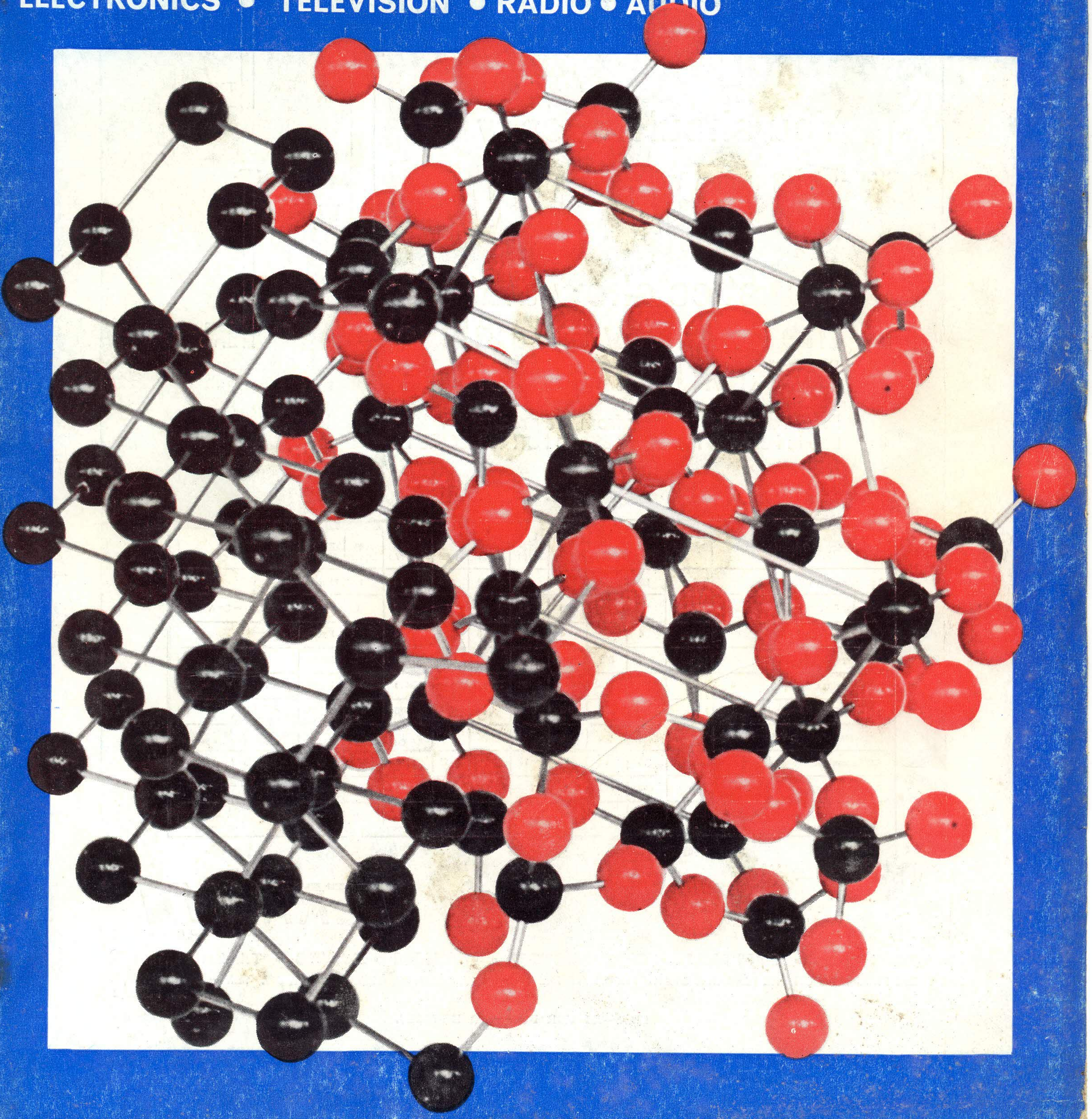
PHYSICS EXHIBITION REPORT

MAY 1965
Three Shillings

Wireless World

ELECTRONICS • TELEVISION • RADIO • AUDIO



Iliffe Electrical Publications Ltd.,
Dorset House, Stamford Street,
London, S.E.1

VOLUME 71 No. 5
PRICE: 3s. 0d

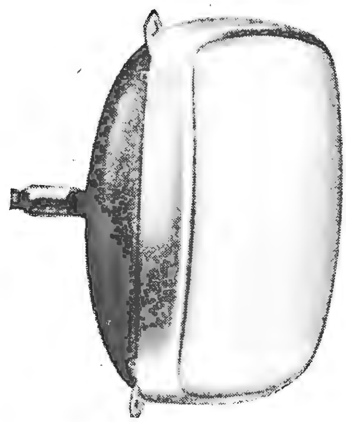
FIFTY-FIFTH YEAR
OF PUBLICATION

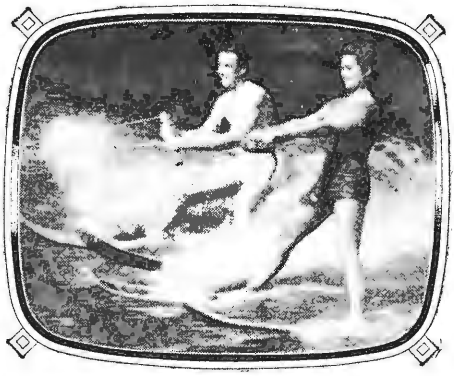
Wireless World

ELECTRONICS, TELEVISION, RADIO, AUDIO

MAY 1965

PUBLISHED MONTHLY (4th Monday of preceding month). *Telephone:* Waterloo 3333 (70 lines). *Telegrams/Telex:* Wiworld Iliffepres 25137 London. *Cables:* "Ethaworld, London, S.E.1." *Annual Subscriptions: Home* £2 6s 0d. *Overseas:* £2 15s 0d. *Canada and U.S.A.* $8.00. Second-class mail privileges authorised at New York N.Y. BRANCH OFFICES: *BIRMINGHAM:* King Edward House, New Street, 2. *Telephone:* Midland 7191. *BRISTOL:* 11, Marsh Street, 1. *Telephone:* Bristol 21491/2. *COVENTRY:* 8-10, Corporation Street. *Telephone:* Coventry 25210. *GLASGOW:* 123, Hope Street, C.2. *Telephone:* Central 1265-6. *MANCHESTER:* 260, Deansgate, 3. *Telephone:* Blackfriars 4412. NEW YORK OFFICE U.S.A.: 111, Broadway, 6. *Telephone:* Digby 9-1197.





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Wireless World

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Science and/or Engineering

OUR front cover this month is symbolic of the complex physical structures which lie at the foundation of modern solid-state electronics. It is intended to show the importance of science, as exemplified in the report elsewhere in the issue on the Physics Exhibition, in breaking new ground for development by the technologist and utilization by the engineer.

Practising scientists and engineers respect each other as compeers exercising the same intellectual powers to different ends, but aspirants to these professions, and in particular young sixth formers deciding upon a career, seem to be attracted more by the glamour of science and less by the prospects of engineering, which many regard as a dull pedestrian pursuit.

What are the essential differences between science and engineering? A quick answer would be that science is easy and carefree whereas engineering is difficult and loaded with responsibility. No stigma attaches to the scientist whose hypothesis is proved false by experiment; only the return of "don't know" as the conclusion from his work can be scored as a failure. Engineering, on the other hand, can never contemplate so negative a termination, though the possibility of failure must always be present as a spur. Success is approached on a broader front. Engineering is a skill and, as R. Hadekel has pointed out recently (*The Chartered Mechanical Engineer,* March 1965, p. 176) it has its roots in craftsmanship. As such it pre-dates science not by centuries but by aeons. The modern scientific method (hypothesis tested by observation and experiment) has been establishd as a discipline for less than 400 years.

To claim that engineering is applied science is to do it less than justice. Applied science may produce a new technique, even a whole technology, but these wait upon the needs of the engineer and are his tools.

What is the superior attraction of science over engineering for the school-leavers of today? Could it be that science combines the freedom of dilettantism with the chance of making a great discovery, whereas engineering calls for iron discipline and steady application to a limited end? If so there are several ways of redressing the balance. One which we rather like was suggested recently at the Annual Dinner of the I.E.E. by its president, Mr. O. W. Humphreys, namely, that young men should be allowed first to sow their wild oats in pure research before moving on in maturity to engineering.

Engineering talent is born, but may remain dormant unless it is fostered by precept and fired by enthusiasm. The difficulty is that there are not enough good engineers to supply the needs of both industry and education. Suggestions that there should be part-time exchanges between these professions have frequently been made, but have not proved practicable. At a recent conference of headmasters in Cambridge, organized by the Engineering Institutions Joint Council and the Royal Society to discuss means of increasing the numbers of aspirants to an engineering career, it was generally agreed that a firm grounding in physics and mathematics *must* be given priority. Sir Willis Jackson expressed himself as against the teaching of engineering in schools but in favour of the use of imaginative experiments and films to show the *relevance* of physics and mathematics to engineering. There should then follow a year in industry before entry to a university where a first-year course common to *both* science and engineering students would be undertaken.

This seems the best way of settling the matter, for by the time the student has reached his second year at university and the real work is about to begin, any early romantic fantasies will have given place to an appreciation of the deeper satisfaction which a career in one or other of these disciplines will give.

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MAY 1965

A SINGLE-CARRIER COLOUR TELEVISION SYSTEM

By E. J. GARGINI*

A STUDY of the possibilities of h.f. wired television distribution has led to the formulation of a new type of colour transmission system[1] which could prove to have considerable advantages if used for colour television broadcasting. In this proposed compatible system, called SEQUIN (Sequential Quadrature Inband System), the colour information is transmitted sequentially by a suppressed carrier signal at the same frequency as the main carrier but in quadrature phase relationship with it. Brightness information is transmitted in the ordinary manner, the main carrier being modulated in the negative sense. The complete signal provides the monochrome picture for existing (625-line) black-and-white receivers.

The colour signal conveys two sets of colour information in sequence. These two sets can be either two colour-difference signals, of the form E_R-E_Y and E_B-E_Y, or two colour-ratio signals, of the form $(E_R/E_e)-1$ and $(E_B/E_e)-1$, where E_e is an equal-energy brightness signal formed from equal proportions of the three camera tube outputs. The first kind of signal, providing chrominance information, permits simple matrixing techniques in receivers but has the disadvantage, common to all chrominance systems, that fine detail brightness information is displayed as fine detail whiteness information[2] on both colour and monochrome receivers. The second kind of signal, conveying chromaticity information, overcomes this defect and permits approximate constant chromaticity and exact constant-luminance operation of the colour receiver[3], with separate luminance signals. Normally the two sets of colour information would be transmitted line sequentially, but theoretically dot-sequential or frame-sequential working would also be possible.

The complete transmitted signal can be considered as a carrier wave modulated both in amplitude and phase. This is shown vectorially, for the chrominance system, in Fig. 1, where the modulus (envelope amplitude) and angle (carrier phase) of the rotating vector are determined by the amplitudes of the luminance signal and of a colour-difference signal in quadrature. Mathematically the vector modulus is given by

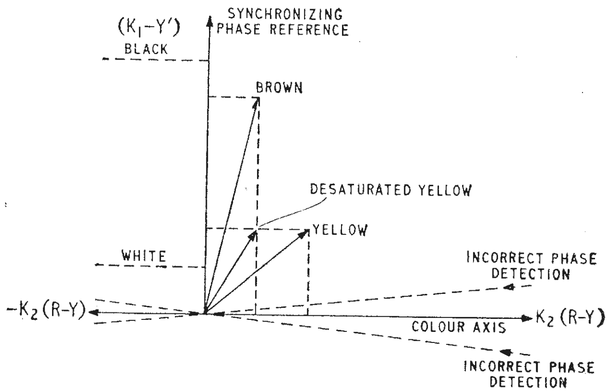
$$|E_{vision}| = [(K_1-E'_Y)^2+K_2(E_{R-Y} \text{ or } K_3E_{B-Y})^2]^{\frac{1}{2}}$$

where $|E_{vision}|$ is the instantaneous carrier amplitude, E'_Y is the amplitude of the luminance component, and K_1, K_2 and K_3 are constants. The carrier wave phase angle is given by:

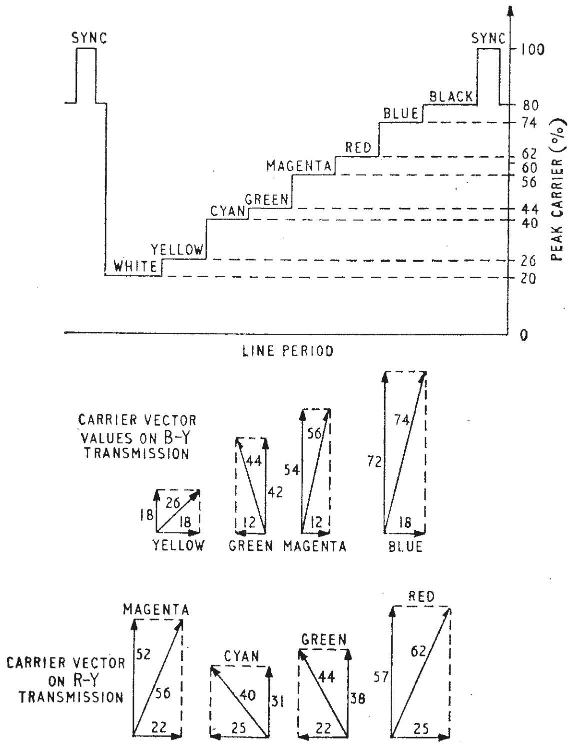
$$\angle E_{vision} = \tan^{-1}\left[\frac{K_2(E_{R-Y} \text{ or } K_3E_{B-Y})}{K_1-E'_Y}\right]$$

where $\angle E_{vision}$ is the instantaneous phase angle of the carrier in degrees, and K_1, K_2 and K_3 are constants as

*Rediffusion Research Ltd.

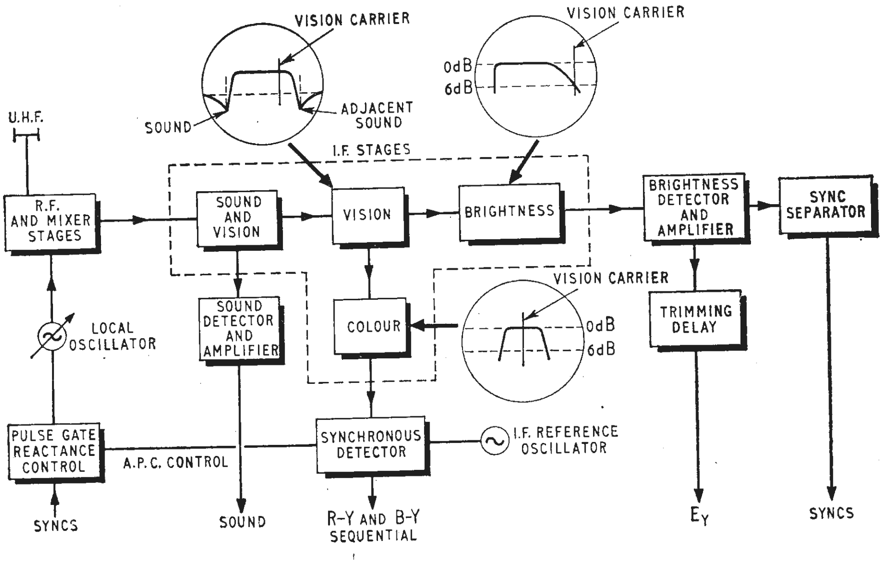


Above:—Fig. 1. Vectorial representation of the complete SEQUIN signal (for the chrominance system). Correct phase detection, (R−Y) + Y=R, etc.; incorrect phase detection, [R−Y ± Δ (K1−Y')] + Y=R ± Δ(K1−Y') etc.

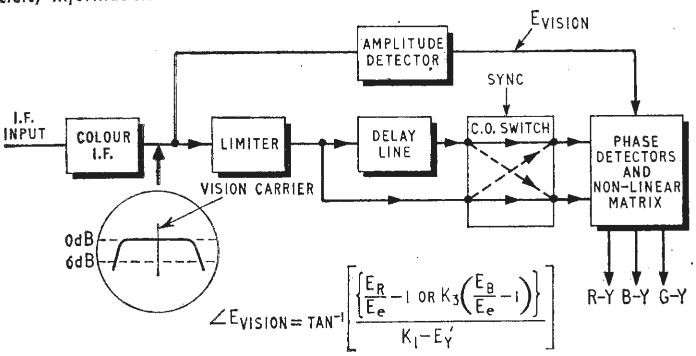


Right:—Fig. 2. Modulating amplitudes and carrier phase angles for a colour-bar transmission on SEQUIN (for R−Y, B−Y version). Maximum values correspond to condition: $E_{B-Y} = E_{vision}$ on yellow, and $E_{R-Y} = 1.8E_{B-Y}$.

Right:—Fig. 3. Receiver schematic, assuming that chrominance information is transmitted.



Below:—Fig. 4. Alternative detection system for receiver, assuming chromaticity information is transmitted.



above. Fig. 2 shows modulating amplitudes and carrier wave phase angles for a colour-bar transmission.

Recovery of the two sets of sequential colour information at the receiver requires a colour synchronizing signal. This is, in fact, transmitted automatically by the system, since, with negative modulation, the line and frame sync pulses constitute large-amplitude, long-duration bursts of carrier frequency in exact phase quadrature with the wanted colour signal. (During these bursts the colour signal is not transmitted and so does not affect the carrier phase.)

In the receiver two types of colour-signal detection are envisaged. The first of these, which assumes that chrominance information is transmitted, line sequentially, uses a single synchronous detector (see Fig. 3). The detection process includes an automatic frequency control system in which the local oscillator frequency is continuously adjusted to maintain the standard i.f. vision carrier in a fixed frequency and phase relationship to a second local oscillator, operating at this same frequency or at a sub-multiple frequency. This second oscillator provides the carrier re-insertion signal for synchronous detection of the sequential $E_R - E_Y$ and $E_B - E_Y$ components of the colour signal. Any departure from the correct phase setting of the synchronous-detector oscillator introduces positive or negative sync pulses into the colour channel and these can be used to maintain the phase angle of the re-inserted carrier at its optimum value. This carrier locking technique used in this type of receiver introduces some complication but it is the author's view that frequency control of u.h.f. colour receivers is desirable with any colour system.

In the second type of colour receiver, which assumes that chromaticity information is transmitted (Fig. 4), conventional frequency changing techniques with less precise frequency control may be possible. The colour signal could possibly be recovered by applying the composite vision carrier signal to a limiter and ratio type phase detector, the output of which would be further processed in a non-linear matrix to obtain colour-ratio or wide bandwidth colour difference signals. Either type of receiver could be arranged to suit chromaticity or chrominance information transmission.

The delay line required in either type of receiver could be a steel wire type, and in the second type of receiver could be operated by the phase modulated signal available at the output of the phase limiter.

A SEQUIN transmission received on conventional black-and-white receivers should not show any degradation of picture quality from that obtainable with monochrome transmissions. On colour receivers the brightness resolution should equal that obtainable on monochrome.

In conventional quadrature transmission systems the two simultaneous signals are recovered by a carrier re-insertion process along the wanted signal axis. When the upper and lower sideband structure is substantially uniform these signals may be recovered independently, that is, free from transient crosstalk. In the SEQUIN proposal medium-detail colour information and brightness information is transmitted double sideband over the normal double-sideband region of the transmission standard, and over this region a colour signal may be recovered which is free of brightness information. The remaining fine-detail brightness components would be transmitted as in normal monochrome practice over the single-sideband region, and as this band of frequencies conveys no colour information the brightness components would be recovered free of colour information.

Because in SEQUIN the monochrome carrier is not suppressed, no carrier re-insertion is necessary along the brightness axis. This feature allows compatible operation of conventional monochrome receivers and also permits a simple brightness-signal detection process in colour receivers, provided two precautions are taken before transmission. Simple diode detectors respond to the modulus of the composite transmitted waveform, which yields an incorrect grey scale. Thus brightness-signal compensation must be introduced to ensure that the modulus of the transmitted waveform is, in fact, the desired brightness signal. The second precaution is the generation of a pre-correcting signal to compensate for vestigial reception of the brightness signal. The main carrier is received at a nominal −6dB point in the receiver response, and without this correction the colour signal sidebands would introduce some brightness-signal transient distortion.

Simple tests have indicated that there is no difficulty in effectively compensating for the receiver modulus distortion at the transmitter, and a theoretical study and simple tests have indicated that because colour transients are less rapid than brightness transients, low order spurious signal generation at receivers may be effectively cancelled by transmitter compensation, although this is a more difficult process. The carrier locking technique mentioned in connection with the chrominance type of receiver is currently in use in wired distribution signal originating equipment for translating from a v.h.f. carrier to an h.f. carrier.

An important advantage of the proposed SEQUIN system is that it would make possible simpler receiver tuning—which, in subcarrier systems, can be a somewhat critical factor in obtaining good colour reproduction. In a SEQUIN receiver (of the first type) the local oscillator would always be locked in the correct frequency and phase relationship to the carrier, and colour reproduction would not depend on correct placing of a sub-carrier on the receiver response curve.

In general the proposed system has the advantages of a sequential system but would also overcome the compatibility problem that has characterized SECAM. Horizontal colour resolution would be superior to that of other systems because of the wider bandwidth colour signal (1.5 Mc/s for the British 625-line standard); and signal/noise ratio would be better, because of the different manner in which the transmitter power is shared between the brightness and colour signal. Low-power v.h.f. or u.h.f. translater stations would be able to handle the SEQUIN signal (which has no video equivalent) by the standard frequency changing technique without recourse to further transcoding. Finally, selective fading would not affect the ratio of brightness information and colour information.

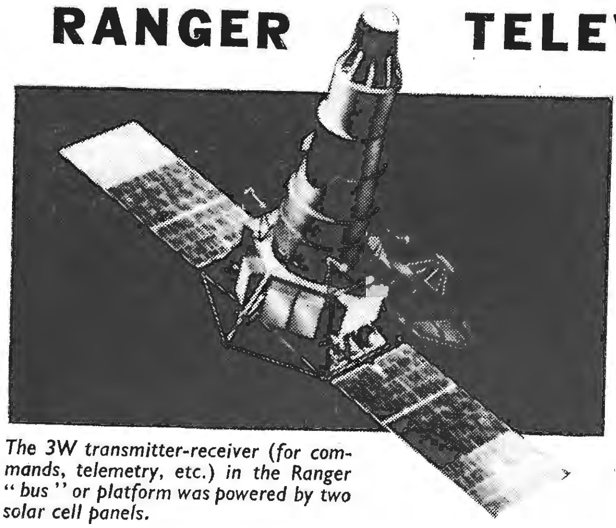
Acknowledgment

The author expresses his thanks to the Directors of Rediffusion Research Ltd. for permission to publish this article.

REFERENCES

1. British Patent Application 17346/64. See also "Colour television by wire," a paper read to the Television Society on 18th September, 1964.
2. "An alternative colour TV system," by E. J. Gargini. *Wireless World*, August, 1957.
3. See "Constant luminance," by Ian MacWhirter. *Wireless World*, November, 1964.

RANGER TELEVISION SYSTEM

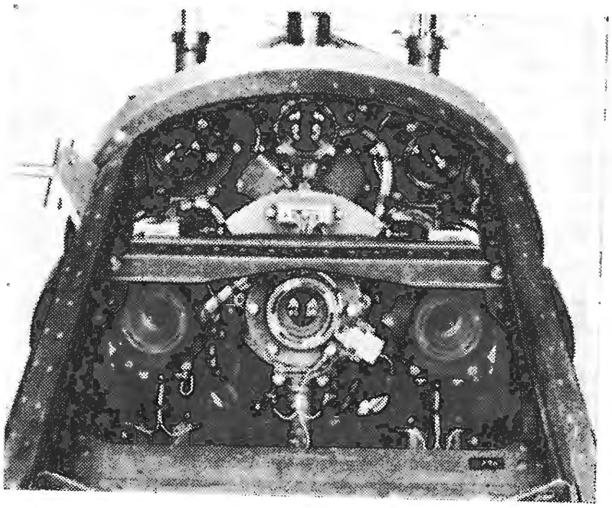


The 3W transmitter-receiver (for commands, telemetry, etc.) in the Ranger "bus" or platform was powered by two solar cell panels.

AFTER transmitting more than 5,800 pictures of the lunar surface Ranger 9, the final in the series, impacted the moon in the Crater Alphonsus on March 24th. Similar successful flights were achieved with Rangers 7 and 8 giving altogether a total of some 16,000 pictures taken at distances varying from 1,500 miles to $\frac{3}{4}$ of a mile from the moon. The resolution of the pictures televised by the six-camera R.C.A. system was excellent, detail being clearly observed in the final pictures of craters estimated to be about a yard across.

The television system, which was powered by two 33V batteries, employed two full-scan and four partial-scan cameras. The full-scan 1,125-line cameras were exposed and read out sequentially at 2.5 second intervals and the partial-scan cameras, which utilized only the central 282-lines of the raster, at 0.2 second intervals. During the intervals between exposure the photoconductive surface of each 1-inch vidicon tube was erased. Two 60W transmitters were employed for the TV system operating on 959.52 and 960.58 Mc/s.

Six R.C.A. cameras (the full-scan are in the centre) pointed at an angle of 38° from the roll axis of the spacecraft.



DUALITY

By "CATHODE RAY"

I DON'T usually have much to say in *Wireless World* about the Government, and the Editor is probably reaching for his blue pencil (or the electronic destructor that has no doubt superseded it) at the mere suggestion of such a thing, but he can relax. All I am going to remark on, and that quite non-politically, is the creation of Ministries of Education and Science and of Technology; because this is a sign of how growingly important these subjects are, and the need for more and better instruction therein. Every year the distance that students have to go through basic matters in order to reach the working face of their subject is greater. So anything that can help speed their effective progress is worth utilizing.

Perceptive teachers would agree, I think, that things are more easily remembered and more clearly understood if a pattern of relationships is seen. One of the admittedly most helpful methods of approaching a new subject is by way of analogy. And so electric currents in wires are likened to water flowing through pipes, difference of potential to difference in height above sea level, and so on. The danger of analogies such as this is that they are not perfect, so if they are followed too far they can mislead. For instance, resistance to the flow of water in a pipe is not inversely proportional to its cross-sectional area, as is resistance to the flow of electric currents in wires.

Duality is a perfect analogy. So it deserves special attention. Readers who have persisted with me for long—I believe there are some—may have noticed my occasional bursts of salesmanship for duality. But there are always others for whom this is their first *Wireless World*, and presumably still more whose ideas (if any) about electrical duals and duality are vague. It is these I invite to gather around.

The most elementary instruction on electric circuits includes the two modes of connection—series and parallel. When we come to a.c. we are told that inductance and capacitance behave in some respects as opposites. Both of these dual concepts occur together in resonant circuits, which contain inductance and capacitance and come in two kinds—series and parallel. If we compare the equations relating to them we should find certain systematic resemblances. To come to the point, all true statements or equations connecting the things in either of the columns below can be transformed into other true statements or equations by substituting the corresponding words or symbols in the other column.

Current, I	Voltage, V or E
Voltage, V or E	Current, I
Resistance, R	Conductance, G
Conductance, G	Resistance, R
Inductance, L	Capacitance, C
Capacitance, C	Inductance, L
Reactance, X	Susceptance, B
Susceptance, B	Reactance, X
Impedance, Z	Admittance, Y
Admittance, Y	Impedance, Z
Series	Parallel
Parallel	Series
Mesh	Junction (or node)
Junction (or node)	Mesh
Short-circuit	Open-circuit
Open-circuit	Short-circuit

Each item in these lists is the dual of the other on the same line. We can take a general equation connecting any of the listed quantities, and construct its dual by substituting the dual quantities. Take the familiar example usually called Ohm's law:

$$E = I R \quad \ldots \quad (1)$$

Substitute the symbols in the opposite column and we get

$$I = E G \quad \ldots \quad (2)$$

which is also true and sometimes more useful, especially with parallel circuits. Equation (1) is quite suitable for attacking Fig. 1(a), because the total R is just the sum of all the resistances, so the particularized version of (1) is

$$E = I(R_1 + R_2 + R_3) \quad \ldots \quad (3)$$

But the first time we are confronted with Fig. 1(b) we have to think a bit and finally come up with

$$E = \frac{I}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}} \quad \ldots \quad (4)$$

which lacks elegance. By applying duality to (3)—i.e., by referring to our parallel columns—we are spared the need for any thought and we arrive directly at the same thing as (4) in the neater form

$$I = E(G_1 + G_2 + G_3)$$

Conductance, G, is of course the reciprocal of resistance, i.e. $1/R$. It is also the dual of resistance, but not all dual quantities are reciprocals; the dual of L is not $1/L$.

As well as dual quantities and dual equations there are such things as dual circuits. You might think that Fig. 1(b) was the dual of (a) because its equation is. But we can see that this is not exactly so if we describe (a) in words and then transform it by using the parallel lists: thus, (a) comprises three resistors all in series with a voltage source. So its dual must be three conductors all in parallel with a current source.

A little difficulty arises when we come to draw the dual circuit diagram. Voltage sources are quite familiar: batteries and d.c. generators for d.c., and a.c. generators for a.c. Ideally they should have no resistance or impedance in themselves, and this condition can be approximated fairly closely in practice. Its dual must be a current source with no conductance in itself, and such things are not practical. The best we can do is use a very

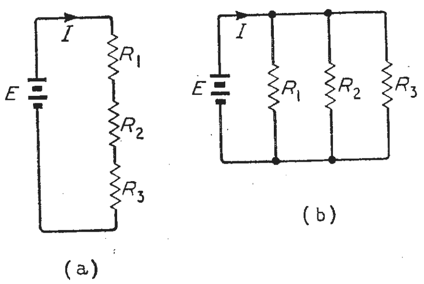


Fig. 1. Although "Ohm's law" is easy to apply to (a) it is slightly less convenient for (b), and its dual is to be preferred.

high voltage source in series with a very high resistance. There isn't even a reasonable symbol for a theoretical current source. Most people use Fig. 2(a), but there are two reasons why they should not: it is an international standard symbol for a transformer, and it doesn't suggest either the dual of a voltage source or a non-conducting path. So I use a dotted line to make clear the absence of conductance, and either the non-committal sine-wave symbol for a.c. or the letter I, Fig. 2(b).

Duality can be applied directly to "equivalent generators." A practical voltage generator has internal impedance, and can be represented in circuit diagrams for algebraical purposes by an ideal generator in series with an appropriate impedance. Dualwise, an actual current generator can be represented by an ideal current generator in parallel with an appropriate admittance. Fig. 3(a) shows the well-known equivalent generator which, for signals only, can be substituted for a valve.

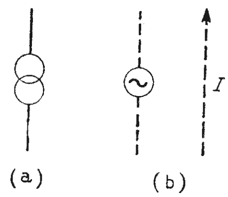


Fig. 2. The symbol (a), though often used to denote an ideal current generator, is unsuitable; (b) shows two possible alternatives.

Here μ and r_a are the voltage amplification factor and anode a.c. resistance respectively, and v_g is the signal voltage at the grid with respect to cathode. (I prefer to use v_{kg} for this, or even just kg, but am making a concession to common usage.)

If one were constructing a dual of the whole valve one would have to replace it by a current-operated device (e.g., a transistor). But when it is an actual valve it is more helpful to retain its voltage-control element, the grid, and just express the output side in its alternative current generator form. The series anode resistance is replaced by the parallel anode conductance, $g_a = 1/r_a$, in Fig. 3(b).

To be really equivalent these two must appear the same to any load connected to the terminals, so let us connect a short circuit to (a) and so find that the current therein is $-\mu v_g/r_a$. It must be the same in (b), and as this is equal to the current put into it by the generator it too is $-\mu v_g/r_a$. Since $\mu/r_a = g_m$, this is equal to $-g_m v_g$ as shown, g_m being the mutual conductance of the valve.

I should like to emphasize that *any* valve can be represented in either of these two ways, and both yield the same answers; but (b) is more convenient than (a) for valves of pentode type, especially if the load is made up of items in parallel.

Returning now to the aside about notation for voltages, I said I denoted the voltage at g with respect to that at k by V_{kg}. There are those who would call it V_{gk}. The latter usage is quite workable within a restricted field, but if one goes out for an integrated system embracing such things as phasor ("vector") diagrams and such well-established conventions (in graphs and other things besides voltage notation) as that "up" is positive and "down" is negative, one is driven to the conclusion that V_{gk} should mean the voltage change on passing from g to k.* The usual custom in common-cathode circuits is to take account of the change on passing from k to g; hence V_{kg}.

People who use a double-subscript notation for voltages—either of the two opposite varieties just mentioned—presumably think it is a good idea, because it indicates both the voltage and its direction (unlike the absurd arrows pointing *both* ways that are still often used) so why not for currents too? Up to that point the line of thought is impeccable, but unfortunately it almost invariably goes astray from there on. The thinker says to himself that if V_{ab} means the voltage between a and b then I_{ab} should mean the current flowing from a to b. He would get away with this in circuits like Fig. 1(a), where the junctions between the resistors might be marked a, b, c, etc. But what about Fig. 1(b)? There are four currents flowing between the only two circuit junctions and they are probably all different. That will never do, so he finishes up by distinguishing them as I_{R1}, I_{R2}, etc., sacrificing the indication of direction in the process. All very arbitrary and unsatisfactory.

If only he had remembered the table of duals he would have realized that current is the dual of voltage, so if the voltage subscripts refer to circuit junctions the current subscripts should refer to circuit meshes. This is perfectly specific and unambiguous; the current flowing through, say R_1 in Fig. 1(b), is not specified by the points between which it flows, for three other currents do the same, but it is uniquely specified by the meshes on each side of R_1. This is not even a revolutionary new idea; it was used for stresses in structures by Bow nearly 100 years ago.

If V_{ab} means the change in voltage on passing from point a to b, then I_{JK} (say) means the change in current on passing from mesh J to K. Just as, according to this notation, v_{ab} is positive if b is at a higher (i.e., more positive) potential than a, I_{JK} will be positive if the current around mesh K is more positive than that around J. There is a well-understood convention that b is more positive than a if electrons show a tendency to desert a in favour of b. (I would say that positive charges tend to move from b to a if somebody wouldn't be sure to jump up and ask what a positive charge is and why.) There is also a convention, probably less well understood, about mesh currents. For easing multi-mesh calculations, the great Maxwell suggested the concept of mesh or circulating currents, according to which each mesh is imagined to have a current circulating around

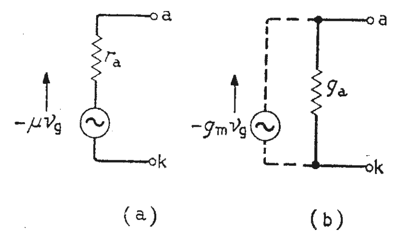


Fig. 3. Dual valve "equivalent generators": (a) voltage; (b) current.

it, the actual current in any conductor being the difference between the currents in the meshes separated by it. The difference, because all the mesh currents are supposed to have the same direction of rotation, so in any conductor they flow in opposite directions. This can be seen in Fig. 4, where the current through R_1 is clearly $I_L - I_K$, which is the meaning we can appropriately give to I_{KL}, just as $V_{ab} = V_b - V_a$.

Strictly speaking, V_a and V_b are meaningless, since the potential at any point is indeterminate unless given an

* The reasons are more fully given in *Essays in Electronics*, Chapter 12.

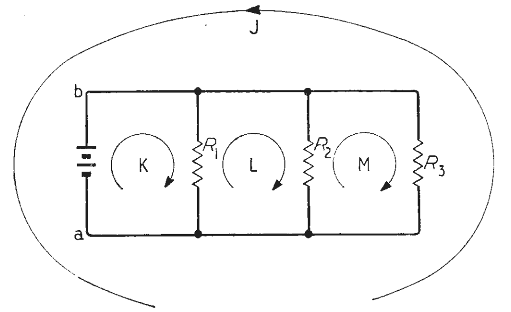


Fig. 4. Fig. 1(b) repeated with junction and mesh labels, to show circulating currents.

arbitrary figure or related to some other potential. Thus the potential of an earthed point is said to be zero. But $V_b - V_a$, or V_{ab}, is definite, because any constant that may be added to both of them cancels out in the difference. Similarly there are an infinite number of sets of mesh currents that could be equal to any set of actual currents, but these are reduced to one set by assuming that the current in the mesh formed by the circuit perimeter is zero. So in Fig. 4 I_{JK}, the actual current through the generator $= I_K - I_J, = I_K$ because $I_J = 0$.

The usual convention is for all the mesh currents (except the peripheral mesh) to flow clockwise. So for I_{KL} to be positive, I_L must be greater than I_K; in other words, a positive I_{KL} is one flowing from right to left as one passes from K to L.

I use capital letters to distinguish currents from voltages, because that renders the repeated symbols I, V and E superfluous, so there is no need for the junction and mesh designating letters to be subscripts. This greatly eases the labours of the typist and no doubt those of the compositor too. By using different letters for currents and voltages, as in Fig. 4, one avoids any oral confusion of AB with ab.

These notations and conventions lead to a simple and clear system of phasor diagrams, perfectly integrated with well-known electrical laws, principles, rules and conventions, including (as we have seen) Maxwell's concept of mesh currents. But there is not room to go into that here.

There is yet another field for duality—laws. Kirchhoff's voltage law in its original form fails to follow the dual pattern of his current law and obliges one to distinguish between e.m.fs. and voltage drops. When the law is extended to include a.c., this is sometimes difficult to do†—and quite unnecessary. So only misplaced sentiment will hinder the bringing of the voltage law into line with the current law and expressing it more neatly and simply as: Around any mesh the sum of the voltages is zero. This can be written in symbols

$$\Sigma V \equiv 0$$

or, in our notation,

$$ab + bc + cd + \dots\dots + na \equiv 0$$

where a, b, etc. are consecutive points around a mesh.

The precise dual of this would read: Around any junction the sum of the currents is zero. And correspondingly

$$\Sigma I \equiv 0$$

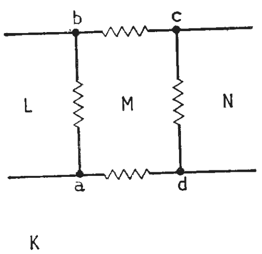
or

$$AB + BC + CD + \dots\dots + NA \equiv 0$$

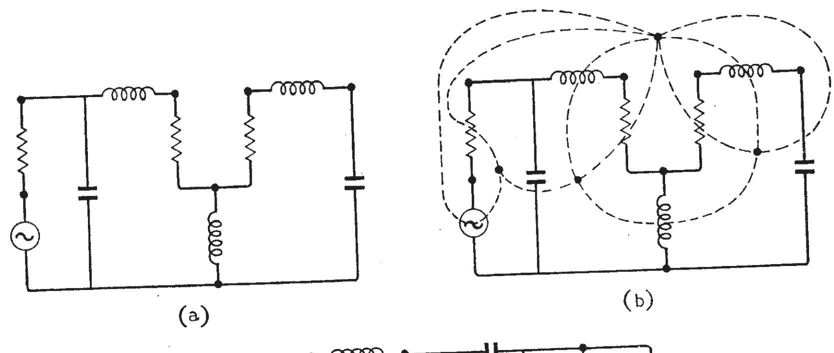
The above form of the current law, an abbreviated version of one suggested by Mr. C. E. Newton, may need a little explanation. Just as in Fig. 5 the voltages ab+bc+cd+da around mesh M add up to zero, so the currents KL+LM+MK (say) around junction a add up to zero, as do those around any of the other junctions. The words " mesh " and " junction " are used in the above statements of Kirchhoff's laws because they are applied to circuits, but the laws are equally true around any enclosures, even in open space. The sum of the changes in potential around any closed path is equal to zero, and so is the sum of the currents into any enclosed space, if Maxwell's displacement currents are included.

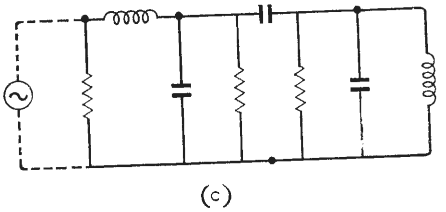
Note how the notation provides an automatic check of Kirchhoff's equations, as used in circuit calculations. The letters show completeness of path by forming a continuous sequence ending at the start.

†"E.M.F.", *Wireless World*, July and August 1964.



Above:—Fig. 5. Part of a circuit network for illustrating Kirchoff's laws.





Right:—Fig. 6. (a) Example of a circuit; (b) how to derive the dual configuration; (c) complete dual of (a).

A useful circuit theorem that has its dual is Thévenin's (or Helmholtz's). The dual is known as Norton's theorem. But as I wrote about this as recently as the January, 1964 issue perhaps it can be taken as read.

A more timely exercise would be to note the procedure for obtaining the dual of a circuit (I nearly said "any circuit," but see later). Because the dual of a mesh is a junction, we begin by putting a dot in each mesh to form the junction of the dual circuit. Don't forget the

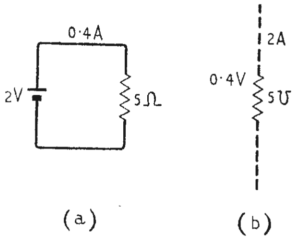


Fig. 7. Extremely simple example of duals with particular values.

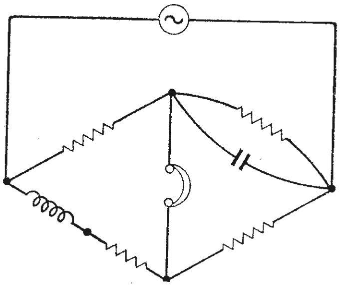


Fig. 8. Maxwell bridge circuit, which is its own dual.

external mesh. Then we join these dots by lines to form meshes around each junction. Lastly we include in these lines the symbols of circuit elements that are the duals of the elements crossed by the lines. So if two junctions in the original circuit were joined through an inductor, the part of the new circuit passing between these junctions would have to contain a capacitor.

Fig. 6 is an example, where the original circuit (a) has 4 meshes and 7 junctions, so its dual, found as shown at (b) and redrawn separately at (c), must have 4 junctions and 7 meshes. And of course the dual of (c) is (a). Note how series tuned circuits become parallel ones, and inductive coupling becomes capacitive. All equations relating to (a) have their duals relating to (c), obtained by simply changing over the symbols according to the list. But how about the actual component values, currents and voltages in (b), given those in (a)?

Fig. 7 (a) shows a very simple example, with all the quantities marked. In its dual (b), if we assume the numerical values pass over unchanged we do find that it still checks: a current of 2 amperes passing through a conductance of 5 mhos gives rise to 0.4 volt across it. But it is quite possible—and for some purposes convenient—to have a dual circuit configuration with different values. In such a simple circuit as Fig. 7 there would be no difficulty in prescribing any values one pleased for two of the quantities and calculating the third by equation (a). But in more complicated circuits where use of duality would be really worth while, much of its effort-saving would be wasted if one had to calculate new values throughout.

So it is perhaps worth knowing that a conversion factor can be used, having the dimensions of resistance (or impedance), to change from a certain number of amps to a different number of corresponding volts in the dual. Call this factor k. Then, if subscript 1 refers to the original circuit and 2 to its derived dual,

$$\frac{V_1}{I_2} = k \qquad \therefore\ I_2 = \frac{V_1}{k}$$

$$\frac{V_2}{I_1} = k \qquad \therefore\ V_2 = kI_1$$

$$R_2 = \frac{V_2}{I_2} = \frac{k^2 I_1}{V_1} = k^2 G_1$$

$$G_2 = \frac{I_2}{V_2} = \frac{V_1}{k^2 I_1} = \frac{R_1}{k^2}$$

This means that if we want the dual voltage (V_2) of a current (I_1) to be numerically equal to k_1, every dual voltage must also be k times its corresponding current, every dual current must be $1/k$ times its corresponding voltage, every resistance, impedance, reactance or inductance must be k^2 times its corresponding conductance, admittance, susceptance or capacitance, and every conductance, admittance, susceptance or capacitance must be $1/k^2$ times its corresponding resistance, impedance, reactance or inductance. So (using this sledge-hammer to crack the nut of Fig. 7) if we want 1.2V in Fig. 7 (b) our k is $1.2/0.4 = 3$, so besides the voltage being $3 \times 0.4 = 1.2$ the current must be $2/3 = 0.67$ and the conductance must be $5/9 = 0.56$. Similarly, we can choose any other ratio between one of the above four classes of duals, but the ratios of all the others are thereby fixed.

Duality can be useful for discovering alternative circuits that may be more convenient in practice; for example, Fig. 6 (c) with its capacitive coupling might cost less to manufacture than Fig. 6 (a), or *vice versa*. Then it is sometimes helpful to realize that two types of circuit that appeared to be quite different are duals of one another, so they behave correspondingly and all the equations for one can be easily derived from those for the other. Usually the dual is a different circuit, but not necessarily. Fig. 8 shows the Maxwell bridge circuit, the dual of which is the

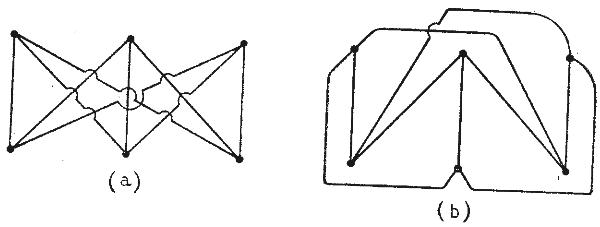


Fig. 9. The simplest network for which no dual exists: (a) in symmetrical form; (b) redrawn to reduce cross-overs to the minimum (one).

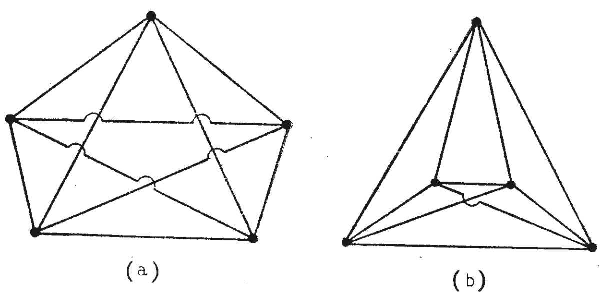
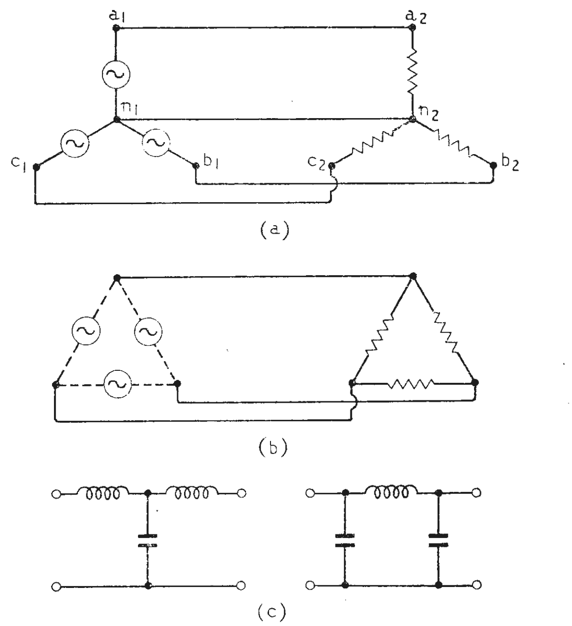


Fig. 10. Another dualless network, again (a) in symmetrical form and (b) with minimum crossing.

Fig. 11. (a) Three-phase star-connected system; (b) its dual, delta-connected; (c) identical with the foregoing modes of connection are the T and Π.



same except for the change from voltage to current generator. Obviously circuits of this kind must have the same number of meshes as junctions, and the same number of inductances as capacitances.

Finally, some circuits have no dual. It has been shown* that duality exists only if the circuit diagram can be drawn on a flat sheet of paper with no wires crossing. That might seem to rule out rather a lot, but in fact most basic circuits can be drawn without crossings. The simplest exception is shown in Fig. 9 (a). It is the basis of a celebrated puzzle, in which three of its points are supposed to be houses and the other three are sources respectively of gas, water and electricity; and the problem is to supply all three houses with all three services without any feeds crossing. It is not difficult to reduce the number of crossings to one—Fig. 9 (b)—but there one sticks.

Another relatively simple dual-less circuit is shown in Fig. 10, (a) being its most symmetrical form and (b) as redrawn with the irreducible minimum of one crossover. In Figs. 9 and 10 I have not bothered to draw the components that are supposed to exist between every pair of points.

Fig. 11 (a) is familiar to all electrical power engineers as a three-phase star-connected system. Drawn in this rather pictorial manner, two wires cross, but this can easily be avoided by interchanging b_2 and c_2 without affecting the circuit. The dual can then be drawn and turns out to be the equally familiar three-phase delta-connected system—Fig. 11 (b). These might be considered irrelevant in *Wireless World* were the star and delta configurations not identical with those well known to us all as the T and Π (c), for these are the basis of all filters and attenuators. They can be regarded as duals of one another.

*By B. D. H. Tellegen in *Philips Technical Review*, Vol. 5, No. 11 (Nov. 1940), pp. 324-330.

BOOKS RECEIVED

Nonlinear and Parametric Phenomena in Radio Engineering, by A. A. Kharkevich. In many of the processes encountered in radio—rectification, oscillation, etc.—the equations involved have variable coefficients or coefficients which depend on the function or its derivatives. This book, translated from the Russian, gives the basic mathematical equipment to tackle such problems and gives examples of its application. Pp. 190. John F. Rider Inc. New York, and published in Great Britain by Iliffe Books Ltd., Dorset House, Stamford Street, London, S.E.1. Price 35s.

The Elements of Pulse Techniques, by O. H. Davie, M.I.E.E. Covers generation, amplification, delay, measurement and application of electrical pulses, with emphasis on physical explanation rather than mathematical analysis. Aimed at students and technicians. Pp. 197. Chapman & Hall Ltd., 11 New Fetter Lane, London, E.C.4. Price £1 15s.

Guide Technique de l'Electronique Professionelle. Fourth Edition (1964/5) of a buyers guide to the French electronics industry, including foreign firms represented in France. In two volumes (weighing over 12 lb). Pp. 1,352. Publéditec, 13, rue Charles Lecocq, Paris 15e. Price (including packing and postage) 130F (but 160F in France).

Solid Circuits and Microminiaturization, proceedings of a conference held at West Ham College of Technology, June 1963, edited by G. W. A. Dummer, M.B.E., M.I.E.E. Contains 28 papers and five discussions on various aspects of the technology, including circuit design, manufacturing methods, descriptions of particular circuits and application to electronic equipment. Pp. 346. Pergamon Press Ltd., Headington Hill Hall, Oxford. Price £3.

Basic Electric Circuits, by A. M. P. Brookes, M.A., A.M.I.Mech.E., provides a grounding in the elements of circuit analysis for university and technical college students. It examines basic resistance, capacitance and inductance circuits and combined RCL circuits. A.C. theory, vectors and transients are dealt with briefly. Pp. 134. Pergamon Press Ltd., Headington Hill Hall, Oxford. Price 10s.

Radio Receiver Design. Part 1: Radio-frequency Amplification and Detection, by K. R. Sturley, Ph.D., M.I.E.E. Completely revised third edition of this standard work in which the application of transistors, where appropriate, has been afforded the same thorough treatment as is given to valves. Pp. 937. Chapman & Hall Ltd., 11, New Fetter Lane, London, E.C.4. Price 105s.

Transistor Bandpass Amplifiers, by W. Th. H. Hetterscheid. Mathematical treatment of the theory of design of single- and multi-stage amplifiers, including neutralization. (A complementary volume on the design and construction of i.f. amplifiers for radio, television and radar is in course of preparation). Pp. 314. Philips Technical Library, Cleaver-Hume Press Ltd., 10-15, St. Martins Street, London, W.C.2. Price 76s.

Aerial Handbook, by G. A. Briggs with R. S. Roberts, M.I.E.R.E., as Technical Editor. Another entertaining book from Wharfedale. Instead of audio the author's topic is this time radio (including television) with the aerial as the central, though by no means the only theme. The introduction says: "The book is not for the expert but for the reader who would like a little mystery taken out of that piece of wire." Pp. 144. Wharfedale Wireless Works Ltd., Idle, Bradford, Yorks. Price 8s 6d.

I.F. SWEEP GENERATOR

TRANSISTOR CIRCUIT FOR 465 KC/S AND 1.6 MC/S

By M. W. RIGNALL*

ALIGNMENT of many i.f. amplifiers may be done with a signal generator and output meter. If, however, a crystal filter is incorporated this is no longer possible except by a laborious point by point plot. For such amplifiers, a sweep generator and oscilloscope provide the only acceptable means of alignment. The unit described is capable of sweeping a 25 kc/s range at any point in the 450 kc/s and 1.6 Mc/s i.f. channels.

The operation of the swept oscillator depends upon the change of input reactance of a grounded-base oscillator as its emitter current is varied by the voltage derived from the horizontal scan. The magnitude of the input reactances at the chosen frequency is dependent upon the f_1 of the transistor, hence for a low-frequency device the input reactance is low. Thus for a given change of emitter current, the corresponding frequency change will be larger than in a high frequency transistor.

Circuit Function

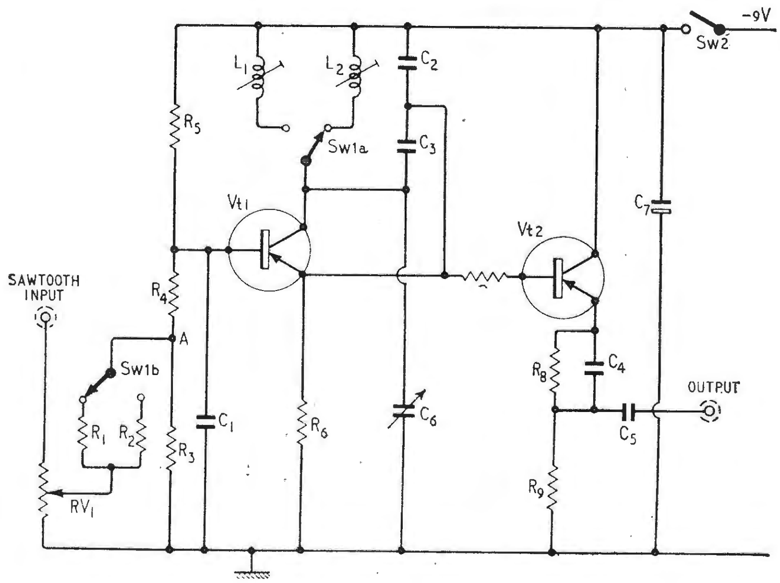
The practical circuit is shown in Fig. 1. A grounded base oscillator employing an OC170 is biased by the normal potentiometer circuit R_1-R_6, which establishes the unswept d.c. condition. The sweep voltage from the oscilloscope is passed via the deviation control RV_1 through a resistor R_1 or R_2 to the point A, thus varying the voltage at this point and adding a linearly increasing voltage to the base potential. The resultant change of emitter current varies the transistor reactances over a range governed by the magnitude of R_1 and R_2. Over the small range required the deviation is almost linear, but since the tuning capacity is greater at the l.f. end of a range and the swept reactance is constant, the deviation for a fixed setting of RV_1 will be lower at the l.f. end than the h.f. end. Figs. 2(a) and 2(b) show the deviation plotted against sweep voltage for both ranges.

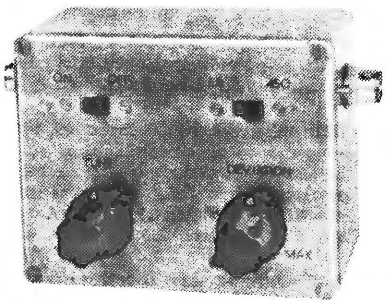
Sw1a selects the appropriate inductance for the range required, while Sw1b adjusts the swept current flowing into point A by selection of R_1 or R_2. This adjustment is necessary because the swept current must be reduced for the 1.6 Mc/s range, where a 25 kc/s sweep represents only a 1.6% deviation, in comparison with 5.5% at 450 kc/s. It should also be noted that the deviation, being dependent upon a change of working point, will also vary with the supply voltage since the sweep voltage at point A will be added to a reduced voltage as the battery discharges. This variation is plotted on Fig. 3.

Changes of ambient temperature do not measurably affect the deviation, but move the mean frequency by approximately 4% for a 25°C variation.

The sweep input required is 150 V peak, which is obtainable from several widely used measuring oscilloscopes. This may be readily modified for the 20 V sweep output from the "Wireless World" 'scope by substituting the input circuit of Fig. 4.

* The Marconi Company Ltd.





Above:—Prototype sweep oscillator.

Left:—Fig. 1. Circuit diagram of sweep generator arranged for 150V sawtooth input.

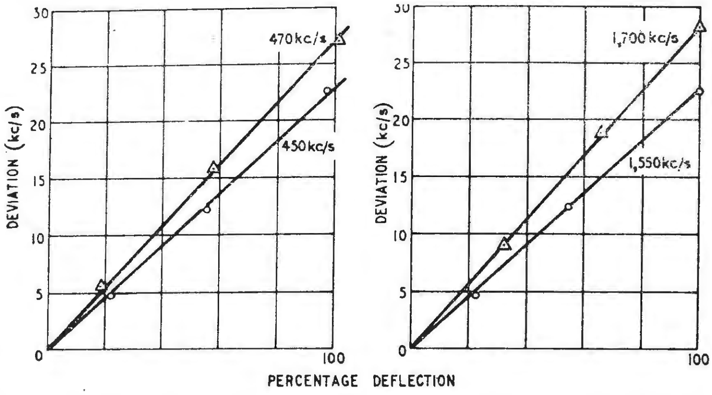


Fig. 2. Deviation plotted against input voltage for both frequency range.

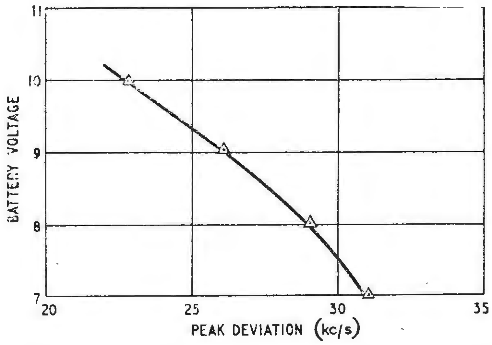
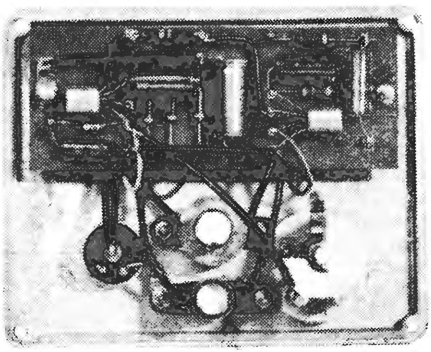


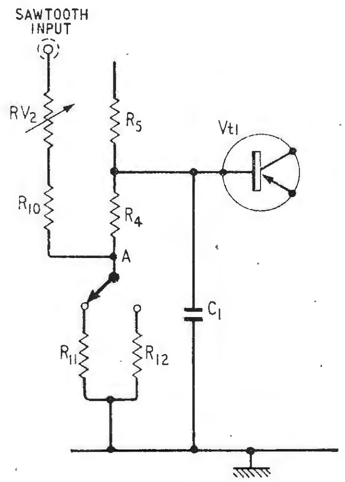
Fig. 3. Reduction of maximum obtainable deviation with decreasing battery voltage.

Since the deviation is a function of the f_1 of the oscillator transistor, the values of R_1 and R_2, R_{11} and R_{12} in Fig. 4 should be selected for the particular transistor used.

The swept output is taken through an emitter follower, giving an output of approximately 0.1 V r.m.s. from a 75Ω source.



Above:—Sweep oscillator component layout.



Right:—Fig. 4. Input circuit to accept 20V sawtooth input.

Construction

The complete unit is easily accommodated in an Eddystone die cast box, Type 650. The layout is shown in the photos. The components are mounted on a tagboard with turret lugs; the layout is, however, not critical, and any of the usual methods of construction may be adopted. The battery, a Vidor VT4 or equivalent, while not shown, is mounted on the floor of the box.

Testing

The first step is to adjust the cores of L_1 and L_2 to the correct ranges. With C_6 set to the maximum, the frequencies on the appropriate ranges (with no deviation) should be adjusted to 440 kc/s and 1,550 kc/s. A digital counter is the ideal setting-up device, but in the absence of a counter a communication receiver may be used. Many such receivers will have an i.f. in the 450 kc/s region. In this case the second harmonic of the generator may be used, noting however that the deviation must be set at 50 kc/s.

With the minimum frequencies set, a direct voltage equal to the peak sweep output should be applied to the sweep input socket with the deviation control set to maximum, i.e. RV_1 slider connected to the sweep input socket (or RV_2 at minimum).

The resistors R_1 and R_2 (or R_{11} and R_{12}) may be then adjusted to give a deviation of 25 kc/s. The approximate values for the correct sweep amplitude will be 100 kΩ and 33 kΩ for the 1.6 Mc/s and 450 kc/s ranges respectively of the circuit of Fig. 1, and 390Ω and 1 kΩ in the circuit of Fig. 4.

Several of these sweep generators have been assembled for the Marconi Company's internal use and all are giving satisfactory performances. It must be stated, however, that no manufacture for external sale is contemplated.

The author wishes to thank the Director of Engineering & Research of the Marconi Company for permission to publish this article.

Component List

R_1, R_2	See text	All 1/8 W±10%	
R_3	1kΩ		
R_4	4.7kΩ		
R_5	6.8kΩ		
R_6	2.2kΩ		
R_7	15kΩ		
R_8	330Ω		
R_9	82Ω		
R_{10}	4.7kΩ		
R_{11}, R_{12}	See text		
C_1, C_4, C_5		0.04μF paper	250V
C_2		0.02μF paper	250V
C_3		470pF polystyrene	250V
C_6		100pF air spaced variable	
C_7		25μF 12V electrolytic	
VT1, VT2		Mullard OC 170	
L_1	30T	Layer wound	On Aladdin
L_2	120T	in 5 slot bobbin	Former No. PP5892
		15/48 stranded	Core No. PP5804
RV_1		25kΩ	
RV_2		50kΩ	

Cathode and Emitter Decoupling

By J. F. YOUNG, C.G.I.A., A.M.I.E.E., A.M.I.E.R.E.

MOST electronic engineers use a certain number of "rules of thumb" in their work. Such rules of thumb are excellent in many ways since they remove the necessity always to think out problems from basic principles and so they can save a lot of the engineer's valuable time. However, such rules require occasional re-examination in order to bring them up to date as engineering techniques change. In some cases rules which have been perfectly adequate in the past become quite useless and must be rejected completely.

One rule which the writer often hears quoted is that the reactance of a cathode (or emitter) by-pass capacitor should be about one tenth of the cathode (or emitter) resistor value at the lowest operating frequency. Indeed, this rule appears in at least one respectable handbook. Now if it is a good rule, then it is sensible to use the highest possible value of cathode (or emitter) resistor in order to minimize either the lowest operating frequency or the size of capacitor required. In turn this implies the adoption of a high supply voltage so that at a given current a higher value of resistor can be used. Is this the true position? In order to find out we have to analyse the circuits mathematically.

Considering firstly the valve case, in Fig. 1 we obtain an expression for the gain:

$$\frac{v_o}{v_i} = \frac{\mu Z_L}{Z_L + r_a + (\mu+1)Z_k} \qquad (1)$$

(It is worth noting in passing that this is the gain which would be obtained with a valve having an anode slope impedance of $r_a+(\mu+1)Z_k$. We make use of this fact if we want to increase the effective anode resistance of a triode so that it can be used as a constant current source.[1]) Now in the usual amplifier circuit of Fig. 2, Z_k takes the form of a cathode bias resistor R_k by-passed by a capacitor C_k. Also the load Z_L takes the form of a resistor R_L. Therefore in this case the cathode circuit impedance can be written as:—

$$Z_k = \frac{R_k}{1 + j\omega C_k R_k} \qquad (2)$$

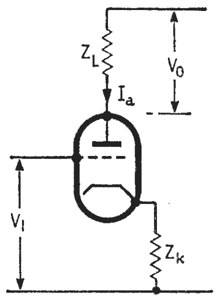


Fig. 1. Valve amplifier stage with cathode impedance Z_k.

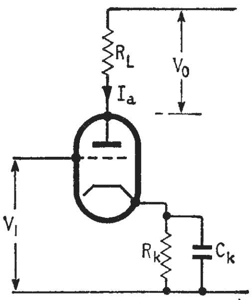


Fig. 2. Valve stage with cathode by-pass capacitor C_k.

Now if the values of Z_k and Z_L are substituted into equation (1), the gain becomes:—

$$\frac{v_o}{v_i} = \frac{\mu R_L (1 + j\omega C_k R_k)}{(R_L + r_a)(1 + j\omega C_k R_k) + (\mu+1) R_k} \qquad (3)$$

Equation (3) can be rewritten as:—

$$\frac{v_o}{v_i} = \frac{\mu R_L}{R_L + r_a + (\mu+1) R_k} \times \frac{1 + j\omega C_k R_k}{1 + j\omega \dfrac{C_k}{\mu+1} \times \dfrac{(R_L+r_a)(\mu+1) R_k}{R_L + r_a + (\mu+1) R_k}} \qquad (4)$$

Equation (4) is not really as complicated as it looks at first sight. The first term on the right:—

$$\frac{\mu R_L}{R_L + r_a + (\mu+1) R_k}$$

should be compared with equation (1). It is the gain which would be obtained if the capacitor C_k was not there at all. Since in these circumstances Z_k would simply be equal to R_k, the first term is completely independent of frequency. The second term on the right of equation (4) depends on the frequency, however, and

SYMBOLS

- μ valve amplification factor.
- Z_L load impedance.
- r_a valve anode slope resistance.
- Z_k cathode circuit series impedance.
- R_k cathode circuit resistance.
- C_k cathode by-pass capacitor.
- ω angular frequency $2\pi f$, where f is the operating frequency.
- R_L load resistance.
- g_m valve mutual conductance.
- I_e transistor emitter current.
- I_b transistor base current.
- I_c transistor collector current.
- α transistor emitter to collector current gain.
- Z_1 base circuit series impedance.
- Z_e emitter circuit series impedance.
- R_e transistor emitter resistance.
- R_2 emitter circuit resistance.
- C emitter by-pass capacitor.
- R_1 base circuit resistance.

this term determines the frequency response of the amplifier. The second term takes the form :—

$$\frac{1 + j\omega C_k R_k}{1 + j\omega CR}$$

where

$$C = \frac{C_k}{\mu + 1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

and

$$R = \frac{(R_L + r_a) \times (\mu + 1)R_k}{R_L + r_a + (\mu + 1)R_k} \quad \ldots \quad \ldots \quad \ldots \quad (6)$$

The imaginary resistor R can therefore be thought of as formed from $(R_L + r_a)$ in parallel with $(\mu + 1)R_k$, while the imaginary capacitor C is $(\mu + 1)$ times smaller than C_k.

Because of the presence of this frequency response term in the gain equation (4), we can see that the overall gain of the circuit of Fig. 2 is not independent of frequency. Instead, when the gain in decibels is plotted against the logarithm of frequency, a curve such as that of Fig. 3 is obtained. From equation (4) we can see that at very low frequencies, when ω is very nearly zero, the gain becomes:—

$$\frac{v_o}{v_i} = \frac{\mu R_L}{R_L + r_a + (\mu + 1)R_k} \quad \ldots \quad \ldots \quad \ldots \quad (7)$$

since the frequency response term equals one when $\omega = 0$. On the other hand, at very high frequencies, when ω approaches infinity, equation (4) gives a gain of:—

$$\frac{v_o}{v_i} = \frac{\mu R_L}{R_L + r_a + (\mu + 1)R_k} \times \frac{R_L + r_a + (\mu + 1)R_k}{R_L + r_a} \quad (8)$$

$$= \frac{\mu R_L}{R_L + r_a} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (9)$$

As might be expected, at high frequencies capacitor C_k removes the negative feedback, gain-reducing, influence of cathode resistor R_k. This is of course the reason for including C_k in the circuit in the first place.

Thus we know the low frequency gain and the high frequency gain. From equation (4) and Fig. 3 we also know the frequencies at which occur the "cut-off" points, where the characteristic curve departs by approximately 3 decibels from the low frequency and high frequency gain values. Now since capacitor C_k was added to increase the gain at any but the lowest frequencies, we are interested in the value f_1 of the lowest frequency at which the capacitor is very effective in holding up the gain. From Fig. 3 it can be seen that this lowest frequency is given by:—

$$\omega_1 = 2\pi f_1 = \frac{1}{CR} = \frac{R_L + r_a + (\mu + 1)R_k}{C_k R_k (R_L + r_a)} \quad \ldots \quad (10)$$

Simply in order to make more sense out of equation (10), let us make the assumptions that $(\mu + 1)R_k$ is so much greater than $(r_a + R_L)$ that we can neglect the latter and also that r_a is so much greater than R_L that we can neglect R_L. On the basis of these assumptions:—

$$\omega_1 \approx \frac{\mu}{C_k r_a} \approx \frac{1}{C_k \times 1/g_m} \quad \ldots \quad \ldots \quad \ldots \quad (11)$$

Thus, insofar as the assumptions are acceptable, the critical frequency below which the gain falls off fairly steeply depends on the relationship between the cathode by-pass capacitor value and the mutual conductance of the valve. The value of the cathode resistor is not very important in settling the required capacitor value. On the other hand the gain stops falling below a frequency f_2 given by :—

$$\omega_2 = 2\pi f_2 = \frac{1}{C_k R_k} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (12)$$

This frequency is clearly very dependent on the value of R_k. However, we are not normally very interested in the value of ω_2, our main interest is in the lowest frequency at which the capacitor is effective in maintaining the gain high, and this is determined by ω_1.

The argument so far is wide open to criticism in that some pretty wild assumptions have been made. In order to clear this up it will be as well to put a few typical values into our equations and to see what the numbers look like. Suppose we take a typical triode and operate it at -1 volt on the grid with an anode current of about 3.7 mA. Under these conditions r_a is 13.5 kΩ, g_m is 4 mA/V and μ is 54. Now suppose R_L is 39 kΩ. In order to obtain -1 volt of grid bias at 3.7 mA, a 270 Ω cathode resistor R_k is required. With these values :—

$$CR = \frac{C_k \times R_k (R_L + r_a)}{R_L + r_a + (\mu + 1)R_k} \quad \ldots \quad \ldots \quad \ldots \quad (13)$$
$$= C_k \times 211\,\Omega$$

Now g_m is 4 mA/V, so $1/g_m$ is 250 Ω and the approximation involved in equation (11) would give in this case a reasonable answer. However, also in this case R_k is 270 Ω so that the rule of thumb, which might be expressed as $CR = C_k R_k$, is not too bad an approximation either. In fact, of course, the only reason that the rule of thumb works at all is that in most of our circuits R_k is not terribly different from $1/g_m$. However, suppose that we keep all conditions the same except that we make R_k to a negative rail so that we can use a higher value of resistor. Can we then reduce the value of capacitor C_k without changing the cut-off frequency? Suppose that we increase R_k by nearly 40 times to 10 kΩ, can we reduce the value of C_k by 40 times and yet still obtain the same cut-off frequency? To obtain the answer, we examine the value of CR in this case. On substituting the correct values, including the new value of R_k, into equation (13), we find that :—

$$CR = C_k \times 873$$

Thus we can indeed reduce the value of C_k without

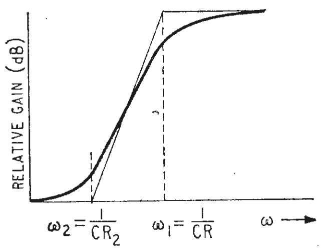


Fig. 3. Variation with frequency of valve stage gain.

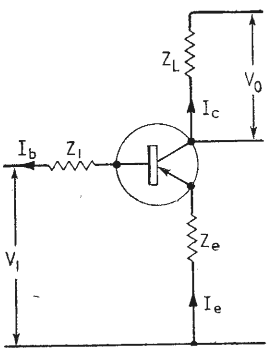


Fig. 4. Transistor amplifier stage.

changing the cut-off frequency, but only by about four times rather than forty times. If a rule of thumb is required, the only safe one is that the reactance of capacitor C_k should be low (say less than ten times) compared with $1/g_m$, rather than compared with R_k, at the lowest operating frequency.

With valves at least the usual rule of thumb is satisfactory for use with normal amplifier circuits, even if this is just a lucky accident. What of transistor emitter by-pass capacitors, what value should they have? Here some people carry over the rule of thumb from valve circuits and say hopefully that the emitter by-pass capacitor should have a reactance of one tenth of the emitter resistor value at the lowest operating frequency. After our experience with the valve case, it will be as well to defer comment until the circuit has been analysed.

In the transistor circuit of Fig. 4, we can say without doubt that $I_e = I_b + I_c$. If required, Kirchhof can be invoked but it would seem to be common sense that what goes in must come out somewhere. In addition, let us make the assumption that $I_c = \alpha I_e$, where α is a constant. This is an assumption which we can use safely at low frequencies with small signals as we can see from examination of the characteristic curves of a transistor. Accepting these two equations of operation, it is not too difficult to derive for the circuit of Fig. 4 an expression for the collector current I_c :—

$$I_c = \frac{\alpha V_1}{Z_1(1-\alpha) + Z_e} \quad \ldots \quad \ldots \quad \ldots (14)$$

Now suppose that Z_L is a resistor R_L, Z_1 is a resistor R_1 and Z_e comprises a resistor R_2 in parallel with a capacitor C, both in series with a resistor R_e as shown in Fig. 5. Thus :—

$$Z_e = R_e + \frac{R_2}{1 + j\omega R_2} \quad \ldots \quad \ldots \quad \ldots (15)$$

By substituting the various component values into equation (14), we can obtain an expression for the voltage gain of Fig. 5. :—

$$\frac{v_o}{v_i} = \frac{I_c R_L}{v_i}$$

$$= \frac{\alpha R_L}{R_1(1-\alpha) + R_e + R_2} \times \frac{1 + j\omega C R_2}{1 + j\omega C \dfrac{R_2(R_e + (1-\alpha)R_1)}{R_2 + R_e + (1-\alpha)R_1}} \quad (16)$$

Equation (16) can be compared with equation (4). Once again there is a fixed term and a frequency dependent term, the latter having the form :—

$$\frac{1 + j\omega C R_2}{1 + j\omega C R}$$

where

$$R = \frac{R_2(R_e + (1-\alpha)R_1)}{R_2 + R_e + (1-\alpha)R_1} \quad \ldots \quad \ldots \quad \ldots (17)$$

The imaginary resistor R can be thought of as a resistor R_2 shunted by the series combination of R_e and $(1-\alpha)R_1$. The frequency response obtained with the arrangement of Fig. 5 can be plotted as shown in Fig. 6. In this case :—

$$\omega_1 = \frac{1}{CR} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots (18)$$

so that the critical frequency is determined by :—

$$CR = C\frac{R_2(R_e + (1-\alpha)R_1)}{R_2 + R_e + (1-\alpha)R_1} \quad \ldots \quad \ldots \quad \ldots (19)$$

Usually $R_e + (1-\alpha)R_1$ will be small compared with R_2 and the former can therefore be ignored as a first approximation in the denominator of (19). On this assumption :—

$$CR = C(R_e + (1-\alpha)R_1) \quad \ldots \quad \ldots \quad \ldots (20)$$

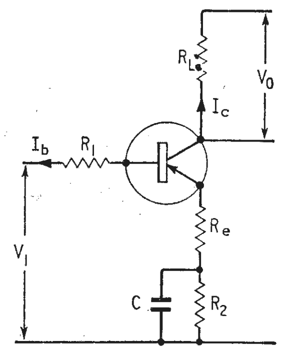


Fig. 5. Transistor stage with emitter by-pass capacitor C.

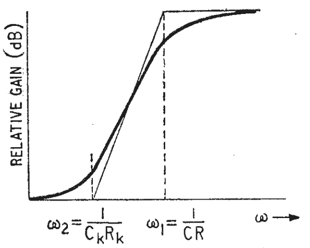


Fig. 6. Variation with frequency of transistor stage gain.

Thus with the transistor circuit, the minimum frequency at which the emitter capacitor C is effective depends largely on R_e, R_1 and α rather than on R_2. The reactance of capacitor C should therefore be small compared with $R_e + (1-\alpha)R_1$ at the lowest operating frequency in order to reduce the amount by which R_2 causes the gain to be reduced, even though R_1 is not in the emitter circuit.

Once again, the insertion of a few typical numerical values will make the position clearer. Suppose that $R_e = 20\Omega$, $R_2 = 1k\Omega$, $R_1 = 10k\Omega$ and $\alpha = 0.99$,

$$\text{then } R = \frac{1000 \times (20 + 10{,}000 \times 0.01)}{1000 + 20 + 10{,}000 \times 0.01} = 107\Omega$$

This value is much nearer to $(R_e + (1-\alpha)R_1) = 120\Omega$ than it is to $R_2 = 1k\Omega$, though if instead we happen to be using a value of R_2 in the region of 100Ω then the old rule of thumb would give a reasonable answer. Unfurtunately a value of R_2 as low as 100Ω would be likely to lead to thermal problems in many cases.

Thus the old rule of thumb should be used with caution, if it is used at all, in either valve or transistor circuits. However, it is always safe to say that the by-pass capacitor reactance at the lowest operating frequency should be low compared with $1/g_m$ in the valve case and with $(R_e + (1-\alpha)R_1)$ in the transistor case. It is interesting to note that the base series resistance R_1 has a large effect on the temperature stability of a transistor stage as well as on the frequency response.

REFERENCE

1. Young, J. F., A Transistor Characteristic Curve Tracer' *Electronic Engineering*, Vol. 31, p.330, 1959.

MANUFACTURERS' PRODUCTS

NEW ELECTRONIC EQUIPMENT AND ACCESSORIES

Plug-in Sampling Unit

A NEW plug-in unit that converts the existing 530, 540 and 550 series of Tektronix oscilloscopes into d.c. to 1 Gc/s sampling scopes is announced by Tektronix UK Ltd., of Beaverton House, Station Approach, Harpenden, Herts. Known as the 1S1 plug-in, it has internal triggering facilities that extend to over 1 Gc/s, calibrated sweep speeds from 0.1 nsec/cm to 50 μsec/cm and a unique "time magnifier" which allows any part of the display to be magnified up to 100 times horizontally without reducing the display dot density. The sweep speed, even when magnified, is read directly from a single knob.

Calibrated vertical sensitivities range from 2 to 200 mV/cm and a d.c. offset control is provided which allows millivolt signals to be observed in the presence of up to ±1 volt input levels. Provision is also made for driving x-y and y-t chart recorders.

5WW 301 for further details

Power Units for Logic Systems

A MODULAR unit for powering digital logic systems is being offered by Standard Telephones and Cables Ltd. Operating from 210-250 V, 50-60 c/s supplies, it provides 1 A at 24 V d.c. and 0.5 A at −6 V d.c. Separate voltage controls are provided and allow adjustment from 20.6 to 27.6 V on the 24 V rail and from −5 to −7 V on the −6 V rail.

The long and short term stability of the Type 19G power unit over the entire load range—and for 20% input variation—is better than 250 mV on the 24 V rail and better than 60 mV on the −6 V rail. The maximum ripple voltage is quoted to be 1 mV r.m.s. and protection is provided against accidental overload by means of a semiconductor current-limiting circuit. Both rack mounting and bench mounting versions of the Type 19G power unit are available from Electronic Services, S.T.C., Edinburgh Way, Harlow, Essex.

5WW 302 for further details

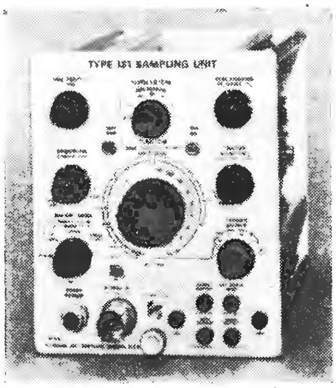
Small Industrial Relay

A COMMERCIAL version of the Clare Type F "crystal can" relay is announced by Clare-Elliott Ltd., a member of the Elliott-Automation Group. This small two-pole relay designated CF is primarily intended for computer and machine tool applications, and has been tested at speeds up to 30 c/s for 10 million operations without failure.

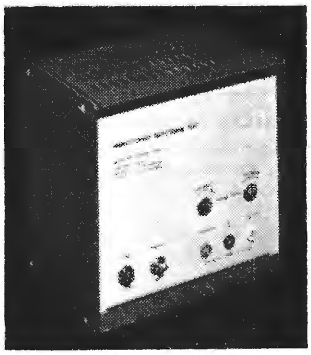
Sensitivity is 300 mW and maximum operate and release times is claimed to be 5 msec. Other specification details include a typical contact resistance of 25 milliohms (75 maximum) and contact ratings of 28 V d.c. resistive at 3A, 115 V a.c. resistive at 1 A and 88 V d.c. inductive at 1 A.

The company's address is 70 Dudden Hill Lane, Willesden, London, N.W.10.

5WW 303 for further details



Type 1S1 plug-in sampling unit for existing Tektronix oscilloscopes.

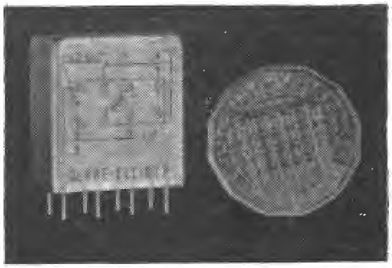


S.T.C. Type 19G power unit provides dual outputs suitable for driving analogue/digital converters and system logic circuits.

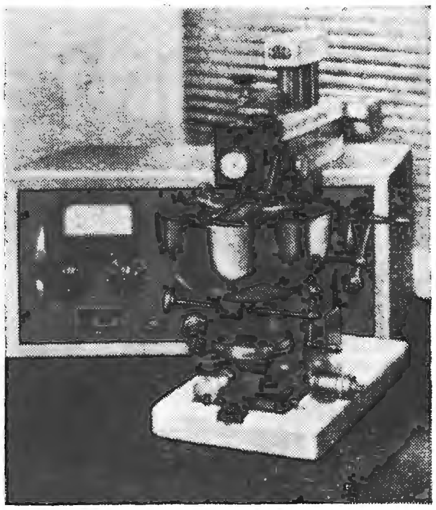
Spark Erosion Machine

A SMALL spark erosion machine suitable for machining extremely small components is announced by the South London Electrical Equipment Company, of Lanier Works, Hither Green Lane, London, S.E.13. This machine, known as the Arcotron, uses a dielectric liquid to reduce the distance between the cutting electrode and the workpiece. This allows a practical working voltage to be used and also serves to cool the operation and by flushing, to carry away the erosion products from the gap.

The Arcotron is capable of cutting slots down to approximately 0.00035 in



Small industrial relay, Type CF, from Clare-Elliott Ltd.



Precision spark eroder for use in the manufacture of micro-miniature components and apparatus. It is being made by the South London Electrical Equipment Company.

wide and alignment is to approximately 0.00002 in. A surface finish of approximately 3 microns is obtainable with this bench-mounted machine. Spark rate is about 1 Mc/s.

Applications for this machine in the electronics industry have so far been in the manufacture of evaporation masks, thin film resistor patterns and microwave components such as millimeter wavelength reflex klystrons.

5WW 304 for further details

"Broadcast" Vidicons

THE range of separate mesh one-inch vidicons manufactured by the English Electric Valve Company has been extended with the introduction of two new units having high peak response in the "blue" region of the spectrum. Entirely new photo-surfaces have been incorporated in these tubes, the 8625 (P846) and 8626 (P847), which give high resolution at high signal currents, correct panchromatic response with tungsten illumination, low lag and reduced long term sticking characteristics, and a very high and uniform sensitivity. The improved features have resulted in new manufacturing techniques whereby the photo-surfaces are "prefabricated" to ensure an overall even deposition. The extra blue sensitivity has also been found to improve considerably the signal to noise ratio in colour television cameras. While the 8625 (P846) has the standard 6.3 V/0.6 A heater, the other tube has a low consumption 6.3 V/0.095 A heater.

5WW 305 for further details

General-purpose Bridge

AN instrument containing a resistance-capacitance bridge, a resistance-capacitance-inductance comparator, a capacitance leakage/inductance-resistance analyser, a d.c. valve voltmeter and a d.c. valve ammeter has been introduced by the EICO Electronic Instrument Co. Inc., of 131-01 39th Avenue, Flushing, New York 11352. Called the EICO 965 FaradOhm Bridge Analyser, this instrument is suitable for measuring resistance from 0.5 Ω up to 500 MΩ (insulation resistance up to 100,000 MΩ) and capacitance from 5 pF to 5,000 μF. The internal supply to the bridge is only 0.45 V a.c. (at line frequency) which allows the instrument to be used for testing very low voltage components. An external voltage at a higher frequency and/or voltage may also be used, and an external polarizing voltage may be applied if required.

The six-range valve voltmeter and eleven-range valve ammeter—required for capacitance leakage/inductance-resistance analysis—may be used externally. The full scale voltage ranges cover 1.5 to 500 V d.c. with an input impedance of 10 MΩ on all ranges. Current range, full scale, is from 150 nA to 15 mA and the full scale voltage drop on all ranges is 75 mV.

The price of this instrument in the United States is $129.95.

5WW 306 for further details

Transistor Tester

AVAILABLE either as a kit of parts or ready made is the new Heathkit Model IM-30U transistor tester. It provides facilities for testing most p-n-p and n-p-n transistors and has a 15 μA basic range for leakage measurements. Tests up to 9 volts are effected from internal batteries and provisions are made for connection to external supplies for higher voltage and current tests. The Model IM-30U costs £24 18s 0d in kit form and £35 10s 0d assembled and is available from Daystrom, of Gloucester.

5WW 307 for further details

Small Closed-circuit Camera

ONLY 4½ inches long and weighing under two pounds is the new all-transistor closed-circuit television camera developed by EMI Electronics Ltd., of Hayes, Middx. The camera can operate on 405, 525 and 625 line standards and changing from one to another is achieved simply by pressing a button. The camera head equipment is contained in two sealed stainless-steel cylinders, each 4½ in long and of 1.7 in diameter. The lens head unit, which is fitted with a half-inch vidicon tube, can be up to 100 ft away from the amplifier head unit and is joined to it by cable. Camera control unit and other units comprising the camera channel can be up to 1,000 ft away.

5WW 308 for further details

Counter-timers

THE 3 Mc/s universal counter-timers (Types TM51B and TM51C) introduced last year by Levell Electronics Ltd. are now being produced under a revised specification which increases their top counting frequency to 6 Mc/s. The sensitivity figures are also revised and are as follows: 35 mV up to 300 kc/s, 100 mV at 3 Mc/s and 300 mV at 6 Mc/s. The ageing rate of the crystals has also been improved and now is 2 parts in 10^6/week for the TM51B and 3 parts in 10^7/month for the TM51C.

Both instruments are portable, have five-digit displays and differ only in the stability of the internal 1 Mc/s crystal reference standard. No change is to be made to the type numbers, or the price of the instruments which is £275 for the Type TM51B and £295 for the TM51C. The company's address is Park Road, High Barnet, Herts.

5WW 309 for further details

Klystron Power Supply

A SOLID-STATE power supply has been developed for medium-power klystrons by Microtest Ltd., of 9 Old Bridge Street, Kingston-upon-Thames, Surrey. It offers a fixed, regulated 300 volt output to drive the cathode (resonator), a continuously variable 0 to −300 volt output for the reflector and a 6.3 volt a.c. output for heaters. Current ratings are from zero to 50 mA, zero to 500 μA and 2 A respectively.

The reflector supply can be internally square wave amplitude modulated at frequencies between 900 and 4,000 c/s or externally frequency modulated by means of sawtooth waveforms or sinewaves. Amplitude of the internal modulation is 200 volts and is provided by a valve circuit.

5WW 310 for further details

Voltage Amplifier & Charge Amplifier

TWO new signal conditioning devices for piezoelectric accelerometers, a Type 1-302 voltage amplifier and a Type 1-

INFORMATION SERVICE FOR PROFESSIONAL READERS

To expedite requests for further information on products appearing in the editorial and advertisement pages of *Wireless World* each month, a sheet of reader service cards is included in this issue. The cards will be found between advertisement pages 16 and 19.

We invite readers to make use of these cards for all inquiries dealing with specific products. Many editorial items and all advertisements are coded with a number, prefixed by 5WW, and it is then necessary only to enter the number(s) on the card.

Readers will appreciate the advantage of being able to fold out the sheet of cards enabling them to make entries while studying the editorial and advertisement pages.

Postage is free in the U.K. but cards must be stamped if posted overseas. This service will enable professional readers to obtain the additional information they require quickly and easily.

303 miniature charge amplifier, are announced by the Consolidated Electrodynamics Division of Bell and Howell Ltd., of 14 Commercial Road, Woking, Surrey. Two standard models of the voltage amplifier are available. One is equipped with a voltage limiter and an adjustable voltage control oscillator reference supply, and the other contains an augmenter (power amplifier) that can drive several hundred feet of cable or very low load impedances (down to 1,200) without distortion of the signal.

The Type 1-303 charge amplifier is the first of a series to be introduced by Consolidated. It features low power drain, wide frequency response (5 c/s without the requirement of a long time constant), good stability under extreme environmental conditions, and low output impedance.

Transistors are used in the voltage amplifiers, which weigh 45 grams, and in the charge amplifier which weighs 25 grams.

5WW 311 for further details

Push-Button Reed Switches

A NEW push-button reed switch providing complete separation between the mechanical and electrical functions is being manufactured by Highland Electronics Ltd., of 26-28 Underwood Street, London, N.1. A cylindical magnet connected to the end of the push-button is used to operate a pair of reed switches which are individually encased in glass tubes and mounted in p.v.c. shock absorbers on the outer part of the assembly.

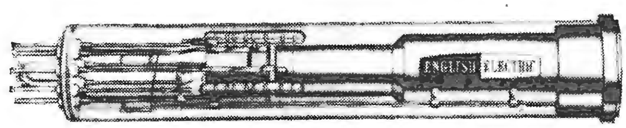
The standard switch is supplied with two make contacts, however, other configurations can be supplied such as two break, one make and one break, and two changeover. The d.c. contact rating varies from 0.5 to 10 watts according to the construction and the type of contact used.

The operating time of the switch, which the makers claim is independent of the speed of operation of the push-button is approximately 500 μsec. Release time is a few microseconds. The magnets in these switches are not demagnetised or influenced by normal stray fields and do not require magnetic shields. At full rating, the life span is 10^7. The approximate dimensions are 2.316 in long by $\frac{3}{4}$ in diameter. Maximum weight is 2 oz.

5WW 312 for further details

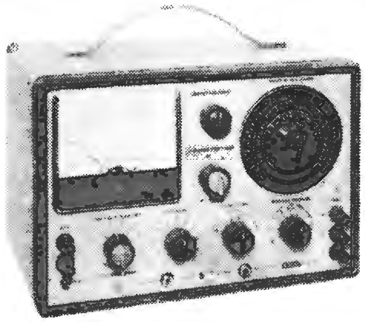
"Domestic" Transistors

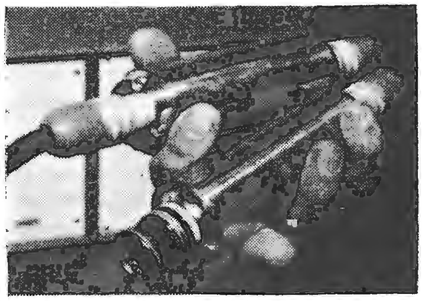
SEVERAL new transistors have recently been introduced by Mullard Ltd. for domestic receivers, including a series with the trademark TVistor. So far there are four transistors in the TVistor



A new photo-surface material has been used on two new one-inch separate-mesh vidicons from the English Electric Valve Company.

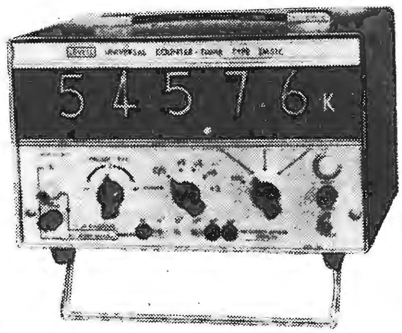
EICO Model 956 FaradOhm Bridge Analyser.



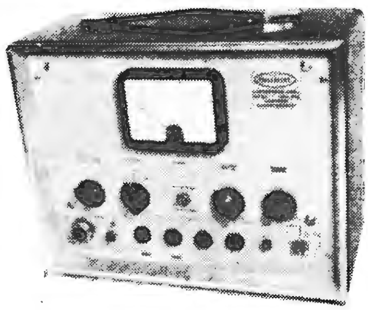


Small television camera made by EMI Electronics Ltd. for closed-circuit applications. The head amplifier for the camera is housed in the rear stainless-steel container.

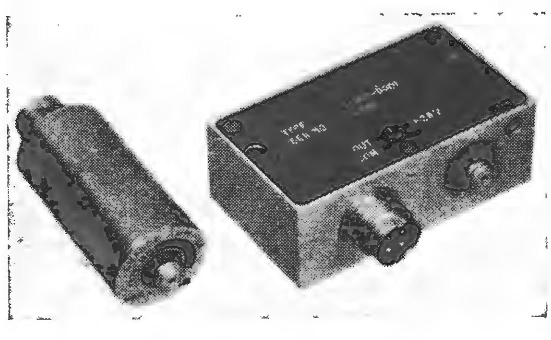
Right: Universal counter-timer Type TM51C with a top counting frequency of 6 Mc/s (Levell Electronics Ltd.).



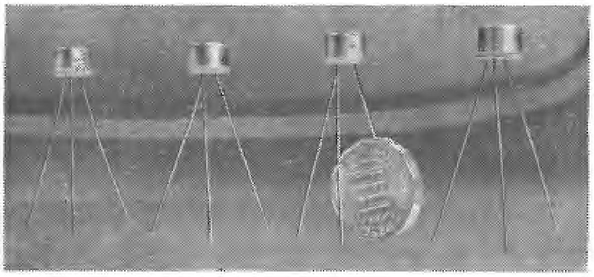
Heathkit Model IM-30U transistor tester from Daystrom Ltd.



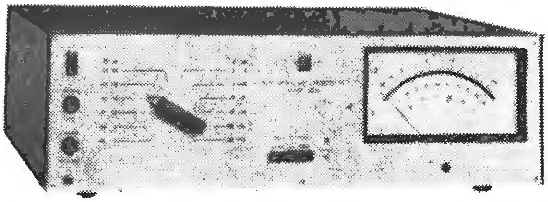
Right: Microtest Type 700 klystron power supply.



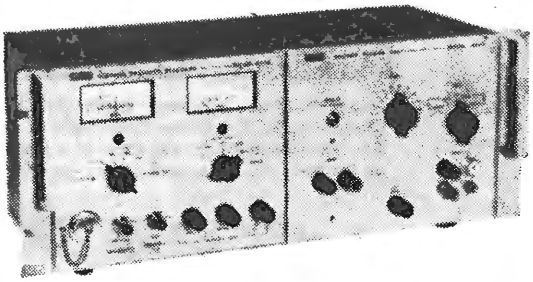
Left: Voltage amplifier and charge amplifier produced by Consolidated Electrodynamics for use with piezo-electric accelerometers.



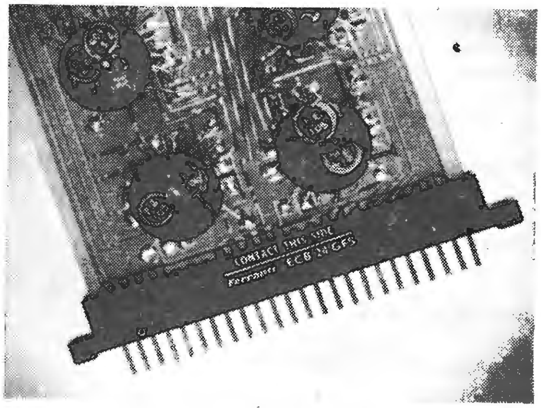
TVistor series of transistors Mullard's have introduced especially for domestic television applications.



Model EMT 125 low-frequency millivoltmeter (Elektromesstechnik Wilhelm Franz KG).



Fluke Model 540B thermal transfer standard. Thermal reversal error is less than 0.01% of input.



Twenty-four contact printed circuit board edge connector (Ferranti Ltd.).

series: AF186, an amplifier and self-oscillating mixer for u.h.f. tuners; AF180, an amplifier for v.h.f. tuners; AF178 a mixer/oscillator for v.h.f. tuners; AF181 and AF179, which are both vision i.f. amplifiers.

The AF186 is an alloy-diffused transistor and can be controlled with forward a.g.c. to give improved signal-handling whilst retaining a low voltage standing wave ratio at the aerial input. The AF178 and AF180 are germanium alloy-diffused transistors and a typical noise figure of 5 dB and a gain figure of 18 dB is quoted for the AF180 which, incidentally has a control range with attenuation of 40 dB. The remaining two transistors, the AF179 and AF181 provide power gains of 75 to 80 dB in typical i.f. stages. The AF181 is primarily intended for use in the first stage of i.f. amplifiers (or as a second stage in a three-stage unit) where adequate gain control is necessary if maximum signal-to-noise ratio is to be achieved. Hence the AF181 has a large control range—greater than 50 dB. The companion transistor, the AF179 is particularly suitable as an output device as it is able to maintain a constant gain at high current levels and has high dissipation characteristics. It also features low bottoming (voltage) at high frequencies.

A line-output transistor designated AU103 and a silicon efficiency diode BY118—both intended for use in conjunction with the A28-13W eleven-inch television picture tube—have been developed by Mullard's for portable television applications. The transistor has a collector-emitter voltage rating of 155 volts and a collector current rating of 10 A with fast turn-off characteristics. Fast switching is also claimed for the diode which has a reverse voltage rating of 300 V and a current rating of 14 A.

Mullard's have also recently produced a new r.f. transistor which they claim will make possible a reduction in the number of i.f. stages in a.m. and f.m. receivers. This silicon epitaxial planar device, designated BF115, is suitable for use up to 100 Mc/s—noise level at this frequency is about 3.6 dB—and has a high forward gain coupled with a low value of feed-back capacitance. A figure of not greater than 0.7 pF is quoted for a collector-to-emitter voltage of 10 V. Other features of this device include good a.g.c. performance, high resistance to voltage surges, a V_{CEO} rating of 50 V and a knee voltage of less than 1 V at 10 mA.

5WW 313 for further details

Low-frequency Millivoltmeter

A NEW high-stability millivoltmeter that can also be used as a laboratory measurement amplifier is announced by the German manufacturers Elektromesstechnik Wilhelm Franz KG, whose address is 763 Lahr/Schwarzwald, Kaiserstrasse 80. Designated EMT 125, it covers 1 mV to 300 V (f.s.d.) in twelve ranges and has an input impedance of 1 MΩ. The output impedance in the amplifier mode is 4 Ω.

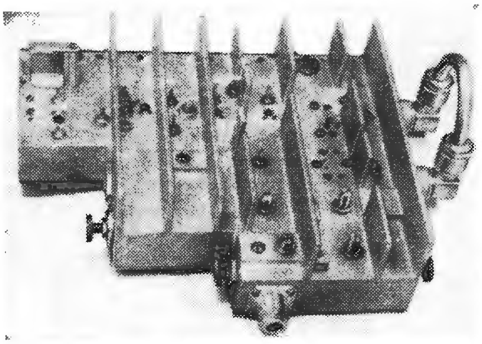
Transistors are used throughout the EMT 125, which conforms to the DIN 45 402 specification. The instrument is fully protected against accidental overloading and bursts of h.f. The upper cut-off frequency of the EMT 125 is 200 kc/s but, by switching, this may be reduced to 20 kc/s.

5WW 314 for further details

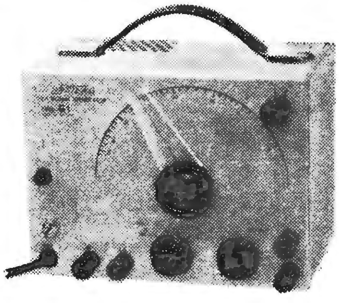
A.C./D.C. Comparator

AN instrument for accurate a.c. voltage and current measurement using thermal transfer techniques is being made by the John Fluke Manufacturing Co. Inc. Called the Model 540B thermal transfer standard, it has fourteen voltage ranges covering 0.25 to 1,000 V r.m.s., with a frequency range of 5 c/s to 50 kc/s and an input impedance of 182 ohms/volt of input.

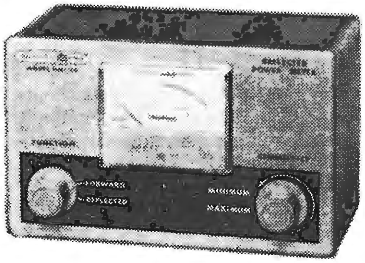
Without the use of calibration curves or correction tables, the basic a.c. to d.c. transfer accuracy is ±0.01%. The transfer is achieved by means of a specially constructed vacuum thermocouple which, incidentally, is protected against overload. Each input range may be used



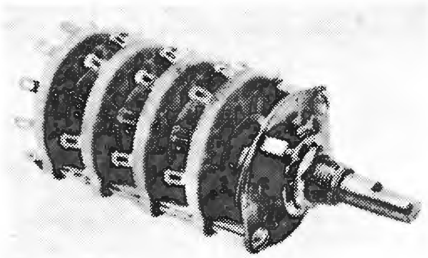
Five-watt transistor local oscillator unit designed to operate at 2Gc/s. This unit is part of the new G.E.C. range of transistor microwave communications equipment.



Low frequency signal generator introduced by Linstead Electronics Ltd.



Heathkit reflected power meter and v.s.w.r. bridge Type HM-11U.



One of the Moduline series of rotary switches offered by Diamond H Controls Ltd.

to measure voltages from $\frac{1}{2}$ to 1 times the range setting; maximum galvanometer resolution varies between 0.0012% of input per scale division at 1 times to 0.006% of input per scale division at $\frac{1}{2}$ of range setting.

A series of thirteen shunts are available for the 540B and allow precision current measurements from 2.5 mA to 10 A a.c. The basic accuracy is $\pm 0.03\%$ and the frequency range is from 5 c/s to 100 kc/s.

Nine high-frequency thermal convertors are also available for the 540B and extend the frequency range of the instrument to 50 Mc/s. One is provided for each voltage range from 0.5 to 50 V and may be used at $\frac{1}{2}$ to 1 times the rated voltage.

This instrument is available in the United Kingdom through Livingston Laboratories Ltd., of 31 Camden Road, London, N.W.1.

5WW 315 for further details

Printed Circuit Board Edge Connectors

A SELECTION of single- and double-sided printed circuit board edge connectors is available from Ferranti Ltd., of Kings Cross Road, Dundee. Contact sizes range from 8 to 40 in multiples of 8. The spacing between contacts is 0·150 in and the d.c. working voltage is 450 V. The current capacity of each pole is one amp.

Polarizing keys are provided which may be inserted into any of the pole positions without removal of, or damage to, the contact concerned. The contacts are of phosphor bronze and the actual contact area is gold-plated to a depth of 0·0002 in.

5WW 316 for further details

Low-frequency Signal Generator

COVERING the frequency range 10 c/s to 100 kc/s in four switched ranges is the Model G1 generator from Linstead Electronics Ltd., of 35c Newington Green, London, N.16. This unit, which operates from the mains, provides up to 6 V r.m.s. sine wave output, up to 9 V p-to-p square wave output, and up to one watt at three ohms over the frequency range 50 c/s to 20 kc/s. The G1 measures $8\frac{1}{4} \times 6\frac{1}{2} \times 6$ in, weighs $7\frac{1}{2}$ lb and costs £20.

5WW 317 for further details

Transistor Microwave Equipment

MICROWAVE communications equipment using transistors throughout is being manufactured by G.E.C. (Telecommunications) Ltd., of Coventry. So far G.E.C. have two units in production, one suitable for main trunk routes and will carry 960 speech circuits—or a television channel—in the frequency bands 1.7 to 1.9 Gc/s and 1.9 to 2.3 Gc/s. Auxiliary equipment for this two-watt link has also been transistorized.

A capacity of 300 speech channels is provided by the second unit, which operates between 7.4 and 7.7 Gc/s. This equipment is suitable for spur applications and a feature is that any part of the baseband may be dropped and re-inserted at any repeater station without demodulation of through circuits.

5WW 318 for further details

Rotary Switches

MODULAR rotary switches introduced in the United States a few months ago by the Oak Electro/netics Corporation, are now being made-up by the British subsidiary Diamond H Controls Ltd. This series of switches, designated Moduline, gives the design engineer a wide range of variables, as follows: 6 different switch sizes; 101 different sections; choice of up to 24 positions; 6 different shaft ends; 24 options of flat angle; 1 choice of bushing; 2 locating key positions; 383 variations of the complete assembly; 5 choices of detent angle, depending on the type of switch; and 24 different shaft lengths.

The address of Diamond H Controls Ltd. is Vulcan Road, Norwich, NOR 85 N.

5WW 319 for further details

Reflected Power Meter & V.S.W.R. Bridge

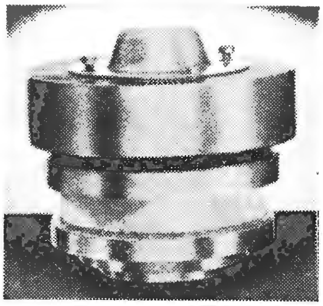
AN inexpensive instrument that can be used to indicate percentage forward and reflected power, and voltage standing wave ratio is announced by Daystrom Ltd., of Gloucester, in the form of the Heathkit Model HM-11U. Although designed primarily for use with amateur radio transmitters, this instrument has an r.f. power handling capability of 1 kW and may be suitable for some commercial applications. The input and output impedance of the Model HM-11U is 75 Ω and the band coverage is from 160 to 2 metres (2 to 150 Mc/s). Insertion loss from 160 to 10 metres is less than 1% and less than 10% up to 2 metres.

This instrument measures $4\frac{5}{8} \times 7\frac{3}{4} \times 4\frac{1}{16}$ and weighs $2\frac{1}{2}$ lb. Assembled, the price of the Model HM-11U is £10 10s 0d and in kit form it costs £8 5s 0d.

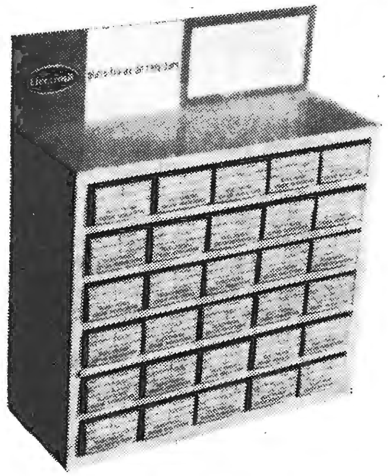
5WW 320 for further details

High-power S.S.B. Tetrode

ABLE to develop a load power of 1 kW, the new Mullard YL1230 tetrode utilizes



Mullard YL1230 metal-ceramic tetrode for s.s.b. applications at frequencies up to 200 Mc/s.



Metal oxide resistor kit from Electrosil Ltd.

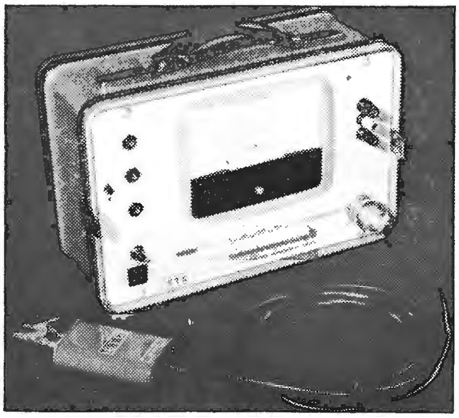
metal-ceramic techniques to ensure optimum stability, high gain and low distortion, and is suitable for single sideband applications. At 1 kW output level −40 dB can be achieved without the use of r.f. feedback.

Typical s.s.b. operating conditions for the YL1230, which is suitable for use at frequencies up to 200 Mc/s, are as follows: Va 2.5 kV; Vg_2 250 V; V.. −50 V; Ia 600 mA; and p-e-p output of 1.2 kW.

5WW 321 for further details

Metal Oxide Resistor Kit

A METAL oxide resistor kit containing thirty values of resistor, each with three ratings (general purpose, high-stability and semi-precision) has been introduced by Electrosil Ltd., of Pallion, Sunderland, Co. Durham. The kit is housed in a cabinet measuring 14×12×5 in and normally covers the E6 range of preferred values, but special combinations of resistance values can be supplied to order. The resistors are



S.T.C. Type 74251 millivoltmeter introduced for general purpose and telecommunications use.

qualification approved to DEF 5114A and have Post Office approval to D.2228A. Stability of all resistors is 0.5% at semi-precision rating, 1% at high-stability rating, and 2% at general purpose rating. Standard tolerances are 5%, 2% and 1%.

5WW 322 for further details

Differential Amplifier Transistors

TWO isolated high-gain, low-noise silicon planar transistors housed in a micro-miniature encapsulation about 150 times smaller than a TO-5 transistor can are being manufactured by the National Semiconductor Corporation. The two transistors in the block, designated NS7070, have a d.c. beta of 100 and are matched to within ±10%; the base-emitter voltages differ by less than 5 mV. The change in base-emitter voltage differential with temperature is 10 μV per degree Centigrade from −55 to +125°C, when the collector voltage is 5 V and current is 10 μA. Connections to the block, which measures 0.080×0.065×0.065 in, are by 0.005 in wires that can be soldered or welded.

These silicon blocks are handled in the United Kingdom by Walmore Electronics Ltd., of 11-15 Betterton Street, Drury Lane, London, W.C.2.

5WW 323 for further details

Millivoltmeter

A NEW general purpose a.c. millivoltmeter, covering 0-1 mV, 0-3 mV up to 30 V f.s.d. in ten ranges, is announced by the Transmission Testing Apparatus Division of Standard Telephones and Cables Ltd., Corporation Road, Newport, Mon. An active probe is employed with the new 74251 millivoltmeter, making it suitable for use in the frequency range 20 c/s to 20 Mc/s. Input impedance is greater than 100 kΩ in parallel with 40 pF.

An easy-to-read meter display containing two r.m.s. voltage scales and a decibel scale for use with 75-ohm circuits is provided and all the switching functions, including range, are by push-button. This portable, transistorized instrument may also be used as a bridge detector, and its calibrating oscillator can be used to supply approximately 100 kc/s at 300 mA for external use. The internal amplifer may also be used for external applications.

5WW 324 for further details

Tunable Magnetrons for Frequency Diversity Radar

TWO tunable magnetrons designed to provide the controlled frequency jumping required by diversity radar systems are announced by Mullard Ltd. These magnetrons, which have been designated JPS9-80 and JPS9-200, operate in the frequency range 8.5 to 9.5 Gc/s and are tuned by a high-speed spinning tuner mounted in a specially designed resonant cavity. This provides a "fail-safe" arc-free type of tuning and is driven by a simple servo-motor. The system covers 450 Mc/s in 500 μsec in a quasi-sinusoidal manner.

This type of drive which utilizes the fringe fields of the magnetron magnet is said to avoid the inherent life limitations of the slower, hydraulic systems and the life of the units is dependent only on the cathode life—as with fixed frequency magnetrons. They are also considerably smaller than the hydraulically tuned magnetrons or the high-power klystrons of the type normally used in the local oscillator power amplifier chain of a radar system. They are in fact only slightly larger than the fixed frequency types. The smaller of the two, the JPS9-80, weighs 8 lb and has a minimum output power rating of 70 kW, while the other weighs 15 lb and is rated at 200 kW.

These spin-tuned magnetrons may be used at fixed or programmed pulse repetition rates with a variation in output frequency, or at fixed or programmed frequencies with a variation in repetition rate. The smaller of the two is now in production and development samples of the JPS9-200 are available.

5WW 325 for further details

Airmec

The upper limit of the frequency range of the Airmec Type 298 counter advertised on page 77 of our April issue is 100 Mc/s, not 50, as stated in error.

WORLD OF WIRELESS

Colour Television Deadlock

THERE now seems little likelihood of an internationally agreed standard for colour television. The two-week meeting in Vienna of the C.C.I.R. television study group, which was attended by some 200 delegates from 45 countries, ended with a majority vote for SECAM (22) with PAL second (11) and N.T.S.C. third (6). It now remains to be seen whether any countries will introduce a service using the system of their choice, although the C.C.I.R. statement at the conclusion of the meeting said efforts to secure agreement on a single system must continue and the subject will be examined again at its plenary assembly in Oslo in 1966.

The countries voting for the three systems were:—

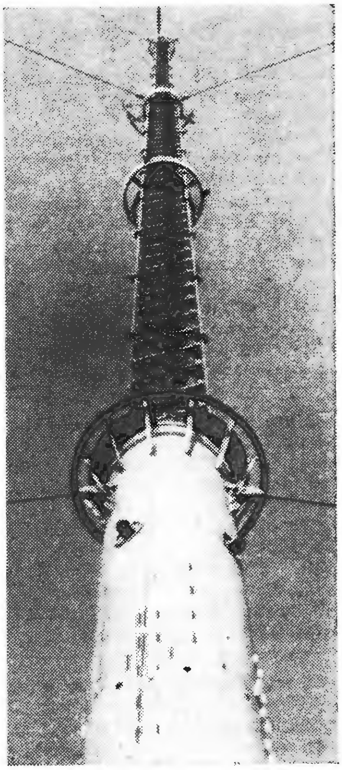
SECAM:—Algeria, Argentina, Bulgaria, Byelorussia, Cameroon, Czechoslovakia, France, Gabon, Greece, Hungary, Luxembourg, Mali, Monaco, Morocco, Niger, Poland, Rumania, Spain, Tunisia, Ukraine, Upper Volta and U.S.S.R.

PAL:—Austria, Denmark, Finland, Iceland, Ireland, Italy, New Zealand, Norway, Sweden, Switzerland and West Germany.

N.T.S.C.:—Brazil, Canada, Japan, Netherlands, U.K. and U.S.A.

Six countries abstained:—Australia, Belgium, Pakistan, South Africa, Turkey and Yugoslavia.

With no decision made at Vienna, there is opportunity for further evaluation of existing and new systems (see, for example, p. 210). A statement by the Postmaster General that the implications of Vienna must be fully considered before a date can be fixed for introducing colour in Britain suggests that the U.K. is not necessarily committed to N.T.S.C. Within days of the end of the conference the Television Advisory Committee met to discuss the situation. Engineering thinking within the I.T.A. and the programme companies, now appears to be favouring PAL.



Cylindrical steel mast *at Winter Hill, near Bolton, Lancs, which will carry the aerials for both the B.B.C. and I.T.A. transmitters. It is 1,015ft tall. The lattice section (above 650ft) will support the aerials which will be enclosed in curved glass-fibre sheets thus keeping a cylindrical shape for the whole mast. The aerials are being supplied by E.M.I. Electronics and the mast by B.I. Callender's Construction Co. A similar mast, but 1,265ft tall, is being built at Emley Moor, Yorks.*

Component Industry's Balance of Trade

ALTHOUGH the overall 1964 import-export figures for the component industry given in the 32nd annual report of the Radio & Electronic Component Manufacturers' Federation show a credit balance (exports £58.7M, imports £24.2M) certain products show an adverse balance of trade. For example, the value of exported transistors and semiconductor devices is given at £2M (a 5% decrease on 1963) compared with imports of £5.3M (a 56% increase). Exports of valves, c.r. tubes and parts increased by only 3% to £9.6M, whereas imports went up by 27% to £7.6M. Capacitor and resistor exports totalled £3.2M although imports stood at £4.3M. It should be stressed however that neither the export nor import figures take account of components used in complete gear.

As in recent years, there were three main sources of component imports, the Netherlands (£3.2M), the U.S.A. (£3M) and West Germany (£2.4M), which together accounted for 77% of the world total. The principal markets for British components were South Africa (£2M), Sweden (£1.9M), India (£1.8M), Netherlands (£1.8M) and Finland (£1.7M).

The R.E.C.M.F. Report also refers to the plans made for the setting up of a European committee for co-operation between component manufacturers' associations in Belgium, France, W. Germany, Italy, the Netherlands and the U.K. The title chosen for the organization is the Committee of European Passive Electronics Component Manufacturers' Associations (C.E.P.E.C.).

Radio Astronomy: Fleck Committee Report

FOR just over three years the Radio Astronomy Planning Committee, set up by the Government under the chairmanship of Lord Fleck, has been considering the probable future developments in radio astronomy. The twelve-man committee* has been considering in particular the proposals for new and large radio telescopes for which Government aid is likely to be required, the best ways of providing and operating them and the question of international co-operation in the field of radio astronomy.

The committee's report has now been issued in which it pays tribute to the work of British radio astronomers, particularly the teams led by Hey at R.R.E., Lovell (Manchester) and Ryle (Cambridge), and recommends that "as a matter of policy for at least the next eight years, the U.K. should press forward with research in radio astronomy at the existing centres giving it generous treatment."

The committee draws attention to the danger of electrical and radio interference which could severely restrict the use of the existing and planned radio telescopes at Jodrell Bank, Cambridge and Malvern, and appeals for the continued co-operation of the appropriate planning authorities in safeguarding this work because they regard it as of national scientific moment.

*Sir Edward Appleton (Edinburgh University), Dr. D. G. Christopherson (Durham University), Dr. W. L. Francis (D.S.I.R.), Dr. J. S. Hey (R.R.E., Malvern), Prof. F. Hoyle (Cambridge University), Sir Willis Jackson (London University), Sir Ewart Jones (Oxford University), Sir Bernard Lovell (Manchester University), J. A. Ratcliffe (Radio Research Station), Prof. Martin Ryle (Cambridge University) and Sir Richard Woolley (Astronomer Royal).

Space Science Laboratory

HOLMBURY HOUSE, a Victorian mansion near Dorking, Surrey, has been purchased by University College, London, and will be equipped as an outstation of the Physics Department and be devoted to space science research. The purchase has been made possible by a gift of £65,000 from the Mullard Company and the centre will be known as the Mullard Space Science Laboratory. It will be headed by Professor R. L. Boyd who will initially have a staff of 50 when the laboratory is opened at the beginning of the next academic year (October).

Scientists at the Laboratory will be engaged both on the planning and design of experiments using instruments to be carried in satellites or rockets, and on the subsequent analysis of information received from these flights, together with related laboratory studies. The teams research programme for the next three years plans to utilize eight satellites—two from the European Space Research Organization (ESRO) and the remainder from America. It will also be employing a large number of high-altitude research rockets. One was recently launched (using a "Skylark" from Sardinia under ESRO auspices to investigate electron temperature in the ionosphere at altitudes between 90 and 170 km.

More BBC-2 Stations:—By the end of this year five more major BBC-2 stations will be brought into service, making seven in all. The locations, transmitter characteristics, and opening dates are: Wenvoe, Glam (channel 51, e.r.p. 500kW) opening Sept. 12th; Winter Hill, Lancs (62/500) Oct. 17th; Emley Moor, Yorks. (51/1000) Oct. 17th; Rowridge, I.o.W. (24/500) Nov. 14th; and Black Hill, Lanarks (46/500) Dec. 12th. The permanent 1000kW transmitter at Sutton Coldfield, Warks., on channel 40, will begin operating on October 4th. All these u.h.f. transmitters will use horizontal polarization.

Stereo Transmissions.—As a result of the extension of the B.B.C's Third Network Music Programme into the afternoons, the experimental pilot-tone stereophonic transmissions from Wrotham three afternoons a week have been discontinued. Instead, pilot-tone stereo items are being included as part of the Music Programme transmissions from Wrotham on 91.3 Mc/s and Swingate (Dover) on 92.4 Mc/s on Mondays from 2.30 to 3.0 p.m. and Thursdays from 11.0 to 11.30 a.m.

R.E.C.M.F. Council.—At the thirty-second annual general meeting of the Radio & Electronic Component Manufacturers' Federation on April 6th the following were elected to the council for 1965/6:— R. Arbib (Multicore Solders), E. E. Bivand (S.T.C.), S. H. Brewell (A. H. Hunt), N. Dundas Bryce (Belling & Lee), R. A. Bulgin (Bulgin & Co.), B. E. G. Harris (Bakelite), Dr. F. E. Jones (Mullard), Dr. G. A. V. Sowter (Telcon Metals) and J. Thomson (Morganite Resistors). At the first meeting of the council the following were co-opted:— K. Hughes (Rola Celeston), F. W. Irons (McMurdo Instrument), C. R. Jennings (Formica), E. Marland (T.C.C.), J. D. Sutton (Parmeko) and E. E. Webster (Plessey). The new chairman is S. H. Brewell.

Valve and Semiconductor Production.—Sales of British valves, tubes and semiconductor devices for 1964 show an increase of 16.9% over those for 1963, according to figures issued by the British Radio Valve Manufacturers' Association (B.V.A.) and the Electronic Valve and Semiconductor Manufacturers' Association (VASCA). The relative figures are:— valves and tubes £48.3M (£42.7M, 1963) and semiconductors £23.7M (£18.9M).

BEAMA.—The Kingsway and Ascot offices of the British Electrical and Allied Manufacturers' Association have been transferred to Leicester House, Leicester Street, London, W.C.2. (Tel.: GER 0678). This is now also the address of the Electrical & Electronic Manufacturers' Joint Education Board.

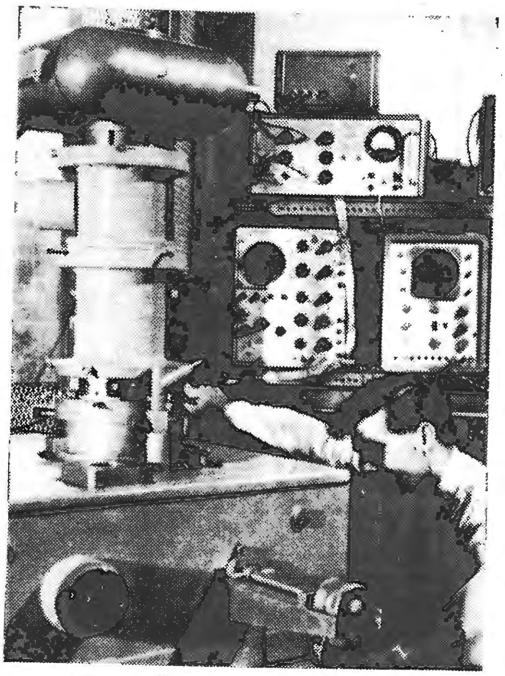
A.I.R.O., the Acoustical Investigation & Research Organisation, Ltd., is to hold open days at its new laboratories at Hemel Hempstead, Herts., on May 6th & 7th. Invitation tickets are obtainable from A.I.R.O., 42, Store Street, London, W.C.1.

Amateur Tribute to I.T.U.—To mark the centenary of the International Telecommunication Union on May 17th, and in recognition of the link between the International Amateur Radio Union and the I.T.U., the secretary of Region I of the I.A.R.U. (John Clarricoats) has been given permission by the G.P.O. to use the call GB3ITU instead of his own (G6CL) during May. Special QSL cards are being prepared to confirm contacts with GB3ITU which will operate in the 3.5, 7, 14, and 21 Mc/s bands and possibly the 28 Mc/s band. It is also hoped to put GB3ITU in operation during "The '65 Show" at Earls Court (Aug. 25-Sept. 4) and also during September when the I.T.U. Plenipotentiary Conference will be in session in Montreux, Switzerland.

R.T.E.B. Exam. Results.—Of the 688 entrants for the practical test for the 1964 Final Radio & Television Servicing Certificate of the Radio Trades Examination Board 462 passed (67% compared with 74% the previous year). A total of 1,646 entered for the intermediate exam. and 1,081 passed. There were only 19 entries for the Final Electronic Servicing Certificate and 14 passed. In the intermediate exam. 154 of the 215 entrants passed. All entrants had previously taken the written papers.

I.E.E. Structure.—A Control & Automation Division is to be formed by the I.E.E. and the title of the Science & General Division changed to the Science & Education Joint Board. This board will co-ordinate the activities of those professional groups within each of the three divisions (Control & Automation, Electronics and power) that deal with basic science and education.

The fifteenth **International Apprentice Competition** is to be held, for the first time in the U.K., from July 18th-31st. Approximately 240 apprentices from Western Europe and Japan will be competing in practical tests in 25 different trades in Glasgow. The City & Guilds of London Institute is responsible for the selection of the British team which is picked (one representative for each trade) from about 1,100 nominations by employers.



Electron Beam Machining.— *At the Mullard Research Laboratories, at Salfords, Surrey, an experimental unit has been built for machining all types of materials—even diamonds—to a very high degree of accuracy, using an electron beam.*

I.T.U. Centenary:— *One of the two stamps being issued by the Post Office on May 17th to mark the centenary of the International Telecommunication Union.*

An international **Aerospace Instrumentation Symposium** will be held at the College of Aeronautics, Cranfield, Beds., from March 21st to 24th next year. It is being sponsored by the College and the Aerospace Division of the Instrument Society of America. Further details are available from M. A. Perry at the College.

A week's full-time lecture/laboratory course on **transistor circuit design** is to be held at the Twickenham College of Technology, Egerton Road, Twickenham, Middx., from May 31st to June 4th. It is intended for graduates or holders of the H.N.C. in electrical engineering. (Fee, 9gn).

The U.K. Government proposes to increase **receiving licence fees** to £5 for a combined television-sound licence and 25s for sound only from August 1st. When announcing this in the House of Commons on April 14th the Postmaster General said that the whole question of broadcasting finance requires further study. This review will be completed as soon as possible and, the P.M.G. said, must be seen as part of the wider review of broadcasting policy which the Government is undertaking, including educational broadcasting, the allocation of a fourth television service and local broadcasting.

1966 Battery Symposium.—The fifth international symposium on batteries will be held in Brighton in September 1966. It is sponsored by the Joint Services Electrical Power Sources Committee which has now taken over the duties of the Inter-Departmental Committee on Batteries, organizers of the earlier symposia. Further information is obtainable from D. H. Collins (secretary of the Committee), Electrical Dept., Admiralty Engineering Laboratory, West Drayton, Middlesex.

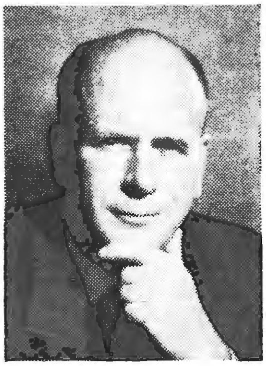
PERSONALITIES

Sir Lawrence Bragg, O.B.E., M.C., M.A., D.Sc., F.R.S., is retiring from the directorship of the Royal Institution at the end of August and will be succeeded by **Professor George Porter,** M.A., Sc.D., F.R.S. Sir Lawrence, who is a Nobel Laureate, gave up his post of Cavendish Professor of Physics at Cambridge in 1954 in order to take over the direction of the Royal Institution. Professor Porter, who is 44 and is at present Firth Professor of Chemistry in the University of Sheffield, recently gave a series of television lectures on "The Laws of Disorder." Since it was founded in 1799 the Royal Institution has been directed by a resident professor for whom it has provided accommodation at its headquarters in Albemarle Street, London, W.1.

S. R. Mullard, M.B.E., M.I.E.E., founder in 1920 of the Mullard Radio Valve Company, has received the honorary insignia award in technology of the City & Guilds of London Institute (C.G.I.A.). Mr. Mullard, who is 81, retired from the managing directorship of the company in 1929 but remained a director of Mullard Ltd., and its associate companies. During the 1914/18 war, he designed and constructed radio valves for the Services, and later, in collaboration with the staff of H.M. Signal School, Portsmouth, invented and developed high-power transmitting valves in fused silica bulbs.

W. R. Thomas, B.Sc., M.I.E.E., has been appointed group chief scientist of Elliott-Automation. He joined Elliott Bros. in 1952 as general manager and has been a director of Elliott Space and Weapon Automation Ltd. since 1963. Mr. Thomas, who graduated at the University of Wales, Aberystwyth, was technical officer in the Radio Dept., at R.A.E., Farnborough, throughout the war, after which he spent six years in the Guided Weapons Dept.

Group Captain E. Fennessy, C.B.E., B.Sc., M.I.E.E., who, as annnounced last month, resigned from the managing directorship of Decca Radar and joined the Plessey company, has been appointed chief executive of the new Electronics Group of the company. Group Captain Fennessy, who is 53, served on the staff of No. 60 (Radar) Group, R.A.F., for the major part of the war having previously been with the original Air Ministry radar research team at Bawdsey Manor from 1938. He had been with Decca since 1945. **E. E. Webster,** M.I.E.R.E., has become chief executive of Plessey's new Components Group. Mr. Webster, who is 56, joined Plessey in 1950 as chief inspector of the Swindon Region of which he became general manager in 1961 and director a year later. He started his career with Marconi Marine and was later with S.T.C. Throughout the war he was in the Air and Supply Ministries, after which he was, for three years, with Fleming Radio as general manager. Other chief executives appointed under the Plessey reorganization are **F. Limb,** O.B.E. (Telecommunications Group), **H. E. C. Nash** (Automation Group), and **D. R. Trowbridge** (Dynamics Group). Mr. Limb, who is 66, is managing director of Ericsson Telephones which he joined 40 years ago as an engineer. Mr. Nash (41) who had been a director of Elliott Processing joined Plessey in January. Mr. Trowbridge (44) joined Plessey in 1939 and has been general manager of the Aircraft Equipment Group since 1962. Plessey also announce the appointment of **G. H. Doust** as chief executive of the Plessey organization in Australia. Mr. Doust, who is 49, joined Plessey in 1956 and has been managing director of Plessey International Ltd.



Gp. Capt. E. Fennessy

E. E. Webster

F. J. M. Laver, B.Sc., M.I.E.E., who joined the Post Office in 1935, at the age of 20, and was employed at the Research Station at Dollis Hill, working at first on radio-frequency measurements and the development of the quartz crystal clock, has been appointed an assistant e.-in-c. In 1951 he was posted to the Radio Planning Branch and dealt with international radio questions and since early 1963 he has been assistant secretary in charge of the Office Machines Branch of the Treasury Management Services. He graduated in logic and mathematics as an external student of London University.

J. E. Flood, D.Sc., Ph.D., M.I.E.E., chief engineer in the Advanced Development Laboratories of A.E.I's Telecommunications Division, has been appointed professor of electrical engineering at the College of Advanced Technology, Birmingham, which is to become the University of Aston. Dr. Flood, who is a graduate of Queen Mary College, University of London, has been closely associated with the development of electronic telephone exchanges and has served on the Electronic Research Committee of the G.P.O. and telephone manufacturers.

G. R. Scott-Farnie, C.B.E., M.I.E.R.E., managing director of International Aeradio Ltd. since 1958, has also been appointed deputy chairman to the new chairman, **Keith Granville,** C.B.E. Mr. Scott-Farnie joined I.A.L. as operations manager in 1947 shortly after the formation of the company. For the major part of the war he was on special signals duties in the R.A.F. and from 1944-45 was signals intelligence officer on General Eisenhower's staff. He operates an amateur radio station under the call G5FI.

G. R. Scott-Farnie

David Ashworth has joined d-mac ltd., of Glasgow, as applications engineer. Mr. Ashworth, who is 27, was previously with I.C.T. Ltd., Stevenage, working on computer developments.

J. H. D. Ridley, M.B.E., head of the Engineering Secretariat of the B.B.C. since 1950, has retired. He was in the radio industry from 1920 until he joined the corporation in 1938. From 1923 to 1932 he was with Burndept Wireless, latterly as chief engineer, after which he joined Edison Swan Electric Co. as chief radio engineer. Mr. Ridley has spent the major part of his 27 years with the B.B.C. in the Engineering Secretariat. He is succeeded by **J. A. Fitzgerald,** A.M.I.E.E., who joined the B.B.C. in 1940 as a maintenance engineer. In 1949 he transferred to the Engineering Secretariat where he was responsible for patent work. He was also secretary of the B.B.C's Engineering Advisory Committee.

Hugh Menown, M.Sc., has been appointed manager in charge of the Gas Tube Division at the Chelmsford factory of the English Electric Valve Company. Mr. Menown graduated in experimental physics at Queen's University, Belfast, and joined the English Electric Valve Company in 1951, as an engineer working on gas tubes. He has been engaged on the development and production of hydrogen thyratrons, and for the past three years has been assistant manager of the division of which he is now in charge.

T. G. Clark, A.M.I.E.R.E., who had been with Decca Radar since 1951, has joined the Plessey Group. For the past three-and-a-half years he was a group leader in the Radar Development Laboratories, Chessington, Surrey, concerned with both marine and special developments. Before joining Decca he was in R.E.M.E. as a warrant officer working on radar and telecommunications equipment.

J. Hale, B.Sc. (Eng.), A.M.I.E.E., production manager of Feedback Ltd., which he joined about a year ago, and **E. G. Bell,** A.M.I.E.E., the company's sales manager for the past two years, have been appointed to the board of directors. Mr. Hale was a student apprentice with A.E.I., then served as an electrical officer in the R.N.V.R. He was for four years with Production Engineering Ltd. before joining Feedback. Mr. Bell was a development engineer with Salford Electrical Instruments before joining Muirhead & Co. in 1954. He went to Servomex Controls in 1958 where he stayed until joining Feedback in 1963.

S. D. Coombs has joined Keyswitch Relays Ltd., as chief development engineer. He comes to Keyswitch from Standard Telephones and Cables where he was general applications engineer, concerned with relays and associated equipment. Prior to this, Mr. Coombs was with de Havilland Propellers Ltd., on the Blue Streak project, and was earlier with Elliott Bros.

Sydney S. Bird, who in 1920 founded the well-known company bearing his name, celebrated his 80th birthday at the end of March. To mark the occasion the directors of the parent company Astaron-Bird Ltd. arranged a banquet at Ferndown, Dorset. Gifts were presented to Mr. Bird by the directors and staff and, on behalf of over 80 friends in the radio and electronics industry, H. J. Barton-Chapple gave him a camera.

Sydney S. Bird

E. G. Lennard has resigned from the position of commercial director of Cosmocord which he joined 6½ years ago. He has represented the company on the council of the Radio & Electronic Component Manufacturers' Federation for several years and has served on its Export-Import Committee.

Eric J. Gargini, A.M.I.E.E., A.M.I.E.R.E., author of the article on page 210 in this issue, is colour television section leader at the laboratories of Rediffusion Research Ltd. He received his technical training at Southall Technical College and, after a short period as a trainee with E.M.I. and then Philco, he served in the R.A.F. throughout the war. He rejoined E.M.I. in 1945 where he was concerned with wire television distribution systems and later colour television receiver development. He left E.M.I. in 1960 to go to Marconi's at Chelmsford and six months later joined the Rediffusion organization.

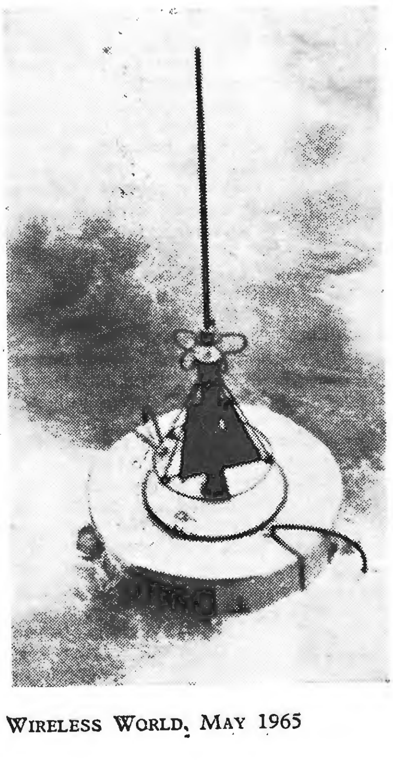
Squadron Leader H. C. Jamieson and **Senior Technician G. W. Honey** have each been awarded £75 by the Air Force Board for a modification to the approach radar installation at R.A.F. Wyton, Hunts, which was regarded as a valuable contribution to flight safety. Their device enabled a flatter angle of approach, as assumed by an aircraft suffering from wing flap failure, to be more positively indicated on the face of the radar tube thereby reducing the possibility of human error by controllers.

NEWS FROM INDUSTRY

Plessey Reorganization.—The Plessey Company's operations in the U.K. are being reorganized and all its subsidiaries will operate under the name Plessey within five groups, these being: Automation, Components, Dynamics, Electronics and Telecommunications. Commenting on this Lord Kilmuir, Plessey's chairman said eventually all products will be marketed under the single name Plessey, although a number of traditional trademarks will be retained. Changes are also being made in the overseas organization.

Eddystone Radio Ltd.—The English Electric Company have agreed to purchase from Laughton & Sons Ltd. the whole of the issued capital of the latter's subsidiary Stratton & Co. Ltd., the manufacturers of Eddystone communications receivers. The purchase price was 220,000 English Electric £1 Ordinary Shares plus £104,157 in cash. It is the intention of the English Electric Co. to change the name of Stratton to Eddystone Radio Ltd. and operate it as a subsidiary of the Marconi Company, a member of the English Electric Group.

Oceanographic Equipment.— *To assist in the collection of information in oceanograpic surveys, EMI-Cossor Electronics Ltd., of Canada, have produced a device for gathering underwater data for recording or relaying to a monitoring station, ship or aircraft. The device consists of a sub-surface float containing measuring equipment (for water-speed, salinity and temperature tests) moored to the bottom by a taut wire and connected to a surface-buoy which houses the recording and radio equipment.*



SGS-Fairchild European Expansion. —The SGS-Fairchild organization announced in London recently that the group is expanding its activities and is now able to supply silicon planar semiconductor devices for all types of electronic equipment. Under the title "Total Planar" the group is now producing and marketing comprehensive ranges of semiconductor devices, including microcircuits, for the military, professional, industrial and consumer markets. To cope with the expansion, it is planned to increase the output of the Ruislip plant—one of the two European manufacturing plants, the other being in Milan—by four times to about ten million units a year, and also to build a new factory in Sweden. SGS-Fairchild also plan to establish research and development laboratories in Europe. Information from the American Fairchild research laboratories will be available to the staff of the proposed European laboratories and in preparation for their opening, a number of SGS-Fairchild engineers are at the Californian laboratories of Fairchild Semiconductors "injecting the European point of view."

Long Term Planning.—Industrial Market Research Ltd., of 34 Sackville Street, London, W.1, have been appointed U.K. representatives and consultants for the long term planning service run by the Stanford Research Institute, which was founded in 1946 by the Trustees of Stanford University and a group of American businessmen. This service is to draw management attention to new business possibilities and new competitive threats and also give the implications of development in technology. More than half of the 2,700 staff are technical and professional personnel and recent reports cover a variety of subjects including electrical test equipment and new semiconductors.

Mullard Research Laboratories.—A further three-storey wing is to be built on to the laboratory block recently completed at the Mullard Research Laboratories near Redhill, Surrey. Work has commenced and will take about a year to complete providing an extra 35,000 sq ft of space.

Texas Instruments Incorporated, of Dallas, have received a contract valued at $5,604,937 from the U.S. Naval Oceanographic Office for a marine geophysical survey. This is one of the largest contracts of its type to be placed with an industrial concern and will be carried out over the broad areas of the eastern and central Atlantic Ocean, and the Mediterranean. Information during the survey, which is planned to take three years, will be collected with seismic and oceanographic instruments installed on two specially fitted vessels now being completed in an American shipyard.

Pantiya Electronics Ltd., which was formed nearly ten years ago when the old Pantiya Tea and Rubber Company ceased to trade, is to go public. In 1956 Pantiya acquired the whole of the issued share capital of Walmore Electronics Ltd., for £100,000 in cash, and last November acquired the issued capital of Marlyne Electronics Ltd. and its subsidiaries for £300,000. Marlyne Electronics manufacture, import, wholesale and retail radio and audio equipment and components for the home constructor; one of their outlets being Stern-Clyne Ltd., who operate twelve shops in London and the provinces. A recently formed subsidiary of Pantiya, Saba Electronics Ltd., now has the sole U.K. concession for the products of Saba, the West German radio, television and audio manufacturers. The combined pre-tax profits of the Pantiya Group and Marlyne Group have increased from £6,500 in 1954-55 to £139,000 in 1963-64.

Associated Electrical Industries Ltd. trading profit for 1964 was up by over £5.25M on the previous year's result at £13.9M. In the year under review, £5.3M was set aside for taxation as against £2.7M in 1963, leaving a net profit of £6.2M, which represents an increase of £2.3M. In a circulated statement to shareholders (65th a.g.m. on 28th April) the company's chairman, Mr. C. R. Wheeler, made reference to an improvement in the profit of the Electronics Group, which comprises the Electronics Apparatus Division, the Instruments Division and AEI Automation.

British Insulated Callender's Cables group sales for 1964 amounted to £216M and showed an increase of £32M on the 1963 figure. Pre-tax profits were up by just over £3M at £15.86M and after providing for taxation and other deductions, the net profit totalled £8,171,000, compared with £6,820,000 in the previous year.

The Amplivox Group, which became public last June, announce a pre-tax profit of £202,748 for 1964, an increase of £54,735 on the previous year's result. After tax, profits rose from £64,085 to £93,176.

N.S.F. Ltd. pre-tax profit for 1964 amounted to £360,000 and showed an increase of £49,526 on the previous year's result. Tax on these profits accounted for £194,000, compared with £163,000 for last year, leaving a net profit of £166,000 (£147,474). The thirty-third a.g.m. to be held on 5th May is the first as a public company.

Marconi Instr. Acquire W. H. Sanders.—Marconi Instruments Ltd. have acquired over 96% of the Preference Shares and over 84% of the Ordinary Shares of W. H. Sanders (Electronics) Ltd.

Painton Acquire Electroprints.—A majority shareholding in Electroprints Ltd., of Portsmouth, who manufacture printed wiring on flexible and rigid materials, has been acquired by Painton & Co. Ltd. Mr. C. M. Benham, Painton's chairman has been appointed chairman of Electroprints Ltd.

Plessey Bid for T.C.C.—The Plessey Company have made a bid, worth £3.6 M, for the Telegraph Condenser Company. The offer, which is subject to 90% acceptance, has been made after consultations with British Insulated Callender's Cables, who own about 65% of T.C.C. and intend to accept the bid. Financial details of T.C.C. apepared in last month's issue.

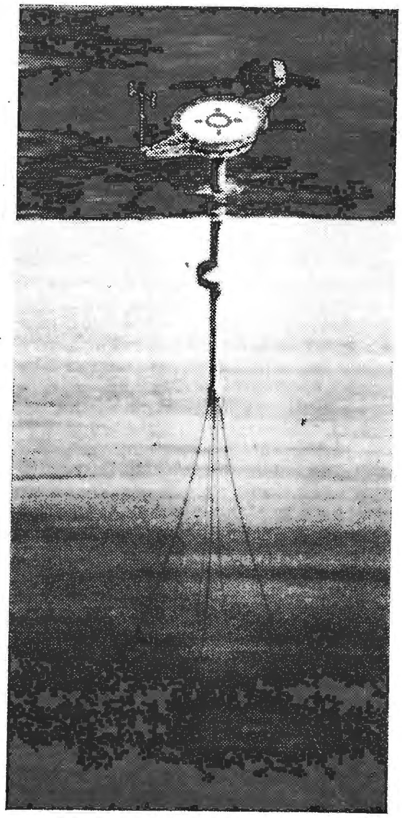
Goonhilly-Bristol Microwave Link.—Standard Telephones and Cables Ltd. have received a contract from the Post Office, worth about £300,000, for a high-capacity microwave link between Bristol, Plymouth and the communications satellite station at Goonhilly Down, Cornwall. This link, which will be the first in the U.K. to operate in the "upper 6,000 Mc/s band," will join the microwave system S.T.C. are now installing between Bristol and the London Post Office tower.

Hughes Expansion.—Hughes International (U.K.) Ltd., who at present are producing a million semiconductors a month at their Glenrothes, Fife, plant are soon to start making planar devices. In preparation for the production of these devices, the floor area has been increased by 13,500 sq ft. Initial production will be 300,000 per month. The company's sales department has moved from Hounslow to larger premises at Heathrow House, Bath Road, Cranford, Middx.

M.E.L. Automation.—While extensions to the company's main factory offices are being completed, the automation division of the M.E.L. Equipment Company has moved from Crawley to Stone Street, Waddon Factory Estate, Croydon, Surrey (Tel.: MUNicipal 4971). The division is expected to return to Crawley at the end of the year.

Floating Navigation Stations

PLAN FOR TRANSATLANTIC CHAIN



BECAUSE of the increasing amount of air traffic using the North Atlantic, a new company called Seastation Telecommunications Ltd., has been formed to investigate a scheme for the setting up of a series of "floating stations" to carry trans-oceanic telecommunications and navigational apparatus.

In collaboration with the Ministry of Aviation—who have awarded the company a design contract worth £60,000—work is being carried out on the feasibility of establishing a number of permanent floating navigation-cum-communication stations connected with each other and with shore by underwater cables.

The proposed floating station consists of a tubular structure—about 400 ft in length and 16 ft in diameter—floating vertically in the sea with the greater part of its length submerged. The upper part of the spar buoy, as it is called, supports a large superstructure that is well above the reach of the waves and provides accommodation for the equipment, for a crew of about twelve, for a helicopter landing deck and for aerial arrays. The station is moored by three cables to anchorages on the sea bed and as the motions of the sea decrease rapidly with distance below the surface, the length of the cylinder makes the station particularly stable in the roughest weather. From tests conducted with a scale-model in water tanks, calculations have been confirmed that for 95% of the time the half amplitude pitch or roll will not exceed half a degree and that vertical motion would not exceed six inches.

In addition to navigation aids such as medium-frequency beacons and d.m.e., and v.h.f./u.h.f. equipment for air traffic control purposes, primary and secondary radar could be provided if required, with the necesary display data being transmitted through the underwater cables to a.t.c. centres either side of the ocean.

The new company is jointly owned by Cammell Laird & Co., shipbuilders and engineers, who are, incidentally, responsible for the marine construction side of the Ministry of Aviation study, and Submarine Cables, which is owned by Associated Electrical Industries and British Insulated Callender's Cables, and is responsible for the communications side. The company's chairman, Dr. J. N. Aldington, has stated that the Ministry of Aviation design study is expected to be completed in five to six months time. He also said a single chain—comprising two to four stations—crossing the North Atlantic would cost approximately £10 M to £15 M to install with running costs of about £300,000 to £400,000 a year. Once the go-ahead is given, it would take two to three years to get a system operational.

These "seastations," Dr. Aldington said, could also be used for other purposes. One of these being to replace weather ships as they have several advantages such as a stationary platform that enables high altitude wind velocities to be more accurately measured, and a direct link—by underwater cable—that allows contact to be made under all adverse conditions. Another example given by Dr. Aldington was the use of "seastations" in underwater cable communication projects where intermediate shore stations in long-distance links are not practicable for technical or political reasons.

The stations are to be self-supporting and able to operate for months at a time. Power for the various communication and navigational equipment will be provided by diesel-oil generators.

Should the scheme be adopted by the British Government, Dr. Aldington stated that subscribers, such as airlines and shipping companies, would pay dues in the same way as they now do for "fixes" and other services from the weather stations.

50 Years of Public Address

A.P.A.E. INTERNATIONAL GOLDEN JUBILEE EXHIBITION

LAST year's A.P.A.E. exhibition was reported in *Wireless World* to be the most ambitious show presented by the Association of Public Address Engineers, and this year's exhibition has beaten last year's records in every respect. The rapidly expanding Association presented its 16th annual exhibition at the King's Head, Harrow-on-the-Hill, on March 17th and 18th and the occasion marked the 50th anniversary of the first application of electrical equipment to address the public. The event, which took place in San Francisco in 1915 under the guidance of Jensen and Pridham makes the p.a. industry older than wireless broadcasting, since no public broadcasts had been made at that time.

The opening ceremony was conducted by the Danish Chargé d'Affaires and the Scientific Attaché of the Danish Embassy in honour of their countryman Peter Jensen (the "father of the loudspeaker"). Shortly afterwards a two-way radio link with New York took place and the past 50 years of p.a. were recalled by engineers on both sides of the Atlantic. The discussion touched on the use of time delays to overcome problems due to reverberation time and frequency shifting in systems to prevent acoustic feedback. However at this interesting point, just as we were about to learn why these techniqes were not used more widely in Britain, the discussion was brought to a close.

B.B.C. Demonstration

An interesting demonstration by B.B.C. engineers was given on the studio control room equipment. The transistorized control console, which was B.B.C. designed and built, has quadrant mixers and also bass and treble controls on each microphone channel. But even these do not meet the demands of present-day entertainment and "presence" controls have been included also.

Live gun shots are notably unrealistic in studios and the B.B.C. use a simulator which gives a very impressive performance. A thyratron white noise generator is used with the high frequency end of the spectrum tailored (coloured?) and gated to give single or machine-gun shots; ricochets are provided by the generator and a multivibrator whose h.t. supply is run down.

Another item used by the B.B.C. was an acoustic table, which transmitted incident sound and thus avoided interference at the microphone.

Veteran P.A. Exhibition

A display of old p.a. equipment aroused much interest. One item dated back as far as 1894, but strictly speaking this was private—not public—address equipment. It was the "Electrophone" system, which used a carbon pencil transmitter disguised as a Bible for use in churches

Part of the veteran p.a. display. The amplifier used by Baird with his television system is shown just left of centre on the upper row. Some collected literature on p.a. is seen behind the equipment, including a number of pages of Wireless World.

connected via Post Office lines to subscribers' headsets. This was provided by the G.P.O. on their display of "50 years of telephones" which included a replica of Graham Bell's original telephone.

The first p.a. apparatus did not use amplifiers and some of the carbon button microphones used passed as much as 5A. Amplifiers were introduced around 1918, but a 3-valve line amplifier used during the war in 1915 was shown. The Western Electric amplifier used by Baird in his television system is illustrated in the photograph of the display. One of the microphones shown was used by King George V at the opening of the Empire Exhibition at Wembley in 1924 (Western Electric double button carbon) and another was the Beyer microphone used by Rommel to address German troops in the desert campaign. Much of the equipment on display was in working order and an old Marconi amplifier with microphone and horn loudspeaker were shown to be capable of feedback at least!

Much of the equipment on manufacturers' stands had been seen before and some of the more recent items are outlined below.

Microphones

Most of the new introductions are dynamic types with multi-impedance connections (low, 20-60Ω; medium, 200-300Ω; and high, 10kΩ and above), often with bass cut and on-off switches. The AKG types D119CS and D119ES have both switches and a front-to-back ratio of 15dB at 1 kc/s. The CS has an output impedance of 200Ω and the ES offers a choice of three impedances. The Beyer M610 (displayed by Fi-Cord) with cardioid polar diagram has both switches with low and medium impedance outputs and the omnidirectional lavallière (neckslung) type M110 is also dual impedance. Fi-Cord also introduced two of their own microphones, the 801 and the directional 901, with responses extending up to 18 kc/s.

A field effect transistor has been used in the head amplifier of the S.T.C. capacitor microphone (type 4126) and this is available with an omnidirectional or a cardioid pattern. Also new is the 4119 ribbon microphone. Reslosound have added a switch to their pencil microphone (type PD); and the Vitavox M100, offering four impedances, has now reached the production stage.

Loudspeakers took a relatively back seat this year although a new range, primarily intended for rental, was announced by Sound Coverage but are electrically similar to the previous range. Goodmans have introduced two small loudspeakers with inverted ceramic magnets and whilst these are not for p.a. work, they will meet a demand for lighter and more compact equipment in other fields. A 3-watt elliptical motor-cycle mounting loudspeaker (Home Office approved) was shown by Rola Celestion.

Amplifiers

The C.T.H. range of p.a. equipment has been augmented with the MA50 (50-watt) transistor amplifier. Their p.a. series of amplifiers were battery operated whereas this unit (and the MB15) is for battery or mains operation. In the event of a mains failure, the amplifier will continue to operate from the battery, this being recharged when the mains supply is resumed. The Grampian 650 amplifier is similar to their 50-watt type 600 but the number of microphone channels has been increased to four. A 100-watt amplifier with six inputs (M.C. 100/6) is added to the VOX range and the volume level meter also monitors circuit voltages. (Similarly with the M.C. 50/6.)

Modular amplifier units are becoming noticeably more popular. The Audix mixer (MXT/6) and mixer-amplifier can be made up with any combination of their units, which include a single-tone generator. The S.T.C. modular transistor units include 35 and 60 watt amplifiers (with 100 V line outputs), two microphone pre-amplifiers, a mixer, master gain-control unit and microphone and loudspeaker switching units. Reverberation units (pre-amplifiers and 20 W amplifiers) for increasing reverberation time at selected frequencies, form part of the system. The pre-amplifier works from a 30Ω microphone in a Helmholtz resonator, amplifying a bandwidth of a few c/s, with provision for phase adjustment.

Contrary to the current trend Reslosound introduce three valve amplifiers (15, 30 and 60 W) and with high and low impedance inputs.

Miscellaneous

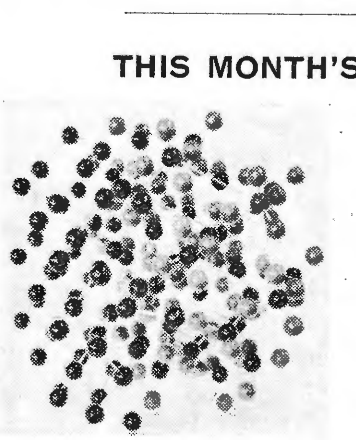
Radio microphones were seen on a number of stands. The transmitters are frequency modulated, often with speech compression and are, of course, crystal controlled, usually around 175 Mc/s according to allocation by the G.P.O. Lustraphone have introduced a combined microphone and transmitter with an output of 10 mW and using voice compression. The receivers are double superhets and on mains types a transmission indicator lamp is included. Magneta and Pamphonic market a Labgear radio microphone using speech compression and the receiver output may be used to feed into a telephone handset or a normal p.a. installation. The transmitter has a range of up to ½ mile under ideal conditions.

An Ultra tape recorder with a 32-track head for standard announcements of up to 6 minutes was seen on the Trix stand. Each track is selected by a push button and the machine can be used for 64 channel work with message lengths of 3 minutes.

3M have added two flat adhesive cables to their Scotchflex range; the 550 type, with two conductors, and the 800 type, with four conductors. Other cables on show included the EMT a.f. cables, shown by Bauch. One of the cables contains 10 pairs of individually screened wires and is reported to be anti-microphonic. The capacitance is about 70 pF per metre.

A transistor portable loudhailer (Bouyer Super Megaflex) was shown by Douglas Lyons Associates. The unit is rated at 7 watts and the rubber microphone is provided with a volume control.

THIS MONTH'S COVER



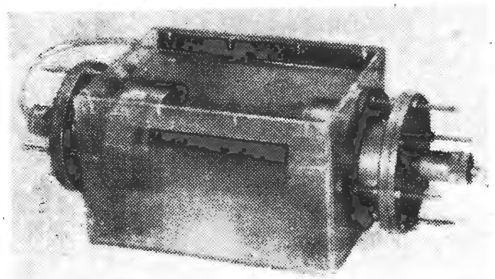
This atomic structure model represents an epitaxial arrangement of silicon on quartz. Work at the Allen Clark Research Centre of The Plessey Company aims to produce new types of integrated circuits in which single crystal films of semiconductor materials are deposited on insulating substrates. The purpose is to reduce capacitance coupling between neighbouring circuits.

PHYSICS EXHIBITION IN THE NORTH

THIS year The Institute of Physics and The Physical Society broke fresh ground by holding their exhibition—the 49th—in Manchester instead of London. Once again the scientific character of the event was maintained, by careful selection of items for their interest to physicists, and only about half of the offers were accepted for display. Last year's innovation, a special section devoted to educational exhibits, was repeated, and proved a popular feature with visitors.

RESEARCH

Non-linear acoustics.—It is often assumed in deriving a wave equation for acoustic waves travelling through a fluid medium that various parameters are independent of acoustic pressure, which results in a linear representation of the system. If waves of sufficiently high intensity are considered the system becomes non-linear, since density and bulk modulus are functions of acoustic pressure. Because of this non-linearity, two sinusoidal pressure waves will interact and give, amongst others, sum and difference frequencies. Birmingham University demonstrated the existence of the difference frequency by propagating pulsed pressure waves along the same axis from two small barium titanate transducers immersed in water and at frequencies around 300 kc/s. In the region of interaction of the two waves a virtual source of directionally propagated audible pressure waves is thus formed. The elastic parameters are analogous to reactive parameters in electric systems, so parametric amplification and sub-harmonic generation may be possible in a similar fashion to electric systems. It is felt that this and similar exploitation of the non-linear effects may ultimately have application in sonar systems.



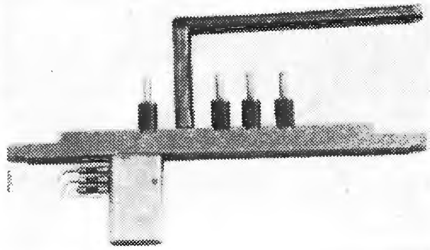
Formation of a virtual source of acoustic energy by exploiting the non-linear characteristics of a fluid. (Birmingham University.)

Protoplasm impedance is an unusual biological parameter being measured by Wayne Kerr to aid research into cancer and into new methods of food production. The effects of electric and magnetic fields on protoplasm and cell membranes are significant, and it is thought that more information may be obtained by a.c. impedance measurements than from the orthodox d.c. measurements, particularly as these living structures transmit electrical impulses by an electrochemical process similar to that of the animal nerve cell. A demonstration was given of measuring the dynamic response of the alga *Nitella* to electrical stimulation by an automatic balancing bridge. The real and imaginary components of the measured impedance (in this case R and C) were displayed on a chart recorder. Low-resistance metal electrodes cannot be used to make contact with the alga as they destroy the cell membrane, so extremely high-resistance glass electrodes are necessary. To avoid measurement ambiguities resulting from these high series resistances, the bridge is a transformer ratio-arm type with a split neutral terminal to permit the use of four electrodes instead of the usual two.

Sub-millimetre source.—Until recently, there have been no strong sources of radiation for laboratory use in the sub-millimetre wavelengths, that is between the short wavelength end of the microwave region and the long wavelength end of the infra-red region. The main difficulty has been finding molecules with suitable energy transitions, but a number are now known which will give stimulated emission in the region between 0.01mm and 1mm. S.E.R.L. have developed a tube using water vapour and emitting microsecond pulses of radiation at 0.0279mm. The N.P.L. demonstrated the Teratron (frequency about 1 teracycle per sec) which uses the CN radical in the form of acetonitrile vapour CH_3CN, and emits at 0.337mm. The acetonitrile vapour is pumped into a tube (about a metre long) and emission is triggered by an electric discharge which causes the molecule to decompose and give an excited CN radical. Since the CN is short lived, the pump is necessary to remove the decomposition products and replace the CH_3CN. The emission at 0.337mm occurs between two regions of strong absorption by water vapour; also, the wavelength is long enough to avoid scattering by most fogs, so there are possibilities for communication at this wavelength.

Reverberation.—A demonstration by the Physics Department of the Manchester College of Science and Technology illustrated the effect of increasing the reverberation time at mid-frequencies of the main theatre in the Renold building. This theatre had been designed for speech and had a reverberation time of 0.8 sec at mid-frequencies, but was found to be "dead" to performances of music. Increasing the reverberation time to 1.2 sec, with delays provided by a multi-head tape recorder and 37 loudspeakers, resulted in increased liveliness.

Cyclotron resonance.—Power dissipation problems in high frequency backward wave oscillators has prompted research into alternative methods of microwave generation. A device employing cyclotron resonance was shown by G.E.C., providing a source which was tunable over the whole of Q band. Interaction occurs between electrons moving in a cycloidal



New microwave vacuum tube, by G.E.C., using cyclotron resonance. The device is tunable over the whole of Q band by variation of the magnetic field in which the tube is inserted.

motion in perpendicular electric and magnetic fields and an r.f. wave from a local source. The r.f. wave propagates along a transmission line formed by the electrodes providing the electric field, and takes up energy from the electron beam so that the cycloid humps decrease in size. The output frequency is determined by the magnetic field which varies the cyclotron frequency of the electrons. The device has achieved a c.w. output of 11 watts with an efficiency of 5% and an anode voltage of 6 kV. It is expected that the tube will operate with up to 10 kV anode voltage and provide an output of 50 watts.

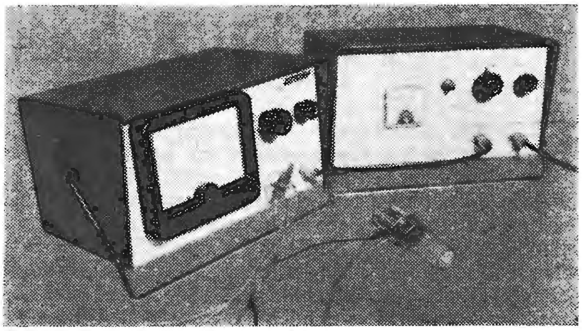
Thermionic generator.—In conjunction with Imperial College, Fairey Engineering Ltd. have been developing a thermionic energy converter for use with radioactive isotopes. The device shown was described as a gas-filled triode converter. Given a heat source, electrons are emitted from a cathode and collected at an anode as in a normal diode. The available power at the anode is limited by the space charge around the cathode and operation of the device depends on its neutralisation, enabling much larger powers to be drawn from the anode. In the device shown, a third electrode is used to cause a discharge in the inert gas which provides a source of ions to neutralize the electrons causing the space charge. The emitter is 90% tungsten with lanthanum and zirconium. The heat source in this experimental model is electrical, but the final source envisaged is a radioactive isotope, in particular a waste fission product available in quantity from nuclear reactors. The emitter has a work function of 2.4 V and is operated at 1,650°C, and the triode gives an output voltage of 0.7 V at a power density of 10 watt cm^{-2}. The power output achieved is in the region of 30-40 watts.

Semiconductor microwave generator based on the little-known Gunn effect was demonstrated by S.T.C. It consists of a 0.01in thick wafer of n-type gallium arsenide with contacts on each plane face, mounted in a coaxial circuit. When a potential of about 100 volts is applied across the contacts, the charge carriers form into domains which move across the material at the carrier drift velocity, producing current instabilities in the form of oscillations. The frequency of oscillation is determined by the transit time of the current carriers, and for a 50-micron wafer is about 6 Gc/s. To avoid excessive power dissipation in the crystal the applied voltage was pulsed, and on an oscilloscope the resulting microwave signals were shown superimposed on the square waves. Several watts of r.f. power can be obtained with this pulsed operation and the efficiency of conversion of d.c. to microwave energy is of the order of 5%. This direct method of generating microwave signals may prove much simpler than the parametric solid-state techniques at present in use.

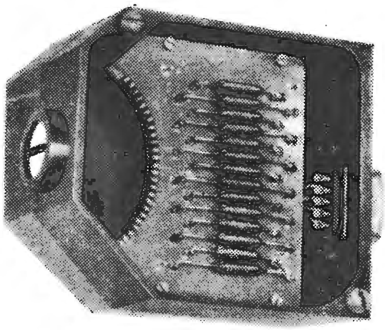
SENSING DEVICES

Space vehicle attitude sensors were shown by R.A.E., Farnborough. One very elegant sensor, for use in U.K.3, was described as an optical potentiometer. A slit image of the sun is formed on an array of phototransistors arranged in an arc of a circle whose centre is at the slit. Each of the phototransistors is connected on to a resistor chain forming a potential divider. On illumination, a transistor conducts and taps the potentiometer chain, with the result that the device gives an output voltage proportional to the angle of incidence of the light.

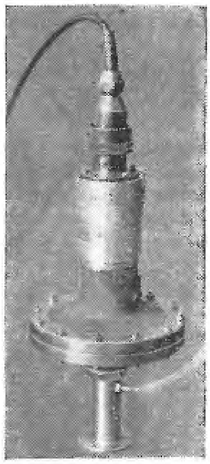
Tidal air integrator for continuously measuring and recording volumetric air flow in human breathing was demonstrated by Mercury Electronics. The patient breathes through a tube in which a wire gauze constriction is placed (pneumotachograph head) and the differential pressure across the constriction is proportional to the velocity of the breathed air. This differential pressure is measured by a micromanometer and the resulting velocity signal is then integrated in a separate unit to give a continuous measure of air volume. Normal breathing rhythm and any other effects such as coughing are clearly shown on recordings. The integrator comprises a transistor circuit controlling the charge applied to a capacitor. Total volume of air breathed during a given period can be registered by an electromechanical counter: this is operated by pulses obtained by discharging the capacitor through an electronic switch when a predetermined charge threshold is reached.



Tidal air integrator developed by Mercury Electronics, showing pneumotachograph head in front and integrator unit on right.



Above: "Optical potentiometer" developed at R.A.E. for use in space vehicles, including U.K.3.



Right: Solartron vibrating cylinder pressure transducer.

Vibrating cylinder pressure transducer, a new type of measuring element suitable for telemetering in widely spaced tank farms and other such plant, was demonstrated by Solartron. Intended mainly for measuring liquid level by head pressure in storage tanks, the device comprises a thin-walled cylinder of magnetic material with one end closed. Inside the cylinder are a drive coil and a pick-up coil, and these are electrically coupled through a small amplifier to form an oscillatory circuit which causes the cylinder to vibrate at its natural frequency. The cylinder is enclosed by a container into which liquid is fed by tube from the bottom of the storage tank, so that liquid plus atmospheric pressure is applied to the outside of the cylinder and atmospheric pressure to the inside. The vibration frequency of the system then varies with the differential pressure on the cylinder walls, according to a known non-linear relationship. Electrical signals produced by the oscillating circuit are transmitted to remote frequency measuring equipment, operating on the counter-timer principle, and the resulting digital display gives the liquid pressure (or related variable such as liquid level or quantity) in appropriate units. The non-linearity of the transducer is compensated in the counter-timer by a pulse dropping technique. Good accuracy and long-term stability of calibration are claimed for the device.

Relative humidity transducers.—The ability of ion-exchange resins to take up water but not dissolve is utilized in a new type of relative humidity measuring element, shown by Wayne Kerr, which provides an electrical output signal. A thin film of resin is deposited on an insulating substrate incorporating two interdigital metal electrodes, and in this arrangement the surface conductivity is proportional to the ambient relative humidity. The resistance between the electrodes is measured by a self-balancing miniature a.c. bridge operating at 2 kc/s and this is displayed in terms of relative humidity on a pointer indicator with two scales, one calibrated 20-60% r.h. and the other 60-95% r.h. Temperature coefficient, constant over the whole measuring range of the transducer, is +0.4% r.h. per 1°C rise in temperature.

Semiconductor radiation detectors are becoming more widely used and in many cases are replacing conventional methods of detection. Gamma radiation, γ-particles and β-particles can be detected with surface barrier semiconductors or with junction types by varying the depletion layer thickness to suit the type of radiation. Semiconductor and conventional radiation detectors were seen on many stands, and a personal gamma dosemeter which gave an audible 2-kc/s tone output modulated to give pips of decreasing duration as dosage increases was featured by Isotope Developments Ltd. Here the detector is an ionisation chamber with an energy range of 50 keV to 2 MeV.

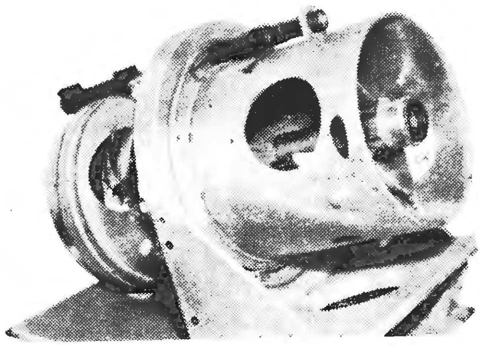
MEASUREMENT AND ANALYSIS

Laser devices held a prominent position in the exhibition and exhibits included two rangefinders. The small beam-widths obtainable, which enable specific objects to be used for ranging without echoes from the surroundings, and the compactness of the apparatus make laser rangefinding attractive, particularly for low-level altimeters. The Services Electronics Research Laboratory displayed an equipment with a range of 1,000 feet and an accuracy of about 5 feet, using a pulsed gallium arsenide transmitter, about the size of a small torch, with a peak power of 10 watts. The equally small receiver has a sensitivity of 0.1 μwatt and is situated at the focus of a parabolic mirror (see picture). Although some high-performance radars have been known to resolve overhead high tension cables, this elegantly simple and compact system has been shown capable of measuring heights of trees on experimental flights.

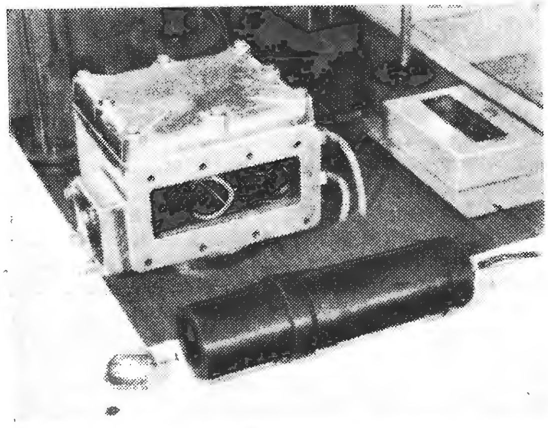
Specific gravity meter demonstrated by Sangamo Weston continuously measures the density of a liquid, on the hydrometer principle, by determining the electrical current necessary to maintain an immersed metal plummet at a given level in the liquid—the buoyancy of the plummet depending on the s.g. of the liquid. The ferrous plummet is suspended by an electromagnet within a vertical open-ended plastics cylinder immersed in the liquid, and its vertical position is measured by search coils fed with 500 kc/s a.c. The position measurement is fed back to the suspension system, giving a closed-loop servomechanism which maintains the plummet at a fixed height in the liquid. Depending on the liquid density, more or less electrical power is needed to maintain the plummet's position, and in fact the suspension magnet current varies inversely with the density of the liquid. This current is measured and used for indicating or recording the s.g., which can be done over a range of 0.4 minimum to 2.0 maximum.

Neutron flux measurement.—A miniature fission chamber was shown by Elliott-Automation for monitoring neutron flux in reactor cores. The device, which is 1in long and $\frac{1}{8}$in diameter, detects thermal neutrons with a coating of uranium 235, 238 or a mixture of both. The usual fission of the uranium nuclei takes place and produces radio-active fragments which are then detected in a stainless steel ionisation chamber containing helium and polarized with 75 volts. The device can withstand a temperature of 550° C and measure flux densities between 10^{11} and 10^{14} neutrons cm^{-2} sec^{-1}. The sensitivity is 2×10^{-17} amps per neutron per cm^2.

Liquid composition meter shown by the N.P.L. is based upon the comparison of dielectric constants. The instrument was required for on-line computer control of chemical processes and measures the composition of an ethanol-water



Laser rangefinder, with application in low-flying aircraft, using semiconductor laser. (Services Electronics Research Laboratory.)

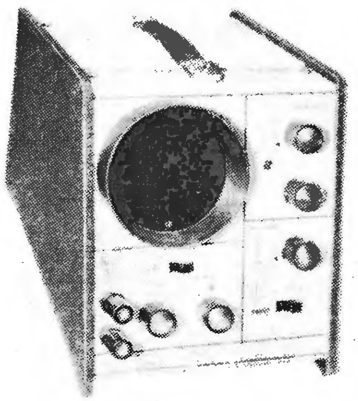


Top of Sangamo Weston specific gravity meter, with a measuring cylinder shown on the right.

mixture. The mixture and a reference solution form the dielectrics of two capacitors which are used as the frequency controlling component in a bridge-type r.f. oscillator. The construction is such that the cell with the reference mixture is placed in a pipe carrying the mixture whose composition is required. A variable frequency oscillator sweeps the range 19-37 Mc/s and at either resonant frequency the oscillator grid current rises sharply giving pulses which are fed to a flip-flop whose output can be used with digital or analogue information processing equipment. Effects of temperature changes in the measured stream are reduced since both mixtures are subjected to the temperature variation, and temperature sensitivity is also reduced by frequency scanning in a linear manner.

The instrument will cover the whole range of dielectric constants of the water-ethanol mixture (26 to 81) and it is anticipated that other mixtures with dielectric constant falling low as 6 could be accommodated.

O-level oscilloscope. A low-priced simple oscilloscope, the Serviscope Minor, developed to meet Nuffield Committee requirements for an instrument for teaching O-level modern physics, was shown in the educational section by Telequipment. Weighing only 5 lb and measuring 6in × 6in × 9in, it has a $2\frac{3}{4}$-in c.r.t. and a Y amplifier bandwidth of 30 kc/s.



Telequipment oscilloscope designed for teaching "O"-level physics.

Sensitivity range is 100 mV to 50 V per 0.5 cm graticule division. Controls have been reduced to a minimum (brightness/on-off, focus, timebase speed, Y-shift, Y-amp. gain) and operation is further simplified by an automatically locking timebase. The timebase speed can be varied from 100 μs to 100 ms per 0.5 cm graticule division.

Automatic recording balance was displayed by U.K.A.E.A. Atomic Weapons Research Establishment. Electronic balances often use the variation of capacitance to determine the balanced condition, but this instrument was required to handle radioactive materials and total enclosure was necessary. This resulted in the use of variation of inductance of a coil, which was external to the glass-enclosed apparatus, by an iron dust core, which was internally connected to a balance pan. Movement of the balance beam changed the frequency of an oscillator tuned to a 10.7 Mc/s. The circuitry which follows the oscillator gives a d.c. output proportional to the frequency change and is used in a servo system to return the pan to balance by a restoring force applied to a solenoid, which is provided with temperature compensation and damping. The current to the solenoid is passed through a standard resistance and the p.d. is measured with a digital voltmeter. The method is useful for measuring weights up to 1.5 gm with a sensitivity of 0.2 mgm.

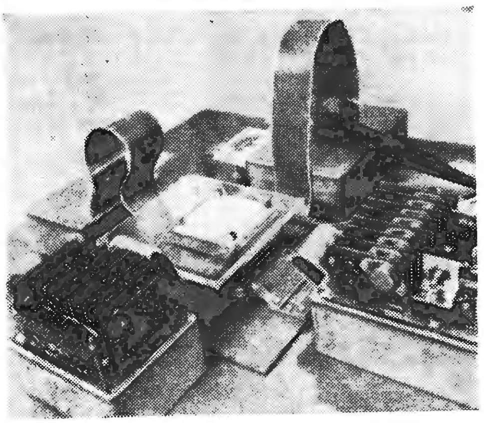
CIRCUITS AND INFORMATION PROCESSING

RC active filters.—Apart from new manufacturing methods microminiaturization has brought about the need for new circuit techniques, one requirement being the elimination of inductances, since these circuit elements are extremly difficult to fabricate on a microminiature scale. One method has been to use crystal filters and follow these with RC amplifiers, but this still leaves a lot to be desired for many applications. Frequency selective RC amplifiers built in thin-film and integrated solid state form were shown by AEI Telecommunications Division and include negative impedance converters and inverters. Response curves normally associated with circuits including inductors have been readily achieved. As an illustration conventional filters were shown and compared with RC filters, and in particular a low pass filter with one pole at a finite frequency and one at an infinite frequency with a ripple of 1dB and a stop band of 30dB was shown.

The current interest in design automation was maintained at the exhibition by the Post Office Engineering Department. A method of using computers to design wide-band transistor feedback amplifiers was presented and relied upon the computer to perform nodal analysis and computer stability margins, with the aid of Nyquist diagrams, of multiple feedback loop amplifiers, from measured admittance parameters. A directly coupled three-stage feedback transistor amplifier circuit was shown which had been designed with the aid of a computer, had constant gain up to 10 Mc/s, and the input and output impedances were precisely defined by the feedback. Computed and measured characteristics of an amplifier up to 1000 Mc/s were also displayed.

Tuning active filters.—One of the difficulties in providing variable tuning controls in active filters (using transistor, R, C combinations) is that several potentiometers, each associated with an active circuit element, have to be ganged. The Royal Radar Establishment showed a technique for providing automatic electronic ganging so that only one variable tuning control has to be adjusted. The circuits demonstrated used electronic integrators as basic units for synthesizing the required filter transfer functions, and normally each of these would be preceded by a potentiometer to permit tuning by variation of the integrator CR product. In the R.R.E. technique the potentiometers are replaced by electronic input-signal sampling switches, which alter the effective CR products according to the sampling period, and all these electronic switches are operated by a common pulse generator with variable mark/space ratio. Ganged tuning is then obtained by applying a variable control voltage to the pulse generator to adjust the mark/space ratio. Examples of circuits demonstrated included a self-tuning filter providing high-pass, band-pass, low-pass and notch characteristics at separate terminals; a tunable two-phase oscillator with a 10:1 range; and a tunable 5th-order low-pass filter with very steep cut-off.

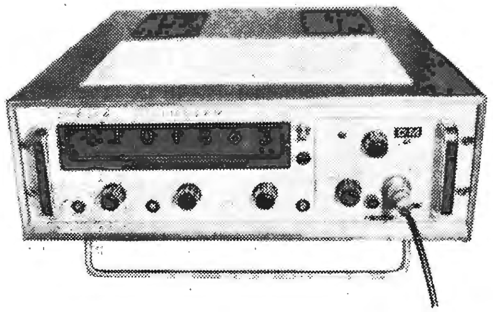
Integrated matrix store of the magnetic, coincident-current type, shown as a demonstration model by Plessey-UK, uses new design and manufacturing techniques to achieve a large-capacity, small-size, random-access store with low cost per bit. Read-out is non-destructive. The magnetic storage elements are produced in thin-film form by electroplating on a substrate and the anisotropic square hysteresis loops are obtained by compressive mechanical stress, achieved by release of a tensile stress applied to the substrate during plating. Conductors are also thin films, laid on separate substrate. The size of a conventional magnetic matrix store is limited by noise resulting from half selection of the elements, so a new method of reading has been adopted in which



Demonstration model of Plessey coincident-current matrix store using thin film techniques.

frequencies of 8 and 9 Mc/s are applied to the X and Y selection conductors respectively. From the non-linearities at the "knees" of the hysteresis loops a 1-Mc/s difference frequency is obtained, and this has two possible phases depending on which knee of a loop, upper or lower, is magnetically biased (i.e. whether 1 or 0 is stored). To avoid destruction of the stored information by this a.c. read-out system, the storage elements are formed by two distinct magnetic films, magnetically coupled. One is of high coercive force and is used for writing in the conventional manner, by coincident-current d.c. pulses, while the other is of low Hc and allows a.c. read-out without wiping out the magnetic biasing of the coupled storage film. In the $16 \times 16 \times 10$ memory stack on show, cycle time was 30 μsec and read cycle time 10 μsec. A 10^6-bit store built on these principles would occupy about 3 cu ft and consume about 250 watts.

DVM with a.c. reference.—The accuracy limitations imposed by a resistive potential divider are avoided in a new digital voltmeter technique in which the usual potentiometer and d.c. reference voltage are replaced by an inductive voltage divider (auto-transformer) and a.c. voltage reference voltage. Such inductive dividers can have division accuracies as high as 1 part in 10^7. As embodied in a new instrument shown by Digital Measurements, the technique makes possible a very wide range of measurement, 10 μV to 1.1 kV, in four switched ranges, with good accuracy (0.001% f.s.d. of the a.c. reference voltage). A high-speed a.c.-d.c. comparator detects the unbalanced between the direct voltage to be measured (which is applied to an electrometer valve) and the a.c. output of the divider. A Weston standard cell is included to enable the first range, 10 μV to 1.1 V, to be set accurately. Resolution is 1 part in the maximum digital reading of 109999.

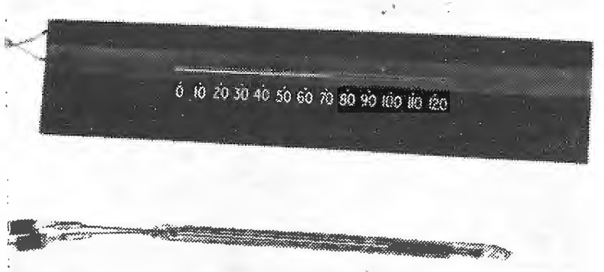


Digital voltmeter with inductive voltage divider, shown by Digital Measurements.

Acoustic telemetry.—Another item in the field of acoustics was a telemetry system used by the Research Department of the British Railways Board. This was designed to transmit acoustically the movements of parts of the overhead power supply system and pantograph, which are at a potential of 2 kV, to recorders at earth potential. This is achieved by using piezo-electric transducers at both ends of glass rods acting as insulators. At the high potential end of the system, measuring transducers are energized at an audio frequency between 3.9 and 7.2 kc/s and the modulated outputs are fed to the piezo-electric transmitters after amplification. This resultant amplitude modulated signal is accompanied by an unmodulated signal and the two are received at the low-potential end of the glass rod, amplified and fed to phase-sensitive detectors. The equipment works from d.c. to 50 c/s and records displacements, accelerations, etc., associated with the power supply system.

DISPLAY DEVICES

Linear milliameter.—A low pressure discharge tube may be used to indicate current by measuring the length of the glow discharge at the cathode. A linear relation between current and length of cathode glow occurs when an anode of equal length is mounted parallel to the cathode and at a sufficiently short distance to prevent the anode from glowing.

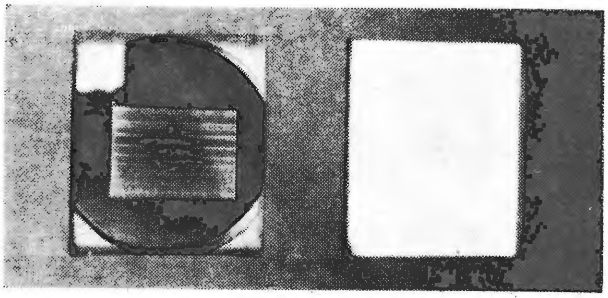


Mullard's glow discharge milliameter, which gives a linear indication of current up to 10mA.

Mullard Research Laboratories demonstrated such a tube with a 5% accuracy of reading. The useful current range is dependent on the gas composition, pressure and electrode diameter. The device has a full-scale indication of 10 mA over a distance of 10 cm. The igniting potential (150 V) and maintaining potential (115 V) are fairly close, so the tube can be controlled by simple transistor circuits. A demonstration showed the use of the tube as a motor speed indicator, with calibration from 0 to 5,000 r.p.m.

Light guides.—Bundles of optical fibres through which light may be ducted were shown by Barr and Stroud. Light is transmitted along the fibres by total internal reflection at the interface of the fibre core and its sheath, which has a lower refractive index than the core. Flexible light pipes are made from 50 μ fibres, and rigid rods from 10 μ fibres which permit image transference owing to their rigidity. If one end of a rigid fibre rod is made larger than the other, a magnified image is produced at the larger end, and *vice versa.* Contrast of the image can be improved by adding an outer absorbent sheath to the fibres and this effectively reduces "cross talk" between the fibres.

Faceplates: Fibres can be fused into a solid block, allowing application to coupling of image intensifiers and cathode-ray tube faceplates. Indeed, a c.r.t. faceplate was shown by R.R.E. for operation in bright surroundings (see picture). A high level of illumination at a c.r.t. screen causes reflections from the phosphor, decreasing the visibility of the image. The use of a fibre-optic plate increases the contrast by allowing light which is approximately normal to the screen to pass through the plate. Light incident at angles greater than the critical angle is absorbed.



Right-hand photograph shows a normal c.r.t. with trace under high ambient illumination. Left-hand picture shows the same trace under the same illumination, but with a fibre-optic faceplate. (R.R.E., Malvern.)

Cascade image intensifier with a light flux gain of 10^5 was shown by 20th Century Electronics. It has two intermediate dynodes for electron multiplication, each comprising a phosphor and a photocathode deposited on opposite sides of a 4 μm thick mica sheet. Overall resolution is 30 line-pairs per millimetre and the final image appears on a screen of 39-mm diameter. Developed on the basis of original work by Professor McGee of Imperial College, London, the intensifier is designed for use in astronomy and particle physics.

Commercial Literature

"**The Sig Gen Book 1**" is the title of a 26-page publication issued by Marconi Instruments Ltd., of St. Albans, Herts., on how to use signal generators for receiver measurements. It is split into seven sections covering source impedance, coupling to loop aerials, sensitivity, automatic gain control, receiver bandwidth (frequency response characteristic), selectivity, and spurious responses.
5WW 326 for further details

"**Impedance Measurements with a Q Meter**" is the title of another reference type of publication recently announced by Marconi Instruments. It gives theoretical and practical information and also possible pitfalls to look out for when conducting these tests.
5WW 327 for further details

"**Ten new products from Imhofs**" are contained in an eight-page catalogue H/143 now available from Alfred Imhof Ltd., of Ashley Works, Cowley Mill Road, Uxbridge, Middx. There are additions to their already extensive range of instrument housings and accessories, and make possible a new "square" form of styling, that is now optionally available on the majority of the racks in their International Series of Imracks. Other new items described in the catalogue include ventilation fan units, handles and chassis runners.
5WW 328 for further details

Modular Construction System.—Details of the ISEP (International Standard Equipment Practice) system of modular construction for electronic equipment housings are contained in a new twelve-page brochure (MG/104) available from the electronic services division of Standard Telephones and Cables Ltd., of Edinburgh Way, Harlow, Essex. The brochure is well illustrated and shows how, with standardized parts, the user can build different sizes of racking, sub-assemblies, circuit boards, multi-pole connectors and cubicles. This publications should be of particular interest to those building electronic equipment for the home and overseas Ministry and P.T.T. authorities as many of these have standardized on the ISEP system.
5WW 329 for further details

SGS-Fairchild **semiconductor products** are now classified under the following headings: Military, Professional, Industrial and Consumer. Catalogues covering these fields are available from the company's offices at 23 Stonefield Way, Ruislip, Middx.
5WW 330 for further details

Mullard Industrial Components.—The 1965 edition of "A quick reference guide to Mullard components" is now available from the company. Over a third of this 36-page publication is devoted to capacitors. Other items in the guide include a selection of resistors, electro-mechanical components, magnets, ferrite materials and assemblies, computer core assemblies, thin-film circuits, and piezoelectric materials. Requests for copies should be made to central enquiry handling, Mullard Ltd., Mullard House, Torrington Place, London, W.C.1.
5WW 331 for further details

The 1965 "**Electronic Valve and Component Data**" abridged catalogue of the English Electric Valve Company contains brief specifications of the products they manufacture at Chelmsford and Lincoln. These include ignitrons, rectifiers and thyratrons, magnetrons, transmit-receive and transmission blocking cells, solid state microwave devices, photo-multipliers, and glass-to-metal seals. Two of the 20 pages are devoted to an equivalents index that lists valves of various manufacturers for which EEV types may be used as replacements.
5WW 332 for further details

An "**Extended Scale Voltmeter**" employing a Zenar diode to achieve zero suppression is described in specification sheet 32 now available from the manufacturers, British Physical Laboratories, Radlett, Herts.
5WW 333 for further details

The 2500 series of "**Radiation-tolerant Television Cameras**" manufactured by Cohu Electronics Inc. are described in leaflet 6-327, which is available from the company's Kintel Division, whose address is Box 623, San Diego, California. One-inch vidicons are fitted to these 525-line cameras.
5WW 334 for further details

The second edition of the 19-page booklet describing the LFK4 "**Audio Transistor Package for Transformerless Amplifiers**" has been issued by the Entertainment Markets Division of Mullard Ltd., whose address is Mullard House, Torrington Place, London, W.C.1. This transistor package is intended for use in portable radio and audio equipment with output powers up to 750 mW at 9 V and 1 W at 12 V. The design method described in the publication is based on a report prepared by R. F. Brown of the Mullard Central Application Laboratory.
5WW 335 for further details

PARIS COMPONENTS SHOW

PARIS, PORTE DE VERSAILLES, 8-13 APRIL

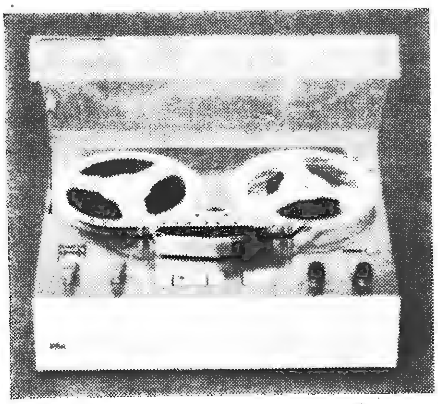
NOW that the exhibition has left the collection of halls on the east side of the Avenue Ernest-Renan and crossed to the main exhibition (*Le Hall Monumental*) under one roof, the *confrontation,* as the French say, which meets the eye on entering is more daunting than ever. The horizon is lost in the haze at the far corners of the hall; there are nearly 900 stands and one has to walk 5 km to see them all.

Obviously, any report must be highly selective and many items, especially those shown by British Manufacturers who will also be at Olympia next month, have been left for our coverage of the R.E.C.M.F. exhibition.

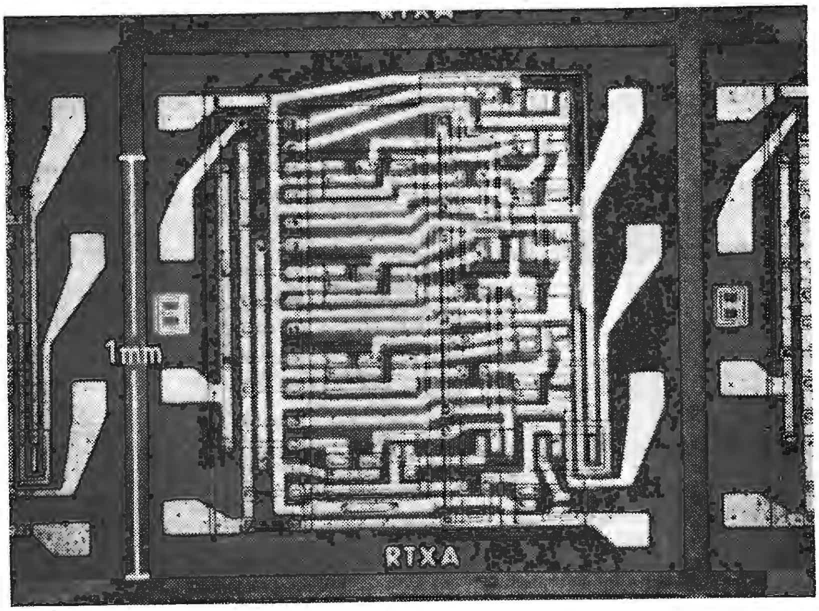
A branch of the main hall was this year set aside for what the organizers term the *1er Salon International de l'Electroacoustique* but which did not differ much from the aggregation of the same firms in last year's general exhibition. Monsieur Gogny, who revives for one U.K. visitor memories of Voigt and his lone work for high quality in the mid '30s, was showing refined versions of his now well-known Orthophase ribbon-driven flat diaphragm speaker cells. Also a number of combinations of conventional moving coil units, conventional that is with the exception of the "woofer" units which incorporate a separate velocity-sensing unit, with separate magnet system, providing feedback to linearize the velocity characteristic of the main coil.

Another interesting audio exhibit was the new Braun TG 60 tape recorder designed to give "studio" performance comparable with the rest of Braun domestic quality equipment. The outstanding feature is the plug-in head assembly which permits rapid change-over between 2 and 4-track working.

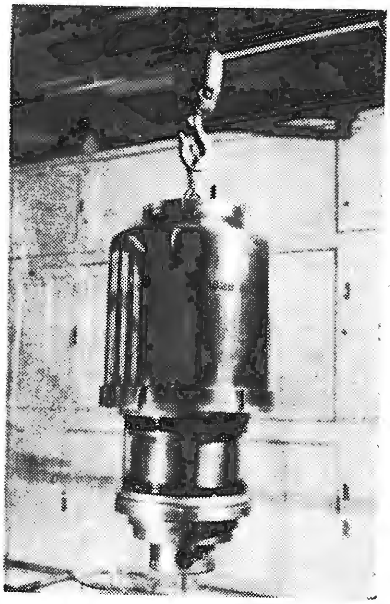
In the main exhibition the real components, *pièce détachée,* are fittingly congregated around the entrance and as one penetrates into the hall the complication increases, with sophisticated measuring equipment at the four sides. For precision and quality in small metal parts it was pleasant to find an old-established Birmingham firm (Brandauer & Co. Ltd.) setting the standard. Many of these minute parts—contacts, transistor headers, etc. —are gold plated and P.M.D. Chemicals Ltd. were expounding their "Duplex" technique in which a heat



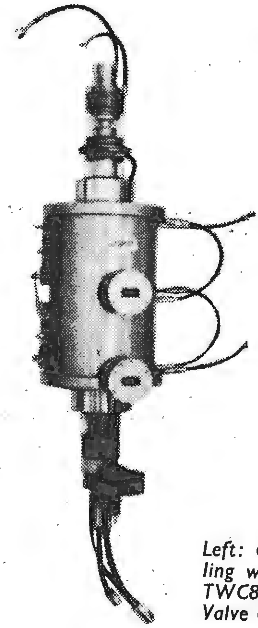
Braun TG60 tape recorder with plug-in heads



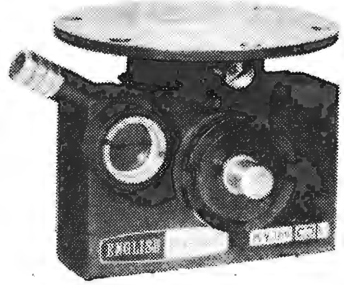
Photomicrograph of the SGS-Fairchild decade counter chip.



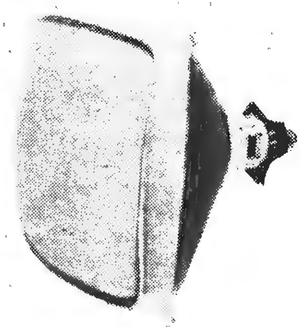
Telefunken 500 kw triode (RS1828).



Left: C-band travelling wave tube, type TWC827, by M-O Valve Company



English Electric KY366 vapour-cooled klystron.



Right: Colour display tube (A63.11X) by "La Radiotechnique" has pre-stressed (auto-protected) 63 cm rectangular screen

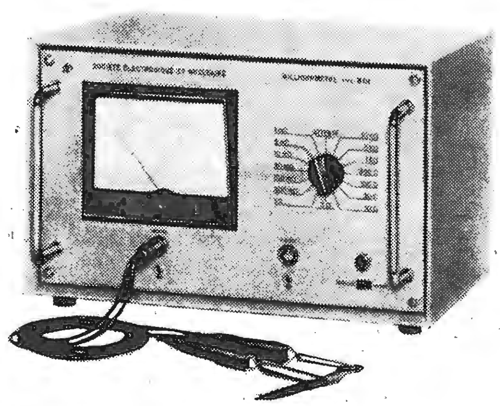
resisting gold layer is combined with a second coating to reduce porosity.

A striking demonstration of the low-noise properties of Filotex coaxial cables was given by inducing large-amplitude traverse mechanical waves in a vibration test bench. Also on this stand was seen a parallel-stranded flexible coaxial shielding (Type FMG) which is easier to strip than the conventional braiding. Sub-miniature coaxial cables shown by Precicable-Bour S.A. are made down to 1 mm external diameter ($50\,\Omega \pm 4$, 93 pF/m, 0.87 dB/m at 200 Mc/s). A useful kit of inter-series cable adaptors and fixing spanners for most NATO stock numbers was shown by Greenpar Engineering Ltd.

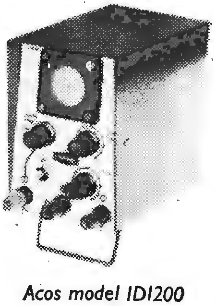
New n-p-n high voltage transistors (700 V, collector-to-emitter) and germanium p-n-p diffused alloy power types (325 V) switching 2A in $<2\mu$sec were announced by Bendix for use in television receivers. The all-planar techniques evolved by S. G. S. Fairchild were well exemplified by a single chip decade counter circuit (CμL958), measuring 1.25 mm square and containing four binary-triggered flip-flops with feedback. There are 24 transistors and 30 resistors and it consumes 160 mW at 4 V. Thin film techniques for R and C in conjunction with silicon integrated active circuits were represented by the Ferranti "Multilin" system.

Some things transistors cannot yet do—for instance, produce 8 kW at 6.3Gc/s; but this is the performance of the M-O Valve Company's travelling wave tube which was on show and which is in use at Goonhilly Down. Nor can they yet do the work of vapour-cooled klystrons such as the KY366 shown by English Electric and used in the Post-Office microwave links between Goonhilly and Plymouth for the "Earlybird" tests. The contrast is even greater at broadcast frequencies for which Eimac have produced a 250 kW vapour-cooled pentode (5CV250, 000A) and Telefunken a triode (RS1828) rated at 500 kW.

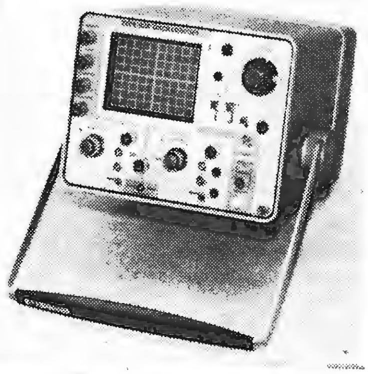
In switching circuits transistors have not yet entirely superseded mechanical relays, particularly glass-encapsulated reeds, typified "dry" by a new G.E.C. model



Milliohmmeter, Type R01, by S.E.N.



Acos model ID1200 1-in oscilloscope



Tektronix Type 422 portable oscilloscope and "mercury-wetted" by the I.T.T. range. These are cheaper and have life expectances up to 10^9 operations. High-speed polarized relays of the Carpenter type are also less expensive than the transistorized equivalent shown by T.M.C., but in unattended situations or where skilled adjustment is expensive, the higher capital cost of the transistor version may be justified.

Two new colour television display tubes, both with rectangular screens, were shown, one by the firm "La Radiotechnique" which markets the Miniwatt and Dario valve and transistor marques in France, and the other by Sylvania. This latter tube has a new phosphor coating for the red dots containing the rare earth europium which enables the brightness to be brought up to the more sensitive green and blue levels. An overall brightness increase of 43% is claimed.

Among measuring instruments a milliohmmeter (Type RO1) by Société Électronique et Nucleaire was noted. It has a range of $10\,\mu\Omega$ to $10\,k\Omega$ and uses long thin leads and crocodile clips for connection to the circuit to be measured. Actually the jaws of each clip are insulated from each other one being used to establish a known current through the circuit under test and the other to measure the voltage developed across it. As the input resistance of the voltmeter is about a megohm the lead resistances can be neglected.

Oscilloscopes showed no striking advances in performance, but there was a trend among the high-grade makers to produce models of smaller size and weight, typical examples being the Hewlett Packard Model 132A double-beam tube, using Nuvistors for low microphony in the channel amplifiers, and the Tektronix 422 measuring only $16 \times 8\frac{1}{2} \times 6\frac{3}{4}$ in, also with double-trace operation and a wide selection of functions for all kinds of scientific work in the field. The ultimate in portability was seen on the Cosmocord stand where a new range of inexpensive vibration measurement equipment included a 1-in oscilloscope measuring approximately $5\frac{3}{4} \times 4\frac{1}{2} \times 3$ in.

COLLOQUIUM ON MEMORY TECHNIQUES

PARIS, UNESCO, 5-10 APRIL

An attendance not far short of 600 served to indicate the breadth of interest in this subject. While the commercial rewards in a future dominated by computers are likely to be high for anyone making a major break-through in capacity and/or access time, this alone would not account for the fascination of the problem for applied physicists, technologists and engineers who have the planning of computer systems. Work on thin magnetic films, opto-electronics, cryogenic devices and ferroelectrics have produced a wealth of paper work and more questions than answers, but the time will no doubt come when the dominance of the ferrite ring core matrix in present-day computers will be superseded.

Successive miniaturization giving better packing densities, and multi-aperture cores permitting non-destructive read-out have kept ceramic ferrite cores ahead of the pack so far. Although a higher Curie point is possible with lithium, and other minor improvements can be obtained with various additives, H. P. Peloschek (Philips) thought that the original manganese-magnesium square loop ferrite was likely to remain the most-favoured type for a long time on account of its uniformity, reliability and fast switching time. He saw no sensational improvement in these directions, but thought that higher saturation magnetization and crystal anisotropy were possible, and that better ceramic structure might be found to improve the squareness of the hysteresis loop, degraded by the increased effect of disturbances (pores, etc.) in miniature structures. Most speakers supported this view and agreed that competitors using other methods were aiming at a moving target.

Much work has been done on thin magnetic films which promise faster and cleaner switching because the change of magnetic state depends on 180° coherent rotation of the molecular magnetization in what is virtually a single domain and is independent of the wall motion between domains which is dominant in bulk materials. J. I. Raffel described work at M.I.T. on a high-capacity film store giving 3,200 word lines on 350 digit lines (1.1×10^6 bits) on a glass substrate only 10 inches long. The magnetic material is deposited by evaporation in a vacuum and special precautions against blemishes (e.g. dust) in preparation are necessary, as one open or shorted line could spoil the whole store. Non-destructive read-out is possible with sandwich films in which a "hard" (Ni Fe Co) film is separated from a soft (Ni Fe) film by a thin non-magnetic layer. The coupling between the magnetic films in these conditions is parallel and identical in direction and this unexpected phenomenon is as yet not satisfactorily explained, though work by Prof. Néel and his colleagues at C.N.R.S. at Grenoble suggests that three mechanisms may be involved: (1) contacts through microholes in the non-magnetic layer, (2) diffusion into this layer of ferromagnetic elements and (3) long-range interaction through the polarization of conduction electrons. The dominant cause is dependent on the metal used for the intermediate layer.

An unusual photoelectronic memory depending on persistent internal polarization (p.i.p.) in a layer of powdered photoconductive material in air, and also exposed to an electric field was described by H. P. Kallmann (Univ. of New York). The information is written-in by a light beam and can be released by light in the absence of the electric field, but with both field and light off it is calculated that the latent image would last, under dry conditions, for 10 to 12 years.

Another unusual memory principle was described by J. T. Chang *et al* (Bell Tel. Labs.) and depends on the rotation of polarization of transmitted light through a mosaic of gadolinium iron garnet crystals on the application of a magnetic field. The magnetization of the iron sub-lattice of the garnet produces a rotation in opposite senses for magnetization along or against the direction of light, so the elements can be interrogated non-destructively.

In the concluding session J. A. Rajchman (R.C.A.), a pioneer of memory techniques, summarized the conclusions of the conference and gave his views of future prospects. Too much emphasis he thought should not be given to miniaturization and perfection of integrated memories themselves without at the same time considering the integration of the access switching circuits which at present cost about as much as the matrix itself. Junction transistors at present capable of being packed at 20 or more to the "chip" were too big, and one had to think in terms of thousands in the same area. Meanwhile diodes which could be laid down at 60 to the inch must offer the best prospect for integration during the next 2 or 3 years. Tunnel diode characteristics were sensitive to manufacturing tolerances and he thought that the future might lie with field effect complementary pairs which were capable of nanosecond switching times with negligible energy requirements. But we would still need 6 to 8 transistors per bit.

In spite of slow progress and pessimism in some quarters he thought that superconducting memories had as much chance as any of beating the ferrite core. They contained only conductors and were simple to manufacture, energy requirements were small and switching thresholds sharp.

The attraction of optics as providing the ultimate in speed of operation was in Dr. Rajchman's view illusory. Compared with fibres, necessary for the conduction of light to the appropriate part of the memory, the copper wire for the conduction of electricity was a great invention; it was just as fast and much more efficient. Lasers with their capability of concentrating large energies in a small spot were not yet sufficiently developed to judge whether a practical application could be made.

LETTERS TO THE EDITOR

The Editor does not necessarily endorse opinions expressed by his correspondents

Class D Audio Amplifiers

THE article in the April issue by Messrs. G. F. Turnbull and J. M. Townsend concerning their "pulse width modulated," or "class D," audio amplifier circuit interests me very much. They have produced a design essentially similar to the one I described in this same journal over two years ago (Letter to the Editor, March 1963), although I am assured that they were unaware of my circuit until after their article was complete. We both advocate arrangements in which overall negative feedback is used to generate the basic switching, and apparently we were led independently to this principle from consideration of different kinds of automatic control system.

Since the publication of my letter I have several times heard the comment that this type of switching must lead to distortion, since it introduces a variation of the basic switching frequency when a modulation waveform is applied and that this variation must give rise to complex sidebands which will spread down into the a.f. band more seriously than would have been the case with the more usual fixed frequency of switching. But is this variation of the frequency necessarily a bad feature? Might not the feedback be cleverer than we are, and "know" that a judicious amount of frequency modulation can actually reduce the troublesome low-frequency sidebands? In fact I am sure that this is the case, and that the feedback effectively modifies both the mark-to-space ratio and the frequency of the switching square-wave in such a manner as to give a very worthwhile reduction of the spurious sidebands at the low frequencies.

Consider the basic arrangement as shown in Fig. 1, which is almost a reproduction of Fig. 8(a) from the article in the April issue. The amplifier A and the capacitor C form an integrator using the well-known "Miller" principle, and the resistors

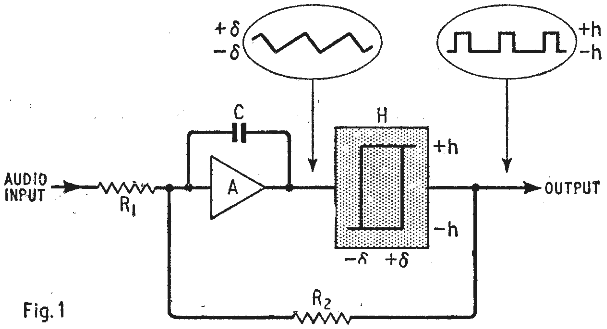


Fig. 1

R_1 and R_2 form a feedback network also in a familiar way. If the amplifier A has a high gain, so that voltage swings at its input are negligible, and a high input impedance, so that no current is wasted, then the feedback network delivers a current proportional to the voltage error at the output point and this current is integrated by the capacitor C. Thus the output voltage of the amplifier A is at every moment a measure of the integral of the error of the overall amplifiers and the hysteresis circuit H trips over whenever this accumulated (error × time) integral threatens to get outside the range represented by the voltages $\pm\delta$.

We can thus draw a diagram of the *error* waveform of the overall amplifier by subtracting the ideal linear output voltage,

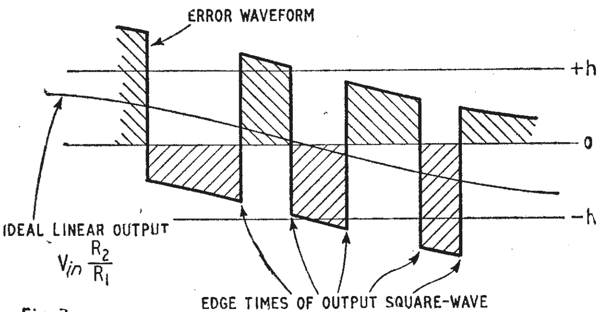


Fig. 2

which is $V_{in}\frac{R_2}{R_1}$ from the actual output square wave that the system gives. The result will look like the waveform in Fig. 2. where the vertical edges have the same height and timing as the edges of the square-wave output, but are joined together by portions of the ideal linear output as a result of the subtraction. Now clearly we require this *error* to be as free as possible from components of frequency in the a.f. band. The modulation system we are discussing, and only this system, has the property that each single pulse in this error waveform has the same voltage × time integral, indicated by the areas shaded on the diagram, as all the other pulses.

Now this means that not only are the very low frequency components of this error waveform always exceedingly small, but that their increase of size along the frequency spectrum is parabolic rather than linear. In contrast to this, conventional fixed frequency p.w.m. generates sideband components of constant amplitude even when their frequency is close to zero, such as when the signals at the input are roughly one-quarter or one-sixth of the switching rate. Now the writer is forced to admit that he has been unable to find a satisfactory method for obtaining a proper Fourier analysis of this switching waveform, perhaps some reader may be able to help, but approximate methods suggest that the advantage gained with this arrangement extends over a band of frequencies up to at least a third or a half of the basic switching frequency, that is to say throughout the range that is of practical importance. It will be realized, of course, that if very heavy modulation of the mark-to-space ratio is used then the switching rate falls drastically and severe distortion occurs, but it will be found that the effects are not really so very much different when a system of the constant frequency type is overloaded, and the only honest course is to quote a figure for maximum output power based on a maximum modulation depth of perhaps 75%.

Thus this basic system of modulation, involving both the mark-to-space and the frequency of the switching wave, obtained with the negative feedback kind of circuit appears to be theoretically superior to the more usual fixed frequency p.w.m. scheme. This means that such a circuit has the practical advantage that a lower switching rate can be used to obtain a given level of performance, and this in turn eases the speed requirements on the final power transistors. The selection of these is at present the most difficult part of any Class D amplifier design, so that easing of the requirements is of considerable value.

But this is not the only advantage of the negative feedback system. Consider Fig. 1 again and think what is actually involved in block H. This is not merely a switch with hysteresis, but a power amplifier capable of driving some watts into a loudspeaker. It will normally comprise four or more transistors of which several are being pushed for economic reasons to their limits of power and switching speed. Thus it is naive to assume that the pulse edges will emerge at the loudspeaker circuit with accurately defined amplitudes and uniform time-delays. But in a circuit without feedback this assumption has effectively been made and if it is wrong even by only a few per cent. then a corresponding distortion will be found in the output. The negative feedback, however, corrects for errors of these types and it is a feature of this kind of amplifier that feedback can be put over so many stages that the correction is easily made almost perfect. The only worry is that the circuit may possibly "squegg" if you are exceedingly careless; it will, of course, "hoot," as it was intended that it should!

This makes it clear that the only way in which the circuit can misbehave is by a weakness of the feedback arrangement. Thus the amplifier A in Fig. 1 must take only a negligible input current and its input voltage must not vary appreciably. If these conditions are not met then not merely does distortion appear, but power line hum is able to creep in and bass response can be lost. My circuit of March, 1963, can be substantially improved in this respect by the use of either a transistor of exceptionally high current gain or a Darlington pair in the first stage. The circuit of Turnbull and Townsend in the April issue has a lower impedance feedback network than mine, so that it will be likely to suffer less, but even so the selection of a high gain transistor for Tr1 will probably be worthwhile. The exact mechanism of this interference can be rather subtle, but the essential effect is that any variation of the collector current of this transistor due to any cause such as variation of the voltage applied to the load injects a current, reduced only by the current gain factor, directly into the feedback bridge. This in turn causes a corresponding change of the voltage at the loudspeaker and hence an unwanted contribution to the output.

It seems rather unkind to criticize the details of the circuit given in the April issue when I am so much in agreement with its basic principles. Accordingly I will content myself with asking that interested readers should compare the two circuits before building either of them, and I would also like to point out that far and away the most difficult problem for many readers will be in obtaining transistors fast and powerful enough to work adequately in the final stage. The day when transistors become like vacuum tubes and are always able to function far beyond the highest audio frequencies whatever their current or power capabilities has not yet arrived. When it does we may well see the Class D circuit as the only type of a.f. circuit used in any numbers.

Cheadle. K. C. JOHNSON

Pulse Width Modulated Audio Amplifier

IT has been my pleasure to read the valuable article by G. F. Turnbull and J. M. Townsend on pulse modulated audio amplifiers in the April issue.

I would like, if I may, to underline the muffled plea (conclusions, p.167) for the development of transistors or G.T.O.s appropriate to power outputs of 20 to 100 watts r.m.s.

In the current range, there is a pronounced notch between audio types having inadequate switching speeds, and h.f. power devices which are too good, and correspondingly expensive for this application. It is to be hoped that the more enterprising semiconductor manufacturers will force the potential of class D systems in the industrial as well as domestic markets.

There is a good choice available for the lower-powered stages with prices ranging from under one shilling to about 4s for planar epitaxial devices. I mention this to make the point that other components, e.g., a decoupling capacitor, can cost the manufacturer more than a transistor.

The editorial of the April issue makes appropriate comment about "habits of thought induced by long experience with valves. . . ." Historically stress has always been laid upon the number of valves employed in a particular piece of equipment. There is surely no longer any reason to regard transistors differently from other circuit components, such as resistors and capacitors.

This argument is relevant when comparing open and closed loop class D systems. It is perhaps worth mentioning that in an open loop system employing double edge modulation the h.f. energy is confined to blocks centred on the *fixed* p.r.f. and its harmonics, and that filtering therefore tends to be easier. Whilst filtering is frequently unnecessary in domestic installations due to the large h.f. resistance of most loudspeakers, it is important in high-power p.a. applications in order to avoid radiation.

On this topic and again referring to "habits of thought," we ought not to be prejudiced against an audio amplifier containing a "local oscillator" any more than we are towards super-het receivers. In both instances, however, adequate design is called for.

Oxted, Surrey. D. R. BIRT

Klystron Action

I CANNOT agree with Mr. K. E. Hancock's qualitative description of the action of the klystron in the October, 1964, issue. Contrary to his statement in the script on page 509, the charge distribution in the resonator of Fig. 4 gives a field distribution most favourably disposed towards accelerating the beam electrons within it.

Furthermore, although a finite transit time in the gap (G_1 to G_2) does affect the intensity of velocity modulation of the beam (by a gap factor $\sin\frac{\phi}{2}\Big/\frac{\phi}{2}$ where ϕ is the transit angle), the phenomenon of bunching can be explained without reference to it. The main factor governing the velocity of an electron leaving G_2 will be the potential to which it has been raised at this point, and it can be easily shown that the velocity of an emergent electron is given by $\mu_0\left(1+\frac{v_1}{V_0}\right)^{\frac{1}{2}}$ where v_1 is the instantaneous potential difference between G_2 and G_1, V_0 is the steady p.d. between resonator and cathode and μ_0 is the electron velocity with no cavity resonance. Bunching is thus obtained by electrons entering the retarding field space near the repeller at different velocities as v_1 goes through its sinusoidal cycle. The modifying gap factor will have little effect upon this as the transit angle is normally of the order of 1 radian.

If the bunch can be timed to return to the resonator when it is again in the phase shown in Fig. 4, it will be retarded in velocity, thus giving up energy to the field.

Cardiff. E. H. JONES
Welsh College of Advanced Technology.

Resistances and Reactances in Parallel

IN reply to Mr. de Visme's letter in the January issue, let me say that the graphical method for determining the equivalent series circuit of a given R and X in parallel, and *vice versa*, has been described in the literature. At a second-hand book shop I bought a nicely bound volume of *Experimental Wireless and The Wireless Engineer* for 1927, from which one obtains an excellent insight into "the state of the art" at that time.

Mr. de Visme's method is used in two articles: "Some New Coil Impedance Diagrams" by W. A. Barclay on page 87, and "Alterations to the Modulating Panel at 2LO," by Green, Hewitt and Petersen on page 467. In each case the authors give credit to F. M. Colerbook for originating the method in an article "The Graphical Analysis of Composite Impedance," in *E.W. & W.E.* for December 1924.

The late F. M. Colebrook is, of course, well known for his book "Basic Mathematics for Radio and Electronics," which, in the 1927 volume of *E.W. & W.E.* was running in serial form. Another contributor, describing the horizontal Hertzian aerial, and a graphical method of amplifier coupling design was that Peter Pan of radio technical literature, M. G. Scroggie.

Brisbane, Qld., Australia. A. R. WHITE

Audio Topics—Nomenclature

IN view of the increasing interest in class D amplifiers it is surely pertinent to begin this new design phase with accurate terminology.

It was in the *Wireless World* of April 1946 that "Cathode-Ray," dealt with the term "pulse width" and showed that this was slovenly jargon for the appropriately designated concept of "pulse duration." However, pulse duration modulation has been customarily used for a different sort than that associated with your class D. Surely the correct and most widely used term for this type of amplifier is "pulse-ratio" modulation?

London, S.W.19. P. F. COOK

I THINK I voice the feeling of the p.a. profession when I say we wish to remain old fashioned enough even with our latest transistor amplifiers, to retain sine wave ratings.

May I make a point about "pop" music? The dynamic range here is much less than the 10dB mentioned—in many cases less than 3dB! As this class of programme takes up so much broadcast time, and accounts for a large volume of disc sales, surely this type of signal must be considered?

Luton, Beds. HAYDON G. WARREN

National Certificate Courses

YOUR correspondent Mr. I. Leslie (April issue) complains that after working for 7 years and having three A Level passes he cannot enter directly a Higher National Certificate Course. When he left school two avenues for his further advancement would in theory be open to him:—

(1) to follow technological courses leading to O.N.C. and H.N.C.

(2) to acquire sufficient G.C.E. passes at O and A level to qualify for entry to a degree course, if he had not sufficient already, and to proceed either as a part-time student for a London External degree or as a full-time grant-aided student (at a university or technical college) for an internal or a London External degree.

He has elected to follow the second avenue and now appears to be ready to enter on the degree course proper. If it happens that he has not yet obtained qualifications acceptable for admission as a corporate member of a particular professional institution, apparently without having years ago considered what he would need for this purpose, he is in no position to complain that the regulations of avenue (1) above are not suited to his particular case.

In any case there are a number of professional institutions to which persons active in the field of electronics might usefully apply.

University of Newcastle Upon Tyne. P. SHORT

Average Power

IN your editorial comment on the question of power ratings of audio amplifiers you use the expressions "watts r.m.s." and "sine-wave r.m.s. power." It is clear from the context that what is actually meant is average watts and average power, and thus the addition of the letters r.m.s. is both unnecessary and misleading.

Virginia Water. L. GOODALL

REPRINTS OF "W.W." ARTICLES

IN response to requests we give below a list of the articles which have appeared in *Wireless World* and are, or will be, available as reprints.

Wireless World Oscilloscope	
Parts 1, 4, 5 & 6 (Mar., June, July & Aug. '63)	5s 0d
Part 2 (April '63)	2s 6d
Part 3 (May '63)	2s 6d
Parts 7 & 10 (Feb. & Oct. '64)	2s 6d
Parts 8 & 9 (Mar. & April '64)	2s 6d
W.W. Audio Signal Generator (Nov. & Dec. '63)	3s 0d
Transistor Audio Power Amplifier & Pre-Amplifier; Tobey & Dinsdale (Nov. & Dec. '61)	3s 6d
Wireless World Crystal-Controlled Transistor F. M. Tuner (July '64)	available soon
Transistor High-Quality (Stereo/Mono) Audio Amplifier; Dinsdale (Jan. & Feb. '65)	available soon
Low-cost High-Quality Amplifier; Baxandall (Feb. '58)	3s 6d
F.M. Tuner (Valve); Amos & Johnstone (April, May & July '55)	2s 0d

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"Where do transistors go . . ."—*Some of those that fall by the wayside find their way to PMD Chemicals Ltd., of Coventry, who find that it pays to recover the headers and also the gold which is plated at considerably greater thickness than on jewellery. Rejects arrive by the 1 cwt sack and stocks awaiting processing can be anything up to 10 tons!*

Satellite Communications Service Begins

GOONHILLY STATION MODIFIED FOR EARLY BIRD SYNCHRONOUS SATELLITE

LAUNCHING of the Early Bird synchronous satellite on 7th April effectively established the first satellite radio communications system to be used in a commercial telephone service. Previous satellite communications systems have been purely experimental. After an initial test period, now nearing completion, the new system will carry a proportion of the transatlantic telephone traffic normally conveyed by cable between Europe and North America. Nevertheless it is still only a trial commercial system. The economics and technical advantages of synchronous satellite working have still to be assessed, relative to h.f. radio, undersea cables and the rival non-synchronous satellite systems, before a decision can be made on the best type of satellite scheme for global communications.

The Early Bird system will provide up to 240 telephone circuits between an American earth station, at Andover, Maine, and any one of three European earth stations, at Goonhilly Downs in Great Britain, Pleumeur Bodou in France and Raisting in W. Germany. Continuous operation is possible, but initially the service will be restricted to peak telephone traffic hours between noon and midnight, Monday to Friday. The system may also be used for occasional experimental television transmissions. The three European stations will operate consecutively, each carrying the whole of the satellite-system traffic for one week in every three week period. The remaining two weeks of the period are for standby operation and maintenance respectively. Switching centres at London, Paris and Frankfurt will establish the required telecommunication circuits throughout Europe, to and from whatever station is acting as the satellite terminal.

Early Bird, otherwise known as HS-303, has been placed at a height of about 22,240 miles and moves in a synchronous equatorial orbit which causes it to be stationary with respect to the earth at a point 27° 30′W above mid-Atlantic. Built by Hughes Aircraft Company, U.S.A., the HS-303 is constructed as a cylinder 3ft in diameter and 4ft 6in high with projecting aerials. The cylinder carries on its surface about 6,000 solar cells, providing a 45-watt power generator, and encloses two communications transponders, a v.h.f. telemetry transmitter, two microwave beacons and a battery of rechargeable cells. The two transponders (one for each direction of signal transmission) receive signals from a colinear aerial array and use a common travelling-wave tube transmitter, which has an output power of 4.3 watts and feeds a co-axial slot aerial. For telemetry, four v.h.f. whip aerials are used.

Communications signals are transmitted from the European earth station on 6.30 Gc/s and received by one of the satellite transponders, which re-transmits them on 4.10 Gc/s to the U.S.A. In the reverse direction, signals are transmitted from Andover on 6.39 Gc/s and received

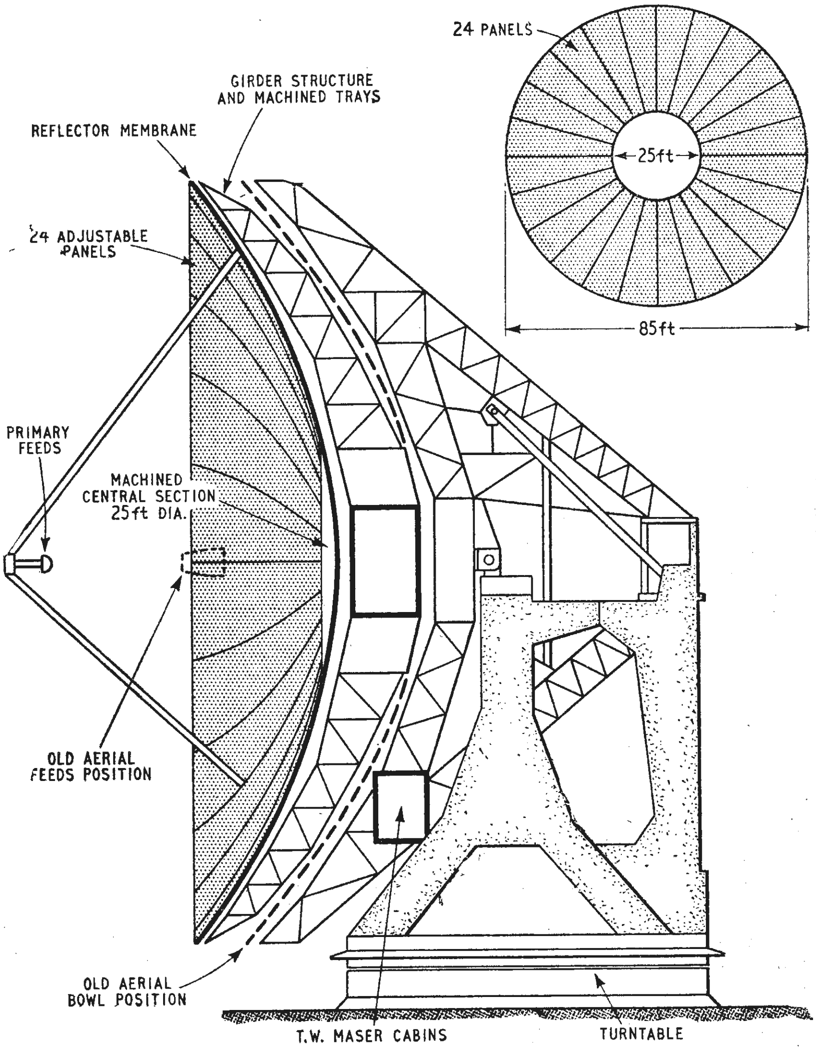


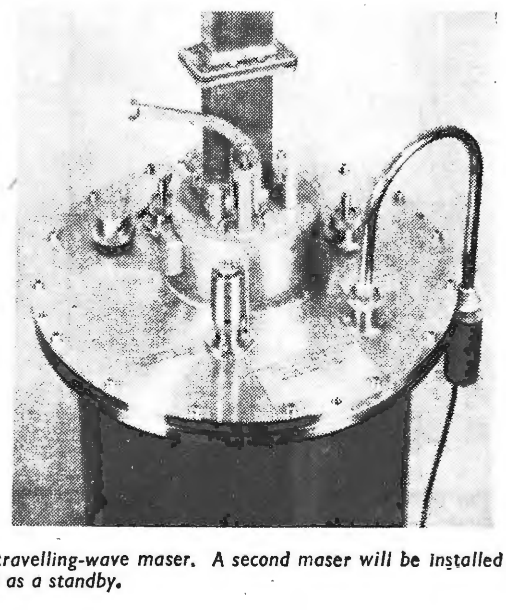
Fig. 1. Main features of the modified aerial, showing the new bowl built on top of the old one.

by the second transponder, which re-transmits them to Europe on 4.16 Gc/s. Beacon frequencies are in the region of 4 Gc/s (transmitted with e.r.p. of 250 mW) and v.h.f. telemetry frequencies are 136 Mc/s. (All figures are approximate.)

In preparation for the Early Bird communication system the British Post Office, as reported earlier, has made extensive modifications to its terminal station at Goonhilly Downs. These have been necessary mainly because different frequencies are now used and because HS-303 is more distant than earlier satellites so that received signals are considerably weaker (power received from the satellite is about 10^{-13} W). Furthermore, since the new communications system is intended for regular commercial use, it must be more reliable than an experimental scheme. The most important aspect of the modifications has been the improvement of the signal/noise ratio in the system. This has been achieved by increasing the gain of the aerial; reducing losses in the aerial waveguides; introducing a new maser receiving amplifier; and increasing the output power of the transmitter.

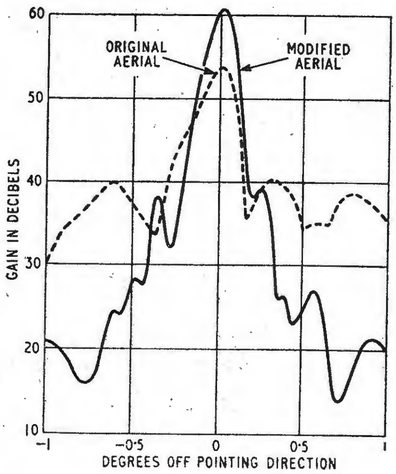
The higher transmitter power (8 kW) is provided by a new water-cooled travelling-wave tube with a cloverleaf slow-wave structure developed by G.E.C. and S.E.R.L. This valve, like the maser, is housed within the aerial structure.

Changes made to the aerial are illustrated in Fig. 1. To obtain more efficient transfer of energy between the primary feeds and the paraboloid reflector, the reflector bowl has been made shallower and the feeds unit moved outwards to the new focus position. As a result the aerial aperture has been reduced from 180° to 140°. The new bowl has, in fact, been built on top of the old one. Precision engineering techniques have been used to obtain high reflection accuracy. The bowl membrane now consists of a solid steel 25-ft central section, machined to an accuracy of 0.015 in to act as a reference, and 24 adjustable stainless steel panels surrounding it. The surface positions of these panels have been adjusted, against a parabolic test template, by the multiplicity of screw jacks mounted behind the membrane on the supporting structure (the bowl having been rotated under the template). As a result the bowl is within ±0.1 in of



New travelling-wave maser. A second maser will be installed later to act as a standby.

Fig. 2. Radiation pattern of new aerial compared with old one, showing improvement in gain and suppression of side lobes.



the optimum paraboloid over 99% of its surface. In addition, the feed supports have been designed and positioned to reduce aperture blocking and feed shadowing, and losses due to these effects are estimated as less than 0.26 dB. As shown in Fig. 2, these aerial modifications have sharpened the radiation pattern and increased the gain by 6 dB to 60.5 dB at 6 Gc/s.

The new Mullard travelling-wave maser has a higher gain (about 7 dB more) than that of the earlier model and the noise temperature has been reduced from 15° K to about 10° K. An unusual feature of the device is the use of a light-weight superconducting electromagnet for tuning in place of the earlier heavy permanent magnet. This has improved the stability of operation of the device. The low temperature necessary for superconductivity in the magnet coils is provided by the liquid helium bath (−271°C) used for the maser.

Detection of the received signals (after they have been converted down to 70 Mc/s) is performed by an f.m. negative feedback demodulator. In this the deviation of the signal is reduced by frequency feedback before it reaches the final discriminator and the noise bandwidth is limited by a filter with a passband narrower than that of the original deviation.

As a result of the modifications the figure of merit (gain/noise temperature) of the overall system has been improved by 4 dB. Of this, 3 dB results from the better aerial performance and 1 dB from lower noise temperature.

Since Early Bird is a "stationary" satellite the aerial tracking requirements are much less stringent. The aerial bowl movement is still controlled from predicted satellite position data (sent from the U.S.A. and converted into azimuth and elevation aerial co-ordinates, by computer at Goonhilly), but the predicted data sent are now more widely spaced in time. Position interpolation is performed by the computer and the aerial control equipment, to give position-demand signals for the aerial digital servos at 1/50th second intervals. Errors in prediction are estimated at not more than 10′ arc. Fine positioning of the aerial beam, to correct errors in prediction or due to wind forces on the aerial bowl, is now performed automatically by a closed-loop control system. In this the beam is made to follow the satellite, by hydraulically powered movement of the aerial feed unit relative to the true focus of the paraboloid, in response to error signals derived from a conical-scan position-detecting system.

ELECTRONIC LABORATORY INSTRUMENT PRACTICE

By T. D. TOWERS,* M.B.E., A.M.I.E.E., A.M.I.E.R.E.

5.—MEASUREMENT OF RESISTANCE

NINE times out of ten in an ordinary electronics laboratory you will use a multimeter to measure resistance. Next time you have occasion to do such a measurement, halt that reflex reaching for the Avo, and think " What am I doing? What will the reading tell me? What accuracy can I expect?" If you think you could, *without reference to a textbook*, score more than 90% for an examination question like this, you need not read on. If, however, your ideas on resistance measurements are, like most people's, a bit hazy, you may be interested in the description given below of the variety of methods (of which the multimeter is only one) which can be used.

Multimeter Resistance Measurements

Most multimeters are provided with direct reading resistance scales. When switched to an " ohms " scale the instrument uses the basic meter movement in combination with an internal battery and resistive network to display a reading of the value of a resistance connected across its terminals.

In most commercial multimeters, the ohmmeter section is of the basic " series-type " shown in Fig. 28 (a) where the current meter M is combined internally with a voltage source, E, (usually a 1½V battery) and a series resistance RV. The component to be measured is connected across the test terminals X-X and its resistance is read off on an ohms scale on the meter.

In practice, the operation is self-calibrating. First you leave the test terminals open, and verify that the meter scale reads zero deflection (infinite resistance). You may have to adjust the meter-preset screwdriver zero-adjustment for this. Then you short-circuit the test terminals and adjust the " zero-ohms " knob (controlling RV) until the meter reads full deflection (zero ohms). Next you connect the unknown R between the test points X-X and read its resistance on the direct-reading resistance scale. The scale (which normally reads forward from left to right for increasing current or voltage) reads backward for increasing resistance, since the current through M falls as the resistance across the test terminals increases. The resistance scale is non-linear, being crowded up towards the left-hand (high resistance) end.

Good commercial multimeters, like the Salford " Selectest," or the Avo Model 8, described in previous articles, have three switched resistance ranges. In these the normal range ($\Omega \times 1$) measures 0-200kΩ, with 2kΩ mid-scale; the high resistance ($\Omega \times 100$) measures 0-20MΩ, with 200kΩ mid-scale; the low resistance ($\Omega \div 100$) measures 0-2000Ω, with 20Ω mid-scale.

How accurately does a multimeter read resistance? When it leaves the manufacturer, the accuracy specification (for example, of the " Selectest ") is typically $\pm$3% from zero to mid-scale, $\pm$5% from mid-scale to 2/3rd full scale and $\pm$10% from 2/3rd up to full scale. After a few " adventures " in the lab., you would be unwise to assume that it is as good as this. If you are prudent you should not rely on its being better than 5% below mid-scale, 10% from ½ to 2/3rd scale, and 20% to 2/3rd to full scale.

These accuracies are sufficient for many requirements in the laboratory but you may want to check more closely on occasion. You can then turn to one of the more specialized instruments described later. Alternatively (and this is very often done) you may check the multimeter resistance range error by measuring a standard cracked-carbon high-stability resistor of known value. These can be obtained quite cheaply to a 1% tolerance

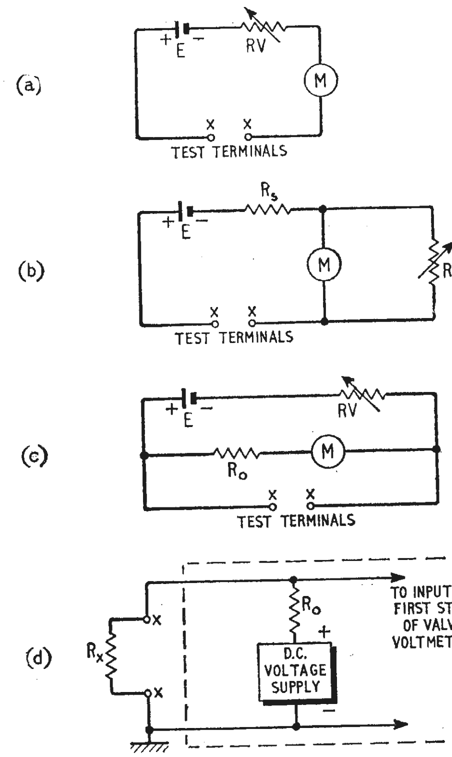


Fig. 28. Basic circuits for resistance measurement: (a) series-type ohmmeter range of multimeter; (b) alternative series-type ohmmeter (c) shunt-type ohmmeter; (d) valve-voltmeter circuit for measuring resistance.

* Newmarket Transistors Ltd.

from your usual electronics supplier or in case of difficulty from specialist firms such as the Radio Resistor Co. Ltd. With a range of these (say 1Ω, 10Ω, 100Ω, up to 1MΩ) you can rapidly check the multimeter resistance scale in the area of resistance where you are critically interested, and apply the necessary correction to your reading of the unknown. A useful tip is to keep the resistances handy in a polythene bag Sellotaped to the top of your instrument.

In using the multimeter as an ohmmeter, remember the few simple precautions following:—

(a) Before commencing test, adjust meter zero-deflection if necessary by screwdriver meter-zero adjustment control.

(b) Check that connections to test terminals are tight.

(c) Check that meter is switched to correct resistance range.

(d) Short-circuit test prods or terminals and adjust full-scale deflection (for zero resistance) with the "set-zero" control knob.

(e) Verify that in short-circuit test, (d), the meter pointer does not "wander" or "jitter"—this indicates a nearly exhausted internal battery. If you cannot bring the pointer up to full-scale deflection at all, renew the battery.

(f) Don't leave a resistor (or short-circuit) across the terminals except in making measurements, as this may run the battery down.

(g) After use, *always* switch away from the resistance range (preferably to a high voltage one).

(h) Remember that without calibration check against a standard, errors as high as $\pm$ 20% can occur at some points of the scale in practice.

Variants of the basic series-type ohmmeter circuit of Fig. 28 (a) may be met with. For example, another version of the series circuit is given in Fig. 28 (b). Here the short-circuit adjustment for full-scale meter deflection is made by a variable resistor RV in parallel with the meter. However, the basic principle of measuring an external resistance connected across the test terminals X-X by measuring the current through it (and an internal resistance in series with it) still obtains.

A different principle is adopted in the shunt-type ohmmeter circuit of Fig. 28 (c) where, on open circuit, the meter is adjusted by RV to full-scale deflection. When a resistance is connected across the terminals X-X, the current through the meter falls to indicate the resistance. This type of ohmmeter reads increasing resistance from left to right, the opposite way to a series ohmmeter, and is less common.

Valve Voltmeter Resistance Measurements

After the multimeter, the commonest instrument used for resistance measurements in an electronics laboratory is the general-purpose valve voltmeter, which now usually incorporates resistance as well as voltage measurements.

Fig. 28 (d) illustrates the basic arrangement of the valve voltmeter in its resistance ranges. Current from the internal d.c. voltage supply flows through an internal precision resistor R_o and the unknown resistance R_x connected across the test terminals X-X. The resultant potential difference across R_x is applied to the input stage of the valve voltmeter, which gives a corresponding pointer deflection. The higher the unknown resistance R_x, the greater the deflection. The resistance scales of a valve voltmeter thus read from left (low resistance) to right (high resistance) in contrast to the multimeter which, as we saw above, reads the other way round.

The valve voltmeter ohmmeter tends to cover a wider range of resistance than the multimeter—and in a greater number of switched ranges. For example, the KLB Paco V70 valve voltmeter has seven switched resistance ranges covering 0-1000Ω (10Ω midscale), 0-10,000Ω (100Ω midscale) etc. up to 0-1,000MΩ (10MΩ midscale). This contrasts with the three internal ranges of the Avo with a 20MΩ maximum. The difference is not so great, however, when the valve voltmeter is transistorized. In the typical good transistorized voltmeter illustrated in Fig. 29, the B.P.L. TVM1063, the resistance ranges available are 0-1MΩ, 0-10MΩ, 0-100MΩ. (Unlike the more conventional valve voltmeters, the resistance scale on this particular instrument reads from right to left like a multimeter.)

The precautions outlined earlier for using the multimeter in resistance measurements apply equally to valve voltmeters, which are provided with the same zero-setting facilities.

Bridges for Resistance Measurements

In the higher resistance ranges, the valve voltmeter is capable of measuring resistances with an accuracy better than the multimeter, but otherwise its accuracy is still only of the order of 5% or so. For better accuracies

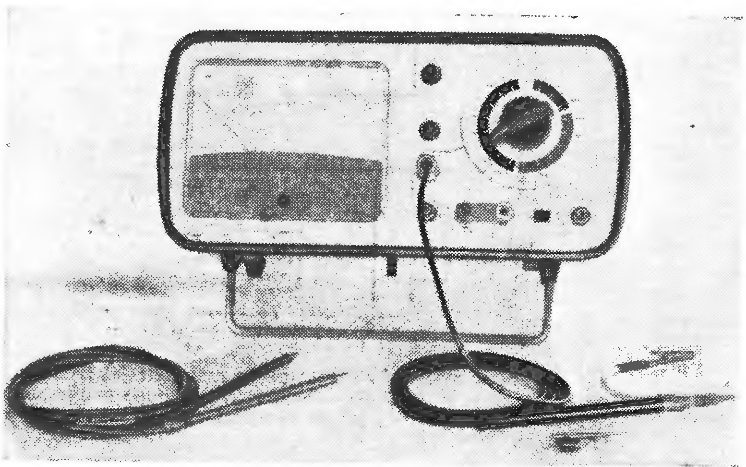


Fig. 29. Typical commercial valve voltmeter with three resistance ranges 15kΩ, 150kΩ, 15MΩ midscale reading (B.P.L. TVM 1063, transistorized).

you must turn to some other measurement method. Now the well-known Wheatstone bridge has been in use since the earliest days of electricity to make accurate resistance measurements and it still finds wide use in ordinary electronic laboratories.

The original Wheatstone bridge for d.c. measurement of resistance, from which many different bridge types have evolved, is shown in basic form in Fig. 30(a). Here E is the d.c. source voltage, A, B and S are the selected bridge resistors; and R_x is the unknown external resistor. The bridge resistors are adjusted until depressing the key produces no deflection in the galvanometer or current meter, M. At balance, it can be shown that

$$R_x = \frac{A}{B} \cdot S$$

The two internal bridge arms A and B in Fig. 30(a) are known as the " ratio arms ". In commercial instruments the ratio of these is selected by switches so that the third arm S (known as the " series " arm), a dial-controlled variable, will yield the maximum number of significant figures.

For low resistances of the same order as the bridge contact and lead resistances, the Kelvin bridge, a modified form of the Wheatstone bridge, is often used. The basic Kelvin bridge circuit is given in Fig. 30(b). In this, B and S are chosen large compared with lead and contact resistances. R_x can then be measured accurately even if it is very low. When the bridge is balanced with b/B = s/S, it can be shown that $R_x = \frac{A}{B}.S$ as before.

For very high resistances, again the accuracy of measurement on a standard Wheatstone bridge falls off, mainly due to lack of a sufficiently sensitive null detector meter, M. The Wheatstone configuration has, however, been used to measure resistance of the order of 1,000,000 MΩ. For this the meter null detector is replaced by a highly sensitive valve detector as shown in Fig. 30(c). A guard ring is used so that leakage across the insulation of the high resistance arm, A, of the bridge does not affect the balance point.

The balancing of d.c. bridges is not difficult, but one precaution it is wise to take is to confirm that the balance is obtained at the same point on the resistance dial when the polarity of the bridge energizing voltage is reversed.

Up till now we have dealt with a d.c. Wheatstone bridge where the source is d.c. from a battery, and the detector a centre-reading galvanometer or meter. Now laboratories also normally require a bridge for impedance measurements (to be discussed in the next article) and this calls for some form of a.c. bridge. If the signal source of the d.c. Wheatstone is changed to an a.c. oscillator and the detector to an a.c. detector (such as a pair of headphones or an a.c. voltmeter), we get a bridge capable of measuring impedances. At low audio frequencies, a " resistance " normally has negligible reactance, so that it is possible to use an l.f. a.c. bridge for " d.c." resistance measurement. The basic circuit of the a.c. Wheatstone bridge is given in Fig. 30(d). If the frequency of the a.c. source is low (50-2000c/s) and the bridge impedances Z_A, Z_B, Z_S as well as the unknown Z_x are effectively resistive then the balance equation becomes, as with the d.c. bridge, $R_x = (A/B)S$.

The a.c. bridge circuits used in commercial l.f. bridges are not often simple Wheatstone types but usually one of the many derivative types, which are beyond the scope of this treatment. Interested readers might well consult E. Hague "Alternating Current Bridge Measurements " (Pitman) where over 100 bridge types are described.

The range and accuracy of resistance measurement

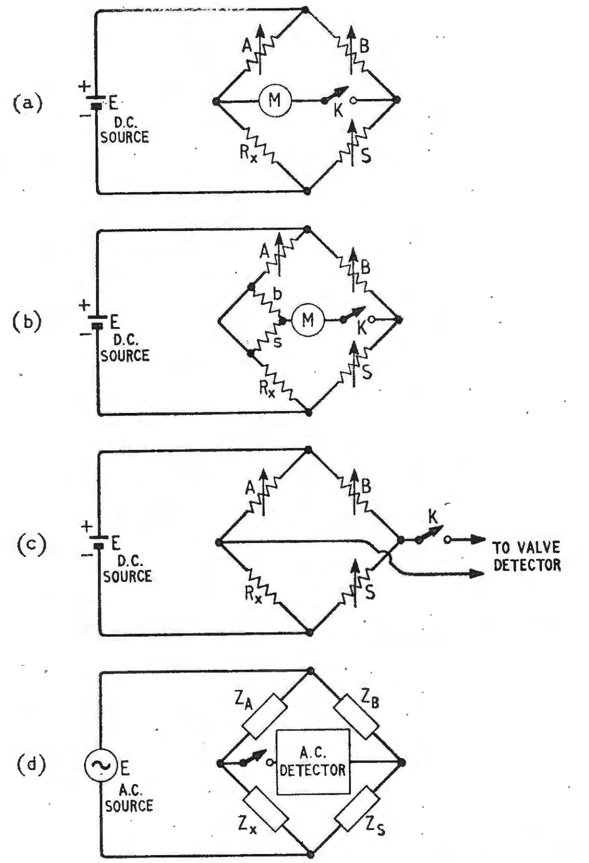
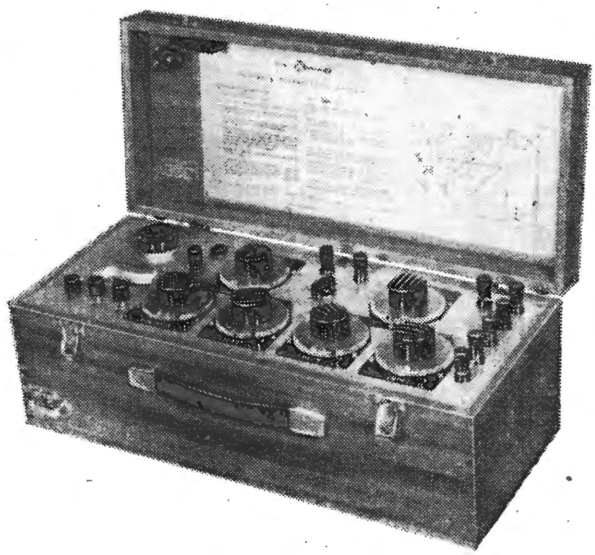


Fig. 30. Basic bridge circuits commonly used for resistance measurements: (a) d.c. Wheatstone; (b) d.c. Kelvin; (c) amplified d.c. Wheatstone; (e) a.c. Wheatstone.

Fig. 31. Typical commercial example of portable Wheatstone d.c. bridge (W. G. Pye 7383).



with the three types of d.c. bridges described for general purpose instruments is approximately as follows:

(a) **D.C. Wheatstone** 1-1,000,000 ohms with an accuracy of the order of $\pm$ 0.1% (can be obtained down to $\pm$ 0.003%).

(b) **D.C. Kelvin (low resistance)** down to 0.001 ohm with accuracy of the order of $\pm$ 0.1% except for very low values of resistance.

(c) **Amplified D.C. Wheatstone (high resistance)** up to 10^{12} ohms with accuracy of $\pm$ 4% up to 10^{10} ohms.

Fig. 31 illustrates a widely used example of a d.c. resistance bridge, the W.G. Pye type 7383 Portable Wheatstone. Capable of measurements from 0.001Ω to 1MΩ. this bridge has a built-in pointer galvanometer and a 4½V internal battery for applications where full portability is required. However, terminals are provided for an external galvanometer and external battery for ultra precise measurements in the laboratory. The series arm comprises four decades in steps of hundreds, tens, units and tenths of ohms, and uses manganin coils adjusted to $\pm$0.02% accuracy, except the 0.1 ohm coils which are adjusted to $\pm$0.2% accuracy. The two ratio arms are each switched selections of 1, 10, 100 and 1000 ohms utilizing manganin coils adjusted to $\pm$0.01% accuracy. Other well-known names in the d.c. bridge field are

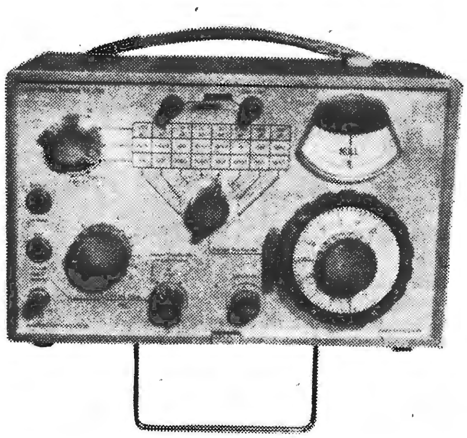


Fig. 32. *Typical commercial example of portable a.c. bridge capable of accurate measurement of resistance, as well as impedance (Marconi TF2700—transistorized).*

Baldwin, B.P.L., Cambridge Instruments, Croydon Precision, Sullivan, Tinsley and Wayne Kerr.

In the lab. you will often find that the l.f. a.c. bridge is used for rapid resistance measurements when accuracies better than the multimeter or valve voltmeter are looked for, and the high accuracy obtainable with the slower-operating Wheatstone is unnecessary. An excellent example of this type of bridge is the Marconi TF2700 illustrated in Fig. 32. This is a new-generation transistorized universal bridge, designed to measure L, C and R, but eminently suitable for rapid, accurate resistance measurements. The internal battery-powered transistor oscillator provides a bridge source at 1kc/s. The TF2700 has eight resistance ranges in decades from 0-1·1Ω to 0-11MΩ. In all ranges except the bottom one, the measurement accuracy is better than $\pm$1% of the reading added to $\pm$0.1% of the range maximum. On the bottom 1.1Ω range, the accuracy is $\pm$2%, $\pm$0.1% of range

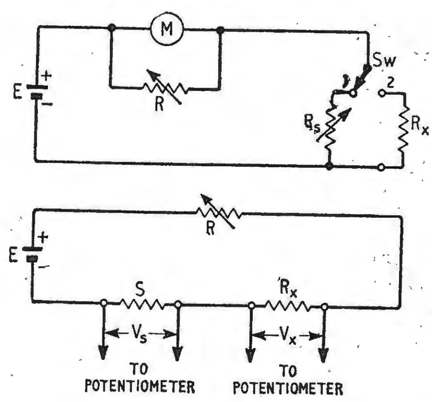


Fig. 33. *Basic circuits for high-accuracy resistance measurement by: (a) substitution; (b) potentiometer.*

maximum. As a general statement it can be said that the accuracy is about 1%. The TF2700 is tending to take over from the well-known TF868 valve universal 1% LCR bridge which has been "a piece of the furniture" in so many electronics laboratories over the last decade. A.C. bridges suitable for resistance measurement will be covered more fully in the next article.

Substitution Measurement of Resistance

A simple "lab. lash-up" method for resistance measurement that can be of considerable accuracy employs the circuit of Fig. 33(a). A battery E is connected via a galvanometer or meter M with a variable shunt resistor R to a switch S. The resistance R_s is a variable standard resistance, and R_x the unknown. With the switch in position 2 the meter current is adjusted to a convenient deflection by means of the variable shunt resistor R. S is then switched to position 1, and R_s adjusted to give the same current reading. At this point $R_s = R_x$. The precision of the method depends on the accuracy of R_s and of the meter scale reading, and can be high if R_x

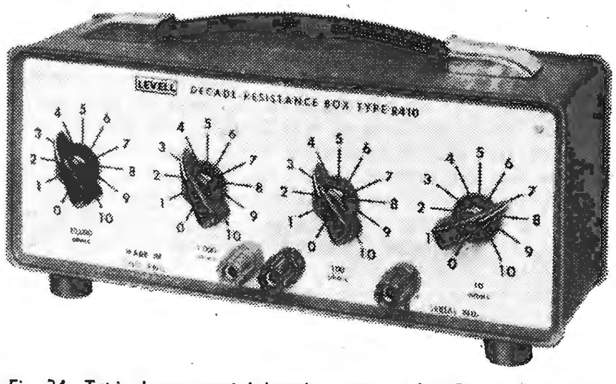


Fig. 34. *Typical commercial decade resistance box for use in methods of Fig. 33. (Levell type R410).*

is large compared with contact and lead resistances.

In Fig. 33(a) the "substitution" resistor R_s is usually a "decade resistance box". This is a useful piece of general purpose laboratory equipment, which can vary from expensive 0.01% accuracy to economical 1% accuracy.

Usually it has four decades of resistors selectable by switches. Typical of the 1% variety is the Levell Type R410 decade resistance box illustrated in Fig. 34. This particular version can switch-select any resistance from 10 to 111,100 ohms with ±1% accuracy. In decade boxes, you are likely to meet units manufactured by such companies as Baldwin, Cambridge Instruments, Croydon Instruments, Daystrom (Heathkit), Furzehill, Rivlin, Sullivan and W. G. Pye.

Besides resistance boxes, most of the firms specializing in d.c. resistance test equipment supply single standard resistances of various degrees of accuracy from 0.001% to 1%.

One feature of the circuit of Fig. 33(a) calls for remark. When you are using a decade resistance box for R_s, watch out that you do not put too much current through it. The high stability resistors in the box are very liable to lose their accuracy if overloaded. Read the instruction leaflet or manual for the decade box very carefully, and ensure you do not exceed the manufacturer's current rating. If you should do so by accident, immediately tie a label to the box saying what has happened. This prevents the next user from placing unjustified reliance on the accuracy of the standard until calibration check has been possible.

Potentiometer Method of Measurement

Another lab. bench method of measuring resistance is by means of a potentiometer as illustrated in Fig. 33(b). The potentiometer, which was described in the February, 1965, article of this series, is used to compare the voltage drop, V_x, across the unknown R_x with that, V_s, across a standard resistance, S. It can be shown easily that

$$R_x = \frac{V_x}{V_s}.S$$

The measurement must ensure that the current through both resistors is constant. Usually a decade resistance standard box is used for S, and adjusted until the potentiometer reads the same voltage when switched repeatedly from R_x to S and back. This makes the method rather tedious but it has the advantage that the unknown can be evaluated very accurately in terms of a suitably chosen standard. This method is capable of extremely high accuracy if a sufficiently good potentiometer and reference resistance standard are used.

Fig. 35. *Typical commercial high-resistance megohmmeter (W. G. Pye 11801 Wide Range Megohmmeter, 3MΩ to 200 million MΩ).*

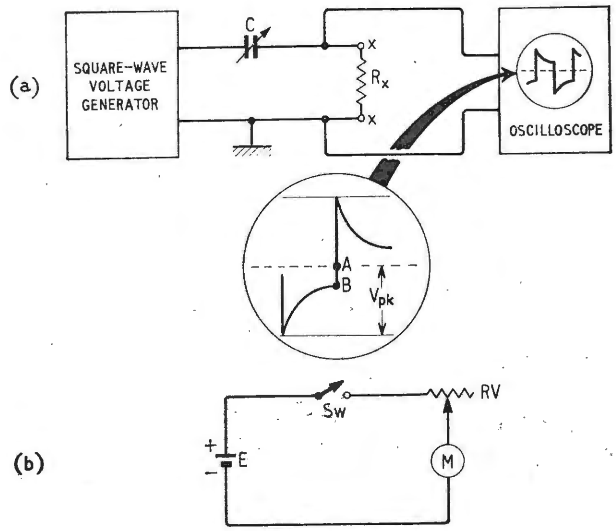


Fig. 36. Basic circuits of miscellaneous resistance measuring techniques: (a) oscilloscope trace decrement method; (b) meter internal resistance measurement by variable resistance.

Low Resistance Measurements

Several of the methods outlined above are useful in the very low resistance field. In particular the Kelvin bridge is very commonly used. Some firms make equipment specially for low resistance measurements, as, for example, Startronic with their "Lohmeter" and "Milohmeter".

A particular problem arises when you are measuring switch contact resistances. You may get variable and misleading results if you do not ensure that sufficient voltage is applied to break down surface oxide layers in the switch.

High Resistance Measurements

High resistance measurements have been discussed generally under the various methods outlined earlier. Again some firms specialize in this field. Most electrical engineers for example, will know of the portable "Megger" type ohmmeter manufactured by Evershed and Vignoles. In electronics laboratories, while the Megger is not uncommon, it is more usual to find more specialized static equipment used if any substantial high resistance measurements are required.

Typical of these specialized high resistance test sets is the W. G. Pye 11801 Portable Wide Range Megohmmeter illustrated in Fig. 35. This covers 3 megohms to 200 million megohms in seven switched ranges. Battery operated, it provides a constant test potential of 500V, and comprises a highly stabilized transistor converter, a range of reference resistors and an accurate transistorized voltmeter. It is particularly suited to measuring capacitors or long cables, and is fitted with a guard terminal to minimize the effect of leakage paths.

Miscellaneous Techniques

One technique of resistance measurement I myself have been working with recently, which has considerable

JUNE ISSUE

Publication date of the June issue of *Wireless World*, which will include a preview of the London Radio and Electronic Component Show, will be brought forward to May 17th, the day before the exhibition opens at Olympia. The Show, sponsored by the Radio and Electronic Component Manufacturers' Federation, will open daily from 10 a.m. to 6 p.m. from May 18th to 21st. The preview will summarize briefly some of the newest products of the 250 exhibitors and will be in addition to the normal quota of articles and regular features.

potential (but is not at present in common use), is the "square wave", or what I call the "scope trace decrement", method. The basic circuit of this is illustrated in Fig. 36(a) where a square-wave generator with output impedance negligible compared with the resistance R_x to be measured is used to drive the differentiating network, CR_x. The wave shape across R_x is inspected with an oscilloscope (with input impedance high compared with R_x). The capacitor C is adjusted until the step "AB" at switch-over on the scope trace is 4.3% of its negative peak value V_{pk}. It can be shown then that $R_x = 1/(2\pi f_o C)$, where f_o is the square wave repetition rate.

A common practical problem in a laboratory is to measure accurately the internal resistance of a d.c. milliammeter or microammeter, particularly when you want to select a shunt or series resistor to attain a specific full scale deflection. There are many ways of doing this, but the commonest (and easiest) is probably the variable resistor method shown in Fig. 36(b). This uses a calirated variable resistance RV (which can be a decade resistance box) and a *steady* d.c. voltage source E (for example a *fresh* 1.5V battery) to test the resistance of the meter M. To make the measurement you close the switch and adjust RV until the meter reads full scale. Let RV_0 be the value of RV for this. Now increase RV until the meter reads half-scale. Let RV value now be RV_1. The meter internal resistance can then be found from $R_M = RV_1 - 2RV_0$. The accuracy of your result depends on how precisely the mid-scale point on the meter represents half current and on how accurately you can measure RV_0 and RV_1. At a pinch you can use a volume control potentiometer for RV, and measure the values at the two settings with an Avo, or, better, a resistance bridge.

Summary

When you have to make resistance measurements, always try to use the best instrument available for the resistance range and accuracy you are interested in. In broad terms,

(a) For accuracies of the order of 10% and not too low or too high resistances, you can use a multimeter or valve voltmeter (but take the precaution of checking it with standard resistances occasionally).

(b) For accuracies of the order of 1% you can usually employ a good l.f. a.c. bridge or a general-purpose d.c. bridge.

(c) For accuracies of the order of 0.1% or better, you must turn to specialist instruments such as refined d.c. bridges.

To return to my original question, you should now be in a position to realize how and with what accuracy an Avo measures resistance. As most run-of-the-mill circuitry works with only 5% or 10% tolerance resistors, and a good well-calibrated multimeter can measure to this accuracy, you can also see why more than nine times out of ten engineers in an electronics laboratory reach for the multimeter, already on their bench, to check a resistor value.

This Month's Conferences & Exhibitions

Further details are obtainable from the addresses in parentheses.

LONDON

May 17-21 — Savoy Place
Components & Materials used in Electronics Engineering
(I.E.E., Savoy Place, W.C.2)

May 17-21 — Grosvenor House, W.1
International Instrument Show
(B. & K. Laboratories, 4 Tilney St., W.1)

May 18-21 — Olympia
Radio & Electronic Component Show
(R.E.C.M.F., 6 Hanover St., W.1)

May 20-21 — R.Ae.S., Hamilton Place, W.1
Electrical Conduction at Low Temperatures
(Inst. Phys. & Phys. Soc., 47 Belgrave Sq., S.W.1)

DUNDEE

May 25-27 — Marryat Hotel
Electronics in Action Exhibition
(I.E.E. Scottish Electronics & Measurement Section, 50 Holeburn Rd., Glasgow)

EASTBOURNE

May 13 & 14 — Grand Hotel
New Materials & Processes in Instrument Manufacture
(Scientific Instrument Research Assoc., Chislehurst, Kent)

SCARBOROUGH

May 24-27 — Royal Hotel
R.T.R.A. Annual Conference
(Radio & Television Retailers' Assoc., 19 Conway St., W.1)

OVERSEAS

May 5-7 — Clearway, Fla.
Microwave Theory & Techniques
(J. E. Pippin, Sperry Microwave Electronics Corp., Box 1828, Clearway, Fla.)

May 6-8 — Boston
Human Factors in Electronics
(I.E.E.E., Box A, Lenox Hill Station, New York 21, N.Y.)

May 10-12 — Dayton
Aerospace Electronics Conference
(NAECON, 1414E, 3rd St., Dayton 2, Ohio)

May 19-25 — Amsterdam
Electronic Exhibition
(Elvabé, Molenallee 63A, Wilp, Gld., Netherlands)

May 24-28 — Montreux
Television Symposium
(R. Jaussi, Postfach 97, Montreux, Switzerland)

May 24-29 — New York
Information Processing Conference
(British Computer Soc., Finsbury Pavement, London, E.C.2)

May 25-27 — Washington
A.F.C.E.A. Annual Convention
(Armed Forces Communications & Electronics Assoc., 1725, Eye St., N.W., Washington, D.C.)

MAY MEETINGS

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

LONDON

3rd. I.E.E. Graduates & Students.—"Some aspects of transistor tape recorder design" by Dr. J. C. Vickery at 6.30 at Savoy Place, W.C.2.

6th. Royal Society.—"The organization of a memory system" by J. Z. Young at 4.30 at Burlington House, Piccadilly, W.1.

11th. I.E.E.—Colloquium on "Semiconductor capacitors in varactor and pulse applications" at 2.30 at Savoy Place, W.C.2.

12th. I.E.E.—"Television recording" by P. Leggatt at 5.30 at Savoy Place, W.C.2.

12th. I.E.E. & I.E.R.E.—"Random access mass stores" by J. Davey at 6.0 at the London School of Hygiene & Tropical Medicine, Keppel Street, W.C.1.

13th. I.E.E.—"Effect of weather on performance of 8mm radar" by O. Nourse and S. G. Nicholls at 5.30 at Savoy Place, W.C.2.

19th. I.E.R.E.—"A groove control system for phonograph disk cutting equipment" by H. Lindskov Hansen at 6.0 at 9 Bedford Square, W.C.1.

21st. Inst. of Navigation.—"A satellite/ground station navigational aid" by R. E. Anderson at 4.30 at the Royal Instn. of Naval Architects, 10 Upper Belgrave St., W.1.

26th. I.E.R.E.—"The impact of electronics on the Army's repair organization" by Major General L. H. Atkinson at 6.0 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

CAMBRIDGE

4th. I.E.E.—"Anglo-Canadian transatlantic telephone cable" by F. Scowan at 6.30 at the College of Arts & Technology.

MIDDLESBROUGH

5th. I.E.E.—"Fuel cells, a branch of electrochemical engineering" by Dr. A. B. Hart, at 6.30 at Cleveland Scientific Instn.

PRESTON

5th. I.E.E.—"Computers" by Dr. R. Feinberg at 7.30 at the Harris College.

CLUB NEWS

Bexleyheath.—Mobile operation will be discussed at the meeting of the North Kent Radio Society on May 13th at 7.45 at the Congregational Church Hall.

Heckmondwike.—Members of the Spen Valley Amateur Radio Society are to visit the Wharfedale Wireless Works at Idle, Bradford, on May 13th. A fortnight later at 7.30 at the Grammar School, H. Tomlinson, of the G.P.O., will discuss communication via earth satellites.

Leamington Spa.—The May programme of the Mid-Warwickshire Amateur Radio Society includes lectures on single sideband reception (3rd), amateur aerial arrays (17th) and the fifth of a series on radio theory (31st). Meetings are held at 7.45 at Harrington House, Newbold Terrace.

Portsmouth.—The Royal Naval Amateur Radio Society is holding a mobile rally at H.M. Signal School—*H.M.S. Mercury*—near East Meon, Hants, on May 30th. Talk-in station GB3RN will operate on 1.88, 70.26 and 144.2 Mc/s and station G3BZU on 3.72 Mc/s for s.s.b. operators. Further particulars from M. J. Mathews (G3JFF) *H.M.S. Mercury*, Leydene, Petersfield, Hants.

LOGIC CIRCUITS

THE second I.E.E. & I.E.R.E. Joint Colloquium on logic circuits early this year was well attended (more than 500 were present) and logic circuit design engineers will no doubt continue to present themselves *en masse* at future meetings, which are expected to be held annually.

As switching times are gradually decreasing the problem of interconnections assumes greater proportions, and engineers must give greater consideration to the design of logic elements driving interconnections. Considering interconnections as transmission lines,* propagation delay will be in the order of 2nsec per foot with normal materials and the characteristic impedance will be about 50-300Ω. Thus elements at each end of interconnections must be matched to this impedance if ringing due to reflections is to be minimized, and logic voltage levels must be kept low in order to keep dissipation within reasonable limits. Line-driver circuits were discussed, including a commercially available type with a 2nsec edge speed.

Some aspects of a balanced 50 Mc/s tunnel diode circuit (Goto Pair) were considered. Here interconnection limitations are severe and in one realization described intermodule connectors were limited to 5in. The impedance of the connections was controlled by interleaving the printed interconnections with earth planes. At speeds of 250 Mc/s, where a maximum permissible length is about 1in, it becomes necessary to use delay lines in interconnections but these do not affect the repetition rate of the system.

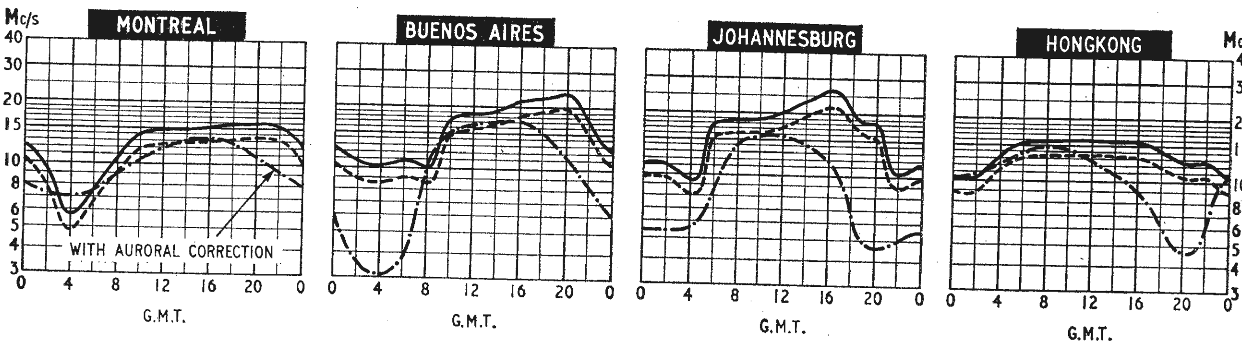
* Detailed analyses are contained in *I.R.E. Transactions on Electronic Computers*, August and October 1963.

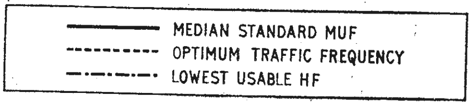
Faster switching times in diodes are realized by shortening carrier storage time and this is achieved in the metal semiconductor diode or hot-carrier diode. But development of the related metal-base transistor is not sufficiently advanced to offer a challenge at the moment to tunnel diode switching times. (A metal-base transistor with a theoretical limit of 20 Gc/s was described at the 1964 Electronic Component Conference, U.S.A.)

Attention was drawn to the fact that a minimal logic design did not necessarily result from a minimal Boolean expression (particularly from the aspect of maintaining a minimum number of interconnections). In realizing a function involving $\bar{A}$, for instance, in AND/OR logic, any one of the following six functions may be used in place of $\bar{A}$: $\bar{A}\bar{B}$, $\bar{A}\bar{C}$, $\bar{A}(\bar{B}+\bar{C})$, $\bar{A}(\bar{B}+C)$, $\bar{A}(B+\bar{C})$ and $\bar{A}\bar{B}\bar{C}$. The function $AB + A\bar{B}$, for instance, can be realized from A, B, $\bar{A}$, $\bar{B}$, using five gates, but if $\bar{A}\bar{B}$ is formed and used in place of $\bar{A}$ and $\bar{B}$, only four gates are required. Similarly, a full adder of 12 modules is reduced to 8 modules.

The brief survey of fluid logic must have surprised some when it was stated that a liquid logic element in moulded plastic capable of switching 1-10 watts and measuring 1½in. was available off the shelf in the U.S.A. Military requirements have resulted in the availability of a range of fluid devices which can handle from milliwatts to kilowatts and with temperature ranges from −100° to 1000°F. At present, however, logic speeds are limited to around 10 kc/s.

H. F. PREDICTIONS—MAY





The predictions for this month show very little difference from those of the same month last year. This is due to the predicted value of IF2 being the same as was used for last year. However, the value of IF2 is expected to rise, throughout the year, now that sunspot minimum has been passed. It is to be hoped that by July, conditions will be similar to those experienced in the same period in 1963.

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

Note that the solid line represents the median maximum usable frequency. This means that communication will be possible for only 50% of the time at this frequency. For a higher grade of service, a frequency some 15% lower should be used.

"Wireless World"
Iliffe Electrical Publications Ltd.,
Dorset House, Stamford Street,
London, S.E.1

Managing Director:
W. E. MILLER, M.A., M.I.E.R.E.

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VOLUME 71 No. 6
PRICE: 3s. 0d

FIFTY-FIFTH YEAR
OF PUBLICATION

Wireless World

ELECTRONICS, TELEVISION, RADIO, AUDIO

JUNE 1965

PUBLISHED MONTHLY (4th Monday of preceding month). *Telephone:* Waterloo 3333 (70 lines). *Telegrams/Telex:* Wiworld Iliffepres 25137 London. *Cables:* "Ethaworld, London, S.E.1." *Annual Subscriptions: Home* £2 6s 0d. *Overseas:* £2 15s 0d. *Canada and U.S.A.* $8.00. Second-class mail privileges authorised at New York N.Y. BRANCH OFFICES: *BIRMINGHAM:* King Edward House, New Street, 2. *Telephone:* Midland 7191. *BRISTOL:* 11, Marsh Street, 1. *Telephone:* Bristol 21491/2. *COVENTRY:* 8-10, Corporation Street. *Telephone:* Coventry 25210. *GLASGOW:* 123, Hope Steet, C.2. *Telephone:* Central 1265-6. *MANCHESTER:* 620, Deansgate, 3. *Telephone:* Blackfriars 4412. NEW YORK OFFICE U.S.A.: 111 Broadway, 6. *Telephone:* Digby 9-1197.

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