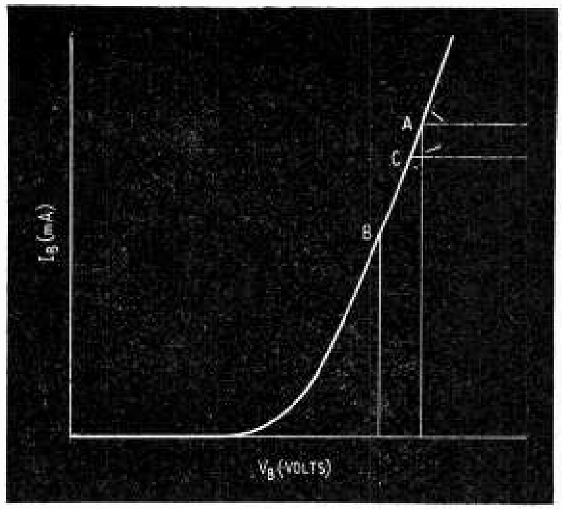


Fig. 5. Typical base potential/base current characteristic showing required operating point (A) and effect of zero—(B) and infinite—(C) impedance base circuits.

The upper limit to oscillator frequency is set by the transistor losses which occur mainly during transition between the conducting and non-conducting states, the collector potential rising to its peak value before the current falls to zero. The transition time is substantially constant irrespective of frequency, as it depends mainly on the transistor characteristics and the effective circuit capacitance. Therefore, the higher the frequency, the higher the losses.

At the oscillator frequency used in this equipment, i.e., 2 kc/s, the total transistor losses are approximately 5W and cooling fins of 24in^2 per transistor are sufficient.

The d.c.-to-a.c. converter feeds outputs to the heater transformer for the magnetron and local-oscillator klystron and to the h.t. transformer which is provided with tappings at levels up to 2kV. A voltage-doubler rectifier delivers 4kV for the magnetron modulator and further rectifiers multiply by six to give 11kV for the cathode-ray tube. High-voltage generation by multiplier was chosen because a suitable transformer cannot easily be wound with a self-capacitance of much less than 50pF. The transformer ratio is roughly 1 to 100 so that the effective capacitance presented by the transistors is about 0.5μF, which requires a charging current of two amps to change the p.d. across it by 40V in 10μ sec (the changeover time). Obviously a 4-kV winding would not be practical because the reflected capacitance would be four times bigger and would thus require a charging current of eight amps; which, together with the load current, is far in excess of the transistor's capabilities.

The lower-potential supplies have fairly low output impedances, as they are obtained directly from full-wave selenium rectifiers. Because of this, and the stabilization of the input to the converter, h.t. stabilizers are not necessary. The overall d.c.-to-d.c. efficiency of the converter and rectifier system is better than 85%, due partly to the absence of losses in smoothing chokes. This is most satisfactory, but even greater efficiencies can be obtained if fewer d.c. outputs are provided.

Transistorized Wien Bridge Oscillator

INEXPENSIVE DESIGN COVERING 20-20,000 C/S

By *F. BUTLER*, *O.B.E., B.Sc., M.I.E.E., M.Brit.I.R.E.*

IT is not altogether a simple matter to design a wide-range variable-frequency oscillator using thermionic valves in the driving amplifier, and it is considerably more difficult to do so using transistors. In the case of the Wien bridge circuit there are three principal factors which complicate the task. The input impedance of a normal transistor amplifier is relatively low and it has a reactive component which can prove troublesome at high frequencies. The low impedance affects the performance of the frequency-determining components of the bridge, restricting the frequency range and making impossible demands on the maintaining amplifier. In the second place it is difficult to design a satisfactory circuit for amplitude control which will work effectively under the very-low power conditions which are normal in transistor circuits. Lastly, the characteristics of transistors vary widely from one sample to another of the same nominal type and these characteristics are strongly temperature dependent. With care it is possible to circumvent these troubles and to build a transistor oscillator comparable in performance with its valve-operated counterpart except in respect of output power and frequency stability. Wide range, low distortion and a good signal-to-noise ratio are readily obtainable. The small size, low power consumption and hum-free output of the battery-operated transistor oscillator are all points in its favour, and a long trouble-free life can be expected since all the electrical components are operated conservatively.

Valve-Operated Wien Bridge Circuits.—Before considering the design of a transistor oscillator it is instructive to examine some of the features of a conventional valve-operated RC bridge circuit. Fig. 1 illustrates a version recently described in *Wireless World*[1]. It is a fixed-frequency device designed to operate at 50 c/s. The frequency-determining elements R_1C_1 and R_2C_2 are of high resistance and reactance. They place almost negligible loading on the driving amplifier. The valve input impedances are virtually infinite so that the attenuation and phase shift of the interstage coupling networks can be held at an acceptable level, even at very low frequencies, by using conventional values of coupling capacitors and grid resistors. So much gain is available from the two-stage amplifier that it is possible to dispense with cathode circuit by-pass capacitors. The resulting negative feedback causes an increase in the already high input impedance of the valves.

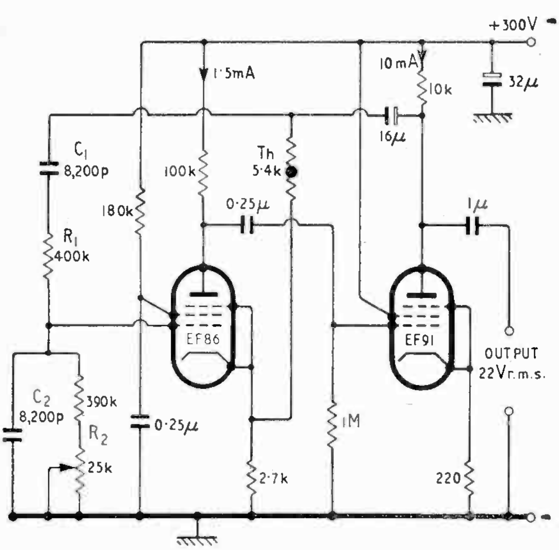


Fig. 1. Wien bridge oscillator using thermionic valves (design due to D. E. D. Hickman).

There is, in consequence of the high impedance of the bridge elements, some risk of high-frequency attenuation and phase shift due to the inevitable capacitance to ground of these and other components, particularly the interstage coupling capacitors. This is of little consequence in fixed-frequency oscillators but in wide-range circuits it may result in a requirement for separate scales on the various ranges. For example, in a three-range oscillator it will normally be found that on the lowest frequency range the phase shift due to the interstage coupling capacitor contributes considerably to the overall loop phase shift of the amplifier and feedback network. On the highest frequency range the interstage phase shift due to the coupling capacitor is negligible but on this range shunt capacitance becomes important. On the middle range, series and shunt capacitance in the amplifier circuit have only a small effect on the oscillator frequency which is determined almost completely by the Wien bridge elements. The effect of amplifier phase shift is to cramp the tuning range of the oscillator. Padding or trimming capacitance is thus required on some ranges if it is desired to use a single scale with decimal or decade multipliers to cover three ranges.

At this point it is worth drawing attention to another design feature of variable-frequency oscillators. In principle a change in either R or C in the bridge elements serves equally well to effect a change in frequency. If C is increased, the operating frequency will be lowered in such a way that the impedance of both arms of the bridge remains unchanged. The load on the driving amplifier stays constant and a change in frequency is not accompanied by a change in output level due to this cause. By contrast, if a frequency change is effected by varying R, then there is a change in the magnitude of the bridge impedance and a consequential change in oscillator output unless the

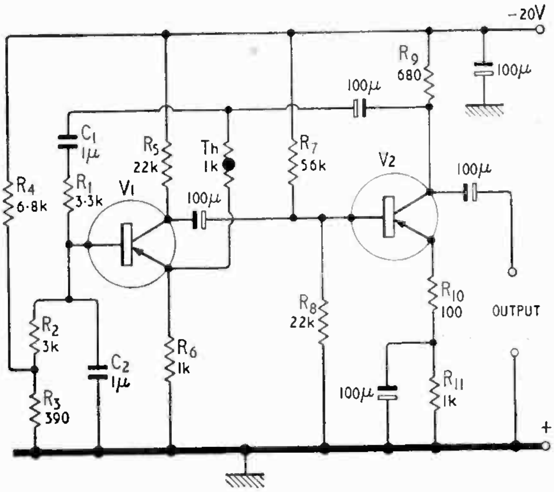


Fig. 2. Transistorized version o' the Wein bridge oscillator of Fig. 1.

driving valve is of abnormally low output impedance.

The thermistor in Fig. 1 serves as an amplitude limiter. It has a large negative temperature coefficient which is exploited to control the oscillator output. Any increase in the output level causes a rise in the power dissipated in the thermistor element. Its temperature rises and the resistance falls proportionately. Since it is the series element in the negative-feedback circuit, the resulting degeneration restores the output very nearly to the original value. There are of course thermistor resistance changes due to room temperature variations but these are effectively swamped by the much larger changes due to internal energy dissipation changes caused by feedback from the output stage.

Consider now the direct transistor equivalent of Fig. 1 which is shown in Fig. 2. Typical component values are shown on both diagrams. In general, the lower impedances of the transistors call for corresponding reductions in resistance and for large increases in the value of coupling and by-pass capacitors. Minor changes in the input circuit of the first transistor V1 are called for to satisfy the base bias requirements. Corresponding changes are also required in the interstage coupling networks, but in other respects the circuits are virtually identical.

In spite of the superficial resemblances between Figs. 1 and 2, the transistor version would perform indifferently even if it worked at all. As shown, the input impedances of V1 and V2 might be of the order of 5,000Ω (using OC 71s, for example). That of V1 would impose a gross load on the parallel RC arm of the bridge, while that of V_2 would shunt the collector load of V_1 and reduce the stage gain. Even though coupling and by-pass capacitors of high values are used, they are associated with such low resistances that unacceptably large phase shifts would be experienced. Objectionable as these may be there are still worse defects to be overcome. Low-frequency operation calls for very large values of capacitance in the bridge network. Fixed capacitors must be used and frequency variation must be achieved by the use of ganged potentiometers. A practical difficulty is at once encountered, since any change of the resistances in the base circuit of V1 will alter its working bias. To avoid this trouble it might be possible to devise some complex resistance network which would serve to provide a fixed base bias current. It might be argued that some of the criticisms of the direct transistor analogue of the valve circuit are too sweeping and severe. For example, the low working voltages of transistor circuits make it quite practicable to use very high values of coupling capacitance, and to counteract the relatively high shunt capacitance it is sufficient to use very low collector load resistances. However, the amplifier gain then falls to an unacceptably low level and the current consumption rises to an uneconomic figure.

Fortunately it is possible to employ direct coupling between transistors with few of the penalties which are incurred when this technique is used with thermionic valves. This at once solves the problem of interstage phase shift and attenuation, though it calls for additional care in bias stabilization.

Finally, the use of negative feedback can transform the amplifier input and output impedances to almost any desired values. This practice can become extravagant in transistors if extremely high input or very low output impedances are required. The use of a single extra stage, properly employed, can raise the input impedance by a factor of 100 or more.

Transistor Amplifiers of High Input Impedance.—Fig. 3 shows three amplifier configurations which have a high input impedance. An emitter follower is shown in Fig. 3(a). It is roughly analogous to a cathode follower but the parallel is not exact. Internal feedback in the transistor circuit is respon-

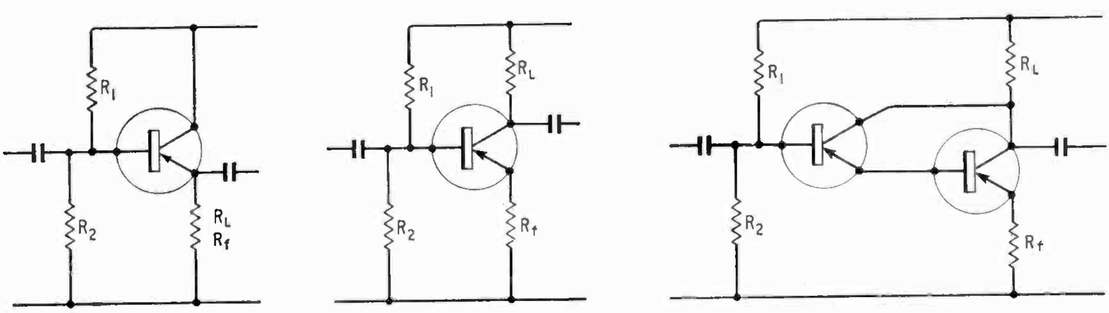


Fig. 3. Transistor amplifiers having a high input impedance: (a) is an emitter follower, (b) a feedback amplifier in which there is no decoupling capacitor in parallel with the emitter resistor, and (c) a "super-alpha" pair.

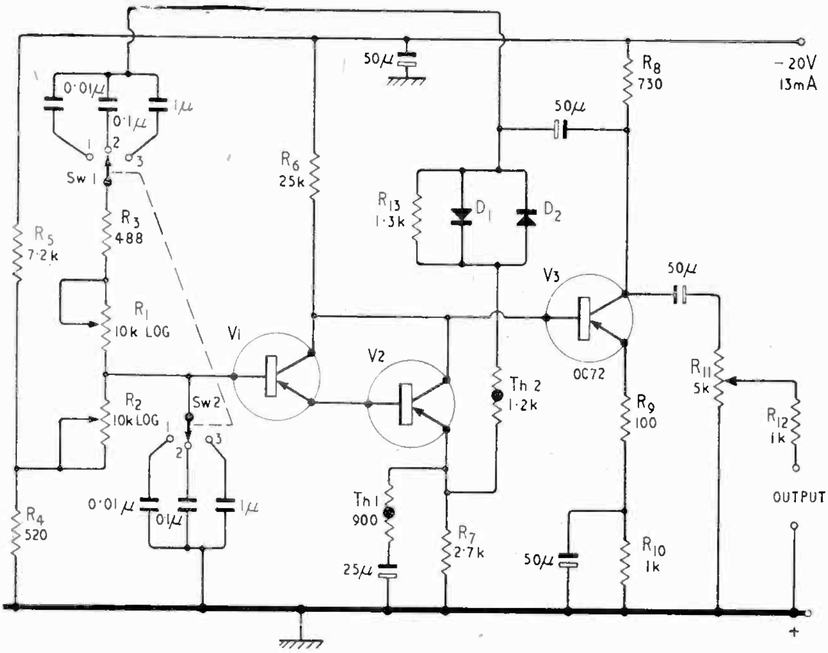


Fig. 4. Circuit diagram of a transistorized Wien bridge oscillator covering 20-20,000 c/s. (Half-watt resistors can be used throughout.)

sible for the differences. An emitter follower has a high input impedance only if it has a large load resistance. It has a low output impedance only if it is driven from a signal source of low impedance. Fig. 3(b) shows a feedback amplifier in which there is no decoupling capacitance in parallel with the emitter resistor. In this case the high input impedance is achieved at the expense of amplifier gain. To be really effective a two-stage amplifier is required with feedback over the two stages from the second collector to the first emitter. Using this technique it is easy to raise the first stage input impedance to a value of several megohms.

A rather less expensive solution is shown in Fig. 3(c). Two transistors are used to form a "super-alpha" pair. The base current of the second stage is the emitter current of the first. The first-stage base current is smaller than its emitter current by a factor which is of the same order as the current gain. Assuming that this is 100 and that the input impedance of the second transistor is 5,000Ω, the effective input impedance of the first stage becomes 0.5MΩ. The arrangement has other desirable properties. A large amount of negative feedback is provided which tends to linearize the characteristics of the transistor pair, and there is some improvement in the stability of the composite circuit in respect of temperature changes. Most textbooks on transistor circuits contain only a brief reference to the "super-alpha" connection although its special properties have been exploited, without explanation, in many recent circuits. Some of the foregoing remarks about its special characteristics thus warrant further comment. An emitter follower of the type shown in Fig. 3(a) has a voltage gain which is always less than unity. It can nevertheless provide a moderately high power gain which is due to current amplification within the transistor. An emitter follower can be used as a pre-amplifier to drive an earthed-emitter amplifier like that shown in Fig. 3 (b). Components may be saved and the composite amplifier may be used down to zero frequency by directly coupling the two stages. To do this it is sufficient to set the operating points of the two transistors at an optimum value by proper choice of the base bias resistances of the first transistor. This first transistor is then an emitter follower of which the load resistance is simply the input resistance of the second stage amplifier. The composite amplifier then has the high input impedance of an emitter follower. A single circuit change is now sufficient to arrive at the "super-alpha" connection shown in Fig. 3(c). It involves disconnecting the collector of the emitter follower from the negative h.t. line and joining it to the collector of the second transistor. The principal effect of this change is to place in series with the collector circuit of the first transistor the whole output voltage developed across the load resistance R_1. This voltage is opposite in phase to the amplifier input voltage and constitutes a large series negative-feedback signal. The effect of this is to cause a further increase in the already high input resistance of the first transistor and to linearize the characteristics of the transistor pair.

Wide-range Oscillator Circuit.—Fig. 4 shows the complete circuit diagram of a Wien bridge oscillator covering 20 c/s to 20 kc/s in three overlapping ranges. A point-to-point wiring diagram is given in Fig. 5. Coarse frequency changes are made by a 2-gang 3-pole switch, used to select matched pairs of capacitors. Fine tuning is effected by a 2-gang potentiometer, R_1 R_2, having a semi-logarithmic winding law. A linear winding is acceptable for most purposes and such a component may be more readily available than that actually used in the prototype oscillator.

Because of the very high input impedance of the first transistor its bias current is quite small and is not seriously affected by variations of the main tuning resistances R_1 and R_2. Direct coupling between the three transistors saves components and avoids the phase shifts which would be caused by coupling capacitors and base-bias resistors. Variations of bridge impedance over each tuning range are due to changes in the resistive arms of the bridge. These effects are minimized by the use of an amplifier V3 of very low output impedance. A Mullard OC 72 is used in this stage. Transistors V1 and V2 should have characteristics similar to the OC 71.

Two thermistors are used for amplitude limitation. The main control is exercised by Th 2, which is the negative-feedback element. It is a glass-

(*Continued on page* 389)

sealed Type A thermistor, manufactured by Standard Telephones and Cables. The sample used had a resistance of 1200Ω, measured at room temperature and near-zero current. This element is not ideally suitable for transistor applications. Preferred types, specially manufactured for low power control and regulation, are the S.T.C. thermistor Types R.53 or R.14. The difficulty with physically large thermistors is that the resistance changes due to ambient temperature variations may exceed those due to changing oscillator signal levels.

The use of a second Type A thermistor, Th 1, (whose resistance should not be significantly greater than that of Th 2) serves to give partial compensation for room-temperature changes. In series with a large capacitor, it is connected in shunt with the emitter resistor of V2. Here the signal level is so low that it has a negligible effect on the thermistor resistance. By contrast, the resistance of Th 1 is markedly dependent on the room temperature. A rise in temperature causes a fall in resistance and a consequent reduction in the negative-feedback voltage applied to V2. This, in part, neutralizes the effect of a decrease in the resistance of Th 2 caused by the same room-temperature changes. The signal level in Th 2 is high enough to cause additional resistance changes, sufficient in practice to give a reasonable degree of control of the output amplitude.

In series with Th 2 is another control element. This consists of a pair of germanium junction diodes (such as B.T.-H. Type GJ3-M) connected in parallel but with opposed polarity. These constitute a non-linear resistance, the magnitude of which depends on the instantaneous voltage drop across the diodes. With an infinitesimal p.d. across the diodes their effective resistance is almost infinite. It drops to a few ohms with an applied e.m.f. of about 250 mV. A resistance shunt R_{13} across the diodes limits their maximum effective resistance at low signal levels. The use of this non-linear circuit element ensures reliable oscillation over a wide range of temperatures. This it does at the expense of some waveform distortion. The degradation is barely perceptible on an oscillogram, but is undesirable when the oscillator is being used to make distortion measurements on high-grade amplifiers. If the oscillator is to be used only at normal room temperatures and is not exposed to extreme variations the diodes may be omitted, or a short-circuiting switch may be fitted if it is desired to retain them for use under abnormal conditions. If a thermistor Type R.53 is substituted for Th 2 the diodes are certainly unnecessary, but a Type A unit should still be used in the emitter circuit of V2.

It might be thought that amplitude control by thermistors must necessarily result in some non-linear distortion. This is not the case, since the thermal capacity of the resistance element is so large that, except at the very lowest frequencies, the resistance does not change significantly during the time of one cycle of the oscillator frequency.

The actual distortion produced by the diodes is dependent on the signal level and on the value of the shunting resistance R_{13}. It is very slightly affected by the thermistor resistance in series with the shunted diodes. Diode distortion is a function of signal amplitude and is virtually independent of frequency.

As regards components, those shown in Fig. 4 are a mixture of preferred and non-preferred values, arrived at by actual measurement. There are only two really critical components, R_3 and R_4. These set the high-frequency limits on each tuning range and their ratio affects the bridge attenuation which, in turn, calls for corresponding adjustments of amplifier gain. The base-bias resistance R_5 is also fairly critical. The best procedure is to complete all the circuit wiring with the exception of R_3, R_4 and R_5. External variable resistances should then be connected temporarily in circuit and the correct settings established by trial. The aim should be to produce the best possible waveform on each range and to equalize the output level at the extreme ends of each range. The maximum undistorted output is 1V r.m.s. into 1,000Ω.

As regards frequency calibration, the best procedure on the low-frequency range is to establish the main points on the scale by reference to a 50 c/s signal. A precise comparison of frequencies which are integral or simple fractional multiples of each other can be made by observation of Lissajous figures on an oscilloscope.

The high-frequency ranges call for the use of

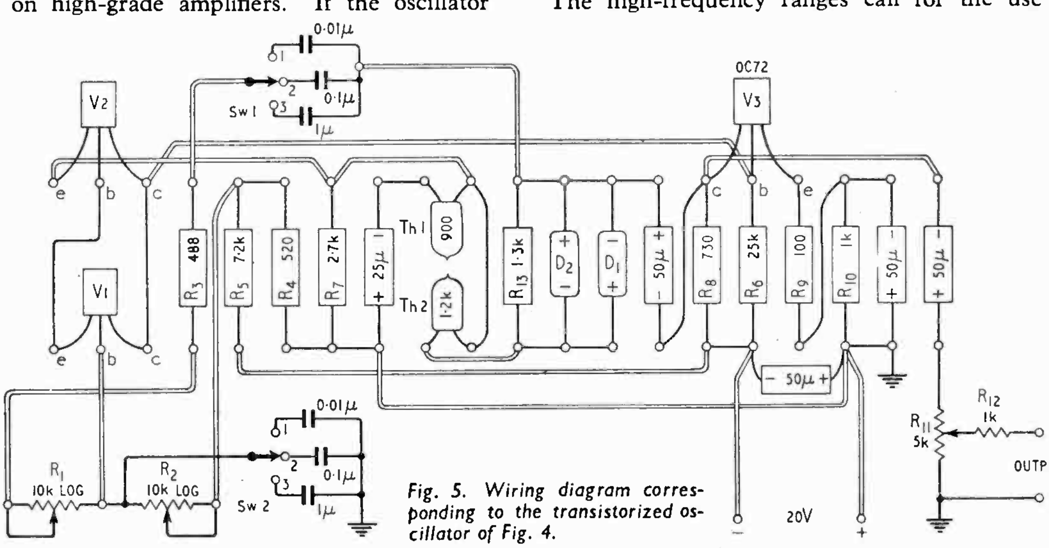


Fig. 5. Wiring diagram corresponding to the transistorized oscillator of Fig. 4.

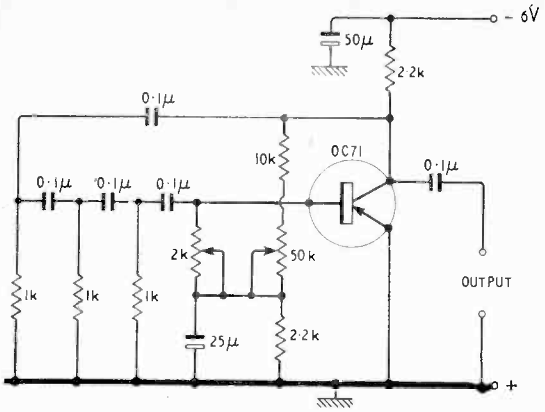


Fig. 6. 1,000 c/s auxiliary oscillator for calibration purposes. (Half-watt resistors can be used throughout.)

auxiliary oscillators. Fig. 6 gives a simple circuit of a 1 kc/s oscillator which can be calibrated against a 50 c/s signal and set precisely on frequency by the adjustment of the 2kΩ potentiometer, again using a Lissajous display. The 50kΩ variable resistor has a small effect on the generated frequency but its main function is to set the transistor base bias for maximum undistorted output. This oscillator can be used to check most of the mid-frequency and high-frequency ranges. On the 20 kc/s range, the higher-frequency points can be checked against a 100 kc/s crystal-controlled oscillator.

To avoid the considerable labour of matching all the ranges to permit the use of a single scale with decade multipliers, it is much simpler and less cumbersome to use separate scales for each range. Alternatively an arbitrary scale of 100 or 180 divisions may be used in conjunction with conversion tables or charts.

Range Extension.—Experiments show that with high-frequency transistors there is little difficulty in adding a further range covering up to 200 kc/s and in fact a slightly modified circuit using American 2N 499 v.h.f. transistors operated reliably up to 2.3 Mc/s. At such high frequencies, variable capacitors become more useful than variable resistors as the tuning element. There is little point in using RC oscillators at frequencies much higher than 100 kc/s since it is simpler and cheaper to use switched tuned circuits.

Crystal-Controlled Oscillator.—The amplifier circuit shown in Fig. 4 is easily convertible to a precision low-frequency crystal oscillator. The crystal is merely substituted for the series RC arm of the Wien bridge network. The other arm is reduced to a pure resistance by removal of the shunt capacitance. At its series resonant frequency the crystal behaves as a pure resistance. Off-resonance it simulates a very high reactance. The crystal acts as one segment of a voltage divider, the other being the resistance between the base of V1 and earth. Off resonance the amplifier input voltage is attenuated and its phase is changed so that oscillation is made impossible. At series resonance the low effective resistance of the crystal results in the development of sufficient amplifier drive to start and sustain oscillation. The amplitude control circuit functions as in the Wien bridge arrangement to ensure strict Class-A operation. Because of the strong negative feedback, variations in transistor parameters due to temperature and supply voltage changes have only a minor effect on the frequency stability. Considerable development work would be required to bring up the performance of such an oscillator to meet the exacting specifications of modern frequency standards. It would be necessary to employ v.h.f. transistors in order to reduce the amplifier phase shift to a satisfactory level. Temperature control of both crystal and amplifier would be required and the supply voltage would need to be stabilized. Preliminary tests show that the performance of the simple circuit is good enough for many purposes. Its outstanding feature is that the operating conditions can be adjusted to set a definite limit to the amplitude of vibration of the crystal. The harmonic content of the oscillator output is then extremely low.

Variable Inductors.—It seems probable that suitably designed variable inductors could be used in conjunction with fixed resistors as the frequency determining elements of an audio oscillator instead of the variable resistors and capacitors normally used.

One possible scheme would be to use twin solenoids with moveable ferrite cores. Range-changing requirements could be met by the use of suitably tapped coils. Such a system would present a constant impedance to the driving amplifier and this would ease the problem of securing constant output over a wide range of frequencies.

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Microwave Instruments, including attenuators, loads, oscillators, transformers, wavemeters, power supplies and many other special components. An extensive illustrated catalogue covering the complete range of products from Decca Radar, Ltd., Decca House, 9 Albert Embankment, London, S.E.11.

Bench Assembly Trays and storage bins in polythene and other plastics. Various sizes and shapes, some designed for stacking and others for interlocking side by side. Leaflets from "Kabi," Precision Components (Barnet), Ltd., 13 Byng Road, Barnet, Herts.

Television Aerials, masts and accessories. The complete range of Band-I, Band-III and combined types, including v.h.f. aerials, is displayed on a broadsheet from Telecraft, Ltd., Quadrant Works, Wortley Road, Croydon, Surrey.

Ultrasonic Cleaning Equipment for use on small parts and assemblies. Operating at 40kc/s, the generator delivers 250 watts peak either into a complete tank and transducer assembly or into an immersible transducer. Technical details on a leaflet from Dawe Instruments, Ltd., 99-101 Uxbridge Road, Ealing, London, W.5.

Industrial TV Equipment, with a photoconductive camera in a cast aluminium weatherproof housing for use under extreme weather conditions. Pan (up to 350°) and tilt (up to ±90°) equipment is remotely operated from a control unit. Operation on 625-line standards. Leaflet from Te-Ka-De, Nuremberg, W. Germany.

Microwave Valves

INTERNATIONAL CONGRESS AT MUNICH

A SOMEWHAT unusual general feature of the recent Munich Congress was the relatively large number of survey papers given. These should lend an added interest to the forthcoming publication of all the congress papers (in their original languages) as volume 22 of *Nachrichtentechnische Fachberichte*. Since as many as 145 papers were given, three simultaneous sessions had to be run. Fortunately, by choosing what he hopes were the most novel and important papers, your reporter generally managed to avoid having to be in several places at once. For reasons of space, this report must be even more selective.

Magnetrons

One of the problems of magnetron design is ensuring complete stability in the desired mode of oscillation. This is because the r.f. waves associated with the many unwanted modes (and indeed also with the wanted one) have velocities which remain constant round the anode structure. Electrons with a constant and suitable velocity can thus interact favourably with all modes. A general way of avoiding such unwanted interaction which was described in a paper by D. A. Wilbur *et al* is to make the velocities of the unwanted modes vary round the anode so that these modes cannot interact with electrons of constant velocity. (At the same time the velocity of the desired mode must of course be kept constant round the anode.) These conditions can be satisfied by making the anode up out of two or more sets of resonators whose frequency/phase shift characteristics are the same only for the desired mode. Two examples of anode structures which can be made to satisfy this criterion are a combination of forward- and backward-wave sections or alternatively, a number of different-sized cavities arranged in a random sequence. Tapering the cavity dimensions towards the end of a travelling-wave tube to suppress backward-wave oscillations in a somewhat similar way was discussed in a paper by M. Chodorow *et al.*

A paper by W. E. Willshaw mentioned a way of facilitating third harmonic operation of magnetrons. This is done by making the anode up out of two sets of cavities—one set resonating at the fundamental frequency and the other at the harmonic. Twice as many harmonic as fundamental cavities are provided, so that electron bunches produced at the fundamental frequency have the correct angular velocity for interacting with the harmonic.

Klystrons

A paper by J. Favalier described an unusual method of electrically varying the frequency of a klystron. This method uses an external tuning cavity in which a gas discharge is set up. To microwaves such a discharge looks rather like a dielectric whose permitivity depends on the electron density and thus also on the discharge current. By varying the discharge current one can thus also vary the tuning-cavity resonant frequency and consequently also the klystron frequency. The frequency of an X-band (~ 9,000Mc/s) klystron could thus be varied by more than 500Mc/s by increasing the discharge current from zero to 250mA.

Travelling-Wave Valves

A paper by O. Doehler and G. Mourier discussed the theory of valves in which an electron beam interacts with a slow-wave structure which is periodic in two dimensions. Such a structure is a more general version of a number of ordinary structures in parallel (in which case the distance between adjacent structures is the second periodicity) so that it should be capable of dissipating high powers. The gain was calculated for the case of the transversotron in which the r.f. energy is propagated in a direction at right angles to that of the beam. This device is reciprocal, i.e., can amplify forward- or backward-going signals equally well. Thus in order to prevent feedback and consequent oscillations, a non-reciprocal device such as an isolator must be included.

Backward-Wave Valves

A paper by W. Wendrich described a way of using such valves as mixer oscillators. (For a description of the backward-wave valve see, for example, the article by C. H. Dix in *Wireless World* for November 1959 (p. 478)). In this modification, the output (at the electron gun end of the slow-wave structure) is terminated in a matched load, and the input is fed to the other end of the slow-wave structure. Both the input and oscillator thus modulate the electron beam and, since the modulation is non-linear, combinations of the oscillator and input frequencies are also produced at the same time. The microwave sum frequency is absorbed in the output load, and the low difference frequency may be picked up at the input.

A paper by A. W. Trivelpiece showed that a longitudinally magnetized ferrite rod can propagate backward waves with velocities of the order of one hundredth of that of light. Interaction with such waves and a beam passing through an axial hole in the ferrite was observed. Such a simple slow-wave structure should be very easy to make.

Crossed-field (M-Type) Valves

Some of the work on the best-known example of this type of valve—the magnetron—has already been described in this report.

A paper by E. Dench *et al* discussed the bitermitron. This is similar to a crossed-field backward-wave oscillator (for a fuller description of which see, for example, the previously mentioned article by C. H. Dix in our November 1959 issue (p. 480)) except that, instead of one end of the slow-wave structure being internally terminated in a matched load, both ends are taken out to external circuits. This difference accounts for the first part of the name, the iron being added, as the authors put it, because this is essential for satisfactory operation. The bitermitron can be operated as a conventional voltage-tuned backward-wave amplifier or oscillator. More interesting is the possibility of operating it as a locked oscillator at high-power levels. An advantage of this arangement is that in the event of failure of the driver oscillator, the bitermitron will continue to oscillate.

A paper by J. E. Orr described a way of controlling the beam current by means of a closely packed parallel-wire grid in front of the cathode emission surface. Normally, any electrodes near the cathode are used for shaping the beam, and the current is controlled by varying the voltage of an accelerator electrode near the entrance to the slow-wave structure. However, the use of a grid control enabled a seven times greater charge in the beam current to be obtained for a given control-voltage change. Little change in the r.f. characteristics was produced by the addition of the grid. An interesting method was used to observe the effect of different electrode positions. A model scaled-up in size (and electrode voltages) was placed in a large evacuated chamber. This was big enough for a man in a space suit to go in and adjust the electrodes to give a suitable beam shape, the beam position being photographed from the light produced through excitation by the beam of the residual gas in the chamber.

Tornadotron

A paper by G. E. Weibel and R. H. Bartram described the theory of a device for converting microwaves to sub-millimetre waves at high powers. Electrons are first injected and trapped inside a chamber in a magnetic field. By making the frequency of a microwave input resonate with that due to cycloidal motion in the magnetic field (cyclotron resonance) orbital motion of the electron cloud is next induced. It is then proposed to multiply the orbital frequency and its associated rotational energy by a factor of between 100 and 1000 by means of a very large ($\gtrsim$ 100,000 gauss) pulsed magnetic field. Power at sub-millimetre wavelengths should then be radiated directly from the rapidly swirling electron cloud. This cloud actually swirls on its own axis as well as round its orbit—hence the name of the device.

Noise Reduction

In spite of, or perhaps because of, the recent discovery of new types of valve—such as the parametric amplifier—with very low noise characteristics, many new ideas for reducing noise in conventional valves are being investigated. Moreover, earlier pessimistic theoretical calculations of the minimum possible noise figure in such valves (which was not much less than what had already been achieved in practice) are no longer regarded as valid. A survey paper by M. R. Currie included a discussion of noise reduction in conventional valves. In such valves it can be shown that nearly all the noise is produced at the beginning of the device, near the cathode and potential minimum. It is on modifying the electron velocities in the multi-velocity region just beyond the potential minimum that many of the newly proposed methods of noise reduction depend. These electron velocities can be modified by depressing the potential minimum by the space-charge effect of high-density injected electron beams or, more usually, by modifying the beam profile either by means of special electrodes near the cathode or by shaping the cathode emissive surface itself. The noise can also be reduced by confining the emission to the edge of the cathode. In general, the use of two- rather than single-dimensional concepts is an advantage in this field. Space-charge effects can also reduce the noise, and since the extent of such reduction varies with the frequency, it may be advantageous to operate at certain frequencies to obtain low noise.

Modulation in an electron beam is usually propagated along it in two waves. One—the fast wave—has a velocity greater than that of the beam itself and the other—the slow wave—a velocity less than (but usually similar to) the beam velocity. Until recently microwave valves have relied on interaction between the slow electron beam wave and a circuit, and it has usually been thought that it is impossible to completely remove the noise from this slow electron beam wave. A paper by P. A. Sturrock, however, not only suggested flaws in the reasoning by which this impossibility is deduced, but also proposed a possible general method of removing the noise from a slow wave. In this method the fast and slow waves are parametrically coupled together by a pump signal in such a way that any noise on the two waves is interchanged periodically along their lengths. The noise can thus be removed from the slow wave if the noise on the fast wave has previously been removed. This can be done by a somewhat similar interchange process which is already known and which will be briefly described later in this report in connection with transverse-field valves.

A method of noise reduction which should be applicable to both slow and fast electron beam waves was described in a paper by R. Adler and G. Wade. This depends on the fact that for an electron beam spiralling in a longitudinal magnetic field, the noise temperature for transverse modulation (at right-angles to the direction of the beam motion and magnetic field) can be shown to be proportional to the ratio of the signal to the spiralling (cyclotron) frequencies. By using a large magnetic field to give a high cyclotron frequency, the noise can thus be reduced. Moreover, the field need not be kept large throughout the valve since it can be gradually reduced beyond the initial noise-reduction region without increasing the noise. Experimental results showed a reduction in the fast wave transverse noise temperature from 1100°K to 180°K for a cyclotron frequency nine times that of the signal. The main problems in applying this method arise in designing a transverse-field input coupler which will operate at a fraction of the cyclotron frequency (rather than, as is usual, at the cyclotron frequency) and, of course, in providing a magnetic field high enough to give a cyclotron frequency several times that of the signal.

Periodic Electron Beams

Until recently microwave valves have relied for their operation on synchronism between r.f. waves and the longitudinal velocity of an electron beam. Thus, since the velocity which can be attained by electrons is necessarily limited, special slow-wave structures which are capable of propagating r.f. waves with velocities as slow as those of the electrons have to be provided. As the wavelength is decreased, such structures become correspondingly smaller. They are then more difficult to make and cannot dissipate so much power. In addition, the r.f. fields also fall off more rapidly away from them and so interaction with electron beams is more difficult to achieve. Slow-wave structures are generally either periodic, like the helix, or resonant, like the cavities in a magnetron. Aperiodic, non-resonant, smooth-wall circuits (such as waveguides), which would be easy to construct, can normally only propagate fast r.f. waves, i.e., waves with phase velocities equal to or greater than that of light and thus greater than that of any possible electron beam. Electrons can, however, interact with a fast wave by travelling not in a straight line but rather in a periodic path which is made to correspond to the spatial or time periodicity of the r.f. wave in such a way that any given electron always sees the same value of the r.f. field.

A paper by C. K. Birdsall and L. Haas discussed beams which are made to follow a zigzag path along a waveguide by means of repelling electrodes outside the guide. Up to 21 crossings have been successfully induced, about 40% of the beam being transmitted through six crossings. In fact, however, only a small number of crossings is necessary for interaction, for similar reasons as in the case of a reflex klystron where the beam passes only twice through the cavity. The beam can interact with either forward or backward waves, possible output frequencies being those at which the r.f. wave slips a whole number of wavelengths per zigzag ahead of or behind the beam.

Birdsall and Haas also discussed beams which are made to follow a helical path between two concentric cylinders by balancing the outward centrifugal force against an equal inward force produced by an electrostatic field applied between the two cylinders. Here for interaction, the frequency of helical rotation must be equal to the required output frequency, neglecting any motion of the electrons in a direction along the cylinders' axis.

Papers by A. Reddish and by A. H. Beck and R. F. Mayo described beams which are made to follow a cycloidal path by means of a magnetic field. (It is interesting to remember that such motion was in some cases responsible for the operation of early magnetrons.) In such motion the cycloidal radius depends on the electron velocity. Thus the unfavourable electrons which gain energy from the r.f. field are automatically separated from the favourable electrons which lose energy to the r.f. field. For interaction, the cycloidal frequency must equal the required output frequency, neglecting any electron motion along the field.

A disadvantage of this system is that to produce short wavelengths high magnetic fields are required (field $\approx$ 10,000 gauss divided by wavelength in centimetres). This could be avoided if the cycloidal motion could be at a sub-harmonic of the required output frequency. The paper by Beck and Mayo showed that in this case interaction is still possible, provided that the r.f. field has an azimuthal spatial periodicity corresponding to the sub-harmonic used. Thus, for example, the TE_{m1} waveguide mode can interact to produce output at m times the cycloidal frequency.

Transverse-field Valves

These are valves in which the r.f. field, and consequently also the electron modulation motion, are at right angles to the electron beam motion. Since a transverse-field parametric amplifier with very low noise was developed by R. Adler (see the *Technical Notebook* section of our November 1958 issue (p. 555) or for a full account *Proc.I.R.E.* for June 1958 (p. 1,300) and October 1958 (p. 1,756)) much interest has been shown in such valves, and a number of devices more or less similar to the Adler tube were described at the conference. Two of these were simply microwave versions of the Adler tube (which has a relatively low operating frequency around 600 Mc/s)—one due to A. Ashkin for 4,140 Mc/s and the other due to T. J. Bridges for 2,700 Mc/s.

The orginal Adler tube used input and output couplers of the Cuccia type, which were first described in *R.C.A. Review* as "long" ago as June 1949 (p. 270). In such couplers the r.f. input signal is applied via suitable circuits across two deflection plates on opposite sides of the beam. This produces transverse r.f. fields across the beam. A longitudinal magnetic field is also applied to produce spiral motion of the beam along the field. When the input frequency across the coupler is made equal to the cyclotron spiralling frequency, the phenomenon of cyclotron resonance produces an increase in the spiral radius. In this device the coupling is between the fast electron-beam and r.f. waves. It has the great advantage that under certain conditions (such as, for example, for a particular length of coupler) the beam noise is, in theory, totally removed to the coupler (and in practice nearly so) as the r.f. input signal is transferred to the beam.

One disadvantage of the Cuccia coupler is the fact that the coupler signal input frequency is tied to the magnetic cyclotron frequency. A paper by P. A. H. Hart discussed theoretically a method of obtaining a somewhat wider choice of possible signal frequencies relative to the cyclotron frequency. In this method, slow-wave deflection circuits are used to produce transverse r.f. signal fields which travel along the electron beam. The phase velocity along the beam of the r.f. signal is chosen relative to the longitudinal beam velocity so that an observer travelling with this beam velocity would see, because of the Doppler effect, a transverse field not at the signal frequency but at the (in this case lower) cyclotron frequency. Resonance between the apparent signal frequency and the cyclotron frequency, fast-wave coupling and noise removal are then possible as in the Cuccia coupler. A greater bandwidth should, however, be obtainable than with a Cuccia coupler. (Doppler shift concepts similar to that just described were of importance in several of the interaction processes discussed at the conference.)

A paper by W. R. Beam described experimental results on the use of a slow-wave helix to couple to a hollow beam. Here again the input frequency was not tied to the cyclotron frequency. Unfortunately the results obtained did not agree with those to be expected on conventional coupling theories and have not yet been explained.

A paper by R. H. Pantell discussed the theory of a transverse-field coupler which uses a d.c. electrostatic rather than a magnetic field. In this coupler, as in the periodic beam device described by Birdsall and Haas which we have already mentioned, spiral motion of electrons is produced between two concentric cylinders by balancing the outward centrifugal force against that produced by an electrostatic field applied between the two cylinders. For interaction the spiralling frequency must equal the signal frequency as in the Cuccia coupler, and again fast-wave coupling and noise removal are possible for a certain critical length of coupler.

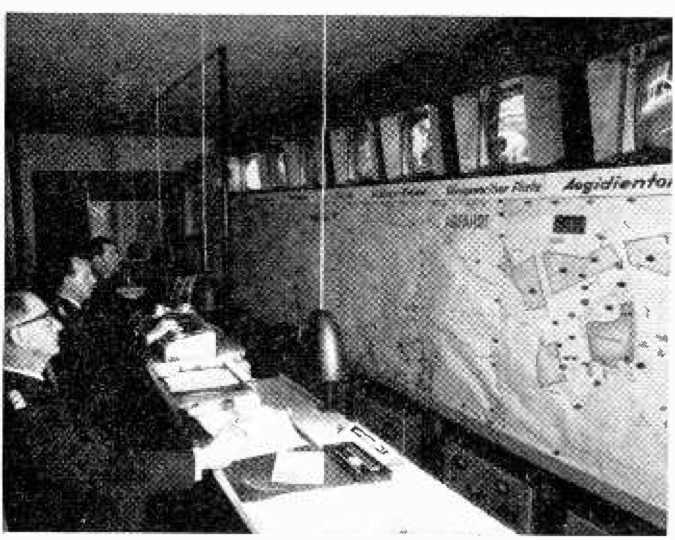
Couplers such as we have just been describing can only put spiral modulation motion on to the beam and are not capable of amplifying this motion. One or more quadrupoles were used to produce amplification in almost all the transverse-field valves described at the congress—indeed one author said he would not have dared to describe his device if it had not used a quadrupole. Such quadrupoles each consist simply of four deflection plates spaced round the electron beam. Adjacent plates are given opposite electric potentials so as to produce fields which are tangential to the spiral motion of the beam. Amplification of the spiral modulation motion is produced by arranging for any given electron to continually see an accelerating tangential field as it spirals along the tube. This can be done by means of either a time- or space-varying quadrupole field, i.e. either by applying a pump r.f. field to a single quadrupole or alternatively, by applying direct voltages to a number of quadrupoles which are rotated and suitably spaced relative to each other. The latter system was used in several of the new devices described at the congress: the former was used in the original Adler tube.

When an r.f. pump field is used, this provides the energy necessary to produce amplification. In the original Adler tube, to correspond to the two pairs of plates in the quadrupole, the pumping had to be at twice the spiral (signal) frequency. A paper by J. E. Carroll discussed the possibility of pumping at a rather lower frequency—two-thirds of that of the signal. In this case the pumping process can be considered as an initial interaction between the pump and signal to produce a difference signal (at one-third of the original frequency), followed by pumping of this difference signal as in the Adler tube at twice its own frequency (i.e., at two-thirds of the original frequency). With this method of pumping the noise should be as low as in the Adler tube. Other effects may, however, prevent its successful practical realization. Pumping at the signal frequency was discussed in a paper by E. J. Gordon and A. Ashkin.

Amplification by means of a number of spaced relatively-rotated d.c. quadrupoles may be loosely described as being with a zero pump frequency. The energy required to produce amplification is, however, no longer obtained from the pump field, but rather from the d.c. beam energy, longitudinal beam kinetic energy being converted into spiral rotational energy by the d.c. quadrupoles. In the example described by J. C. Bass, adjacent quadrupoles are spaced one quarter of a cyclotron wavelength apart and rotated through ninety degrees relative to each other. Identical results are obtained by not rotating the quadrupoles but instead reversing the signs of the applied direct potentials between adjacent quadrupoles. Apparently d.c. quadrupoles will not give low noise, but should on the other hand be capable of producing higher power outputs. The absence of an r.f. amplifying structure would, of course, be an advantage in constructing very high-frequency devices.

Possibilities of getting away from the quadrupole as an amplifier by using a helix and hollow beam were described in the paper by W. R. Beam already mentioned. In this case also pumping need not be at twice the signal frequency. The possibility of using a number of spaced magnets as a spiral motion amplifier was mentioned in a paper by K. Blotekjaer and T. Wessel-Berg.

TRAFFIC CONTROL AT HANOVER



RADIO communications play an important part in the special police arrangements for traffic control in Hanover, particularly during the period of the annual Trade Fair, when upwards of 40,000 cars may be added to the normal traffic streams during the morning and evening rush hours.

Television cameras mounted at strategic points are connected by links in the 6,700 Mc/s band with display units at a control centre on the top of the 170 ft high Electrotechnical Hall of the exhibition. These displays give an overall picture of the traffic situation in Hanover and its environs.

This year remotely controlled steerable cameras (supplied by Te-Ka-De and Felten and Guilleaume of Nürnberg) were used for the first time at multiple road junctions and an additional circuit was made available for a camera fitted in a patrolling helicopter.

The traffic-control officer (second from left) is operating the "joy stick" of one of the remotely controlled television cameras.

LETTERS TO THE EDITOR

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

Circuit Conventions

AS the subtitle to Patrick Halliday's article, "Better Circuit Diagrams," was in the form of a question, presumably comments were invited.

The use of the nanofarad is a practice I applaud—see the preface to "Radio Laboratory Handbook," 6th edition. The same goes for omitting Ω, F and H, with the object of making it easier to specify values on the circuit diagram instead of in a list.

Saving time in the drawing office is certainly a valid motive for re-examining our graphical symbols. But any competitive candidates must themselves be able to stand examination. The following are some comments on Mr. Halliday's recommendations.

The rectangle for a resistor is much less easy to sketch than the traditional zig-zag, nor need the latter take up much time in more formal drawings if the number of strokes is kept small. If the rectangle can be drawn with a stencil, so too can the zig-zag. There are other things than resistors for which rectangles are more suitable—general impedances, for example. The wattage code shown makes no provision for resistors of unspecified wattage; unless otherwise specified they are all ¼W! The same objection applies to the capacitor voltage code.

For sketches, the present inductor symbol is unrivalled, but for formal drawings there is certainly an advantage in the row of semicircles, and in the "block" method of drawing mains transformers.

The proposal to substitute a single stroke for both earth and chassis connection symbols is most ill-advised, however, as the vital distinction between these two is thereby obliterated.

There is no need whatever to cause confusion by using a black spot (which already signifies "electrode with special function") in place of the BS.530 cathode symbol —admittedly a time waster if drawn accurately to standard. A simple curved or bent line is sufficient. And as for the segmented spot to indicate a cathode common to other parts of a multiple valve, it seems to have nothing in its favour. It fails to show which other electrodes it is related to, and is not even easy to draw. Again, what is wrong with a simple line?

To sum up: some, at least, of the foreign practices deserve consideration *for working diagrams of equipment.* Presumably they were put forward with this qualification understood. They are less suitable for diagrams illustrating principles or techniques, and still less for engineers' sketches.

Bromley, Kent. M. G. SCROGGIE

AS a technical author, I agree strongly with Patrick Halliday about circuit element symbols. In the production of literature on electronic subects, circuit diagrams are major items. Currently conventional symbols demand space which is very scarce in a big, complicated diagram; they convey only one order of information—"values" take up added space; they are tiresome to draw neatly and their sizes create difficult problems in overall lay-out. These archaic shortcomings give rise to consumption of time and money, in the preparation of diagrams, which could be greatly reduced by universal adoption of an intelligent new code of symbols.

The most significant word, however, in the last sentence above is "universal." Confusion arising from regional codes and styles is already present and will increase if anarchy in symbolic representation is allowed to continue. We may eventually need "dictionaries" to understand "local dialects" in electronic pictorial language. There is, therefore, I suggest, a real and urgent requirement for the setting up of some authoritative body to devise a new code which, by virtue of its advantages, would soon replace all regional variants from Tokyo to London.

London, E.17. W. H. CAZALY

IN your editorial of June, 1960, you speak of "following BS 530 slavishly." This is not possible in every case since BS 530, like so many British Standards, frequently offers a choice with a preference instead of laying down a unique standard. The convention of crossing wires is a case in point.

Then when symbols are required for heavy electrical applications not included in BS 530, one looks in BS 108. Here one finds some useful additional symbols but a whole lot more which are in direct conflict with BS 530. An example is relay or contactor contacts, where BS 108 distinguishes between relays and contactors, main and auxiliary contacts, and different physical assemblies of contact (single and double break), and at no point agrees with BS 530.

The British Standards Institution's intention to coalesce these two standards is urgently needed, but it is no small task.

London, N.W.10. R. S. FERGUSON
Leo Computers Ltd.

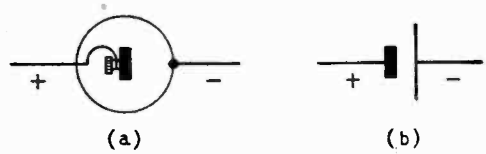
REFERRING to Mr. L. H. Bedford's letter (April 1960) concerning circuits diagrams, I wish to express to yoúr goodselves that I was very glad that you did not fall in with his ideas, maintaining the usual procedure in drawing diagrams.

With looped crossings and staggered junctions, one minimizes the chances of mistakes. As regards the valve's envelope, I believe that same ought also to be drawn: one cannot think of a vacuum tube without its envelope, therefore said envelope plays its role and should appear on the diagrams.

A. EDUARDO DINIZ SCHLAEPFER,
Eng. Diretoria de Rotas Aéreas,
Ministério da Aeronáutica.

Rio de Janeiro, Brazil.

I REMEMBER the time when the symbols representing the various components in a circuit diagram (I refuse to use that horrible Americanism—"schematics") were simplified sketches of the actual thing. For example, a standard dry cell, then the most commonly used source of electrical energy, was represented as in (a). The thick black rectangle is the carbon plate and is, of course,



positive; while the thin circle indicates the zinc can and is negative. Later, as a time and space saving expedient, the zinc can was flattened and the terminal omitted as in (b).

Modern draughtsmen insist on reversing the polarity of the symbol so that the thick black stroke is negative and the thin stroke positive. When this is queried, it is pointed out that the present back-to-front polarity is laid down in a Government publication. I should be interested to hear if there is a valid reason for this change.

London, W.13. J. C. BAKER

V.H.M./F.M. Car Radio

Mr. Blanchard (July issue) was disappointed with the results given by his v.h.f./f.m. car radio, both here and on the Continent; however, his remarks indicate likely causes of this unsatisfactory performance.

I stated that an omnidirectional aerial is desirable and that a ground plane, using the car roof, is ideal. Enlarging on this point, a quarter-wavelength in Band II is only $2\frac{1}{2}$ feet, a dimension common to many features of a car body. Because of reflections, and its asymmetrical mounting, a wing aerial must have most unfortunate and pronounced directional properties, making it quite unsuitable for v.h.f. reception in any but the strongest signal areas.

Good sensitivity coupled with fading in strong signal areas and difficulty in tuning for best a.m. rejection all point to inadequate limiting action in the tuner. This would also account for the troubles experienced with interference suppression

Mr. Crossland mentioned noise picked up inside the receiver as another difficulty; the avoidance of multiple earthing in the receiver and the use of a remote power supply unit together with the filters I recommended have made further precautions unnecessary in my experience.

Using a Jason tuner (fringe area model) I have had no interference suppression difficulties, nor has other traffic caused any bother. Certainly the only noise entering the receiver does so by way of the aerial, and then it is removed by the limiting circuits in all but weak signal areas. When demonstrating the receiver in South London an unfiltered vibrator pack was used with a considerable length of cable between the power supply and a.f. units. A filter was fitted on the a.f. chassis; even then noise caused no trouble. Subsequent removal of the filter to the vibrator end of the cable (as indicated in the article) has eliminated vibrator noise.

As for coverage of the country, there certainly are gaps, but in noise-prone areas (which coincide with the population centres covered by v.h.f. transmitters) the f.m. receiver is capable of far better performance than any a.m. receiver. The ideal is a combined a.m./f.m. receiver but no British firm makes one. On the Continent, where I have also used a v.h.f. car radio with satisfactory results (tuned usually to B.F.N.), combined receivers are made by many firms. They seem to find no difficulties with noise, the normal h.t. suppression being adequate in most cases.

Danbury, Essex. R. V. TAYLOR

Deeper Amplitude Modulation

WITH reference to recent correspondence in your journal commenting on the difference in modulation levels of British and French a.m. stations to the detriment of British stations, I would like to comment from another point of view.

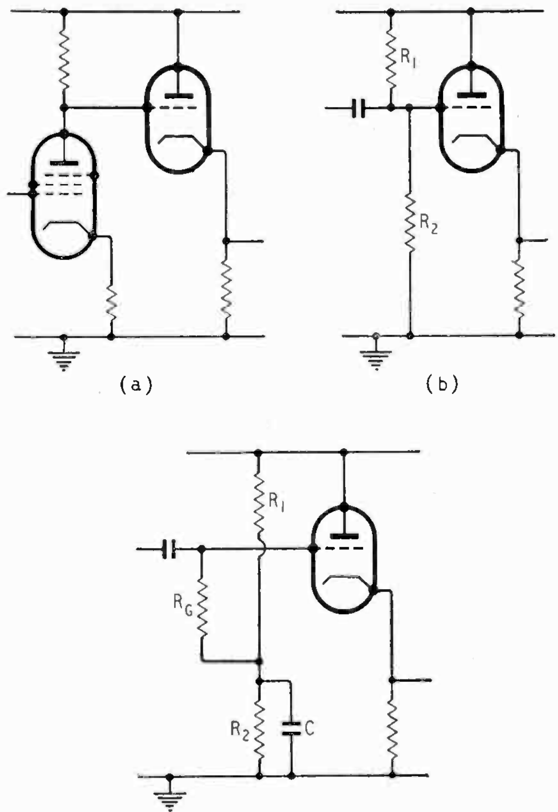
Here in Switzerland, French stations are notorious for their amount of sideband splatter. Even under good reception conditions, foreign (including British) stations are often unreadable because of French stations on nearby channels.

I have operated a receiver in Great Britain and know from experience that British a.m. stations are very free from sideband splatter. It would be a shame if this were spoilt for the sake of a few dBs' increase in audio level.

Geneva. F. KONOPASEK

Cathode-follower Biasing

IN his letter in the June issue, Mr. Bailey shows one way of translating my elementary circuit (which was in-



tended merely to convey the essentials of a cathode-follower, and not to represent a practical one) into a physical reality. It is not the only way, and in particular, it is not necessary to have a negative supply line if response down to zero frequency is not required.

The whole subject was covered by "Cathode Ray" in the June, 1955 issue,* but this may be inaccessible to newer readers, and it is perhaps worth repeating some of the circuits discussed in it.

If the cathode-follower is driven from a valve, a simple direct coupling as shown at (a) is the ideal solution. Where this cannot be done, one is obliged to apply a positive bias between grid and earth in order to make possible the use of a normal-sized load resistance. Two ways of doing this are shown here. The method shown at (b) is the simplest, but it has disadvantages. If there is any ripple on the h.t. supply, a fraction of it is developed between grid and earth, and appears almost unattenuated at the output. Moreover, to preserve a high input resistance, R_1 and R_2 must be high resistances, running perhaps into tens of megohms. Practical high-value resistors have a reputation for instability, and if their resistances vary in this circuit the biasing of the valve is upset. Circuit (c) shows how these difficulties may be overcome. R_1 and R_2 may now be low resistances, and ripple can be removed by the capacitor C. R_G can have a high value: if it is unstable, the input resistance is affected, but not the biasing of the valve. Variations in input resistance are often unimportant provided that the latter is always above a certain minimum value.

An objection to these circuits is that they almost invariably lead to the use of grid resistances far in excess of the valve manufacturers' maximum ratings. If

* "Cathode Followers, With Particular Reference to Grid Bias Arrangements." *Wireless World*, June, 1955, p. 292.

one uses the same high-value grid resistors in a normal amplifier, the anode current is often found to be different from the expected value. This is the result of small stray currents. For example, a high-resistance leak between anode and grid may set up an appreciable positive bias between grid and earth. Fortunately, in a cathode-follower, such voltages result in the development of opposing voltages across the cathode resistor. Their effect on the actual grid-cathode voltage is reduced by a factor of 1/(1-A) where A is the "gain" of the cathode-follower.

Croydon. G. W. SHORT

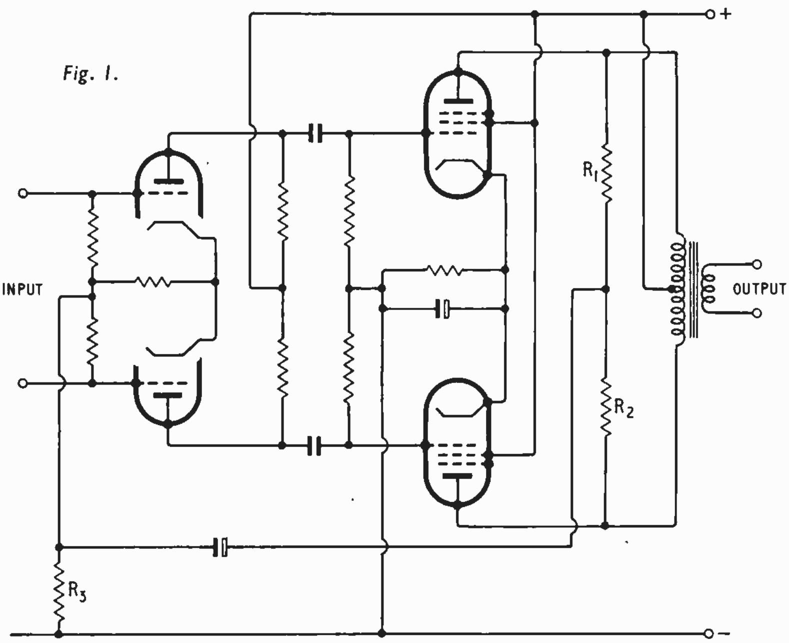
Self-balancing Push-pull Circuits

UNDER "Electronic Circuitry" in *Wireless World* of August 1948 J. McG. Sowerby showed how a high degree of negative feedback can be applied over three cascaded stages *via* an impedance common to the first and third cathodes. This gives the clue to self-balancing push-pull. A three-stage push-pull amplifier with feedback from the common output valves bias resistor to the common first stage bias resistor (*via* a large electrolytic capacitor to take care of bias voltage difference) gives such tight control of balance that the large cathode impedance of the Schmidt splitter is unnecessary, at least for reproduction of speech and music. As D. R. Birt hints in the last section of his June instalment, Class A working of the output stage is essential since the bias resistor is un-bypassed. The high gain from three stages enables heavy overall n.f.b. to be applied, and to give a very long time-constant to the middle stage grid coupling in the interests of l.f. stability (if not directly coupled) grid-leak bias—10MΩ with 0.1μF and earthed cathodes—can be used.

In any method of control by feeding back the error-signal such as this, the tightness of control depends upon the gain from the point of application of the error-signal to the point from which it is taken. An advantage of the above method over Mr. Birt's use of an amplifier in the first stage cathode circuit is that all valve stages are used gainfully as far as a.f. is concerned.

In a *two*-stage amplifier the error-signal can be fed back from the output anodes to the common cathode resistor of the input stage, but Mr. Birt's method of taking the error-signal from a resistor at the output transformer primary centre has some weaknesses. To obtain a substantial error-signal, R_7 (Fig. 5, May issue) must be large and of high wattage rating, and robs the output valves of precious h.t. voltage, and, I suspect, complicates the output loading. I would suggest the alternative in Fig. 1 herewith, R_1 and R_2 being selected for equality and together at least six times the optimum output load. R_3 in this case would be about equal to R_1 (the higher it is the greater the applied error-signal since R_1-R_3 and R_2-R_3 are potentiometers across the two phases of the output): normal Schmidt working of the first stage applies. Here, the output valves are not restricted to Class A if the bias resistor is properly bypassed.

Fig. 1.



To my pleasure at reading Mr. Birt's first instalment—because of my interest in his subject—was added surprise at reading his second, as I have done some work on cross-coupled cascode pairs also (and labelled them "Croscode"!). A point worth emphasizing is that the arrangement provides "free" phase-division without the Schmidt resistor or any other device. I have used two ways of providing automatic bias for the upper pair—Fig. 2—different again from Mr. Birt's method, not necessarily better.

However, as I see it, neither the self-balancing method in his first instalment nor that in this letter can be applied to the "Croscode". Assuming one of the upper valves has lower gain than the other, it will be seen that the error-signal applied positively to one side and negatively to the other, attempting to restore balance, is fed to *both* sides through the cross coupling, and the overall effect is exactly nil. Perhaps Mr. Birt's solution to this problem will appear in his promised design of a complete amplifier.

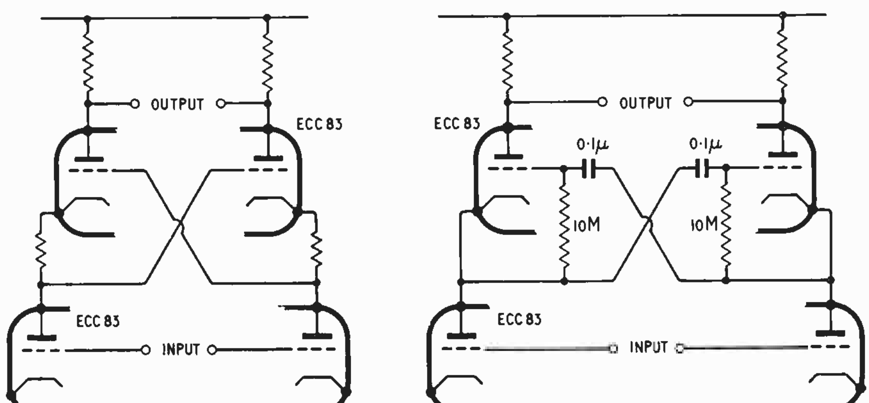


Fig. 2.

For those wishing to try out the Croscode, I would mention that I found it necessary thoroughly to bypass the common bias resistor of the lower pair, or to earth the cathodes directly with grid-leak bias, to prevent l.f. instability.

Walsall, Staffs. STANLEY MAY

The author replies:—

I have read with interest Mr. May's letter, and I should like if I may to make some comments about the suggestions he has made.

An impedance common to the input and output cathodes of a triple does indeed provide control of the output stage balance. Since the resistance to earth of the input cathodes is that of the output stage cathode resistor (100Ω) no coupling takes place within the input stage, and all the drive to the earthed-grid triode of the input pair has to be developed by the out-of-balance output stage current. This drive (and the unbalance) increases if negative signal feedback is taken to the "earthed" grid. As Mr. May states, the degree of balance is proportional to the total gain between the cathodes, but the condition of perfect balance cannot arise, unless there is cross-coupling within the amplifier. In practice, it is difficult to achieve a very large loop gain and sufficiently low phase shift, because three h.f. time-constants are involved, and the cut-off frequencies of two of these (the first and second stage anode circuits) are comparable when maximum gain is realized in each stage. The performance is therefore inferior to that of the multi-loop systems previously discussed, where less overall feedback is required for a given degree of balance and where the cascode anode time-constant provides the dominant phase lag at high frequencies. It is perhaps worth pointing out that if comparable balance is obtained by employing a common cathode resistor in the middle stage of the triple, together with favourable component tolerances, then the earthed-grid triode becomes redundant as far as signal amplification is concerned.

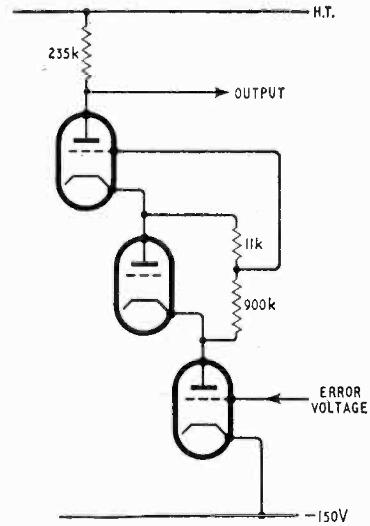
Error voltage feedback, as distinct from any form of signal feedback is restricted to Class A operation; whether this feedback involves many stages or is provided over the output stage only by an un-bypassed cathode resistor. This is because it is implicit in Class B operation that the increase in anode current in one valve cannot be instantaneously balanced by a decrease in the anode current of the other valve, the latter being zero.

Referring now to Fig. 5 (page 226, May issue) if V4 and V5 are typical 25-watt pentodes operating from 300V h.t., and $R_1 = R_2 = 220k\Omega$, then the error loop gain is 36 dB when $R_7 = 100\Omega$. The effective h.t. is reduced by approximately 5% and the wattage rating of R_7 is 2.5 watts. I suggest this is not too gloomy!

In Mr. May's alternative circuit (Fig. 1), even if one output valve is removed, there will be no error voltage at the junction of R_1, R_2 since the magnetic coupling in the output transformer will provide a balanced voltage across the potentiometer R_1, R_2. Thus R_1 R_2 and the electrolytic capacitor are redundant components! If the load impedance is constant the situation can be remedied at some cost by the inclusion of an L R network in the lead to the transformer centre tap.* Even then, we are not out of the wood, for if the source impedance at the input terminals is low compared to R_{g1}, the impedance "seen" by the junction of R_1 R_2 is not R_3, but R_3 in shunt with the cathode impedance of the input stage $(\frac{1}{2}g_m + R_k)$—about 1500Ω. Furthermore, inequality between the source impedances can influence the amplifier balance.

I am not quite sure what Mr. May has in mind in his penultimate paragraph, because it is intentional that the error voltage should be fed in the same phase to both sides of the amplifier.

The self-balancing methods discussed *can* be applied to the circuit of Fig. 11 (page 284, June issue). I think



perhaps the source of confusion is the connection between the grid and cathode of the upper valve in the push-push equivalent circuit shown in the accompanying diagram. The upper valve does not contribute appreciably to the error loop gain, but it should be remembered that the middle triode will not provide more gain because of its increased load. The measured error loop gain from the point marked "feedback" in Fig. 11 to the output terminals is 150 times at 400 c/s, which is generally sufficient to maintain the output stage balance to within 0.1%.

I should like to point out that a cross-coupled cascode circuit is inherently stable, and that it is not necessary to decouple any common cathode resistance. Any time constant in this part of the circuit can only cause instability when it forms part of a feedback loop (intentional or otherwise), involving at least two further time-constants.

In conclusion I should like to point out that the grid current bias which Mr. May favours can cause considerable distortion if the source impedance is high.

D. R. BIRT

* *Electronic Technology*, Jan. 1960, p. 41.

Standing Wave Ratio

I NOTE with dismay that in his article in the June issue, Mr. J. Robson elects to use the "American" rather than the "British" convention regarding v.s.w.r. "as the use of this convention appears to be increasing." I hasten to add that my dismay arises from no spirit of jingoism but merely from a feeling that confining a variable to the range 0 to 1 is a rational procedure followed in many "normalization" processes whereas to let it "roam" in the wilderness between 1 and infinity smacks of rank carelessness. And "Cathode Ray" in his current essay on hyperbolic functions admits that the world in which x/r is less than unity is more familiar than its "imaginary" counterpart.

However, there is one other somewhat analogous case arising also most commonly from transmission line problems, namely the impedance chart. The Cartesian form of this chart is rarely used for the very good reason that complete coverage of the impedance plane would require an infinite sheet of paper. Instead we use the polar form or Smith chart in which all passive impedances are constrained within a finite (unit!) circle. Why not apply the same criterion to v.s.w.r? After all, we do sometimes wish to plot v.s.w.r. against some variable or other and in spite of the possible indication to the contrary by the length of this protest, my supply of paper is strictly finite.

North Baddesley, Hants. L. C. WALTERS

Transistor Inverters and Converters

I—Basic Principles of the Ringing-Choke System

By M. D. BERLOCK,* Grad. I.E.E., and H. JEFFERSON,* M.A.

PASSIVE methods of storing and of generating electrical energy deliver it in the form of a unidirectional current which, in the most efficient systems, is produced by units having a nearly constant potential difference at their terminals. This ideal of a fixed electromotive force and zero internal impedance is characteristic of the well-established primary and secondary cells and the new fuel cells, and is the aim of the makers of solar cells. The designer of the simpler forms of transistorized equipment is well content with energy sources of this kind, asking only for more watt-hours per pound, avoirdupois or sterling. The designer of valve equipment has always found this kind of energy source unsatisfactory except in very large installations, since he requires a number of different supply voltages and is constantly faced with the problem of balancing the advantages and disadvantages of single packs and multiple packs of batteries. The combined h.t. and g.b. battery of the older portable broadcast receivers was a typical compromise.

For most devices, of course, the supplies are derived from the a.c. mains and the use of a simple and efficient device, the transformer, permits a free choice of voltages. At the highest power levels mercury arc inverters may be used. It is when we turn to battery-operated equipment consuming power measured in watts, or hundreds of watts, that difficulties are encountered. This equipment may not necessarily be mobile equipment; it may be vital equipment which is normally operated by supplies taken from the a.c. mains but which cannot be allowed to stop operating if there is an interruption of supply.

Until recently the only available methods for converting the d.c. from a battery into a.c. for voltage transformation were by the use of vibrators or rotary converters. Both these methods rely on mechanical systems with moving parts: contact life in the vibrator and brush wear in the rotary converter are serious limitations in situations where skilled maintenance is not available. For low powers it has not been found possible to achieve high efficiencies.

The transistor inverter is bringing about a radical change in our views on battery operation: we may expect that the silicon controlled rectifier inverter will continue this minor revolution. It has now become practicable to construct efficient devices to generate, for example, 50mW at 100 volts from a 6-volt torch battery or 100W at 230 volts, 50c/s, from a 12-volt car battery. Existing but expensive semiconductor devices extend the range up to perhaps a kilowatt.

To the electronics engineer these semiconductor inverters, for generating a.c. from d.c., and converters, which include a voltage transformation and rectification, are particularly attractive. By conservative design he can assure himself of an extremely high reliability, limited only by factors with which he is already familiar. Precautions and protective techniques are those required for the remainder of the equipment and the inverter is the same kind of thing as the rest of the system so that it marries well into it. Furthermore the equipment designer can either design the inverter himself or, if he buys from another manufacturer, can understand exactly how it works. Rotary converters are regarded by most electronic engineers with all the doubt and suspicion reserved by rotary machine designers for electronics.

Three basically different types of transistor inverter appear to be in use. One of them, the class-B (or class-C) oscillator seems to us to be of little special interest: it is not a particularly efficient system and it wastes its power where it can do most harm, in the transistors. Its merit is that the output is sinusoidal.

The two types of inverter which have attracted most attention are the ringing-choke system and the transformer-coupled inverter. The latter, which has several variants, is probably the most important and will be discussed in detail in later articles. The remainder of this article will be devoted to the ringing-choke inverter.

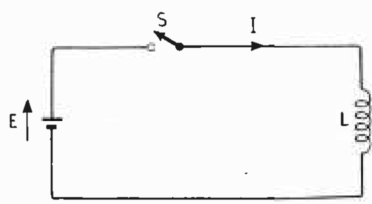


Fig. 1. When the switch is opened a high voltage appears across L.

We must begin by saying that the ringing-choke inverter, as such, is probably almost useless. In all the applications which we can see the ringing-choke system is used with a rectifier to provide a d.c.-d.c. conversion: the reasons for this will appear in the analysis. We must next say that we cannot see any particular reason why the choke should ring, in the sense indicated by T. R. Pye in *Electronic and Radio Engineer* for March 1959. It would appear to be more correct to describe the circuit as a blocking-oscillator inverter (or converter) when, as is usual, it is self-driven and to describe the corresponding device with separate drive, which as far as we know has not been used, as a pulsed-choke system.

In order to understand the operation of what we shall now call the blocking-oscillator converter it is necessary to build up the circuit piece by piece. The mode of operation of these circuits is so different from the conventional sinusoidal circuits that any

★ The Phœnix Telephone & Electric Works Ltd.

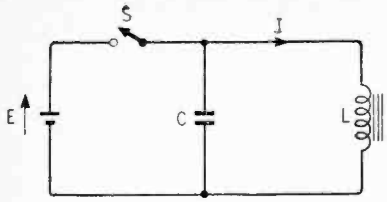


Fig. 2. The presence of C reduces the voltage appearing when the switch is opened.

attempt at short cuts can lead the unwary into difficulty. To start off, therefore, we consider the circuit shown in Fig. 1. When the switch is closed there is initially no current, but the current in the loop increases steadily, satisfying the equation.

$$I = \frac{1}{L}\int E\,dt \qquad \ldots \qquad \ldots \qquad (1)$$

or, in fact

$$I = E/L \,.\, t \qquad \ldots \qquad \ldots \qquad (2)$$

After some time t, then, the inductance is storing an amount of energy

$$W = \tfrac{1}{2}LI^2 = \tfrac{1}{2}EIt = \tfrac{1}{2}E^2t^2/L$$

If now the switch is opened we are faced with an intolerable situation. We may very conveniently refer to the simple mechanical analogue of a mass L moving with velocity I, which has kinetic energy $\frac{1}{2}LI^2$. Opening the switch brings it to rest *instantly*, which is getting close to the irresistible mass hitting the irresistible object. The old-fashioned induction coil for providing electric shocks and the coil used in motor-car ignition systems show what happens. For analytical purposes we must now put a capacitance in parallel, as shown in Fig. 2. When we open the switch the energy stored in the inductance has somewhere to go: in our mechanical analogue the object has become a spring. The capacitor has initially stored energy $\frac{1}{2}CV^2$ but when the switch is opened the voltage swings to some value V_1 which satisfies the equation

$$\tfrac{1}{2}CV_1^2 = \tfrac{1}{2}CV^2 + \tfrac{1}{2}LI^2$$

The energy is then passed back again, the system ringing until the unavoidable resistances have dissipated it.

Instead of putting a capacitor across the choke let us connect a rectifier and a resistor R, as shown in Fig. 3. The added components have no effect on the current build-up, because the rectifier isolates the resistor. The switch is again opened when the current has reached a value I, given as before by equation (2). The "magnetic inertia" keeps I flowing and it can now flow through the resistor by the path shown dotted in Fig. 3. Consequently Y must be positive with respect to X and the instantaneous voltage reached will be

$$V_{yx} = IR.$$

The current will now decay exponentially in the usual way until all the stored energy has been dissipated in the resistor.

The sudden jump from the situation in which Z is positive with respect to Y, switch closed and diode backed off, to the situation in which X, and thus Z, is negative with respect to Y will be slowed down by any stray capacitance, the capacitance shown as C in Fig. 2. If, in addition, we add a capacitance across R and make this (C_1 in Fig. 4) large enough to hold the voltage constant while we repeat the switching operation quickly, we will get the following sequence of operations:

(a) switch closes, current in L grows linearly,

(b) switch opens,

(c) current in L flows into C, charging it until E_{zy} exceeds E_1,

(d) diode conducts, current flows into C, until the linear fall in current through L produced by E_1 (this satisfies eq. 2) brings the current to zero, when,

(3) The diode cuts off, leaving C and L to oscillate in the usual damped sinusoid.

This sequence is shown in Fig. 5.

If now we arrange that when E_{zy} goes positive (or reaches zero or a small negative value) the switch is closed we can produce condition (a) again, and if we arrange to reopen the switch at some chosen current we produce (b). The system is then a self-maintaining one. It is very important to notice that it is basically a two-stroke system, drawing energy from the battery when the switch is closed and passing it on to the load when the switch is open. This is, of course, a consequence of the introduction of the diode and it is for this reason that the circuit is used in converters rather than inverters. The other reason is that the two-stroke mode of operation gives a waveform which is thoroughly inconvenient for use in any a.c. device.

The switch used is, as you might expect, a transistor. In Fig. 6 we have the basic circuit with the battery E in series with the inductance L_1 and the collector-emitter path of the transistor switch. Bias, in this rudimentary circuit, is applied to the base through L_2 from a bias battery E_b. When first switched on this bias E_b is enough to allow some collector current to flow, and the growth of this current produces additional bias across L_2 to keep the transistor conducting. The current in L_1 therefore rises linearly and obeys equation 2. Meanwhile the voltage across L_2 is proportional to the

Fig. 3. The energy stored in L is now transferred to R when the switch is opened.

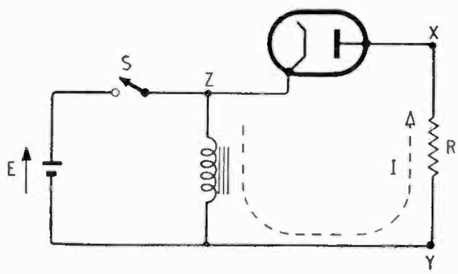
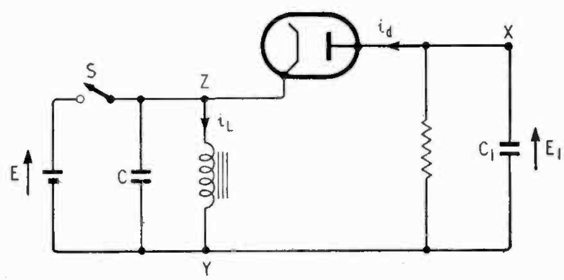


Fig. 4. With these additional capacitors we get the waveforms shown in Fig. 5.



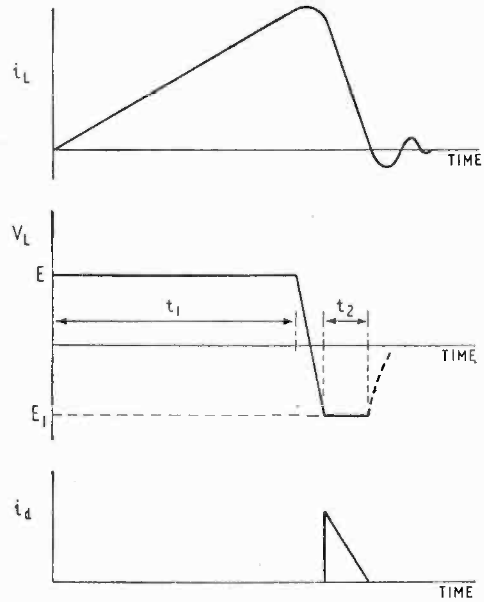


Fig. 5. The conditions in the circuit of Fig. 4. The charging stroke lasts for time t_1 and the discharging stroke for time t_2.

rate of change of the current in L_1 and is thus constant with a value

$$E_{L2} = (L_2/L_1)E.$$

Neglecting the effect of E_b, I_{co} the internal resistance r_b and other oddments, which only make the equations more elaborate, this voltage E_{L2} will drive a current I_b into the base, where

$$I_b = E_{L2}/R_b$$

In turn this base current makes available a collector current of

$$I_c = \beta' I_b.$$

As the current through L_1 grows the collector-emitter path passes it freely so long as it is below this available value I_c but when the current reaches I_c it cannot increase any more. We have travelled up the diode line of the transistor to the knee and now move round the knee to the high impedance region. The current now increases only very slowly through L_1 and, in consequence, the voltage E_{L2} falls to a low value. Now the base current I_b is reduced and even the existing limit of I_c is too much for the transistor so that the current actually starts to fall and, in doing so, produces a reverse

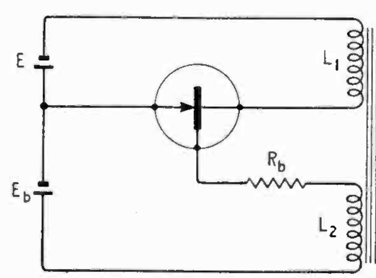


Fig. 6. The basic blocking oscillator.

bias at the base. The transistor is well and truly cut off.

The sequence described above is the charging stroke in which energy is fed into L_1 through the switch and the operation terminated by opening the switch. We now add to Fig. 6 a diode, a capacitor and a load resistor across L_1 so that the discharge stroke, which is quite independent of the transistor, can follow the pattern already described.

Towards the end of the discharge stroke the diode cuts off under conditions which depend on the reactance structure. The detailed analytical techniques used for pulse-generating blocking oscillators do not seem to have been found necessary by any converter designers. It is usual to consider that the circuit would settle in a damped oscillatory mode if the first overswing did not drive the transistor into conduction, but if the value of bias is suitably chosen an over-damped settling would bring the system into the region where a new charging stroke could begin. The oscillatory mode is probably advantageous because it speeds up the transition phase and produces a more definite switch-on in the transistor. It goes without saying that since the storage and delivery of energy is in the magnetic flux through the inductor core a third winding may be used for the diode and load circuit.

One very important factor has not yet been mentioned explicitly. We have seen that the voltage across L_1 will shift violently until the diode conducts. If the swing needed is too great the voltage actually applied across the transistor may be sufficient to destroy it. This represents one of the most important factors in design.

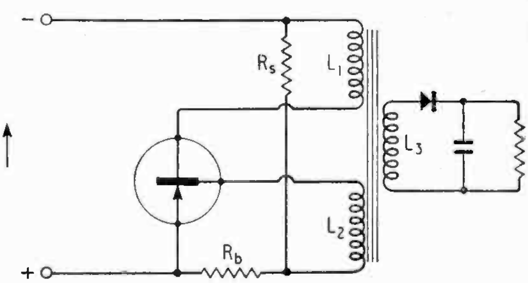


Fig. 7. The practical converter.

We may now turn to the problem of establishing a practical design. The circuit is shown in Fig. 7 in which the base bias battery is now replaced by a voltage divider R_s, R_b. The three windings of the transformer have inductances L_1, L_2 and L_3 with corresponding turns ratios $N_1 : N_2 : N_3$.

The first step is to define the requirements, an output power W at some voltage V to be obtained from a supply E. From experience with similar converters we make a guess at the efficiency which will be obtained: this depends on a number of factors which are discussed below and for purely arithmetic (and typographical) reasons we shall choose the very low value of 50%. We need then to draw a total power of 2W from the supply. For 83% efficiency the figure will be 1.2W and in a practical, rather than tutorial, problem this might be more correct.

This power of 2W is drawn in a series of pulses with spaces between them. If the pulses last for a time t_1 and the spaces for a time t_2 the power must all be drawn at the rate of

$$2W\ (t_1 + t_2)/t_1 \text{ watts}$$

The average input current must therefore be $(2W\ (t_1 + t_2)/t_1)/E$ and, as this current has the form of a series of triangular impulses, the peak current must be twice this, or $(4W/(t_1 + t_2)/t_1)/E$

The voltage which appears at the collector during the energy discharge stroke is equal to

$$E\ (1 + t_1/t_2) \text{ and also, of course, to}$$
$$V = (N_3/N_1)\ E\ t_1/t_2$$

We know from the transistor data that we may not apply more than E_{pk} to the transistor, so that, working to the limit (and the wise designer will put in his own safety factor)

$$t_1/t_2 = (E_{pk}/E) - 1$$

This number can now be substituted in the expression for current,

$$I_{pk} = \frac{4W}{E}$$

and this can be compared with the permitted figure for the transistor already tentatively chosen.

Assuming all is well the value of β for the transistor at this current, or the value of I_b required (some transistor manufacturers seem rather chary of disclosing data on their products) is now found. Then we must make

$$I_b = I_{pk}/B = (N_1/N_2)/R_b.$$

We would wish R_b to be very small, so that minimum energy would be diverted into it, were it not for the fact that then R_s would need to be small too, so that the small forward bias of about 0.15 to 0.2 volt might be developed. A compromise is to allow the R_s, R_b divider to dissipate a few per cent of the converter energy. The value of R_b is then known and the equation above gives the turns ratio N_1/N_2.

Only one factor remains to be decided: we have determined the turns ratio N_3/N_1 and the turns ratio N_2/N_1. What value of inductance, how many turns, should we use? The choice of operating frequency is involved here too, and the criteria to be used are difficult to define precisely in a simple survey. One limitation is set by the short pulse t_2. The edges of this should be fairly square, occupying, let us say, less than 0.1 t_2. The repetition frequency must be chosen so that $10/t_2$ is less than the highest frequency the transistor will handle: we know that $t_1/t_2 = r$, so that $(t_1 + t_2) = (1 + r)\ t_2$ and as

$$f_{rep} = 1/(t_1 + t_2) = 1/(1 + r)\ t_2$$
$$f_{rep} < f_{max}/10\ (1 + r).$$

The establishment of a minimum frequency of operation is associated with the transformer design. We know that

$$f_{rep} = 1/(t_1 + t_2) = r/(r + 1)\ t_1$$

and that, following from eq. 2

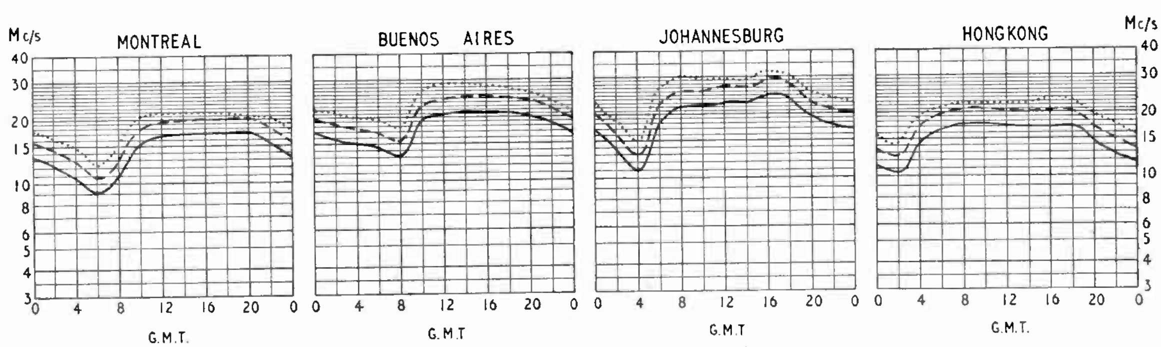
$$t_1 = L_1\ E/I_{pk}$$

We thus need a transformer having one winding with an inductance L_1 which will not be too near saturation at a current I_{pk} and which has a resistance small compared with E/I_{pk}. Having made a tentative choice, we check that the resulting frequency satisfies the inequality given earlier.

For a close design we must examine the losses which are introduced by the various elements and attempt to minimize them. There is a loss in the transistor during the conduction period when the collector voltage is low and equally important losses during the transitions. Some power is necessarily fed into the base circuit. Core and copper losses in the transformer are probably the main source of inefficiency. The rectifying diode is more wasteful than one would expect, because it operates at high current for a short time. In a completed design both the overall efficiency and the transistor losses alone should be calculated, because it is essential to ensure that no overheating takes place.

SHORT-WAVE CONDITIONS

Prediction for August



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 August.

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

•••••••••• FREQUENCY BELOW WHICH COMMUNICATION SHOULD BE POSSIBLE FOR 25% OF THE TOTAL TIME

— — — PREDICTED MEDIAN STANDARD MAXIMUM USABLE FREQUENCY

——— FREQUENCY BELOW WHICH COMMUNICATION SHOULD BE POSSIBLE ON ALL UNDISTURBED DAYS

Inverted Triode Voltmeter

NOVEL CIRCUIT USING A TRANSISTOR TO GET GREATER SENSITIVITY

By R. B. ROWSON, B.Sc., A.M.I.E.E. and A. P. WILLIAMS, A.M.I.E.E.

THE inverted triode voltmeter, as shown in Fig. 1, is occasionally mentioned in the literature as having a very desirable high input impedance but as being suitable only for very high voltage measurements. This last-mentioned disadvantage we have sought to overcome, and the simple instrument described will give full-scale deflection for only 0.3 volts input. The circuit uses a combination of valve and transistor and takes advantage of the best features of each, i.e. the high input impedance of the valve and the current amplification properties and low output impedance of the transistor.

The first reference to the inverted triode voltmeter known to us is a paper by Terman[1], who mentions how it can be used for operating an oscillograph without taking current from the source. The inverted triode is thus a power amplifier and can also be used as a voltage amplifier if a high ratio* step-up transformer is put in the grid circuit. This is possible because the output impedance is low.

In operation a negative or positive potential applied to the anode (Fig. 1) causes a decrease in grid current and thus a reduction in the reading of the meter in the grid circuit, the highest grid current flowing when the anode potential is approximately zero. Intuitively a negative anode potential can be visualized as forcing the electrons back into the cathode, thereby reducing the grid current. If the anode is made positive it draws electrons through the grid and thus again reduces the grid current.

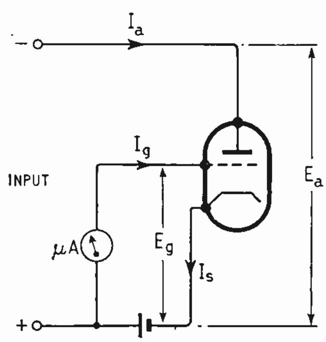


Fig. 1. Basis of the conventional inverted triode voltmeter.

More precisely we can consider the equation originated by van der Bijl[2], which gives the electron current I_s in terms of the grid and anode potentials, i.e.

$$I_s = f[E_g + (E_a/m)] \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

neglecting the term covering the intrinsic potential difference between cathode and grid-anode system. In this equation m is similar to the usual μ and can be shown to be C_{ak}/C_{gk} and thus the inverted triode can be looked upon as acting as a capacitance divider. While E_a is sufficiently negative no current flows to it and thus $I_s = I_g$, and under these conditions one can readily see that a negative E_a results in a decrease in grid current, if E_g is held constant.

* Greater than the value m which appears in equation (1) and is defined just below it.

If E_a is made positive the condition is more complex, I_a ceases to be zero and the split-up of I_s is confused by secondary electron effects. It has been shown by Chaffee[3] that lines of constant emission current plotted on axes of E_a and E_g have discontinuity for low positive values of E_a and E_g. Spangenberg[4] shows that whilst E_a is less than E_g, I_g is greater than the primary electron current, but if E_a is greater than E_g it is less. Based on an empirical law he finds

$$I_g = I_s/[1 + d(E_a/E_g)^b] \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

"b" is 0.5 if $E_a/E_g > 0.8$ or 2 if less, and "d" is the current division factor, i.e. I_a/I_g when $E_a = E_g$.

By substituting for I_s from (1), an expression in measurable factors is obtained. Unfortunately "d" changes rapidly for small values of $E_a = E_g$ due to the change in position of the virtual cathode. The numerator of (2) changes very slowly with changes in E_a if m is high. For example, a tenfold change in E_a may only result in a 7% change in the numerator. If $E_a = 0$, the denominator is a minimum and thus I_g is at its maximum. For increasing positive or negative E_a the denominator increases quite rapidly and thus I_g falls in both cases. As the particular virtue of the inverted triode voltmeter is its high input impedance it is desirable to avoid anode current and in the arrangement described later a minimum bias has been built into the circuit.

As $I_a = 0$ for negative values of E_a and as I_a has a value for positive E_a the valve has a rectifying action. This can be made use of to measure a.c. by inserting a capacitor in the anode lead (capacitance somewhat greater than C_{ak}). This charges up when the impressed wave goes positive and thereafter current flow is zero.

Having considered the general theory, it is useful to examine the various practical circuits which have been suggested. Ref. 5 describes a circuit using a special valve (Westinghouse, RH507) having an internal earthed wire touching the inside of the glass envelope to drain away static charges, and draws attention to the need of constant filament current. It also shows that the maximum sensitivity occurs at around $I_a = 0$. With this design currents of 10^{-14} amp are measurable. In contrast, the circuit described by Kepferberg[6] uses a 211-D and was designed for voltages up to 5kV and has an input impedance of 5×10^9 ohms.

Several engineers have used a slide back arrangement; Foster[7], for example, puts a voltage E_b on the anode (positive to anode) and finds the grid voltage for zero or known I_a. He then puts the voltage to be measured, E_x, in series with the battery and anode, and adjusts the grid voltage to give the same I_a as before. In this case

$$E_x = (E_b \, . \, E_{g2}/E_{g1}) - 1$$

This method is referred to by Hund[8] and is used by

F

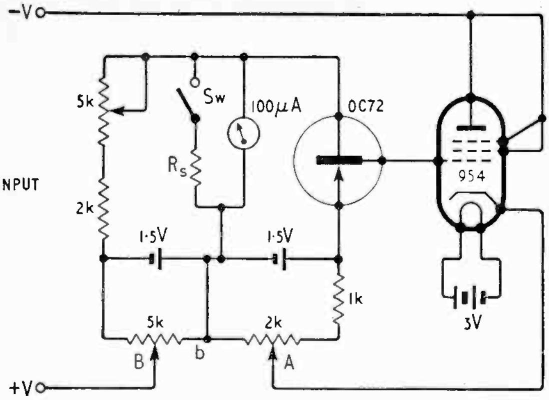


Fig. 2. Improved circuit incorporating a transistor. Battery switches are not shown.

Yuan.[9] To prevent splash current Yuan puts a 7.5-volt battery in the anode lead. He also gives graphs showing that I_g/V_g is a curve but V_g/V_a is a straight line, the moral being that I_g should be kept constant.

One way of overcoming this lack of linearity was mentioned above; another, due to Scheenburger[10], is to use a tetrode, returning the screen to the cathode via a high resistance, again resulting in lack of sensitivity. Scheenburger's instrument had an input resistance of 10^{13} ohms, tested by charging the anode with a comb run through the hair and finding the time for the volts to drop to 63%. Knowing the anode/cathode capacitance, the resistance can be calculated.

One difficulty of the inverted triode voltmeter is the very low grid current to be measured needing a very sensitive meter for a low reading instrument. A way of overcoming this is given by Genin[11], where the measuring valve, a pentode EL8, is the upper part of a cascode pair. Here the grid current is fixed, the cathode of the top valve (i.e. the anode of the lower one, a 6AU6) moves, and the change in voltage is applied to a cathode-coupled pair.

It will be seen that what is required is a method of maintaining the grid current relatively constant and of amplifying the very small changes in voltage which occur, so that a relatively robust meter can be used. It is felt that the circuit shown in Fig. 2 meets these conditions. The input impedance is very high, no noticeable difference in reading being observed when a 50-MΩ resistor is placed in series with the incoming voltage. The circuit, using a 954 valve which can be bought very cheaply and has very well insulated electrodes, gives in effect an electrometer for a very moderate cost. As the electron current required is small the heater can be run at half, or even less, voltage, which also has the advantage of reducing secondary emission from the grid.

With the shunt R_s (say 1/20 R_m) across the meter and no backing-off current (the backing-off current is merely to balance the static collector current through the meter), potentiometer A is adjusted to give a reading of about 1mA to bring the sensitivity of the transistor to about optimum and to give a reasonable grid current. The backing-off current is then increased to give about zero reading, when the shunt can be opened. Either control is then slightly adjusted to give full-scale reading.

For some purposes potentiometer B, taking the positive end of the incoming voltage, is adjusted so that the same reading is observed when the incoming terminals are either short-circuited or open-circuited; depending on the valve it may be necessary to connect end "b" of potentiometer B to the slider of A instead of to the junction point of the batteries to achieve this condition. Application of a positive voltage to the anode reduces the reading. As described, 0.3 volts give a change of 100 microamps in the reading of the meter. A "charged" fountain pen held about one foot away drives the pointer off-scale. In view of the sensitivity, for general use the terminals could be shunted by a 50-MΩ resistor.

To read a.c. Medina[12] used a rectifier to charge a polystyrene capacitor, which was connected across the incoming terminals, thus obtaining a peak voltmeter. He used a 6V6G, removing the base and painting the envelope with methylchlorosilane to reduce leakage further. By this means the charge was retained in the capacitor and readings could be taken some time after the phenomenon being measured had occurred. A probe incorporating a silicon rectifier and a 100-pF or less capacitor gives satisfactory results with the present instrument. Alternatively, having set B to give no change in reading, a.c. can be applied directly via a 10-pF capacitor.

"Anode"	"Grid"	Earthed Screen†	D.C. Range
$a+g_3+g_2$	g_1	—	0—0.3 volts
$a+g_3$	g_1+g_2	—	0—50 ,,
$a+g_3$	g_1	g_2	0—75 ,,
a	g_1+g_2	g_3	0—600 ,,

† In the instrument described there is no appreciable difference whether the earthing is direct or via a resistor.

In order to reduce leakage currents to a minimum it is advisable to use a ceramic valve holder and to bring the leads for the anode, suppressor and screen grid through the case via ceramic bushes. Higher voltages can be measured by connecting the valve electrodes to form the effective grids and anodes in the manner indicated in the table. Line 1 of this table corresponds to Fig. 2, and is the most sensitive arrangement.

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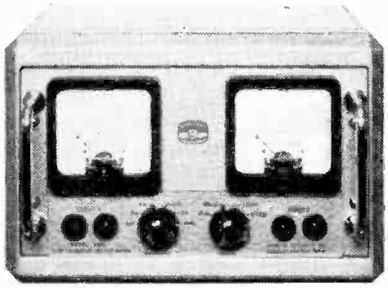
Manufacturers' Products

NEW ELECTRONIC EQUIPMENT AND ACCESSORIES

Stereo A.F. Power Meter

THE new Amos of Exeter Model 158 comprises two of their Model 156 a.f. output meters. These are housed together in a single cabinet and have their impedance and power-range selection switches ganged together. The four power ranges give full-scale deflections with inputs of 10mW, 100mW, 1W or 10W (the meters are



Amos of Exeter twin-channel a.f. power meter.

also graduated in dB), and the input transformer can be matched to impedances of 3, 5, 7.5, 15 or 600Ω. The accuracy is ±0.5dB from 10 to 20,000c/s: the two channels are matched to 2%. The Model 158 costs £34 10s (carriage paid in U.K.), and is manufactured by Amos of Exeter Ltd., of Weircliffe Court, Exwick, Exeter.

H.F. Wide-band Amplifier

APERIODIC amplification over the frequency range 1Mc/s to 30Mc/s is provided by a wide-band amplifier, Type VM 30, recently developed by R. H. Minns Electronics, of The Lower Mill, Kingston Road, Ewell, Surrey. An output of 15 watts into an impedance of 100Ω is obtained for frequencies up to 26Mc/s with 1 volt applied across the 100-Ω input circuit. The output falls to 10 watts at 30Mc/s for the same input. Models are available for various input and output impedances, coaxial or balanced. Amplification is carried out in three stages, the last two using Mullard QQVO6-40A valves. Inter-stage coupling throughout is by means of a new range of wide-band transformers developed by R. H. Minns Electronics. The equipment operates from the mains supply, through a germanium rectifier. Several of the amplifiers are being used by the B.B.C. to provide drives for h.f. broadcast transmitters.

A wide-band distribution amplifier, Type VM 40, is also available, enabling up to three of the Type VM 30 wide-band amplifiers to be fed from a single source. There is a voltage gain of 3 : 1 between the input and each output of the distribution amplifier.

Tunable Mobile Aerial

IN mobile v.h.f. radio systems transmitters and receivers frequently operate in channels too widely separated for the average whip aerial to operate at best efficiency and a compromise aerial has to be employed. With the new "Avel Mobile Antenna," however, maximum efficiency is obtained by automatically tuning the aerial to the transmit and receive frequencies as required.

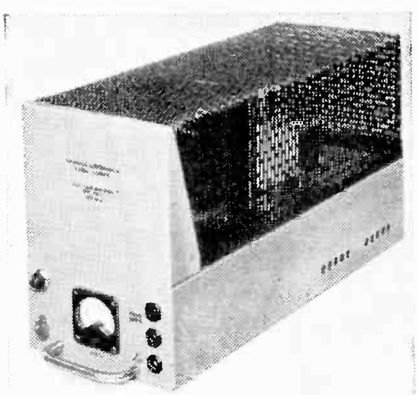
The tuning unit, which is illustrated, forms the base for the usual vertical aerial and it incorporates trimming capacitors and a coil, the inductance of which is changed, as required, by a solenoid-operated dust-iron core. By this means the aerial can be tuned correctly and in turn to any two frequencies up to 15Mc/s apart. The unit is built to withstand severe vibration and is protected by a toughened fibre-glass moulding. While designed initially for use on motorcycles operating in the 80-100Mc/s band, models are becoming available for frequency bands between 30 and 174Mc/s for use on cars, vans and launches, and for 6V, 12V or 24V operation.

The makers are Aveley Electric Ltd., Ayron Road, Aveley Industrial Estate, South Ockendon, Essex.

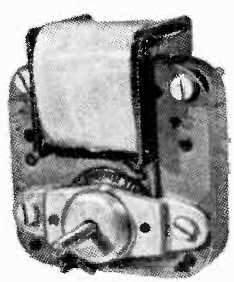
Small Induction Motor

A COMPACT, fractional-h.p. induction motor, intended for use in tape recorders, record players and electronic equipment generally, has been introduced by R. B. Pullin and Co. Ltd., Phœnix Works, Great West Road, Brentford, Middlesex. It is a shaded-pole, squirrel-cage type with the rotor supported in self-aligning bearings embodying oil-impregnated lubricating pads.

The working voltage is 200 to 250V, 50c/s and the

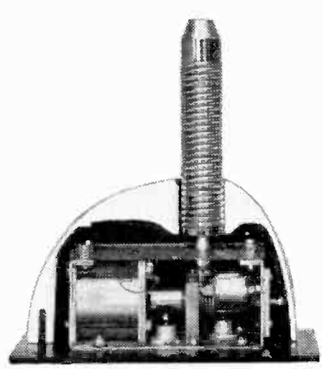


Wide-band amplifier for communication frequencies by R. H. Minns Electronics.



Above: Pullin shaded-pole fractional-h.p. induction motor.

Below: Aveley remotely tuned, mobile-aerial unit.



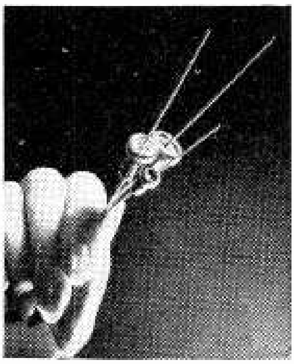
starting torque is greater than 60gm cm. A no-load speed of 2,900 r.p.m. is attained falling to a minimum of 2,600 r.p.m. with a torque of 80gm cm and 230V input. Under these conditions the input current does not exceed 0.2A, and the maximum power output is 0.003 h.p. (2.5W). The maximum temperature rise without a fan is 50°C.

Motors are available with the driving shaft at one end (Type ASP1), or with extended shafts at both ends (Type ASP2). The price is 15s.

New Tantalum Capacitors

HAVING concluded an agreement with the Fansteel Metallurgical Corporation of America the Plessey Company are now marketing the extensive range of tantalum capacitors made by the American firm.

The new range extends from 325μF at 6V to 1.75μF at 125V d.c. working and they are available in three



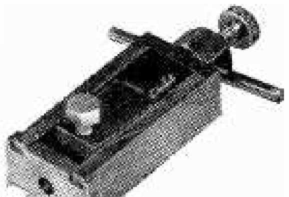
Examples of the three sizes of Fansteel Corp. tantalum capacitors marketed by Plessey.

sizes, the smallest measuring 15/32 × 5/16in and the largest 49/64 × 37/64in.

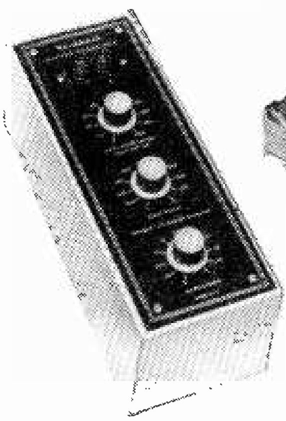
All three sizes are available with the alternative tolerances of −15 to +20% or −15 to +50% at an ambient temperature of 25°C, but they may be used up to 125°C (ambient) at reduced working voltages. Full details are obtainable from the Plessey Chemical and Metallurgical Division at Towcester, Northants.

Capacitor Decade Box Kit

THIS unit achieves the ten capacitance steps in each decade by switching a combination of four ±1% silvered-mica capacitors. With all switches at zero the residual capacitance is 18pF and the maximum of 0.111μF is reached in 100pF increments.



Adcola soldering-iron bit extractor.



Left: Heathkit DC1 capacitor decade is about 10⅝in long.

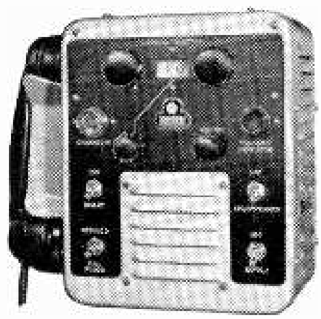
Costing £5 18s 6d in kit form the Heathkit DC1 capacitor decade box is rated at 350V d.c. and is available from Daystrom, Ltd., Two Mile Bend, Bristol Road, Gloucester.

Marine V.H.F. Radio Telephone

THE new Marconi "Argonaut" v.h.f. radio-telephone equipment provides a maximum of 50 working channels in the international maritime band of 156Mc/s to 163.4Mc/s. It is designed to enable ships to communicate on the frequencies assigned for emergency calling, port operations, public correspondence, inter-ship and private maritime use. It has received the British G.P.O. approval for these services.

Basically the "Argonaut" comprises two separate units, a control unit measuring 10¼in × 11½in × 6½in and incorporating loudspeaker, channel-selecting switches, microphone-telephone handset and all necessary controls. This unit is used for either local or remote operation of the transmitter-receiver which, with its power supply, is a separate unit measuring 36¾in × 20¾in × 7½in and may be installed up to 300ft from the control point.

The equipment operates on either 110V or 220V d.c. or 115V or 230V, 50-60c/s a.c. Maximum r.f. output is 20W (the limit under the Hague agreement) but a "reduced-power" switch permits a reduction in output to about 0.5W to be effected. Direct operation from 220V d.c. mains (without an internal power unit) is possible, and under these conditions an r.f. output of about 7W is available. Frequency modulation is employed.



Compact control unit of the Marconi "Argonaut" marine v.h.f. radio telephone.

The addition of a switching unit enables the equipment to be operated, including channel selection, from either one of two control positions. A "watch" unit may be added also to provide unattended monitoring of two independently selected channels. Duplex or simplex operation is possible.

Further details can be obtained from the Marconi International Marine Communication Co. Ltd., Chelmsford, Essex.

Soldering Equipment

THE extractor tool illustrated has been designed to facilitate the removal of worn and seized bits from Adcola miniature soldering irons. Normally the extractor is operated by hand, but for particularly stubborn cases of seizure it can be set in a vice and the extractor screw turned by an ordinary ⅜in spanner. Separate thrust plates and chucks to take the three normal sizes of bits, ⅛in, 3/16in and ¼in, are available.

The combined protective unit and stand made for Adcola soldering irons has been redesigned and now embodies wiper and abrasion pads for cleaning the bit, also a handy reel of solder wire, all accommodated in the base of the unit.

Further details can be obtained from Adcola Products, Ltd., Gauden Road, Clapham High Street, London, S.W.4.

Elements of Electronic Circuits

16.—THE TRANSITRON TIMEBASE

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

THE transitron circuit has been previously dealt with, in the March, 1960, issue, in connection with the generation of rectangular waveforms, and its action as a triggered relay has been described. Slightly modified, it can be used as a freely running generator of sawtooth voltages, and such an arrangement, known as the Fleming-Williams circuit, is shown in Fig. 1. Before describing the action it will be helpful if some general properties of transitron-type circuits are outlined:—

(a) Under certain conditions the space charge existing between screen and suppressor grids can act as a "virtual cathode"; hence variations in suppressor grid potential can vary the anode current. When these conditions obtain, it is possible to regard the pentode as consisting of two separate triode valves. One triode is formed by anode, suppressor grid and "virtual cathode," the other by screen grid, control grid and true cathode.

(b) A reduction in anode voltage diminishes the anode current, increases the screen current and hence lowers the screen voltage.

(c) A reduction in screen voltage, however, reduces both anode and screen grid currents, so that the anode voltage rises.

(d) When anode current flows the screen current is low and the screen voltage is high. When anode current is cut off, screen current is high and screen voltage is low. These are the limiting conditions operating in a transitron circuit.

(e) With certain values of anode voltage and suppressor voltage, a rise in suppressor voltage causes a decrease in screen current and a rise in screen voltage. A typical static characteristic is illustrated in Fig. 3. A further rise is caused due to the external coupling between screen and suppressor and this action is cumulative. When the suppressor volts fall (over the same region of the characteristic) the screen voltage falls. This is again a cumulative action.

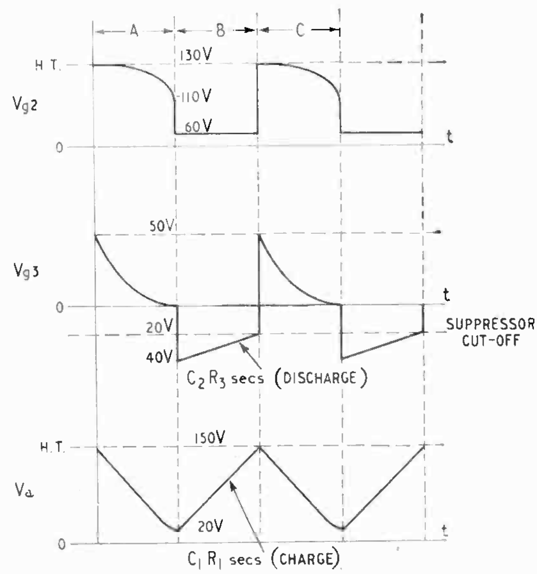


Fig. 2.

With these properties in mind, let us examine the sequence of events in the circuit in more detail.

Stage A

At the commencement V_{g3} is assumed to be positive, I_a is flowing and is larger than the C_1 charging current through R_1, V_a is falling and V_{g2} is at its maximum value. C_1 discharges rapidly and V_a falls. I_a, however, remains constant until the

Fig. 1.

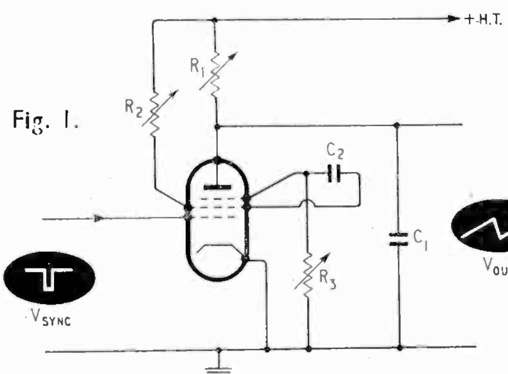
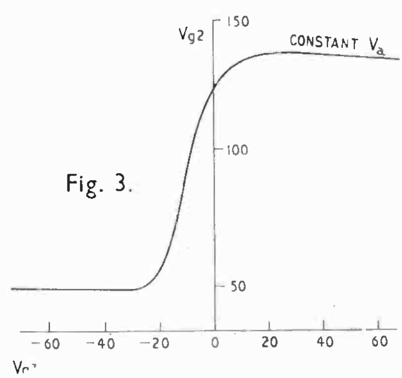


Fig. 3.



"knee" of the V_a/I_a characteristic is reached and then it falls. V_{g3} is falling; ultimately a condition is reached when a "virtual cathode" starts to form between screen and suppressor grids. The fall in V_{g3} causes a fall in V_{g2} (*vide* suppressor volts/screen volts characteristics) and there is a further reduction due to the coupling circuit C_2R_3. I_a is finally cut off and the suppressor is driven beyond the suppressor cut-off bias.

Stage B

C_2 discharges through R_3 and the suppressor voltage starts to rise. V_{g2}, however, remains constant as the suppressor volts are still below suppressor cut-off bias. C_1 charges through R_1 and V_a starts to rise. Ultimately V_{g3} reaches suppressor cut-off and I_a starts to flow. I_{g2} drops as a result. V_{g2} rises, taking V_{g3} with it. I_a increases further, I_{g2} drops. The action is cumulative at the end of this stage until I_a cannot increase any further (the "knee" of the characteristic has been reached). By this time V_{g2} has taken V_{g3} well positive.

Stage C

The production of the large I_a causes C_1 to discharge at the commencement of this stage. C_2 now starts to charge and V_{g3} falls gradually to zero. V_a falls as C_1 discharges and the cycle repeats.

By an adjustment of R_1 and R_3 the charging time, and hence the duration of the sawtooth, is made controllable. R_2 controls the mark/space ratio of the square waveform at the screen. The oscillations can be synchronized if negative pulses are applied to the control grid, or alternatively if positive pulses are applied to the suppressor grid. The cumulative action occurring at the end of Stage B is initiated by either of these methods of synchronization.

Finally, whether the cumulative action can occur or not depends very much on the relative grid potentials, and, in particular, that of the anode should be fairly low.

TUNNEL DIODES

By "CATHODE RAY"

NEGATIVE RESISTANCE WITH TWO ELECTRODES

HERE is another request programme. And it made me yearn for the good old days when the task of producing a convincing explanation of how an electronic device worked could be undertaken without risk of mental collapse, either for oneself or one's readers. What made me particularly nostalgic in this case was that the characteristic curve of a tunnel diode (Fig. 1) is practically a repeat of that of the old screen-grid tetrode or dynatron. Would that its cause were as easy to understand!

To build up our self-confidence by continuing to see daylight for at least another paragraph or two, let us consider the effect before the cause.

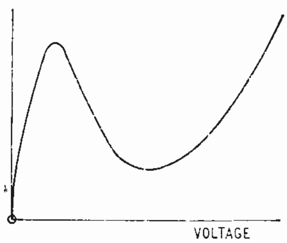


Fig. 1. General shape of tunnel diode current/voltage curve. It reminds those who are old enough to remember such things of the dynatron.

The characteristic curve of ordinary resistance, as known to Prof. Ohm, is, of course, a straight line passing through the origin and sloping upwards from left to right. The amount of resistance represented is inversely proportional to the steepness of slope. Two parts of the curve in Fig. 1 at least slope upwards from left to right. One of them even passes through the origin, and the other looks as if it could do if it continued its trend. But between them is a section sloping downward from left to right. An increase in voltage causês a decrease in current. The resistance within the limits of this section is, therefore, negative. Unlike positive resistance, practical negative resistance can't extend indefinitely. In this case, it changes over to positive resistance at each end of its limited range by passing through infinitely high resistance. There are other devices in which the resistance passes through zero, as in Fig. 2. This is sometimes called an S curve, to distinguish it from the N curve of Fig. 1.

There are more important distinctions between these two kinds of negative resistance, which we looked into at some length in the January and February, 1957, issues. The most practically important is that whereas the S or current-controlled type is most likely to make a circuit oscillate if its resistance is low, the N or voltage-controlled type does so if its resistance is high. This is shown in Fig. 3, where two load lines are drawn, APB representing a lower positive resistance than the negative resistance, and CPE a higher resistance. And if you are unaccustomed to load lines and think I must be getting muddled in saying these represent positive resistances, I must explain that their scale of voltage runs to the left from A and C, not to the right from O, so the sign is reversed.

If the total voltage OA is applied to the low positive and the negative resistance devices in series, the one point P common to both their graphs means that the voltage OA divides between them in the proportions OF and AF, and the current through both is represented by OG.

On the other hand, if voltage OC is applied to the high positive and the negative resistance devices, there are three possible states, represented by D, P and E. And, whereas E and D are stable, P is unstable, which means that if the line EPDC represents the dynamic resistance of a tuned circuit at

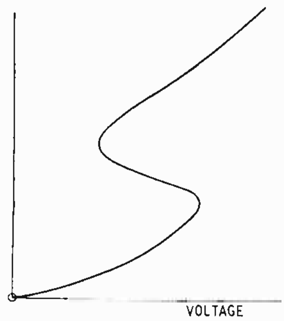


Fig. 2. This is an alternative type of negative - resistance curve.

some frequency it will be made to oscillate at that frequency, while if it is an ordinary d.c. resistance the current and voltage will flip over to either E or D.

The uninitiated may be surprised at this, arguing that since EPDC represents a larger positive number of ohms than the negative number of ohms in series, the total resistance must be positive. As I hope those who were with us in 1957 saw, however, the N type of negative resistance works in such a way that the rest of the circuit is effectively in parallel; and if you calculate the combined resistance of, say, -400Ω and $+500\Omega$ in parallel you will find that the answer is $-2{,}000\Omega$.

If the figures were reversed, so that -500Ω was combined with $+400\Omega$, the result would be $+2{,}000\Omega$; which means that the circuit would be stable but with a greatly increased positive resistance. If the 400Ω was a dynamic resistance, the effect of the negative-resistance device would be to raise it five-fold, increasing its Q, selectivity and sensitivity.

So a negative-resistance device can be gainfully employed either to improve the performance of tuning circuits or to stimulate oscillations therein, as desired. In untuned circuits it can be used as a high-speed switching device. For instance, if the working point were initially E, a positive voltage pulse CC′, sufficient to lift it over the hump, would make it flip across to H, and thence to D at the end of the pulse. The status quo could similarly be restored by a negative pulse.

The most familiar negative-resistance devices work by means of positive feedback, which requires a minimum of three electrodes to operate it. And so

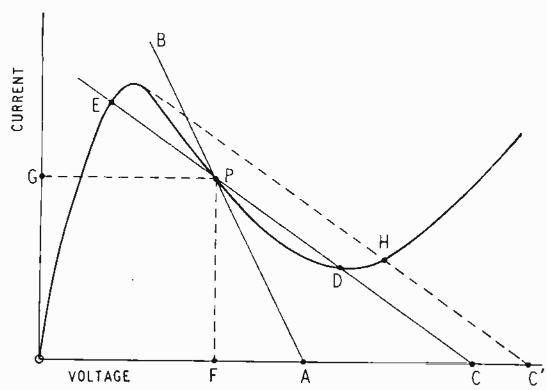


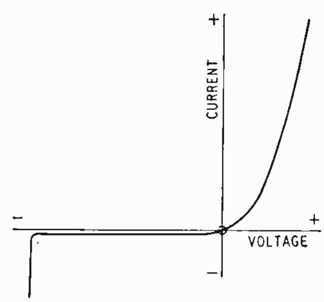
Fig. 3. Load lines applied to Fig. 1 show that interesting results are obtained when the load resistance is greater than the negative resistance; for example, EPDC.

we need valves and transistors. The snag about them is that they—especially transistors—get into difficulties at very high frequencies because of the time taken for electrons or holes to cross from one electrode to another; the "transit-time effect." There are also complications due to capacitances between the various electrodes.

Esaki's Diode

These difficulties are not necessarily avoided in two-electrode devices—diodes. Some, such as the ordinary metal rectifiers for 50 c/s, have so much interelectrode capacitance as to be unsuitable for high audio frequencies, let alone very high radio frequencies. Although point-contact germanium and silicon diodes—and junction types, if small enough—have reasonably little capacitance even by v.h.f. standards, their transit time may not always be negligible. And in any case, diodes don't normally show any kind of negative resistance. Fig. 4 is a typical characteristic curve, with the usual familiar features: hardly any current due to reverse voltage,

Fig. 4. Typical characteristic curve of conventional rectifier diode.



until the breakdown point, and rapid increase of current with comparatively small forward voltage, of the order of tenths of a volt.

Such characteristics are just what one wants in a rectifier, and are obtained by a junction between semi-conductors of the same material distinguished from one another by only perhaps one or two parts of opposite kinds of impurity in every thousand million. One can vary the breakdown voltage and the top working frequency to suit requirements by varying the proportions of impurity. The more the material is "doped" with impurity, the lower the breakdown voltage; and although this tendency may be acceptable, within reason, for the sake of a higher working frequency, there is a limit. If it is carried too far, the breakdown voltage becomes so low as to be practically non-existent; in which case the thing ceases to be a rectifier at all. Most people wouldn't pursue the matter any further, but there is sometimes something to be said for the generally anti-social occupation of carrying things too far. Considerable fame has come to a Japanese experimenter, Dr. Leo Esaki, for doing just that. He tried something like a million times as much impurity as in ordinary rectifiers—10^{20} atoms of it per cubic centimetre, or one part in a few hundred—and at the same time reduced what is called the depletion layer between the two sides of the junction to one millionth of a centimetre, or about a fiftieth of a wavelength of light. As we shall see, the extreme thinness of layer tends to result automatically from the extremely heavy doping.

Although a diode constructed on these lines offers hardly any reverse resistance, the forward curve above about one-third of a volt is hardly affected. The important thing, however, is what happens within that first third of a volt. It is shown in Fig. 5, with the characteristic of a typical rectifying diode dotted in for comparison.

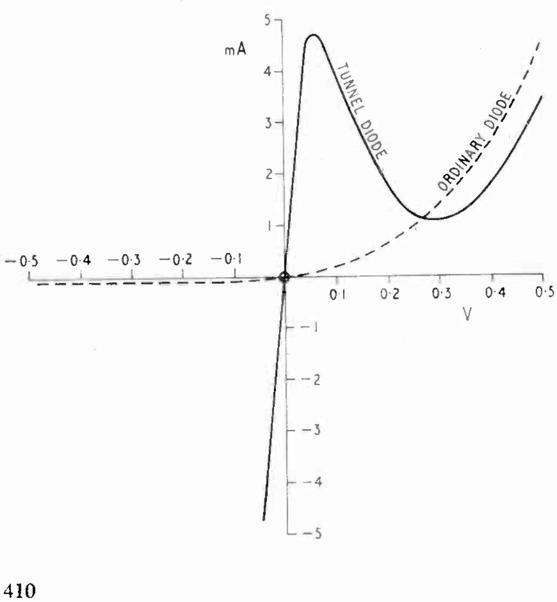
This is the sort of thing that you and I could hardly have foreseen, and even when confronted with the experimental fact we would be hard put to it to think up a plausible explanation. I'm not at all sure that you will regard the official explanation, when we come to it, as plausible; if not, the onus will be on you to produce a better one. Meanwhile, shall we continue to put off the evil day by taking note of the practical side of this development.

We have become so accustomed to reading about fabulous new semiconductor devices proposed by exotic scientists, not obtainable in the foreseeable future, if at all, that it may be hard to take in as an actual fact that this most unlikely one can be obtained now by ordinary people, in at least six varieties with such commonplace type numbers as JK10A and JK11A, by sending a finite amount of cash to Standard Telephones & Cables, Ltd., Footscray, Kent. But so it is.

10,000 Mc/s

Laying a ruler parallel with the downward slope of Fig. 5 and reading off current and voltage, we find that the negative resistance is of the order of 40 ohms. This compares with 10kΩ for an exceptionally good dynatron valve. Remember, the lower the value of an N-type negative resistance the more potent it is, for it will produce oscillation in any circuit with a dynamic resistance numerically higher. Tunnel diodes with lower values than 40Ω are even easier to make. In fact, the lowness of their negative resistance tends to be embarrassing because of the difficulty in getting the power supply and connecting lead impedance low enough for the system to be stable at all frequencies, except perhaps one. On the other hand, there is no difficulty in getting

Fig. 5. Curves of tunnel diode and ordinary diode show some striking differences.



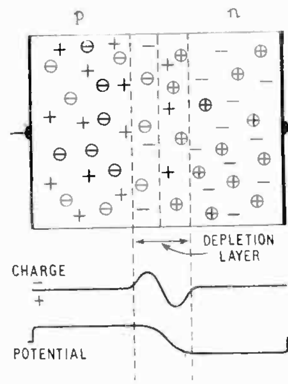


Fig. 6. (Below) Diagram of the ionized impurity atoms scattered about a piece of n-type semiconductor.

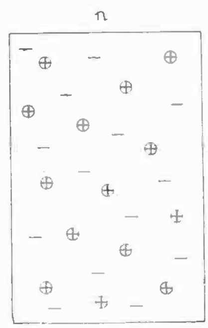


Fig. 7. (Above) In a single crystal with p and n zones, migration of the mobile charges builds up a difference of potential just sufficient to stop further migration.

the dynamic resistance of oscillatory circuits low enough, even at the highest frequencies. That, of course, would be no consolation if the diode ceased to function as per Fig. 5 at the said frequencies. But experimentally at least, tunnel-diode oscillation has been reported up to 5,300 Mc/s, and 10,000 Mc/s is confidently expected.

Before considering why this is possible, we will probably find it helpful to remind ourselves why a decade of struggle with transistors has failed to make them work at anywhere near such frequencies. One reason is that there is not merely one junction for the current carriers—electrons or holes—to cross, there is the whole base layer between two junctions. And except in the comparatively recent "drift" transistors, in which the base doping is tapered to produce an accelerating field for hurrying the carriers along, they just stroll across it in their own time.

In a *pnp* transistor, for example, the base—the meat in the sandwich—consists of *n*-type semiconductor. That is to say its material (usually germanium) is doped with an impurity whose atoms have one movable electron each. The main body of each atom, fixed permanently in the crystal structure, is therefore one electron short and so is electrically a positive charge. These fixed charges are denoted in Fig. 6 by plus signs in circles, and their mobile electrons by uncircled minus signs. The electrons are called majority current carriers because —well, they are in a majority, greatly outnumbering the few holes knocked out of the germanium atoms by heat, etc., or straying in from the neighbouring emitter. These emitter holes—the minority carriers —are responsible for the operation of the transistor, however, for they are the ones collected by the negatively biased collector. The base as a whole has hardly any electric field in it, because the equal and opposite charges distributed throughout it, as indicated in Fig. 6, cancel out.

In tunnel diodes, on the contrary, it is the majority carriers that count, and their journey is very short indeed. But we are still no nearer accounting for the essential feature of the tunnel diode: the low-

(*Continued on page* 411)

voltage hump and negative-resistance slope in Fig. 5.

Again, let us remind ourselves how the conventional pn junction diode works. Fig. 7 is a diagram of one, the n half being originally the same as Fig. 6 and the p half the same in reverse. As we have seen, when separated they have no net electric charge. The mobile carriers in both halves are moving randomly all the time, and when both share the same crystalline structure there is nothing at first to stop the carriers nearest the boundary from straying across it. Electrons doing so leave behind an equal number of unneutralized fixed positive atoms on the n side, and incoming stray holes increase the positive charge there, as well as leaving behind a negative charge on the p side. The potential difference thus created checks further straying and a balance is quickly reached. This p.d., of the order of quarter of a volt in germanium, necessitates an external voltage of that order, positive to p, to overcome it and make current flow freely across the junction. Hence the rather slow start of the dotted curve to the right of zero in Fig. 5.

If the voltage applied externally to p is negative, it increases the existing p.d. between the two sides of the junction and stops all current flow (except the

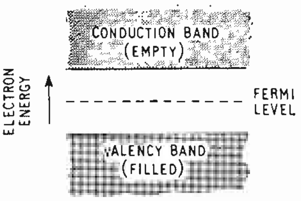


Fig. 8. Energy-level diagram for a perfectly pure semiconductor.

small leakage due to hole-electron pairs created among the germanium atoms, due to heat, etc.). Note that, provided the material changes abruptly from p to n at the junction, the more heavily the material is doped the greater the total charge created by a withdrawal of mobile carriers each side of the junction for a given distance, and therefore the less that distance for a given number of volts p.d. So one would expect a tunnel diode to have a phenomenally thin depletion layer.

The Fig. 7 sort of picture tells only part of the story. It fails to take account of the fact that in solid materials the existence of current carriers and an e.m.f. isn't enough to guarantee a current. There must also be vacant energy levels right at hand for the current carriers to step into. (If that remark doesn't make sense to you, a little homework will be necessary before proceeding further. Most of the 1958 Cathode Ray instalments refer, especially the one in the July issue.) In a pure semiconductor the mobile electrons completely occupy a band of energy levels called the valency band, and the nearest available levels are in the so-called conduction band, separated by a gap, or band of forbidden levels, as in Fig. 8. As the vertical scale in such diagrams indicates the energy of electrons, upwards is negative. The Fermi level is a sort of reference, like sea level in geography. Below it, more than half the available energy levels are filled; above it fewer than half are filled. At absolute zero temperature, when all the electrons are at rest like a calm sea, it marks their "surface." At ordinary temperatures, heat disturbs the electrons, giving them enough energy to lift some to higher-than-Fermi levels; and as they leave behind an equal number of lower-than-Fermi holes the situation is vertically symmetrical, so the right place for the Fermi level is in the middle of the gap.

The promoted electrons have plenty of room to move about in the nearly empty conduction band, and likewise the holes in the valency band. What this amounts to in practice is that these "particles," very few in number, are available as current carriers; they are responsible for "intrinsic" or both-way leakage conduction, which is a nuisance in transistors and diodes, and as one might expect increases with temperature.

Impurities upset the balance by creating a very narrow empty band just above the valency band in p material, or a filled band just below the conduction band in n type. These gaps are so small that they are crossed freely by electrons at ordinary temperatures, leaving holes behind. The increased conduction so caused normally far outweighs the intrinsic conduction, which we shall now ignore. The new balance is indicated by the Fermi level rising towards the impurity gap in n material and falling towards it in p material.

While impurity greatly increases conduction throughout material of either kind, the state of affairs is more complicated in a crystal which is p at one end and n at the other. If no voltage is applied externally, the Fermi level is the same for both sides, as shown in Fig. 9. This creates the potential step we have seen already at the foot of Fig. 7, preventing current flow from one side to the other. Connecting a battery to the crystal diode alters the relative potentials of the p and n halves, shifting their Fermi levels and either reducing or increasing the step according to whether the battery is positive to p or to n.

The more impurity is included, the more it dominates the situation, until, with the altogether abnormal amount used by Esaki, the upper levels of the valency band are practically cleared and the lower conduction levels filled, so the Fermi level is actually inside the main bands, as in Fig. 10. So far from explaining the early rise of current in Fig. 5, this would seem (in the light of all we have remembered) to make it even more impossible, by increasing the height of the potential step.

Tunnelling

To rescue us from this difficulty we must look to one of the most apparently fanciful theories of modern science, which tells us that when things are as small as electrons it is impossible for them to be clearly defined particles. They behave as waves of probability. I tried to explain that not very easily intelligible concept in the November 1958 issue.

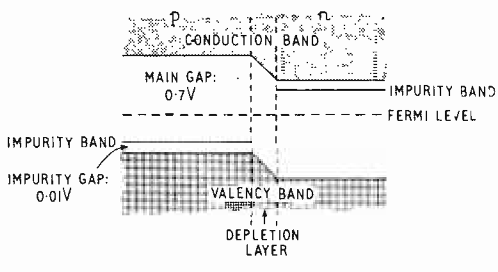


Fig. 9. Energy-level diagram for p-n junction with very small impurity content, as in a rectifier diode.

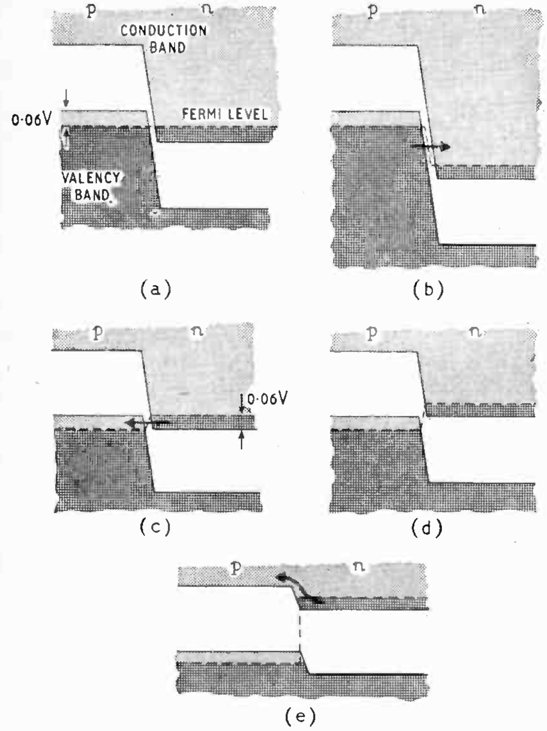


Fig. 10. Diagram corresponding to Fig. 9, for a high-impurity (tunnel) diode.

Discarding all set ideas about what extremely small particles are like, because we have no right to assume they are just like particles we can see only smaller, we must accept experimental evidence of their dual personality, wave-like as well as particle-like. Just as the band of waves that combine to form a square signal pulse can never have a perfectly defined start and finish, and the uncertainty is negligible with wide pulses but appreciable with very brief ones, so there is uncertainty about the position of a particle as small as an electron. It can be visualized as a sort of haze; the local density of the haze, which is greatest in the centre and gradually tails off as the distance therefrom increases, being a measure of the probability of finding the electron there at any given moment.

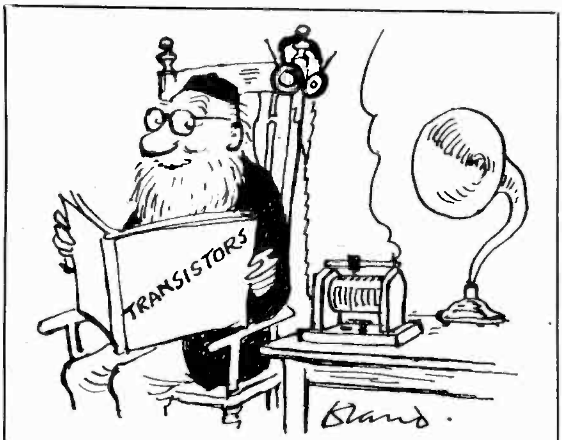
Now if an electron is close to a potential barrier as thin as in a tunnel diode, its haze extends beyond the barrier, and if there is a vacant place for it an appreciable possibility exists of its being there, even though it doesn't possess enough energy to climb over the barrier. With one electron, that is rather like the statistics which say that if you are alone in a room that room contains 0.01 (or whatever it is) tuberculous persons. Just as you get a more sensible result by applying such information to a crowd outside Buckingham Palace, so one reaches the conclusion that when there are trillions of electrons milling around close to a thin potential barrier an appreciable number are on the far side, and since they couldn't have climbed over it they are regarded as having tunnelled through it.

Taking another look at Fig. 10, we see that in diagram (a), which represents zero applied voltage, there are no filled levels alongside empty levels on either side, so there is zero current, even when tunnelling is allowed. But when the p side is made negative, by what is usually called back voltage, as indicated by the step in the Fermi level in (b), part of the valency band on the p side, bursting with electrons, is separated only by a fantastically thin depletion layer from empty levels on the n side. This means a fairly good conductivity across (or through) the barrier, the arrow showing direction of electron flow. This accounts for the steep downward slope to the left in Fig. 5, in contrast to the ordinary diode (Fig. 4).

A *small* forward voltage (c) permits current in the opposite direction. But as this forward voltage is increased, the number of empty levels opposite full ones decreases (d), so the current falls off, causing the negative-resistance slope. Finally, further increase of forward voltage (e) progressively reduces the potential barrier, causing a rising current as in an ordinary diode.

Besides the useful features we have already noted, tunnel diodes are less upset than transistors by radiation of various kinds. This may be important in nuclear equipment. They are more tolerant of temperature, working happily at hundreds of degrees below and above zero. They are likely to be much less affected by contamination, and the expensive precautions against it needed for transistors and rectifier diodes should be largely unnecessary. They are very small and simple. On the other side of the balance sheet: Being diodes, they are not even approximately one-way in action as are transistors. For their resistance to be high enough to match reasonable circuitry, their size is necessarily small and their power-handling correspondingly limited. Fig. 5 shows how limited is their working voltage range.

But these are early days, and there is already reason to believe that the conventional germanium and silicon may not display the full capabilities of tunnel diodes. Indium antimonide and gallium arsenide are being tipped as winners. Computers performing operations at 50 Mc/s, compared with 1 Mc/s which is regarded as quite good in present practice, are forecast. Uses in television receivers, especially frequency changing and amplification in bands IV and V, seem likely. All in all, then, I'm not disposed to lodge an objection against the claim that the tunnel diode is the most important semiconductor development since the junction transistor.



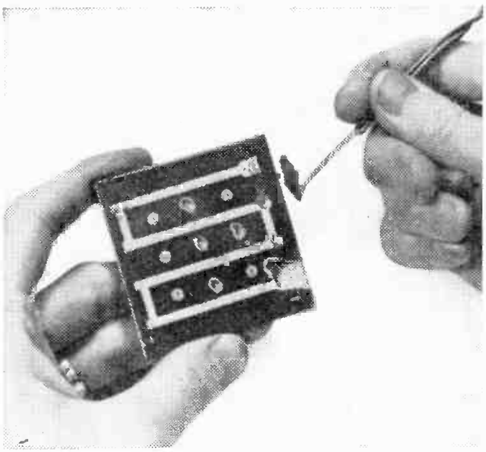
IMPROVED PRINTED WIRING

NEW TECHNIQUE GIVES GREAT BOND-STRENGTH

MANY criticisms have been made of printed wiring in the few years it has been with us. Today many of the troubles discovered in its early use have been, if not overcome completely, reduced in their incidence; but the application of palliatives has not been easy. A new method for producing printed-wiring boards, developed by Electronic Circuits, Ltd., shows great promise in being free from the majority of nasty habits that have possessed most foil-laminate circuits in the past in varying degrees.

The wiring pattern is printed on the substrate with a bonding medium and finely divided copper is then applied, resulting in a granular-copper pattern. This is then deoxidized and very quickly tinned by a roller-coating process to give a solder-coated wiring board. Conductor resistance is equivalent to that achieved by the use of 1-oz copper foil (1.5×10^{-3}in thick).

This technique shows greatly improved bond-strength compared with the normal foil-laminate construction. The photograph shows a test-piece to which a strong wire was soldered, end on. It was possible to pull off by hand the wire, but only with considerable effort. The result in each case was a rupture of the board material: the wire came away with the printed wiring attached to it bearing on the back a considerable amount of synthetic-resin-bonded paper board material.



Deep ruptures of the substrate material occur in ordinary pull test. Wiring pattern does not separate from board material.

The normal peel test which demands an "end" of copper to peel cannot be applied; but performance should be eminently satisfactory, as in none of the pull tests did the wiring separate from the board material. No etching process is involved, as it is with the traditional construction, so that a section through the pattern shows, instead of undercut conductors, a meniscus form.

Switch and plug contacts can be plated on to the solder in the normal way, following milling down of the surface to provide a level base. Particularly successful are palladium or gold over hard nickel.

Ordinary flow solder and solder-dip techniques may be used for connecting component leads. Normally, with solder-tinned leads, no fluxing is required. The solder of the bath, leads and circuit dissolve into each other forming a good joint even in the presence of foreign matter. Advantages here, of course, are that the risks of corrosion from decomposed or damp flux deposits are completely eliminated, as are "dry" joints. It is possible, by repeated application of fresh copper-free solder, to dissolve away the copper particles on a very thin (too thin to be of use as part of the circuit) line; but provided normal soldering practice is followed this does not occur. The use of a copper-rich solder for servicing work naturally eliminates even this slight opportunity for failure.

Last, and in this case definitely least, is cost. It is expected that this process will allow the production of punched boards at about the same price as etched-foil boards unpunched. Further economies could be made in assembly-line working due to the rougher treatment and simpler processing possible so the final all-round result should be cheaper, more-easily made equipment of better reliability.

The address of Electronic Circuits Ltd. is 177 Kensington High Street, London, W.8.

RANDOM RADIATIONS

By "DIALLIST"

The Report

THE Television Advisory Committee's report is clearly the result of much hard work and of much hard thinking. With many of its recommendations most people agree. What I do regret is that a 625-line standard should have been recommended. The Committee feels that this is the last opportunity we shall have for 25 years of improving the definition of our television and I really can't feel that the 625-line standard will be accepted as adequate for anything like such a time. Nor do I find it all that much better than 405 lines. Readers who have been for holidays or on business to countries using 625 lines will, I fancy, hold similar views. It *is* better, but not strikingly better. I should have liked to see a much bolder proposal: to use Bands IV and V for something like 1000-line television. If you've been to France and seen the R.T.F.'s 819-line pictures on a good set, you must have been struck by their enormous superiority to ours.

Other Considerations

There are, I know, several reasons against the adoption of a really high standard. Not the least of them is that nine viewers out of ten don't seem to care two hoots about the quality of the pictures on their screens. No doubt you've found, as I have, that non-technical friends aren't in the least worried about all sorts of shortcomings that would drive you and me crazy, and they make no attempt to have them put right. Faults, I mean, such as poor focus, incorrect height or width, "soot-and-whitewash," ringing, poor h.f. response—and dozens of others. Against that, the desire for a big screen is very strong and with the present standard you can't profitably have a very large screen in the smallish rooms of modern homes unless you're prepared to put up with lininess. Another suggestion of the Committee's is that the adoption of their proposals would enable us to have eventually no fewer than five TV networks. Five!—but where's the material coming from? The supply of actors, singers, comedians, instrumentalists, variety artists . . . and so on and so forth for even two networks doesn't appear to be superabundant nowadays. Wouldn't it just mean more and more films? Surely, television should stick as much as possible to actualities—the presentation of things as they happen; and TV films should be mainly recordings of them.

More DX Feats

LONG-DISTANCE reception of both v.h.f./f.m. and television signals seems to be gaining increasing popularity. A reader writing from Twyford, in Buckinghamshire, tells me he has had a receiver specially modified to 625 lines and with this he has been remarkably successful. This set is a standard domestic model, not even a fringe-area type. He uses normally a Channel 1 vertical "H" aerial, but he has also a Channels 4-8 combined aerial, also vertical. So far this year, he writes, he has had direct TV pictures from Italy, Czechoslovakia, Spain, Hungary, Russia, Italy, Germany, Rumania, Sweden and the Netherlands. He sends some remarkably good photographs of pictures from some of these countries received on his screen. A reader who lives at Antwerp (though he's not a Belgian) tells me that he has at any time a choice of seven or eight stations in Holland, Belgium, France and West Germany, all of which provide first-rate reception. He is the fortunate owner of an aerial rotatable in azimuth and provided with a motor to turn it in the right direction

819 Lines Too

Though I'd heard that the French 819-line transmissions could produce a locked picture on a 405-line receiver, I'd never, until recently, had any definite evidence on the subject. Now it has come along in the form of clear photographs of his screen from a reader living at Shenfield, Essex, who uses a standard domestic set. What does come as a biggish surprise is that his successes have been achieved with a 5-element Band III aerial, mounted at first in the loft of his bungalow and now fixed to a 14-foot pole outside. He tells me that on an average of five evenings a week he can obtain a picture. On the best evenings it is not much inferior to those of the B.B.C. and I.T.A., which should be first rate at Shenfield; on other evenings it is just usable. Perfection couldn't be expected, naturally, for our standard receivers aren't designed to cope with such large modulation bandwidths as are used in French television. I'd be glad to hear of any other instances of successful 819-line reception on standard 405-line receivers.

Prehistoric Electric Cell?

THE June issue of the *Journal* of the I.E.E. contained a note by C. MacK. Jarvis concerning an article recently published in the German journal *Elektric* on an object discovered near Baghdad about 1936. Archaeologists put the date of other objects excavated on the site as between 300 B.C. and A.D. 300. It is a kind of vase, about 6-in high, made of yellow clay. Inside it is a copper cylinder held in place by the asphalt lining of the vase and containing an iron rod kept in position by asphalt discs at top and bottom. It is suggested in the German journal that this was an early form of electric cell and that galvanic gold plating had been carried out with the aid of similar cells from as early as 2500 B.C. A fascinating idea, but there doesn't seem to be much to support it. One can hardly believe that the galvanic cell, if developed by the Parthians and used over a long period, would simply have disappeared until Galvani "rediscovered" it. And C. MacK. Jarvis suggests something that seems fatal to the idea of the practice of gold plating by electricity in those days; no solvent of gold was known to the ancients and there were, therefore, no gold salts.

The Moon's Surface

INVESTIGATIONS into the nature of the moon's surface were recently undertaken by V. A. Hughes of the Royal Radar Establishment at Malvern. He used a 2MW radar transmitter, the wavelength being 10cm, in conjunction with the Malvern 45ft radio telescope. In a letter in *Nature* of June 11th he states that the surface appears to have numerous small ups and downs. The height or depth of these is not great, being mainly a matter of a few feet; but their width may be 20 times greater. I wonder if further investigations will confirm these conclusions? They don't agree very well with the results of optical methods, which give ground for believing that the moon's surface is covered mainly by fine volcanic dust. I suppose that hillocks and depressions could occur in this, though there can't be any wind to make them.

Servicing Exams

LAST month I incorrectly referred to the "R.T.R.A. exams. and certificates." The servicing examinations in question are, of course, run jointly by the Radio Trades Examination Board and the City and Guilds of London Institute.

UNBIASED

By FREE GRID

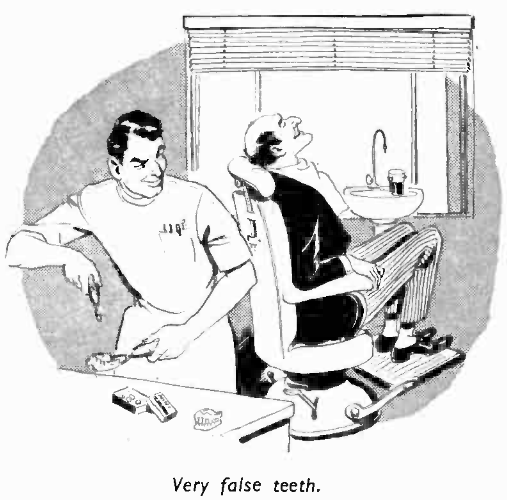
From the Horse's Mouth

JUST lately we have heard a lot about miniature secret transmitters concealed in the furnishings of conference rooms used by high diplomatic dignitaries. Even the gifts to our own Home Secretary on a recent tour were subjected, we are told, to strict screening by secret-service agents to see if they contained any hidden devices of this nature.

The menace of having our private conversations broadcast in this manner is a very real one, but I think secret-service Sherlocks are—if I may mix my metaphors—barking up the wrong tree when they examined things like Mr. Butler's "Presents from Margate." I cannot think the agents of any foreign power would be so crude as to place secret transmitters there when much more intimate places are available.

I was thinking of this as I was examining the "radio pill" on a stand at the Instruments, Electronics and Automation Exhibition held at Olympia in May. This pill, as many of you will know, consists of a small capsule which is swallowed by the patient. It houses a tiny radio transmitter which radiates information about the pressure, temperature and acidity of the patient's alimentary tract through which it passes.

It should be possible to fit it with a miniature mike so that it radiated the patient's conversation as it journeyed through his innards. But the danger of its use for espionage is negligible, as no statesman would go to a conference with one of these inside him, and in any case it only remains in the patient's body for a limited time.



Very false teeth.

As a precaution, however, it would probably be advisable for the breakfasts of all statesmen to be vetted on the morning of a conference, as it would be possible, I suppose, for an unscrupulous chef to conceal a capsule in the porridge.

In my opinion, however, it is not in the alimentary tract but in quite a different part of a statesman's body that a search should be made for a concealed transmitter. It must be clear to any thinking person that if a transmitter can be concealed in such a small space as the capsule exhibited at Olympia, it would be a simple matter for a dentist in the pay of a foreign power to conceal one in a cabinet minister's denture.

Enemy agents listening on their nearby receiver would thus have secret information straight from the horse's mouth, as the saying goes. It seems to me the remedy would be for a secret-service agent or a police officer to stand at the door of the cabinet room with a tray and collect all dentures as ministers passed inside, or, less comfortably, to hold the meeting inside one of those screened rooms one sees in microwave research laboratories.

Homo Infrasapiens

I MUST thank the many readers who wrote in answer to my query (June issue) to tell me that the circle is divided into 360 degrees because the astronomers of old—some say the Babylonians—were a bit out in their calculations and thought the year contained this number of days instead of 365 and a bit.

This is, I feel sure, the correct *conventional* explanation because all the books of reference are more or less in agreement about it. But the fact that this explanation seems to be accepted by all the best people does not necessarily mean that it is correct. After all, in every biography of King Edward VII we are told that he had his appendix removed when undergoing an operation in 1902. The only man to disagree is the late Sir Frederick Treves who was the presiding surgeon on that occasion. But he was in a minority of one like myself in this Babylonian affair.

My idea is that at some time in the life of the solar system the speed of the earth's journey around the sun may have been such that there were indeed just 360 days in the year. Needless to say, this was long before the coming of homo sapiens who has only been on the earth some 500,000 years and in that relatively short period of time, the earth's speed cannot have changed much, if at all.

If, however, we go back a sufficient number of million millenia, there may have been exactly 360 days in the year. I cannot say exactly when that was as I haven't an electronic computer handy to feed in the necessary data.

In my opinion, it may well be that in those distant days, the earth was inhabited by a race of pre-men (homo infrasapiens) much more advanced than ourselves in scientific knowledge but less well developed in the matter of morals, intelligence and political wisdom—hence the name infrasapiens—who wiped each other out in a nuclear war. According to my theory fragments of their ancient records which escaped destruction were found by the Babylonians who failed to realize that days and years had lengthened and therefore 360 was no longer the correct figure.

In the same way, fragments of our own records may be discovered a few million millenias hence when the solar system may have slowed down still more, and the people of those far-ahead days (homo supersapiens) will wonder what it was like to have had a year of such a few number of days as $365\frac{1}{4}$, and a day of such brief duration as 24 hours. They may even wonder what we meant by the word "war."

Why?

I AM always thirsting for information, and I wonder if any of you can tell me why an angstrom unit is so called? Now before you all take up your pens or typewriters to tell me all about Ångström and his work, I should like to say I am not ignorant of all that. What I want to know is why the seemingly unnecessary word "unit" is tacked on to angstrom. After all, we don't speak of an ampere unit nor yet an ohm unit, do we?

I wonder if it is due to sheer ignorance, of the type shown by certain people who tack the superfluous word wine on to Port when they wish to speak of the drink which comes from the valley of the Douro, but omit it when speaking of the bubbling beverage of the Champagne country, and of other forms of nectar.