Wireless World

ELECTRONICS, RADIO, TELEVISION

JUNE 1959

VOLUME 65 No. 6

PRICE: TWO SHILLINGS

FORTY-NINTH YEAR OF PUBLICATION

Offices: Dorset House, Stamford Street London, S.E.1

Please address to Editor, Advertisement Manager, or Publisher, as appropriate

PUBLISHED MONTHLY (4th Monday of preceding month) by ILIFFE & SONS LTD. Dorset House, Stamford Street, London, S.E.1 *Telephone:* Waterloo 3333 (65 lines). *Telegrams:* "Iliffepres, Sedist London." *Annual Subscriptions: Home and Overseas* £1 15s. 0d. *Canada and U.S.A.* $5.00. Second-class mail privileges authorised at New York, N.Y. BRANCH OFFICES: *BIRMINGHAM:* King Edward House, New Street 2. *Telephone:* Midland 7191. *COVENTRY:* 8-10, Corporation Street. *Telephone:* Coventry 25210. *GLASGOW:* 26B, Renfield Street, C.2. *Telephone:* Central 1265. *MANCHESTER:* 260 Deansgate 3 *Telephone:* Blackfriars 4412. NEW YORK OFFICE: *U.S.A.:* 111, Broadway, 6 *Telephone:* Digby 9-1197.

Transistor Automatic-keying Circuit

Various modulation arrangements can be used with the 500kc/s marine-distress transmitter (see previous advertisement). For c.w. operation a morse key can be connected in series with the base winding of the modulator transistor, together with an r.f. choke and a bypass capacitor to prevent r.f. voltages floating across the key.

Low-power modulation is used for radio telephony. The modulator transistor is biased into Class C operation, using a parallel CR combination, to a point where the output of the transmitter falls to half its normal value, and an a.f. signal is applied across the bias resistor.

The circuit shown here is for an automatic-keying device which generates the distress signal. A time interval of 0·1 sec was chosen for the duration of a dot and for the interval between successive dots or dashes. The duration of a dash is then 0·3 sec.

Transistors Tr1 and Tr2 form the dot multivibrator and the Tr2, Tr3 combination is the dash multivibrator. As the spacing between dots is the same as the spacing between dashes, no gate is required for mixing and so the output can be taken from the collector of Tr2, the common transistor. To square-off the waveform of this output an emitter follower Tr4 is added. The output from Tr2 is inverted by Tr13 to the negative-going pulses required for keying the transmitter. A positive line is provided for the combined multivibrator by connecting the three emitters to a suitably decoupled resistor R2. This ensures that the appropriate transistor (Tr1 or Tr3) is definitely cut off by the sequence multivibrator which acts as an on-off switch in the base leads of Tr1 and Tr3.

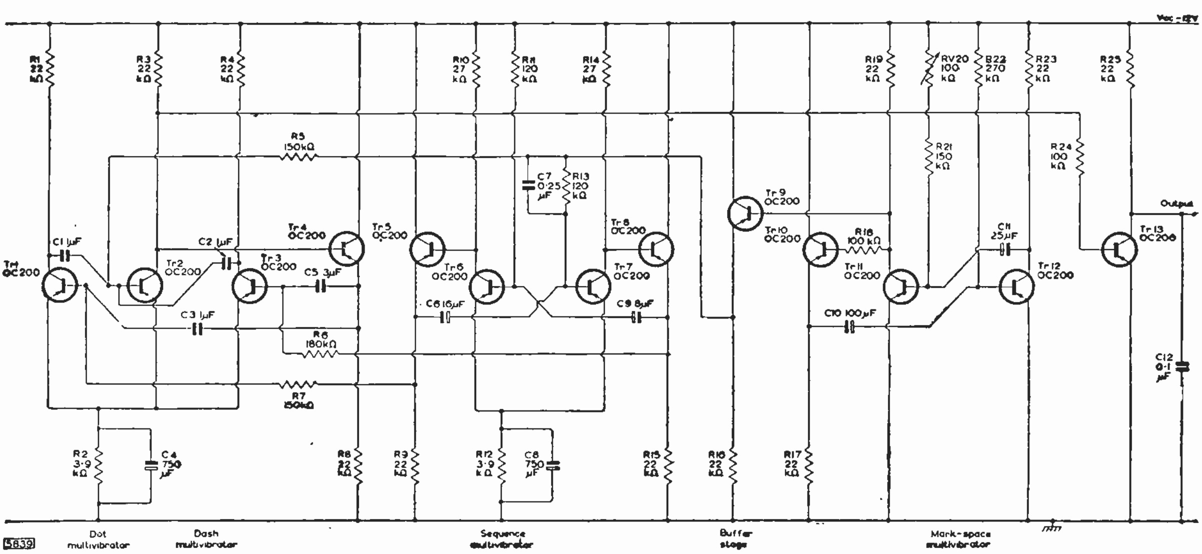
This multivibrator consists of transistors Tr6 and Tr7, which conduct alternately, switching the supply voltages across the base resistor R7 and R6 respectively. When Tr6 is on, Tr5 is off and the voltage across R9 (approximately V_{cc}) appears across R7, the base resistor of Tr1, and three dots are generated. The timing of this sequence is mainly governed by the combination C9R11.

The capacitor C7 reduces the switch-on time of transistor Tr7. If it is omitted, the inhibiting signal from Tr7 does not reach the dash multivibrator soon enough and a spurious dash precedes the dot-dash sequence. When Tr7 is on, Tr8 is off, the supply voltage appears across R6, and Tr3 generates three dashes. Transistors Tr5 and Tr8 are emitter followers which square-off the collector waveforms from Tr6 and Tr7. The sequence multivibrator is in turn controlled by the mark-space multivibrator by connecting R13, the base-feed resistor to Tr7, across the emitter load of Tr9. The mark-space multivibrator is the only free-running one in the whole circuit. It controls the whole automatic timing circuit. Tr10 is an emitter follower which squares-off the collector waveform of Tr11. A buffer stage, Tr9, is required to reduce interaction between the mark-space multivibrator and the previous stage.

The resistor R18, in the base lead of Tr10, is necessary to prevent pulses, fed back from the sequence and dot-dash multivibrators, triggering the mark-space multivibrator. It also reduces the voltage developed across the emitter resistor, R17, thereby reducing the on-period of Tr11. This time can be easily adjusted because it is the off-period for the complete timing circuit. If R22 is 270kΩ and C10 is 100 μF, the space period between signals is about 15 sec.

Some of the timing components need careful selection; all the resistors for these circuits should be of high stability, and the capacitors should have low leakage currents. These capacitors should preferably be metallised paper types (C1, C2, C3, C5, C7, C12), and tantalum electrolytic for the others. All the transistors operate at less than 500μA per stage; the total current drain from a 12V battery is about 4mA. The circuit operates satisfactorily with supplies down to about 10V, and over a range of temperature from 0 to 60°C. Taking into account the on-off power ratio of the combination of transmitter and keying circuit, a life of 50 hours can be expected from a 4 ampere-hour accumulator.

It cannot be emphasised too strongly that indiscriminate transmission of the international distress signal, whether licensed or not, is very undesirable. However, the principles of the design described can be used for the automatic keying of any morse signal, such as a call sign, by suitable adjustment of the timing components.



JUNE 1959
Vol. 65 No. 6

Wireless World

Monodic Sound

THE current interest in stereophony, one might almost describe it as an obsession, has brought with it many headaches, not the least of which has been caused by the difficulty of finding a terse word to describe the other kind of sound reproduction—the one we used to enjoy before two-channel stereophony became a commercial proposition.

Most of the proposals to date have not been entirely satisfactory: some have been plainly ludicrous—"monaural" and "monophonic," for instance.

No normal person would dream of listening to free-field sound from whatever source or sources except with two ears, and it is useless to argue that the sound might have been picked up by a single microphone, for in that case a better term would be "monomicrophonic."

As for "monophonic," this calls to mind only tuning notes, test oscillators and other uninteresting laboratory noises; certainly not the rich polyphonic sounds of music and well modulated voices which often come through reasonably well even on "non-stereophonic" equipment. Let us therefore dismiss "monophonic" as an abortive attempt by the stereophonists to denigrate a system of high-quality sound reproduction of which we have by no means heard the last.

Thinking of why "monaural" and "monophonic" should sound so funny and out of context we chanced to remember a pedagogic dissertation on the origins of humour in which a high place was given to "the juxtaposition of the incongruous." False comparison, inadequate antithesis—here surely are the root causes of our trouble. "Monaural" is the antithesis of "binaural" which, by common consent, refers either to the normal act of hearing or to a system using headphones separately excited by independent reproducing channels. "Mono" should not be associated with "phonic" because the first part describes the channel of transmission whereas the second refers to the nature of the information conveyed. With "stereophonic" we are on firmer ground, because not only does it pass muster by referring exclusively to the quality of the sound, but it is now so well established that no etymological argument is likely to displace it. Therefore all we have to do is to find the Greek antonym for "stereo"—or do we?

The opposite of solid is plane or flat, and good single-channel sound reproduction is far from being that. By the judicious use of reverberation and by varying distances from the microphone the skilful broadcaster or recording technician can convey the impression of spaciousness in depth. In fact the best results could justly be described as "single-channel front-to-back stereophony." True, the use of two or more channels gives width in addition to depth, so one might call it "second-order stereophony" to distinguish it from the "first-order stereophony" which we sometimes get from single channel.

Both systems have their strength and weakness. Obviously multichannel stereophony is best suited to orchestral and choral music, especially when this is written with antiphonal effects in mind; and single-channel "stereophony" should be best for solo instruments and voices with a subsidiary orchestral accompaniment. It is technically difficult to centre the virtual image of a voice, so that it seems to come from a point midway between two loudspeakers, but it can be done as Mr. Briggs demonstrated recently in the Festival Hall in London. The audience by a show of hands preferred two-channel stereophonic reproduction of the soprano voice to a single-channel recording, admittedly of a different singer but by the same recording company. Other experiences have shown that either system can beat the other at its own game when it is at the top of its form and the other is not. At the present stage of development it is therefore unsafe to try to draw a distinction based solely on the criterion of performance.

Until recently this journal has favoured the term "single-channel" for non-stereophonic systems, but since the B.B.C.'s revival of interest in stereophonic broadcasting the possibility that two audio channels may eventually be broadcast over a single radio channel introduces an element of ambiguity. Radio people can with some justification lay a prior claim to the use of the term channel and we see no reason why they should not keep it if they will allow us the use of "monodic" (suggested on p. 304 of this issue by our sometimes unruly but often inspired contributor "Free Grid") to describe the audio-frequency part of the chain. It is self-consistent in describing the system without reference to the nature of the information conveyed, and it enables us to make free and confident use of the contraction "mono" in the knowledge that if challenged to explain what it stands for we shall be spared the embarrassment of trying to justify "monophonic" or "monaural."

FERROELECTRICS

I.—THE PHYSICS OF A SINGLE DOMAIN

By J. C. BURFOOT, Ph.D.*

THE prominent property of a ferroelectric is that it has a spontaneous polarization P_r analogous to ferromagnetic remanence, and that this polarization can be reversed by applying an opposing electric field E stronger than the coercive field E_c (Fig. 1). The name "ferroelectricity" was coined because of this similarity; there is no connection with "iron." The discovery of ferroelectrics is very much more recent than that of ferromagnetics. Weber's theory of magnetic substances in the middle of last century and Ewing's later extensions had led already in 1907 to the Weiss domain theory; the discovery of ferroelectricity in Rochelle salt was not made until 1921 (Valasek). Inevitably, progress in understanding the phenomenon has been more rapid, leaning on analogy with the magnetics. However, a closer look shows that the differences are at least as striking as the similarities, as I shall show in these articles.

About thirteen groups of ferroelectric materials are now known, and new ferroelectrics are being added constantly to the list. The physics of a ferroelectric material is most easily approached in terms of a single good crystal which is all one domain, though such a state may be difficult to maintain in practice; this first article deals with this topic. Later I shall consider the effect of multi-domain structures on these basic properties, and then the even more complicated nature of polycrystalline materials. Ferroelectrics have been used for many years, usually in the form of ceramics, in a great number of piezoelectric devices and transducers, and in capacitors. After considering these, I shall examine work carried out in the last decade on the "dielectric amplifier" and associated modulation devices, and towards uses in digital computers, for storage and switching purposes.

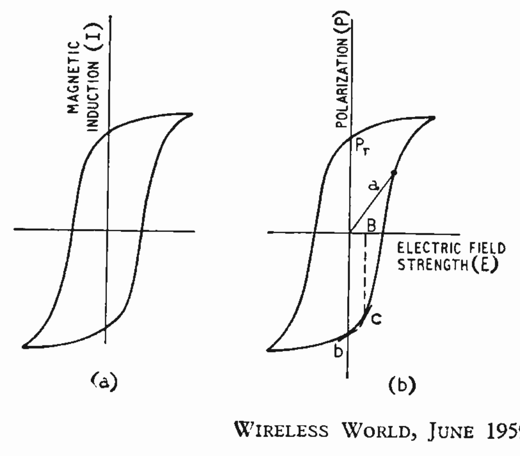
Single Domains.—In view of the historical lag, it is not surprising that understanding of the basic phenomena is considerably less well advanced than in magnetics. But it seems too that the underlying facts are genuinely less simple. For it is possible to describe ferromagnetism by treating each atom as though it were an elementary magnet. Then the complications of alignment and domain formation are described in terms of those external properties of magnets which have been known since William Gilbert's study of them about 1600: (1) a magnet produces a dipole magnetic field in its neighbourhood, and (2) a magnet aligns itself with a magnetic field if it is free to do so; interactions between magnets are described in terms of these two facts. At first sight this looks like describing ferromagnetism in terms of ferromagnets. But in fact the magnetic moment, or strength, of our elementary magnets undergoes no change in a field, and it is precisely such changes which are of interest (Fig. 1(a)) and which we succeed in describing, in materials, in terms of our conception of the atom as a *permanent* dipole.

In ferroelectrics, permanent (electric) dipoles also occur, but one cannot usually identify a particular atom with the dipole, and certainly not a particular electron, as in magnetics. The "spinning" electron responsible for ferromagnetism is inside the atom, screened electrically from neighbouring atoms. But for ferroelectricity, the various structures which cause it are intimately associated with the bonds *between* atoms, so that even in the relatively simple crystalline form of solids it is difficult to find any conception of microscopic subdivision which will effectively isolate the essential dipoles. The complication is increased because the cohesive forces holding matter together are largely electrical in nature.

Three elementary magnets, the atoms of iron, cobalt, and nickel, largely account for ferromagnetics; but in ferroelectrics there are many possible elementary dipoles, and the same unit may behave quite differently in different materials. In many cases the unit involved is not yet known for certain. Also, *induced* dipoles become important in ferroelectrics; the polarizability of a molecule may well determine whether the material containing it is ferroelectric. Polarizability is the extent to which a particular atom or molecule can be given a dipole moment by an electric field.

Permanent Dipoles.—An electric dipole is a body which is electrically neutral, but with the effective centres of its positive and negative charges not at the same place. There is no reason to suppose that either of these charges is concentrated at a point, but it is sometimes convenient to think of the dipole as made up of two equal charges, $+q$ and $-q$, fixed at a

Fig. 1. Magnetic and electric hysteresis loops. The inductions are respectively $B=H+4\pi I$ and $D=E+4\pi P$, or in these materials, to a good approximation, $B=4\pi I$ and $D=4\pi P$.



* Queen Mary College, London University.

separation 2d, and then we define the electric dipole moment as $p = 2dq$. The axis of the dipole is the line joining the charges. If a molecule or a crystal cell in a crystalline solid behaves like a permanent dipole whose axis can be turned into any direction or into any one of a number of particular directions, spontaneous polarization might result from alignment of these dipoles in strings head-to-tail in some particular direction, and alignment of the neighbouring strings in the same sense. If the alignment is complete, and there are N dipoles in a unit volume, then $P = Np$. Such an alignment may have been caused initially by the application of a suitable external electric field E, subsequently removed. But it is retained by the *internal* fields due to the dipoles themselves. It is believed that such internal fields are very much greater than any practical value of applied E, and they are very important to an understanding of ferroelectricity. For at any reasonable temperature, random thermal motions, which we have ignored above, spoil the alignment (so that many p are in wrong directions) unless there is some field F to counteract it; this field can be the internal field. The way P falls off if F is too small is shown in Fig. 2(a).

Induced Dipoles.—The above ideas are common to both ferromagnetism and ferroelectricity, though the reasons for the existence of p are very different in the two cases. But now turn your attention from permanent dipoles to the possibility of induced dipoles. That is, consider material in which the positive and negative centres of the units do coincide. The function of the field F is to separate them, against the influence of the forces holding the unit together. And now we meet the following curious possibility. Because polarization produces internal fields, it is possible for a material containing no permanent dipole to exhibit a polarization. The polarization creates the field and the field creates the polarization—it is only necessary that the polarizability should be "large enough"; equation (2) below puts this condition more precisely.

In a small field F, the strength of dipole induced, p_i, will be proportional to F,

$$p_i = \alpha F \quad \cdots \quad (1)$$

but in larger fields, p_i approaches some maximum value set by the structure and cohesion of the unit. This is known as "saturation." See Fig. 2(b). α is the polarizability. It is clear from Figs. 2(a) and (b) that the effects of permanent and induced dipoles will be similar, though the values and temperature dependences will be different. Probably both types of effect occur.

It is worth while to compare the induced dipolar effects that can occur in magnetic materials. Our electric induced dipoles may be due to relative movements, in the field F, of atoms carrying positive and negative charges ("atomic" or "ionic" polarization), or to displacements of the electrons of an atom relative to the positive nucleus of the atom ("electronic" polarization); in either case, the dipole produced is directed with the field rather than against it, so that the susceptibility I/H is positive, and we may even have a ferroelectric if the co-operative effect is large enough. In magnetics, induced dipolar effects are due to precessions of electron †orbits about the field direction, and the

† Not to be confused with electron spins.

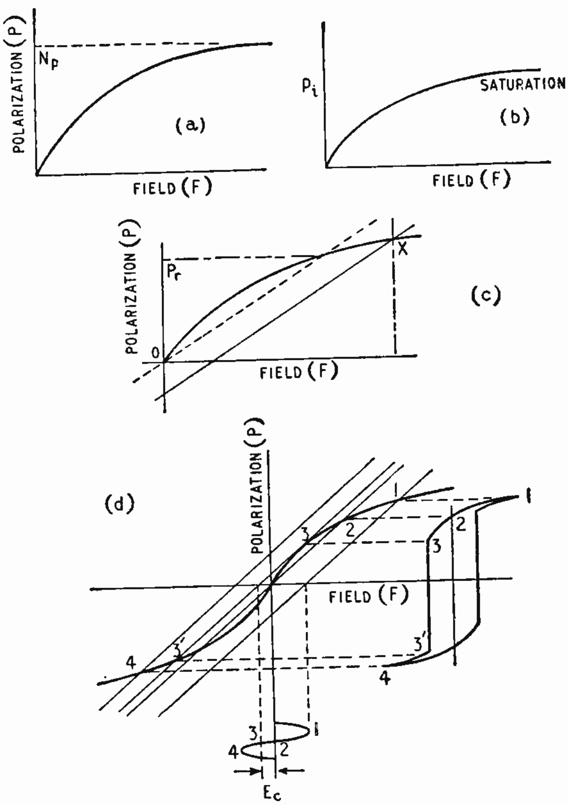


Fig. 2. Polarization and field curves. In Fig. 2 (a), $P = Np\left(\coth\frac{pF}{kT} - \frac{kT}{pF}\right)$ *for free dipoles; near 0, this is* $P \simeq Np\left(\frac{pF}{3kT}\right)$. $k = 1{\cdot}381.10^{-16}$ *erg/deg.*

laws of *magnetic* induction are such that the result must oppose the applied field. So the associated susceptibility is negative, and materials in which this effect predominates are called diamagnetics rather than paramagnetics; such materials try to move away from, rather than towards, regions of high-field.

Two points of contrast with magnetics result: (1) In electrics we cannot distinguish permanent from induced dipoles by the mere sign of a force; the terms dia-electric and para-electric are hardly in use, in fact. (2) In ferroelectrics we cannot be certain that permanent dipoles underlie the phenomenon, for here induced dipolar effects do have the right sign to allow co-operative effects.

Spontaneous Polarization—Fig. 2 will not explain why spontaneous polarisation remains when $E = 0$ unless we can identify the value of F when E is removed. To do this, let us first imagine that we do apply E (which we shall later remove) and describe the behaviour of F and P on the same Figure 2. This is done by the full straight line $F = E + \beta P$ in Fig. 2(c). That is, the extra field at a point inside the material, due to the overall polarization P of the surrounding material, is written as βP where β represents the strength of the co-operation. In ferromagnetics, exchange forces make β very large indeed, perhaps 10,000, but in ferroelectrics it is of order 1. The two full curves in Fig. 2(c) represent the two parts of the statement

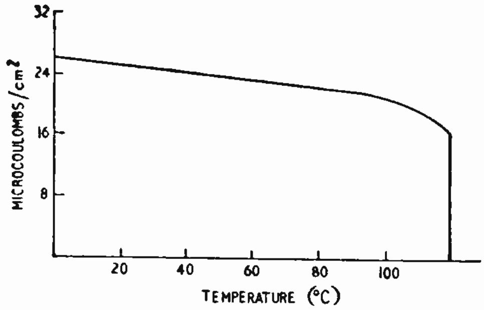


Fig. 3. Spontaneous polarization in a single domain of barium titanate, in microcoulombs per cm².

"polarization creates (some of the) field, and field creates polarization." The only state that satisfies both conditions at once is at the intersection X, which therefore determines F for that value of E. Now the effect of removing E is to slide the straight line towards the left to the dashed position, and P_r then gives the value of the spontaneous polarization.

On the same figure can be seen circumstances under which P_r will be zero, so that the material is no longer ferroelectric. This happens if the straight line, whose slope is $1/\beta$, is steeper than the slope of the curve at 0, which we can get from $P = Np_i$ and $p_i = \alpha F$. That is, the condition for ferroelectricity is that $N\alpha$ should be greater than $1/\beta$ or

$$\alpha > 1/N\beta \quad \ldots \quad (2)$$

Temperature Variations.—Now in fact if the temperature is raised above some transition temperature T_o, P_r again will be zero in the same way. It is most readily seen for the permanent dipoles, for which T_o is the temperature at which the thermal disordering overcomes the co-operation. For it is possible (but see next paragraph) to think of orientation of permanent dipoles in terms of a fictitious polarizability.

$$\alpha' = \frac{p^2}{3kT} \quad \ldots \quad (3)$$

Then the slope of the curve at 0 is $N\alpha'$, and unless this is greater than the slope $1/\beta$, P_r will be zero. That is, for ferroelectricity we need the equivalent of equation (2), $N\alpha' > 1/\beta$, which is now

$\frac{Np^2}{3kT} > \frac{1}{\beta}$ or $T < \frac{N\beta p^2}{3k}$. Thus the transition temperature is

$$T_o = \frac{N\beta p^2}{3k} \quad \ldots \quad (4)$$

In the case of induced dipoles, the equation (2) shows no temperature dependence, and it must be supposed that the polarizability α decreases as the temperature rises, until equation (2) is no longer satisfied. Fig. 3 shows the way P falls off, for barium titanate.

Equation (3) is based on the idea of a dipole free to rotate, and is not strictly correct, first because an electric dipole is probably not free, and second because for rotatable dipoles our treatment of F is not quite correct. However, the equation will serve our purposes. Electric dipoles may be able to jump fairly freely between a number of alternative positions, and expressions for P have been worked out similar to those in the caption of Fig. 2(a).

When alignment is not complete, P is less than Np, say Np', and the caption shows that near the origin, this p' is $p' = \frac{p^2}{3kT}F$, which by comparison with equation (1) gives equation (3). In these expressions, T is measured on the Kelvin temperature scale, so that T°K means t°C where $T = t + 273$.

Hysteresis.—The hysteresis loop of Fig. 1(b) can be seen on an oscilloscope by applying a.c. across two capacitors in series, one of which (A) has the ferroelectric for dielectric. The spontaneous polarization induces charge on the plates of A. When P changes, some of the induced charge is liberated, and, passing to the ordinary small linear capacitor, is displayed as a proportional voltage on the Y plates of the oscilloscope. The applied a.c. is connected to the X plates. In working with ferroelectrics, the plates or electrodes must be in exceedingly intimate contact with the material, because the dielectric constant is very high, say 5,000 in some cases. So an unsuspected air capacitor, only d/5,000 thick in series, halves the applied field, and in large-signal work will grossly distort the results. Evaporated electrodes or liquid electrodes are used. Notice that, just as in magnetics, the area of the hysteresis loop represents an energy loss per cycle, which we shall later have to take into account.

It seems that now we can explain the hysteresis loop, though we shall see later (see section on "Domains") that this is deceptive. Fig. 2(d) shows an extended version of 2(c), in which four stages of a

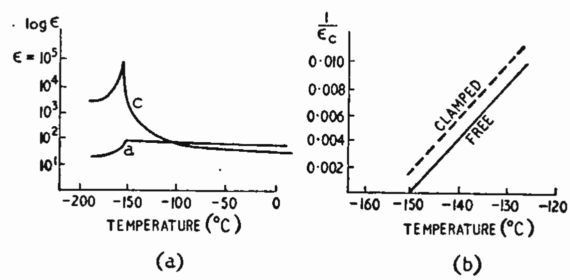


Fig. 4. Dielectric constants of potassium dihydrogen phosphate (divide e.s.u. by 900,000 to get μF.cm⁻¹). The c direction is the ferroelectric axis.

cycle of an alternating E are shown (1, 2, 3, 4). At some moments, three intersections of the graphs occur. Some will be unstable. I shall not discuss this, since domains will modify the results.

Thermodynamics.—Our subject matter is to be largely the dielectric and piezo-electric values in these ferroelectric materials, many of which values are anomalous, i.e. are unusually large or unusually small and show large variations as the temperature changes. These properties relate S, X, P and E, where X is a mechanical stress applied to the material and S is its relative change of size. The magnitude of a change of P in response to an applied E is represented by‡ the dielectric constant ϵ; change of S in response to X is elastic compliance; the other four possible relationships are all exhibitions of

‡ See caption of Fig. 1. Permittivity D/E or dielectric constant is $1 + 4\pi\eta$ where η is the susceptibility P/E. But in ferroelectrics P is so large that $\epsilon \simeq 4\pi\eta$ (or $\epsilon \simeq \eta$ in m.k.s. units) so that it is common to use the terms almost synonymously.

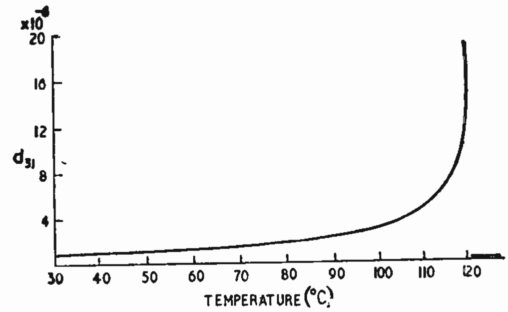


Fig. 5. One of the piezoelectric coefficients of a single-domain barium titanate crystal.

piezoelectricity, either "direct" (electrical changes caused by mechanical changes) or "converse" (mechanical changes caused by electrical), and it can be shown that they are equal in pairs; for example I shall use *d* to indicate the value of the response of P to X (a "direct" effect), which is equal to the response of S to E (a "converse" effect).

Any one of these values may appear to be very different, in ferroelectrics, depending on the conditions of measurement. For example, one may measure a property "at constant E", i.e. with opposite faces of the material connected together through a low impedance rather than open circuited. Or ϵ may be measured "at constant S", i.e. with the material "clamped" rather than "free". But clamping may not be intentional. It will occur to some extent if there are domains present which restrict one another's expansions under field, and even without domains, clamping will occur if measurements are made by fields whose frequency is above the mechanical resonance frequency of the piece of material, so that inertia prevents the rapid expansions. This resonance frequency alters with the size and shape of the piece.

So in practice one must specify rather carefully all the conditions of measurement, and the formal methods of thermo-dynamics state the relationships between them and give the equalities above, and also show that if we can explain one or two of the anomalies, the rest may be deduced. Therefore I shall not explore all the inter-relations whose complexities I have hinted at, but shall content myself with a short examination of ϵ and *d*.

Dielectric Constant.—The d.c. dielectric constant is the slope of a line such as *a* in Fig. 1(b), but usually of more interest is the incremental a.c. constant ϵ_{ac} defined, for example, when $P = P_r$, by the slope *b*. Lag effects make a slender ellipse of this line and cause losses, just as in ordinary dielectrics. If there is a bias B applied in addition to the small measuring field, the defining slope is *c*, and this alteration with bias is important in applications such as modulating devices. If the applied a.c. amplitude E_m is large, it is clear that the changes of P do not vary linearly with E. If E_m exceeds E_c, the loop is traversed, and the apparent ϵ is an overall value, not very different from P_r/E_c, say $0.025\mu F.cm^{-1}$ for barium titanate crystals. In this case also, there is a large loss specific to ferroelectrics, equal to the loop area, of order 1 mW per cu.mm at 50 c/s. ϵ varies not only with B, and with E_m, but also with frequency $\omega/2\pi$, and with temperature T. In addition, it is different when measured by a.c. in different directions (anisotropy), and when measured free or clamped, as discussed above. Fig. 4 illustrates several of these points. ϵ reaches values 1,000 times greater than in normal dielectrics.

Above T_o the ferroelectricity disappears. The polarizability is no longer large enough to maintain the spontaneous polarization in zero field, but it is apparent that its value is still large, for the effect on P of an applied field still results in an anomalously large ϵ. Above T_o, ϵ falls off, unlike most normal dielectrics, in which it rises. In many cases it falls off in such a way that its reciprocal (or strictly, that of η) is a straight line (Fig. 4(b)). This is known as a Curie-Weiss law. In equation (3) the polarizability varies as 1/T, or, say, $N\alpha' = C/T$, where I write C for the constant $Np^2/3k$. Then the earlier equations $P = N\alpha' F$ and $F = E + \beta P$ show that

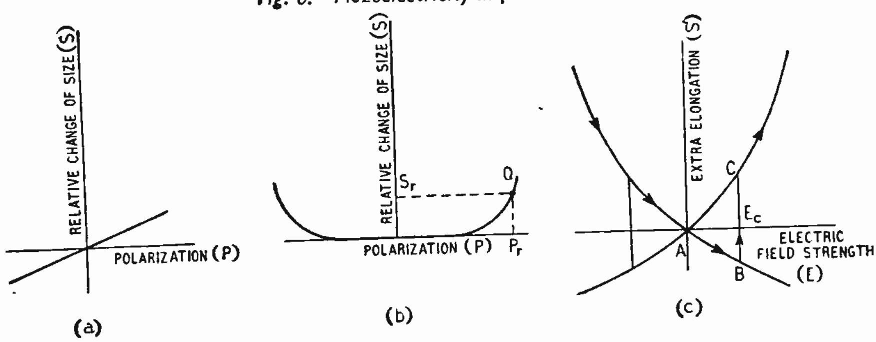
$$\frac{E}{P} = \frac{T - \beta C}{C}.$$ This is a Curie-Weiss law,

$$\frac{1}{\eta} = \frac{T - T_c}{C} \quad \cdots \quad (5)$$

The constants T_c and C are known as the Curie temperature and the Curie constant. A similar derivation can be made in other cases where α is proportional to 1/T. In this case based on equation (3) we see that $T_c = \beta C$, which from equation (4) is $T_c = T_o$. That is, as T falls, in the non-ferroelectric temperature region, towards the transition temperature T_o, η and ϵ rise towards a value which in principle is infinite at the transition temperature. In some ferroelectrics, T_c is several degrees below T_o (though still T_o is often called the Curie temperature), but in any case, though ϵ reaches a high value, it falls again in the ferroelectric region, either sharply, or more gradually as in Fig. 4(a). Now the spontaneous saturation of P has left relatively little possibility of extra polarization being acquired under an applied field to show up as a high ϵ value.

The mechanisms responsible for ϵ under small voltages are not necessarily the same as those acting when voltages are large enough, below T_o, to reverse P and cause a hysteresis loop. But where the values are anomalously large, it is probable that there is much in common. P has taken up one direction,

Fig. 6. Piezoelectricity in ferroelectrics.



so it is not surprising that ϵ is very different in that direction. It is usually larger in the direction of P in materials where the cross-directions are *not* available as alternative easy directions for P.

Piezoelectric Constants.—Fig. 5 shows the anomaly of one of the *d* values of barium titanate, associated with its dielectric anomaly. The *d* states the fractional elongation S resulting from a small field E; another piezo-coefficient *b* states the S resulting from a small polarization P. Several *d* values (and several *b*, etc.) are needed to describe the piezoelectricity of any crystal, e.g. a field in direction *c* may cause elongation in that direction and also shear effects in cross-directions. For simplicity I shall write only of the former, though in fact Fig. 5 is a cross-coefficient. Many piezoelectric materials are known and used, which are not ferroelectric, e.g. quartz. Ten of the 32 symmetry classes of crystalline solids, being centrosymmetric, cannot be piezoelectrics, and one other is not. Fig. 6(a) is drawn for an ordinary non-ferroelectric dielectric which happens to be piezoelectric; the slope is the coefficient *b*. Fig. 6(b) shows a non-piezoelectric; its slope is zero (for small P). But it is electrostrictive for larger values, and this we may approximate by $S \propto P^2$; such a curve could be found for most materials, and a similar one on an S-E plot, provided breakdown does not first occur.

All ferroelectrics are piezoelectric in the temperature range below T_0 where they remain ferroelectric. It is convenient to divide them into two groups, A and B respectively, according to whether or not they are also piezoelectric above T_0. Group A we might describe as inherently piezoelectric, though in fact the ferroelectricity profoundly modifies *d*; this group includes Rochelle salt and potassium dihydrogen phosphate. I shall discuss group B, in which all the piezoelectricity is, in a sense, given to the crystal by the ferroelectricity; barium titanate is an example.

It is a harmless simplification now to think of S as resulting from two steps: the applied E produces P and this P would produce S if "inherent *b*" existed or if P were large enough to show the electrostrictive region. But in group B, this region is reached without any applied E because of the spontaneous P_r. So the working point is at Q (Fig. 6(b)), showing that the crystal has also a spontaneous deformation S_r. For example, the cell of barium titanate, which is cubic above T_0, is 1% larger in the direction of P, below T_0. In a good crystal plate, this "*c* axis" is directed through the thickness of the plate. Now if an external E is applied, the extra P drives the point Q up the curve, producing *extra* elongation S′. So the effective piezo-coefficient *d* is S′/E, i.e. it is related to the slope of the curve at Q. The nature of this response is thus seen to be different from that of quartz, for example, Fig. 6(a). Because P_r is large the effect can be large. The effect plotted against E instead of against P is a butterfly loop traversed as shown in Fig. 6(c). From A to B, E opposes P_r but does not reverse it till E_c is reached. Reversal reaches C and thus at that point the effective *d* is changed in sign.

ACKNOWLEDGMENTS: Fig. 4(a) has been drawn from a paper by G. Busch in *Helv. Phys. Acta*, **11**, 269, 1938; Fig 4(b) from a paper by H. Baumgartner in *Helv. Phys. Acta*, 24, 326, 1951; and Fig. 5 from a paper by E. J. Huibregtse, M. E. Drougard and D. R. Young in *Phys. Rev.*, 98, 1562, 1955.

BOOKS ON CRYSTALLINE FORM OF FERROELECTRICS:

Helen D. Megaw, "Ferroelectricity in Crystals," Methuen (1957).

Werner Känzig, "Ferroelectrics and Antiferroelectrics," in Solid State Physics, vol. 4, Academic Press (1957).

(*to be continued*)

Improved Audio Input Circuit

Use of Input Alternator Resistors at the Source

By R. C. MARSHALL, B.A., Grad.I.E.E.

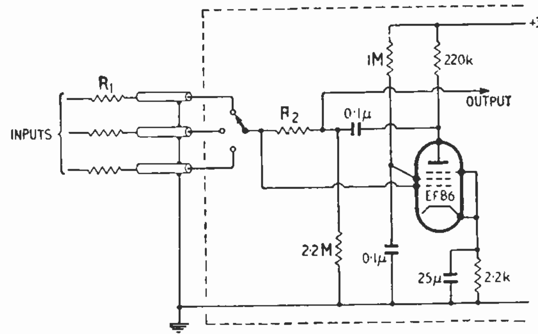
DOMESTIC audio equipment must now accept inputs from an a.m. radio, f.m. radio, gramophone or tape recorder. Usually these inputs are selected by a switch, which is connected to the various sources by screened cables 2 to 5ft long with a capacitance of 50 to 150pF. Taking the latter case of 150pF, for a loss of 3dB at 20kc/s, which is an acceptable limit for one element in a high-fidelity system, the output resistance of the unit driving the cable is limited to 50kΩ. This is inconveniently low.

Furthermore the various inputs are at different levels, and attenuators in the control unit or alternatively an anode follower with different input resistors adjust the overall gains to the required values. These adjustments are rarely correct, as details of the sources are not accurately known when the control unit is built.

It has been shown[1] that the anode follower or see-saw can be used to counteract the effect of cable capacitance by placing the input resistor at the source end of the cable, as in the circuit diagram. This is convenient also as the resistor can then be adjusted to suit the source without affecting the control unit. Some experimental figures obtained with this arrangement are given in the tables. Overall gain and permissible cable capacitances are given for a range of values of the source resistor R_1. It can be seen that for $R_2 = 4.7M\Omega$ a 30dB range of gains can be obtained with input resistors

TABLE 1

$R_2 = 2.2\ M\Omega$			Load capacity = 50 pF	
R_1 (KΩ)	Gain(dB)	Capacity (pF) for −3dB at 20kc/s	Maximum Height of peak (dB)	Capacity (pF) for − 3bB at 20kc/s
47	31	750	1	920
100	26	690	1	870
220	19.5	650	1.5	830
470	13	630	1.5	800
1000	6.5	610	1.5	790
2200	0	600	2	790



Improved input selector. The grid resistor of the following stage should be 1MΩ.

varying from 220kΩ to 8.2MΩ, with adequate frequency response. The corresponding input resistance values in Table I are roughly half those in Table II, so that a proportionately larger capacitance is possible. The bandwith does not vary with the overall gain provided that there is appreciable feedback, and is theoretically equal to $A/2\pi R_2C$ c/s, where A is the open loop gain, in this case 170 times (measured), and C the cable capacity. This gives a figure in good agreement with the experimental results. The overall gain of the stage is approximately R_2/R_1. An analysis of this circuit, and bibliography, has already appeared in *Wireless World*[2].

If the capacity of the load is appreciable, a wider bandwidth is obtained and a "hump" in the response may occur. This is characteristic of a feedback amplifier containing two lag circuits. For a 50pF load, the maximum rise for any cable capacity, and the cable capacity for 3dB loss at 20kc/s are given in the last two columns of Table I. The other measurements were taken with negligible load capacity.

TABLE II
$R_2 = 4.7M\Omega$

R_1 (KΩ)	Gain (dB)	Capacity (pF)
47	36	450
100	31.5	330
220	25.5	280
470	19.5	270
1,000	13.5	260
2,200	6.5	260
4,700	0	260
8,200	−5	260

TABLE III
$R_2 = 1M\Omega$

R_1 (KΩ)	Gain (dB)	Capacity (pF)
47	25	1,300
100	19.5	1,150
220	12.5	1,100
470	6	1,100
1,000	0	1,100
2,200	−6	1,100

REFERENCES

[1] T. G. Clarke, "An Electronic Transformer," *Electronic Engineering*, Sept. 1958, p. 545.

[2] P. J. Baxandall, "Negative Feedback Tone Control," *Wireless World*, Oct. 1952, p. 402.

V.O.R. AIRWAYS BEACON

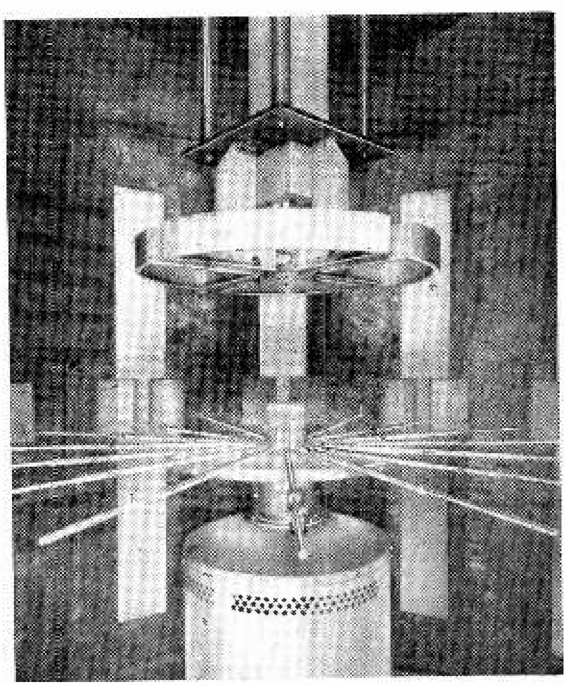
THE Marconi Omni-directional Radio Range Beacon (V.O.R.),* with which the U.K. airways are to be equipped, operates on a spot radio frequency in the 112 to 118-Mc/s v.h.f. band and with a power output of 200 watts. The V.O.R. beacon transmits two signals on a single radio frequency, one modulated at 30 c/s. One has a constant phase throughout 360° of azimuth (the reference signal) whilst the other (the variable signal) has a phase which varies with azimuth. The former is radiated from an omni-directional aerial and the latter from a rotating loop and exciter system which produces a figure-of-eight radiation field. After detection in the receiver the latter produces a 30-c/s sinusoidal voltage.

Usually the system is arranged so that the phase of the rotating field pattern coincides with that of the reference signal's pattern, after demodulation, when the former passes through magnetic north, or zero degrees. At all other points in azimuth the positive maximum of the variable signal will be reached after the positive maximum of the reference signal. The fraction of the cycle between these two maxima at any point in azimuth gives the relative bearing of that point.

In the aircraft receiver the received signals are fed to a computor unit which compares the phases and displays the difference as a bearing to or from the V.O.R. ground beacon. Usually it is the magnetic bearing from the aircraft to the ground beacon. It is also possible to include a centre-zero meter which shows the aircraft's position to right or to left of a manually selected bearing. The latter provides facilities for track flying along a desired bearing to or from a V.O.R. beacon.

Marconi V.O.R. beacons also radiate a 1020-c/s tone signal keyed by a simple code sender at about 7 w.p.m. which is repeated every 30 seconds for beacon identification.

* *Wireless World*, Feb. 1959, p. 98.



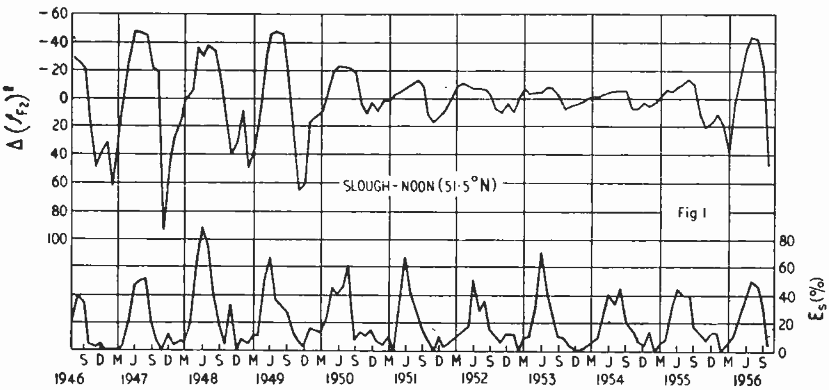
The aerial system of the Marconi V.O.R. installed in an aerial tower. Above is the omni-directional radiator with the figure-of-eight exciter below it.

Sporadic E and the F_2 Layer

By T. W. BENNINGTON*

ONE of the most mystifying of ionospheric phenomena is that of sporadic E. This is the name given to the relatively intense ionization "clouds" or "patches" which appear, in a sporadic manner, within the normal E layer. In the temperate and tropical zones this is largely a daytime phenomenon, and, though of a sporadic character, it has well defined seasonal variations which are rather more complex than is often supposed.

Speaking only of the sporadic E which appears in these zones, and leaving out that known as "auroral sporadic E," we may say that its cause, and the source from which its ionization comes, is at present unknown.



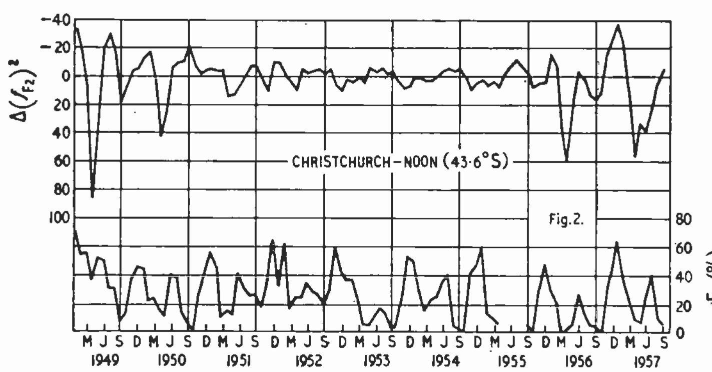
Several different types of sporadic E are, in fact, observed. Among the possible causative phenomena which have, up to now, been suggested, are meteors, thunder clouds in the troposphere, corpuscles from the sun and ionospheric current effects; but none of these possibilities has the nature of a proven fact.

In the bottom curve of Fig. 1 are plotted the monthly values for the percentage of the total time when sporadic E with a critical frequency greater than 5Mc/s was observed at noon at Slough. The curve shows a large peak in the incidence of sporadic E centred approximately on June, i.e. near the summer solstice but it also shows a small but well defined secondary peak occurring year by year round about December. In the bottom curve of Fig. 2 similar data are plotted for Christchurch, New Zealand, a station having a somewhat similar latitude to that of Slough but in the southern hemisphere. We notice a striking difference in the curve as compared with that for Slough in that the secondary peak occurring in local winter (around June) is much larger, in fact often of amplitude almost equal to that for local summer (around December), producing, in fact, the effect of a biannual peak.

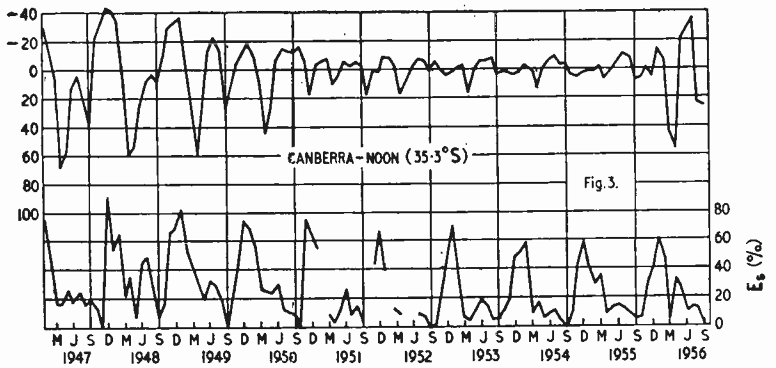
Returning to Fig. 1 it may be remarked that, to correlate the main peak with any other ionospheric phenomenon would indicate nothing much beyond the fact that they were both summertime phenomena. But if it could be shown that any other phenomenon also had a small winter fluctuation, and if, moreover, it had, in the southern hemisphere, a fluctuation of such different form from that in the northern hemisphere as to be more in the nature of a pronounced biannual fluctuation, then it might be supposed that the two phenomena were, in some way, interrelated.

It was remembered that the ionization of the F_2 layer does have an annual fluctuation of different form as between the two hemispheres, and it was desired, therefore, to compare this with that of the sporadic E. Accordingly the noon monthly mean critical frequency values f_{F2} for Slough and Christchurch were read off for the years in question, and $(f_{F2})^2$ (to which the ionization of the layer is proportional) obtained. Since the sporadic E figures do not show any systematic variation with the sunspot number, it was desired to remove from the $(f_{F2})^2$ values the secular effect due to the sunspot cycle, leaving only the seasonal fluctuations. In order to do this the twelve-month running mean value of $(f_{F2})^2$ for each month (representing the sunspot cycle variation) was subtracted from the monthly value, and the result was called $\Delta(f_{F2})^2$. It is to be noted that, though the secular variation is thus removed, the seasonal variations themselves still vary in amplitude over the sunspot cycle.

The Slough values of $\Delta(f_{F2})^2$ for noon are plotted in the top curve of Fig. 1, being inverted with respect to the sporadic E values, so that troughs in the $\Delta(f_{F2})^2$ values appear as peaks in the curve. It is seen that, in addition to the regular summer trough in $\Delta(f_{F2})^2$ corresponding to the main sporadic E peak, there is a small but definite trough in six of the winter periods shown, corresponding approximately in time with the secondary peak in the sporadic E. Furthermore, in several of the years when no definite trough in $\Delta(f_{F2})^2$ appears, there is strong evidence of one which is masked by a subsequent further $\Delta(f_{F2})^2$ variation. It is true that the secondary trough in $\Delta(f_{F2})^2$ does not always correspond *exactly* in time with the secondary peak in sporadic E, but the troughs and peaks in each are near enough to appear to be significantly connected. The $\Delta(f_{F2})^2$ troughs tend in fact to lag on the sporadic E peaks.



* Research Department, British Broadcasting Corporation.



and south of the magnetic equator, and nearer to the equator, and coincident with a permanent region of sporadic E, the F_2 ionization is depleted.

All the above facts seem to indicate that where intense sporadic E exists for a high percentage of the time, as at noon in local summer and at noon on the magnetic equator throughout the year, the F_2 ionization is depleted. Further, that when there occur, in both hemispheres, secondary increases in the percentage time for intense sporadic E, as at noon in local winter, the F_2 ionization is again depleted, and the magnitude of the depletion corresponds approximately to the increase in the incidence of sporadic E. These facts may account, in some part, for the anomalous seasonal behaviour of the daytime F_2.

In the top curve of Fig. 2 the $\Delta(f_{F2})^2$ values for Christchurch are plotted, and it is evident that the fluctuations are of a different character from those shown in the top curve of Fig. 1. In fact the curve shows, in general, a strong tendency for a biannual trough, which troughs appear to be connected with the peaks of the bottom curve. It is seen, in fact, that the major peak in the sporadic E curve is connected more often with a smaller trough in the $\Delta(f_{F2})^2$ curve than is the secondary sporadic E peak. (During a few months of 1955 no measurements were available for Christchurch but it was possible to estimate the $(f_{F2})^2$ values by interpolation; this was not possible for the sporadic E.)

It is convenient, in order clearly to distinguish the annual variation, to regard each year as starting at the vernal equinox in both hemispheres, and the vertical lines in the graphs are used to divide the time into years in this way.

Similar results can be obtained for stations in other latitudes. Consider, for example, Fig. 3, in which the values of sporadic E percentage time and of $\Delta(f_{F2})^2$ for Canberra are plotted. There are several breaks in the data but the general features can be clearly seen. The secondary peak in sporadic E is less prominent than is the case for Christchurch, but it appears to be connected with one of the biannual troughs (often the major one) in $\Delta(f_{F2})^2$.

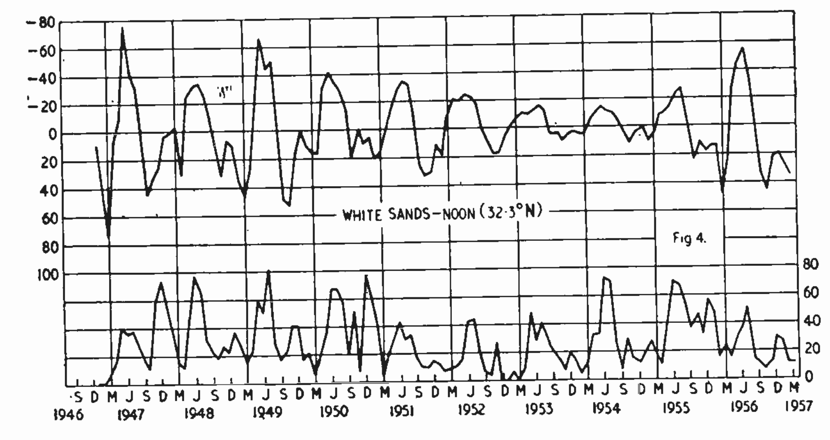
In Fig. 4 similar data are plotted for White Sands, a station in the northern hemisphere with a lower latitude than that of Slough. Here the winter peaks in sporadic E are much larger than those for Slough (in fact they are sometimes of greater amplitude than the summer peaks). Correspondingly, the winter troughs in $\Delta(f_{F2})^2$ are much more pronounced than in the case of Slough, and the similarity between the peaks and troughs of the two curves of Fig. 4 is, all things considered, quite pronounced.

There is one further phenomenon which furnishes evidence of a like nature to that shown in the graphs. If one examines the sporadic E data for local noon for a station near the magnetic equator (such as Huancayo, Peru or Ibadan, Nigeria) it is found that sporadic E with critical frequency greater than 5Mc/s is present for from 90 to 98% of the total time during every month of the year. This effect is found to prevail in a narrow belt along the magnetic equator and within that belt a trough is found to exist in the geographical distribution of $(f_{F2})^2$. In other words the highest values of $(f_{F2})^2$ exist, at noon, a few degrees to the north

The above facts seem to suggest that the dense ionization which appears in the E layer, and is called sporadic E, comes in fact from the F_2 layer, and that its occurrence leads to a depletion of the F_2 ionization in all cases. This might occur by reason of some sort of "subsidence" or downward drift of ionization from the F_2 into the E. The difficulty is to see, if this be so, how the sporadic E would have the "thin layer" characteristics which it does, in fact, usually display. Even so there appears to be the possibility that, above the thin sporadic E layer, phenomena such as a downward drift may be occurring but are not easily observable by ionospheric measurement techniques. As was first reported by Appleton and others in 1939†, a kind of downward drift is often observed during the formation of sporadic E. The ionization in these cases is first observed at the height of the F_1 layer and, during the course of several hours, it decreases in height and increases in critical frequency until the normal E layer height is reached. What physical process could occasion such a downward drift, and cause it to occur only sporadically, is a subject for speculation. But the facts mentioned here, and the evidence of the graphs, do suggest that sporadic E may come from the F_2 layer.

A further possibility is that the coincident biannual peaks in the sporadic E and troughs in the F_2-layer ionization are both due to some common cause of extra-ionospheric origin, though it is difficult to see how any ionizing agency could produce such effects. A more likely possibility would seem to be the presence of an ionospheric current, capable of causing interaction between the two layers.

†Appleton, E. V., Naismith, R. and Ingram, L. J., "The Critical-Frequency Method of Measuring Upper-Atmospheric Ionization". *Proc. Phys. Soc.*, Vol. 51, pp. 90-91, January 1939.



Simple Oscilloscope Camera

Using Printing Paper to Record Stationary Traces

By A. J. KEY, B.Sc. (Eng.), Grad. I.E.E.

ONE often requires a record of a steady oscilloscope trace. As students, I remember, we used to trace the waveform on tissue paper obtained from a local plentiful supply, but the only merit of this method was cheapness. The alternative, an oscilloscope camera complete with shutter, film and driving motor, is an expensive improvement. I had thought of a contact printing process, which would involve holding contact paper against the tube face, but of course this would result in only a very blurred image. Some sort of focusing device is necessary; in fact a simple camera using printing paper as the film.

The camera and method of mounting the lens are shown in Fig. 1. The body of the camera is made from aluminium sheet rolled into a 2½-inch diameter tube, to suit, of course, a 2½-inch screen c.r.t. The length of the tube depends upon the focal length of an available lens and the required image size. The minimum length of the tube would be 4× focal length of the lens, giving a magnification of unity. However, in the interests of image brightness, it is as well to use a magnification of ½. This requires a camera length of 4½× focal length of the lens, as is shown in the appendix.

The front end plate (also made from aluminium sheet) has a circular window, slightly smaller in diameter than the aluminium tube, but fixture to the tube can be made easier if three tabs are cut and bent away from the sheet before cutting the window. These tabs then fit into the tube, which fits flush with the end plate. The rear end plate has a rectangular window slightly smaller than the printing paper size. It can be fitted to the tube with four aluminium brackets, but the screw heads on the rear face of this end plate must be countersunk to enable the paper to lie flat upon the end plate. The backing plate is a plain piece of aluminium sheet which holds the printing paper during exposure against the window of the rear end plate, by being clamped to it with a pair of bulldog clips.

The lens is held by two rubber rings clamped between two aluminium "washers." These washers fit the inside of the tube, leaving a small clearance, and have apertures slightly smaller than the diameter of the lens. The washers are held together, sandwiching the lens between them, by three clamping screws. One of the washers has three tabs cut and bent from its edge to take the three 6 B.A. screws which project through axial slots in the tube. The lens assembly can then be moved nearer

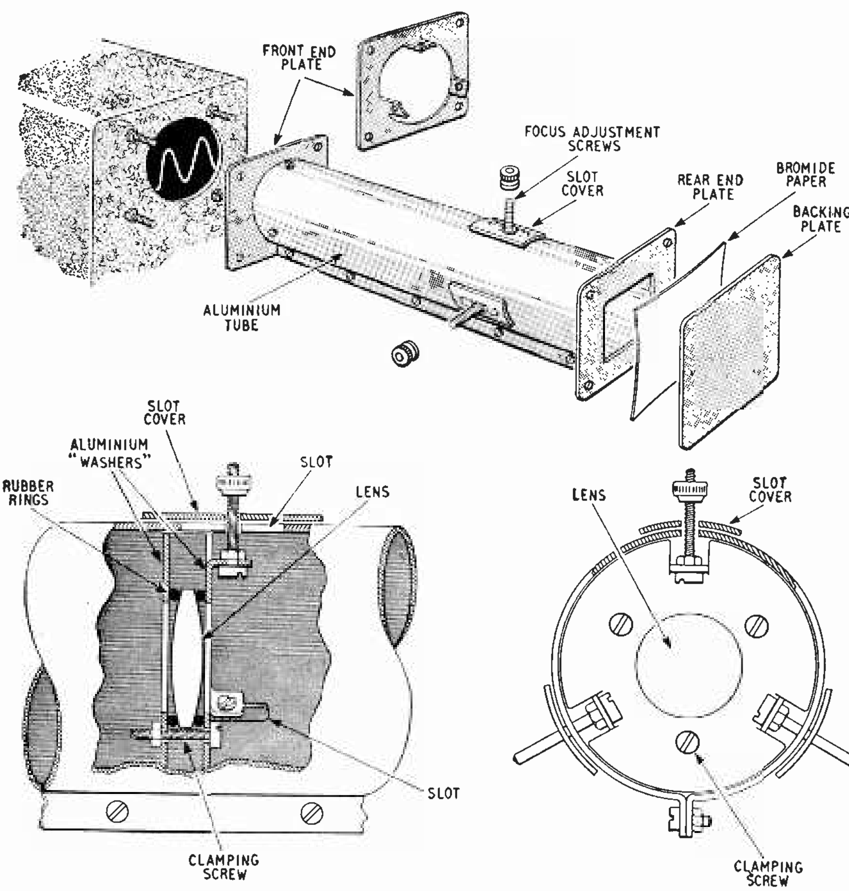


Fig. 1. Construction of the camera tube and lens mounting system.

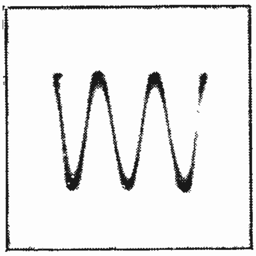


Fig. 2. Example of a 1,000-c/s sine wave recorded by the camera.

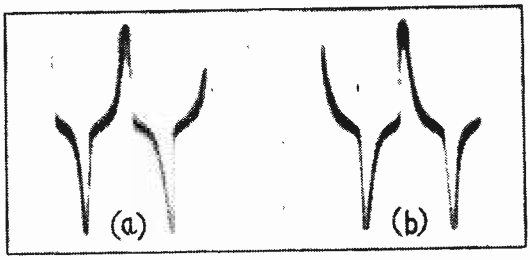


Fig. 3. (a) Mirror image obtained of a differentiated square wave with a forward-running timebase, (b) the same wave with a backward-running timebase.

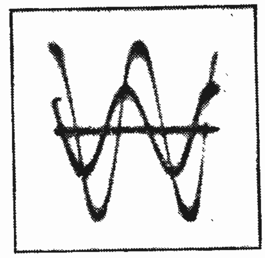


Fig. 4. Superimposition of two sine waves to show phase difference.

to or away from the screen to enable focusing adjustments to be made. Three sliding covers fit over the slots to prevent light ingress into the tube and the whole assembly is clamped by three 6 B.A. terminals. Although this may seem a rather complicated assembly, in practice it is very easy to make, requiring no tools other than a drill, a file and a pair of scissors. Finally, the inside of the tube is coated with a black matt paint (made actually from soot and nail varnish).

Requirements for the Lens

The choice of lens will depend largely upon those available. In the interests of a bright image, the diameter (aperture) of the lens should be as large as possible, but if the lens is uncorrected for spherical aberration, a certain amount of blurring of the image will occur. The object lens from an old telescope is ideal. It will have a rather large focal length, making the camera rather long, but the spherical aberration will be reduced. If a simple uncorrected lens is used it should have a long focal length for this reason.

Contact paper does not appear to be sensitive enough; bromide paper is far better, using a reasonable brightness level. Two to three minutes' exposure, followed by two minutes' development and subsequent fixing, gave the results shown in Fig. 2 for a 1,000-c/s sine wave. As long as the paper is fitted into the camera in darkness, the exposure can be made in reasonable light conditions in the laboratory when the camera is fitted on to the oscilloscope. If trouble is experienced with fogging of the paper, draping a black cloth over the camera during exposure should cure the trouble. Synchronization must be used, of course, but the occasional jump does not affect the image.

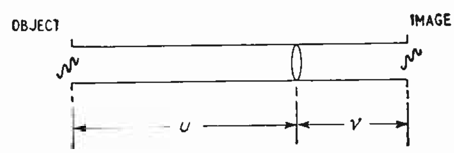
The image produced will be a black trace on a white background, which is convenient when adding comments and making measurements. One snag, however, is that the image is a mirror-image (see Fig. 3(a), the trace of a differentiated square wave). This can be overcome by either reversing the X plates (thereby reversing the timebase) or reversing the Y plates (inverting the image) whichever is the more convenient. Luckily, on my oscilloscope, reversal of the X plates could easily be accomplished by a modification to the X selector switch. Otherwise, a double-pole double-throw switch could be fitted for this purpose. Fig. 3(b) is a trace obtained with a backward running timebase.

These results were given by a green trace cathode ray tube and bromide paper, WFL.2D. It may be that other printing paper is more sensitive to green light and that other colour traces require other grades of paper.

The system is quite useful for measurement of phase differences. Normally one needs a double beam oscilloscope for this, but even then the thickness of the tube face and lack of a zero line make the measurement only approximate. Suppose one wishes to measure the phase difference between two voltages occurring at points A and B in a circuit. The oscilloscope is synchronized from the voltage at A and an exposure is made for two minutes to the trace of this voltage. Another exposure, to the waveform of the voltage at B, is now made, retaining the synchronization from A. Finally, an exposure is made to the undeflected trace to obtain a zero line. The result for two sine waves is shown in Fig. 4. Of course, any number of waveforms may be superimposed in this manner.

The cost of each exposure is negligible. Cutting sheets of $3\frac{1}{4}$in $\times$ $4\frac{1}{4}$in bromide paper into four makes each print about $\frac{1}{4}$d. The developer and fixer can be made up from powder and stored for two or three months.

APPENDIX



Putting u and v as positive distances, for a double convex lens

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v} \text{ where } f \text{ is the focal length of the lens}$$

$$\text{Magnification } M = \frac{v}{u}$$

$$\text{therefore } \frac{1}{f} = \frac{1}{u} + \frac{1}{Mu}$$

$$\text{From which } u = \left(1 + \frac{1}{M}\right) . f$$

$$\text{Total length } = u + v$$

$$= \left(1 + \frac{1}{M}\right) . f + M\left(1 + \frac{1}{M}\right) . f$$

$$= \left(2 + M + \frac{1}{M}\right) . f$$

Thus if magnification is $\times 1$, total length $= 4f$

If magnification is $\times \frac{1}{2}$, total length $= 4.5f$

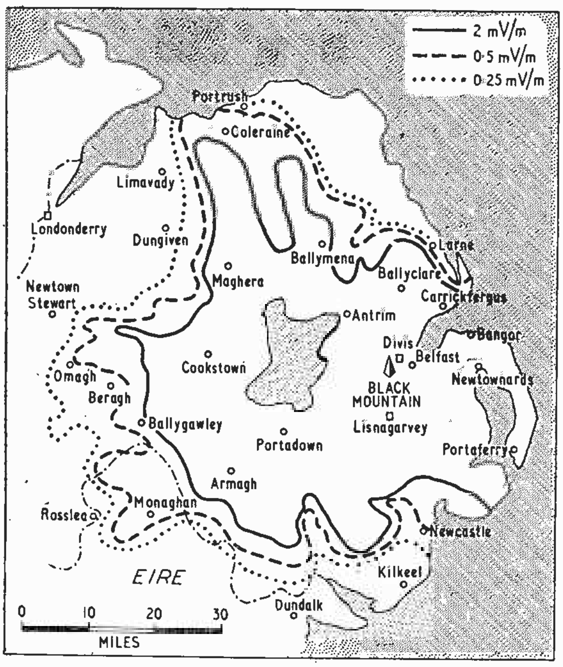
WORLD OF WIRELESS

Medical Electronics Conference

OVER 120 papers on the application of electronic techniques to medicine will be presented by experts from 18 countries at the Second International Conference on Medical Electronics to be held in the new U.N.E.S.C.O. headquarters in Paris from 24th to 27th June. A commercial exhibition of electromedical equipment will be held in the building at the same time. Subjects of the conference papers range from the measurement and telemetering of physiological data during space flight to the control of artificial limbs by muscle action potentials; from "radio pills," which are swallowed and transmit physiological data from inside the body, to the use of electronic computers for statistical methods of diagnosis. Registrations for the conference can still be arranged through the treasurer, B. Shackel, E.M.I. Electronics, Ltd., Feltham, Middlesex.

MSF Standard Frequencies

IN calculating the frequencies of the 60-kc/s transmissions from the Rugby station MSF in terms of the caesium resonant frequency a value of 9,192,631,770±20c/s will be assumed instead of the former value of 9,192,631,830c/s. The change is the result of the adoption of Ephemeris Time (ET) instead of corrected Universal Time (UT2). From March, 1959, corrections will be measured to



I.T.A. IN N. IRELAND.—Estimated service area of the new I.T.A. transmitter on Black Mountain, near Belfast. The station will radiate in channel 9 using horizontal polarization. The directional aerial atop the 700-ft mast, giving a height of nearly 1,700-ft above sea level, will have an e.r.p. varying from 20kW to 100kW. Full-power test transmissions are planned to begin in August.

±1 part in 10^{10} and the results will be published monthly, as usual, in our sister journal *Electronic & Radio Engineer*. For a detailed discussion of the background to the changes readers are referred to *E. & R.E.* for March, p. 117.

Receiver Production & Sales

THE total turnover of the domestic receiver side of the radio industry during 1958 was just over £90M; about £3M more than in 1957. Of this total £3.4M worth of receivers was sold overseas. The export of sound receivers dropped from £2.89M in 1956 to £2.12M last year, while the overseas sales of television receivers rose from £462,000 to £914,000 during the same period and radio-gramophones from £271,000 to £399,000. The largest market for domestic equipment was Sweden, who purchased £329,809 worth, of which £293,983 was for television receivers. Well over a fourth of the value of radio-gramophone exports went to the U.S.A. These figures are culled from the statistics section of the annual report of the British Radio Equipment Manufacturers' Association.

During 1958 the popularity of the 17-in television screen continued to increase; accounting for approximately 83 per cent of all home sales—an increase of 11 per cent during the year. The percentage of models with 21-in tubes fell from 8 to 5 and those with 14-in tubes from 20 to 12 during the year.

Dip. Tech.

THE number of students taking advance courses leading to the award of the Diploma in Technology has increased more than two-and-a-half times during the past eighteen months. The second report of the National Council for Technological Awards published on April 23rd records that 2,518 students, including 52 women, are now following 66 diploma courses at 20 colleges.

Lord Hives, chairman of the Council, in paying his tribute to industry in a foreword to the report, refers to the fact that 82% of the 2,323 students following sandwich courses leading to the Diploma in Technology have their fees paid by their employers.

In addition to the 66 courses (53 of which are sandwich type) referred to above, the Council has recently approved a further 21 and all the 87 courses are included in the latest list (No. 10) available from the Council at 9, Cavendish Square, London, W.1.

"Trader Year Book"

FIRST published in 1925 the "Wireless and Electrical Trader Year Book" has become the *vade mecum* for the radio trade. A few of the features of the 1959 edition are:—condensed specifications of nearly 250 current television receivers and over 400 sound receivers; tables of television tuning frequencies (giving i.f.s of superhet receivers and sideband characteristics of both superhet and t.r.f. models) and also the i.f.s of sound receivers issued since 1946. It is also a valuable book of reference for trade names and manufacturers' addresses. The 416-page volume, issued by the Trader Publishing Co., costs 12s 6d.

Television Society Premiums have been awarded for outstanding papers read before the London meetings in 1957/58. For his paper "Transistors in Television Receivers," B. R. Overton, head of the television division of Mullard Research Laboratories, receives the *Wireless World* premium. The E.M.I. premium goes to Dr. R. Theile (Institut für Rundfunktechnik) for "Recent Investigations into the Operation of Image Orthicon Camera Tubes"; the *Electronic Engineering* premium to Dr. J. C. Parr (formerly Kelvin & Hughes) for "Some Aspects of Waveguide Technique"; the Pye premium to L. J. Griffen (Kolster Brandes) for "Dressing Television: Cabinet Design"; the Mervyn premium to K. H. Smith (Siemens Edison Swan) for "Performance of Television Receiver Turret Tuners"; and the Mullard premium to J. Polonsky (Compagnie Générale de T.S.F.) for "A French Portable Television Camera."

Television Society Council.—New members elected at the annual general meeting on May 8th, to fill the four vacancies on the council of the Television Society are: Dr. A. J. Biggs (G.E.C. Research); G. G. Gouriet (Wayne Kerr); B. R. Overton (Mullard Research); and Dr. J. D. McGee (Imperial College).

B.R.E.M.A.—The member firms of the British Radio Equipment Manufacturers' Association forming the new Council of the Association (with the firms' representatives in parentheses) are: A. J. Balcombe (E. K. Balcombe); Bush Radio (G. Darnley-Smith); E. K. Cole (G. W. Godfrey); Ferguson Radio Corp. (F. T. Holmes); G.E.C. (M. M. Macqueen); Gramophone Co. (F. W. Perks); Kolster-Brandes (L. R. Tyne); Philips Electrical (A. L. Sutherland); Radio & Allied Industries (Bentley Jones); Trix Electrical (D. A. Lyons); Ultra Electric (E. E. Rosen); and Roberts Radio (H. Roberts). F. W. Perks and A. L. Sutherland have been re-elected chairman and vice-chairman respectively.

Outward Form.—An international cabinet-styling exhibition is again being arranged by B.R.E.M.A. It will be held from October 6th to 8th and will this year occupy both the North and South Halls of the Victoria Halls, Bloomsbury Square, London, W.C.1. Manufacturers of metal embellishments, plastics materials, glassware, fabrics, ornamental controls and aerials are being invited to participate in this "stockroom" exhibition.

University Scholarships.—Over 500 applications were received for the second series of 20 university scholarships offered by the English Electric Co. The scholarships, worth £450 a year, cover a three-year course at a university to study for an honours degree. Commenting on the applications, E. R. L. Lewis, Controller of Education in the English Electric group of companies, stated that the standard of entry was very high. About one-third of the entrants were interviewed, from these 40 were invited to attend a two-day residential selection board, and from these the 20 recipients were chosen.

Plastics materials are used so extensively in the radio industry that we make no apology for drawing readers' attention to the International Plastics Exhibition to be held at Olympia, London, from June 17th to 27th. Over 300 U.K. and overseas manufacturers of plastics materials and finished products and machinery are exhibiting at the show which is organized by *British Plastics*. A three-day convention (June 22nd to 24th) is being held in conjunction with the exhibition. Admission tickets to both the exhibition and convention are obtainable free from *British Plastics*, Dorset House, Stamford Street, London, S.E.1.

Institution of Electronics is offering four new premiums for papers published in the proceedings of the Institution, which is issued quarterly. They vary in value from 15 to 25 guineas.

"Transipack" Convertors.—The two semiconductor h.t. units described on page 248 in the May issue weigh 1 lb 2 oz and 1 lb 15 oz respectively and not 11 lb as stated.

Manchester Electronics Exhibition.—The 14th Annual Electronics Exhibition and Convention of the Institution of Electronics will be held at the Manchester College of Science and Technology from July 9th to 15th. There will be two main sections in the exhibition; one for manufacturers and the other covering scientific and industrial research. Further particulars of the exhibition and the associated convention are obtainable from W. Birtwistle, 78, Shaw Road, Rochdale, Lancs., from whom complimentary tickets may also be obtained.

Industrial Electronics.—From May 26th to 29th at the Rutherford College of Technology, Newcastle-upon-Tyne, Farnell Instruments Ltd., of Wetherby, Yorks., are holding their third industrial electronics exhibition. It will open daily at 10.0 and close at 5.30 on the first and last days and 7.0 on the two intervening days.

Receiving Licences.—During March the number of combined television and sound licences throughout the U.K. increased by 102,495, bringing the total to 9,255,422. Sound only licences totalled 5,480,991 including 376,053 for sets fitted in cars.

I.R.C.M.S.—The duplicated bulletin of the International Radio Controlled Models Society is now available to non-members from N. R. Armstrong, 3 Lilburn Gardens, Newcastle on Tyne 3 (price 2s 10d). The bulletin includes not only reports on the groups operating in different parts of the country, but also useful notes on radio control techniques.

Radio Control.—The annual contest of radio-controlled model boats, cars, etc., organized by the I.R.C.M.S., will be held on August 2nd and 3rd in East Park, Kingston-upon-Hull. Entry forms and copies of rules are obtainable from B. E. Veal, 33 Steynburg Street, Newbridge Road, Hull, Yorks.

Essay Competition.—To encourage and promote improved and more effective reports of scientific and technical work the Waverley Gold Medal Essay Competition is again being sponsored by *Research*. Details of the competition, entries for which must be received by July 31st, are obtainable from the Editor of *Research*, 4 and 5 Bell Yard, London, W.C.2.

Personalities

A. H. W. Beck, B.Sc.(Eng.), A.M.I.E.E., who was for some years in charge of the Vacuum Physics Division of Standard Telecommunications Laboratories at Enfield before joining the staff of the Engineering Department of Cambridge University last year, has been elected a Fellow of the American Institute of Radio Engineers "for contributions to the development of the thermionic valve." After graduating at University College, London, and undertaking a year's post-graduate work on secondary electron emission, he joined the research staff of Henry Hughes & Sons in 1937. He was at the Admiralty Signals Establishment extension at Bristol during the war, after which he returned to Hughes, where he stayed until 1947, when he joined Standard Telephones and Cables. He has twice received a technical writing premium from the Radio Industry Council.

R. S. Medlock, B.Sc., A.R.I.C., A.M.I.E.E., technical and home sales director of George Kent Ltd., of Luton, Beds., is the new president of the Society of Instrument Technology. He joined the company in 1935 and was chief research and development engineer for five years before assuming his present position in 1956. He is a past chairman of the control section of the Society. He succeeds **J. F. Coales**, O.B.E., M.A., M.I.E.E., reader in control engineering at Cambridge University, whose presidential address at the conclusion of his term of office dealt with the education of instrument technologists and control engineers.

Air Commodore W. C. Cooper, C.B.E., M.A., M.I.E.E., M.Brit.I.R.E., has had conferred on him by the City and Guilds of London Institute the Insignia Award in Technology (C.G.I.A.). Five of these awards are made each year in various branches of industry to "persons of distinction in recognition of their outstanding achievements in technology." He joined the R.A.F. in 1922 at the age of 16, was gazetted in 1926 and after taking a Specialist Officers' Signals Course at Cranwell he went to Cambridge University for the engineering tripos course. When he retired from the R.A.F. in 1946 he was Director of Communications, Research and Development in the Ministry of Aircraft Production. He then joined Ericsson Telephones as factory manager at Beeston, Notts., and in 1957 became chairman and managing director of Manlove, Alliott and Co., of Nottingham, who are engaged in the development of process control equipment.

Herman Baker, for the past six years Far East Regional Manager for Marconi's, has been appointed managing director of Marconi (South Africa) Ltd. He joined the company in 1930 as a student apprentice and on completion of his technical training remained in the Test Department until the outbreak of the war, during which he served in the Royal Artillery, attaining the rank of Major. Since 1951 he has been responsible for the company's activities in the Far East and took charge of a large-scale survey for the establishment of the main Malayan v.h.f. multi-channel telecommunications trunk routes.

Donald G. Fink, formerly editor of *Electronics*, has been appointed director of the research division of the Philco Corporation, which he joined in 1952. He was a member of the editorial staff of *Electronics* from 1933, except for a period during the war when he was granted leave of absence to join the Radiation Laboratory of M.I.T. where he subsequently became head of the Loran division. He was president of the I.R.E. for 1958.

H. de A. Donisthorpe has retired from the G.E.C., which he joined in 1926. He had been for some years deputy manager of the company's Valve and Electronics Department. He was for 11 years chairman of the Radio Industries Club prior to being elected president for the year 1948/49.

G. E. Spark is joining the Garrard Engineering and Manufacturing Company as sales manager of the division being formed to market the tape deck to be introduced by the company. Mr. Spark, who is chairman of Audio Fairs Ltd., was previously with M.S.S. Recording Co.

D. W. Rippin has resigned his position as export manager of Belling & Lee to emigrate to Canada where he is joining the Astral Electric Company, of Toronto, who are Belling & Lee's Canadian agents. **J. E. Bailey,** B.Sc.(Elec. Eng.), who has been with Belling & Lee for two years, succeeds him as export manager. After graduating at Manchester University in 1948, Mr. Bailey joined the Navy for two years and was commissioned in the electrical branch. He then joined Marconi's as a graduate apprentice and subsequently worked on airborne and marine radar equipment. From 1954 to 1956 he was with Decca Radar.

M. T. Elvy, A.M.Brit.I.R.E., has been appointed joint manager and chief engineer of the R.F. Heating Division of Pye, Ltd., Cambridge. He was formerly chief engineer of the Industrial Electronics Laboratory of Redifon, Ltd.

D. C. F. Bartlett, B.Sc.(Eng.), has been appointed a director of Alma Components Limited, manufacturers of precision wirewound resistors. He was formerly on the commercial manager's staff in the Components Group of Standard Telephones and Cables.

E. R. Deighton, recently appointed Assistant Superintendent Engineer, Television (Regions and Outside Broadcasts) by the B.B.C., has been assistant to the Controller, Television Service Engineering, since 1953. He joined the B.B.C. television service at the Alexandra Palace station in 1936. He succeeds **W. D. Richardson,** Assoc.I.E.E., who is retiring after nearly 30 years' service.

G. D. Cook, A.M.I.E.E., is appointed by the B.B.C. Engineer-in-Charge (Television), Manchester, in succession to **V. G. Hawkeswood,** who, as announced in our February issue, has joined Southern Television. Mr. Cook joined the Corporation in 1946 and has been assistant to the Superintendent Engineer Television (Regions and Outside Broadcasts) since 1955.

J. J. S. Smith, A.M.I.E.E., works manager of British Communications Corporation, Ltd., was recently appointed to the board of directors.

OUR AUTHORS

J. C. Burfoot, Ph.D., contributor of the article on ferroelectrics in this issue, is a lecturer at Queen Mary College, University of London. Educated at Christ's College, Cambridge, he obtained first-class honours in his tripos in 1949 after an interval of three years as a Signals Officer in the R.A.F. His doctoral thesis at Cambridge and subsequent research at Aberdeen University were on aberrations in electron lenses. Since 1955 Dr. Burfoot has been investigating ferroelectricity and computers.

R. G. Christian, A.M.Brit.I.R.E., Grad.I.E.E., who describes in this issue a circuit for displaying valve anode curves and their axes on a c.r. tube, is a teacher at the College of Technology, Liverpool. Before joining the staff at the College in 1954 he was for three years in industry. From 1946-48 Mr. Christian was in the Royal Army Educational Corps following which he was for three years a student at the Regent Street Polytechnic. He operates amateur station G3GKS.

W. A. Cole, B.Sc., author of the article on magnetic matrix stores, served with the R.A.F. as a Flight Lt. on ground radar during the war. Subsequently he attended London University, where he obtained a special physics degree. In 1951 he joined Mullard Research Laboratories, Salfords, eventually taking charge of a group working on magnetic storage devices. Recently, he transferred to the component division at Mullard House.

Jean Walton, who recently contributed an article on pickup design, discusses the design of a pickup arm in this issue. Miss Walton, who has had twelve years' experience in the development of audio equipment, has been with Cosmocord for the past 18 months.

OBITUARY

Sir Stanley Angwin, K.C.M.G., K.B.E., D.S.O., M.C., who died on April 21st, aged 75, was for eight years engineer-in-chief of the Post Office before being appointed chairman of Cable and Wireless, Ltd., on the Government's acquisition of the company in 1947. He resigned in 1951 to become chairman of the Commonwealth Telecommunications Board, from which he retired in 1956. Sir Stanley joined the Post Office engineering department in 1906. "In recognition of his outstanding life's work in the field of telecommunication, both national and international," the I.E.E. granted him honorary membership in 1956. Three years earlier he had received the Institution's Faraday Medal. He was for some years a member of the Radio Research Board of the D.S.I.R. and was appointed chairman in 1947.

Pickup Arm Design

By I. WALTON*

Requirements for Low Tracking Weight and Immunity from Vibration

THE following considerations arose in the course of the design of the 1-gm pickup described recently in *Wireless World* (April issue, p. 182). A general reassessment of arm design was found necessary since most arms now available were designed when tracking weights were in the region of 5 to 10 gm, and side thrusts (intentional and otherwise) of about 1 gm seem to be quite common even after careful levelling.

The requirements for a suitable arm are that under operating conditions there should be:—

(1) *Low side thrust.* Side thrust may be produced by (a) pivot system friction, (b) an unlevel base, (c) the torque resulting from the head angular offset and friction between the stylus and both plain and modulated grooves, and (d) the " lateral " inertia of the arm acted upon by any eccentricities in both the disc and turntable. For 1-gm tracking, the total side thrust should be under 0.1 gm.

(2) *Constant and correct vertical stylus force.* This force is affected by (a) the " vertical " inertia of the arm acted upon by any warps in the disc and turntable, (b) friction of the " vertical" pivot system and (c) stability of vertical balance. This stability is determined by the distribution of mass above and below the vertical pivot, and any spring counterbalance which may be used.

(3) *Immunity from vibrations.* Such vibrations can be internal (rumble, etc.) or external. Excitation in any direction at the stylus or pickup base or both together should not produce undue vertical or lateral pressures at the stylus tip. Internal excitations are limited by disc and record player standards, whereas external excitation varies with the rigidity of the user's floor!

(4) *Facility of use.* There should be no need for weighing machines, spirit levels, etc.

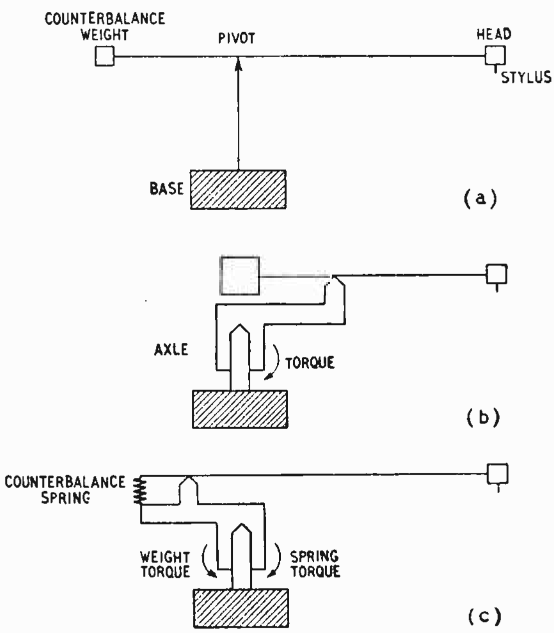
There appears to be some scope for arm development to fulfil these requirements, and to this end the various principles of construction were reduced to the following:—

(a) Single pivot (including vertical pivots directly over lateral) as in Fig. 1(a).

(b) Axle and pivot (vertical pivots offset from lateral) as in Fig. 1(b), and

(c) Spring counterbalance as in Fig. 1(c).

Fig. 1 Basic principles of pickup arm construction:— (a) single pivot, (b) offset pivots with axle and weight counterbalance, and (c) offset pivots with axle and spring counterbalance.



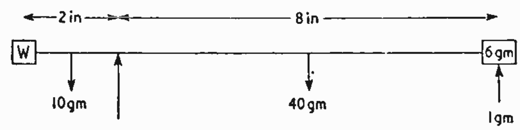


Fig. 2 Dimensions and weights in a typical single-pivot system.

Low Side Thrust.—As a result of measurements made on existing arms, low side thrust became the first consideration. It can be seen that friction at the lateral pivot is an almost constant minimum only in the case of the single-pivot system, since extra thrust on the side of the essential axle part in the other two principles of construction gives extra friction according to the balance moment required. An example will emphasize this point.

Consider a pickup to track at 1 gm with a head mass of 6 gm at a distance of 8 in from the lateral pivot. The three principles of construction then give the following results:—

(1) *Single pivot as in Fig. 2.*

Taking moments about the pivot we have:—

$$(W \times 2) + (10 \times 1) = (40 \times 4) + (5 \times 8)$$

$$\therefore W = 95 \text{ gm}$$

$\therefore$ Total weight on pivot

$$= 95 + 10 + 40 + 5 = 150 \text{ gm}$$

$\therefore$ To a first approximation, frictional force at pivot $= 150 \times \mu$ gm

where μ is the coefficient of friction.

If $\mu = 0.2$ and the pivot tip has a radius of 0.02 in then, taking moments about the pivot,

Maximum side thrust at stylus

$$= 150 \times 0.2 \times \frac{0.02}{8}$$

$$= 0.075 \text{ gm}$$

(2) *Offset pivots as in Fig. 3.*

With a 2-in offset and 2-in axle we have, taking

* Cosmocord Ltd.

moments about the vertical pivot

$(W \times 2) + (10 \times 1) = (30 \times 3) + (5 \times 6)$

$\therefore W = 55$ gm

$\therefore$ Moment about axle

$= (55 + 10 + 30 + 5) \times 2 + (10 \times 1)$

$= 210$ gm-in

$\therefore$ To a first approximation, frictional force at extreme lower end of an axle even as unusually long as 2-in

$$= \frac{210 \times \mu}{2} \text{ gm}$$

If $\mu = 0.2$ as before, and the axle has a diameter of $\frac{1}{8}$ in then,

$$\text{Side thrust at stylus} = 105 \times 0.2 \times \frac{0.0625}{8}$$

$$= 0.164 \text{ gm}$$

To this must be added the side thrust due to friction at the pivot at the top of the axle. If the pivot tip has a radius of 0.02 in then, from a calculation similar to that with a single pivot,

Extra side thrust at stylus

$$= (55 + 10 + 30 + 5 + 10) \times 0.2 \times \frac{0.02}{8}$$

$$= 0{\cdot}055 \text{ gm}$$

$\therefore$ Total side thrust at stylus

$$= 0{\cdot}22 \text{ gm}$$

(3) *Spring counterbalance.*

This can be arranged to have the same friction as the single pivot by countering the moment of the weight about the axle by the spring torque, using a rearward offset of the vertical pivot (see Fig. 1(c)). This, of course, is for only one value of the tracking weight.

The idea of using pivot friction to counter the side thrust caused by pickup head angular offset and friction between the stylus and groove was dismissed, since this thrust not only varies with the tracking weight required, but also with the recorded modulation as well as with the tracking error. It was thought that a considerable reduction in the side thrust would occur when tracking within the elastic limit of the record, because of reduced friction between the stylus and groove.

If British Standard 1928:1955, giving the allowable eccentricity of discs and turntables is taken as a basis, it can be shown that a pickup arm tracking a micro-groove disc may find itself at rest occasionally. Thus it is clear that static as well as sliding friction must be taken into account in the lateral pivot. A figure of 0.05 gm static frictional force was designed for, and even lower values were attained in practice.

The worst feature of the two offset pivot systems is the extra necessity for levelling the arm base. If this is not done, the laterally unbalanced moment of the whole weight of the whole arm may produce a side thrust proportional to the sine of the angle of arm base tilt. Again the spring system could be elaborated to avoid this, but only conveniently for one value of the tracking weight. In a true self-levelling, single-pivot system (i.e., one in which the arm can freely rotate about the pivot in any direction) the side thrust is only equal to the actual stylus force multiplied by the sine of the angle of turntable tilt. Considering 1-gm trackers, a $2\frac{1}{2}°$ tilt produces a side thrust of 0.044 gm for a true single pivot, and $0.044 \times \frac{1}{8}(6 \times 8 + 40 \times 4 + 10 \times 1) = 1.2$ gm for example for the offset pivot case of Fig. 3.

If the effective stylus force is momentarily reduced by vibration or excessive modulation to less than the side thrust, then the stylus will ride up out of the groove. With an unlevelled offset system, due to the out-of-balance side thrust, the stylus will then skate with increasing momentum and destructive power across the record. With a true single-pivot system, owing to its "self-levelling" properties, the side thrust due to an unlevel turntable is only proportional to the contact force between the stylus and groove and thus falls to zero if the stylus leaves the groove. In fact the developed pickup, which incorporates a true single pivot, will not skate across the record under the most adverse conditions even at very low tracking weights.

Again consulting British Standard 1928:1955, it can be deduced that the combined allowable eccentricity of disc (0.002 in) and transcription turntable (0.001 in) will produce a lateral acceleration of $(2\pi \times 33\frac{1}{3} \div 60)^2 \times 0.0015 \times 2.54 = 0.045$ cm/sec^2, with a proportionate side thrust at the stylus tip according to the inertia of the arm about its lateral pivot. In this respect the advantage is with an offset pivot, but the reduction of side thrust with an offset rather than a single pivot is only about 30% comparatively, and absolutely the reduction is very small, being in this case only of the order of a few tenths of a milligram. For example, the equivalent effective head masses in the cases of the offset pivot of Fig. 3 and single pivot of Fig. 2 are 20 and 26 gm respectively, and at an acceleration of 0.045 cm/sec^2 these masses produce side thrusts of 0.9 and 1.2 mgm respectively.

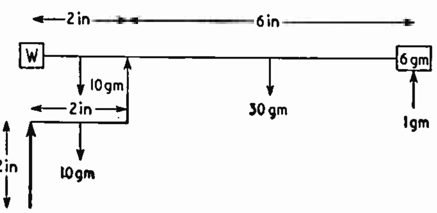


Fig. 3 Dimensions and weights in a typical offset-pivot system with axle and counterweight. The distance of the pickup head from the lateral pivot is the same as in Fig. 2.

Constant Vertical Stylus Force.—It is when considering the constancy of the vertical force on the stylus as determined by the disc flatness and vertical inertia of the arm that the only basic advantage of the spring system arises. Again the gain is comparatively small, being only a 50% change at most, for the inertia can ideally only be halved by the elimination of the counterweight.

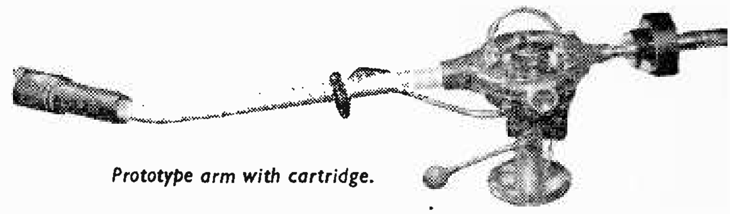
A vertical offset between the disc and vertical pivot centre can cause friction between the stylus and groove to alter the stylus pressure, and an integration of the extra frictional impulses due to groove modulation can then cause temporary changes in the stylus pressure.

The worst feature found on most arms is the difficulty of adjusting the pressure on fixed vertical pivots accurately enough to keep the pivot friction within a reasonable limit. Self-adjusting spring-loaded pivots should be used.

Where the centre of gravity of the arm is below that of its vertical pivots, "weighing" of the stylus force may be quite inaccurate if the arm is not in its usual playing position. Both this and the spring system must be weighed at disc level.

(*Continued on page 271*)

Immunity from Vibrations.—Let us consider the simplest example of vibration transmitted to the pickup base from the motor board when the pickup base moves vertically or laterally as one with the turntable spindle. Then, in the case of the spring-counterbalance system for vertical movement and both offset systems for lateral movement, due to the unbalanced inertia of the arm, an enormously greater variation in the force at the stylus tip is produced than with a balanced single-pivot system. In a single-pivot system with its centre of gravity below the pivot as is required for stability, longitudinal movement (along the arm length) can produce small variations in the stylus pressure.


Prototype arm with cartridge.

If the pickup base moves while the turntable spindle remains fixed the advantage is with the unbalanced inertia systems, at least for small accelerations, since in a balanced system the stylus tends to move more with the pickup base. The problem of small movements of the pickup base in this way (for example internal vibrations) can be better tackled with elastic washers between the base and motor board. Large rotational movements of the base while the turntable spindle remains fixed hardly ever occur in practice.

The previously discussed advantages and disadvantages of the three principles of arm construction when acted upon by disc and turntable eccentricities and warps also apply to externally applied similar lateral and vertical motions of the turntable spindle relative to the pickup base.

Thus, considering all the requirements for a suitable arm, the single-pivot system appears to offer by far the most attractive prospects, and these were developed as follows.

Single-pivot System.—A true single-pivot system with rotational freedom in any direction is used. The fact that the angle of the stylus in relation to a tilted turntable in such a self-levelling system might minutely affect the separation and balance of a stereophonic pickup was considered to be less significant than the advantage gained of more equal pressures on the groove walls due to the reduction of side thrusts.

If the sideways balance is to be stable the arm must have its centre of gravity below the pivot. A stabilizing weight below the pivot was therefore added (see Fig. 4). This weight was kept to the minimum required to provide sufficient torsional inertia for a maximum force of 5 gm at the stylus. Keeping the stabilizing weight as small as possible also ensures the minimum possible movement from sideways vibration at the base.

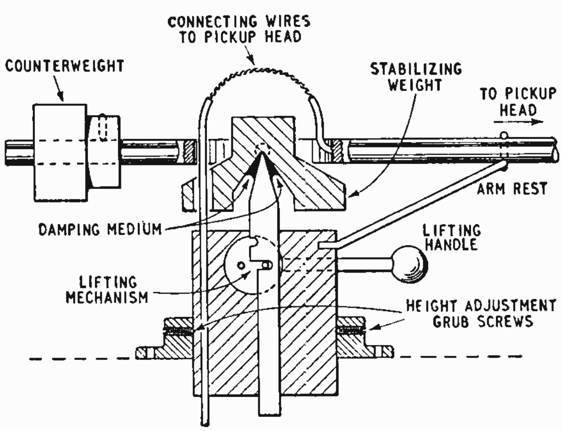


Fig. 4 Side-view sectional sketch of part of prototype arm showing stabilizing weight, damping medium, connecting wires and lifting mechanism.

To absorb any such resonant motion which could occur at the single pivot, this was designed both to retain a damping medium by capillary action and also to alternately push out and "suck in" the medium if the stabilizing weight swings from side to side (see Fig. 4).

To make accurate vertical balancing easy, and to eliminate sensitivity to longitudinal vibrations, the stabilizing weight was "uncoupled" by two pivots for vertical movement on opposite sides of the single pivot. The vertical pivots were spring-loaded to ensure correct pressure.

Sideways balance of the head offset is obtained in this design by adjustment of the lateral positions of the vertical pivots about the single pivot. Alternatively the pickup heads themselves could be made to provide sideways balance by suitable distribution of their mass in relation to stylus and arm, or an asymmetrical counterweight could be used. These alternative schemes were abandoned to ease the design and adjustment problems respectively.

If the linear offset of the arm is kept large, then due to the extra freedom of sideways balance, some of the vertical motion of the arm due to disc warping, etc., will be converted into rotational motion about the single pivot. If the rotational inertia is kept as low as possible, then this effect will play its maximum part in reducing stylus pressure variations. In fact the developed arm can be seen to rotate if the turntable is lifted suddenly whilst playing. An otherwise completely balanced system with spring pressure to provide the stylus force cannot conveniently make use of this principle.

In the case of the counterweight a compromise must be made between a long cylindrical shape which gives the minimum possible rotational inertia about the arm length as is required by the considerations of the last paragraph, and a thin disc shape which gives the maximum range of stylus pressures for the restricted length of movement available in a record player cabinet. Thus the optimum shape is approximately a cylinder whose height is equal to its diameter.

Calculation of both bending and torsion of a tubular arm shows that extremely large diameters are required to put all arm resonances above the audio range. It would therefore be desirable to have sufficient lateral and torsional inertia in the head alone if arm resonances are to be minimized. If the pickup is a one-gram tracker with a compliance of 15×10^{-6} cm/dyne, and the bass resonance is required to be 15 c/s, then, to inhibit the lateral arm resonances, the total mass of the head should be $(15^2 \times 4\pi^2 \times 15 \times 10^{-6})^{-1} = 7.5$ gm. Likewise, considering that the compliance is usually inversely proportional to the tracking weight, about 40 gm would be required for a 5-gm tracker. Accurate vertical pressures are ensured by balancing the arm and then inserting a calibrated pellet into the head.

The biggest problem was now that of the electrical connections. Various schemes were considered and rejected, and it was finally decided that a controllable torsion was preferable to the possibility of unseen foulings and erratic behaviour. Thus the connecting leads are brought visibly over the top of the pivot to an exit tube at the rear (see Fig. 4). By this arrangement, as the arm moves, the wires flex at only one point instead of two as in the more usual arrangement with the flexing portion of the wire all on the same side of the lateral pivot.

A raising and lowering mechanism was thought desirable, and this is incorporated in the arm base (see Fig. 4) to lower the arm gently on to the disc. By altering the sideways balance, this lowering mechanism can be used to move the stylus between 5 microgrooves ahead and 10 microgrooves behind its previous position to an accuracy of ±3 microgrooves or better.

The arm produced has a measured side thrust of 0.02 gm and vertical friction of 0.05 gm. It should be eminently suitable for tracking down to 0.2 gm.

Displaying Valve Characteristics

Cathode-Ray Tube System for Presenting Anode Curves with Their Axes

By R. G. CHRISTIAN,* A.M.Brit.I.R.E., Grad. I.E.E.

A METHOD of displaying valve characteristics on a single-beam cathode-ray tube has been described by Buckingham and Price[1]. The result is a trace representing the anode-current/anode-voltage curve of the valve for a given grid bias plotted on a screen without axes. Since valve characteristics were required to be demonstrated in a convincing manner to engineering students it was felt that the addition

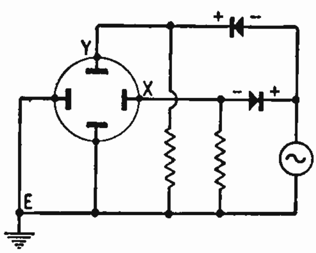


Fig. 1. Basic circuit for generating the X and Y axes for the display.

of axes was essential. A further disadvantage of the method referred to above was the use of both d.c. and a.c. to feed the valve. In the apparatus to be described the valve characteristic is presented in the same way as it would be shown on a blackboard during lectures, and the circuit is simple and compact.

One beam of a dual-beam c.r.t. is used to trace the axes. The deflection voltage for the X axis is obtained by means of a half-wave rectifier so that the axis is only traced during one half-cycle. On the other half-cycle a similar half-wave rectifier, connected in the reverse direction, produces a half-wave pulse which deflects the spot in the Y direction. The basic circuit to produce the axes is shown in Fig. 1.

The valve whose characteristics are to be displayed is fed by a.c. and conducts on one half-cycle only. The anode current produces a half-wave pulse across an anode resistor and this is fed to the second Y plate. It was found that a large anode resistor had to be used in practice in order to obtain sufficient Y scan for the second beam, which traces the valve characteristic. The X scan, which represents anode voltage, is supplied by the same half-wave rectifier which deflects the first beam to write the X axis. The basic circuit for displaying the characteristics is shown in Fig. 2, from which it will be seen that the X plate section is the same as that in Fig. 1.

It will be seen that the scan voltage used to represent the anode voltage is, in fact, the sum of the voltages across both the valve and the anode resistor. The error is small only if the anode resistor is small, which is not so in this case. There would be no error if the anode was used as a common earth reference but since the purpose of the circuit was to demonstrate the approximate shape of the valve characteristics it was not considered to be of importance. If accurate characteristics are required the X scan voltage must be that developed between anode and cathode of the valve.

The circuits of Figs. 1 and 2 are combined in the

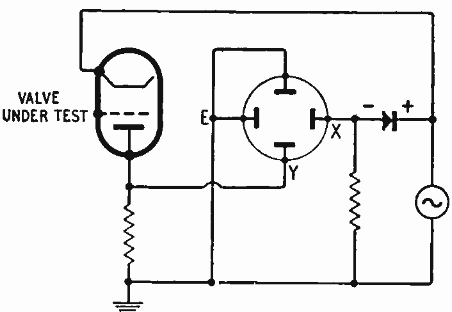
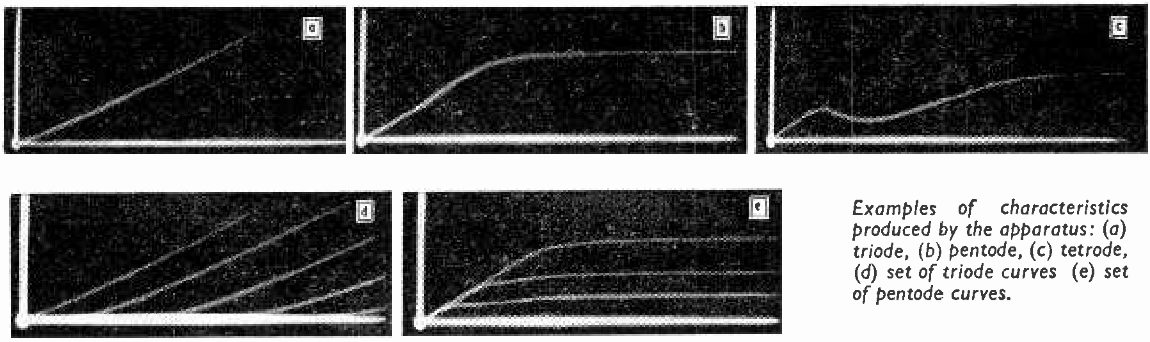


Fig. 2. Basic circuit for obtaining the anode characteristics of the valve.

practical circuit of Fig. 3 which also includes d.c. supplies to the screen and control grids of the pentode under test, the control-grid bias being variable in the negative direction. The screen and control grid must be supplied by steady d.c., which accounts for the inclusion of the two capacitance-resistance smoothing circuits. This will be apparent

* Liverpool College of Technology.
[1] H. Buckingham and E. M. Price, "Principles of Electrical Measurements" (English Universities Press, 1955), page 304.



Examples of characteristics produced by the apparatus: (a) triode, (b) pentode, (c) tetrode, (d) set of triode curves (e) set of pentode curves.

if the effect of supplying the screen grid with half-wave pulses is considered, since the resulting variation in screen-grid potential would follow that in anode potential and a triode characteristic would result.

All the supplies are obtained from a transformer with two simple secondaries, one for the scan and bias voltages, and one for the three valve heaters. The component values are not critical and those indicated happened to be available at the time. The valve under test is an EF36, with which it was possible to demonstrate triode, tetrode and pentode curves quite satisfactorily, the change-over being carried out by switching. When the switches, which are ganged, are set to position 1, the screen grid is connected to anode, the suppressor grid to cathode, and the valve behaves as a triode. On position 2, both screen and suppressor grids are connected to the screen supply and the valve operates as a tetrode; while on position 3, the suppressor is connected to cathode and the valve operates normally as a pentode. The photographs show the results obtained with various values of grid bias and for different connections.

The possibility of showing a family of curves is interesting and is easily effected in the case of two curves by feeding the output from a square-wave generator into the control grid. The amplitude of the generator output controls the spacing between the curves, the bias control being kept operative so that both curves may be shifted simultaneously.

In attempting to demonstrate more than one pentode or one tetrode curve it was found that the return of the trace was along a different path from the initial scan, producing an effect reminiscent of a hysteresis loop. No satisfactory explanation has so far been developed, neither has any attempt been made to overcome the difficulty, since it was felt that the circuit did all that was required of it, at least for the present. It would probably be possible, with suitable electronic switching, to produce more than two curves. Two possible methods would seem to be either the use of a stepped waveform applied to the grid or the use of an electronic switch to select different fixed values of grid bias. In the equipment described, however, no attempt was made to do this, since it was desired that the circuit should be as simple as possible.

The families of curves shown in the photographs were obtained by means of multiple exposure, which, while suitable for recording, is of no use from the point of view of live demonstration, which is the object of the apparatus. In this connection it is emphasized that the only purpose of the demonstration is to show practically and rapidly the general shape of the characteristics of triodes, tetrodes and pentodes and the effect of variation of control grid bias.

Thanks are due to V. Attwood for carrying out the practical work, for incorporating some of his own ideas into the circuit, and for taking the photographs.

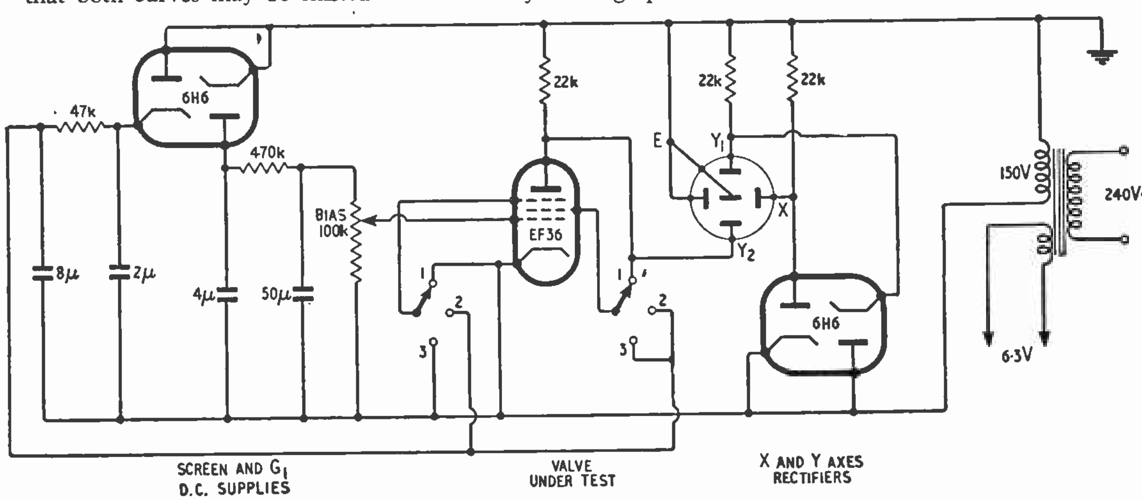


Fig. 3. Practical circuit for display of characteristics and axes. Direct-current supplies are included for the grids of the pentode test valve.

Feedback Amplifiers as Filters

Application of Familiar Principles to Feedback-synthesized Filters

By THOMAS RODDAM

IN the course of a study of a rather simple feedback amplifier recently I found myself confronted by some equations which looked familiar, though not in this context. Generally, of course, one does not do very much mathematics when designing feedback amplifiers: at any rate, I don't, because the amplitude and phase response plots, together with the filter $\mu\beta$ effect calculator, provide all the information needed for the usual task of making it flat, making it stable. As every schoolboy knows, quite a lot has been written on the design of particular feedback circuits with particular shapes of end characteristic but all the articles I can remember are of the kind which describe a circuit for a special job. As some hardened readers may know, I like to make one lot of analysis serve as many purposes as possible, even though this reduces the amount I can write on a given topic and thus gives more hope to the wolf which hovers outside my door, my door and everyman's.

The general feedback amplifier is shown in its old familiar form in Fig. 1. As that abominable

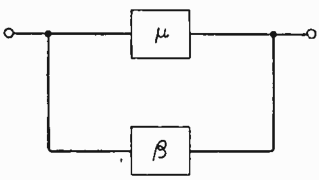


Fig. 1. The general feedback amplifier.

schoolboy of Macaulay's will point out, the gain of the whole system is:—

$$\mu_t = \mu/(1+\mu\beta) \quad .. \quad .. \quad .. \quad .. \quad (1)$$

We know that in a practical configuration with negative feedback both μ and β will have the same sign so we need not indulge ourselves in the academic practice of writing $(1-\mu\beta)$ and then making β negative. Sooner or later we shall be taking logarithms, to get ourselves into decibels, and as log μ_t is the same as $-\log 1/\mu_t$ we can rewrite Eqn. 1:—

$$1/\mu_t = (1+\mu\beta)/\mu = 1/\mu+\beta \quad .. \quad .. \quad (2)$$

This very simple equation is our starting point, for the behaviour of $1/\mu_t$, or $-\log(1/\mu_t)$ if you like, is the response of the feedback amplifier. As you see, it depends on two factors, μ, or $1/\mu$, and β. Usually we say cheerfully that β is much bigger than $1/\mu$, so the response is dominated by β, but of course this is no longer true at the edges of the working range when all kinds of things may happen. In many applications we manage to keep this region well away from the band which contains our signal and then our only interest is in the stability conditions which amount, more or less, to determining the phase of $\mu\beta$ when $\mu\beta = 1$. Stability is a bit more complex than that, but it is true that usually we are so preoccupied with stability that we don't worry about the shape of the μ_t response in this region.

Suppose now that the amplifier—we might even call it the μ-amplifier to show that we mean the upper box in Fig. 1—has only one stage and it is completely dominated by a single shunt capacitance. The response will then be that of the simple network shown in Fig. 2. We can easily see that we have:—

$$\begin{aligned} 1/\mu &= (1/\mu_o)(1 + j\omega CR) \\ &= (1/\mu_o)(1 + j\omega/\omega_o) = (1/\mu_o)(1 + j\Omega) \quad (3) \end{aligned}$$

where $\omega_o CR = 1$ and $\Omega = \omega/\omega_o$.

Suppose, too, that β is just a constant, that the β-network is made up of pure resistance elements. Then we have:—

$$\begin{aligned} 1/\mu_t &= 1/\mu + \beta = (1/\mu_o)(1 + j\Omega) + \beta = (1/\mu_o + \beta) \\ &\quad + j\Omega/\mu_o \\ &= (1/\mu_o + \beta)(1 + j\Omega/(1 + \mu_o\beta) \\ &= (1/\mu_o + \beta)(1 + j\omega/\omega_o[1 + \mu_o\beta]) \quad .. \quad (4) \end{aligned}$$

I have churned through the transformation in the string of Eqn. 4 in order to arrive at that last expression: next time I shall leave out some of the steps. The final form is the product of two factors which we can call the gain factor $(1/\mu_o + \beta)$ and the shape factor (which needs a line of its own). The gain factor is just what we expect and I do not propose to say anything more about it. The shape factor is rather interesting because if we write $\omega_o' = \omega_o(1 + \mu_o\beta)$ and $\omega/\omega_o' = \Omega'$ the shape factor becomes $(1 + j\Omega')$.

This is exactly the same form as we had for the basic μ-amplifier in Eqn. 3, except that whereas for the basic amplifier the response was 3dB down at $\omega = \omega_o$ the new response is 3dB down at $\omega = \omega_o'$ and $\omega_o' = \omega_o(1 + \mu_o\beta) = (1 + \mu_o\beta)(1/CR)$

It is easy to see that this sort of result should be expected. There is only one element, the C, in the whole system which can do anything to the frequency characteristic and the overall behaviour must therefore contrive to be what I find is convenient to call a first-order response. This result also contains the information that, for a first-order system anyway, the use of negative feedback does nothing to improve, or degrade, the gain-bandwidth product. There is a straight trade of gain for bandwidth which does not depend on a particular definition of bandwidth, because the shape is unaltered. What is more, if you can think of a suitable circuit configuration, the feedback can be positive without altering the terms of trade. From this we can go on to say that if we use enough positive feedback to make the gain infinite the bandwidth must be zero. Do you care? Well, if we replace the capacitance by a series inductance-capacitance pair and replace ω by $\Omega = (\omega/\omega_o - \omega_o/\omega)\omega_o$ we move the frequency at which we have infinite gain and zero bandwidth up from $\omega = 0$ to $\Omega = 0$ or $\omega = \omega_o$ This is the basis of the simple oscillator and the simple Q-enhancer.

Let us get back to the main line of our discussion and now consider the possibilities of second-order circuits. The term "second-order circuits" is a rather formal way of saying circuits with two reactances in them. There are general possibilities here. The second frequency-dependent term can be added in the feedback network, as an isolated term in the μ-amplifier or as a coupled term in the μ-amplifier. One special form we can throw away immediately, especially as it's only an approximation, is when β and $1/\mu$ have the same shape term $(1+jk\omega)$, although with different values of k. This rapidly reduces to a single factor, so we are back in the first-order class.

The most ordinary form we can take seriously is the form we find with a two-stage μ-amplifier when each stage has a network of the kind shown in Fig. 2. If one network has components C_1R_1, and $\omega_1 = 1/C_1R_1$, the other giving $\omega_2 = 1/C_2R_2$, we can see that:—

$$1/\mu = (1/\mu_o)(1 + j\omega/\omega_1)(1 + j\omega/\omega_2) \quad .. (5)$$

and therefore

$$1/\mu_t = (1/\mu_o)(1 + j\omega/\omega_1)(1 + j\omega/\omega_2) + \beta \quad .. (6)$$

We must, I am afraid, expand this and the most convenient form is, at first:—

$$1/\mu_t = (1/\mu_o + \beta) \quad [1 + jk\omega(1/\omega_1 + 1/\omega_2) - k\omega^2/\omega_1\omega_2],$$

where

$$k = (1/\mu_o)/(1/\mu_o + \beta) = 1/(1 + \mu_o\beta).$$

We may now concern ourselves only with the shape factor, the expression:—

$$1 + jk\omega(1/\omega_1 + 1/\omega_2) - \omega^2 k/\omega_1\omega_2$$

This is the simple second-order characteristic and if we call it S we need only devote ourselves to:—

$$|S|^2 = 1 + \left\{ k^2[(\omega_1 + \omega_2)/\omega_1\omega_2]^2 - 2k/\omega_1\omega_2 \right\} \omega^2 + k^2\omega^4/\omega_1^2\omega_2^2 \quad .. \quad .. \quad .. (7)$$

The term in this which is of chief interest, as I showed in "Filters Without Fears"*, is the term in ω^2. If the coefficient of ω^2 is zero we have the Butterworth or maximal flatness response: if it is negative the response is of the Tchebycheff, or humped, type. Readers of "Filters Without Fears" will remember that it is not always possible to make expressions of this form give the Tchebycheff type of response because the coefficient of ω^2 may be obstinately positive. Here, however, we can do a quick check by putting $\omega_1 = \omega_2 = 1$ so that the coefficient of ω^2 becomes just $4k^2 - 2k = 2k(2k - 1)$ Thus if we make $k = 0.5$, or $\mu_o\beta = 1$, we shall get the neat, square Butterworth response, while any more feedback, making $k < 0.5$, will give us a bump before the response falls away. This is exactly what our experience with feedback amplifiers leads us to expect. Our experience also tells us that if $\omega_1 \neq \omega_2$ we need more feedback, or a smaller value of k, before we reach this happy state. Sometimes we know that we want k to have a particular value,

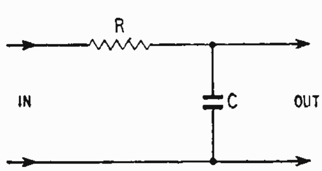


Fig. 2. The simplest frequency - response determining network for a forward path.

say 1/10, or 20dB of feedback. If we also want a Butterworth response we can put the coefficient of ω^2 equal to zero and solve for ω_1/ω_2. I have done this on a separate piece of paper, to save filling th page with algebra, and the result is:—

$$\omega_1/\omega_2 = (1/k)[(1 - k) \pm \sqrt{(1-2k)}] \quad .. (8)$$

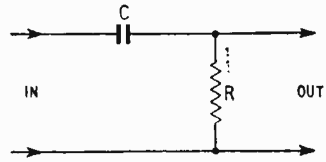
We also know that the response is 3dB down at some value of $\omega = \omega_o$ where $k^2\omega_o^4/\omega_1^2\omega_2^2 = 1$ so that

$$\omega_1\omega_2 = 1/k\omega_o^2 \quad .. \quad .. \quad .. \quad .. (9)$$

The two equations, (8) and (9), enable us to fix the values of ω_1 and ω_2.

All this analysis, of course, applies equally well if we perform the simple frequency transformations on it, so that although this is the ordinary low-pass filter case, the same pattern appears for the high-pass

Fig. 3. The simplest frequency - response determining network for a feedback path.



and band-pass cases. I have been into all that before and you can look it up.

A difficulty which occurs in using amplifiers as filters is that μ_o may vary. Obviously the response will vary too and there will be two effects. The coefficient of ω^2 will no longer be what you hoped, which for the calculation we have just done is zero, and the coefficient of ω^4 will also change, moving the asymptotic 12dB/octave cut-off. When k is small it is also very close to $1/\mu_o\beta$ and a 6dB change of μ_o will move the asymptotic line by a factor of $\sqrt{2}$, which is a rather large variation. Feedback amplifiers of this kind which are designed as filters must therefore have the gain of the μ-amplifier held constant by some means. One obvious solution is a fair amount of feedback in each cathode or emitter circuit. This is just another example of the fact that you cannot get anything free: if the feedback is used up in one function it cannot play its full part in another.

The other important way of introducing a second frequency dependent element is to put it into the feedback network. Since the basic type of filter we are considering is the low-pass filter the obvious form of feedback network to use is that shown in Fig. 3. For this the response will be:—

$$V_{out}/V_{in} = j\omega CR/(1 + j\omega CR)$$
$$= (j\omega/\omega_2)/(1 + j\omega/\omega_2).$$

Then the feedback term β can be taken as:—

$$\beta_o(j\omega/\omega_2)/(1 + j\omega/\omega_2)$$

and the overall performance with a single Fig. 2 network in the μ-amplifier becomes:—

$$1/\mu = (1/\mu_o) \quad (1 + j\omega/\omega_1) + \beta_o(j\omega/\omega_2)/(1 + j\omega/\omega_2).$$

Without going into any details we can see that the shape of the response is going to depend on an expression of the form:—

$$(1 + ja\omega - b\omega^2)/(1 + jc\omega).$$

This is a system having a first-order cut-off, only 6dB/octave, but it is complicated in the region of the transition from flatness to asymptote as you can see. The easiest way of analysing it is to notice that when we go over to decibels we have the difference between the decibels corresponding to the numerator and the decibels corresponding to the denominator. The one is a second-order expression

*Wireless World. Vol. 60 (1954), pp. 367, 445, 561 and 603; (August, September, November and December.)

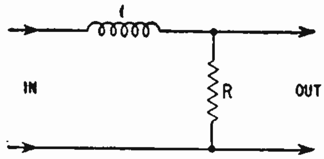


Fig. 4. Another first-order low-pass network.

of the form we discussed immediately above, while the other is an ordinary first-order expression.

I do not want to go into any more detail on designing these circuits because you can look up some specific designs in the literature, or work out your own problem for yourself. The really important thing is to go back to Eqn. 2 again:—

$$1/\mu_t = 1/\mu + \beta.$$

We can reasonably guess that this will be simplest if all the frequency dependent factors are in the μ term, as we discovered in the examples. Suppose, then, that we have:—

$$1/\mu = (1/\mu_o)\,(1 + jf_1(\omega) + f_2(\omega))$$

and immediately

$$1/\mu_t = (1/\mu_o + \beta)\,[1 + jf_1(\omega)/(1 + \mu_o\beta) + f_2(\omega)/(1 + \mu_o\beta)]$$

When this is converted into the standard $(1/\mu_t)^2$ form the coefficients of ω^{2h} will contain factors which depend on $(1+\mu_o\beta)$. This is of the nature of an interaction parameter, and, as we have seen, it plays an important part in fixing the shape of the response. If we consider a system in which the network of Fig. 4 is in tandem with that of Fig. 2; but in which a buffer amplifier is used between the two, the shape of the overall response will be expressed by an expression of the form:—

$$(1+j\omega/\omega_1)\,(1+j\omega/\omega_2).$$

This has a very limited range of shapes and at the best provides an extremely rounded cut-off. By rearranging the network elements so that the L and C are adjoining we know that we can get a more general second-order filter characteristic. The reason is that L and C can interchange their stored energy and it is this interaction between them which provides us with the one extra generality. In just the same way, in the feedback amplifier the $(1+\mu_o\beta)$ term represents the return to the first reactance network of energy which has passed through the second reactance network. One network can, as it were, see the other. Another way of looking at it is to regard it as a special form of coupling between the two networks. In band-pass filters this view gives us the possibility of three kinds of coupling: inductive, which falls with frequency; capacitive, which rises with frequency; and feedback, which in its basic form is independent of frequency.

The use of feedback as an energy interchange medium is of especial importance when the frequencies involved are low. By using feedback we store energy in a capacitor to return it to a capacitor; whereas without feedback we could only get the required interaction by using inductance—and large inductances for low frequencies are not easy to realise without excessive losses.

This short survey has, I hope, been enough to show that the kind of response you can get from a feedback amplifier is the same as that you can get from a conventional filter and that the algebra is consequently the same. It is always, to my mind, agreeable to find that one only need do the basic work once.

Elements of Electronic Circuits

3 — Amplitude Limiting

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

In order to eliminate unwanted fluctuation in the peaks of a waveform, or perhaps to discriminate between wanted or unwanted pulses, it is often necessary to limit the positive or negative excursions of such a wave. A further possible use is the derivation of rectangular pulses from a sinusoidal input. A common method of achieving amplitude limiting is by overloading a valve amplifier so that the peaks of the input are cut off by the flat regions of the dynamic characteristics. It is, therefore, possible to limit both the positive and the negative excursions by suitably biasing the amplifier.

In grid limiting the grid-cathode portion of the valve is operated as a diode. Grid current flows during the positive half cycles of the input wave, and if a resistor of the correct value is inserted in series with the grid the major part of the positive excursion of the input is developed across it instead of between grid and cathode. The positive-going anode current is thereby limited, as is also, of course, the negative-going anode voltage. This action is more fully explained later.

Simple Limiting.—As the diode provides the commonest example of amplitude limiting we will examine the simplest case first, i.e., with a sine-wave input. In the following circuits it is assumed that

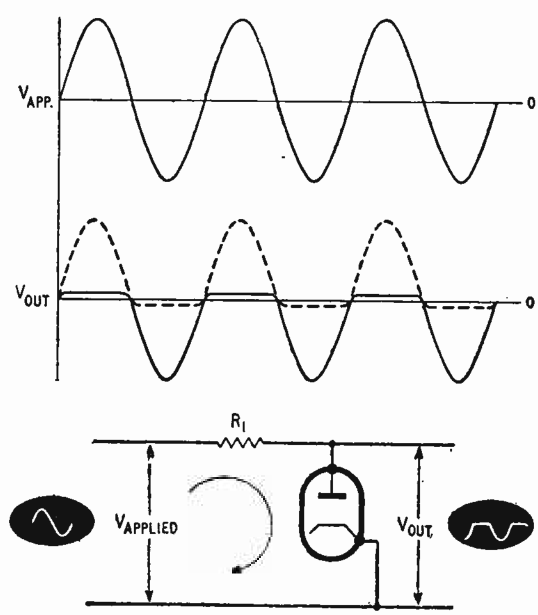
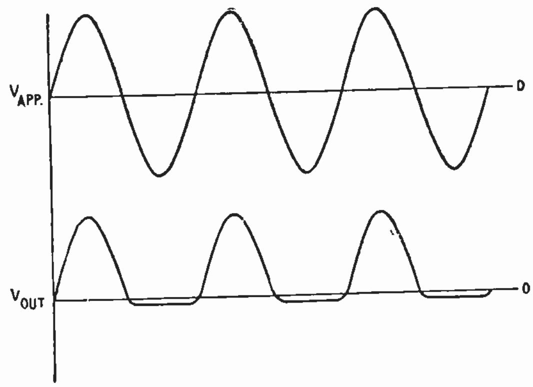


Fig. 1



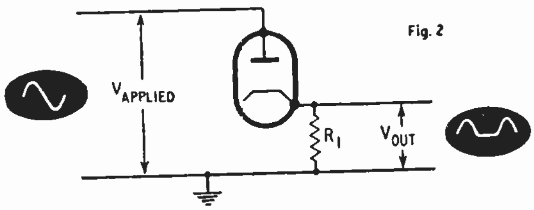


Fig. 2

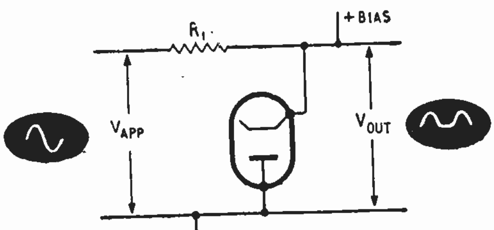


Fig. 3

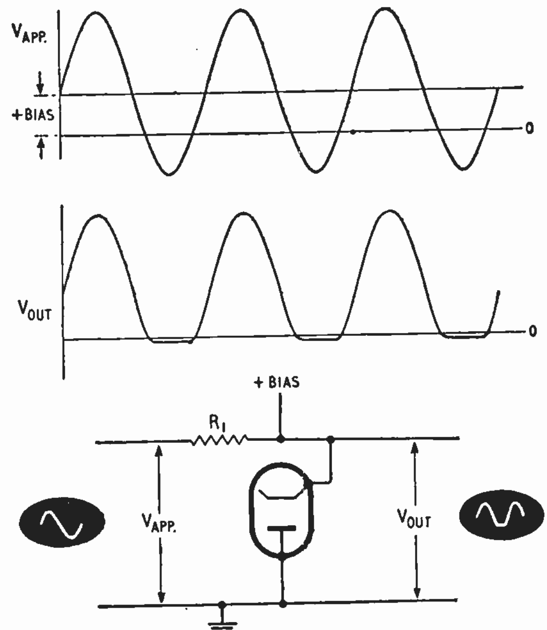


Fig. 4

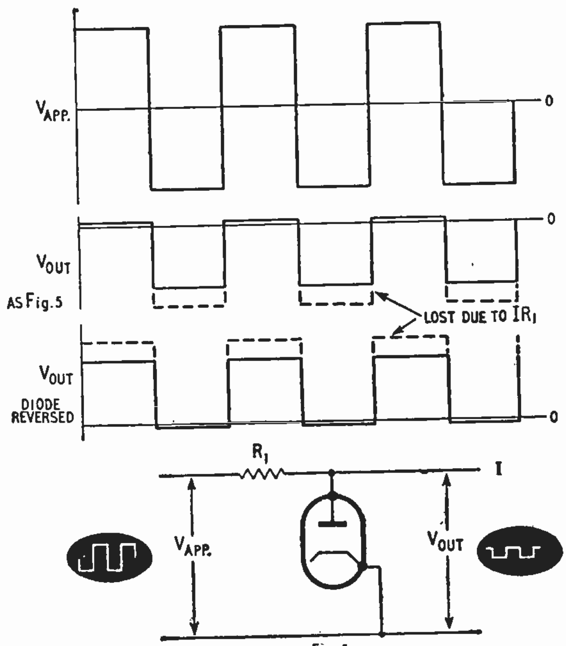


Fig. 5

the series resistor R_1 is large compared with the resistance of the valve R_{ak} (not R_a but V_{ak}/I_a) when the valve is conducting and small compared with the impedance of the valve when it is not. In Fig. 1, during the positive half cycles the voltage across the diode is limited. During the negative half cycles the voltage across R_1 is limited (shown dotted). It follows, therefore, that if we wish to limit the negative peaks we take our output from across R_1. In Fig. 2 R_1 is shown in the cathode circuit of the diode as an alternative position. Fig. 3 shows an alternative way of limiting negative peaks, by reversing the diode shown in Fig. 1. If we choose to bias the diode it will then not conduct until the input voltage exceeds the bias voltage; in other words, we have shifted the level at which the limiting action commences (Fig. 4). Similar reasoning will show that it is possible to extend this action to positive peak limiting.

Parallel Diode with Applied Square Wave.—The limiting action on a square wave (Fig. 5) is similar to that shown for the sine wave. The loss of voltage during the non-conducting period of the diode is determined by the load current and the value of R_1.

It will be noted that the shape of the limited waveform is similar to the shape of an identical input after "clamping," i.e., the occurrence of d.c. restoration. The difference lies in the action of the CR coupling circuit immediately preceding the input (which for clarity is not shown in Fig. 5). The bias produced by choosing the correct time constant for the associated CR circuit is a necessary part of the action of a "clamping" circuit device, whereas in limiting the CR coupling circuit time constant must be chosen so that *no* slide-back occurs.

Limiting Using Two Diodes.—If two diodes are coupled as shown in Fig. 6 and provided with bias voltages X and Y, it is possible to limit the applied waveform at the same time as permitting it to continue to alternate about zero. Limiting of the positive excursion by diode D_1 will not take place until the positive-going input exceeds the positive bias X. Similarly the limiting of the negative excursion by diode D_2 will not take place until the negative-going input exceeds the negative bias Y. The amount of bias determines the limit of the positive and negative excursions.

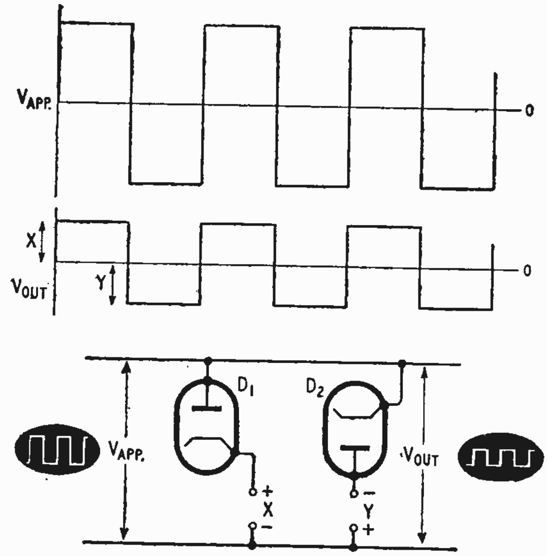


Fig. 6

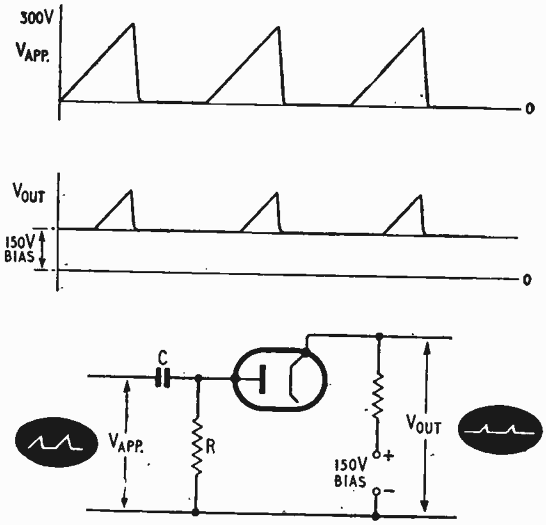


Fig. 7

Series Limiting.—Here the diode is used as a "biased switch" in series with the applied wave. As an example let us consider the action of a sawtooth waveform applied to the circuit in Fig. 7. The diode is biased to 150V while the amplitude of the sawtooth wave is assumed to be 300V. All the time the applied wave is less than 150V the diode is non-conducting; the "switch" is, therefore, "open." When the anode voltage of the diode exceeds 150V the diode conducts, the "switch" is "closed" and the output voltage follows the input.

Grid Limiting.—As has been stated earlier, both positive and negative peak limiting can be achieved by driving an amplifier into the flat regions of the dynamic characteristic. So far as negative peak limiting is concerned, the point at which it occurs is determined by the cut-off bias and the amount of bias applied to the amplifier (see Fig. 8).

To obtain positive peak limiting a large amplifier load resistance is necessary so that I_a reaches the upper bend condition at relatively low grid voltage swings. Owing to this and to the undesirability of driving the valve far into the grid current region, grid limiting is often resorted to for restricting the positive voltage excursions.

Let us assume that a sine wave is applied to the circuit shown in Fig. 9. During the positive half cycle of input grid current I_g flows and the grid-cathode resistance R_{gk} drops to a low value. As R is large compared with R_{gk} when the valve is conducting, most of the applied voltage is developed across it (I_gR) and a negligible amount across R_{gk}.

During the negative half cycle of input no grid current flows and the input is applied directly between grid and cathode. However, the negative swing drives the grid beyond cut-off. The resultant V_a waveform is, therefore, approximately square on both positive and negative excursions.

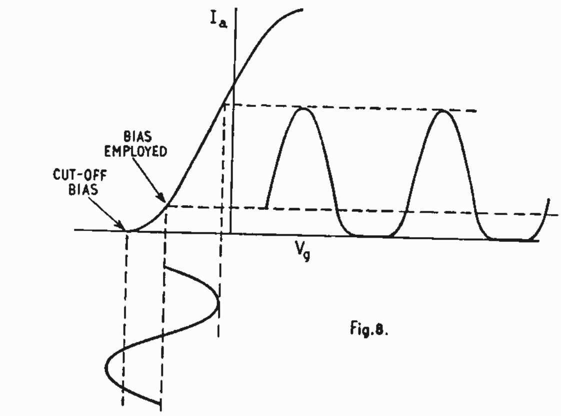


Fig. 8.

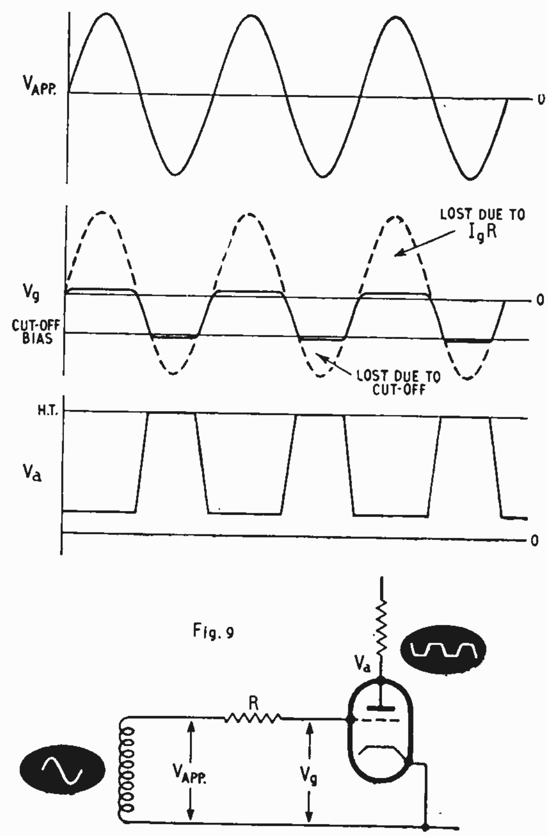
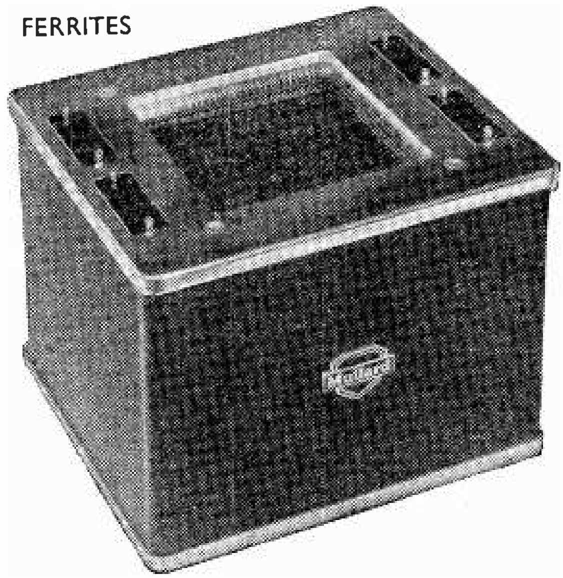


Fig. 9

Magnetic Matrix Stores

COMPUTER STORAGE SYSTEMS BASED ON FERRITES WITH RECTANGULAR HYSTERESIS LOOPS

By W. A. COLE,* B.Sc.



A stack of 20 matrix storage planes in practical form for use in a computer. The capacity is 81920 digits.

ANY computer, whether human, mechanical, electro-mechanical or electronic, requires a memory, or storage system, in which to store the numbers involved in the calculation, the operations to be performed on the numbers, the intermediate answers and the final answers. The storage system may be simply a pencil and paper used by a person doing arithmetic; or it may consist of some combination of punched cards, punched tape, magnetic tape, magnetic drums, delay lines, cathode-ray tubes, valves, transistors, magnetic cores, etc., with a storage capacity of up to several million numerical digits in the case of a large scale electronic computer.

The speed at which an electronic computer can complete a problem, once the required information and instructions have been supplied to it, is governed by two things: the speed at which it can do individual arithmetical operations, and the speed at which it can obtain the next piece of information or instruction from the store. The time taken by many machines to perform the addition or multiplication of two numbers, each consisting of many digits, is measured in microseconds. It is obviously desirable that a machine of this speed should also be able to obtain information from its store in a few microseconds. If the access time to the store was even as long as a millisecond then the arithmetic units of the machine would spend the greater part of their lives waiting for something to do.

Wide Applications

Seven years ago the first magnetic ferrites to have substantially rectangular hysteresis loops were produced in the U.S.A. Since then the application of these materials to high-speed digital storage systems has been so successful that there is hardly any large, fast, electronic computer under development anywhere in the world which does not incorporate a magnetic matrix store. The capacity of these stores varies from a few thousand to a few million binary digits, and the cycle time, that is, the time to select an address,† read the information stored and rewrite information into the address, is usually in the range from five to fifteen microseconds.

In a magnetic store the individual memory cells consist of tiny ferrite rings of less than one-tenth of an inch diameter linked by an array of insulated enamelled wires. Each ring is capable of storing one digit or piece of information, but in common with most devices used in computers, a magnetic memory works with numbers expressed in the binary system. In the decimal system, with which everyone is familiar, there are ten digits, namely 0 to 9, and a number 4275, reading from right to left, means $(5 \times 1) + (7 \times 10) + (2 \times 10 \times 10) + (4 \times 10 \times 10 \times 10)$. In the binary system there are only two digits, 0 and 1, and a number 1101, again reading from right to left, means $(1 \times 1) + (0 \times 2) + (1 \times 2 \times 2) + (1 \times 2 \times 2 \times 2)$. This is much easier to represent, as nature provides many devices with two stable states but it is difficult to find anything with ten discrete stable conditions.

The ferrite rings store the information in the form of the remanent magnetization, which simply means that if the ring is left magnetized in a clockwise sense, as in Fig. 1 (a), it is storing a digit "1," say, and if it is left magnetized in the opposite sense as in Fig. 1 (b), it is storing a digit "0."

Fig. 2 shows a typical hysteresis loop of Ferroxcube Type D ferrite. When a magnetizing field of amplitude $+H_m$ is applied to the ring-shaped core, the resulting flux density will be B_m and when the

* Mullard. Ltd

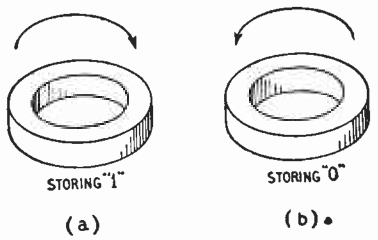


Fig. 1. Method of storing information by remanent magnetism in ferrite rings, (a) clockwise magnetization and (b) anticlockwise magnetization.

† Addresses are places in the store where items of information are held, and are usually identified by numbers like houses in a street.

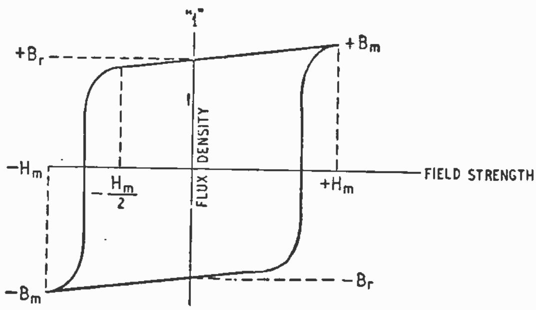
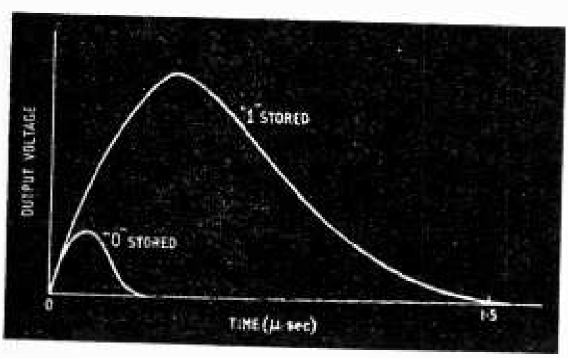


Fig. 2. Rectangular hysteresis loop, flux density against field strength, of a ferrite material.

field is reduced to zero the flux density will decrease to B_r. If a field of $-H_m$ is now applied there will be a change of flux density of $(B_m + B_r)$ and the flux density will be $-B_r$ when the field is removed. A further application of a field of $-H_m$ will produce a flux change of only $(B_m - B_r)$. Thus the polarity of the remanent magnetization can be readily determined by measuring the change of flux density, or the e.m.f. induced in an output winding on the core, when the core is subjected to a magnetizing pulse of amplitude $-H_m$. The output voltages induced in the two cases are shown in Fig. 3.

Fig. 4 shows a single binary storage cell comprising a core with two windings. A digit "1" is written into the cell by applying a positive current pulse to the write/read winding. The information is read by applying a negative current pulse to the write/read winding. Since the cell is always left in the "0" state after a read pulse no pulse is required to write a further "0" into the cell. The reading process necessarily destroys the information stored in the cell; therefore it is necessary to rewrite the information if it is required to retain it.

A store with a capacity of 1024 digits would require 1024 cores, and have 1024 inputs and 1024 outputs, although a single common output winding could be used if the information were required one digit at a time. The selection of 1 in 1024 inputs is a difficult problem and the magnetic matrix store, as first suggested by Forrester in 1951, greatly simplifies this problem by making further use of the rectangular form of the hysteresis loop.



If a ring core in the "1" state with remanent flux density $+B_r$, is subjected to a magnetizing pulse of amplitude $-H_m/2$ the flux density falls to B_1 and returns to B_2 when the pulse is removed. Repeated applications of pulses of $-H_m/2$ take the core around a closed minor loop and there is no further reduction in the remanent flux density. Thus the ring core has the ability to discriminate between pulses of amplitude H_m and $H_m/2$. The larger pulse is sufficient to change the direction of magnetization of the core whilst the smaller produces only a negligible change.

Fig. 5 shows 16 rings assembled in a 4×4 matrix. Each core is threaded by one horizontal and one vertical wire. To switch a given core from one state to the other, current pulses of amplitude $I_m/2$ corresponding to a magnetizing field of $H_m/2$ are simultaneously applied to the horizontal and vertical wires linking that core. The selected core is thus subjected to a field of H_m and will be switched while the other cores linked by the energized wires will only experience a field of $H_m/2$ and are not affected. The addressing problem is then reduced to selecting 1 in 4 and 1 in 4 wires to gain access to 1 in 16 cores. If 1024 cores are assembled in this way as a 32×32 matrix, only 1 in 32 and 1 in 32 wires need be selected to gain access to 1 in 1024 cores.

Output Winding

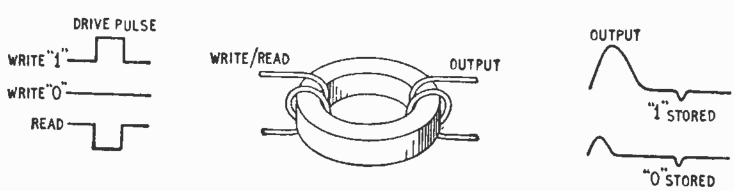
Since only one core can be switched at one time, the output winding can be common to all cores. It takes the form of a single conductor linking all cores and is so arranged that the mutual inductance between it and any drive wire approaches zero. The output wire is also arranged to link half the partially energized cores in one sense and half in the other so that the small signals from these cores tend to cancel one another.

It is obviously much simpler to assemble such an array of cores if the windings are restricted to single conductors rather than multi-turn windings. This is possible if the cores are made sufficiently small so that the current pulses required are kept to amplitudes which can readily be obtained from valve or transistor circuits. The most commonly used memory cores have an outside diameter of 0.08in and inside diameter of 0.05in and are 0.025in thick, but during the last two years cores of only 0.05in outside diameter, 0.03in inside diameter and only 0.015in thick have become commercially available, and in many cases these smaller cores are more suitable for use with transistor drive circuits.

The switching time T of the ferrites, that is the time for the reversal of the magnetic flux, is given by $T(H_m - H_0)$ = constant, where H_m is the applied field and H_0 is the maximum field for which no switching occurs. For a material with an ideally rectangular hysteresis loop H_0 would be equivalent to the coercive force of the material. Under the conditions of use in a coincident current matrix system the value of H_m is limited to approximately $1.7H_0$ so that the

Above: Fig. 3. Output voltages obtained from a core when the polarities of remanent magnetization are different.

Right: Fig. 4. Binary storage cell consisting of ferrite core with two windings.



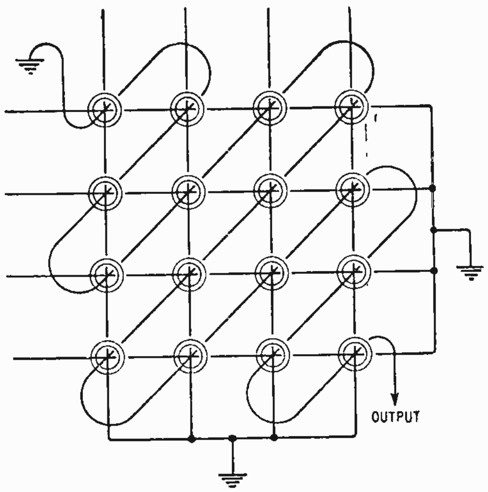


Fig. 5. A matrix store formed by 16 cores with threaded vertical and horizontal wires.

switching time is determined by the coercive force of the material, and a material of high coercive force will give a fast switching time and vice versa. For example, 0.08in cores in Ferroxcube D2 material require a drive of 700mA-turns to give a switching time of 1.5 microsecond and an output of 100mV per turn, while similar size cores in Ferroxcube D3 require 450mA-turns to give a switching time of 2.5 microseconds and an output of 60mV.

In many computers it is necessary to have access to all the digits of a number at the same time. This can readily be achieved by taking as many planes as there are digits in the numbers to be stored and connecting them electrically in series as shown in Fig. 6. Each plane would contain as many cores as there are words to be stored. When a particular pair of horizontal and vertical wires is energized the core linked by those wires in each plane is subjected to a pulse sufficient to switch it. Thus to read the information stored in a particular set of cores linked by the horizontal wire number x, and the vertical wire number y, positive current pulses are applied to these two wires. Each matrix plane has its own output winding and the information stored in the selected core in each plane appears as a voltage on the output wire of the plane, a large voltage for "1" and a small voltage for "0". To rewrite the information back into the cores the polarity of the current pulses is reversed. But this alone is insufficient since it would switch all the cores selected to the "1" state. Each plane, therefore, has an additional wire which links all the cores in that plane in the same sense. If a pulse of the same amplitude but of opposite polarity to the writing pulses is applied to this wire in a particular plane for the duration of the writing pulses, the selected core will remain in the zero state since the extra pulse inhibits the switching of the core. If no pulse is applied to this wire during the writing pulses then the selected core is switched to the "1" state.

As has been previously stated, in the coincident current system so far described, the signal appearing on the output wire is not only due to the flux change in the selected core but to the flux changes in the other cores on the selected row and column drive wires. Although the output from any one of these cores is very small, the sum of these outputs can well be several times that of the selected core. To overcome this, the output wire is arranged to thread half the cores in each row and column in one sense and half in the other so that the unwanted outputs tend to cancel. As a result of this wiring arrangement the polarity of the output of the selected core depends upon its position in the matrix plane.

Word Address Store

The word‡ address matrix store used in the EDSAC II computer constructed by the Mathematical Laboratory of Cambridge University avoids the problem of unwanted outputs from half-selected cores by arranging the wiring so that there are no half-selected cores. The matrix consists of a single electrical plane with as many columns as there are words and as many rows as there are digits per word, as shown in Fig. 7. Thus one word is stored in the cores in one column and during the reading process the read drive pulse is applied to the selected column wire and the outputs appear on the row wires. In this way there is no output from any core other than the selected cores and the output circuit has only to discriminate between the largest "0" output and the smallest "1" output from any core. In addition the read pulse can be larger than that permissible in a coincident current read system, resulting in a larger and faster output from the selected core. To write information a half-amplitude write pulse is applied to the column wire, which, by itself, is too small to switch any cores. An additional half-amplitude write pulse is applied

‡ A "word" in computer terminology is a group of binary digits which can be either a number or an instruction.

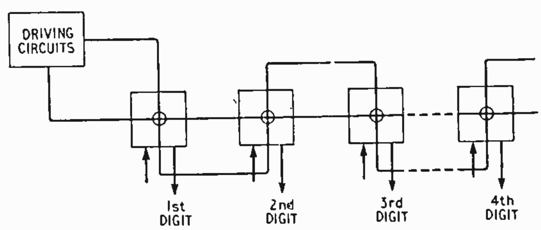


Fig. 6. Arrangement of matrix storage planes to give simultaneous access to all digits of a number.

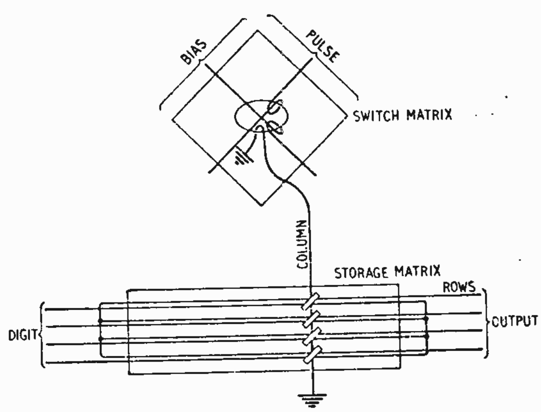
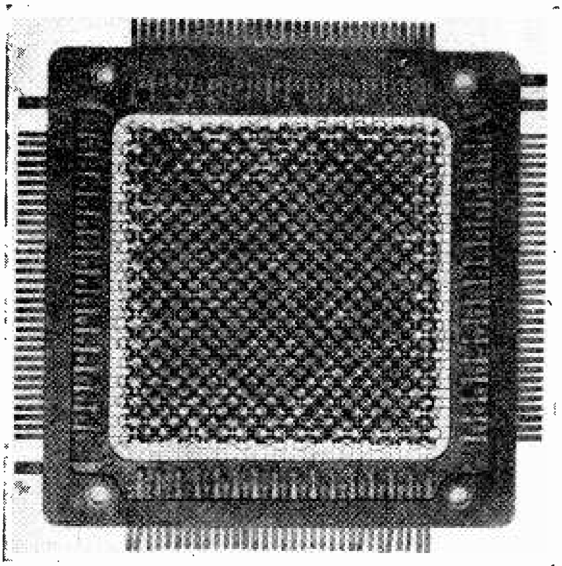


Fig. 7. Word address system with switch matrix.



Typical 32 × 32 matrix storage plane.

to the row wires which thread those cores which are required to store a digit "1."

The read pulses and the half write pulses applied to the store column wires are obtained via biased switch cores arranged in the form of a matrix. Each switch core has an output winding linking one column of the store matrix. To read the information from a given column of the store matrix the bias is removed from the appropriate row and a pulse is applied to the selected column of the switch matrix which switches the selected switch core and induces a read pulse in its output winding. When the bias is re-applied the switch core returns to its biased state and a half write pulse is induced.

In 1956 Rajchman of R.C.A. produced a modification of the core matrix store which uses ferrite plates 0.8in square containing 256 holes of 0.02in diameter. The areas of ferrite around the holes behave in much the same way as the separate ring cores of a conventional matrix store. The surface of the ferrite is metal-plated in such a way as to provide a conductor linking all the holes. This is equivalent to the "row winding" in the Cambridge University word address system. The plates are stacked one above the other and the column windings consist of straight wires threaded vertically through the equivalent holes in each plate as shown in Fig. 8. Two holes are required for each digit to be stored and a third hole is used as the switch core. Thus a store with a capacity of 256 words, each of 20 digits, would require 60 plates.

The two holes associated with one digit are equivalent holes in adjacent plates. The reading process leaves the material in the vicinity of both holes magnetized in the clockwise state, say. A digit "1" or a digit "0" is written in by applying a half-amplitude write pulse to the "column winding" threading both the holes, plus a half-amplitude write pulse to the plated conductor threading the upper hole or the lower hole respectively. Thus when the read pulse is applied the material around one or other of the holes is switched back to the clockwise state and the store presents an impedance which does not depend upon the information stored. During the read process the plated conductors of the two plates concerned are connected in series opposition so that a "1" output appears as a positive pulse and a "0" output as a negative pulse.

High Speed System

Quartly of Mullard Research Laboratories has recently produced a ferrite store with a cycle time of less than one microsecond. This employs two cores per bit, wired in a manner similar to the Rajchman system. In this fast store, however, the flux swing in the cores is limited to approximately 50% of the possible total by limiting the duration of the drive pulses. The two cores used to store a single digit are linked in the same direction by a drive wire and in opposite directions by the digit and output wires as shown in Fig. 9.

After a read process both cores are left in the same state. The main writing pulse is of large amplitude and fast rise time, but of short duration, so that the cores begin to switch rapidly, but the switching is incomplete. A digit pulse of the order of 10% of the amplitude of the drive pulse is applied at the same time as the writing pulse so that one core will undergo a larger flux change than the other. The reading pulse is of similar form but of opposite polarity to the writing pulse and returns both cores to their original states. The core which has experienced the larger flux change will give the larger output so that the polarity of the resultant signal appearing on the output wire will depend upon the polarity of the previously applied digit pulse.

Experiments have shown that a cycle time of less than one microsecond is possible using 0.05in diameter cores in a low coercive force ferrite, with writing pulses of approximately 500mA-turns and 0.1 microsecond duration.

To sum up, magnetic matrix storage systems have

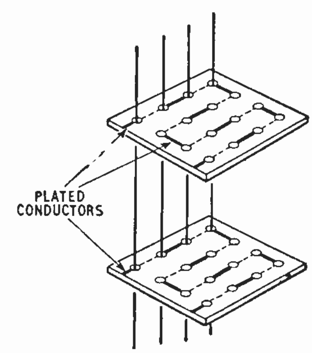


Fig. 8. Matrix store made up of perforated ferrite plates.

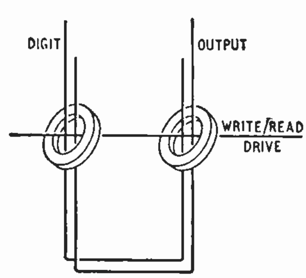


Fig. 9. High speed storage system based on two cores per digit.

the following advantages over most other forms of storage devices:—

1. Very short access time.
2. Information stored in any position in the store is available in the same short time.
3. Long life.
4. No moving parts.
5. Information stored indefinitely.
6. No regeneration of information required.
7. No energy required except to insert or extract information.

REFERENCES

J. W. Forrester, *J. App. Physics*, Jan., 1951, p. 44.
J. A. Rajchman, *Proc. I.R.E.*, Oct., 1953, p. 146.
W. N. Papian, *Proc. Eastern Joint Comp. Conf.*, Dec., 1953, p. 37.
W. N. Papian, *Electronics*, Mar., 1955, p. 195.
M. A. Alexander *et al.*, *Electronics*. Feb., 1956, p. 158.
A. A. Robinson *et al.*, *Proc. I.E.E.*, Supp. 103B, 1956, p. 293.
R. E. Merwin, *I.R.E. Trans.*, EC5, Dec., 1956, p. 219.
J. A. Rajchman, *Proc. Eastern Joint Comp. Conf.*, Dec., 1956, p. 107.
C. J. Quartly *et al.*, *Proc. I.E.E.*, Supp. 104B, No. 7, 1957, p. 457.
D A. Ridler, *ibid*, p. 445.
W Kenwick, *ibid*, p. 436.
W N. Papian, *Electronics*, Oct. 1957, p. 162.
E. D. Foss *et al.*, *I.B.M. Journal*, 1, April, 1957, p. 102.
V. L. Newhouse *et al.*, *Proc. Nat. El. Conf.*, 1957, p. 641.
V. L. Newhouse *et al.*, *Electronics*, 31, No. 41, Oct., 1958, p. 100.

LETTERS TO THE EDITOR

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

Long Distance V.H.F. Reception

I AM not surprised that Mr. Terry (May issue) obtains more frequent sporadic-E propagation in Tangier than we do at Tatsfield. I would rather have expected this, but the fact that his peak year was 1957 is more difficult to explain. Also, over the shorter distance paths in the order of 1,500 km or less, there is difficulty in deciding whether the mode of propagation is sporadic-E or tropospheric. In v.h.f. Band II, it is assumed that reception must invariably be by the tropospheric mode since the highest critical frequency for sporadic-E seems too low for the refraction of signals as high as 90 Mc/s.

Tatsfield. H. V. GRIFFITHS.

Masers and Caesium Resonators

"CATHODE RAY" appears to be keen on rhymes. How does he like the following?

In March, seven seven nought was taught,
It used to end in eight three nought.
And when a caesium beam is bent
It's by magnetic gradient.

Harrow-on-the-Hill. F. G. CLIFFORD.

The author replies:

Not being in a poetic mood I will prosily thank Mr. Clifford for pointing out the revised figure for the frequency of the caesium clock. His specifying of it by the last three figures reminds me of the similar R.A.F. practice with regard to personal numbers. When, in accordance with this customary method of identification at pay parade, the N.C.O. demanded of the new recruit: "Last three?" He received the proud reply: "Ted, Margie and Baby!"

Since my account of the magnetic deflection of the caesium beam was not precise. it is as well to have Mr. Clifford's reminder that it is the non-uniformity of the field that deflects the atoms.

"CATHODE RAY."

Printed Circuits

LAYING aside for the moment all reference to the difficulty of tracing circuits and identifying components, it seems to me that most correspondents have missed the most vital factor in connection with these gadgets. Quality! We of the service profession encounter all makes and kinds of sets: after enough experience with them, we can begin to separate the electronic sheep from the goats. There *are* certain sets on the American market, using PC boards, which give very little trouble with the PC boards themselves: a shining example of these is Westinghouse: so far, in three years, not a single case of true PC defects. On the other hand, two of our very largest manufacturers (who shall be nameless because I don't want to open any packages which tick!) persist in utilizing PC assemblies which, to me, are entirely too cheaply built. The phenolic board itself is quite thin, and the "printing" is very, very thin. This leads to the inevitable thermal difficulties; the semi-rigid mounting of the boards causes breakage, and the hair is then firmly deposited in the butter, as far as the serviceman is concerned.

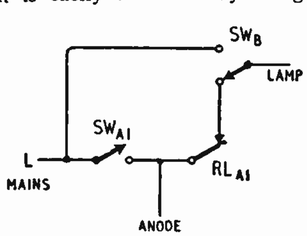
So, insofar as the serviceman is concerned, one major objection could be overcome by making the boards "just a little bit better," as one of our more obnoxious TV commercials puts it. If the perspiring technician were fairly certain that he had only "normal" part-failures to cope with he would not view the apparatus with such a jaundiced eye.

Mena, Arkansas, U.S.A. JACK DARR.

Inexpensive Photographic Timer

I SHOULD like to suggest one or two improvements to Mr. J. H. Jowett's photographic timer (p. 385, August 1958 issue). With the time setting controls on zero the grid follows the cathode and the cathode load is shunted by R_{13}. If now SW_B is closed for focusing, say, the mains potential is applied to the valve anode via the normally closed contact of relay RL_{A1} and the latter will buzz under self-interruption.

This fault is easily corrected by using a switch for



SW_B having a changeover set connected as shown in the diagram.

The use of a normally closed contact to light a mains voltage lamp of possibly 100 watts or more in such a timing circuit is bad because the current rise in the winding causes the contact pressure to be progressively reduced to zero, at which point the relay operates. The least vibration, under these low-pressure conditions can result in serious burning of the contacts as well as modifying the lamp output.

A better arrangement is to employ a make contact of RL_A to operate a relief relay on a local circuit, the latter relay carrying a normally closed contact suited to the load it serves, the contacts being preferably of Elkonite or similar material.

Although the type of relay used for RL_A is not specified in the description, its winding resistance leads me to think that it is probably one of the Siemen's high-speed relays readily available on the surplus market. This type of relay is admirable for use in this way if a relief relay is added as described above, the high-speed relay being easily adjustable to operate on 3.5mA as its normal test operate figure is about 4.5mA. Its contacts, however, though of platinum, are not insulated for mains voltage and the relief relay should preferably be chosen for a lower voltage.

If a small transformer is used to supply 12.6 volts for the valve heater, this supply could be used for operating the relief relay with a simple 4-plate selenium bridge rectifier.

New Barnet, Herts. H. d'ASSIS FONSECA.

The author replies:

Mr. H. d'Assis Fonseca's suggestion for modification of the "focus" switching arrangements is excellent and there is no reason why this should not be used. In practice, however, the conditions under which relay buzzing can occur are seldom realized, as the controls are set to a definite value during use.

The Siemens high-speed relay mentioned has in fact been used with the contacts directly connected to the mains and appears to withstand the ordeal satisfactorily; no deterioration of the contacts has occurred over a period of two years' use. A back-up relay (as mentioned in the original article) would obviously increase contact life, but at the expense of the simplicity achieved in the original circuit. J. H. JOWETT.

TV Test Programmes

CANNOT the B.B.C. be prevailed upon to show "Test Card C" throughout their television test transmissions instead of interspersing tantalizingly brief glimpses of it between what appear to be someone's holiday snapshots (which are useless for setting-up purposes)? Perhaps things are better during the week: my experience is confined to Saturday mornings.

One wonders whether there is any supervision of what is transmitted during these periods, as recently a caption announcing a stereophonic transmission was kept on the screen for several minutes after the stereophonic experiment had ceased.

Incidentally, the pernicious practice of showing pictures instead of the test card has now spread to the I.T.A. Is this a further ramification of the plot (exposed by L. W. Turner in your last issue) to drive service technicians mad?

Surbiton, Surrey E. MANSFIELD

All-purpose Receivers?

IS it not neglectful of television manufacturers not to provide "pickup" and "extension loudspeaker" sockets on the combined TV/v.h.f. receivers they now produce? Such a set may well be the only source of radio and a.f. amplification (e.g., for record turntables) in some homes, and it is asking rather too much of the customer to buy a costly television-cum-radio set, only to find that he has also to buy another small radio or a.f. amplifier in order to enjoy his records or recording facilities. Lots of a.c./d.c. radio sets have these facilities provided, so why not a.c./d.c. television/radio raceivers as well.

Paisley. J. D. HAWORTH.

Mc/s and Mc/ms

I DO have objections to the unwieldv abbreviation Mc/ms for 1000 Mc/s, proposed by "Free Grid" in your February issue.

Isn't there an internationally agreed abbreviation for 1000? That is "k", so that the abbreviation would be kMc/s, that is kilomegacycles per second instead of megacycles per millisecond.

More than that, if the British would use the equally internationally agreed (was it at Scheveningen in 1935?) abbreviation Hz for c/s, 1000 Mc/s would simply become kMHz.

Voice crying in the wilderness, however! The position of the British in the matter of measure units is quite hopeless!

Rome, Italy. ALDO SUGLIA.

NATIONAL GRAMOPHONE CONFERENCE

MANY of those present at the 1959 Conference in April at High Leigh, Hoddesdon, organized by the National Federation of Gramophone Societies, took part in the first gathering 21 years ago, as the chairman, Mr. W. W. Johnson, reminded his audience at the opening session.

The visitors had little time to relax as, from the Friday evening until the Sunday night, 11 sessions were presented by some eminent names in the audio world, in addition to excellent record recitals by the four companies, EMI, Decca, Philips and DGG. Always sure of a warm reception, the president, Sir Adrian Boult, who had just celebrated his 70th birthday, answered musical questions informally for two hours to the delight of his audience.

A welcome innovation at this year's Conference was an exhibition illustrating the history of recorded music from its beginnings to the advent of electrical recording around 1925, presented by Frank Morgan and G. Frow and other members of the Dulwich and Forest Hill Gramophone Society. Altogether 25 veteran machines were exhibited, and in most cases demonstrated. The technical highlight of the week-end was the daring experiment by F. H. Hugh Brittain, with colleagues of the G.E.C. Research Laboratories, in which he juxtaposed "live" music with its reproduced counterpart. A specially composed "Sonata" by Eric Hughes (G.E.C.) for piano, drums, flute, clarinet and double-bass, was performed in front of the large audience, faced by two widely separated "Periphonic" loudspeaker enclosures (fitted with metal-cone bass units and two "Presence" units). The playback (from a Brenell deck) was started in synchronism with the performing musicians and then, one by one, in the manner of the players in the famous Haydn "Farewell" Symphony, they dropped out, to be replaced by their previously recorded tape facsimiles substantially without any significant change in the quality or continuity. From a central listening position, at one point, the image of the drums did seem to wander slightly, which Mr. Brittain explained was caused by an inadvertent change in the level of one of the recording microphones. The original recording was made by Allen Stagg, of I.B.C. Studios, London.

The many problems encountered (from correcting mains voltage to obtain correct pitch on playback and locating the speakers in the room) can easily be appreciated, and Mr. Brittain is to be congratulated on this unusual demonstration.—D. W. A.

R.H.F.

By "CATHODE RAY"

LOOKING OVER OUR NEIGHBOURS' FENCE

WE electronicians (have the Americans thought of that one?) don't usually admit being impressed by the work of heavy old civil engineers, but we can hardly fail to admire the precision with which their steelwork leaps forth simultaneously from each side of some savage African gorge and meets in the middle without any embarrassing gap or misalignment. Much more remarkable is the corresponding feat performed in the bowels of the Alps, miles from the sight of their colleagues tunnelling from the other side. But it ought not to go unnoticed that radio engineers, who have been steadily working in one direction towards higher frequencies, are now making contact with physicists working in the opposite direction from visible towards longer wavelengths. The familiar spectrum diagrams displaying all known varieties of electromagnetic radiation (Fig. 1) have for long shown a gradually shrinking gap between "radio waves" and "infra-red." This gap may now be said to have been closed.

Generating Signals

The meeting-point or boundary is a little vague. For one thing, is there a natural distinction between the two approaches? The difference between a radio engineer and a physicist gets less and less every day. But perhaps a distinction may be found in the ways in which they generate their "signals." Both of them, of course, cause their currents or radiation by making electrons vibrate at the frequencies concerned. The traditional method of the radio engineer is to produce continuous oscillation by some kind of positive feedback in a circuit. Before it is modulated it usually works on a single definite frequency. The limit to the frequency that can be generated is set by difficulties connected with the wavelength being small compared with any reasonable circuit structure. The highest radio frequency I have come across so far is 390 Gc/s (=390 kMc/s), corresponding to a wavelength of 0·77 mm, obtained as a harmonic from a 23 Gc/s klystron oscillator. There are now klystrons available working at up to 75 Gc/s fundamental, and at least one firm offers waveguide "plumbing" for 140 Gc/s ($\lambda = 2{\cdot}15$ mm). The practical limit would seem to be in the region of 1 mm (300 Gc/s). Incidentally, the highest frequencies officially classified by radio engineers are "extremely high frequencies" (e.h.f.), from 30 Gc/s to 300 Gc/s, corresponding to wavelengths of 10 mm to 1mm.

The physicist, on the other hand, doesn't bother about circuits, but sets atoms and electrons vibrating by direct application of energy, usually heat. So generally the resulting oscillations are not executed in step, with the military precision contrived by the engineer (and termed by him "coherence") but are more like an undisciplined rabble. Sometimes they do at least keep to a nearly equal rate—as for example in a neon tube, where a particular energy transition is stimulated in the gas atoms—but often even the frequency is random, as in a hot filament, which radiates energy over a very wide band of frequencies, with only a blunt maximum somewhere, depending on the temperature.

Here we come once again to the inevitable fact that the sizes of the parcels in which energy is handed out and taken in are fixed by the quantum relationship, which says that they are directly proportional to frequency:

$$E = hf$$

in which E signifies the size of energy parcel or quantum (in electron-volts), f is the frequency in c/s, and h (Planck's constant) is $4{\cdot}13 \times 10^{-15}$. As we have seen recently, at the frequencies of visible light this works out at several electron-volts per quantum, and even over the whole infra-red band known to photographers it is more than 1eV; but at the frequency of 1 mm wavelength (300 Gc/s) it is little more than 1 electron-*milli*volt, and at what we look on as the very high frequency limit of 300Mc/s it is about 1 electron-*micro*volt. So the physicist's problem in moving towards this (to him) unfamiliar territory is the difficulty in detecting such feeble lumps of energy, and distinguishing them from the general background generated by room temperature. At this year's Physical Society's Exhibition the R.R.E. demonstrated apparatus working at wavelengths as long as 0·11 mm, which was reckoned to be something rather special.

The two traditions meet in the maser (see the April issue) which is remarkable in taming molecular energy transitions and bringing them under the dis-

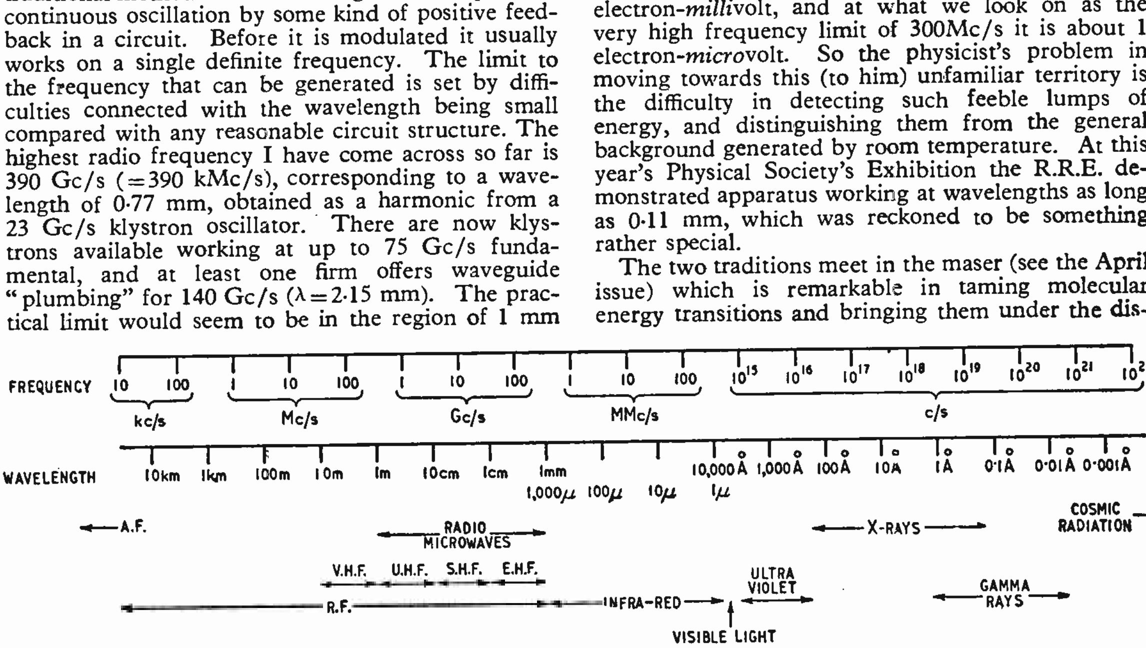


Fig. 1. Outline of a universal spectrum diagram showing the frequencies and wavelengths of the main varieties of electromagnetic radiation. The symbol "μ" stands for "micron", which is 0.001 mm; and "Å" for "angstrom", which is 0.0001μ.

cipline of the engineer, who trains them to amplify, and even to maintain continuous oscillation by positive feedback.

It looks as if we practitioners in electronics (if you prefer a more genteel British title) will have to be seeing a lot more of the physicists' point of view. We have been seeing quite a lot of it already if we have troubled to look into what goes on inside crystal diodes and transistors. Even if we have no intention of crossing over their boundary into the infra-red it will do us no harm to take a look at that neighbouring territory.

First, we shall have to consider nomenclature. The physicists' unit of wavelength, the micron, is denoted by the symbol—oh dear, yes!—μ. Being equal to 0.001mm, as regards magnitude it is quite convenient for the infra-red band, which begins at about 0.75μ and ends (if my arbitrary 1mm is accepted) at 1,000μ. But as we already use μ for at least three things it is not the happiest choice for us. Millimetres are too large, and angstroms are too small. I doubt whether frequencies in MMc/s will be popular with physicists, but frequencies do at least have the merit of being unambiguous (provided that one is not travelling at high speed relative to the source of the waves), whereas wavelength depends largely on what the waves are travelling through.

And what will our authorities do who have, to date, ordained the use of the terms v.h.f. (very high frequencies), u.h.f. (ultra high frequencies), s.h.f. (super high frequencies) and e.h.f. (extremely high frequencies)? Seeing that the next step breaks through into the infra-red, and "infra-red" means "not quite red" or "reddish," and "ruddy" is defined as "reddish," there may perhaps be something to be said for r.h.f. (ruddy high frequencies).

The whole infra-red band stretches from our own boundary, say 1mm or 1,000μ or 300 Gc/s or 0.3 MMc/s, to a frequency rather more than a thousand times greater—0.75μ or 400 MMc/s, where visible light begins at the red end (Fig. 2).

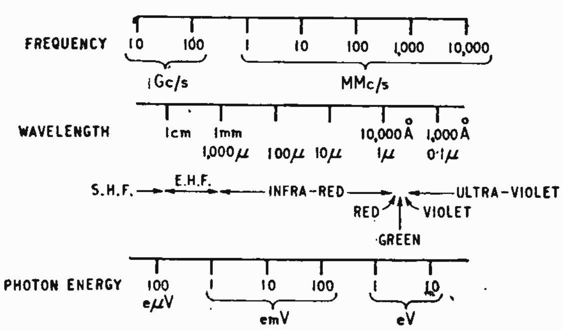


Fig. 2. Enlarged view of the part of Fig. 1 concerned with the infra-red band and its neighbours.

Historically one must begin at that (to us) far end. Sir William Herschel, the famous astronomer, investigated it 160 years ago and found that the invisible rays from the sun, beyond the red end of the light spectrum, were even more effective in heating than any of the visible ones. His detectors were pretty crude by present standards—just ordinary thermometers. Since then, the story has been very largely a search for better detectors. The problem of signal generators, which has always been so present with radio engineers, hardly arose at first, since any hot body will do. However, we may be a bit hazy about this part of it, so let us begin there.

Everything above the absolute zero of temperature (−273°C or 0°K) has its atoms and their component parts in a state of vibration, the intensity of which increases with the temperature. Any movement of mass means mechanical energy. This is obvious if the mass is something visibly large that hits us, but if it is of only atomic size we don't feel it in the same way. If, however, the atomic vibration of something we touch is enough to impart such strong vibrations to our skin and underlying flesh that physical and chemical changes (i.e., rearrangements of the atomic structure) are caused therein, we rapidly withdraw the affected part, remarking (possibly with embellishments) that that thing is hot.

Not only does heat increase the intensity of vibration (temperature) of cooler things in contact; it radiates heat energy to the surroundings, even across empty space. If other things in the room are cooler, it receives less radiation from them than it gives out, so its temperature falls and theirs rises, until all are at the same temperature—unless, of course, heat is being generated somewhere by release of energy, say by the atomic rearrangements we call burning.

Temperature Frequencies

A very important question is how the intensity of heat radiation varies with frequency. In practical situations it is nearly always complicated by some degree of selectivity; for instance, a glass window acts as a filter by passing the higher heat frequencies but not the very low ones now being explored; and the gases in the atmosphere absorb radiation at certain frequencies with quite sharp selectivity. So for basic study one assumes complete absence of selectivity, in what is called "black-body" radiation (because it would happen with a theoretically perfect black surface).

Using statistical methods of calculation—the only way possible with systems containing such unimaginable numbers of moving parts—the physicists calculated how radiation from a black body at a given temperature would be distributed as regards frequency. Unfortunately, the differences between the calculation and the results of actual experiments were too great to laugh off as "experimental error," and it was not until 60 years ago when Planck put forward his revolutionary quantum theory that the two could be reconciled. Fig. 3 shows a few calculated frequency characteristics for different temperatures, which are well supported by experiment.

One important feature of these curves is that maximum energy is radiated at a frequency which is directly proportional to the temperature*. Another is that a higher temperature gives more radiation—very much more!—at *all* frequencies.

So you can see the difficulty in generating a strong signal at very low infra-red frequencies. If the temperature is lowered to place the maximum there, the intensity is too weak to be any good at all. For example, for our 1-mm waves the temperature for peak signal would be 3°K, or −270°C! The output here is negligible and would be entirely buried under interference from surroundings at higher temperatures. Raising the temperature brings the

* The peak frequency in MMc/s is approximately one-tenth the temperature in °K (=°C+273).

peak farther away, but it does nevertheless increase the low-frequency strength, though very slightly for an enormous increase in total energy output. At 2,000°K (a bright white heat) the intensity at 1mm is eight thousand million times less than at the peak wavelength (0.00144 mm).

All this applies to the theoretical entirely aperiodic black (?) body. In practical radiators the frequency characteristic is modified. For low infra-red frequencies (below 15 MMc/s) a favoured source is a heated silicon carbide rod called a Glowbar. Another much used "signal generator" is the formerly famous Welsbach gas mantle, which emits strongly in the low-frequency infra-red as well as in the visible band.

That glass lenses are effective for infra-red radiation from the sun was seen by us all at an early age when we used them to set fire to pieces of paper or to make our unsuspecting neighbour in school jump and attract the unfavourable notice of the teacher. But their transparency extends to less than four times the longest visible wavelength. Beyond that, crystals of such halogen compounds as common salt are effective; but below 10 MMc/s there is a band where no materials are sufficiently transparent for (say) spectroscopes, and mirrors and gratings have to be substituted for lenses and prisms.

Coming to detectors, we realize that for serious scientific work our jumping schoolmate lacked both sensitivity and precision. Even Herschel's thermometers were limited to the near-visible infra-red, by opacity of the glass and poor sensitivity. Both these types of detector are examples of one of the two fundamental classes—thermodetectors, as distinct from photodetectors. That is to say, their indications depend on some indirect result of the heat, such as muscular or vocal activity, or thermal expansion. One has to wait until the detector material has heated up for such indications to occur, so even if the material to be heated is made very small it can hardly be expected to respond within microseconds—as is sometimes desirable.

On the other hand thermodetectors are not inherently frequency-selective, so can be used throughout the band, provided they are sensitive enough to respond to the weak low-frequency end, and are not limited by features such as glass.

Thermodetector Principles

After thermometers came the first really effective thermodetector—the thermocouple; still, in greatly improved form, much used. The early thermocouples were just junctions between metals, which, when heated, give rise to a small e.m.f. Modern thermocouples are made from special semiconductor alloys and can detect as little as 0.0001 microwatt per square millimetre of absorbing surface.

An alternative is the bolometer, which responds to heat by varying its resistance. Bolometers originally used very fine metal wire, but nowadays the thermistor with its vastly greater temperature coefficient is far more sensitive, and faster in response.

A more recent thermodetector (second world war) is the Golay cell, in which the heat expands a small volume of gas, causing movement which is mechanically magnified. Rather surprisingly, this is quite sensitive and quicker in response (a few milliseconds).

An even more improbable thermodetector is the evaporograph, in which the received radiation causes a thin film of oil to evaporate, and the changes in thickness are shown up by an optical device. Although not so sensitive, it has the advantage that the distribution of heat over a surface can be observed as a "picture," rather analogously to the action of a television camera screen as regards light.

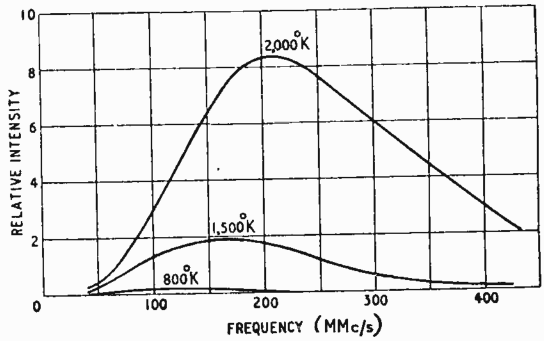


Fig. 3. Distribution of heat radiation as regards frequency, from a perfectly aperiodic radiator ("black body"), at three different temperatures.

Detectors of the other main class are called photodetectors. This is not to suggest that they respond only to light, but because the packets or quanta of radiation—which are called photons whatever their wave frequency—produce an immediate effect by their action on the electrons in the detector. Because the energy of the photons is exactly proportional to the frequency, and electrons usually need a certain minimum injection of energy for any response at all, photodetectors are more or less limited to the high-frequency end. If the frequency is too low for a quantum to reach this minimum, it doesn't make any difference how *much* radiation is available. Billions of peashooters are no substitute for one anti-tank gun, if one wants to make an impression on an armoured vehicle.

The first kind of photodetector was photographic plate or film, in which the photons make instant chemical changes in the coating. The fact that the ordinary kinds (non-pan) can be developed by red light shows that they fail to respond to visible red frequencies, let alone the infra-red. Panchromatic film is specially sensitized to cover the whole visible range, and in infra-red film the principle is extended to still lower frequencies; but even now the extension is quite small. However, by using filters to cut out the visible light—more subject to scattering by haze—one can, among other things, take extensive land photographs from high-flying aircraft when ordinary photography would fail.

Another line of attack is to extend the range of emissive photoelectric cells. (For a review of photocells, see August, 1958 issue.) Most surfaces need to be hit by quanta of at least several electron volts to give their electrons enough energy to kick some of them right out. So their response is mainly to ultra-violet or, at most, light near the violet end. But special surfaces, such as cæsium on silver, yield up to less violent photons, over the whole visible range and even into the infra-red.

Like photographic materials, photo-emission can be applied to picture-making. If an infra-red image is shone on to an emissive surface, and the emitted electrons are drawn forward by a positive-going field, at the same time being kept in formation by suitable focusing fields, they can be projected on to a fluorescent screen with sufficient violence to make it glow, thereby reproducing the picture visibly. The difference between this image converter (as it is called) and a television tube is that all the screen is being bombarded all the time, instead of sequentially by a fine beam of electrons. The technique had obvious uses during the war for "seeing in the dark," and there are also scientific applications.

Semiconductor Cells

The other kinds of photoelectric cells—photovoltaic and photoconductive—don't lend themselves to simultaneous picture formation, but only detection; on the other hand some of them work to considerably lower frequencies, though nothing like as far as the thermodetectors, which (with an exception to be noted later) are the only kinds available for two out of the three infra-red frequency decades. The interesting thing about them from our point of view is that they make use of semiconductors.

Of the two kinds, the photovoltaic have not so far proved themselves very useful, so I will mention only photoconductive types.

Most of them use semiconductor *compounds*, which are less familiar to students of transistors than the semiconductor elements, germanium and silicon. Here again the second war was a great stimulus to development. The German "lightspeaker" used thallium sulphide cells to receive a speech-modulated infra-red beam for secret communications. In another field of application, competition was keen to increase the sensitivity of detectors, with the object of locating the enemy's aircraft (by the heat of its engines) before he located yours.

Other compounds used are the sulphide, selenide and telluride of lead. Some of them are extraordinarily sensitive, and also quick acting—e.g., less than 100 microseconds. A commercial lead sulphide cell, without benefit of concentrating or focusing devices, or cooling for the cell, is said to detect the heat from an ordinary soldering iron at 100 yards. For the highest sensitivity, however, cooling by liquid air or even liquid helium is needed; the idea being to reduce self-generated noise. With a suitable mirror the range from the same source can be increased to about 10 miles.

And now we have indium antimonide, which is less sensitive but far faster.

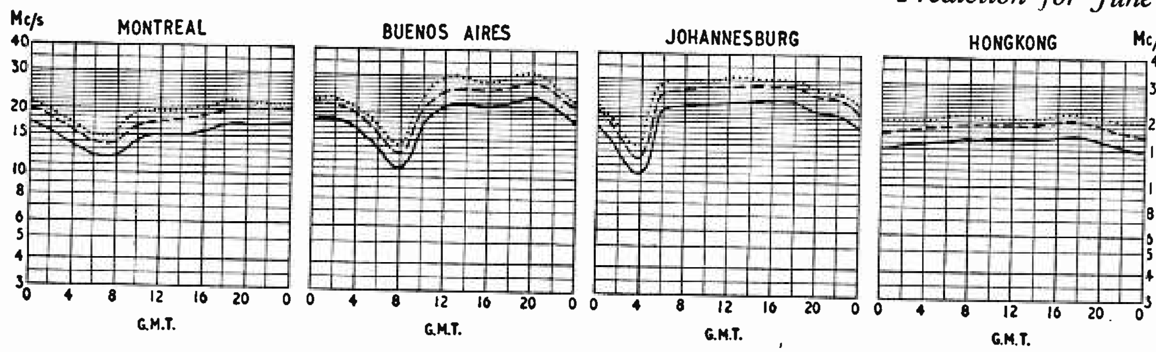
The low frequency limits of these are all higher than 36 MMc/s. If, however, we can remember our basic transistor physics we will know that the usual intentional impurities in germanium and silicon provide very small energy gaps—about 0.01 electron-volt, corresponding to quanta with a radiation frequency as low as 2.4 MMc/s or wavelength 0.125 mm. It is because the heat energy of the surroundings at ordinary temperatures is sufficient to excite nearly all the impurity electrons that transistor materials conduct. That state of affairs would obviously be no use for detecting infra-red radiation, any more than a coconut shy would be a fair test of marksmanship if all the coconuts had already been knocked off by swarms of small boys. So the detector material has to be cooled to a temperature at which most of the impurity electrons are unexcited, by keeping it in liquid helium—say 4°K.

Although r.h.f. can certainly be used for communication (and radar), as we have seen, perhaps the most important applications are in research concerning molecular structure, by infra-red spectroscopy. That is far too big a subject to embark on at this stage, and anyway rather off our beat, but perhaps if the maser is still in mind (April issue) it will give just a little clue to the sort of thing.

If anyone wants to know a lot more about all this, I can recommend the script of the Kelvin lecture on the subject by Dr. G. B. B. M. Sutherland (to whom I am indebted for much of the foregoing information), published in *Proc. I.E.E.*, Part B, July 1958.

SHORT-WAVE CONDITIONS

Prediction for June



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

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

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

— — — PREDICTED AVERAGE MAXIMUM USABLE FREQUENCY

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

Electronics and the Phonetician

Speech Analysis and Synthesis

By H. J. F. CRABBE

MODERN experimental phonetics is rapidly becoming an all-embracing subject which endeavours to comprehend the working of the human speech mechanism as a whole. Speech is an immensely complex phenomenon, involving linguistics, mental processes both conscious and unconscious, brain, nervous system, vocal tract, sound waves, and the hearing and understanding mechanism of the listener. The attempt to understand the nature of speech in this dynamic sense involves much research and some controversy, and it is becoming increasingly useful to construct electronic models of parts of the speech mechanism. Also the investigation of the acoustical aspects of speech involves a variety of electrical measuring instruments.

As a result, a stranger, coming by chance into a modern phonetics laboratory, might be forgiven for thinking himself in a department of physics or electrical engineering. Gramophones and tape recorders, still the everyday tools of the phonetician, are augmented by a range of electronic apparatus of considerable complexity. It is the purpose of this article to describe some of the devices and techniques used in this field, from the point of view of the electronic technician.

Nature of the Vocal Mechanism.—One of the more limited aims of the phonetician is to achieve a more detailed understanding of the acoustics of speech[1], so it will be convenient to start with a brief description of the basic vocal machinery.

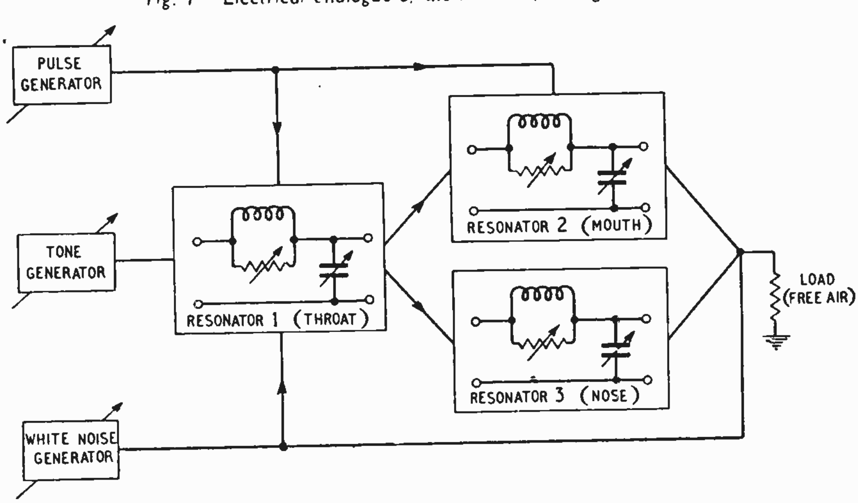
Most readers of *Wireless World* will be acquainted with the useful practice of producing electrical analogues of simple acoustic devices, such as loudspeaker enclosures, and it is a natural first step to produce a similar model of the human vocal tract. However, the resulting circuit would be rather complex in its entirety, since nearly every element is continuously variable, so we must content ourselves with a simplified version (Fig. 1). Here it will be seen that the output of a tone generator of variable frequency and amplitude is fed to a load via a number of tuned circuits of variable Q and resonant frequency. Also "white noise" can be fed to this same point, either directly or via the above resonators. Finally, these resonant circuits can be excited by single transient pulses of various widths.

The tone generator has a spiky waveform rich in harmonics, and is equivalent to the larynx, which contains the vocal chords. The larynx interrupts the flow of air from the lungs, thereby producing a note whose loudness and pitch can be controlled at will. This signal first passes through the pharynx or throat cavity resonator, and then via the mouth and nasal passages into the radiation resistance of free air. Continual unconscious adjustments of these three cavities take place during speech, and the various vowel sounds which we recognize are determined by the groups of harmonics or formants which are passed as a result. The "white noise" simulates the various high-frequency hissing sounds, or fricatives, which can be produced at the back of the throat or between the teeth and lips. It is interesting to note how the "white noise" becomes "coloured" on passing through the throat and mouth, in much the same manner as 78 r.p.m. record surface noise is coarsened by a resonant loudspeaker system. The sounds (sh), (s), (th) and (f) bring the point of hiss injection progressively further forward in our circuit, with a corresponding reduction of dependence on the shape of the mouth cavity for the final sound quality. The pulse generation corresponds to the production of various transient or plosive sounds such as (k), (t) and (p), which are essentially short bursts of energy.

These processes, functioning in continuous and rapid succession with frequent complex transitions which almost defy analysis, constitute the raw material of phonetics from the acoustic point of view.

Speech Analysers.—Phoneticians spend much of their time filling in the details of the above picture, and to do this various analysing devices are necessary. The most useful of these is the sound specto-

Fig. 1 Electrical analogue of the human speaking mechanism.



graph known in one commercial form as the Sonagraph, which provides a three dimensional visual display of sound patterns on electro-sensitive paper. A typical sonagram is reproduced in Fig. 2. The time and frequency dimensions are plotted horizontally and vertically respectively, and intensity is indicated by the density of the trace. The sound depicted is the word "master" and the characteristic formants of the two vowels are clearly displayed, with the (s) and (t) as long and short bursts of high frequency noise. Only the (m) remains obscure, and many consonants are very difficult to define acoustically, as they appear to depend for their intelligibility almost entirely on the subjective interpretation of the listener and the linguistic context.

Machines which produce a display of this sort (see Fig. 3) will usually only handle a limited quantity of material at one time. The words to be analysed are recorded on a magnetic drum and then replayed at a higher speed. Each revolution of the recording causes the writing pen to traverse the paper in the time dimension, while the signal from the replay head passes through a tuned filter, whose output amplitude is used to control the density of the trace. A lead screw causes the pen to move slowly up the paper on the frequency ordinate, at the same time changing the resonant frequency of the filter by moving the slider of the potentiometer. So each time the recording is scanned the writing pen draws a trace corresponding to the sound energy at a particular frequency and slowly a complete picture is built up. This means that it takes several minutes to analyse a sound passage lasting only a few seconds, and it is one of the aims of technicians in this field to design an instantaneous sonagraph which will produce a continuous analysis of material fed straight in from a microphone or tape recorder. To do this it is necessary either to scan the paper in the frequency dimension with very great rapidity, which is difficult both electrically and mechanically, or to produce a large number of traces simultaneously in the time dimension. At the resolution of Fig. 2 this latter would need fifty or more lines to the inch, which is not achievable with actual writing pens. One solution is to produce the display

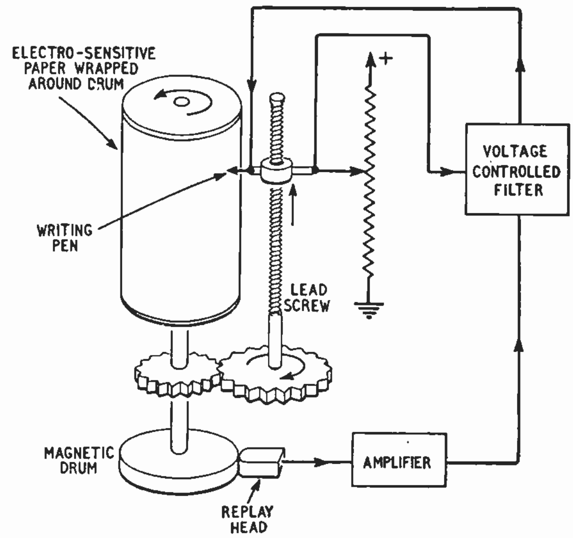


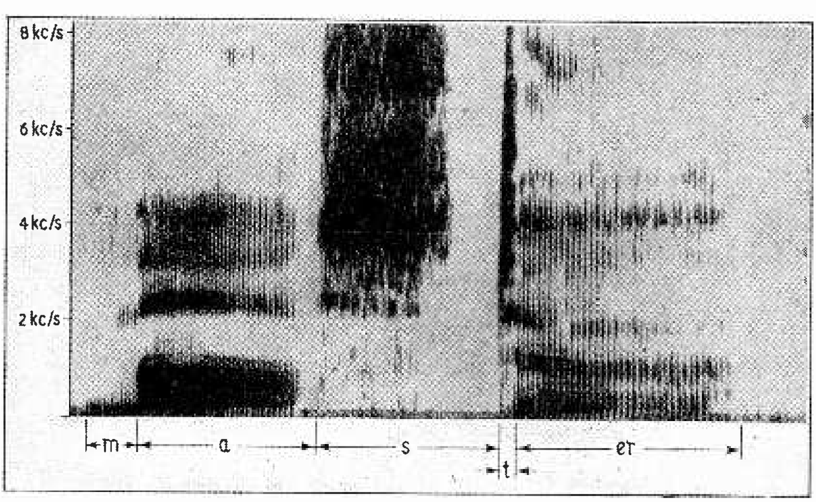
Fig. 3. Essential features of a Sonagraph type of sound analyser. The magnetic recording and the drum carrying the paper rotate together with the lead screw, altering the input to the voltage-controlled filter and causing the writing pen to move slowly up the paper as the analysis proceeds.

on a c.r.t. and to photograph it continuously on moving film. Recording papers sensitive to various forms of excitation are now becoming available, but so far there is some practical objection to each for this application, so the matter remains one for continued research.

In addition to waveform analysis of the individual sounds of speech, it is sometimes interesting to investigate the general distribution of energy against frequency in various languages or dialects. By this method it may be possible to establish some general correlations between particular languages and their acoustic spectra. It is easy to imagine for instance that the excess of fricatives in German, or nasal sounds in French, would produce corresponding peaks in the response curves. The results would be largely statistical, however, since many speakers would have to be examined to swamp the effects of individual characteristics.

The problem here from the electronic point of view is to produce an integrator which will indicate the energy sum of a given length of recorded material at a large number of spot frequencies. A normal narrow-band filter of variable frequency may be used for the latter, but the integrator itself has to meet somewhat stringent requirements. Periods of silence play an important part in speech, and it is essential to achieve an extremely low noise level and rate of drift

Fig. 2. Sonagram of the word "master" illustrating the differing ways in which energy (indicated by the density of the trace) is distributed in the three types of consonant and two vowels.



during these. Also the device must be linear over an input range of at least 40 dB. A Miller type of circuit cannot be made to perform this well, and one solution is to revert to the simplest of all integrators: a plain R and C. In this arrangement the a.c. input is amplified up to several thousand volts peak and rectified by an e.h.t. diode. The resulting d.c. is applied to the integrating condenser via a chain of high stability resistors, and the voltage across the condenser is measured by a long-tail pair in a starvation circuit to eliminate grid current. This scheme reduces drift and leakage to a minimum, and linearity is maintained by restricting the charge on the condenser to one per cent of the maximum applied voltage. On the completion of each charging period a Schmitt trigger circuit is used to register one digit on an electro-mechanical clock and to discharge the condenser ready for the next cycle. The instantaneous integral at any moment during a cycle is also indicated on a voltmeter, thus ensuring an accuracy of at least two figures on even very short speech passages.

An interesting "extra-phonetic" application of this type of analysis would be to discover the spectra of various commercial disc recordings of the same piece of music; also to study the high frequency attenuation resulting from record wear, which at the moment is a matter of subjective guesswork on all but pure tone test records.

Speech Typewriter.—A type of analyser which has a more dramatic and popular appeal than those discussed so far is one that converts the spoken word straight into a typewritten script; a sort of ideal shorthand typist. Several attempts have been made to produce such a machine and one of particularly advanced design [2, 3, 4, 5, 6, 7] is in use at the Department of Phonetics, University College, London.

Reference to the diagram (Fig. 4) shows that the speech input is fed to a bank of filters, the outputs of which are rectified. Thus a number of d.c. voltages are obtained which vary continuously according to the sounds uttered. Ideally, for most speech units, or phonemes, there are at least two frequencies at which major concentrations of energy appear, corresponding to the formants mentioned earlier, and at each of these frequencies there will be an associated rectified filter output. For each sound in the machine's vocabulary the appropriate two voltages are multiplied together in a valve multiplier circuit, and at any particular instant one multiplication product will be greater than all the others and will represent the phoneme being spoken. This instantaneous "winner" is selected by a maximum detector circuit and used to operate a key on an electric typewriter.

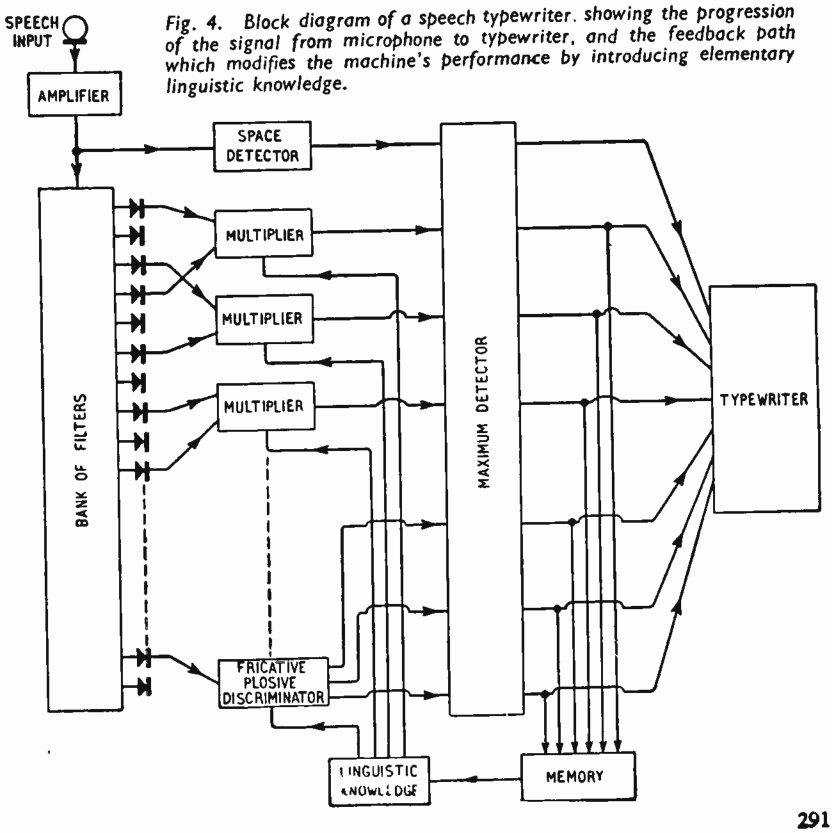


Fig. 4. Block diagram of a speech typewriter, showing the progression of the signal from microphone to typewriter, and the feedback path which modifies the machine's performance by introducing elementary linguistic knowledge.

So, as the voltage maxima shift from one pair of filters to another during the course of a word, the appropriate keys of the typewriter are depressed in sequence. This method of phoneme detection is not suitable for some fricative and plosive sounds, which have similar spectra, so with these the machine makes its decisions according to the duration and/or amplitude of the signal. To achieve this a number of flip-flop timing circuits are triggered at the commencement of any hiss energy, and their operating times made to correspond to the length of the sound to be recognized. When the sound ends, the circuit within whose time band it comes causes the appropriate character to be typed. Similarly, differences of amplitude can be detected by Schmitt trigger circuits. The spaces between words are detected by a separate circuit, which examines the speech input and records a space when the signal disappears for more than a specified minimum time.

This basic instrument as it stands is not very efficient, and makes many mistakes, due largely to the extreme inconsistency of speech, which seldom lives up to the hypothetical acoustic pattern. Humans are able to recognize words with comparative ease, despite extremes of dialect or frequency distortion which would completely baffle a purely physical analyser. This is made possible by our knowledge of the language and of the probable occurrence of particular combinations of phonemes and words. We draw on this information unconsciously when listening to speech and thus extract a meaning from a jumble of sounds, as noted by Cherry recently in *Wireless World*[8].

The blocks marked MEMORY and LINGUISTIC KNOWLEDGE in Fig. 4 represents circuits which attempt to simulate this especially mental part of the speech-recognizing process, though at a very elementary level. The linguistic knowledge takes the form of a matrix of potentiometers on which are set voltages corresponding to the probabilities of any sound following any other sound in the machine's vocabularly. As a particular character, say (m), is typed, so the machine "remembers" what the sound was by operating a self-holding relay. At the same time a voltage is applied to a column of potentiometers in the matrix appropriate to sounds following (m). The circuits used to multiply the pairs of rectified filter outputs are actually three-stage devices, the third inputs to which come from these potentiometers. This means that the next character to be typed will depend on three voltages, two derived from a frequency analysis of the input waveform, and one indicating the probability of following the previous sound. Thus the recognition of every succeeding sound is affected by the machine's knowledge of which phoneme is most likely to follow the one already identified, and of those which are impossible in that position.

This very simple one-stage memory arrangement greatly improves the performance of the apparatus and makes it noticeably less dependent on one particular speaking voice. The complete instrument, which is shown in the photograph, will correctly type 44% of words and 72% of individual sounds; and though it is limited to a vocabulary of 13 phonemes for the present, this is a third of all English sounds and provides the material for several hundred words. An extension of the principle of built-in linguistic knowledge to enable the machine to assess the sequential probabilities of sounds on the basis of the previous two or three characters would greatly improve the performance, but would involve the use of a large computer.

It would be unrealistic to hope that such a machine could ever work perfectly with an unrestricted vocabulary, but it may be possible to achieve a reliable response to an agreed and limited range of words, such as telephone numbers or similar messages where the spoken word needs to be converted into a series of coded impulses. An instrument which could break down a complex speech wave to the forty phonemic units used in English would achieve an immense reduction of the bandwidths needed in communication channels, and if made to drive a corresponding synthesizer at the receiving end, it would provide a valuable advance in analysis-synthesis telephony methods[9].

Speech Synthesizers.—This brings us to synthesizers, which in one form or another have been in use now for some years[10]. Certain general principles of design have been established, though detailed circuit arrangements vary widely. It is convenient to make such a system in two functionally separate parts; one being a control circuit which will produce a succession of switching voltages of proper duration and sequence, and the other a generating circuit similar to Fig. 1, the output of which feeds a loudspeaker. In many synthesizers the control voltages are derived from a set of shaped patterns which are scanned in various ways. A design using a different method of control is in use at University College, and its basic layout is shown in Fig. 5.

The sequence timer consists of a series of ten flip-flop circuits which trigger each other in succession. The operating time of each one can be adjusted separately, and each on period corresponds to the duration of one speech unit in a short sentence. Associated with each time unit is a column of potentiometers on a control panel (only one of the ten columns is shown in Fig. 5) and when a particular sound in the sequence has been reached, the appropriate column is energized with a d.c. voltage and a set of signals sent into the generating half of the synthesizer. The form of these signals is preset according to the type of sound to be produced, and the various parameters which can be varied are marked on the control panel (see Fig. 5). The larynx tone generator is an oscillator rich in harmonics, the fundamental frequency of which can be varied over the normal range of fundamental speech tones by means of a d.c. voltage. The formant filters are simply tuned circuits of an appropriate bandwidth, whose centre frequency can also be varied by means of a d.c. voltage. The amplitude of signal fed to each filter is determined by the gate units, and these will pass anything from full level to zero, depending on the applied voltage. The hiss generator produces continuous noise with a suitable spectrum.

If, for instance, one

(Continued on p. 293)

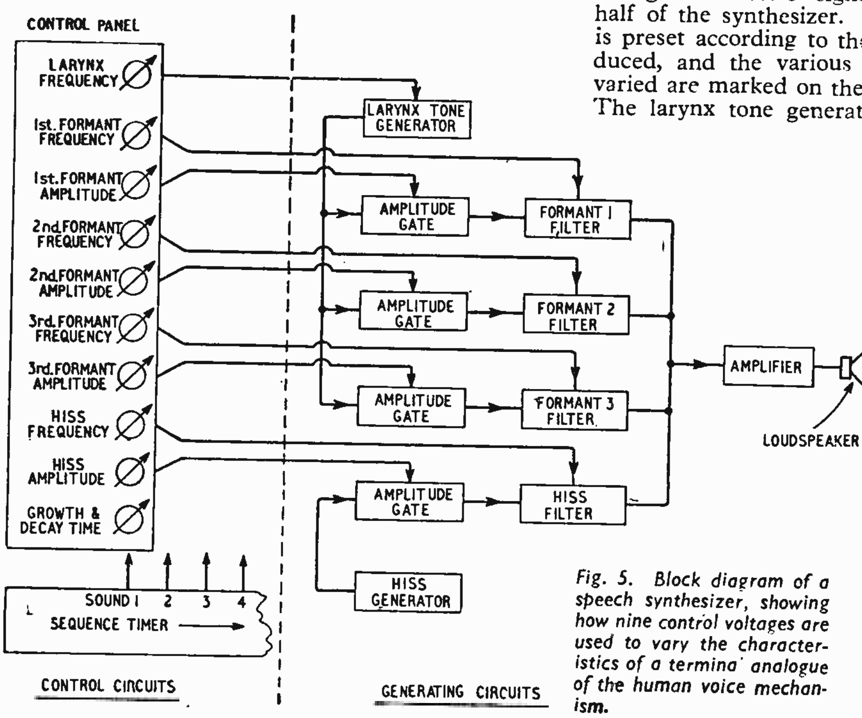


Fig. 5. Block diagram of a speech synthesizer, showing how nine control voltages are used to vary the characteristics of a terminal analogue of the human voice mechanism.

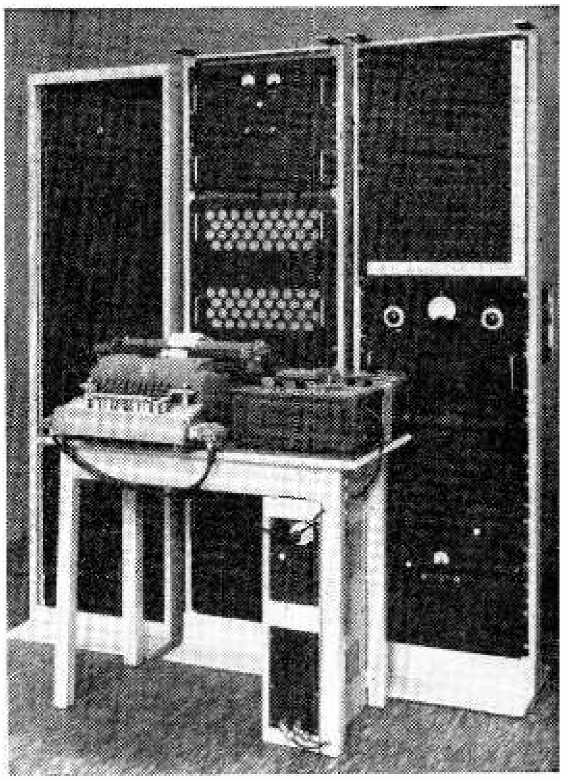
wished to generate the sound (ee) as spoken by the average male, then reference to published data[11, 12] shows that the larynx frequency will be 136 c/s and the three formants will be at 270, 2300 and 3000 c/s respectively. Also their relative amplitudes will be 0, −20 and −24 dB. Thus, by setting seven knobs, the sound can be synthesized in a few moments. The rate of change of the amplitude and frequency of the sound can be set by a variable time constant circuit, but the requirements here depend on what precedes and follows the phoneme in question. If a fricative sound is required, then here again the amplitude and frequency content of the hiss signal can be adjusted in a similar manner. For plosives, short bursts of hiss will normally produce satisfactory results.

Although for economic reasons the machine is restricted to sequences of ten sounds, it can still pronounce short meaningful sentences like "How are you, baby?" and "Where are you, Sir?". As a tool for research it is very valuable, both for testing data derived from speech analysis and for determining the minimum information necessary to define speech sounds[13].

Interfering with Speech.—In the course of their investigations, phoneticians sometimes find it convenient to have independent control of the fundamental pitch, or larynx tone, in a continuous speech pattern, while leaving the other parameters unaltered. One way of achieving this is to adapt an instrument sometimes used in telephone systems and called a Vocoder[14]. This consists essentially of an analyser rather like the filter and rectifier part of the speech typewriter described previously, feeding a number of slowly varying control voltages through a communication channel to a corresponding synthesizer. The transmitted information relates to the changing distribution of energy in the spectrum. This is a less fundamental process than is involved in locating the actual phonemes, so the consequent reduction in bandwidth is not so great.

At a suitable point in the Vocoder an electrical signal corresponding to the instantaneous pitch can be intercepted and replaced by an artificial one under the control of the experimenter. Thus a speaker can talk into the system and, regardless of his own intonation, the output will vary in pitch according to the turn of a knob or the depression of key switches. The uninitiated might imagine from this that one could recite "John Brown's Body" into the microphone and produce an output of the same voice singing the same words. Alas, this easy conversion of soap-box orators into budding Carusos is not to be had! The characteristic formants associated with vowel sounds are, in singing, accompanied and even masked by others which are absent in ordinary speech[15]; so the result of this arrangement would be to produce a singing voice of very unnatural tone quality.

However, there is a useful application of this pitch control, as psychologists sometimes need to investigate the influence of intonation on the emotive content of words or sentences. For this a recording is made of a suitable sentence, and a number of painted patterns are produced corresponding to changes of pitch in various words or parts of words in the sentence. Each pattern is then scanned by a cathode-ray following device to produce an equivalent pitch control voltage in synchronism with the replayed recording. By this method the investigator



View of the complete speech typewriter outlined in Fig. 4. The control table carries the input material on recorded tape and also the typewriter. The racks from left to right contain the filters and rectifiers, multipliers and maximum detector, and memory and linguistic knowledge circuits respectively.

ensures that *only* the pitch is changed, which is important if listeners who are asked to assess the meaning or emotional content of an utterance are not to be misled by other variables introduced by a live speaker.

Another interesting way of interfering with speech is to upset the feedback loops in the human nervous system while the subject is speaking. This has become a very popular joke, and no doubt many *Wireless World* readers have submitted to it in the B.B.C. studios at the Radio Show in previous years. The voice is simply amplified, delayed by about one-quarter of a second on a tape loop, and fed back to the speaker's ears at high level via a pair of headphones. We normally unconsciously correct our speech as we go, but by this method we correct according to the wrong information and are reduced to a stuttering gibberish. Only the deaf can survive this experiment without loss of pride, as no amount of concentration will enable one to speak normally. Because of this it is a fairly reliable method of discovering whether a suspected malingerer is really deaf.

This short survey, based on the work of one University Phonetics Department, does not claim to be exhaustive. No doubt many gadgets and techniques of importance have been omitted, and the Americans particularly, with their vast laboratories, can afford a tolerant smile. However, if Shaw's

Professor Higgins could see us he would certainly find much to admire; the crude acoustic devices of an earlier age have now been completely superseded by the electronic approach, to the advantage of all.

The author would like to thank Professor D. B. Fry for permission to publish many of the above details. It should be noted that authorship of this article does not imply responsibility for the design of any of the items mentioned, which are the product of a technical team. Particular credit should go to Mr. P. Denes, M.Sc., A.M.I.E.E., who is in charge of the Phonetics Laboratory, and to the writer's colleague Mr. J. E. West. Some of the work described in this article has been financed by the U.S. Air Force under Contract No. AF61 (514)—1176.

REFERENCES

[1] H. Fletcher: Speech and Hearing in Communication, Van Nostrand, New York (1953).

[2] D. B. Fry and P. Denes: "Mechanical Speech Recognition", Communication Theory, ed. W. Jackson, Butterworths (1953), p. 426.

[3] D. B. Fry and P. Denes: "Experiments in Mechanical Speech Recognition", Information Theory, ed. C. Cherry, Butterworths (1956), p. 206.

[4] D. B. Fry and P. Denes: "On Presenting the Output of a Mechanical Speech Recognizer", *J. Acous. Soc. Amer.*, Vol. 29, p. 364 (1957).

[5] D. B. Fry and P. Denes: "The Solution of Some Fundamental Problems in Mechanical Speech Recognition", *Language and Speech*, No. 1, p. 35 (1958).

[6] D. B. Fry: "Theoretical Aspects of Mechanical Speech Recognition", *J. Brit. I.R.E.*, Vol. 19, p. 211 (April 1959).

[7] P. Denes: "Design and Operation of the Mechanical Speech Recognizer at University College, London", *J. Brit. I.R.E.*, Vol. 19, p. 220 (April 1959).

[8] C. Cherry: "Hearing and Seeing," *Wireless World*, Vol. 63, p. 164 (1957).

[9] "Analysis-Synthesis Telephony", *Wireless World*, Vol. 62, p. 291 (1956).

[10] W. Lawrence: "The Synthesis of Speech from Signals which have a Low Information Rate", Communication Theory, ed. W. Jackson, Butterworths (1953), p. 460.

[11] G. E. Paterson and H. L. Barney, "Control Methods used in a Study of the Vowels", *J. Acous. Soc. Amer.*, Vol. 24, p. 175 (1952).

[12] R. K. Potter and J. Steinberg, "Toward the Specification of Speech", *J. Acous. Soc. Amer.*, Vol. 22, p. 807 (1950).

[13] G. F. Arnold, P. Denes, A. C. Gimson, J. D. O'Connor and J. L. M. Trim, "The Synthesis of English Vowels", *Language and Speech*, No. 2, p. 114 (1958).

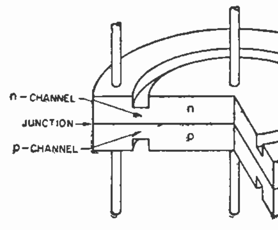
[14] R. J. Halsey and J. Swaffield, "Analysis-Synthesis Telephony, with Special Reference to the Vocoder", *Proc. I.E.E., Part III, Vol.* 95, p. 391 (1948).

[15] D. B. Fry and L. Manén, "Basis for the Acoustical Study of Singing", *J. Acous. Soc. Amer.*, Vol. 29, p. 690 (1957).

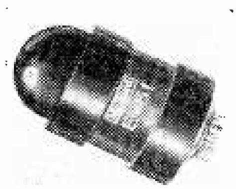
Technical Notebook

Aluminium-Backed Polyester Magnetic Tape for high-speed video recording or computer applications has been produced by the M.S.S. Recording Company. At high speeds a considerable static charge can build up on the normal polyester backing. This has been avoided by M.S.S. by spraying a very thin (10^{-5}in) coating of aluminium on the back of the polyester to produce a low resistance ($\approx 50\Omega$/ft for $\frac{1}{4}$-in tape). At slower speeds it is sufficient to treat the polyester with an anti-static agent, as is normally done with tape for audio recording.

Field Effect Tetrode is a new experimental four-terminal semiconductor device recently produced at Bell Telephone Laboratories. It is said to be capable of operating as a transformer, a gyrator, an isolator, or as a non-distorting modulator. The tetrode consists of a disc of semiconductor material with a diffused junction. A circular trench is cut and etched into each face of the disc, to within about 1 mil of the junction on either side. Two leads are then attached to each face, one inside the trench and the other outside (see diagram). When a voltage is applied across the junction, the thickness of the depletion layer adjacent to it is increased or decreased, depending on the direction of the biasing voltage. This in turn increases or decreases the resistance of each "channel" between the bottom of the trench and the junction. One of the most important applications, according to Bell Telephones, may be as a distortionless modulator, or electronically controlled resistor for large signals. In this use, a relatively low frequency control voltage varies the width of the depletion layer, and thereby the resistance of the device. Simple capacitors can act as high-pass filters to isolate the control voltage from the signal if the frequency ratio is maintained at a high level. The signal voltage does not appear across the junction and has no effect on the depletion layer. Consequently it can be magnitudes higher than the control voltage, without being distorted by self-modulation. For the same reason, it is not limited by junction capacitance.

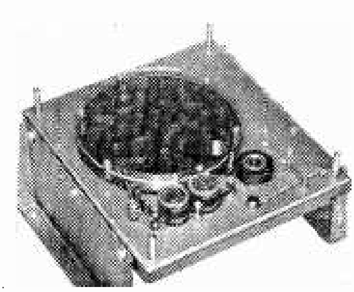


High-Speed Counting Tube, capable of operating at pulse rates up to 1Mc/s has just been introduced by Mullard. Designated the ET51, it is actually a trochotron decimal stepping tube. As distinct from the Dekatron glow-discharge type of counter, the trochotron is a vacuum device depending on the deflection of an electron beam. It makes use of crossed electric and magnetic fields to form the beam between a thermionic cathode and any of ten groups of three electrodes mounted radially about the cathode. The electric field is provided by the inter-electrode potentials within the tube and the magnetic field by a cylindrical permanent magnet fitted externally around the glass envelope. Each group of electrodes consists of a "spade," which forms and locks the beam in position, a target, which makes the beam available as a constant current output, and a grid, for switching the beam from one spade to the next. When power is first applied, all spades will be equally positive with respect to cathode and, due to the action of the magnetic field in preventing electrons reaching the electrode-groups, the tube will be in a cut-off condition, with no beam formed. If, however, the potential of any spade is reduced, by means of a high-speed pulse or a d.c. voltage, the beam will form on the electrode group associated with that spade, and an output will appear on the corresponding target. Once formed, the beam is held in this position by a combination of the spade series resistance and spade current until it is stepped to the next position by lowering the voltage on

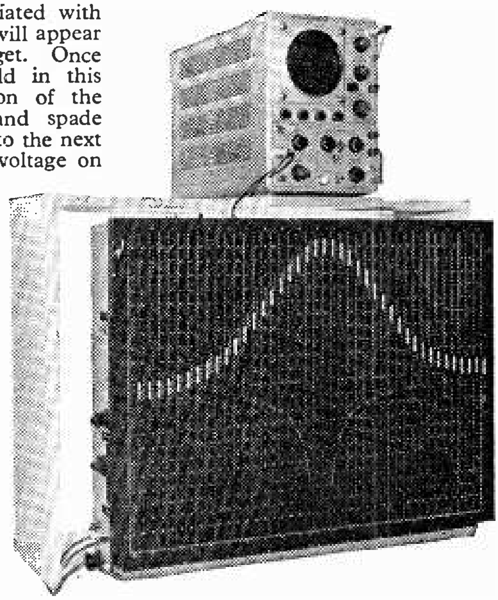


the associated switching grid. Since only the grid in its immediate vicinity will affect the beam, the grids are connected internally in two groups; the odd-numbered grids in one, the even-numbered in the other. This makes it possible to use a d.c. input for switching and still obtain single position stepping, thus avoiding the necessity for a pulse of critical width. The output characteristic of the trochotron is similar to that of a pentode valve, and in the ET51 over 80% of the beam current appears in the output, the remainder being used to form and lock the beam.

Tape Cassette consisting simply of a hollow cylindrical "pill-box" several inches in diameter but only slightly taller than the tape width has been devised for use in the Gate Electronics Continuous Tape Deck. Two narrow corridors protruding from the circular edge of the pill-box guide the tape in and out and keep its width parallel to the pill-box's height. Inside the pill-box the tape curls itself randomly into S-shaped lengths as may be seen from the photograph taken through the perspex end. With a $4\frac{3}{8}$-in diameter pill-box and a tape speed of $3\frac{3}{4}$in/sec, a loop 80ft long has been successfully stored.



Fourier Transform Analogue Generator, developed as a specialized research tool by the B.B.C., is shown below. With this instrument any function can be set up in graphical

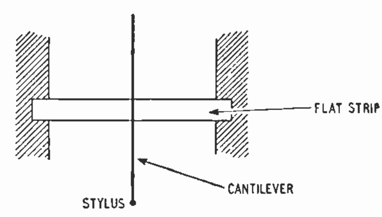


form by adjustment of potentiometer sliders on a calibrated panel and the resultant Fourier transform displayed on an oscilloscope. Each potentiometer is connected to one of twenty harmonically-related sinusoidal voltages, and the voltages on all the sliders are combined to form the signal which represents the Fourier transform. The equipment was developed for a programme of research work on lenses as a means of avoiding the tedious calculations which would otherwise be necessary to obtain Fourier transforms.

Microwave Infra-Red Detector recently developed by the GB Electronics Corporation in America makes use of r.f. energy, propagated in a waveguide system, to detect the changes which occur in semiconductor material when infra-red or other radiation is directed on to it. The resistance and dielectric constant of the semiconductor (a germanium crystal) are affected by the incident radiation, and these produce changes in the phase and amplitude of a wave reflected from a tuned cavity. Indication of these phase and amplitude changes is obtained by combining the wave in phase opposition with a corresponding wave reflected from an identical tuned cavity (also containing a germanium crystal but not irradiated). Normally cancellation occurs, but when the semiconductor causes phase and amplitude changes in the first wave an unbalance signal is produced. The system, described in *Electronics* for 30th January, 1959, is said to be very sensitive and has the advantage of eliminating contacts to the semiconductor, which are normally a source of noise in conventional infra-red detectors.

Brazing Under Vacuum, at temperatures up to 1100°C, was one of the requirements which had to be provided for by Edwards High Vacuum recently when designing a pumping plant for ceramic disc valves. At such high temperatures it was impossible to use normal sealing techniques, and metal seals had to be employed. At the same time the vacuum had to be extremely high because getters cannot be used in ceramic valves as they are in conventional glass valves. The pumping plant finally built by Edwards has a water-cooled vacuum chamber made of mild steel, inside which six ceramic valves can be moved round on a rotary work table. Movement is transmitted from outside the chamber to the work table via flexible metal bellows, to obviate the need for organic sealing gaskets. Similar metal bellows are used for raising and lowering the small brazing furnace, inside the chamber, on to each valve station in turn. Sealing between the cylindrical vacuum chamber and its baseplate is done by indium wire.

Mechanical Separation of Stereo Pickup Movements in two directions at 90° by a simple method was described recently by S. Kelly. A flat strip and a cantilever link carrying the stylus at one end are joined together at right angles to form a cross as in the illustration. The flat



strip is also fixed at both ends and runs parallel to one of the two directions of motion. Motion in this direction at the stylus end of the cantilever then causes this end of the cantilever to hinge about its join to the strip so that the motion *is not* transferred to the other end of the cantilever. Motion at the stylus end of the cantilever in the other direction (at right angles to the paper in the illustration) causes the strip to twist and the motion *is* transferred to the other end of the cantilever.

New Units introduced by the Los Alamos Laboratory of California University, according to an advertisement in the April issue of *Astronautics*, include the Babe (20keV), Shake (10^{-8}sec), Jerk (10^{-16}ergs) and Zerk (10^{25}ergs).

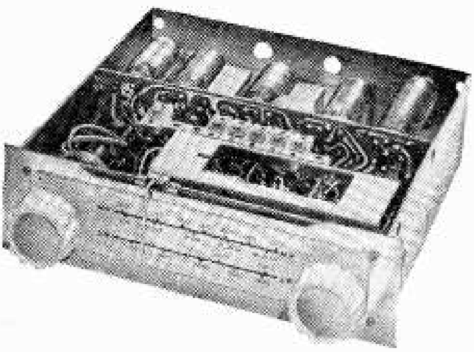
Manufacturers' Products

NEW ELECTRONIC EQUIPMENT AND ACCESSORIES

Hybrid Car Radio

A SET of parts for the construction of a "hybrid" 12V car radio receiver is now available from Mayra Electronics Ltd., 551, Holloway Road, London, N.19.

The receiver (to a S.T.C. circuit) uses five Brimar valves—two 12AC6, 12AD6, 12AE6, 12K5 and a Pye V15/10P transistor for the a.f. output stage. It is a superhet with an r.f. stage, which accounts for the excellent sensitivity and a.g.c. characteristic. Permeability tuning is employed, covering the medium and long wavebands and a printed-wiring panel for the receiver proper ensures consistent results. The output transistor is mounted on a heat sink on the back of the loudspeaker and the heat sink is insulated from the circuit. Battery consumption is 1.5A at 12V.



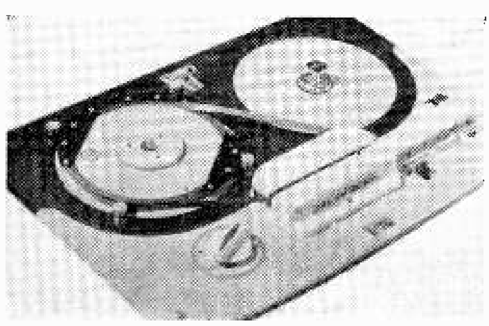
Mayra Electronic hybrid car radio receiver (case removed).

The complete set of parts including the receiver case, loudspeaker, knobs and dial trim costs £13 10s.

Tape Loop Cassette

FOR speeds of 15in/sec or less, up to 200 ft of tape can be wound in an endless loop on the "Brittape" cassette. This cassette is bolted over one of the spool spindles of the deck, and it can be used with most tape recorders which can take 7-in or larger-diameter spools. In the cassette the tape is wound on a central freely rotating 5-in diameter spindle and, when in motion, unwinds from the inside and winds in from the outside. To allow this motion, the tape must be wound on the cassette clockwise or anticlockwise (from the inside out when viewed from the top) according as the direction of tape travel is from left to right, or, as in the illustration with the Regentone recorder, from right to left. The direction of travel for the 200 ft of tape usually supplied with the cassette must thus be specified when ordering. The cassette costs £6 12s 9d with tape and £6 6s without. The address of the manufacturer is Guy's Calculating Machines, Ltd., Truro Road, Wood Green, London, N.22.

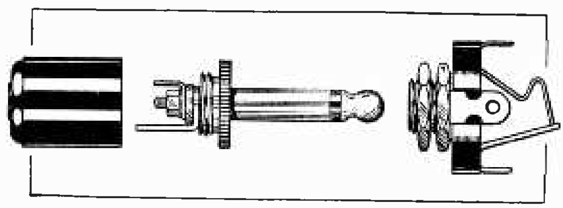
"Brittape" endless loop tape cassette.



Miniature Plug and Jack

THE new Bulgin P519 plug and J30 jack are designed for use in modern miniaturized equipments and their small size makes them particularly suitable for this purpose. The plug is the familiar "concentric" type with a shank measuring $\frac{3}{16}$in in diameter. It has a $\frac{1}{2}$in diameter phenolic screw-on cap and with the plug seated this projects about $\frac{7}{8}$in from the panel.

Phenolic insulation is used for the jack which is fitted with a $\frac{5}{16}$in diameter fixing bush which fits metal panels up to $\frac{1}{8}$in thick. The fixing bush is also the contact for the shank of the plug and this will normally be "earthy." Two spring contacts are provided, one for the tip of the plug and another which mates with this spring when the plug is withdrawn. Maximum ratings are: current 1A, voltage 50, loading 10W. Test voltage is 250.



Bulgin miniature P519 plug and J30 jack.

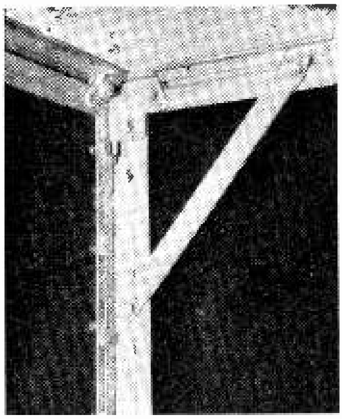
The makers are A. F. Bulgin and Co., Ltd., Bye Pass Road, Barking, Essex, and the prices are 2s 6d for the plug and 3s for the jack.

New Rack-mounting Principle

THE convenience afforded by the 19-in Post Office rack has made it an almost-standard form of mounting for electronic equipment; but it does suffer from several disadvantages—these being mainly cost, due to the number of tapped holes necessary, and the difficulty of excluding dust from the apparatus or providing forced-air cooling.

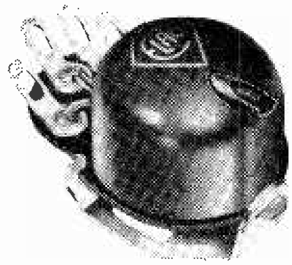
The new Widney-Dorlec rack-mounting system (also see R.E.C.M.F. review, May issue, p. 216) represents an effort to overcome the major disadvantages and, at the same time, it increases considerably the scope of the prefabricated cabinet system. The tapped-hole problem is overcome by the use of a pressed metal strip which holds against the front member of the cabinet at $1\frac{3}{4}$in spacing, rectangular nuts providing two threaded holes on $\frac{1}{2}$in centres: these are used only where they are required for the mounting of units. Holes in the cabinet-frame strip are drilled using the backing strip as a guide and any desired thread may be fitted by using the appropriate nut: the nut may be retained, if necessary, by a screw passed into it from the rear, through the stamped strip.

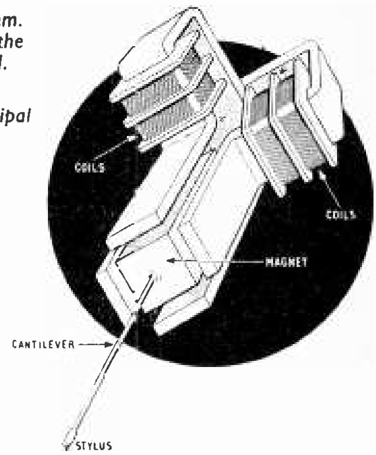
This system can naturally be used with any suitable Widney-Dorlec assembly; but the new "cubicle" cabinet for which it was designed offers some advantages. If units are mounted with their front panels exposed, the



Left: View from inside of cabinet of new system. Note that it is necessary to drill holes in the front member only where they are required.

Illustration and (right) sketch of principal parts of Elac stereo pickup cartridge.





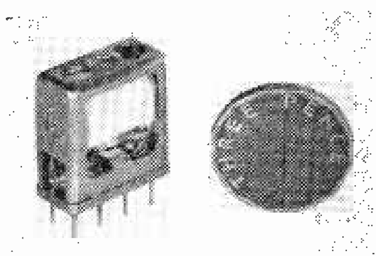
cubicle doors give side access to the chassis; however, by turning the cabinet through 90° and fitting ready-drilled bearers running from front to back equipment may be mounted so that the door closes on the front panels, still using the rectangular nut mechanism for securing the units. The makers are:—Hallam, Sleigh & Cheston, Ltd., Oldfield Road, Maidenhead, Berks.

Sub-miniature Relays

A hermetically sealed, miniature relay which measures 0.875in × 0.8in × 0.396in and weighs only 0.52oz is now obtainable from C. P. Clare Ltd., 70 Dudden Hill Lane, London, N.W.10. This is the Clare Type "F" relay, and is made under licence from the C. P. Clare Co. of Chicago, U.S.A.

Type "F" is a 2-pole 2-way relay with contacts rated at 3A at 28 volts d.c. or 115 volts a.c., the nominal operating power being 250mW. The "make" time is 3.5 msec and the "fall-out" time 1.5 msec. A balanced armature form of construction is adopted and the relay is claimed to withstand considerable shock and vibration.

The relay is designed especially for use in printed



Clare Type "F" relay with a 3d coin outline for comparison of size. Cover cut away to show internal assembly.

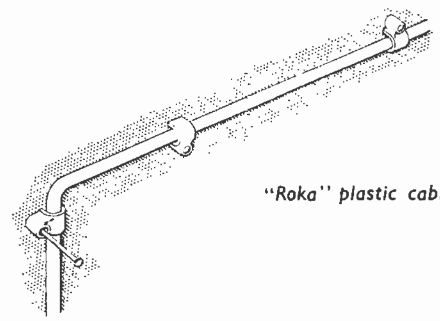
circuits and the glass-to-metal seal contact tags are spaced 0.2in apart in two rows also 0.2in apart.

Two Stereo Pickups

IN both the Elac stereo pickups types STS200D and STS300D there is a gap at each side of the square cross-section magnet so that a balanced system with two pairs of gaps is formed (see sketch). The compliance at the 0.7 × 10^{-3}in radius diamond tip is stated to be 4.1 × 10^{-6}cm/dyne for both these pickups, and they each produce about 4% intermodulation distortion for recorded lateral velocities less than about 22cm/sec (using 400 and 4,000c/s with an amplitude ratio of 4 to 1, and a tracking weight of 5gm). The crosstalk for the STS200D is given as about −20dB at frequencies up to 5kc/s, rising to −10dB at 10kc/s: the crosstalk for the STS300D is about 4dB less than these figures. The effective mass at the stylus tip is stated to be 2.5mgm for the STS200D and 2.16mgm for the STS300D. The STS200D costs £17 17s 7d and the STS300D £27 12s 10d, both these pickups being distributed in this country by Thermionic Products (Electronics) Ltd., Hythe, Southampton.

Plastic Cable Clip

THE illustration shows a novel plastic cable clip of German design made of tough polystyrene. It is admirably suited for fixing television coaxial down leads and



"Roka" plastic cable clip.

extension-point cables, also the wiring to extension loudspeakers, to walls or wood surrounds.

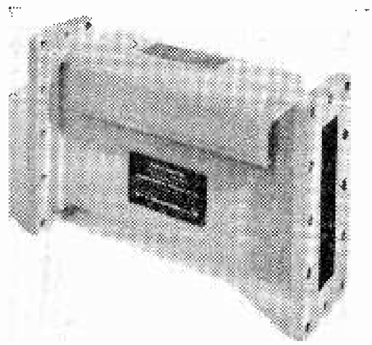
Known as "Roka" plastic clips, they embody a captive hardened-steel nail, a feature which greatly facilitates fixing the clip in awkward places.

Clips are available for cables of from $\frac{1}{8}$in to $\frac{3}{8}$in diameter, and prices vary with size. For example, clips for a $\frac{3}{16}$-in diameter cable cost 2s 5d a hundred, while for $\frac{1}{4}$-in cable the price is 4s 3d a hundred.

Further details can be obtained from Perihel Ltd.. 146 New Cavendish Street, London, W.1.

Ferrite Isolators

ABOUT 30dB isolation at any selected frequency in three ranges (1.8 to 2.3, 3.3 to 5.5 and 8.1 to 12.5kMc/s) falling to about 20dB 5% away from the selected frequency, is provided by a new range of isolators introduced by Marconi's. The power handling capacity is 80W for isolators in the 8.1 to 12.5kMc/s range and 20W for those in the other two ranges The cost of

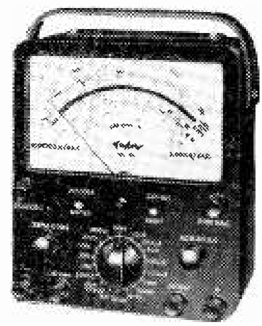


Typical ferrite isolator (centre frequency 2kMc/s) in the new Marconi range.

each isolator is £45 or £50 depending on the frequency range, and they are manufactured by Marconi's Wireless Telegraph Co., Ltd., of Chelmsford, Essex.

Multi-range Meter

IN the new Taylor model 100A a sensitivity of 100,000Ω/V on the d.c. ranges has been achieved by using an 8μA centre-pole movement. This movement can withstand a momentary overload of 100 times and a cut-out is incorporated, whose operating time and current have been used to determine the rating of all the meter resistors. Those resistors across which the voltage drop is measured on the ohms ranges are protected against the application of a.c. by a rectifier which produces a d.c. current to operate the meter cut-out, but which does not conduct when the internal battery is connected on the ohms ranges. All the d.c. and a.c. range scales are coincident except for the most sensitive a.c. range (10V f.s.d.), thus avoiding most of the confusion produced by offset a.c. calibrations. This has been achieved by using a "half-bridge" rectifier on the a.c. ranges with selected loading resistors (the two resistors which replace two of the rectifiers in the full bridge). A double-section half-wave rectifier cannot be used, for on application of d.c. of incorrect polarity to one of the a.c. ranges, one section of the rectifier would short circuit the meter and render the cut-out inoperative. Another useful facility is a push-button for interchanging the connections to the meter so that inputs of the incorrect polarity can be measured without reversing the connecting leads. The 8 internal d.c. voltage ranges on this meter extend from 0.5V to 2.5kV f.s.d. and an external adaptor (available at extra cost) containing a 2.25MΩ resistor enables measurements to be extended up to 25kV f.s.d. The current ranges extend from 10μA to 10A d.c. f.s.d., and the ohms ranges from 20Ω to 2MΩ centre scale. Decibel and output ranges are also provided. This meter costs £31 10s and is manufactured by Taylor Electrical Instruments Ltd., of Montrose Avenue, Slough.



Taylor multi-range meter model 100A with 100,000Ω/V sensitivity on d.c. ranges.

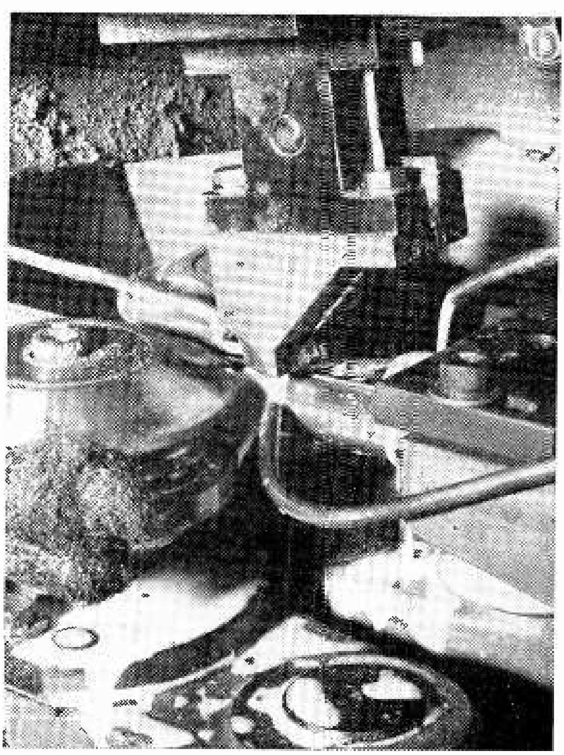
High-Speed Tube Production

Continuous Seam Welding with R.F. Current

A MACHINE recently imported from America by Elm Engineering Ltd (one of the Antiference group of companies) is capable of welding together the edges of rolled-aluminium or rolled-aluminium-alloy tube at speeds up to 400 ft/min.

Aluminium strip is formed into tube by passing it through a series of rollers, each of which imparts an increased degree of curvature to the strip until it forms a tube with a split in it corresponding to the edges of the original flat strip. About 50kW of r.f. power at 450kc/s is applied to the edges of the split by two copper shoes and then the tube passes through another pair of rollers which force the edges together. As the r.f. current is discouraged from taking the "long" path round the circumference of the tube by a ferrous core, an intense heating effect, resulting in the melting of the edges is produced at the join. The squeezing action of the rollers expels nearly all the molten material giving a weld with only a small section of grain structure differing from that of the rest of the tube. After the welding process the expelled material over the weld is removed and the tube passes through a further set of rollers to bring it finally to size. The machine accepts strip of 14 to 22 s.w.g., can produce tubes of outside diameter ½in to 1½in and can weld metals other than aluminium and its alloys.

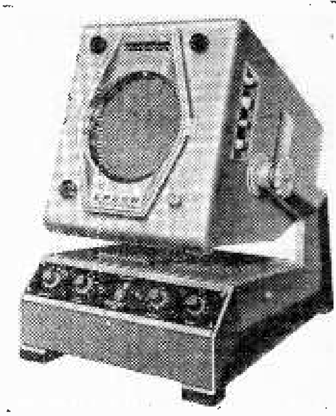
The welding process is known as the "Thermatool" process and it was developed, and the machine made, by the New Rochelle Tool Corporation, New York, U.S.A.



"Thermatool" tube-welding process in operation. Tube moves from right to left; picking up r.f. from copper shoes.

NEW MARINE RADAR

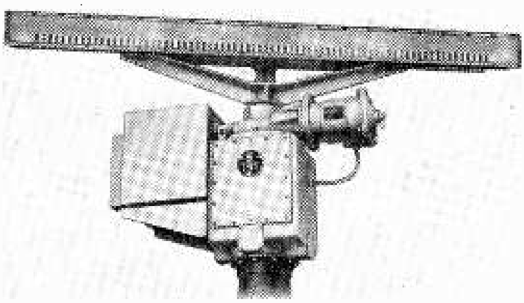
Details of the B.T.H. "Escort" Motion-Stabilized Equipment



Display and "Chart-Plan" control unit of B.T.H. "Escort" marine radar. Controls (such as local oscillator tuning) which should not need resetting during operation are concealed by drop-flap below "Chart-Plan" control knobs.

ONE of the problems associated with the use of radar and similar complex electronic devices is that the large number of controls provided usually either scares away the non-technical user, or leads to inefficient operation of the equipment. In an effort to overcome this problem B.T.H. in their new "Escort" 3-cm, motion-stabilized marine radar, have reduced the number of "user controls" to the absolute minimum—four relating to the motion-stabilized display, such as tide speed and direction; four for actually using the display (bearing graticule, range scale, etc.) which are mounted on the front panel, and eight subsidiary controls, e.g., marker brightness, i.f. gain, anti-clutter, etc. These last eight controls are mounted on the sides of the indicator unit and each has a differently-shaped knob for immediate and easy identification by touch.

The radar follows the general lines of any modern marine radar with a stabilized display (called "Chart Plan" by B.T.H.) but many small "convenience features" provide for ease of handling; for instance the bearing marker is differentiated from the heading marker by starting it from the continuously-variable range ring. This marker "paints" each time the radial scan



Aerial system of "Escort" radar. No parts other than turning gear and echo box are mounted with the aerial, so easing servicing problems.

passes over its position: normally the resetting of the marker occupies several revolutions of the aerial; but in the "Escort" the whole procedure is much simplified by ganging the electronic bearing-marker angular control to the parallel-ruled c.r.t. graticule. Thus it is necessary only to line up the graticule to line up the bearing marker; also a control knob and a scale are dispensed with, for the graticule has a scale calibrated in degrees round its edge. Another feature which should prove most useful is that, on switching from a "ship's-head-up" display to the compass-stabilized "north-up" display no manual realignment of heading and course markers is necessary—this is done automatically.

Five malfunction indicator lamps are fitted just below the c.r.t.—these automatically indicate an abnormal condition of the equipment. Another feature is that an echo box is joined permanently to the waveguide; but it is "disconnected" normally by a ferrite isolator: switching-in this provides a very quick check that the equipment is operating, a fact which need not necessarily be apparent in the absence of echoes.

The slotted-waveguide aerial, fairly high p.r.f. (1200/sec) and short minimum pulse-length (0.12μsec) combine to provide a high-definition picture on the 12-in c.r.t. and the 45kW transmitter peak-power output ensures that the smallest scale of 48 nautical miles can be used effectively The power input required is 1.3kW and, as a motor-generator with an electronic voltage regulator is used to supply the equipment practically any ship's mains can be used. The "Escort" weighs about 1,000 lbs in all and the cost is in the region of £3,000, excluding waveguide, cabling and installation.

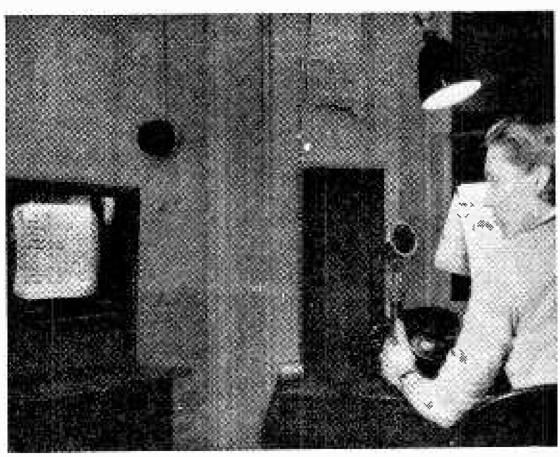
Data-Handling at King's Cross

AT a main-line railway station information concerning the running of trains has to be passed from its source (the signal box) to several other people such as the enquiry-office staff, the station announcer and the arrival-indicator operators. In the past this has been done by telephone, which suffers from the disadvantages of demanding the whole attention of the users and of providing a considerable risk of cumulative errors.

In an effort to improve efficiency British Railways have arranged with Decca Radar Ltd. to install the Deccafax* system at King's Cross terminal station for a trial period.

The flying-spot transmitter unit is housed in the signal box and information is written on a prepared transparency. At the receiving units a change in the information recorded is announced by the ringing of a bell. Apart from reducing the work in the signal box to the writing-in of times as they are received from stations down the line, the information is presented for as long as it is required and in such a way that it is possible to gain an overall picture of train movements into the station. The system uses the 405-line, 50-frame, positive-modulation standard and the video signal is carried on coaxial cable at a level of about 1½V.

* *Wireless World*, October 1957, p. 470.



Station announcer at King's Cross reads details from Deccafax screen.

News from the Industry

Relay Exchanges Ltd.—The annual report of Relay Exchanges for 1958 reveals that the group's total assets are now over £12M, compared with £7.6M at the end of the previous year. The value of television and sound receivers installed in subscribers' homes accounts for over £9M of the assets. During last year the group, which includes the Rentaset companies, acquired the whole of the share capital of Goodmans Industries. After providing for taxation, the group's profit for 1958 was £391,276 against £236,288 the previous year.

T.C.C.—In his statement at the annual general meeting of the Telegraph Condenser Company the chairman, D. W. Aldridge, announced a net profit for 1958, after providing for taxation, of £187,486 compared with £131,257 the previous year. T.C.C.'s wholly owned subsidiary, the United Insulator Company, has since April last year operated as a division of the parent company.

Ferranti's wholly owned Canadian subsidiary, Ferranti-Packard Electric Ltd., has developed an electronic seat reservation system which is being installed for Trans-Canada Airlines. The system uses a device known as a Transactor which is installed at each TCA booking office across Canada, and is used to send information to, and receive answers from, a central computer. The equipment will be available in this country and on the continent through Ferranti Ltd.

I.C.T.—International Computers and Tabulators Ltd. has formed a subsidiary, I.C.T. G.m.b.H., with headquarters in Düsseldorf. It will take over the existing business in Western Germany conducted through the Düsseldorf office of Powers-Samas Accounting Machines (Sales) Ltd. It is planned to open branch offices in Berlin, Hamburg, Hanover, Munich, Nüremberg and Stuttgart.

Plessey International Ltd. has set up a German manufacturing company to be known as Plessey Maschinen Elemente G.m.b.H. It will operate from Neuss, near Düsseldorf.

Elliott - Automation Ltd. has established a new subsidiary, The Swartwout Co. Ltd., to manufacture and sell the electronic control systems developed by the Swartwout Company, of Cleveland, Ohio. Two years ago, Elliotts entered into an agreement with the American Swartwout Company to handle their products in this country.

S. N. Shure, president and founder of Shure Brothers, Inc., of Evanston, Ill., manufacturers of microphones, pickups and recording heads, is arriving in this country on May 31st to investigate the possibility of establishing a factory here. Engineers and manufacturers interested in discussing such a project are invited to leave their names and addresses at the office of the Commercial Attaché at the American Embassy, London.

FIFTEEN closed-circuit television channels in the new rolling mill of the Steel Company of Wales at Port Talbot provide a composite view of about 700ft of railway track. This installation by Marconi's is for the remote observation of the conveyance of red-hot steel ingots from the soaking pits to the rolling mill.

Audio Fidelity gramophone records, produced in the U.S.A. by Audio Fidelity Inc., are now being made available in this country through its recently formed subsidiary, Audio Fidelity (England) Ltd., of 44 Crawford Street, London, W.1. The distribution of these records in London, East Anglia and South-East England is being handled by Scientific and Technical Developments, of Melbourne Works, Wallington, Surrey.

Ketay Ltd., manufacturers of synchros, resolvers, tachometer generators and other servo components, are now a Design Approved Manufacturer under the Ministry of Supply Instrument and Electrical Equipment Design Approval Scheme. The company is owned jointly by the Plessey Co., of Ilford, and Norden-Ketay Corp., of New York. Four Ketay synchros have been granted Certificates of Technical Approval by the Royal Aircraft Establishment.

Southern Instruments Ltd., of Camberley, Surrey, has made an arrangement with the Ampex Corporation of America and its U.K. subsidiary, Ampex Electronics Limited, for the manufacture and marketing of Ampex tape instrumentation equipment in Great Britain.

Winston Electronics' production during the year ended in February exceeded £500,000. F. W. Reynolds, the managing director, recalls that the first year's output (1950/51) was £15,000.

Pye closed-circuit television equipment, including a new lightweight cylindrical camera, has been installed in the Conservative Party's television studio in London. The studio is employed mainly for the training of M.P.s and candidates in the use of the medium.

Leland Instruments' old address was given in the note on the Leroux measuring relays on p. 247 of our last issue. They are now at Abbey House, Victoria Street, London, S.W.1. (Tel.: Abbey 3585.)

Tube rebuilding service operated by C.R.T. Ltd., of Baldock, Herts, is to be known as C.R.T.'s TV Tube Exchange Service. The reduced prices recently introduced by C.R.T. Ltd. take into account the supply by dealers of an old tube for re-gunning.

Mayra Electronics Ltd., manufacturers of Maykit car radio kits, have moved from North London to 118, Brighton Road, Purley, Surrey (Tel.: Bywood 1263). The newly appointed general manager is Maurice Reed.

Mullard.—Two new laboratory blocks are being built on a site adjacent to the existing buildings of Mullard Research Laboratories at Salfords, Nr. Redhill, Surrey. An extra 45,000 square feet of floor space will be provided by the new buildings. They will house the electronics, telecommunications, transistor applications and television laboratories. The company is also to build a new factory on a site next to their existing cathode-ray tube factory at Simonstone, Lancs. It will produce glass for the production of tubes, which is at present purchased as pre-fabricated parts.

Marconi's are to supply the Post Office with the equipment for a wide-band u.h.f./s.h.f. radio link between Birmingham and Norwich. The twin-path bi-directional link will carry the B.B.C. television programmes between the two cities and serve *en route* the transmitter being built at Peterborough. The equipment at these three centres and at the three repeater stations will employ English Electric Valve Company's travelling-wave tubes.

E.M.I. colour television equipment was used to enable a large audience at a recent Anatomical Society symposium in University College, London, to see, on a 4-ft by 3-ft screen, experiments being carried out under an electron microscope. The demonstration was arranged by Smith, Kline and French Laboratories Ltd.

Ekco airborne search radar has been ordered by British European Airways for six de Havilland Comet 4Bs now being built. B.E.A.'s flight of Comet 4s is already fitted with Ekco radar.

Siemens Edison Swan supplied the marine radio equipment for the recently opened radio officers training school in the College of Technology, Belfast.

EXPORT NEWS

Iran.—The v.h.f. multi-channel radiotelephone/telegraph system installed by Marconi's along the National Iranian Oil Company's 600-mile pipeline from Abadan to Teheran is to be extended. The extension, which will link five new booster pumping stations with the main v.h.f. installation, calls for the supply of 20 multi-channel equipments together with aerial towers. The carrier equipment is being supplied by the Telephone Manufacturing Co.

Radiotelephones.—Pye Telecommunications have been awarded a contract by the Iranian Oil Operating Companies to install a 12-channel radio communications system between Kharg Island in the Persian Gulf and the oilfields at Gachsaran and Agha Jari, a distance of 160 miles.

Multi-channel Radio Link.—The Posts and Telegraphs Administration of Finland has placed a contract with Marconi's for the supply of s.h.f. radio terminals and repeaters for a single-path 600-channel two-way radiotelephone link between Pori and Tampere, a distance of 65 miles.

Computer for Australia.—An EMIAC II two-module analogue computer has been ordered from E.M.I. Electronics, Ltd., for installation in the Australian Government Aircraft Factory at Melbourne.

Film scanning equipment for a new commercial television station in Brisbane, Australia, which is scheduled to be opened later this year, has been ordered from E.M.I. Electronics.

Navigational Equipment. — Two Decca Navigator chains are to be erected in the Persian Gulf. It is planned that these chains will be brought into operation at the end of this year.

Radar Simulator.—The Royal Swedish Air Board has purchased a Solartron ten-target early-warning and height-finding radar simulator for the country's Air Force.

I.L.S.—The government of the Belgian Congo has ordered the Pye Instrument Landing System for Elizabethville and Leopoldville airports.

Telecommunication measuring equipment valued at $200,000 has been ordered by the Canadian Department of Defence Production from Marconi Instruments through the Canadian Marconi Co. In all, nearly 200 instruments, including signal generators, portable frequency meters, oscilloscopes, wave analysers and transmission test sets are to be supplied.

Radar.—Seven double-ended ferry boats operating between Brooklyn and Staten Island, New York, are to be fitted with Decca Type D303 radar. Each boat will carry two radar sets.

Airborne search radar with Doppler drift measuring equipment is being supplied by Ekco Electronics for the Viscount fleet of Kuwait Airways.

Valves and C.R. Tubes.—As part of a drive to extend their sales of valves and tubes in North America, the M.O. Valve Co. has seconded F. T. C. Dixon to their agents, British Industries Corporation, of New York. Mr. Dixon was previously in charge of cathode-ray tube sales at the company's Hammersmith works.

Honduras.—Agencia René Sempé, of Apartado 219, Tegucigalpa, wish to represent a U.K. manufacturer of television receivers. A television service operating on the American 525-line standard is starting shortly.

RANDOM RADIATIONS

By "DIALLIST"

Improving East Anglian TV

TO those who live in East Anglia it is good news that a two-way radio link between Tacolneston and Birmingham is to be built. At present the Norwich station receives its television programmes by direct pick-up of the Crystal Palace transmissions at a receiving station near Bury St. Edmunds, whence it is routed by a radio link to Norwich. Reception can be very good over a wide part of the area and it's much improved since Tacolneston's e.r.p. was raised. But one big disadvantage of a long-distance pick-up system is that it is apt to gather in other things besides the wanted signal. And once received interference has willy-nilly to be relayed. The result has been that under certain conditions pictures have been no better than fair to moderate. I'll willingly admit that interference bad enough to spoil the picture has been but rarely in evidence lately. But one is sometimes conscious that the picture, though worth looking at, ought to be better than it is. I understand that even after the introduction of the new link Tacolneston will still have to rely for some time on the direct pick-up of a main station but this time it's Sutton Coldfield. However, this will be dispensed with when the radio links have been completed. When the I.T.A. station at Mendlesham, with its huge mast and high e.r.p. gets going, too, East Anglia should find itself very well served by television.

Peterborough, Too

In addition to linking Tacolneston with Birmingham, the proposed link will serve *en route* the B.B.C. station being built at Morborne Hill, near Peterborough. The project will be carried out in two stages. At the end of this year a u.h.f. twin-path one-way link will be installed between Norwich and Peterborough where a B.B.C. receiving point will pick up the Sutton Coldfield programmes which will then be sent along the link to the Tacolneston station. The final installation will consist of a twin-path bi-directional link over the whole distance with three intermediate repeater stations. At Peterborough back-to-back terminals will be employed which provide complete modems (modulation/demodulation facilities) making it possible to extract a programme at that point to feed the new transmitter or to feed in a broadcast originating in the Peterborough area.

A New Use for Radar

READERS who were concerned with p.p.i. radar receivers at the beginning of the war may remember those mysterious, large illuminated patches which sometimes appeared on the screen, usually at night-time. They were specially in evidence during the spring and autumn months and often covered large areas of the screen. It was established that they weren't due to high flights of aircraft and some wag suggested that they must be echoes from flocks of angels winging their way over the sky. The name "angels" stuck. It was eventually established by using powerful telescopes on clear, moonlit nights that the fliers were not 'planes or angels, but birds. In spring and autumn birds migrate in vast numbers, and so dense are the flocks that they give rise to good radar echoes. For some little time now both p.p.i. tube and height-range radar have been in use for studying bird migration and quite remarkable results have been obtained. The big snag is that individual species can't be identified—there's no ornithological equivalent of i.f.f.—but it's often possible to deduce the identity from the height, speed and size of the flocks, from the direction they are taking and from the fact that birds have previously been seen massing for migration in this place or that, or that tired incoming migrants are seen in certain areas on the following day.

Transatlantic Television ?

ALMOST the whole continent of Europe either is or can be linked up for television purposes and we get some very good and interesting programmes from distant parts via our cross-Channel link. What so many people would like to see realized is transatlantic television. The Americans already operate radio-links for their forces in Europe; but these are used for sound only, for so far it hasn't been possible to utilize channels wide enough for TV. There seem to be two possible ways in which it might be done. When the whole of France was served with views of the Fourteenth of July Ceremonies taking place in Algiers, the method successfully used to span the Mediterranean was to employ a circling aeroplane as a relay station.

A chain of aeroplanes circling over the Atlantic seems a possibility—though only just, for weather conditions might make station-keeping very difficult and it would at times be a risky business. But I don't see why, if the money were available, ships shouldn't be used with captive balloons to extend their effective horizon. They would remain in their allotted positions, as the weather ships now do, picking up transmissions and relaying them on. I'm sure that transatlantic television will be a commonplace occurrence one day. May that day come soon!

It All Helps

REDUCTIONS in taxation are always welcome, and I'm sure that all radio folk—manufacturers and their customers alike—were delighted by the lowering of the rates of purchase tax. This has made it possible to bring down the prices of sound and TV sets quite a bit, and it should make for increased business. Better still, to my way of thinking, is the removal altogether of purchase tax on replacement c.r. tubes. Before the budget announcement the position as regards rebuilt tubes was rather a queer one: if you got your own c.r.t. back duly renovated, it wasn't liable to tax. But should you receive one that had been someone else's, then the tax could be slapped on. Such a weird state of affairs must have meant a lot of extra work and expense in the way of checks and inspections, which couldn't have done anybody much good.

A Record to Find All Records?

WRITING from Worcester Park in Surrey, a reader tells me that he has a Marconiphone Type 702 television receiver, which was made in 1938 or '39 and is still giving good reception for about five hours every day on the screen of its original tube. When bought second-hand in 1949 it had a number of faulty capacitors, the e.h.t. transformer was out of action and one valve was dud. Otherwise it was, as my correspondent puts it, in mint condition. It has given consistantly good service since, and despite its 20 or 21 years, it shows no signs of deterioration. My correspondent's only 'plaint is that with its ⅛-in steel chassis and plywood cabinet the set needs two strong men to lift it! By the way, the serial number of the cathode-ray tube is D26019, in case makers care to check its age.

UNBIASED

By FREE GRID

Homostereo and All That

IN its early days, the B.B.C. had a well-deserved reputation of being a centre of learning and culture, and those members of the staff—other than engineers—who were not alumni of Oxford or Cambridge were apt to be looked at askance; in fact it was rumoured that even the "hewers of wood and drawers of water" were Cambridge poll men.

All that is past history, however, and today things are vastly different as can readily be seen by the B.B.C.'s patronage of a dreadful word like "monophonic" to designate single-channel reproduction as distinct from its stereophonic counterpart.

The utmost that can be said in favour of monophonic is that it is somewhat less offensive than monaural; this latter word implies reproduction which is, in some way, specially adapted for those who have the misfortune to be totally deaf in one ear. The word monophonic is, however, not very much better. To my mind, monophonic reproduction —which means one-sound reproduction—conveys the idea of a solo performance on, say, a triangle or big drum.

Many people who ought to know better are woefully ignorant of the precise meaning of words. I once knew a Cambridge man who didn't know the difference between an exhibitioner and an exhibitionist; now and again, of course, the former is also the latter. At any rate, I do not hesitate to suggest that the correct word for single-channel reproduction is "monodic"*; it is surely *le mot juste* for it does literally mean single-channel. But I don't want you to think that I want to displace the familiar word stereophonic in favour of stereodic; obviously stereophonic —solid sounding—is the correct word.

The only possible objection that could be raised is that the word monodic with its meaning of single-channel may be needed one day to describe stereophonic broadcasting on a single *radio* channel.

There is, however, a far better word to describe such a system of broadcasting, and to emphasize the fact that the two "stereo" channels are sharing the same radio channel; obviously the word is "homodic"—same channel. This would convey an unmistakable meaning. In actual practice I do not doubt that this system will come to be known by the name of "homostereo broadcasting" to distinguish it from ordinary stereo broadcasting on two radio channels which might be called "heterostereo." May we expect that the Yanks, just to be different, will fuse Latin and Greek and call it "solo stereocasting"?

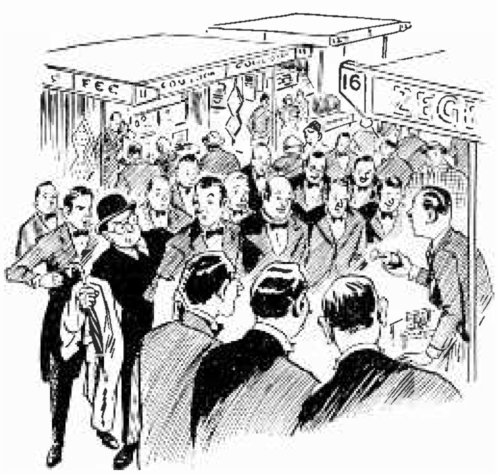
* A contraction of *monos* (one or single) and *hodos* (a way, path or channel). In such combinations the "h" is usually dropped, e.g., electrode.

Better Audio Fare.

IT is said that a rolling stone gathers no moss, but that is certainly not true of the Audio Fair of two months ago which again had a new home this year—the third in its brief history—and was as crowded as ever. Maybe, however, its organizers moved it away from the Strand area this year so that it should not gather so much Moss, with a capital M, in the form of waiter's dress, a subterfuge adopted in previous years by visitors unable to obtain an invitation card.

Even this year I was surprised at the extraordinary interest shown by the large catering staff of the hotel in which the Fair was held.

The highlight of the show was, as might be expected, stereophonic reproduction which is still a nine days' wonder. I was glad to see that the over-dramatized juggling with railway trains and suchlike things—which were a feature of the Audio Hall at last year's Radio Show —had been, to a large extent, abandoned, but I did not find the audio fare provided in the demonstration rooms very convincing.



Extraordinary interest

This was largely due to the limitations of space in an hotel bedroom. They may be roughly the size of an average living room, but certainly do not simulate the listening conditions of the home. As I explained to one exhibitor who tried to convince me to the contrary, even if *he* usually packs a dozen or more perspiring people in one half of his living room, *I* certainly do not, and nor do most ordinary people.

The arrangements in most of the demonstration rooms seemed to me to be such that only one or two of the audience were in a suitable position to perceive a stereophonic effect.

I think it would be far better if the exhibition authorities revised the order of things, and gave a separate bedroom to each manufacturer for his stand, and turned the exhibition hall into a properly fitted-up demonstration theatre. Each manufacturer could be allotted a certain period of the day for demonstrating his apparatus.

Why Psi?

LAST December I was talking about ψ (psi) waves, and I said that this symbol was probably used because it was the first letter of the word "psyche," which, among other things, means the basis of all things. I was ignorant at that time that "psi" was also used to describe such things as telepathy and other kinds of E.S.P. (extra-sensory perception), as well as ghost-hunting.

According to a book review I recently read under the title of "The Pursuit of Psi," it seems as if ψ is the label applied to anything we know little about. I still think that the symbol "psi" is short for "psyche" but I am certainly not sure. So if any of you classical "scolards" can help to lighten my darkness I shall be very grateful. I have a vague idea that ψ may be the initial letter of a word unknown to me or even to our old friends Liddell and Scott.

Talking of psi reminds me of what may be an instance of it. I recently heard from somebody who is well known in the world of audio technology. He was asked to help in tracking down strange noises heard by two aged ladies which were inaudible to others.

On the face of it, one would say that the two ladies were suffering from aural hallucinations, but their doctor gives them a clean bill of health and says that all the usual causes of "hearing things" are absent. The recording apparatus is quite deaf to these sounds, and it has been suggested that the ladies may be able to hear frequencies which are lower than those normally audible.

Personally I wonder if they "hear" the noises telepathically and wrongly think they are coming in through their ears. I am hard at work to see if I can devise something to record telepathy.