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COLOUR BRINKMANSHIP

FOR a long time now colour television in this country has been in the doldrums. Those who want to get under way and who expected a wind from the Television Advisory Committee's Report were disappointed, but they have recently received what in nautical language might be termed a puff from an unexpected quarter.

The T.A.C. Report (May, 1960) said, amongst other things: " . . . we are of the opinion that present technical and economic limitations make it undesirable to introduce a colour television system in the near future," and that "any decision with regard to the introduction of colour must follow a decision on line standards."

The Director-General of the B.B.C. in a speech to the Radio and Television Retailers' Association in London (October 25th, 1960) said: "We in the B.B.C. are ready and very eager to proceed with a small compatible colour service within the framework of our existing programme in Band I on 405-lines, without waiting for a decision on whether there is to be a future move to 625-lines in Bands IV and V . . . to wait for colour on 625-lines means that there will be no colour for a national audience for something like another ten years—and that, after the development work the B.B.C. has done during the past six years, would be most regrettable."

All very confusing and reminiscent of the ancient battle in which "those behind cried 'Forward,' and those before cried 'Back'." At least that is how it must appear to the layman who is confronted with such contradictory statements. But he should understand the feelings of the D.-G. His engineers have produced for him a beautiful toy. No one who has seen recent B.B.C. colour transmissions on a good colour receiver in any of the industry's research laboratories will deny that they are superb. Naturally he wishes to share his pleasure with others; the more the merrier, and the sooner the better. It may seem a small favour to ask of the P.M.G. that he should give permission to take the out-of-hours experimental transmissions which the B.B.C. has been putting out regularly for years, double their duration and include them in regular broadcasting hours: a start would have been made. A start of what? Not of colour television; that was made by the B.B.C. nearly six years ago. The start of a service, and we should be over the brink.

Once a service is started anything may happen. The public may cold-shoulder it on the score of cost, or a few Joneses may set the pace, and industry may be inundated with orders from their neighbours before it is in a position to meet the demand. If it decides to supply the die will have been cast and the pattern will be difficult to change.

Six years ago the Americans took the plunge and committed themselves to the N.T.S.C. system which, with the shadow-mask three-gun tube and with competent handling, is capable of giving superb results, but which failed to fulfil in the field the high promise of its sponsors. As a result of the American experience significant improvements have been made in receiver stability and reliability, but the three-gun shadow-mask picture tube, to the characteristics of which the N.T.S.C. system is tailored, is costly and likely to remain so. More important, the formulation of colour information in the signal has been compromised in its favour to produce an improved, though still not technically perfect, overall system performance. In so doing, difficulties have been placed in the way of the development of alternative and cheaper display tubes. These difficulties are not insuperable, as the article on a single-gun beam-indexing tube, which starts in this issue, will show, but a strong case can be made[1, 2] for complete independence of brightness and colour information to give more freedom for possible future developments. In other respects the N.T.S.C. standards were a masterpiece of ingenuity and the basic concepts leading to compatibility with ordinary black-and-white television will no doubt be retained in any future standardization.

At the moment the shadow-mask three-gun tube undoubtedly leads the field, but it is being strongly challenged by single-gun tubes[3] of various types which are cheaper to produce, and if proved and adopted could help to remove the present obstacles of high first cost and maintenance. In the running are electro-luminescent and eidophor (oil film light gate) methods, and there may be as yet unknown outsiders working their way up towards the leaders.

On the present showing the B.B.C. has undoubtedly backed a winner in the shadow-mask tube, which even removes the lininess from the 405 standard! But it has also made sure of success by giving it the N.T.S.C. track to run on; other promising runners have at times found the going a little hard. The B.B.C.'s proper function is to provide and maintain the track, not the horses, and the choice of going will be the privilege and the duty of the Postmaster General after hearing the advice of the Pilkington Committee. They have called for evidence and it is now up to industry to bring out all those promising ideas on which they have been working for so long, so that their requirements may be taken into account in arriving at colour standards which are fair to all, and will endure.

[1] "N.T.S.C. Colour Information," by E. L. C. White. *Wireless World*, February, 1957.

[2] "An Alternative Colour TV System," by E. J. Gargini, *Wireless World*, August, 1957.

[3] "Single-Gun v. Three-gun Tubes: Their Influence on Colour Receiver Design," by R. N. Jackson, *Journal of the Television Society*, April-June, 1960.

Beam Indexing Tubes

1.—AN ALTERNATIVE TO THE SHADOW-MASK PRINCIPLE FOR COLOUR TELEVISION DISPLAYS

By IAN MACWHIRTER,* A.M.I.E.E.

The deficiencies of the shadow-mask colour display tube are outlined and proposals are made for the design of a tube which is completely free from these deficiencies. It is shown that the N.T.S.C. type of colour television signal is not suitable for direct application to the new tube and means are described for transforming the N.T.S.C. signal into a suitable form. The problems of synchronizing the colour signal with the instantaneous beam position are discussed and various solutions are suggested.

Comments are made on the advisability of modifying the formulation of the N.T.S.C. type of signal into a form better suited to the new display.

THE Television Advisory Committee has made no specific recommendations to the Postmaster General in connection with colour television standards.[1] Potential manufacturers of colour display tubes now have an opportunity for investigation of the usefulness of display tubes other than the shadow-mask tube. It is clear that had the early introduction of a public colour television service been recommended in the United Kingdom, the manufacturers of colour receivers would almost certainly have had to use a three-gun shadow-mask cathode ray tube. This tube, pioneered by R.C.A., has now been engineered to a standard with which all new developments in single unit colour display tubes will be compared. There are, however, operational shortcomings which are well known and can be briefly stated as follows:—

1. Only a small percentage of beam current reaches the phosphor because of shadow-mask trapping. Result: the maximum useful high-light brightness is limited to some 20ft. lamberts.

2. Because the phosphors have unequal efficiencies and because cathode ray tube guns have power-law characteristics, it is not easy to match the three guns in operating conditions. Result: the grey scale requires critical adjustment.

3(a). Each of the three beams must be individually aligned to excite the appropriate phosphor dots exclusively and completely. Result: incorrect purity adjustment will cause a colour shade in the picture both in brightness and in hue.

3(b). The three beams must converge on to one trio of phosphor dots. Failure of this requirement will cause colour fringing around the boundaries of picture components quite independently of the three differential driving voltages applied to the tube.

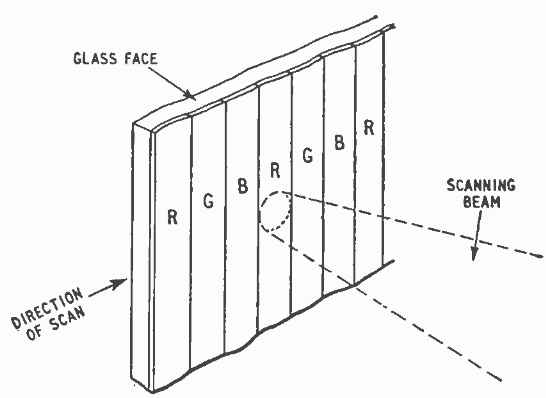


Fig. 1. Enlarged section of screen showing vertical phosphor strips.

4. Presently available tubes have a deflection angle limited to some 70°. Result: the tube is significantly more bulky than a 110° black and white tube of similar screen area.

A fundamental drawback is that the three-gun shadow-mask tube is difficult and expensive to make. Moreover, the tube must be used with a variety of magnets for convergence, beam-positioning and field purity, all of which help to increase receiver costs.

Proposed Solution. All four operational drawbacks may be obviated with the use of a single-gun tube whose beam can scan sequentially a series of tricolour phosphor strips; such strips may be arranged either horizontally or vertically, but this discussion relates primarily to tubes with vertical phosphor strips.[2,3] A steady beam current will

*Associated Electrical Industries, Ltd.

produce equal current excitation of the three phosphor strips during scanning and it is a fundamental requirement of this type of tube that the relative efficiencies of the phosphors should be balanced, so that white light is produced for a steady beam current. Small errors in the white point may conveniently be adjusted by means of external colour-correction filters.

The inevitable decrease in brightness caused by the balancing of the phosphor efficiencies, mainly in the green, can be alleviated if an elliptical spot is used whose minor axis is no greater than the width of a phosphor strip, and whose major axis is such that the scanning lines almost touch, i.e., satisfy the conditions for a "flat field." The brightness of a tube with such a gun can be as good as a modern black and white tube.

Fig. 1 is a drawing of a cutaway portion of the screen of such a tube, but the phosphor strips need not necessarily be contiguous as shown. It is of some importance that should the beam "spread" with increasing video drive, the intended excitation of, say, one primary should not be accompanied by unwanted partial excitation of the other two primaries.

Ideally, there should be a sufficient number of colour phosphor triplets such that the highest frequency component of the video luminance signal would be unable to excite less than one complete triplet of colour phosphors; it is axiomatic, then, that the average eye would be unable to resolve the individual colour strips at a normal viewing distance. In other words, a normal video signal applied to the tube would appear as a black and white picture, free from purity, convergence and electron-gun differential contrast characteristics. In practice, however, the use of a coarse strip structure appears to simplify some of the circuitry to be described later, and the number of triplets is chosen by a compromise.

In order to show a colour picture, it is necessary that the beam current should be excited with voltages proportional to the colour signal when it is passing over the appropriate colour phosphor. This implies that an indicating or index mechanism is necessary to seek out the instantaneous horizontal position of the beam and to switch on, or "gate," the appropriate colour signal: red, green or blue.

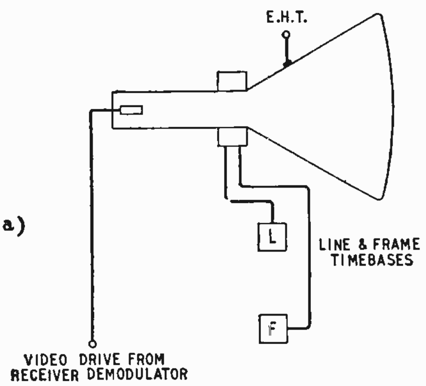
At this stage it is useful to make a comparison between the relative complexities of the following displays, a black and white, a single-gun strip phosphor and a three-gun shadow-mask. Fig. 2 illustrates this comparison. It should be appreciated that the fundamental difference between the three-gun shadow-mask display and the single-gun beam indexing display is that the former requires a three-stimuli, simultaneous-colour signal, whereas the latter requires a three-stimuli, dot-sequential signal.

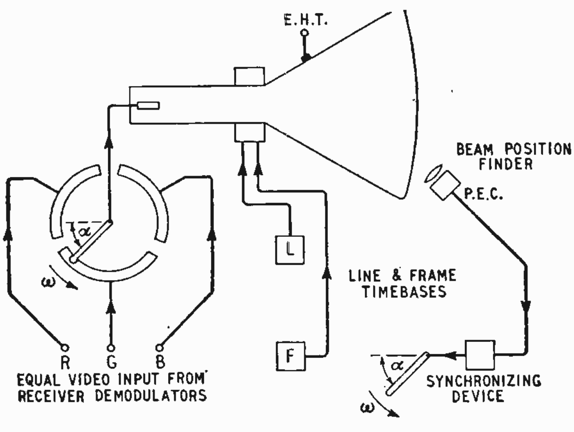
The use of a beam position indexing mechanism in a colour receiver creates great problems and some time must now be spent in understanding them.

As an introduction to this, it would be as well to see how a typical band shared colour television signal is matched by the requirements of the three-gun shadow-mask display and by a "beam position indexing" display.

A typical colour signal, e.g., the N.T.S.C. signal, consists of two parts: (i) a wide-band black and white, or luminance, signal E_Y' and (ii) two bandwidth-limited components proportional to monochromatic colour minus luminance, $a(E_R^{1/\gamma} - E_Y')$, $b(E_B^{1/\gamma} - E_Y')$ which doubly modulate a carrier in balanced

(a)





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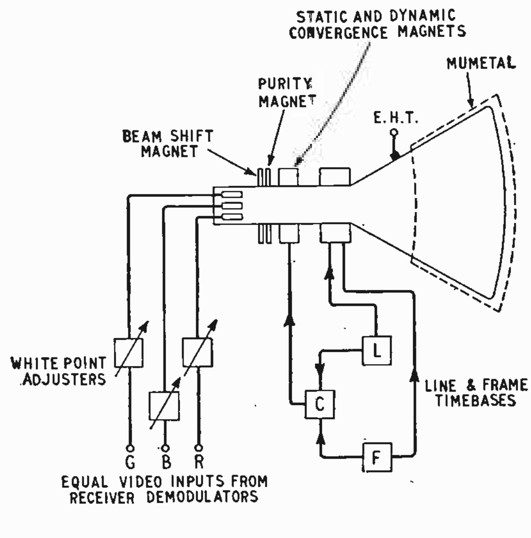

(c)

Fig. 2. Basic elements of (a) a black and white display, (b) a single-gun beam sensing display, (c) a shadow-mask display.

modulators, and these constitute the chrominance signal.[4] (The carrier of single frequency is divided into two orthogonal components, i.e., a quarter of a cycle apart, before the modulators). The composition of the luminance signal E_Y' is of some importance; starting with three suitable reproducing primaries, the amounts of red, green and blue are proportioned according to their relative contributions to luminance, which give rise to the visual sensation of brightness. This is because the colour difference channels are scaled so that they contribute nothing to brightness; this brightness reproduction is left entirely to the luminance signal. For N.T.S.C.

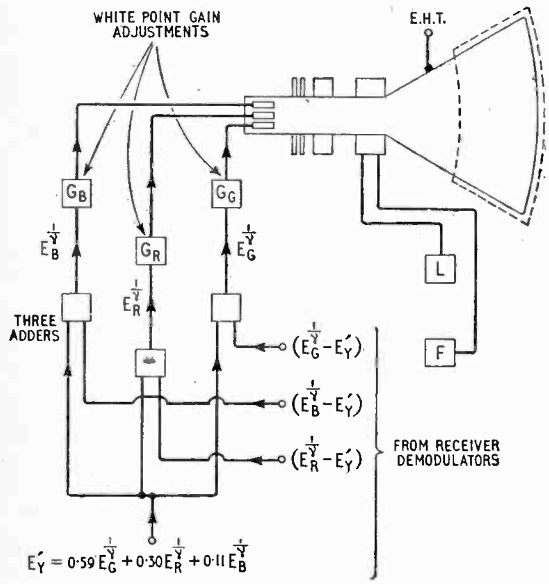

Fig. 3. In a typical display, $G_G = G_B = 0.7G_R$, but may vary with different phosphor conversion efficiencies.

primaries and for a normalizing white of 6,500°K, $E_Y' = 0.30\, E_R^{1/\gamma} + 0.59 E_G^{1/\gamma} + 0.11 E_B^{1/\gamma}$.

The colour difference signals $(E_R^{1/\gamma} - E_Y')$, $(E_B^{1/\gamma} - E_Y')$ and the derived $(E_G^{1/\gamma} - E_Y')$ when added to the luminance signal E_Y', produce colour signals for the display.[4]

Fig. 3 shows a three-gun shadow-mask display and the associated driving voltages derived from a colour signal proportioned to N.T.S.C. specifications.

If colour difference signals only are applied to the display, their relative contributions to luminance will be:

$$Y_R = 0.30\,(E_R^{1/\gamma} - E_Y')$$
$$Y_G = 0.59\,(E_G^{1/\gamma} - E_Y')$$
$$Y_B = 0.11\,(E_B^{1/\gamma} - E_Y')$$
$$\therefore Y_{total} = \sum Y_{RGB} = 0.30\ E_R^{1/\gamma} + 0.59\ E_G^{1/\gamma} + 0.11\ E_B^{1/\gamma} - 1.0\, E_Y' = 0$$

i.e., the colour difference signals themselves do not contribute to luminance changes (in a linear system). Therefore, the relative gains in the chrominance channels of the receiver may be proportioned so that an interfering signal present on all three colour difference signals will produce changes only in chromaticity of the display, i.e., constant luminance operation can be achieved. These necessary changes in relative gains are recognized in the formulation of the N.T.S.C. signal.

From the foregoing it will be appreciated that the three-gun shadow-mask tube is well matched to the N.T.S.C. colour signal.

Fig. 4 shows a single-gun beam indexing display and its associated driving voltages from which it will be seen that the N.T.S.C. simultaneous colour signal is transformed into a dot sequential signal by means of gate circuits. Again the display exhibits constant luminance but the three gate circuits must either be very linear in order to preserve the inherent perfect grey scale of the single gun tube or they must gate colour difference signals.[5,6]

The composition of the luminance signal which results in the smallest voltage swings in the colour difference gates, has equal weightings by red, green and blue.

Thus $E_L' = \frac{1}{3}E_R^{1/\gamma} + \frac{1}{3}E_G^{1/\gamma} + \frac{1}{3}E_B^{1/\gamma}$.

From this it is possible to predict the maximum excursion of the colour difference signals, and how these are matched to the permissible amplitude swing of the video signals in the gates for linear operation. If a saturated primary colour is transmitted, e.g., blue, then $E_L' = \frac{1}{3}$, since $E_R^{1/\gamma} = E_G^{1/\gamma} = 0$ and $E_B^{1/\gamma} = 1$, $\therefore$ $(E_B^{1/\gamma} - E_L') = 1 - \frac{1}{3} = 0.67$. Now let the complementary colour yellow, be transmitted then

$$E_L' = \tfrac{2}{3},\ \text{since}\ E_R^{1/\gamma} = E_G^{1/\gamma} = 1\ \text{and}\ E_B^{1/\gamma} = 0$$
$$\therefore (E_B^{1/\gamma} - E_L') = 0 - \tfrac{2}{3} = -0.67.$$

Thus the peak excursion of the $(E_B^{1/\gamma} - E_L')$ signal is from $+ 0.67$ to $- 0.67 = 1.33$. Because of the composition of the luminance signal, the peak excursion of all three colour difference signals is 33% greater than for single primary signals. This means that the gates must be designed to accept this increase in voltage swing. However, small differential contrast errors will not be objectionable since, for neutrals, the colour difference signals vanish.

A better use of the display tube would be one in which the chrominance signal is applied directly to the tube and so allows the sequential scanning of the colour phosphors to " gate " the chrominance signal at the appropriate time intervals.[7] Assuming that the line scanning is linear and that the phosphor strips are of equal width, the separation of vector components of the chrominance signal should be equi-angular rather than that of the N.T.S.C. signal formulations. A suitable chrominance vector signal is shown in Fig. 5, and superimposed is the N.T.S.C. chrominance signal which has been merely redrawn with three vector components.

Two points arise from this new chrominance vector.

1. The angular rotation, i.e., colour switching frequency, is decided by the number of phosphor strips on the screen. This frequency should be a little higher than the sub-carrier (if the visibility of the strip structure is not to be objectionable at a

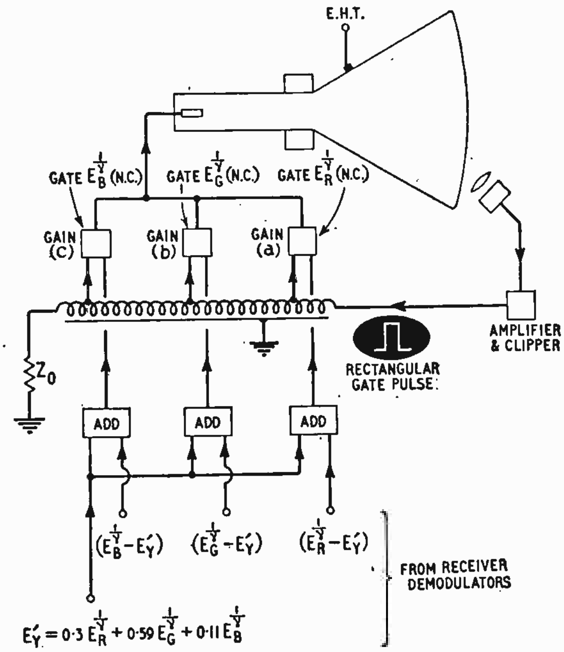

Fig. 4. Essential elements of a single-gun beam indexing display.

normal viewing distance), and it will vary if the line sweep is non-linear, or if the amplitude of the line sweep changes. Means must therefore be provided for synchronizing the new chrominance vector to the colour switching rate.

2. The vectors are shown as having equal amplitudes and the reason for this may not be immediately obvious. It will be recalled that in the design of a three-gun shadow-mask receiver, the gains in the colour channels (either in the three demodulators or in subsequent amplifiers) are such as to achieve constant luminance and the relative amplitudes of the transmitted colour vectors match the receiver requirements. Now the three " demodulators " of the single-gun display are made by the screen structure itself and although the relative " gains," or conversion efficiencies, of the three phosphors may be adjusted so that an interfering signal in the band shared channel will appear with minimum luminance disturbance, the colour of the screen will no longer be white. Because the screen must show white when an unmodulated beam scans it, it is not possible to change the " gains " of the single-gun " demodulator?." Therefore an equi-amplitude chrominance vector is necessary.

In order to complement this equi-angular, equi amplitude chrominance signal, a luminance component of the form $E_L' = \frac{1}{3}E_R^{1/\gamma} + \frac{1}{3}E_G^{1/\gamma} + \frac{1}{3}E_B^{1/\gamma}$ is required to provide the residual drive signals, $E_R^{1/\gamma}$, $E_G^{1/\gamma}$, $E_B^{1/\gamma}$. (This composition also happens to satisfy the requirement giving the smallest voltage swings in the colour-difference gate circuits.)

It should now be clear that, unlike the three-gun shadow-mask display, the single-gun beam indexing tube when screened with phosphors of balanced efficiency is not at all well matched for *direct* use with the N.T.S.C. formulated signals. Even if the widths and spacings of the three phosphor strips were made to match the non equi-angular spacings of the N.T.S.C. chrominance vectors, both constant luminance operation would remain unachievable and there would be incorrect colour rendering.

It is possible to transform the N.T.S.C. luminance and chrominance components into a form suitable for a single-gun display and also permit constant luminance operation to be achieved.[8] (In practice, however, certain simplifications which do not give an exact transformation may be justified on the grounds of economy, even though the resulting colour reproduction will not be exact.)

Now the N.T.S.C. luminance signal is weighted according to the relative luminosities of the specified primaries, i.e.,

$$E_Y' = 0.30E_R^{1/\gamma} + 0.59E_G^{1/\gamma} + 0.11E_B^{1/\gamma}$$

but for the single-gun beam indicating tube, the required luminance signal E_L' is given by

$$E_L' = \tfrac{1}{3}E_R^{1/\gamma} + \tfrac{1}{3}E_G^{1/\gamma} + \tfrac{1}{3}E_B^{1/\gamma}.$$

The difference $(E_L' - E_Y')$ vanishes for a neutral colour, i.e., $E_L' = E_Y'$

$$\therefore (E_L' - E_Y') = \tfrac{1}{3}(E_R^{1/\gamma} - E_Y') + \tfrac{1}{3}(E_F^{1/\gamma} - E_Y') + \tfrac{1}{3}(E_B^{1/\gamma} - E_Y')$$

From the N.T.S.C. colour signal formulation,

$$(E_G^{1/\gamma} - E_Y') = -\,0.51\,(E_R^{1/\gamma} - E_Y') - 0.19\,(E_B^{1/\gamma} - E_Y')$$

$$\therefore (E_L^1 - E_Y') = 0.33\,(E_R^{1/\gamma} - E_Y') + 0.33\,(E_B^{1/\gamma} - E_Y') - 0.51\,(E_R^{1/\gamma} - E_Y') - 0.19\,(E_B^{1/\gamma} - E_Y')$$

$$= 0.16\,(E_R^{1/\gamma} - E_Y') + 0.26\,(E_B^{1/\gamma} - E_Y^1)$$

$$\therefore E_L' = E_Y' + 0.16\,(E_R^{1/\gamma} - E_Y') + 0.26\,(E_B^{1/\gamma} - E_Y')$$

Rewriting this in terms of N.T.S.C. colour difference signal weightings,

$$E_L' = E_Y' + 0.18\,\frac{(E_R^{1/\gamma} - E_Y')}{1.14} + 0.58\,\frac{(E_B^{1/\gamma} - E_Y')}{2.03}$$

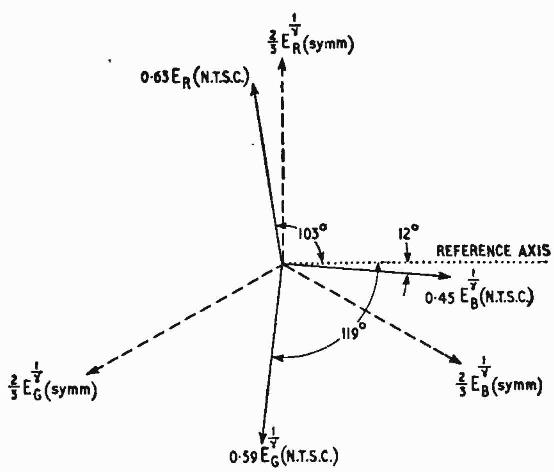

Fig. 5. Equi-angle and N.T.S.C. chrominance vectors.

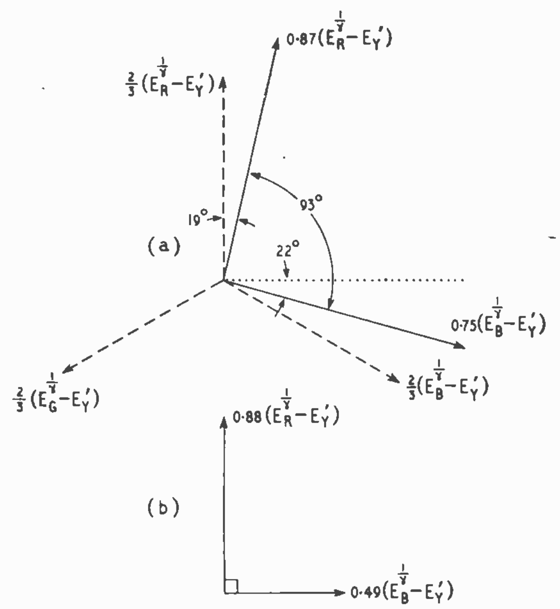

Fig. 6(a). Transformation of equi-angle vectors to two-colour difference vectors, (b) Orthogonal N.T.S.C. chrominance vectors.

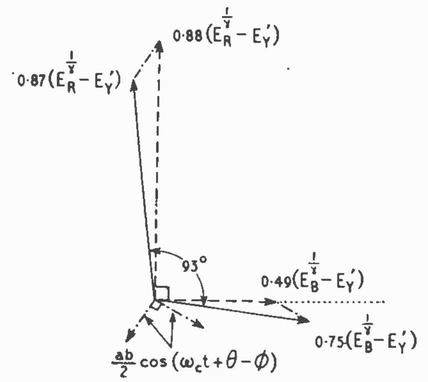

Fig. 7. Transformation of N.T.S.C. colour difference vectors.

i.e., the correcting signal ($E_L' - E_Y'$) which must be added to (E_Y') can be derived by demodulating the N.T.S.C. chrominance signal with a gain of $\sqrt{0.18^2 + 0.53^2} = 0.56$ and at an angle of $\tan^{-1}\frac{0.18}{0.53} \simeq 19°$ i.e., $0.56\angle 19°$.

It is of interest to note that the luminance correcting signal is derived directly from the two colour difference chrominance components which have been band limited. These components, i.e. ($E_L' - E_Y'$) in no way impair luminance detail since, during an achromatic transition in picture information, $(E_L' - E_Y') = 0$ and the transition is described by (E_Y') only.

The N.T.S.C. chrominance signal can be transformed into an equi-angle, equi-amplitude signal and Fig. 6 (a) shows the redrawing of the required symmetrical vectors into two colour difference vectors. In order to facilitate this transformation, a signal ($-\frac{2}{3}E_Y'$) has been added to each vector. These should be compared with the available N.T.S.C. colour difference vectors in Fig. 7, from which it will be seen that whilst the ($E_B^{1/\gamma} - E_Y'$) vector is greatly increased in amplitude, the ($E_R^{1/\gamma} - E_Y'$) vector is slightly reduced. In addition, the new vectors are no longer orthogonal, but are separated by an angle of 93°.

This vector transformation is conveniently accomplished with an amplifier whose gain is varied with the second harmonic of sub-carrier frequency, (ω_c). Let the gain $G = a\cos(2\omega_c t + \theta)$ and the input signal be $E_c = b\cos(\omega_c t + \phi)$. Then output $= GE_c = ab\cos(2\omega_c t + \theta)\cos(\omega_c t + \phi)$.

$$= \frac{ab}{2}\left\{\cos(3\omega_c t + \theta + \phi) + \cos(\omega_c t + \theta - \phi)\right\}$$

Filtering out all components above (ω_c), output $= \frac{ab}{2}\cos(\omega_c t + \theta - \phi)$. Clearly, this includes the input signal with a reversed phase sequence ($-\phi$), and this may be added in a suitable proportion to the unmodified N.T.S.C. chrominance signal, see Fig. 7. It is suggested that this proportion and the phase (θ) of the frequency-doubled sub-carrier be adjusted when observing the output signal on a calibrated vectorscope. A suitable test signal consists of colour bars containing primaries, complementaries and a neutral. In practice it has been found possible to set the vector angles to within 2 or 3 degrees of their correct value.

It will be appreciated that a beam indexing display when used with a N.T.S.C. type of signal needs to have rather complex signal translation apparatus in order to give correct colour rendition. There is, however, a further colour error for which correction should be provided. Fig. 8(a) shows a diagrammatic section of a typical beam indexing tube screen and a chrominance signal corresponding to a saturated blue field (the luminance value of the blue field is not considered here). Clearly, there will be considerable excitation of the adjoining red and green phosphors, and this will cause desaturation of the intended pure blue light. Although this defect does not cause serious distortion of pastel colours, the loss of saturation on highly coloured objects is rather objectionable and correction for this can take one of three forms.

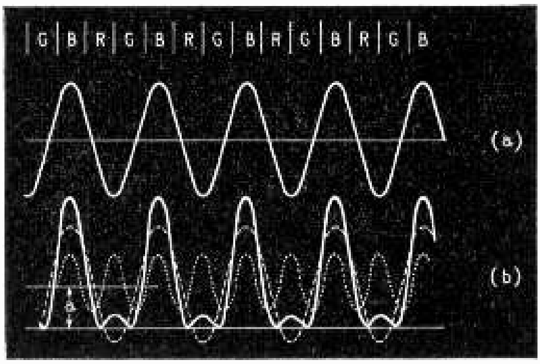

Fig. 8. (a) De-saturation of pure blue field. (b) Effect of adding 2nd harmonic term.

(i) The phosphor strips may be spaced with inert bands between adjacent colours, so that the conduction angle of the phosphors will be reduced.

(ii) The conduction angle can be reduced electrically by deducting from the luminance signal a signal proportional to chrominance carrier amplitude.[9] This idea is based on the fact that whilst the phase of the chrominance signal is proportional to saturation. An envelope detector will generate a signal proportional to saturation only, and this can be used to control the luminance amplitude. The inevitable decrease in brightness can be corrected by an increase in the gain of the chrominance channel.

(iii) The most satisfactory method for saturation correction requires the use of a second harmonic chrominance component which is added to the original chrominance signal[10]. In Fig. 8(b) is shown the effect of this where the added signal is of the form $a + b\cos(2\omega_B t + \phi)$ where (ω_B) is the colour switching rate.

(*To be concluded*)

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Silicon Carbide Transistor

NEW HIGH-TEMPERATURE DEVICE

By MICHAEL LORANT

RESEARCH scientists of the Westinghouse Electric Corporation in the United States have recently developed a transistor capable of operating above 650 degrees Fahrenheit, a temperature higher than the melting point of lead. The new transistor is the first to be successfully made from silicon carbide, a hard crystalline material which, in impure form, is used as an abrasive in grinding wheels.

The high-temperature capabilities of the new transistor mark it as a significant advancement in the technology of these semiconductor devices. Present-day transistors, manufactured almost exclusively from germanium and silicon, can operate at temperatures no higher than about 200 degrees F (germanium) or 400 degrees F (silicon). Germanium and silicon transistors, however, cannot always meet the high-temperature requirements of today's existing and planned aircraft and space vehicles. Such applications, therefore, have furnished strong motivation for the development of higher-temperature transistors. Because of its great chemical stability and desirable electrical properties which it retains at elevated temperatures, silicon carbide is one of the most promising transistor materials for extremely high-temperature applications. Laboratory tests show that the new silicon carbide transistor still amplifies at 670 degrees F, and with further development, an upper operating temperature of more than 925 degrees F should be achievable.

The new device is actually a " unipolar " or " field-effect " transistor, which differs in operating principle from those usually made from germanium and silicon. Such conventional transistors regulate the flow of an electric current through them by the injection of electric charge carriers across a junction built into the semiconductor material. The unipolar transistor, on the other hand, acts more like a valve which opens and closes to regulate the electron flow.

The new transistors are made from exceptionally-pure crystals about two-thousandths of an inch thick. The necessary junction is built into the material by exposing it to vaporized aluminium at the white-hot temperature of 3,900 degrees F. The aluminium atoms diffuse into the silicon carbide crystal, changing its electrical behaviour from so-called n-type material to p-type. The junction is formed where the two types meet, and the process is controlled to an accuracy of a few millionths of an inch.

Then, to establish the input and output terminals of the transistor, the wafer is etched at two points in such a way that the silicon carbide is eaten away until the junction within the body of the crystal is reached. Electrical connections at these two points and to the body of the wafer complete the transistor.

A typical finished transistor is about 80-thousandths of an inch long and 40-thousandths of an inch wide, and the " working " area of the crystal surface is smaller than the head of a pin. Electrical measurements on the finished transistors show them to give a power gain of about 60 at room temperatures.

Electronic Telephone Exchanges

RECENT DEVELOPMENTS DISCUSSED AT THE I.E.E.

THE papers presented at the Institution of Electrical Engineers' Conference on Electronic Telephone Exchanges on November 22 and 23 were contributed by experts from Europe, Asia and America and covered a very wide field in considerable detail. They will be reprinted in full in 1961 in Part B of the Proceedings, and the following notes are intended only as an introduction for those who may wish to study the subject further.

Time Division

In Great Britain, feasibility studies of the design of a completely electronic exchange have been carried out. The studies, undertaken independently by the Post Office and five principal manufacturers of telephone equipment, and later by the Joint Electronic Research Committee, have resulted in the experimental exchange shortly to be installed at Highgate Wood, in London.

In order to provide consistency of service to subscribers during the experimental period, a complete electromechanical exchange will be installed. If, at any time, the electronic exchange is removed from service to allow modification, the mechanical system will function in its place, and in fact will remain permanently in service when the experiment reaches its conclusion.

The electronic system employs the time-division multiplex method of switching, each unidirectional "highway" carrying 100 channels. Each connection requires two antiphase channels, ½ cycle (50μsec) apart, and is established by switching line and inter-highway diode gates by means of channel pulses, which are obtained from a channel store consisting of a circulating delay-line of the magnetostriction variety.

The central control equipment of the exchange is also, in the main, composed of magnetostriction delay-lines, which employ channel pulses to set up and supervise the progress of calls.

The speech-path channels are amplitude-modulated, the slight loss encountered during transmission through gates being made good by amplification in the demodulator.

Permanent control information, such as directory numbers, and transient information such as state of line, is stored on a magnetic drum. The drum is a magnetically coated cylinder with reading and writing heads. In the case of the permanent information, the writing head is normally isolated from its amplifier, to prevent accidental mutilation of the information. The type of permanent store employed lends itself to modification as a service expands.

When the design of the experimental exchange commenced, it was thought that transistors would restrict the transmission performance of the system and thermionic valves and semi-conductor diodes were chosen. It is reasonable to suppose that advances in semiconductor research have brought an exclusively solid-state exchange within the bounds of possibility.

Space Division

An American experimental exchange, the Morris Electronic Central Office, is described in a paper by Keister, Ketchledge and Lovell. This exchange, designed by Bell Telephone Laboratories, employs a space-division system using gas-filled diodes as switching elements. The diodes have a negative-impedance characteristic which offsets loss in transformers and other elements in the transmission path.

Permanent control information is stored in a flying-spot photographic store, while transient information is held on barrier-grid tubes.

The more important sections of the equipment are duplicated, while fault detection and, in certain cases, correction are automatic.

Novel facilities provided by the exchange include the possibility of obtaining frequently called numbers by dialling two digits only, and of connecting extension telephones, via the exchange, in an intercommunication circuit.

Switching Elements used in modern space-division systems fall broadly into two classes, electronic and electromechanical. Representative of the electromechanical switch are the reed relay, and a development known as the "ferreed."* The reed relay consists of contacts mounted on two metallic strips or reeds, the whole being mounted in a sealed glass tube. Surrounding the tube is a solenoid carrying the control current, which magnetizes the reeds and brings them into contact. Long life is a feature of this type of switch. In the ferreed, the reeds form part of a magnetic circuit, in part of which is ferrite material. The remanence of the ferrite is capable of maintaining closure of the contacts in the absence of controlling current.

Electronic switches include the neon-filled diode and the p-n-p-n junction diode. Both of these devices have the slight negative slope to their characteristics referred to earlier. The junction diode requires a much lower operating voltage than the neon diode, heat-dissipation problems with both these devices being negligible.

Exchanges employing time-division and space-division multiplexing are under active development in many parts of the world, and it may reasonably be assumed that one or more systems, both economically and technically competitive with the electromagnetic exchange, will have proved themselves within a few years.

* The Ferreed—A New Switching Device. A. Feiner *et al.* B.S.T.J. Vol. XXXIX. No. 1.

PHYSICAL SOCIETY EXHIBITION

MANUFACTURERS AND RESEARCH ESTABLISHMENTS EXHIBITING

THE 45th show of scientific instruments and apparatus which has become known as the Physical Society Exhibition will open at the Royal Horticultural Society's Halls, Westminster, on January 16th for five days. This year, however, the exhibition assumes a new official title, the Annual Exhibition of the Institute of Physics and the Physical Society, because of the recent amalgamation of the two organizations.

On a very large proportion of the 150 stands there will be equipment of interest to radio and electronic engineers and, as in the past, the emphasis will be on new developments in instruments and research techniques as well as on standard instruments and equipment.

From 10.30 to 2.0 on the opening day admission is limited to members of the society and the Press. On succeeding days the exhibition will be open to ticket holders at 10 a.m. It will close at 7.0 on the 16th, 18th, and 19th, at 9.0 on the 17th and 1.0 on the last day. Tickets are obtainable from exhibitors or from 47 Belgrave Square, London, S.W.1.

Wireless World, together with our associate journal *Electronic Technology*, are among the publications which have taken space in the exhibition.

The following demonstration-lectures will be given at 5.45 on the middle three days: "Hydrodynamic Research" by F. S. Burt of the Admiralty Research Laboratory (17th); "The Physics of the Oceans" by Dr. G. E. R. Deacon of the National Institute of Oceanography (18th); and "Some Physical Problems in Travelling at Supersonic Speed" by Dr. F. P. Bowden of Cambridge University (19th). The Acoustics Group is holding a symposium on traffic noise at 2.0 on the 18th.

A.E.I.
Admiralty Research Estabs.
Advance Components
Airmec
Archæology and the History of Art, Research Lab.
Avo

Baird & Tatlock
Baker, C., Instruments
Baldwin Industrial Controls
Barr & Stroud
Beck, R. & J.
Bellingham & Stanley
Birmingham University
British Iron & Steel Research Assoc.

C.N.S. Instruments
Cambridge Instrument Co.
Casella, C. F., & Co.
Cawkell
Cooke, Troughton & Simms
Cossor Instruments

D.S.I.R.
Dawe Instruments
Decca Radar
Distillers Co.
Dobbie McInnes
Doran Instrument Co.
Dynatron Radio

E.M.I. Electronics
Edwards High Vacuum
Ekco Electronics
Electro Methods
Electronic Instruments
Electronic Tubes
Electrothermal Engineering
Elliott Brothers
English Electric Valve Co.
Ericsson Telephones
Evans Electroselenium

Ferranti
Flann Microwave Insts.
Fleming, J. & R.
Fleming Radio
Furzehill Laboratories

G.E.C.
Gallenkamp, A., & Co.
General Radiological
Griffin & George
Guy's Medical School

Hilger & Watts

International Computers & Tabulators
Isotope Developments

Joyce, Loebl & Co.

Kelvin & Hughes

Labgear
Lintronic
Locarte Co.
Lucas, Joseph

M-O Valve Co.
Marconi Instruments
Marconi's W/T Co.
Marshall of Cambridge
Megatron
Mervyn Instruments
Metals Research
Ministry of Aviation
Morgan Crucible Co.
Muirhead & Co.
Mullard

N.G.N. Electrical
N.P.L. & Post Office Engg.
Nagard
Nash and Thompson
National Res. Dev. Corp.
New Electronic Products
Newport Instruments
Northern Polytechnic
Nuclear Enterprises (G.B.)

Oertling, L.
Oliver & Boyd
Optica United Kingdom
Optical Works
Ottway, W., & Co.

Panax Equipment
Paton Hawksley Electronics
Perkin-Elmer
Planer, G. V.
Plessey Co.
Post Office Engineering Dept.
Prior, W. R., & Co.
Pullin, R. B., & Co.
Pye, W. G., & Co.

Racal Instruments
Rank Cintel
Reading University
Royal College of Surgeons
Royal Meteorological Society
Royston Instruments

S.T.C.
Sanders, W. H. (Electronics)
Sangamo Weston
Science Museum
Servomex Controls
Shackman, D., & Sons
Singer Instruments Co.
Solartron Electronic Group
Solus-Schall
Stanton Instruments
Stanley, W. F., & Co.
Sunbury Glass Works

Taylor, Taylor & Hobson
Techne (Cambridge)
Telcon Metals
Texas Instruments
Thermal Syndicate
Thompson, J. Langham
Thorn Electrical Industries
Tinsley, H., & Co.
Tintometer
Towers, J. W., & Co.
Townson & Mercer
20th Century Electronics

U.K.A.E.A.
Ultrasonoscope Co.
Unicam Instruments

Venner Electronics
Vinten, W.

Watson, W., & Sons
Wayne Kerr Laboratories
Wray (Optical Works)

Industrial Groups—IV

WITH the growing practice of diversification in industry new names are coming into the field of radio and electronics as companies or groups are merged with concerns in such industries as mining, steel and ship-building. A case in point is **Metal Industries, Ltd.** The M.I. group which now comprises 38 companies in the U.K. and overseas and employs over 12,000 came into our field with the acquisition in 1959 of Avo (formed in 1923) and its subsidiary Taylor Electrical Instruments (1938). The group had been on the fringe of our field since its acquisition of several electrical concerns including Brookhirst Switchgear and Igranic Electric, now known as Brookhirst Igranic.

The group recently doubled its size with the acquisition of Lancashire Dynamo Holdings. Among the Lancashire Dynamo companies is Lancashire Dynamo Electronic Products and also the International Rectifier Company (Great Britain) which was formed in May, 1959, jointly by L.D. and the International Rectifier Corporation of Los Angeles.

The Metal Industries group now includes:—

Avo
Brookhirst Igranic
Cable Jointers
Cox & Danks
Crypto
Crypton Equipment
Dynamo & Motor Repairs
Farmer Brothers (Shifnal)
Fawcett Preston & Company
Foster Electrical Supplies
Foster Transformers
Hughes Bolckow
J. G. Statter & Company
John Allan & Company (Glenpark)
Lancashire Dynamo & Crypto
Lancashire Dynamo Electronic Products
Lancashire Dynamo Nevelin
Malcolm & Allan (London)
Metal Industries (Salvage)
Minerva Mouldings
New Eagle Foundry Company
Shipbreaking Industries
Taylor Electrical Instruments
Towler Brothers (Patents)

Overseas Companies

Brookhirst Igranic S.A. (South Africa)
Fawcett Preston (Europe) S.A (France)
Lancashire Dynamo Central Africa (Rhodesia)
Lancashire Dynamo South Africa
M.I. Australia
Metal Industries Europe S.A. (Belgium)
Olaer France S.A.

Associated Companies

Bepco Canada
International Rectifier Company (G.B.)
Soc. Representation d'Appareils Mecaniques (France)

Scientific Radio Conference

U.R.S.I. AND INTERNATIONAL RADIO MEASUREMENTS

By R. L. SMITH-ROSE, C.B.E., D.Sc., F.C.G.I., M.I.E.E.

DURING September, the International Scientific Radio Union held its XIIIth General Assembly at University College, London, when over six hundred scientists and engineers from twenty-four countries discussed various fields of scientific research ranging from precision laboratory measurements to the propagation of radio waves and communications in space. In his opening address, Dr. L. V. Berkner, the president since 1957, briefly reviewed the work of the Union over the past three years. It was during this period that the outstanding programme of the International Geophysical Year (1957/58) had been completed according to the carefully arranged plan, and this was followed by a year of International Geophysical Co-operation in 1959.

Since its formal organization in 1921 as an international scientific union, U.R.S.I. (the initials of its French title "Union Radio Scientific Internationale") has taken a keen interest in the characteristics of the atmosphere which determine the transmission of radio waves, and of the influence outside the atmosphere which determine these characteristics. It was thus perhaps a natural consequence that as the president remarked, U.R.S.I. was the first union to express its confidence in the scientific benefits that would result from artificial satellites in orbit around the earth. It is significant to note that the spectacular developments in the launching and use of such satellites and other vehicles in outer space have all taken place in the past three years. To deal with the scientific aspects of this work, an International Committee on Space Research (C.O.S.P.A.R.) was formed with U.R.S.I. as a charter member and having direct representation.

During the past triennium the allocation and protection of frequency channels for the use of radio astronomers has been actively discussed. With the coming of artificial earth satellites and their associated radio transmissions, this question has become of much greater importance. Although some frequency assignments were made for research purposes at the Geneva conference of the International Telecommunication Union at the end of 1959, it has been considered necessary to explore the future needs much more thoroughly; and at the recent U.R.S.I. General Assembly, representatives of U.R.S.I. and C.O.S.P.A.R., together with members of the International Astronomical Union, agreed to set up an inter-union committee for this purpose.

Scientific Programme of U.R.S.I.

The work of the International Scientific Radio Union is divided among seven commissions, dealing with individual portions of the field as indicated by their titles. These, together with the names of the chairmen appointed in September for the current three-year period (1960-63), are as follows:—

I	Radio measurements and standards	Dr. U. Adelsberger (Germany)
II	Radio and troposphere	P. Voge (France)
III	Ionospheric radio	J. A. Ratcliffe (U.K.)
IV	Radio noise of terrestrial origin	Prof. R. A. Helliwell (U.S.A.)
V	Radio astronomy	Prof. A. C. B. Lovell (U.K.)
VI	Radio waves and circuits	Dr. J. Loeb (France)
VII	Radio-electronics	Prof. W. G. Shepherd (U.S.A.)

At the General Assembly in London, the programme was arranged so that all these commissions met concurrently to discuss subjects which had been selected. A few joint sessions were also held to deal with subjects of common interest to two or more commissions. Outstanding among these was a morning session for the whole assembly allotted to the radio aspects of space research. Several papers described experiments made with rockets and satellites for studying the ionosphere and outer atmosphere as well as cosmic noise and solar ionizing radiations. Other papers stimulated a discussion on the scientific and technical aspects of communications by means of active and passive satellite relay systems. One of these papers outlined a proposal to discharge from a satellite large quantities of small metallic filaments into an orbital belt of microwave-resonant dipoles, which would reflect radio waves for long-distance communications purposes. This proposal was viewed with some misgivings by both optical and radio astronomers, since the existence of a permanent reflecting or scattering belt might seriously impair future scientific research in the astronomical field.

At the closing plenary session, the individual chairmen reported on the activities of their commissions and working parties; and put forward resolutions and recommendations for adoption by the Union. The individual papers presented at the meetings of all commissions, together with reports of the scientific discussions, will be published as a series of U.R.S.I. monographs in the near future. In the meantime, a brief review of some of the items discussed will be given in this and succeeding contributions.

It was at the closing session also, that the following officers were elected for the next triennium.

President:	Dr. R. L. Smith-Rose (U.K.)
Vice-Presidents:	B. Decaux (France)
	Professor I. Koga (Japan)
	A. Prochorov (U.S.S.R.)
	Professor G. A. Woonton (Canada)
Hon. Treasurer:	Professor Ch. Manneback (Belgium)

The Headquarters of the Union are at 7 Place Emile Danco, Brussels 18, Belgium, and the secretary-general is E. Herbays.

These, together with the commission chairmen listed above, will prepare for and organize the next General

Assembly to be held in Tokyo in 1963, when the Union will be celebrating its Jubilee. It grew out of the International Provisional Commission of Scientific Wireless Telegraphy formed in 1913.

From the earliest days of U.R.S.I., one of its most important activities has been to establish agreement throughout the world on the accuracy of measurement of such quantities as frequency, power and field-strength, which form the basis of all international research in the radio field.

As a result of intensive research and development over the past quarter of a century in several national laboratories, the frequency of an alternating current can now be measured to an accuracy which surpasses that of any other type of physical measurement. After passing through phases when a temperature-controlled tuning-fork and, later, a specially cut quartz crystal, formed the essential element in a standard frequency source, one of the resonant modes of a cæsium atom has now proved to be the most accurate and stable basis of reference.[1] The stability of radio-frequency oscillators controlled by a cæsium atomic standard has been shown to be of the order of one or two parts in 10^{10}.

Direct comparisons have been made in the same laboratory between the standard developed at the National Physical Laboratory in this country and the corresponding U.S.A. standard. The results[2] showed that the standards of the two countries agreed to within about 2 parts in 10^{10}, and that part of this discrepancy could be attributed to the different electronic arrangements used to drive the cæsium oscillators.

In order to state the actual frequency of such an oscillator, it is necessary to specify what standard of time is to be used. It is convenient for many purposes to adopt a uniform scale of time; but for precise scientific work, it is now internationally agreed that ephemeris time, which is based on the revolution of the earth round the sun, should be used. As a result of a joint programme of measurements carried out between the National Physical Laboratory in this country and the United States Naval Observatory, Washington,[3] the mean value of the frequency of the cæsium oscillator was found to be 9 192 631 770 cycles per second, with a probable error of ± 20 c/s (Ephemeris Time). At the recent U.R.S.I. General Assembly, it was recommended that the Bureau International de l'Heure should keep under review the appropriate astronomical observations and announce a nominal value of this frequency for use during the following year.

In order to make such a standard available to users in various laboratories, programmes of international standard frequency transmissions have been established in several countries on various frequencies between 2.5 and 25Mc/s. In this country, the transmissions are emitted by a G.P.O. station at Rugby under the call sign MSF; and they are now supplemented on an experimental basis with a much lower frequency (16kc/s) from Rugby (GBR). These signals are measured at the N.P.L. by reference to the cæsium standard, and the values of the deviations from the nominal frequency are published monthly in *Electronic Technology*.

At a meeting of Commission I of the General Assembly of U.R.S.I., a review of the present position of "Standard Frequencies and Time Signal Transmissions" was introduced by U. Adelsberger (Germany), who gave particular attention to the problem of modulating or interrupting the continuous wave emissions in order to produce accurate time signal ticks. The Commission recommended that the day-to-day phase stability of the very low-frequency transmissions should be measured in various countries in order to assess their usefulness for high precision time synchronization and frequency comparison purposes.

Another radio measurement of reasonably high accuracy is that of the velocity of electromagnetic waves in a vacuum. At the XIIth General Assembly at Boulder, U.S.A., in 1957, a value of 299,792.5 ± 0.4 km/s was adopted; and this has been found to give consistent results in the measurement of geodetic distances by electronic means. At the last Assembly it was recommended that agreed formulæ for the refractive index of the atmosphere should be adopted for both light and radio frequencies, so that the value of the velocity can be corrected for the appropriate ambient conditions, which prevail in practical use.

Considerable attention has been given by U.R.S.I. at previous meetings to the specification of field strength measuring techniques and their international comparison. As the frequencies in use have increased into the microwave region, it has become customary to specify a received signal in terms of power flux rather than field strength; and a recommendation was made in 1957 that the national laboratories should compare their standards of power measurement in the neighbourhood of 3,000 and 10,000Mc/s. On this occasion, a paper by J. A. Lane (U.K.), presented the results of measurements made at the Radio Research Station, Slough, at a frequency of 9.375 Gc/s (wavelength 3.2cm) on wire and film bolometers submitted by the National Bureau of Standards, Boulder, U.S.A., and by the University of Tokyo, Japan. The measurements were made in several ways, including one using a constant-flow water calorimeter in which the microwave power was dissipated.[4] The general conclusion from these comparisons was that the techniques used in the three participating countries agree within the limits of their estimated accuracy, about 1.5 or 2.0%.

In view of the general trend of radio research and application to increasingly higher frequencies, the U.R.S.I. General Assembly recommended that this work should be extended to 140 Gc/s; and that similar experimental comparisons should be made on other electrical parameters, such as voltage, attenuation, impedance and voltage standing-wave ratios in waveguides. Such measurements are clearly fundamental to the design of terminal radio equipment as well as to the study of radio wave propagation.

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[4] (a) J. A. Lane. "The Measurement of Power at a Wavelength of 3cm by Thermistors and Bolometers." *Proc. I.E.E.*, 1955, Vol. 102, Part B, p. 819.

(b) J. A. Lane. "Transverse Film Bolometers for the Measurement of Power in Rectangular Waveguides." *Proc. I.E.E.*, 1958, Vol. 105, Part B, p. 77.

WORLD OF WIRELESS

Audio Festival

PLANS are well in hand for the International Audio Festival and Fair being organized by a committee of audio manufacturers for April 6th to 9th at the Russell Hotel, London, W.C.1. Over 50 British manufacturers are subscribers to this international show at which quality of reproduction will be the keynote.

The following have been elected to form the council:—H. J. Leak chairman, R. Merrick (Ferrograph) vice-chairman, R. Arbib (Multimusic), D. Chave (Lowther), Major J. F. E. Clarke (Clarke & Smith), H. Farquharson (Armstrong), H. S. Futter (Gramophone Co.), L. B. Livingstone (Tannoy), J. Maurice (Lustraphone), J. Rogers (Rogers Developments), L. Stone (E.A.R.), L. Smith (Wharfedale), J. Swift (Goodmans), P. Walker (Acoustical), and L. Young (Vitavox). G. A. Briggs (Wharfedale) and J. Maurice have been appointed Trustees.

In addition to the usual stands and individual demonstration rooms for the 60 or more exhibitors, plans are being made for special lecture sessions covering reproduction from disc, tape and radio. Admission to the exhibition will be by ticket obtainable free from exhibitors and audio dealers.

Further details are obtainable from C. Rex-Hassan, 42 Manchester Street, London, W.1.

Television Afloat

The new 42,500-ton P. & O. luxury liner Oriana, now on her maiden voyage, has a television installation which provides not only a closed-circuit service but also for the reception of 405-, 525- and 625-line transmissions. The incoming television signals are, where necessary, converted to 525 lines for display on Ekco receivers and, moreover, where alternative programmes are available the viewer can make his own choice. Initially 60 receivers have been installed in public rooms and first-class cabins but provision is made for nearly 400. The television system was installed by Marconi's who also provided the ship's communications equipment, navigational aids and sound reproducing equipment incorporating 1,600 loudspeakers.

Radio Research

MANY interesting aspects of the research programme initiated by the Radio Research Board and carried out by the Radio Research Station at Slough are given in "Radio Research 1959"* which contains the report of the Board and of the Director of Radio Research. As might be expected the advantages to research in radio propagation afforded by rockets and satellites is given more than a passing reference. O. W. Humphreys, chairman of the Board, stresses that in order to obtain the full effect from the opportunities offered, the Radio Research Station "should devise its own experiments for flying in rockets and satellites." The proportion of the station's effort devoted to the general field of space research is being increased to 50%.

The present members of the Board are:—Prof. H. E. M. Barlow (University College, London), Prof. W. J. G. Beynon (University College of Wales), Dr. R. L. F. Boyd (University College, London), Prof. E. C. Cherry (Imperial College, London), O. W. Humphreys (G. E. C. Research Labs.), Dr. F. E. Jones (Mullard), K. I. Jones (Ferguson), C. J. V. Lawson (Cable & Wireless), F. C. McLean (B.B.C.), A. W. Montgomery (S.T.C.), Capt. J. S. Raven (Admiralty) and Capt. F. J. Wylie (Radio Advisory Service).

The 22-page report of Dr. R. L. Smith-Rose is of particular interest as it is his last as Director of Radio Research; he is succeeded by J. A. Ratcliffe.

*H.M.S.O. 3s.

College of Aeronautics.—For the past year or so the College of Aeronautics, Cranfield, Bletchley, Bucks., has been pursuing a policy of diversification of teaching activities, and as a result a number of new advanced courses have been developed in subjects which although relevant to aeronautics are of equal interest to many other branches of engineering. It has therefore been decided to change the titles of some of the departments thereby giving a better indication of the scope of their activities. Under this re-arrangement the Department of Aircraft Electrical Engineering becomes the Department of Electrical and Control Engineering. Professor G. A. Whitfield has been head of the department since its formation in 1955. In addition to providing specialized courses for aeronautical engineers as part of the two-year diploma course the department is now offering advanced courses in industrial control engineering and flight control as well as courses in space technology and guided missiles.

Satellite Tracking.—Two of the chain of 18 stations to be used for tracking the first American manned space satellite—those at Kano (Nigeria) and Zanzibar—are to be staffed by Cable & Wireless men for maintaining point-to-point communications. The stations will be linked by radio to London whence information will be passed to the U.S.A. *via* the transatlantic cable. W. A. Coslett, who during the war was engineer-in-charge of one of the mobile telecommunication units known as Blue Trains and until his retirement in 1959 at the age of 55 was C. & W. manager in Jamaica, has been appointed engineer-in-charge at Kano. The assistant engineers are J. D. Munday and T. Shepherd. At Zanzibar, D. G. Hicks will be E.-in-C. with P. J. Harlow and D. J. Payne as assistants.

S.O.N.D.E.—The Society of Non-Destructive Examination is to hold the first Croxson Memorial Lecture (in memory of the late Charles Croxson the founder chairman) on February 17th at 6.15 in the Caxton Hall, Westminster. Dr. L. Mullins will speak on "The Evolution of Non-Destructive Testing". Free tickets—not more than two per applicant—are obtainable from the Hon. Secretary of the Society, D. T. Carter, E.S.A.B. Ltd., Gillingham, Kent.

Computer Consortium.—The reconstituted British Conference on Automation and Computation, of which Sir Walter Puckey is chairman, has set up three panels to cover the following aspects of its interests:—education and training (with Professor G. D. S. MacLellan, of Glasgow University, as chairman); research and development (J. F. Coales, Cambridge University); and public relations (W. C. F. Hessenberg, British Iron and Steel Research Association). The general title of the conference of the B.C.A.C. to be held in Harrogate from June 27th to 30th is "Automation—Men and Money".

Television Society.—Sir Harold Bishop, Director of Engineering, B.B.C., has accepted the invitation of the Television Society to become president in succession to the late Sir George Barnes. He took office on December 8th for two years. The Society, which was formed in 1927 "for the furtherance of research in television and allied problems" now has a membership of over 1,200.

R.S.G.B. Membership.—For the fourth successive year after a period of recession the membership of the Radio Society of Great Britain had again increased at the end of June, 1960, when it passed the 10,000 mark. The year's increase recorded in the Society's annual report was 496 bringing the total to 10,036. Of the U.K. total of 8,729 holders of amateur (sound) licences, 6,473 (60%) were members of the Society.

Annual Dinner of the Royal Flying Corps Wireless Operators Old Comrades Association will be held in London on March 18th. Details are obtainable from E. J. F. C. Hogg, 57 Hendham Road, London, S.W.17.

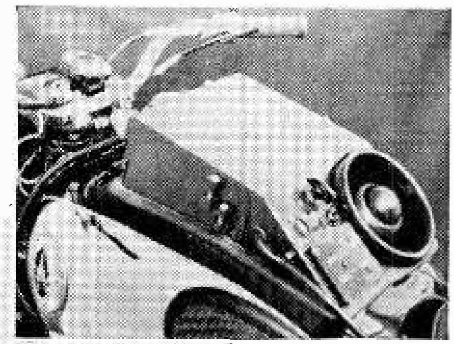
African Radio Union.—Broadcasting organizations in Morocco, Tunisia, the United Arab Republic, Ghana, Guinea and Libya have set up an international organization under the name of African Radio Union. Principal aim of the Union is for technical and administrative co-operation between the different national broadcasting organizations in Africa. Abdoulaye Toure, director of the state-owned broadcasting service of Guinea, is the first president.

V.H.F. Sound Broadcasting.—The sixth edition of the list of European v.h.f. sound broadcasting stations, giving the situation on January 1st, will be published by the European Broadcasting Union early in February. The cost, including five bi-monthly supplements, is 50 Belgian francs. The list can be obtained from the E.B.U. Technical Centre, 32 avenue Albert Lancaster, Brussels 18, Belgium.

Receiving Licences.—During October the number of combined television and sound licences current in the U.K. increased by 82,397 bringing the total to 10,962,867. Sound-only licences totalled 4,226,094 including 459,856 for sets fitted in cars.

Pulse Techniques.—An 11-week laboratory course on pulse techniques begins at the Borough Polytechnic, Borough Road, London, S.E.1, in January. It will be held on Monday afternoons commencing January 9th and will be repeated on Thursday evenings from January 12th. The course will also be repeated on Monday afternoons from April 10th. (Fee £1).

Educational Publications.—The latest pamphlets in the series "Demonstrations and Experiments in Electronics" issued by the Mullard Educational Service give details of an all-transistor one-watt amplifier (No. 13) and an "echo" method of determining the velocity of sound (No. 14). The pamphlets are available free to schools, technical colleges and training establishments from the Mullard Educational Service, Mullard House, Torrington Place, London, W.C.1.



***Police Radio**—Features of this latest motor-cycle f.m. transmitter-receiver, produced by G.E.C. to a Lancashire Police design, are a handlebar press-to-talk switch, loudspeaker unit on the petrol tank and microphone-earpiece in the helmet.*

Television receiver production in Hungary for the next five years, has been planned to total 1M. More than half the receivers are scheduled for export.

Moscow TV.—A tower carrying the aerials for five transmitters is a feature of the new television centre being built in Moscow.

Can you Help?—An American reader is anxious to secure a copy of *Wireless World* for January, 1952, to complete a 15-year file. Offers should be addressed to the Editor.

CLUB NEWS

Bradford.—Dr. G. N. Patchett of the Bradford Technical College will speak on transistors at the January 10th meeting of the Bradford Amateur Radio Society. A fortnight later D. Millard (G3OGV) will deal with amateur receiver alignment. The club meets at 7.30 at Cambridge House, 66 Little Horton Lane.

Cleckheaton.—"'Scope Interpretation" is the title of the talk to be given by T. C. Isaac of Bradford Technical College at the January 4th meeting of the Spen Valley Amateur Radio Society. On the 18th a member of staff of Philips Electrical will discuss tape recording. Meetings are held at 7.30 at the Labour Rooms.

Mitcham.—Lifeboat radio equipment is the subject of the talk being given by W. D. Pye to the Mitcham and District Radio Society on January 13th at 8.0 at "The Canons," Madeira Road.

Personalities

G. A. Marriott, B.A., is retiring in March from the managing directorship of the M-O Valve Company, a wholly owned subsidiary of the G.E.C., and is to be succeeded by **J. Bell,** B.Sc., F.Inst.P., at present deputy director and manager of G.E.C. Research Laboratories, and a member of the M-O Valve board. Mr. Marriott, who is 68 and a graduate of Caius College, Cambridge, has been with the G.E.C. throughout his professional life. He served on the board of the British Radio Valve Manufacturers' Association (B.V.A.) for nearly 20 years, and is now chairman of V.A.S.C.A., the associated organization which was formed in 1959 to take over from the B.V.A. the responsibilities for semiconductors and industrial valves and tubes. He was president of the Brit.I.R.E. from 1956 to 1958. Mr. Bell, deputy director of the G.E.C. Research Laboratories, Wembley, where he was manager of the telecommunications division from 1953 to 1958, was appointed to the board of the M-O Valve Company a few months ago.

G. A. Marriott

J. Bell

Paul Adorian, M.I.E.E., M.Brit.I.R.E., F.C.G.I., managing director of Associated-Rediffusion Ltd., has been elected a Fellow of the Institute of Radio Engineers of America, "for the development of electronic distribution networks used in broadcasting and television." He is the only British recipient among the 76 elected for 1961. Mr. Adorian is on the board of a number of companies within the Rediffusion group and is chairman of Central Rediffusion Services Ltd., Redifon Ltd., and Rediweld Ltd.

E. S. Hall, M.I.E.E., this year's chairman of the Rugby Sub-Centre of the I.E.E., is a director of A.E.I. Sound Equipment, Ltd., and divisional assistant chief engineer of A.E.I. Electronic Apparatus Division, New Parks, Leicester. He joined B.T.H. as a student apprentice in 1924 and on completion of the course in 1929 went to the research laboratory on the development of sound film equipment. In 1946 he was appointed chief assistant to the manager of the B.T.H. Electronic Engineering Department. Mr. Hall has held his present position since the formation of the A.E.I. divisions in 1959.

R. H. Booth, at one time chief engineer of the industrial division of E.M.I. Electronics Ltd., which he joined in 1949, and now personal assistant to the company's technical director, has gone to North America for a two-year tour of duty. He will maintain liaison with E.M.I.'s representatives in the U.S.A. and undertake a survey of the American market.

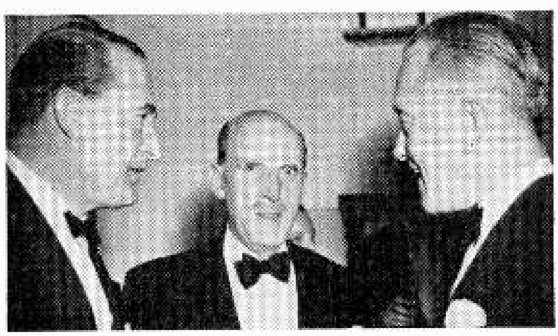
Professor F. C. Williams, O.B.E., D.Sc., D.Phil., F.R.S., of Manchester University, has received the American John Scott award in recognition of his work on the development of I.F.F. (Identification, Friend or Foe) during the war. Dr. Williams, who joined Watson-Watt's radar research team at Bawdsey in 1939, was employed throughout the war on radar circuitry. In 1947 he was appointed professor of electrotechnics at Manchester University, where he is now professor of electrical engineering and has been working on the development of digital computers. He is 49. The John Scott award is made by the City Trust of Philadelphia for "developing inventions for the benefit of mankind."

Professor A. C. B. Lovell, O.B.E., F.R.S., director of the Nuffield Radio Astronomy Laboratory of the University of Manchester at Jodrell Bank, has been awarded one of the two Royal Medals of the Royal Society for 1960, "for his distinguished contributions to radio astronomy."

Dr. D. Gabor, professor of applied electron physics at Imperial College, and **Dr. D. Jones** have been granted £2,000 by the Paul Instrument Fund Committee of the Royal Society for additional equipment for use in connection with the development of an electron interference microscope.

W. E. J. Farvis, B.Sc.(Eng.), M.I.E.E., senior lecturer in applied electricity and head of the post-graduate School of Electronics and Radio at Edinburgh University, has been appointed to the newly established chair of electrical engineering at the university. He has been in the Electrical Engineering Department for the past 12 years, prior to which he was for three years a lecturer at University College, Swansea. During part of the war he was engaged on the development of decimetric radar systems and later headed a radio counter-measures group.

P. L. Stride, formerly manager of Ekco's Malmesbury works, has become manager of the aviation division of Ekco Electronics Ltd., which is now centred at Southend. The division handles the design and technical liaison for ground and airborne equipment for the aviation industry. **P. J. Harvey,** formerly chief electronics engineer, becomes manager of the nucleonics and industrial division which is responsible for research and development covering nucleonic and physical instrumentation and control. **E. B. Thompson** continues handling the commercial activities of both divisions as sales manager.



S. R. Mullard, M.B.E., recently celebrated his 40th anniversary as a director of the Mullard company. He is seen here with (left) Sir Arthur Vere Harvey, C.B.E., M.P., who has been with the company 25 years and (right) S. S. Eriks, O.B.E., managing director of the company.

Sir Leslie Gamage has retired from the chairmanship of the General Electric Company and is succeeded by **Arnold Lindley,** who joined the company as an engineering apprentice in 1918. In 1958 he was made an assistant managing director in charge of the company's heavy engineering group, and for the past 18 months has been vice-chairman and a managing director.

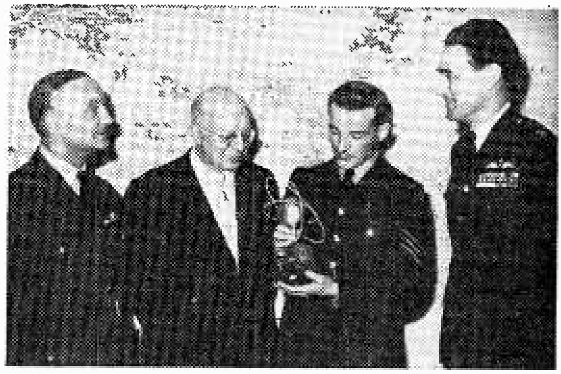
E. Green, M.Sc., M.I.E.E., formerly head of the transmitter advanced development group of Marconi's, and for the past six years consultant engineer to the company, has retired. He has been with Marconi's since graduating at Manchester University in 1913. In his early days with the company Mr. Green was engaged in the installation of marine radio equipment and in 1915 he was seconded to the R.N.V.R. and was sent to Hong Kong to assist in the installation and operation of a 25-kW spark set and a Poulsen arc transmitter for the Royal Navy. In the years following World War I, he was assistant to C. S. Franklin during the whole of the development work on the short-wave beam system. His textbook "Amplitude-Frequency Characteristics of Ladder Networks" is a standard source of reference.

E. Green

L. C. Jesty

L. C. Jesty, B.Sc., M.I.E.E., has been appointed manager of Sylvania-Thorn Colour Television Laboratories in succession to **B. C. Fleming-Williams,** B.Sc., A.M.I.E.E., who has resigned. Mr. Jesty joined the Laboratories in 1957, and has been mainly responsible for the research and development programme on colour television and cathode-ray tubes. For seven years prior to joining the Laboratories he was with Marconi's, where he led the television research group and was closely associated with the development of the Anglicized version of the American N.T.S.C. colour system. From 1927 to 1946 he was at the G.E.C. Research Laboratories, and for three years at the Cinema-Television Laboratories. **J. K. Oxenham,** M.A., who has been in charge of the circuit work on colour and closed-circuit television at the Sylvania-Thorn Laboratories, has been appointed deputy manager.

T. E. Greenfield has been appointed sales development manager of the industrial process control division of Gresham Automation Ltd. After war service in the Merchant Navy he joined J. Langham Thompson Ltd. in 1946, and three years later went to the General Electric Co. at Stanmore, where he was concerned with flight instrumentation trials. In 1953 he returned to J. Langham Thompson, and since 1957 he has been with English Electric Aviation Ltd. He was appointed head of quality control for the production of guided weapons at their Stevenage works, and was also test project engineer for the Thunderbird II.



*The **Rietzke Award** being received from the donor Eugene Rietzke, founder and president of Capitol Radio and Engineering Institute, of Washington, by Sgt. J. H. O. Willacy "the airman showing the greatest promise in the field of electronics" at the R.A.F. Bomber Command Station at Cottesmore, near Oakham, Rutland. On the left is Air Commodore J. R. Morgan, Command Education Officer, and on the right Group Captain A. D. Mitchell, station commander. Some 70 airmen on the station took the electronics course of C.R.E.I.*

J. D. MacEwan, B.Sc., A.M.I.E.E., A.M.Brit.I.R.E., has been appointed by the B.B.C. engineer-in-charge, television, Birmingham, in succession to **H. G. Whiting,** who recently became Regional Engineer, Midland Region. Mr. MacEwan joined the Operations and Maintenance Department of the B.B.C. in 1947. Since 1956 he has been senior lecturer (technical operations) at the Corporation's Engineering Training Department.

G. W. Short, the first part of whose article on the bootstrap follower is on page 21, was for two years on the editorial staff of our sister journal *Electronic Technology* until 1958, when he joined the B.B.C. He served in Royal Signals from 1944 to 1947. He then went to Oxford University, where he graduated in 1951 and the following year received his M.A. From 1953 to 1956 he was assistant press officer at Mullard's.

Horace Freeman, who, as already announced, retired recently from active business life after spending nearly 40 years in radio and electrical advertising, has been elected an honorary vice-president of the Radio Society of Great Britain. It was appropriate that the certificate was presented to him at the opening of the Radio Hobbies Exhibition in the Royal Horticultural Society's Old Hall, for it was there that he organized the first all-British wireless exhibition in 1922.

B. M. Lee, son of E. M. Lee, director and general manager of Belling & Lee, Ltd., has been appointed manager of the company's industrial group and to the board of executive directors.

OBITUARY

Dr. W. R. G. Baker, vice-president of the General Electric Company of America when he retired in 1958, has died at the age of 67. He joined the company in 1917. Since his retirement he had been vice-president of Syracuse University. Dr. Baker's best-known contribution to the American radio industry is probably the direction of its two National Television System Committees, the first to establish standards for the American monochrome service and the second, appointed in 1950, to set up standards for what is now known as the N.T.S.C. colour system.

News from Industry

Telemeter "Pay-TV."—A new company, British Telemeter Home Viewing, has acquired from International Telemeter Co. the British rights of the "Pay-TV" system developed by its associates, Paramount Pictures Corp. The system, which is being used in a pilot scheme in Toronto, provides for the reception of a television programme specially transmitted by wire or over the air which is un-scrambled by a coin-in-the-slot unit fitted to a standard receiver. The subscribers to the new company include British Lion Films and the Granada Group.

Decca.—E. R. Lewis, the chairman of the Decca Record Company, announced at the extraordinary general meeting on November 10th that the year's results for the group were "by far the best in the company's history." The balance from the trading account was £3,714,547—an increase of some £400,000 on the previous year. The net balance carried forward was £1,821,984, a 28% increase on the previous year.

Plessey's consolidated profit and loss account for the year ended last June shows a trading profit of over £4M. After allowing for taxation and making various deductions the balance carried forward into the current year was £2,240,044 compared with £1,536,042 the previous year.

M.S.S. Recording Company have arranged with E.M.I. to manufacture and distribute the discs and disc cutting apparatus previously undertaken by M.S.S. who are concentrating on the production of their Mastertape and Data Tape.

Non-destructive Testing.—Solus-Schall, Ltd., of County Building, Honeypot Lane, Stanmore, Middx., have produced an information booklet reviewing the site methods of non-destructive testing provided by the company. Copies of the booklet are available free of charge.

The Gramophone Company are developing a combined four-track tape recorder and 45/33 r.p.m. record reproducer in which the tape and record are driven (simultaneously if required) by means of the same motor.

Aero Electronics Ltd., of Gatwick Airport, have been appointed the exclusive export agents and sole distributors to U.K. aircraft manufacturers of the products of Communications (Air) Ltd., of Bagshot, Surrey. Their products include a V.O.R./I.L.S. simulator and airborne V.O.R./I.L.S. equipment.

Beme Telecommunications Ltd., of 24, Upper Brook Street, London, W.1, a member of the Derritron Group of companies, has announced two new marine radio products—a depth indicator and a f.m./a.m. receiver. The transistor depth indicator "Diver 60" has a range of 0 to 360 feet.

Southern Instruments Ltd., who in association with the Drayton Regulator and Instrument Company of West Drayton, some months ago formed Drayton-Southern Ltd. (specializing in instrumentation and control systems), have more recently formed Storno-Southern Ltd. in association with the Danish Storno Radio Co. Storno-Southern is to manufacture in this country under licence v.h.f. communications equipment designed by the Copenhagen company. Another company, Southern Analytical Ltd., has been formed to take over the analytical instrument work of the parent company.

Ocean Weather Ships.—Four transmitters, eight receivers and two direction-finders are being supplied by Marconi's for each of two frigates *Amberley Castle* and *Pevensey Castle* which are being converted for use as ocean weather ships. The company is also modernizing Admiralty ranging and height-finding radar in the vessels. *H.M.S. Amberley Castle* has been renamed *O.W.S. Weather Adviser.*

Raytheon Co., of Waltham, Mass., have supplied two air traffic control radar systems for Switzerland's major air routes. The radars will be connected by microwave links to the Geneva-Cointrin and Zurich-Kloten airports which they will serve. The Geneva installation will be located on the 5,500-foot La Dole, 16 miles away, and the Zurich equipment on a mountain some seven miles away.

Central Electronics Inc., the recently formed wholly-owned French subsidiary of Zenith Radio Corporation, are building a factory in Paris for the production of components and receivers.

J. W. Maunder, U.K. agent for Shure audio components, now has an office at 22 Orchard Street, London, W.1 (Tel.: Hunter 4116).

NEW FACTORIES

Associated Transistors, Ltd., which is jointly operated by A.T.E., English Electric and Ericsson Telephones, has acquired an 18-acre site at Basingstoke, Hants, on which a transistor factory covering about 120,000 sq ft is to be built.

G.E.C.—A mill at Reddish, near Manchester, has been acquired by the G.E.C. Semiconductor Division. It will be known as Broadstone Works and has a working space of 600,000 sq ft. Manufacture of semiconductors is expected to start in the early part of this year.

Nottingham Electronic Valve Co., Ltd., manufacturers of Nev cathode-ray tube pumping equipment, have moved their offices and works from Netherfield to Main Street, East Bridgford, Notts. (Tel.: East Bridgford 276).

Elremco.—An extension to their factory at Bush Fair, Harlow, Essex, has increased the production area of the Electrical Remote Control Co. to 14,000 sq ft.

Marconi's Aeronautical Division is being regrouped in new premises at Basildon, Essex, where the bulk of the company's aeronautical equipment is manufactured.

L. E. Simmonds Ltd., relay manufacturers of 5 Byron Road, Harrow, Middx., have opened a new factory at Thetford, Norfolk. The factory gives an additional 6,000 sq ft to the company's present manufacturing capacity at Harrow, which will remain the headquarters.

Alma Components Ltd., manufacturers of precision wire-wound resistors, have recently opened a new factory in Diss, Norfolk (Tel.: Diss 2288). The London works have been closed but an office is being maintained at the old address: 551 Holloway Road, London, N.19 (Tel.: Archway 0014).

Sifam.—A new factory with a total floor area of 21,000 sq ft and accommodation for 260 employees has been opened in Torquay by Sifam Electrical Instrument Co.

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

TRANSISTOR INVERTER

FREQUENCY STABILIZED CIRCUIT SUITABLE FOR RUNNING A TAPE RECORDER

HIGH-POWER transistor inverters commonly use two or a multiple of two transistors in a special type of push-pull oscillator circuit which is designed to give a square-wave output. High-efficiency operation is secured because the transistors alternate between two conditions in each of which the internal energy dissipation is very low. In one condition the transistor is cut off and there is no energy loss. In the other state the transistor is bottomed and although it then carries a large current the voltage drop across it is quite small and the energy loss is again very low.

If a sinusoidal output waveform is required the maximum efficiency is lower and cannot possibly exceed 78.5 per cent. In a practical case the efficiency would be nearer 60 per cent compared with about 85 per cent for the square-wave case.

Frequency Stability of Self-excited Inverters.—Push-pull square-wave oscillators are of two distinct types. In one of these the rectangular waveform results from magnetic saturation effects in the core of the oscillator transformer. High-efficiency

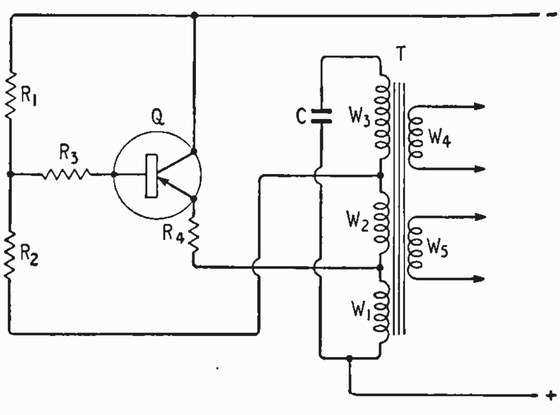


Fig. 1. Driver oscillator circuit for frequency-stabilized inverter.

operation therefore calls for the use of low-loss core materials. Suitable magnetic alloys are expensive but economy in the core size can be achieved by operation at a relatively high frequency, usually between 400 and 1,200 c/s. Within this range of frequencies the sum of all the losses (eddy current, hysteresis, dielectric and copper winding resistance) reaches an acceptable minimum value.

The second type of self-excited square-wave generator also employs a ferro-magnetic core but operates at flux densities which are always below the saturation level. Losses are thus reduced and it becomes possible to make use of conventional core materials. Amplitude limiting of the square-wave output is in this case caused by cut-off or saturation (bottoming) in the transistors. These must be accurately matched if it is important to generate a square-wave output with a mark-to-space ratio of unity.

Oscillators which make use of core-saturation effects generate a frequency which is proportional to the battery supply voltage. A constant output frequency thus calls for a regulated power supply. The output frequency is not markedly dependent on the connected load. A valuable feature is that the circuit is self protecting against overloads.

By contrast, inverters which operate with unsaturated transformers deliver an output frequency which is dependent on the supply voltage and on the connected load. A heavy overload will normally result in the destruction of the transistors.

Constant-frequency Inverters.—When used for d.c. to d.c. conversion there is no particular need to specify precisely the frequency of the oscillator. It is convenient to make this fairly high in order to simplify the output filtering arrangements, and a value in the region of 1000 c/s is entirely suitable.

There are cases in practice where there is no such latitude regarding the choice of output frequency. This is certainly true if the equipment to be operated contains squirrel-cage or synchronous motors which are required to be run at a fixed speed. A tape-recorder capstan drive motor comes into this category and for use in vehicles, in aircraft, or on board ship it must be supplied from a battery-operated constant-frequency a.c. source.

To operate mobile equipment a 28-V d.c. supply is normally available. Experience shows that it is possible to design an inverter for operation from such a supply which will give a continuous output of 100 W at any fixed frequency between 40 and 60 c/s.

In principle, a constant output frequency could be derived by amplifying the output of a low-power oscillator of stable frequency. If a sinusoidal voltage waveform is required with a substantial power output, a practical scheme would be to drive a Class-B amplifier from the oscillator, using intermediate amplifiers as necessary. Such an assembly would be expensive and inefficient. At best, the output stage would have an efficiency of under 70 per cent. The amplifier would have a high output impedance so that the voltage regulation would be extremely poor. This could be corrected by the use of negative feedback which in turn would call for higher gain in the amplifier, requiring at least one extra stage. At the expense of further circuit complication it might be possible to devise some form of automatic gain control to give a constant output voltage.

The situation is much more favourable if a square-wave output is acceptable. It is not considered very good practice to run large a.c. motors under these conditions. Heating is increased by the harmonic currents and the motor may tend to " cog " round at a small fraction of its fundamental synchronous speed. Nevertheless, many low-power motors appear to perform satisfactorily with a square-wave input.

In respect of its output impedance, the square-wave inverter is effectively an electronic switch, periodically reversing the supply battery connections to the primary of the inverter transformer. The output impedance at the transformer secondary terminals includes the secondary winding resistance plus the total primary circuit resistance referred to the secondary side, i.e. multiplied by the square of the transformer turns ratio. It also contains a term sufficient to account for all the other circuit losses. The voltage regulation of an inverter is normally about 20 per cent between no load and full load. During the conduction phase there is also a voltage drop across each transistor of about 0.75 V. Assuming that a 28-V battery supply is used, this is responsible for a further reduction in efficiency of 2.7 per cent.

As regards the design of a constant-frequency oscillator to drive the square-wave amplifier there are two possibilities to be considered, remembering that the output stage calls for a substantial drive power. One is to use a high-power tuned-circuit oscillator and the other is to use a low-power version, say of the Wien bridge type, followed by an intermediate power amplifier. The requirements for high oscillator stability and high output power are incompatible, but the amplifier drive power requirements can be reduced by making this stage regenerative. Sufficient positive feedback may be applied from the output stage to cause incipient self-oscillation and if the regeneration control is adjustable it may be set at such a level that only moderate power demands are made on the stable-frequency driving source. This technique is used in the actual equipment to be described later.

A circuit diagram of the 50 c/s oscillator is shown in Fig. 1. It is of a conventional feedback type, the arrangement being such that the transistor collector terminal may be connected directly to the negative supply lead which is at earth potential. The chassis can thus be employed as a convenient heat sink. The iron-cored transformer T carries five windings. Of these, W_4 and W_5 are the output secondaries used to couple the oscillator stage to the output amplifier. The primary windings W_1, W_2 and W_3 are connected series aiding, the total inductance being such as to resonate with C at a frequency of 50 c/s. A convenient value of C is about 0.5 μF which calls for a very large number of turns on W_3. The windings W_1 and W_2 are calculated to provide the requisite feedback voltage for reliable oscillation and to match the input and output impedance of the power transistor Q. The resistances R_1, R_2 and R_4 set the base bias of Q, while R_3 is sufficiently large to ensure a constant-current drive to the transistor base circuit. The transformer employs a C-core of grain-orientated silicon steel and has a small airgap to avoid magnetic saturation due to the d.c. component of the collector current.

Practical Inverter Circuit.—Fig. 2 shows the complete circuit diagram of a 100-W inverter. A power transistor Q1 associated with the transformer T1 constitutes the master oscillator, operating at 50 c/s. Apart from the specification of the transformer, to be given later, this stage calls for no further comment.

The output transistors Q2 and Q3 feed power to a centre-tapped winding on the transformer T2, each half-primary having N_1 turns. Two additional windings, each with N_2 turns, serve to provide positive feedback to the bases of Q2 and Q3, in phase with the oscillator drive from the secondaries W_4 and W_5 of the transformer T1. The magnitude of the feedback is controllable by the slider settings on the two variable resistors R_5 and R_6. If excessive regeneration is employed the master oscillator may lose control and the output stage will run as a self-

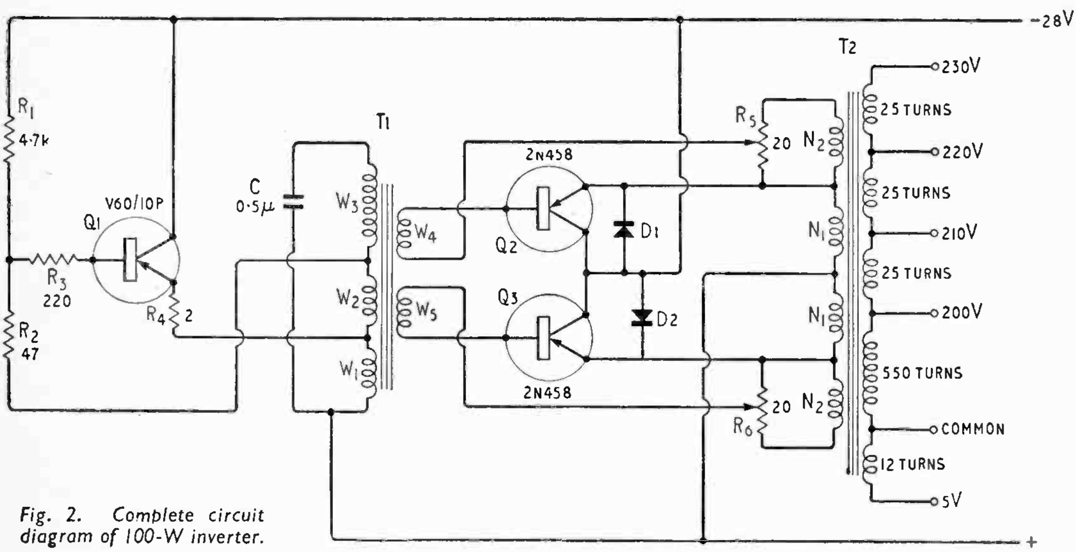


Fig. 2. Complete circuit diagram of 100-W inverter.

excited inverter. This condition must be avoided but a moderate amount of feedback makes the amplifier stage easier to drive. The two resistances also serve another useful purpose in that they can be used to equalize the drive to the output transistors if these have widely-differing characteristics. Heavy-duty wire-wound potentiometers should be chosen for this purpose. Except for R_4 the remaining resistors can be of 1-W rating and 5 per cent tolerance; R_4 should be a 5-W wire-wound component.

The diodes D1 and D2 call for comment. They must be in circuit if the inverter is used to supply a highly inductive load. Under these circumstances the output transistor load line degenerates into a distorted ellipse and there is a reverse flow of current which is in fact carried by the diodes. They are unnecessary if the load is resistive or if power-factor correction is applied. They can be of the germanium or silicon junction type, rated to carry a maximum current of 5 A and with an inverse voltage rating of 100 V.

The transformer specifications are as follows:—

OSCILLATOR TRANSFORMER T_1

Core: Double-C pattern, centre limb 1in × 1in (1 sq in cross-sectional area)
Airgap: 0.031in (1/32-in paxolin spacer)
Windings (all enamel and rayon covered):—

W_1: 160 turns, 22 s.w.g.
W_2: 70 „ 24 „
W_3: 4330 „ 34 „
W_4: 15 „ } 18 „ Bifilar wound
W_5: 15 „ }

OUTPUT TRANSFORMER, T2

Core: Double-C pattern, centre limb 1½in × 1½in (2.25 sq in cross-sectional area)
Airgap: None (butt joint)
Windings (all enamel covered):—

N_1: 56+56 turns, 14 s.w.g. } Bifilar wound
N_2: 8+ 8 „ 16 „ }

Secondary windings as shown in Fig. 2, 22 s.w.g.
In both cases the heavy gauge wire is wound on first (nearest to the core).

The two transformers are bolted to a rectangular sole plate of ¼-in thick aluminium which constitutes the heat sink for all three transistors. These are in direct contact with the plate which is connected to the negative terminal of the supply battery. It may be earthed if required. The circuit wiring is straightforward and the layout of components is in no way critical.

Alternative types of transistors suitable for use in the circuit are readily available. They include the following:—

MANUFACTURER	Q1	Q2 and Q3
Ediswan-Mazda	XC142	XC155
	XC155	XC156
G.E.C.	GET 9	GET573
Mullard	OC28	OC28
	OC29	OC29
Newmarket	V60/10P	—
	V60/20P	—
	V60/30P	—
Texas Instruments	2N457	2N457
	2N458	2N458

Operation with Inductive Loads.—The dynamic characteristic of a power amplifier is almost a straight line for a purely resistive load. As previously mentioned it becomes a distorted ellipse if the load is reactive. The normal square-wave output from the inverter can under some circumstances be transformed to that shown in Fig. 3. This waveform was actually observed when the capstan drive motor of a high-grade tape recorder formed the inverter load. The motor called for a nominal input of 70 VA at 230 V and although its operation appeared to be entirely normal an attempt was made to correct the waveform by adjustment of the load power factor. It was found that a shunt capacitance of 1μF removed the effect but introduced some ringing on the leading edge of the square wave. This in turn was eliminated by connecting a resistance of 400Ω in series with the capacitor.

Power Output and Efficiency.—The inverter shown in Fig. 2 is easily capable of delivering 100 W into a resistive load. It can be switched on in the

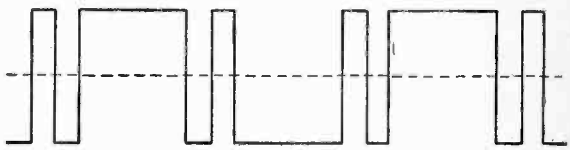


Fig. 3. Inverter output waveform with inductive load.

battery circuit with a 100 W lamp as the connected load and will quickly bring the lamp up to full brilliance in spite of the very low initial resistance of the cold filament. At full load the transistors remain cool and are clearly being run well below their rated maximum dissipation.

Measurements show that the unit draws 4.8 A from a 28 V battery when delivering 220 V, 0.46 A. An output of 101 W is thus obtained when the input is 134 W, corresponding to an efficiency of almost exactly 75 per cent. Some caution must be used when making measurements with rectifier-type a.c. meters. These in fact measure mean values but are calibrated to indicate the r.m.s. value of a sinusoidal voltage or current. They read about 10 per cent high when used to measure square waveforms.

The no-load current is 0.4 A at 28 V and the voltage regulation is about 10 per cent between one quarter load and full load output. Load changes have a negligible effect on the generated frequency, while halving the battery supply voltage changes the frequency by about 1 c/s. Finally the unit forms a suitable driver stage for a very-high-power amplifier. Using four Texas Instruments Type 2N 514B transistors in parallel push-pull an output in excess of 1 kW could easily be obtained.

Tape-Recorder Wow and Flutter.—There is no obvious reason why the performance of a recorder in respect of wow and flutter should be worse when the capstan drive motor is supplied from an inverter than when it is run from the mains. Elastic couplings, eccentric capstans and stretched tape are the usual causes of these types of distortion and are common to both cases.

Careful observations have shown that there is still another source of irregularity. This is due to a periodic fluctuation of motor torque which appears to be a function of the number of stator slots or rotor bars. It is sufficient to cause a slight frequency modulation of any recorded tone unless the torque variations are smoothed out by a mechanical low-pass filter.

Actual measurements on a particular recorder (E.M.I. Type TR 52) give a total figure of 0.2 per cent wow and flutter from all causes when the machine is operating from the mains. The figure is exactly the same when running from the inverter provided that the battery gives a full 28 V output. When the voltage is reduced to 24 the figure rises to 0.3 per cent.

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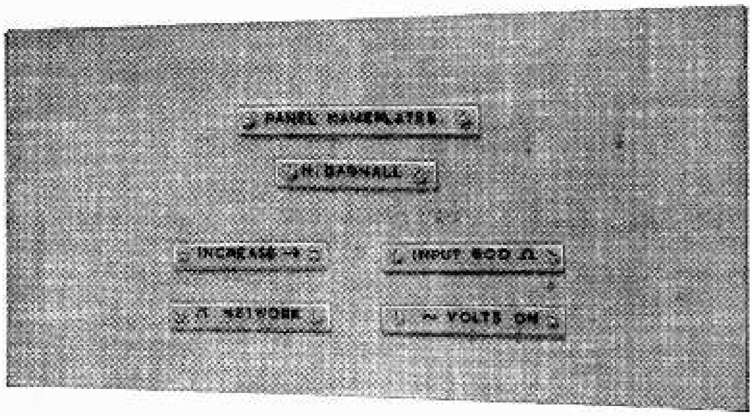


Typical nameplates as they appear on plastic-faced hardboard.

A "DO-IT-YOURSELF" METHOD

By H. DAGNALL, M.A.

PANEL NAMEPLATES

THE use of transfers does much to improve the appearance of home-built equipment and helps to give it a professional finish. But, excellent as they are for many purposes, ready-made transfers do not entirely solve the problem of panel lettering for the amateur constructor. He is soon likely to discover that the exact wording required does not exist on any of the sheets available, and he is then forced either to abandon his chosen name for that switch or socket or to make up the word from single letters. If he attempts the latter alternative, the difficulty he has in aligning them will remain for ever distressingly visible—at least in the writer's case it does. Another difficulty likely to be encountered is that transfers cannot be applied to a crackle surface, nor can they easily be curved, compressed or expanded to fit a particular requirement.

The object of this note is to describe a method by which neat panel nameplates can be made in any desired size and wording. Lettering is done with the aid of a "Uno" stencil in black Indian ink on the reverse side of a strip of Perspex. Since the letters are on the back of the strip when it is affixed to the panel they are fully protected from damage and, being in optical contact with the Perspex, they appear intensely black.

Perspex having a thickness of 1/24 in is the most suitable kind to use. It should be cut into strips ¼ in wide and about 12 in long.

A jig to hold the Perspex and stencil in alignment while lettering is essential for neat work, but it need be nothing more elaborate than a board about 12 in × 4 in on which are nailed two pieces of hardboard of the same thickness as the Perspex. These should be ¼ in apart so that the Perspex strip is a push fit in the gap; if the edges of the hardboard are purposely left rather rough, the strip will be gripped quite securely between them. A rail, parallel to the strip, against which the top edge of the stencil moves, completes the jig and ensures that the letters are aligned along the centre of the strip.

"Uno" stencil UC.1½ (UF.1½ for figures) and pen No. O are suitable for the smallest (¼-in) nameplates, but of course other sizes of strip and stencil can be used as required.

Writing on the Perspex is not difficult providing that it has been cleaned with carbon tetrachloride or other degreasing agent and the pen is kept clean to ensure free flow of ink. As the lettering is done on the rear surface of the Perspex the stencil must be reversed and writing done from right to left. To obviate the need for accurate centring of words on the strip, several legends are written on one strip and separated later.

The nameplates are fixed to the panel by means of countersunk 10 BA or 12 BA bolts. The heads of the bolts can afterwards be enamelled to match the panel.

On a light-coloured panel the words show up clearly but on a dark surface they should be backed with a light-coloured paper or paint; this also permits the use of colour coding for distinguishing different channels. Since the nameplates are transparent they are particularly suitable for mounting on light-coloured wood veneers or plastic-faced hardboard.

A circular dial plate can be lettered in a similar manner using a simple jig; circular plates can also be attached with 12 BA bolts to the brass bush of a knob to form a skirt.

Do not be put off because a required symbol does not appear on the stencil, for with a little ingenuity two or more characters or parts of characters can be combined to form the wanted symbol, for example parts of "O" and "L" to produce a neat capital omega symbol.

The Bootstrap Follower

ITS USE IN AUDIO AMPLIFIERS

By G. W. SHORT

THE title of this article might well have been "When Is A Cathode-Follower Not A Cathode-Follower?" However, I have a feeling that the Editor would have found that a wee bit too long. Moreover, using this as an opening gambit enables me to have the best of both worlds, since readers will have guessed that the answer to the question is "When it's a bootstrap follower," whatever that may be.

The object of the exercise is to investigate the behaviour at audio frequencies of the "cathode-follower" circuit of Fig. 1(a). This circuit is arrived at when it is desired to operate a cathode-follower with a cathode resistance much larger than is required for obtaining "cathode bias." A logical way out of the difficulty is then to use a normal-sized cathode-bias resistance in series with the desired high resistance, and to return the grid to the appropriate point, as in Fig. 1(a), so that only the voltage drop across the smaller resistance R_{k1} is operative as grid bias. In many practical circuits C_k is omitted, and the output is taken directly from the cathode.

The difference between this type of circuit and a true cathode-follower (Fig. 5(a)) is apparently trivial. It is merely a question of convenience in biasing, or so I thought for a long time. My first misgivings came when I encountered Jeffery's phase-splitter.[1] In this circuit use is made of the fact that, in the Fig. 1(a) type of circuit, the signal source "sees" not r_g, but a resistance many times greater. Thus the source delivers an increased voltage to the valve, since less is dropped across its internal resistance r_s. If r_s is large, the increase may be substantial. (In Jeffery's circuit, r_s is the anode resistance r_a of a pentode valve, and runs to several megohms.) This "impedance multiplication" effect is one which does not make itself very obvious in a true cathode-follower, where all it does is to reduce the input capacitance a little, without altering the input resistance.

It came as something of a surprise to have it pointed out years later, by "Cathode Ray,"[2] that the Fig. 1(a) circuit differs from a true cathode-follower in another important respect; it has less negative feedback. This is because the proportion of the output voltage which is fed back negatively to the grid is reduced by the source resistance r_s, because r_s and R_g act as a potential divider. The amount actually fed back; i.e., the amount developed between grid and cathode, is therefore $R_g/(R_g+r_s)$ times the actual output voltage. Thus the fraction fed back approaches unity as r_s approaches zero,

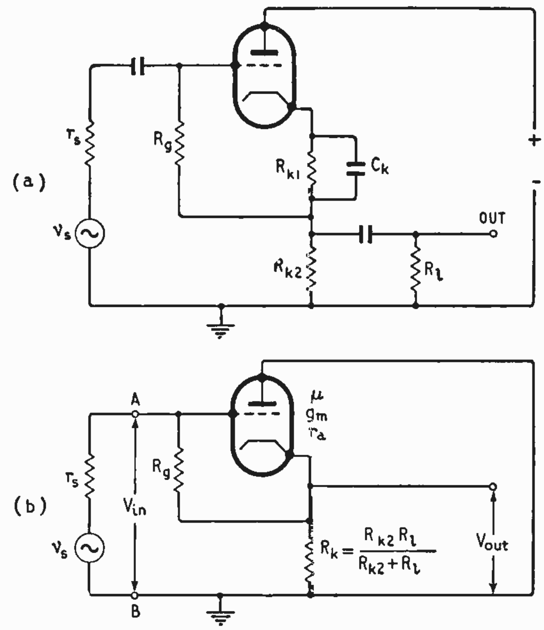


Fig. 1 (a) "Cathode-follower" circuit. (b) An a.c. equivalent circuit.

and it approaches zero as the signal-source resistance becomes infinite.

One thing which puzzled me at the time was this: if the feedback fraction is reduced, then the *gain* of the triode ought to be increased. Yet nobody seemed to have got out more voltage than he put in. Odd. But there are so many more interesting things to do than get out pen and paper and analyse circuits. Easier things, too, as far as I'm concerned. It wasn't until the circuit appeared again recently in *Wireless World*[3] that I finally got around to it, and discovered that, unlike the true cathode-follower which it so closely resembles, this circuit has an input impedance which depends on the load impedance, and an output impedance which depends on the signal-source impedance. The gain, oddly enough, is the same as that of a cathode-follower proper, though this depends on how it is defined.

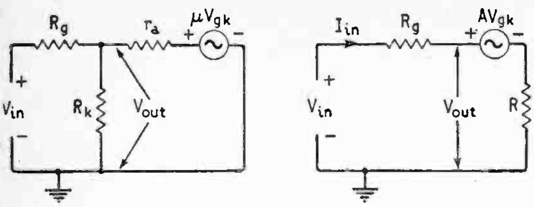
For the purposes of analysis, Fig. 1(a) can be simplified to Fig. 1(b) which shows only those parts which are relevant to an a.c. signal. R_k is now the effective value of R_{k2} and the external load R_l in parallel.

Input Resistance.—This is the resistance "seen"

[1] "Push-Pull Phase-Splitter," by E. Jeffery, *Wireless World*, August 1947, p. 274.

[2] "Cathode Followers, With Particular Reference to Grid Bias Arrangements," by "Cathode Ray," *Wireless World*, June 1955, p. 292.

[3] "Economical High-Gain A.F. Amplification," by A. R. Bailey, *Wireless World*, January 1960, p. 25.



(a) (b)

Fig. 2. Equivalent circuits of Fig. (1); (a) with normal equivalent valve circuit, (b) with valve and load combined.

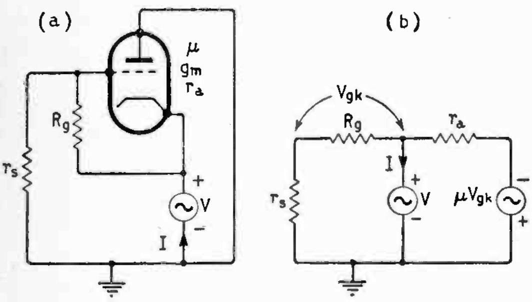


Fig. 3 (a) Circuit for calculating output impedance. (b) Equivalent circuit.

by the signal source. It is the resistance measured between points A and B with the source disconnected. If a voltage V_{in} is applied between A and B, a current will flow in R_g. The voltage drop across R_g is the true input to the valve; i.e., the voltage between grid and cathode (V_{gk}). The voltage across R_k is the output, and is AV_{gk}, where $A = \mu R_k/(r_a + R_k)$. The situation is shown in the equivalent circuit of Fig. 2(a). It is simpler, instead of analysing this circuit as it stands, to convert it into the straightforward series circuit of Fig. 2(b) by using the Thévenin equivalent for the valve and its load. This is a generator with an open-circuit output AV_{gk} and an internal resistance $R = R_k . r_a/(R_k + r_a)$. The current supplied by V_{in} is

$$I_{in} = (V_{in} - AV_{gk})/(R_g + R)$$

where $V_{gk} = I_{in}R_g$. These expressions yield $V_{in}/I_{in} = R_{in} = R + R_g(A + 1)$. The term $(A + 1)$ represents the impedance multiplication effect. The grid-cathode resistance appears to the source to be much larger than the actual physical value.

Gain.—It is clear from Fig. 1(b) that the voltage across R_k cannot exceed V_{in}. If it did, current would flow into the source instead of out of it. Thus V_{out} can approach V_{in}, but not exceed it, and the maximum possible value for the gain is 1, as in a normal cathode-follower. Here V_{in} is regarded as the input voltage. If v_s is considered to be the input voltage, then the gain is smaller and falls to zero as r_s becomes infinite.

From Fig 2(b),

$$V_{out} = AV_{gk}$$
$$= AI_{in}R_g$$
$$= AV_{in}R_g/[R + R_g(1 + A)]$$
$$V_{out}/V_{in} = AR_g/[R + R_g(1 + A)] = A'$$

In most practical circuits, R is 100kΩ or less, and $R_g(1 + A)$ is 10MΩ or more, so that $A' \approx A/(1 + A)$, which is the same as the "gain" of a cathode-follower.

Output Resistance.—This is the resistance seen by the load R_k in Fig. 1(b). To compute it we replace R_k by a generator of e.m.f. V, and let V_s be zero. The situation is then as shown in Fig. 3. Only that part of V which is developed across R_g acts as an input voltage (V_{gk}) to the valve.

We have,

$$I = (V + \mu V_{gk})/r_a + V/(R_g + r_s)$$
$$\text{and } (V_{gk} = VR_g/(R_g + r_s)$$

The second term in the first equation merely represents a current through R_g and r_s which would flow even if the valve were not there. If we ignore it, we obtain,

$$r_{out} = \frac{V}{I} = \frac{r_a}{1 + \dfrac{\mu R_g}{R_g + r_s}}$$

When r is zero; i.e., when the amplifier is driven from a constant-voltage source, the expression for r_{out} reduces to $r_a/(1 + \mu)$, which is exactly what one would expect from a cathode-follower. But

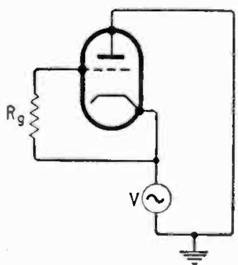


Fig. 4. When r_s is infinite, it can be removed without altering the output impedance.

when r_s is infinite; i.e., when the amplifier is driven from a constant-current source, $r_{out} = r_a$, which is what would be seen by the load if the circuit were a straightforward amplifier with no feedback. This is what it is, under these conditions, as far as output resistance is concerned. We have made r infinite, which means that it can be removed without altering the output resistance. The circuit then becomes that of Fig. 4. Here, V is applied directly between anode and cathode, and there is no input between grid and cathode, so that the resistance seen by V is r_a.

At this point it is instructive to see what sort of values one gets in practice. Using a valve such as the ECC81 (12AT7) one might choose working conditions such that $\mu = 60$, $r_a = 17k\Omega$, $A = 34$, $R_k = 22k\Omega$, $R_g = 1M\Omega$, $r_s = 100k\Omega$. With these values, the input resistance is 35MΩ, and the output resistance is about 300Ω (compared with 275Ω for a true cathode-follower using the same valve). So for most practical purposes the circuit can be regarded as an ordinary cathode-follower. In some circumstances, it may be positively useful to increase the output impedance; for example, one might want to match a line impedance. On the other hand, there is no difficulty in raising the output resistance of a true cathode-follower: all one needs to do is to connect a suitable resistor in series with the live output terminal.

Hybrid Circuit.—The foregoing analysis shows

(*Continued on page 23*)

that the behaviour of the circuit is conditioned largely by the impedances to which its input and output terminals are connected. The impedance of the source of input voltage is usually the most important, since it governs the output impedance. When $r_s = 0$, the circuit becomes a true cathode-follower (shown in idealized form in Fig. 5(a)). This has a gain of $A/(A + 1)$ where A is the gain without feedback, in other words the gain defined as V_{out}/V_{gk}. The output resistance of the valve is then low, being $r_a/(\mu + 1) \approx 1/g_m$. (In practical circuits, the output is usually shunted by something, so that the net output resistance is less than this.)

When r_s is infinite; i.e., when the triode is driven from a constant-current source, the valve presents the usual non-feedback output resistance r_a. Under these conditions the circuit becomes as shown in Fig. 5 (b); it has no feedback, and the input voltage is IR_g. This voltage is developed directly between grid and cathode, as in an ordinary triode amplifier. The difference is that the output is taken from the cathode, the anode being earthy. Now, a triode amplifier with a floating input voltage and cathode output is a bootstrap amplifier, and this is what our circuit becomes under these conditions.

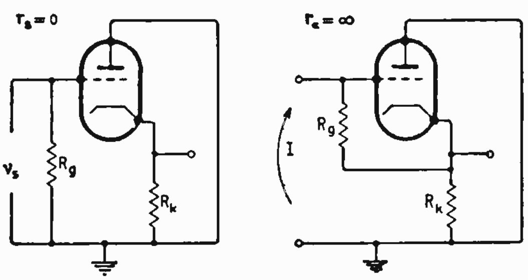


Fig. 5 (a) True cathode-follower. (b) "Bootstrap follower" with current drive. This has the same characteristics as a bootstrap amplifier with voltage drive.

Practical signal sources have neither zero nor infinite resistance, so the circuit behaves in practice like a hybrid between a cathode-follower and a bootstrap amplifier. It seems logical to call it a bootstrap follower. No originality is claimed for this title: it is so obvious that somebody must have used it before now.

In a slightly modified form (Fig. 6) this circuit forms part of the phase-splitter described in this journal by Jeffery[1]. Advantage is taken of the impedance multiplication effect to present the pentode with a high effective load, thereby increasing its gain to an appreciable fraction of the pentode μ, instead of the miserable fragment of it which is all one usually gets. The great advantage of making use of impedance multiplication is that the anode load resistor can have the usual sort of resistance and the pentode can be operated with the usual anode current (say 1mA) yet a large gain can still be obtained. Moreover, because the pentode is operating under normal conditions, as opposed to "starvation" conditions, it can deliver a large output voltage. For example, one might have an effective anode load of 3MΩ, even though the actual load resistance is only 100kΩ. With an anode current of 1mA, the voltage drop across the load is only 100V. With a high tension voltage of 250V, the remaining 150V is available for the valve, which might well deliver a peak voltage of something approaching 100V before "bottoming" begins: this is more than the triode could handle. The gain of the pentode might be 1,000 or more.

While one might get a high gain by operating the pentode under starvation conditions with a physical anode load resistance of a few megohms, it is unlikely that the gain would be as high or that the available output voltage would be as large as the values obtained using the bootstrap follower.

These facts have led to the use of a *single-ended* combination of a pentode and a bootstrap follower as a means of obtaining high overall gain from a pentode and a triode. An equivalent circuit for this combination, neglecting direct voltages, is given in Fig. 7. This is the same as Fig. 1 (b), except that r_s is now the anode resistance of the pentode (r_{ap}) and v_s is $\mu_p V$, where μ_p is the pentode μ, which may be several thousand.

The maximum gain of the combination cannot exceed the pentode amplification factor. This is much less than the maximum possible gain of the

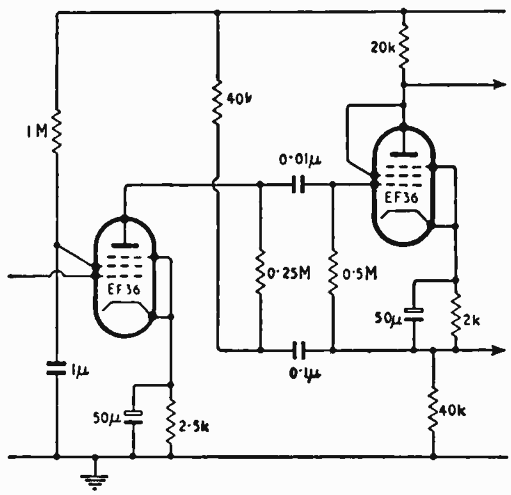


Fig. 6. Jeffery's phase splitter.

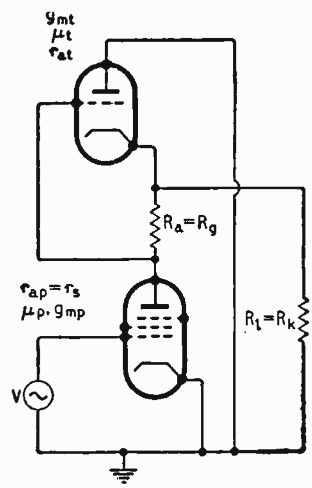


Fig. 7. Single-ended pentode—b.f. triode combination. Simplified circuit neglecting direct voltages.

two valves in cascade, which is the product of the two amplification factors. In practice, however, a cascaded circuit would have an overall gain much less than this product. All the same, the cascade amplifier might be expected to produce more gain than the bootstrap follower with pentode drive.

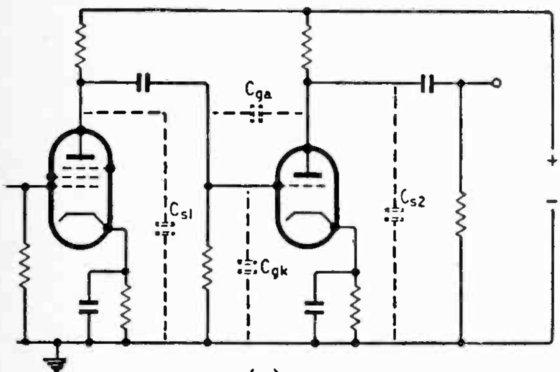
However, one requires gain over a band of frequencies, and to compare the two circuits on this basis it is useful to calculate the products of gain and bandwidth. This is done in the Appendix. In terms of the stray capacitances of Fig. 8, the ratio of the gain-bandwidth product of the cascade amplifier to that of the pentode-bootstrap follower combination is:

$$\frac{GB_1}{GB_2} = \left[\frac{(c_{s1} + c_{ga})(A_2 + 1) + c_{gk}}{c_{ga}(A_1 + 1) + c_{s1} + c_{gk}}\right]\left(\frac{A_1}{A_2}\right)$$

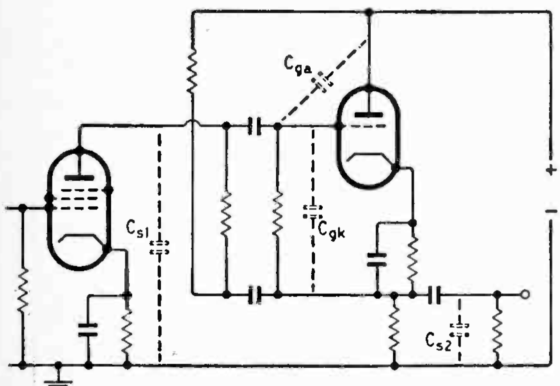
where A1 is the gain of the triode in the cascade circuit and A2 is the gain (V_{out}/V_{gk}) in the bootstrap follower circuit. In the numerator, the stray capacitance c_{s1}, which contains the output capacitance of the pentode in Fig. 8, is multiplied by (A2 + 1), but it is not multiplied by anything in the denominator. In practice, c_{s1} usually exceeds c_{ga}, so the effect of this difference can be very large.

The effect of c_{s1} in the cascade circuit is to add to c_{gk}. This is comparatively harmless, since the important capacitance is the Miller capacitance $c_{ga}(A_1 + 1)$. But in the bootstrap follower amplifier, cs_1 adds to c_{ga}, and the result is disastrous. In the bootstrap follower amplifier, the impedance seen by the preceding stage is the normal sort of triode input impedance, including the part due to Miller effect, multiplied by $(A_2 + 1)$. The effect of adding c_{s1} to c_{ga} is the same as would be the effect of adding it in the cascade circuit, only in the cascade circuit it is not added.

Before leaving the subject of gain and bandwidth, it should be mentioned that, with the cascade circuit, one has the opportunity of putting the triode in the first stage and the pentode in the second. With some values of signal-source impedance and load capacitance this might produce a marked improvement. In the bootstrap follower combination there is no point in putting the triode in the first stage since its amplification cannot exceed about 100 even with the best high-μ valves. We shall continue to consider circuits in which the pentode is always in the first stage, partly to preserve a sound basis for comparison, and partly because the best audio pentodes are rather better than the best triodes in regard to hum. In a high-gain amplifier it would be logical to use a pentode such as the EF86 in the first stage.



(a)



(b)

Fig. 8 (a) Cascade amplifier and (b) bootstrap follower combination showing stray capacitances

Appendix

Gain-Bandwidth Products

To find these, we calculate the pentode gain and bandwidth for each circuit and multiply their product by the triode gain. (The effect of the triode bandwidth is discussed in the article). To find the pentode gain, we need to know the load resistance and capacitance. In the cascade amplifier, the load resistance is just R_a in parallel with the triode grid resistance R_g. The load capacitance, however, contains a portion due to Miller effect. This portion is here taken to be $c_{ga}(A + 1)$, where c_{ga} is the inter-electrode capacitance (grid-anode) of the triode, plus any stray capacitance between grid and anode. This is not strictly correct, because the Miller capacitance is not a pure capacitance. A small resistance appears in series with it, but at audio frequencies, with c_{ga} of a few pF, this resistance is negligible, and for all practical purposes the Miller capacitance is a pure capacitance. Similarly, in computing the anode load of the pentode when the triode is a bootstrap follower, a resistance which appears in series with $R_g(A + 1)$ is neglected. (See under "Input Resistance"). Again, this is justified in practical circuits, where $R_g(A + 1)$ is nearly always much larger.

By neglecting these unimportant resistances, we get the equivalent circuits shown in Fig. A, which have the advantage of being readily comparable. In each case, the pentode is shown by the current generator g_mV and the anode resistance r_a. The circuits are simple parallel RC circuits. The pentode gain is g_mR, where R is the net resistance, and the bandwidth is $1/2\pi RC$, where C is the total capacitance.

R and C are different for the two circuits. If we call the values in the cascade circuit R_c and C_c, and the values in the bootstrap follower amplifier R_b and C_b, we have for the pentode in the cascade circuit, a gain-bandwidth product

$$g_m R_c \times 1/2\pi R_c C_c = g_m/2\pi C_c$$

The overall gain-bandwidth product is A_1 times this, where A_1 is the triode gain in the cascade circuit,

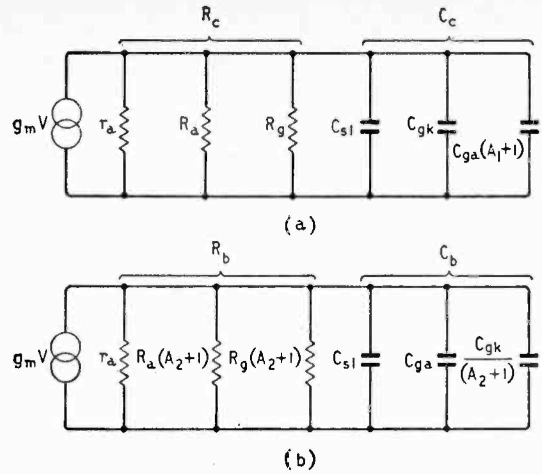


Fig. A (a) Pentode operating conditions in the cascade amplifier. (b) Pentode operating conditions in the bootstrap follower combination.

so we can put, for the cascade amplifier, $GB_1 = A_1 g_m / 2\pi C_c$

For the pentode in the bootstrap follower amplifier, the gain is $g_m R_b$ and the bandwidth is $1/2\pi R_b C_b$. The gain-bandwidth product for the pentode is thus $g_m/2\pi C_b$. To obtain the overall gain-bandwidth product for the bootstrap follower amplifier, this must be multiplied, not by A_2, the gain V_{out}/V_{gk} of the bootstrap follower triode, but by $A_2/(A_2 + 1)$. This is because the output of the pentode is applied between the grid of the triode and "earth," like V_{in} in Fig. 1(b). The "gain" of the triode is then $A_2/(A_2 + 1)$, as shown in the article. So the overall gain-bandwidth product for the bootstrap follower amplifier can be written

$$GB_2 = \frac{g_m}{2\pi C_b} \times \frac{A_2}{A_2 + 1} = \frac{(A_2)\, g_m}{2\pi C_b (A_2 + 1)}$$

The ratio of the gain-bandwidths is

$$\frac{GB_1}{GB_2} = \frac{A_1 g_m}{2\pi C_c} \times \frac{2\pi C_b (A_2 + 1)}{A_2 g_m} = \frac{C_b A_1 (A_2 + 1)}{C_c (A_2)}$$

If $A_1 = A_2 = A$, this approximates to

$$\frac{AC_b}{C_c} = \frac{A(c_{s1} + c_{ga}) + c_{gk}}{Ac_{ga} + c_{s1} + c_{gk}}$$

In practical circuits, c_{s1} is the largest of the strays, so the cascade amplifier is much superior. However, A_1 is not likely to be the same as A_2. For greater precision, we must write the full formula,

$$\frac{GB_1}{GB_2} = \frac{A_1(A_2 + 1)\left[c_{s1} + c_{ga} + \dfrac{c_{gk}}{A_2 + 1}\right]}{A_2\left[c_{s1} + c_{gk} + c_{ga}(A_1 + 1)\right]}$$

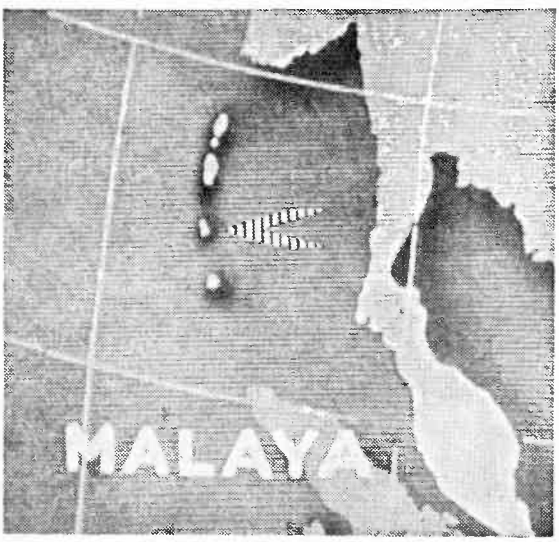
$$= \frac{(c_{s1} + c_{ga})(A_2 + 1) + c_{gk}}{c_{ga}(A_1 + 1) + c_{s1} + c_{gk}} \times \frac{A_1}{A_2}$$

To get an idea of what this means in practice, we substitute the following typical values:
$c_{s1} = 10\text{pF}$, $c_{ga} = 2\text{pF}$, $c_{gk} = 5\text{pF}$, $A_1 = 30$, $A_2 = 25$
This produces a ratio of just under 5. For equal bandwidths, the gain of the bootstrap follower, amplifier is nearly 14 dB below that of the cascade amplifier.

(To be concluded)

Electronic Pointer Generator

ALTHOUGH a conventional lecture pointer can usually be used with large-scale diagrams for illustrating television talks, there are often occasions when this is impracticable, for example, in describing surgical operations or in microscopy. To meet these and other requirements, Pye, Ltd., have developed an electronic pointer generator by means of which an arrow can be superimposed on the picture and moved to any desired point by a remote-control "joystick," which carries a push-button for switching on or off. An auxiliary switch reverses the direction of the pointer.



The "joystick" movement is resolved into settings of horizontal and vertical potentiometers which provide d.c. shifts for the arrow blanking pulses in the line and field periods. The arrow formation is generated by mixing sawtooth waveforms in diode coincidence circuits and can be adjusted in size. It is made more clearly visible by filling with black and white vertical striations which are generated by bursts from a triggered Hartley oscillator.

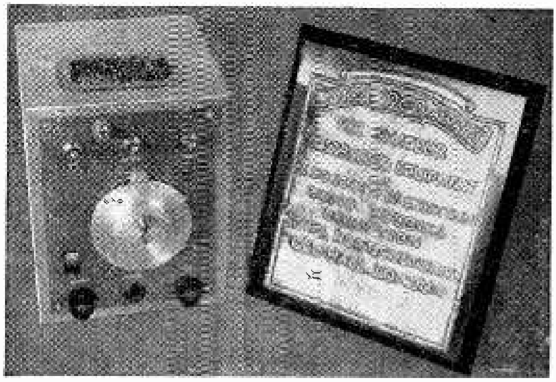
The equipment is designed to operate on 405-, 525- or 625-line systems and is available for rack mounting (Type 2443) or in portable form (Type 2444).

"Permeability Tuners for Television"—a correction

In the formula for the conditions for balance (right-hand col., p. 476 of the October 1960 issue) it is regretted that a term was omitted from the denominator of the left-hand expression. The equation should read:—

$$\frac{C_{gk} C_c}{C_c C_d + C_g C_d + C_g C_c + C_{gk} C_c + C_{gk} C_d} = \frac{C_{ak}}{C_{out} + C_{ak}}$$

RADIO HOBBIES EXHIBITION

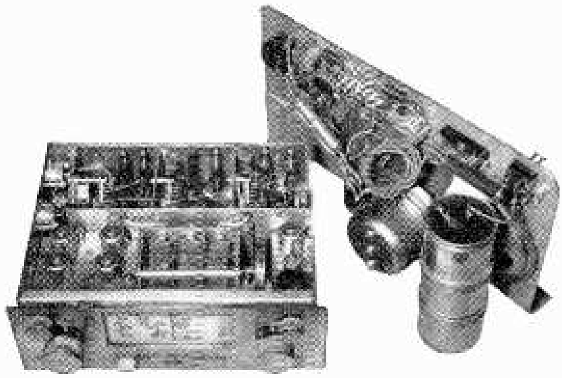


E. St. B. Sydenham's silver plaque winning wavemeter.

AMATEUR TRANSMISSION, "HI-FI" AND MUSIC-MAKING ON SHOW

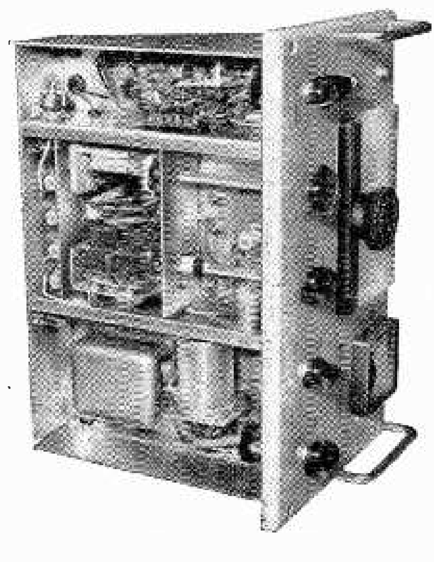
IN the competition organized by the R.S.G.B. for home-constructed apparatus a heterodyne wavemeter, made by E. St. B. Sydenham, G3LOK, was the Silver Plaque winner. R. H. Hammans' (G2IG) transistor communications receiver, covering 1 to 30Mc/s with a.m., s.s.b. and c.w. facilities, was judged the best entry from the outside-London area: this set is only 4½in by 6in by 5½in. The best club entry was from Aquila Radio Club, who submitted a six-band transistor car receiver covering 1.8 to 30Mc/s, made by C. J. Salvage, G3HRO. This receiver is split into two units, as is fairly common practice, with the output stage on the loudspeaker panel. The receiver proper has three i.f. stages, an r.f. stage, and b.f.o. for c.w. reception. The band switch on the front panel takes the form of a sliding control and this is coupled to a rotary switch at the rear of the set by a mechanical linkage.

The interest shown by R.S.G.B. members in mobile operation extends to the motor cycle—exemplified by s.s.b. equipment shown by V. Page, G3IVP—and even the humble "push-bike": R. G. Scutt's (G3IBI) 2-metre bicycle transmitter-receiver does not depend on foot power, but uses a miniature 24-V accumulator.



Aquila Radio Club entry—transistor mobile communications receiver made by G3HRO. Band selection is achieved by the rotary switch at the rear, operated by the slide-bar below the dial.

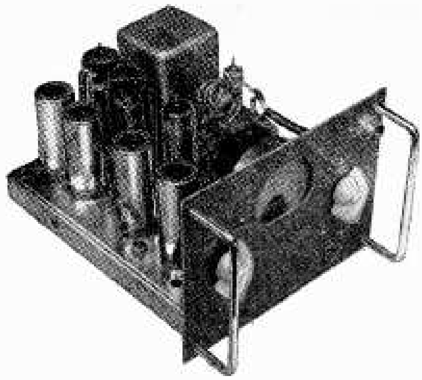
Another exhibit by E. St. B. Sydenham showed how members of the Royal Amateur Emergency Reserve may be alerted automatically. A super-regenerative 2-metre receiver fitted with an r.f. stage to eliminate the characteristic radiation, covers, due to its wide bandwidth, the whole 144Mc/s band. The output from this feeds, through a tuned a.f. amplifier, a pendulum relay. This relay will respond only when fed with pulses at its resonant frequency, and these pulses must be composed of a.f. to which the amplifier responds. Thus only a transmission satisfying these requirements broadcast at any frequency in the 144Mc/s band will energize the pendulum and ring the alarm bell. In the event of a mains failure, the receiver is automatically switched to battery operation.



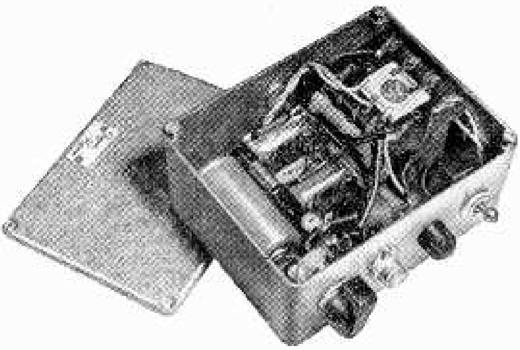
Underside of "Pathfinder" 160m transmitter by Electroniques (Felixstowe). Four-stage TV interference filter is adjustable and is seen in back compartment of centre row.

Five companies producing equipment for the amateur were seen in the "commercial" section for the first time. Electroniques (Felixstowe) (who also produce temperature-compensated tuning coils and coil packs) were showing a complete "top-band" (160m) transmitter called the "Pathfinder." This uses germanium

K. W. Electronics "One Sixty" top-band transmitter.



TW2 10-watt 144Mc/s transmitter by Withers.



Interior of "Tiger Talking Box" transistor modulator-drive amplifier.

diodes as a speech clipper, which enables a high level of modulation to be achieved without danger of over-modulation. A four-stage low-pass output filter (to prevent television interference) is fitted in a screened compartment and the aerial current is monitored permanently by a plug-in thermocouple feeding the front-panel meter. Another new 'top-band" transmitter on show was the K.W. "One-Sixty," which uses multiplication from the v.f.o. frequency of about 900kc/s. Like the "Pathfinder" this transmitter is complete in a small case, and can run at over the 10 watts input permitted. K.W. Electronics (who incidentally are importing Hammarlund receivers) won the award for commercial equipment this year, with their Viceroy s.s.b. exciter unit. Another new exhibitor was Tiger Radio, who were showing a very wide range of equipment. Items that particularly caught our eye were a 750W p.e.p. linear r.f. amplifier for 10 to 80 metres and the "Tiger Talking Box." The tetrode output stage (QY3-65) of the amplifier has its screen grid supplied from a cathode follower whose control grid is normally at chassis potential. When drive is applied a diode rectifies it providing a positive potential for the cathode-follower grid, consequently lifting the screen potential of the QY3-65 and allowing it to amplify. Complete absence of p.a. anode current (and output) is thus assured until drive is applied. Power supplies for the unit are derived by a chain of silicon rectifiers, whose good regulation is an advantage, and a bias control allows operation in any condition between Classes AB1 and C.

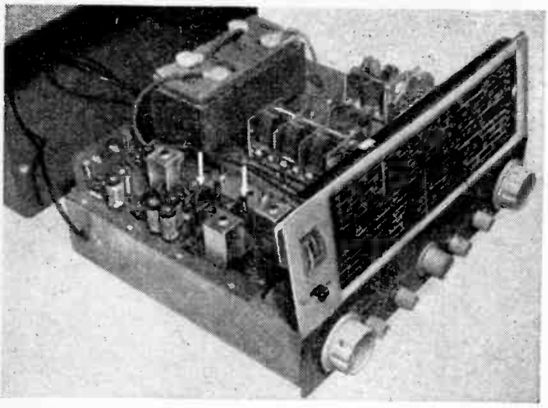
The "Tiger Talking Box" is a small transistor a.f. amplifier which derives its power supply from the 6.3V heater line. It is designed to be used as a microphone stand and it is capable of driving fully a pair of KT88 or 807 valves as the final stage of the modulation amplifier. The sensitivity is 10mV at an impedance of 750kΩ and the 150-V grid-to-grid output is achieved by two OC74s feeding two transformers.

Equipment made for the amateur for use in the 144Mc/s band is a comparative rarity; but this is a speciality of Withers Electronics. This company were showing for the first time a 10-watt transmitter, receiver converter and aerial, all suitable for mobile or fixed-station working. The TW2 transmitter is crystal controlled, tripling and doubling from 24Mc/s, whilst a clamp valve operates on the QQV03-10 output stage. The aerial is a $\lambda/2$ dipole, bent into a circle to reduce the directional characteristics and fed with a γ-match section which allows an 80-Ω feeder to be used although the basic aerial impedance has been changed by the "rolling up" process.

Another unusual form of aerial—called the "birdcage"—was shown by Minimitter: this is designed to act as a directional high-gain aerial for 14Mc/s. Its mode of operation can best be visualized by considering two V-dipoles, stacked, with reverse-V reflectors behind them. Little loss of performance of a dipole is incurred by bending away at right-angles to the main axis half of each of the "rods." The lower dipole and reflector have their ends "bent" upwards to meet and join, as the stacked arrays are $\lambda/4$ apart vertically, the ends of the upper array so forming the coupling between the two arrays. A gain of 10dB is claimed for the "birdcage" which, Minimitter point out, is roughly equivalent to a five-element Yagi with a boom length of nearly 60ft. The "diameter" of the birdcage aerial is under 20ft.

Sound Vision Services—the fourth of the newcomers—were showing telescopic masts embodying an ingenious principle. The lowest extending section is raised by winding up on a ratchet barrel a wire rope joined to its base and passing over a pulley at the top of the fixed section; but the upper sections have the guy-wires attached to their bases in a similar manner. Thus having made fast the guys, winding up the lowest extending section raises the upper sections. For non-telescopic rotating masts a rotating guy-ring using nylon bearing inserts which do not need greasing should eliminate the necessity for climbing the mast which always seems to be necessary during the worst blizzard of the winter.

James Scott, importers of Hallicrafters receivers, have added Dow-Key accessories to their range. Items on



Heathkit "Mohican" transistor communications receiver using ceramic i.f. transformers (arrowed).

show included a.c.-energized coaxial relays for aerial switching and automatic TR switches which operate by allowing the transmitter output to build up a high bias on the grid of a valve connected as an amplifier in the aerial lead to the receiver. On "receive," the bias decays, allowing the valve to give a slight gain.

Judging by the R.S.G.B. exhibits, transistors have made an enormous impact on the amateur during the last two or three years, particularly for use in receivers; but this year sees the first introduction of a commercial communications receiver using them. The Heathkit "Mohican" was certainly the centre of attraction among the kits on Daystrom's stand: this set covers 550kc/s to 32Mc/s in five bands, using OC171s for r.f., mixer and local oscillator stages. The 455kc/s i.f. is amplified by three type OC45, and to achieve a bandwidth of 3kc/s piezoelectric ceramic i.f. "transformers" are used. Two of these are of ring and dot construction and approximate to double-tuned transformers, whilst two more behave as single-tuned "acceptor" circuits in the emitter leads of the second and third i.f. stages. Control of the b.f.o. is exercised by a voltage-variable capacitance diode and the whole receiver with its 400-mW output stage takes only 35mA from the 12-V battery—much less than the dial lamps, for which a separate switch is provided!

Minimitter were showing a transistor converter covering the amateur bands up to 14Mc/s. This has an i.f. of 600kc/s, to feed into an ordinary receiver and the consumption is 1mA (one) from the internal 4.5-V battery.

Not all the exhibition was devoted to amateur radio—high fidelity enthusiasts would have found something to interest them from say, Jason, Heathkit or Aveley, who were showing American Dynakit designs and new output and mains transformers using toroidal windings. For mains transformers this offers the valuable advantage that the hum field is greatly reduced.

For those who want to make their own music the British Recording Club were demonstrating "electronic music" with the aid of a tape reproducer, and showing some of the equipment used. For instance, a ring modulator can be used to produce the very thing that most of us spend time getting rid of—intermodulation—which has many musical possibilities, or another undesirable—valve noise—can be turned into a "new sound" by passing it through filters.

Finally, for those who want to make the means of making music, Jennings, our fifth newcomer, were showing a basic electric guitar kit. This consists of guitar body parts, strings, etc., and a magnetic pickup unit placed under the strings, which are of steel. Thus an output is produced when a string is plucked and, after passing through a volume and a "top-cut" control (which, as it is connected in an inductive circuit, has a greater variety of effect than is usual) mounted on the instrument this can be fed into an amplifier. Jennings claim that the output is comparatively high and, as most modern radio receivers are fairly sensitive, the gramophone amplifier section of a radio-gram or radio can be used.

NEW DATA RECORDING EQUIPMENT

UNUSUAL TAPE TRANSPORT MECHANISM

A NOVEL design of magnetic-tape transport mechanism is a feature of new digital data recording equipment manufactured by the Computer Department of Redifon Limited. This mechanism moves the tape past the recording and reading heads in small separate steps, instead of continuously as in conventional systems. The new mechanism permits controlled variations to be made independently in the speed of recording and read-out data: controlled variations can also be made in the time delay produced by the passage of data from the recording to the reading heads.

The tape (35mm wide) accommodates up to sixteen recording tracks side by side. The drive system operates in such a way that the tape is quickly started, advanced at a uniform speed during most of the step, and then quickly stopped. The interval of uniform forward motion in each step is made to coincide with a recording or read-out period.

To get the variation in tape transit time between the recording and read-out heads two sprocket drive wheels are used; one wheel is near the recording heads and the other near the read-out heads. If both sprocket wheels drive the tape at the same speed, then the length of tape between the wheels remains the same, and the time delay between the two heads is constant. If, however, the "read-out" sprocket wheel is made to move at a different speed from the "recording" sprocket wheel, then the length of tape between the two wheels alters, and the time delay between the recording and read-out heads varies accordingly. For driving the two sprocket wheels at independent speeds two separate stepping motors are used. These are energized by pulses from variable-frequency pulse generators—the recording or read-out rate varying according to the pulse repetition frequency.

A great advantage of this type of data recording system is that, since the tape velocity is fast during each step, cumbersome high-frequency carrier or flux-sensitive head recording techniques can be avoided, and simple saturation recording by d.c. pulses is effective.

RING AERIALS

By H. PAGE*, M.Sc., M.I.E.E.

INSTALLATION AT MOTALA LONG-WAVE BROADCASTING STATION

IT is unusual nowadays to read of major developments in long-wave broadcasting, and this makes the recently published description of the station under construction at Motala, Sweden[1], all the more interesting.

The station works on a wavelength of 1,571m (191kc/s), and at present the transmitter power of 150kW is radiated from a single relatively low aerial; this arrangement is similar to the B.B.C. long-wave station at Droitwich. The useful range of such a station may be limited by interference (either man-made or from stations working on nearby channels), by fading, or both. Interference can be minimized by increasing the transmitter power, and it is proposed to increase the power of Motala fourfold, i.e., to 600kW. However, this by itself would not be worth while unless at the same time the aerial is made "anti-fading," i.e., unless the upwards radiation towards the ionosphere is reduced. The usual way of achieving this on medium wavelengths is to use a mast between 0.5 and 0.6 wavelength high, but this is impracticable for long-wave broadcasting—the mast would have to be about 3,000ft high. However, substantially the same performance can be achieved by using, instead of a single tall mast radiator, a number of low aerials in the form of one or more concentric rings, and the interest of the Motala project centres round the decision to use a system of this kind.

Let us consider first a ring containing an infinite number of aerials; from considerations of symmetry we can see that two arrangements will give uniform radiation in all horizontal directions—the usual requirement for a broadcasting station. The aerials may be driven with equal co-phased currents (in-phase ring), or with the currents of the same amplitude but with the phase progressing uniformly round the ring, the total phase shift being an integral multiple of 2π radians (progressive-phase ring).

In order to achieve anti-fading characteristics the in-phase ring must be associated with a central aerial,

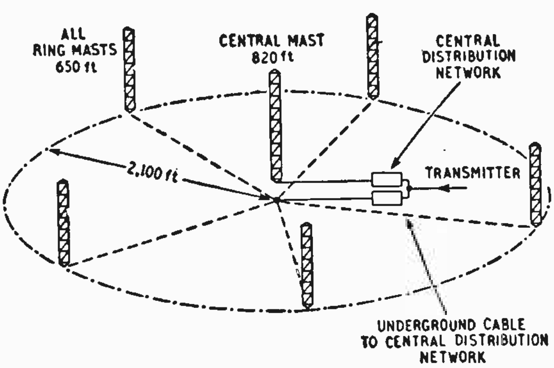


Fig. 1. Schematic diagram of the Motala ring aerial system.

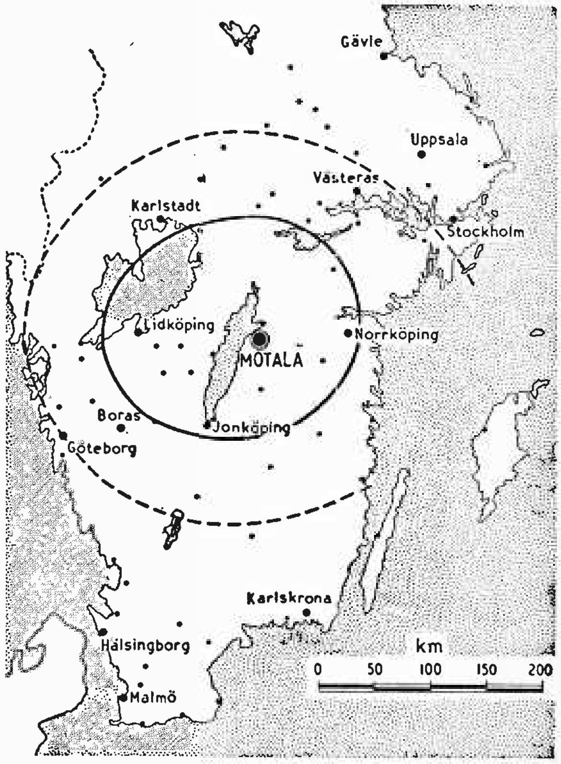


Fig. 2. Fading limits of the old (solid line) aerial system at Motala together with estimated limits of the new ring aerial. This map is reproduced from Magnusson and Stranden's article in the E.B.U. Review.

carrying a current opposite in phase to that of the ring (the central aerial can be regarded as a ring of zero radius). By changing the ratio of the current in the central aerial to that in the ring, the radiation at any specified angle to the vertical can be reduced to zero; in other words, we can achieve a vertical radiation pattern which is very like that for a single aerial of the optimum height. The progressive-phase ring does not require a central aerial, but the vertical radiation pattern is similar to that for a half-wavelength aerial, so that the anti-fading characteristics are less favourable than for the in-phase ring.

The above discussion has been in terms of a ring containing an infinite number of aerials. The effect of using a finite number is to introduce serrations in the horizontal radiation pattern, and a sufficient number of ring aerials must be used to reduce these serrations to an acceptable value. For the in-phase ring it is advantageous to use an odd number.[2]

The Motala ring aerial. shown schematically in Fig. 1, will employ a central mast 820ft high,

* B.B.C. Research Department.

and an in-phase ring comprising five masts, 650ft high, fed by underground cables from a central point. The ring radius will be 2,100ft and the earth system will occupy an area of 725 acres. For a system adjusted to give zero radiation at an angle of 45° to the vertical (i.e., having a vertical radiation pattern similar to that for a single mast 0.59 wavelength high) the current in each mast is expected to be approximately 200A and the voltage at the base to be approximately 30kV r.m.s. The initial complication of a ring aerial is therefore very high in respect of the number of masts, the area of the site required, and the equipment for energizing aerials. It is, however, the only practicable way of achieving a worth-while increase in the coverage of long wavelengths. The estimated fading limit for the new Motala station, shown in Fig. 2, is almost double that of the present installation.

The use of ring aerials to achieve anti-fading characteristics is by no means new. An in-phase ring was first used (but only experimentally) in Germany in 1931.[3] In 1939 the B.B.C. also tested an in-phase ring aerial on a wavelength of 342m at Brookman's Park; here the object was to increase the range of the Regional medium-wave service without infringing a severe Air Ministry restriction on the height of masts permitted at this station. However, when this restriction was lifted after the Second World War the B.B.C.'s aim was achieved more economically in the case of this medium wavelength station by erecting a single high mast, which is still in service.

The progressive-phase ring aerial was first proposed in 1936.[4] One was put into service in 1939 at Allouis, France, working on a wavelength of 1,648m, and designed for a power of 900kW.[5] The station was destroyed during the Second World War and the aerial system was not rebuilt in ring form.

Although much thought has been given over the past thirty years to the application of ring aerials to long- and medium-wave broadcasting, as far as the author is aware the Motala station, when completed, will be the only such system in service. Broadcasting engineers will await with interest to hear how the performance of the station compares with the expectations of the designers.

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[1] Magnusson, E., and Stranden, F: "Planning the New Motala Long-Wave Broadcasting Station." *E.B.U. Review*, Part A—Technical, No. 61, June, 1960, p. 107.

[2] Page, H.: "Ring-Aerial Systems — Minimum Number of Radiators Required," *Wireless Engineer* (now *Electronic Technology*), October, 1948, p. 308.

[3] Harbich, H., and Hahnemann, W.: "Vorläufiger Bericht über Versuche zur Bekämpfung der Schwunderscheinungen im Rundfunk mit Antennengebilden Üblicher Höhe (λ/4) and Grosserer Horizontalausdehnung," *Elektrotechnische Zeitschrift*, 17th December, 1931, p. 1545.

[4] Chireix, H.: "Antennes à Rayonnement zénithal réduit," *L'Onde Electrique*, July, 1936, p. 440.

[5] Adem, M.: "Le Nouveau Poste National de la Radiodiffusion Française à Allouis (Cher)," *Le Génie Civil*, 11th November, 1939.

BOOKS RECEIVED

Television Antenna Handbook by Jack Darr. Practical handbook for the service technician covering the principles, choice and installation of all types of television aerials (v.h.f. and u.h.f.). Profusely illustrated by examples of American commercial practice and including a chapter on roof techniques and safety precautions. Pp. 248; Figs. 260. Howard W. Sams & Co., Inc., 2201 East 46th Street, Indianapolis, Indiana, U.S.A. Price $3.95, U.S.A. Obtainable in U.K. through R. S. R. Hutchison, 60 Arno Vale Road, Woodthorpe, Nottingham.

Antennes voor FM, KG en TV by Ing. H. J. A. Smit and A. J. Dirksen. Practical handbook (in Dutch) of design and installation of f.m., short-wave and television aerials systems. Calculation of element length and spacing, impedance matching; mechanical problems of aerial erection, and a chapter on communal aerial systems. Pp. 191; Figs. 239. De Muiderkring N.V., Bussum, Netherlands. Price Fl. 5,90.

Electronische Muziekinstrumenten by H. Meijer Jr. and W. Heggie. Circuits in theory and practice, with descriptions (in Dutch) of the electrical and mechanical details of some representative designs. Pp. 168; Figs. 153. De Muiderkring N.V., Bussum, Netherlands. Price Fl. 7,50.

Grundzüge der Electroakustik by F. A. Fischer, Dr. Phil. Second edition, revised and enlarged, of an authoritative treatise on the theoretical foundations of electroacoustics. Provides a succinct mathematical treatment of transducers both as emitters and receivers of acoustic energy. Pp. 210; Figs. 141. Fachverlag Schiele & Schön, Markgrafenstrasse 11, Berlin, S.W. 61. Price, DM 24.

Handbuch des Rundfunk-und Fernseh-Grosshandels 1960/61. Illustrated guide with specifications and prices of current West German radio and television receivers, car radios, record players and tape recorders. Pp. 315, Verlag für Radio-Foto-Kinotechnik G.m.b.H., Berlin-Borsigwalde. Price DM 4,80.

Glossary of Terms Used in Telecommunications (including Radio) and Electronics. British Standard 204: 1960. Third revision of this standard, including the five supplements to the previous edition. Based on current usage, but with guidance in the choice of preferred terms. Covers general electrical terms, telecommunication components and circuits, radio terminal equipment, propagation and media, classification of radio waves and transmissions services, e.g., telegraphy, telephony, broadcasting, radar and navigational aids, and inductive co-ordination (design of systems to minimize interference from power supplies). Pp. 351. British Standards Institution, 2, Park Street, London, W.1. Price 35s.

Radio Engineering Formulæ and Calculations by W. E. Pannett, A.M.I.E.E. Collection of useful formulæ covering a wide field in radio transmission and reception, and dealing with problems in the every-day practice of design, installation and operation of radio stations. Pp. 200; Figs. 165. George Newnes, Ltd., Southampton Street, London, W.C.2. Price 17s 6d.

The Story of the Ionosphere by J. A. Harrison, M.A., M.Ed., Ph.D. Elementary exposition of radio propagation from Hertz to the first artificial satellite with sidelights on the development of radio technique, radar and radio-astronomy. Pp. 103; Figs. 123. Hulton Educational Publications, Ltd., 161/166, Fleet Street, London, E.C.2. Price 10s 6d.

TRANSISTOR NOISE

By "CATHODE RAY"

EVERYTHING must have a beginning, and incredible though it may seem there are people for whom this will be their very first *Wireless World*. They must be warned that in order to avoid vain repetition such as the heathen use I am assuming readers' knowledge of my remarks—or their equivalent (if any)—on valve noise in the last issue, and indeed of those on k in the issue before that. It being unrealistic to suppose that such knowledge will return instantly and fully to the minds of even those who read the said remarks, I will recapitulate.

Quite apart from any man-made interference, all amplification is limited by random (or "white") noise caused by electricity and matter not being continuous but made of particles. That is why very weak signals are heard against a background of escaping gas, or seen on a background of animated graininess. There are two main sources of such noise. One of them is the continuous agitation of electrons in matter, caused by heat. (You may say it *is* a form of heat.) The constant that connects the electrical noise power with the absolute temperature is the k mentioned above, equal to 1.38×10^{-23} joules per degree. The maximum noise power of this self-generated kind that can come from any bit of circuit is

$$kTB \quad \ldots \quad (1)$$

where T is the absolute temperature (beginning at $-273°C$) and B is the frequency bandwidth in cycles per second. In practice this power usually

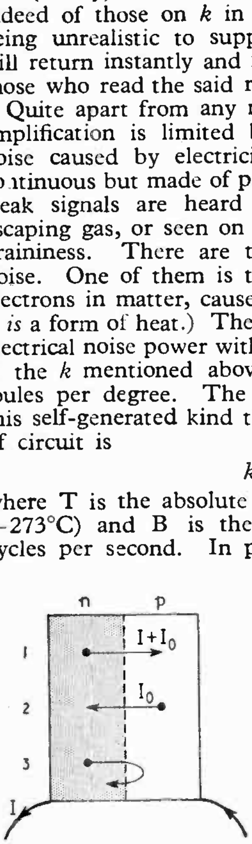

Fig. 1 Diagram of a p-n junction, showing the movements of typical electrons. Internal arrows show directions of electrons; external arrows, positive direction of current.

yields a few microvolts, and the only source of it worth bothering about is the input circuit of the amplifier. The maximum electrical power of any kind always results when a source works into a resistance equal to its own (say R), and from that it follows that the equivalent noise e.m.f. E_N is given by

$$E_N{}^2 = 4RkTB \quad \ldots \quad (2)$$

That is Johnson or circuit noise.

The other main kind is shot noise, caused where electrons stream from one electrode to another under the influence of an electric field, as in a valve. The individual electrons do not follow one another at exactly equal intervals of time, but randomly, and it is the resulting irregularities that constitute shot noise. The basic equation is

$$I_N{}^2 = 2eIB \quad \ldots \quad (3)$$

where I_N is the noise current, e is the charge on an electron, and I is the total current.

In any valve as normally used, the anode current I is not limited by the temperature of the cathode but by the crowd of electrons hanging about just outside it (the space charge) and these have a considerable smoothing effect on the noise, reducing it to perhaps only a tenth of the amount given by the above equation. On the other hand, whenever the current divides up—say between an anode and a screen grid—a further random element is introduced which is not smoothed. This contribution, which in a pentode usually exceeds the former kind of shot noise, is called partition noise.

Now we are about ready to start on transistors. But to prevent disappointment I had better make clear that transistor theory is almost always more complicated than valve theory, and the noise aspect is no exception. In fact, until fairly recently I wouldn't have presumed to expound it at all. A paper by an (perhaps *the*) outstanding authority on the subject, van der Ziel, published in 1955,[1] had a most discouraging appearance. But, as so often mercifully happens, theory which at first looks beyond the reach of any but Nobel prize-winners is eventually found to be capable of being explained to school children. By 1958,[2] van der Ziel (with a collaborator, Becking) had been having second thoughts to such good effect that they produced what has been described as a more rigorous proof in about half the number of pages, and in spite of that condensation most of it is intelligible even to me. What follows is based on it.

The original transistors, of the point-contact variety, were excessively noisy, and their workings mysterious withal, so it is fortunate that they soon retired in favour of junction types, which are the only ones to be considered now. A feature of the treatment by van der Ziel and Becking that particularly appealed to me was the type of diagram shown here as Fig. 1, in which the various possible ways in which particles could move were considered in turn. This diagram, which applies to junction diodes, shows electrons only, and divides them into three classes. Most of the free electrons in the diode crystal are those belonging to atoms of the "donor" impurity put there to make one end of the crystal n type. These diffuse around, and of those that cross the frontier into the p-type zone some of them —the majority, if the p end if positive or forward-biased—are gone for good. They form Class 1. Others, in their aimless wanderings, find themselves back again in the n zone; they are Class 3. There are also a few electrons liberated by heat throughout the crystal, regardless of the type of impurity present. Those in the n zone need not be separately considered, because all that cross the frontier can be

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[1] *Proc. I.R.E.*, Nov. 1955, p. 1639.

[2] *Proc. I.R.E.*, March 1958, p. 589.

included in Classes 1 or 3. Those in the p zone that cross over to n form Class 2.

Note that this classification is the same whatever external e.m.f. may be applied, but of course the numbers of electrons in the three classes are greatly affected thereby. The external current is denoted by I. If I_o stands for the reverse current due to Class 2 (remember, electrons being negative move oppositely to the conventional direction of current) Class 1 must add up to $I+I_o$. Class 3, unable to make up its own mind, obviously adds nothing to the external current.

The "emission" of electrons in Classes 1 and 2 from their zones, and their journeys to the opposite zones, are analogous to the crossing of electrons from cathode to anode in a thermionic diode—except for the absence of space charge, which is one respect at least in which semiconductor electronics is simpler than valves. (The electron charges are neutralized by the equal positive charges of their parent atoms.) So the shot-effect formula in its simpler form without space-charge smoothing (eq. 3) applies:

$$i_1^2=2e\,(I+I_o)B \quad \ldots\ldots\ldots\ldots \quad (4)$$

$$\text{and } i_2^2=2e\,I_o\,B \quad \ldots\ldots\ldots\ldots \quad (5)$$

where i_1 and i_2 are the r.m.s. noise currents due to all the electrons in Classes 1 and 2 respectively. These formulae are for current-squared, partly because they are simpler that way, and partly because random noise powers (proportional to current-squared or voltage-squared) can be added together simply, whereas currents and voltages can't—if one wants a correct answer.

The movements of Class 3 are random, due entirely to thermal agitation, and so their contribution to noise is given by an adaptation of eq. 2. That was in terms of voltage, but "Ohm's law" enables us to adapt it:

$$i_3^2 = \frac{E_N^2}{R^2} = \frac{4kTB}{R} = 4kTGB$$

where G is the appropriate conductance. The question of what is appropriate here is a little tricky. It turns out that G is equal to $G_a-e(I+I_o)/kT$, where G_a is the conductance of the junction to a.c. So

$$i_3^2 = 4kT\left(G_a - \frac{e(I+I_o)}{kT}\right)B \quad \ldots\ldots \quad (6)$$

The total noise-current-squared (say i^2) is $i_1^2+i_2^2+i_3^2$ and substituting their values from (4), (5) and (6) we get

$$i^2=i_1^2+i_2^2+i_3^2=2e\,(I+I_o)\,B+2eI_oB+4kTG_aB-4e(I+I_o)B=4kTG_aB-2eIB \quad \ldots\ldots\ldots\ldots \quad (7)$$

I_o very conveniently disappears, leaving us with i^2 in terms of the external current I.

This calculation may seem a bit dodgy in places, but it is confirmed by practical measurements, which is a comfort.

So far our currents have been composed exclusively of electrons. In an actual junction diode each class of electrons has its counterpart in a class of holes moving in the opposite direction. The current I includes both, and I don't think it would have occurred to me to doubt that the noise currents are in the same proportion therein as they are in the electron currents just calculated. But just to make sure, van der Ziel gives formal proofs that what holds for holes alone does also for electrons alone and for both combined.

Skipping that, we pass on to transistor triodes. Unlike a triode valve, a transistor consists of a pair of diodes back to back. So it can be tackled as an extension of what we have just done. Fig. 2(a) shows how the electrons move in a p-n-p transistor. The first three classes correspond to those in Fig. 1, with the base as the n zone and the emitter as the p. One might expect the same three to be duplicated in the base-collector junction. But, unlike the base-emitter junction, under working conditions it is always biased in the "reverse" direction, preventing electrons from flowing towards the collector. So Classes 1 and 3 are absent.

Fig. 2(b) shows hole movement. The first four classes are the same as for electrons in reverse, but there is one extra class which is in fact the most important of all, comprising the holes that pass right through and on into the external circuit.

If equation (1) is true for diodes in general it should be true of the two transistor diodes in particular. Let us apply it first to the emitter diode, in which the current and conductance can be called I_e and G_e respectively to distinguish them, and of course i_e is the corresponding noise current. Substituting these in (7) we get

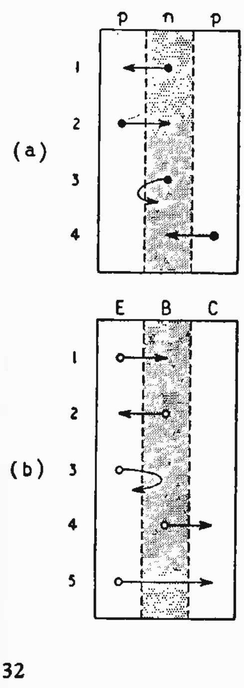
$$i_e^2=4kTG_eB-2eI_eB \quad \ldots\ldots\ldots \quad (8)$$

The formula for the collector diode is the same except for c instead of e, but we can save ourselves the trouble of writing the first term, because we have already decided that the collector diode is reverse-biased and so its conductance is negligible. And because I_c in this case flows from n to p instead of p to n (which we have taken as the positive direction without actually saying so) it is negative. So

$$i_c^2 = 2eI_cB \quad \ldots\ldots\ldots\ldots \quad (9)$$

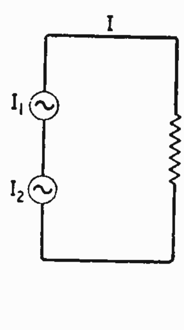
The noise current i_e can be regarded as coming from a current generator in parallel with the input junction of a noise-free transistor, and i_c as coming in parallel with the output junction. But that is not quite all.

In Fig. 3, I_1 and I_2 are currents from two a.c.



(Left): Fig. 2 A transistor consists of two diodes back-to-back, and here are shown the typical movements of (a) electrons and (b) holes.

(Below): Fig. 3 Given I_1 and I_2, what is the total, I?



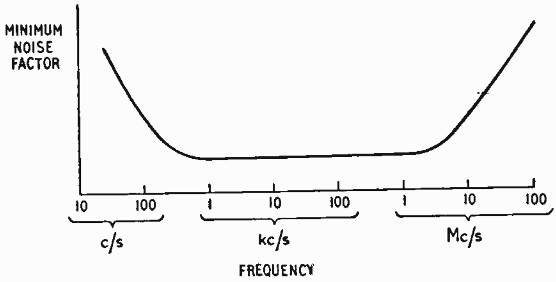


Fig. 4 Typical noise/frequency characteristic for a transistor.

generators working simultaneously. How much is the total current, I? The answer is that it depends on whether the two generators are synchronous or not. If not, then the rule we have been following is correct: $I^2=I_1^2+I_2^2$. But if they have the same frequency, then $I^2=(I_1+I_2)^2$. For example, if I_1 happened to be equal to $-I_2$, I would clearly be 0. But if they were unequal in frequency, or random, then it wouldn't even be possible to say $I_1=-I_2$, because there couldn't be a constant 180° phase difference between them.

The second method of addition applies even when the currents have no definite frequency—as with noise currents—so long as they are synchronous. This is so with the straight-through current of Class 5, but as that is not the whole current the total result is somewhere between the two extremes. In technical language, the noise currents i_e and i_c are *partially correlated.* Note that the difference between $i_e^2+i_c^2$ and $(i_e+i_c)^2$ is $2i_ei_c$. We might think that even a partially correlated current would therefore be larger than a totally uncorrelated one, but in this case the correlated parts of i_e and i_c have opposite signs, so the total noise is reduced by the correlation. Because i_5 is the main current, correlation is nearly complete, at least at low frequencies.

To calculate the total noise, one has to fit the noise generators given by eqs. 8 and 9 into a transistor equivalent circuit, and, since one is very much interested in how it depends on frequency, this equivalent circuit should include capacitors and anything else that may be necessary to simulate high-frequency effects in the transistor. The calculations then become no easy task. They have been performed—and, what's more, checked with measurements on actual transistors—by J. M. Stewart.[3] The badness of noise is best expressed as noise factor or figure, which is a measure of the extent to which it affects weak signals and so limits effective amplification. Stewart used a common-base circuit for his analysis, but found that the noise factor was essentially the same for the other two configurations. He circumvented another complication—that the noise factor depends on the external impedances connected to the transistor—by assuming that they would be adjusted to give the lowest and therefore best noise factor.

An interesting point is that the forking of emitter current into collector current and base current causes partition noise, analogous to that in multi-electrode valves; but because the base current is usually a very small fraction of emitter current the effect is relatively small.

[3] *Proc. I.E.E.*, Part B Supplement No. 17, May 1959, p. 1056.

A more serious thing is that there is also Johnson noise due to the resistances of the various parts. The most important is that due to what is usually denoted by $r_{bb'}$—the resistance between the base terminal and the active part of the base.

Such calculations reveal a frequency characteristic in which noise is flat or " white " over a wide middle range, but slopes upward at each end somewhat as in Fig. 4. Why?

At the low-frequency end the additional noise is more or less inversely proportional to frequency, so it is often called $1/f$ noise. Like the rather similar " flicker " noise in valves, it seems to lack a comprehensive explanation, but for our purpose it may be sufficient to note that it has been traced to surface leakage and similar imperfections of manufacture. While at one time it seriously affected the a.f. band, it has been pushed progressively down towards the sub-audio frequencies. Even those strange types who work among such things as servo-mechanisms and bio-electricity, to whom 20 c/s is an ultra-high frequency, are helped by this, because the lower the frequency at which the $1/f$ noise starts the less there is of it at any given frequency.

At the other end the rise is due chiefly to the various effects that cause transistor performance in general to fall off. Even " white " noise sources, if inserted in networks that include capacitors, give a net output that varies with frequency. Correlation becomes less, for one thing. It must be remembered that noise factor is worsened by anything that reduces signals more than noise. Against this gloomy thought there is the information that over the valuable middle frequencies the noise factor for junction transistors can be lower even than that for valves. But don't assume that this is necessarily so with the transistors you buy!

Brit.I.R.E. Premiums

THE first recipients of the newly established Associated-Rediffusion premium of the British Institution of Radio Engineers are K. G. Freeman (Mullard) and D. C. Brothers (B.B.C.) who share the £50 prize. Their papers "A Gating Circuit for Single-gun Colour Television Tubes" (Freeman) and "The Testing and Operation of 4½-in Image Orthicon Tubes" (Brothers) were read at the Institution's 1959 Convention.

The Heinrich Hertz premium (20 gn.) goes to P. B. Helsdon (Marconi's) for his Convention paper "Transistors in Video Equipment." K. Burrows, of Imperial College, receives the new A. F. Bulgin premium (15 gn.) for his paper "A Rocket Borne Magnetometer."

Four co-authors who are with the National Research Council of Canada receive the Brabazon award (15 gn.) for "A Low-drain Distress Beacon for a Crash Position Indicator." T. C. R. S. Fowler, of Bristol Aircraft, is awarded the Leslie McMichael premium (10 gn.) for "A Six-channel High-Frequency Telemetry System."

The new Charles Babbage award for an outstanding paper on electronic aspects of computers (15 gn.) is shared by Dr. T. B. Tomlinson (Southern Instruments) whose paper was "Switching Circuits Using Bi-directional Non-linear Impedances" and Dr. M. Prutton (I.C.T.) for "Ferro-electrics and Computer Storage."

I. J. P. James' paper "A Vidicon Camera for Industrial Colour Television" has been awarded the 10 gn. Marconi award. He is with E.M.I.

All three recipients of the graduateship examination prizes are from overseas—C. S. Sujan (India), O. Smikt (Israel) and W. W. Cridland (Canada).

Elements of Electronic Circuits

21.—Differentiation and Integration

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

EARLY sections in this series have illustrated how a simple series C-R combination can " differentiate " or " integrate " a rectangular input waveform with an accuracy depending on the relation between time constant employed and the length of the waveform. These circuits, with the aid of feedback amplifier, can be used to produce waveforms approximately proportional to the derivative or the integral of the input waveform. If certain precautions are taken it is possible for high accuracies to be achieved.

Most of the commonly-used methods are based on the fact that

$$v_c = \int i_c \, dt \quad \text{or} \quad i_c = dv_c/dt$$

where v_c is the voltage developed across the capacitor and i_c is the current taken by it.

L-R differentiating networks may also be encountered but the resistance of the inductor introduces errors. However, in some applications these errors can be tolerated.

Figs. 1 (a) and (b) illustrate an improvement on the simple C-R circuit for differentiating and integrating respectively. It can be shown mathematically that if the gain of the amplifier without feedback (A) is constant; then the time constant of the differentiating circuit of Fig. 1(a) is effectively divided by (A+1). This is accomplished without the corresponding decrease in amplitude of the output (which would have occurred in the ordinary way with the simple C-R circuit). The gain of the amplifier compensates for this and an improvement in accuracy of waveforms due to the decreased time constant results. A similar treatment for the integrating circuit of Fig. 1 (b) leads to the result that the use of the feedback amplifier effectively multiplies the time constant by the factor (A+1), resulting again in a more accurate integrated waveform.

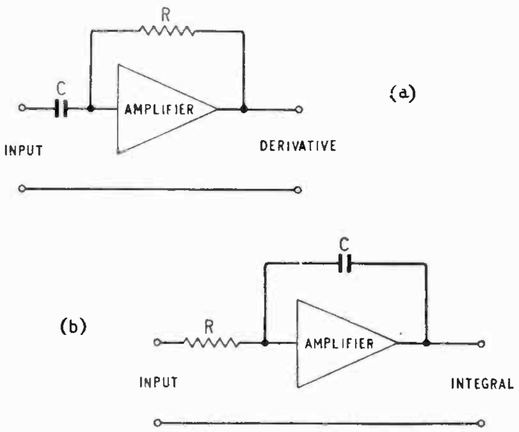
To compensate for stray capacitances which introduce time delays in the feedback loops of differentiators, and leakage resistance and dielectric absorption in the integrating capacitor of integrators, it is usual to introduce compensating circuits. Fig. 2 shows an integrating circuit of the Miller type (see description of the Miller time base in No. 14, June 1960) followed by a compensating amplifier. The object of this amplifier is to provide a current which is always equal and opposite to the leakage current through the integrating capacitor and the variable resistor is set so that balance of charge and discharge is achieved. One of the aims in both feedback differentiating and integrating circuits is to keep the voltage variations at the first grid to a minimum. The closer one can get to this ideal the nearer will the output be to either the derivative or the integral of the input. A high loop gain is essential and several stages of amplification are often used to achieve this.

Mention must be made of current, as opposed to voltage, feedback for differentiation or integration. Referring to Fig. 3, it will be seen that this circuit acts as a differentiator.

$$v_K \propto \int i_K = i_a$$

and due to feedback $v_K = v_{in}$. The anode current therefore varies as the derivative of the input voltage.

Before leaving this section it should be noted that a number of mechanical and electro-mechanical devices are available for carrying out these operations, but their response time is much longer than that of the circuits considered here.



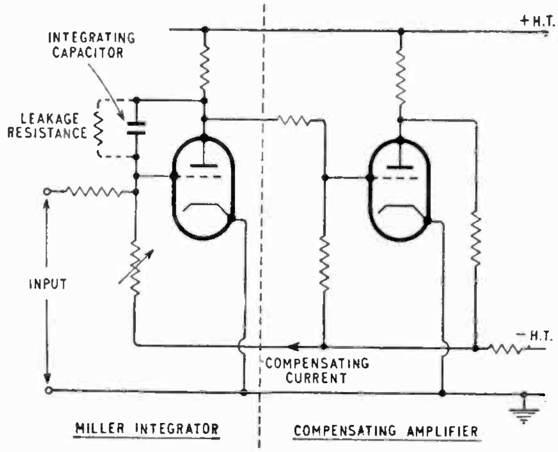


Fig. 2

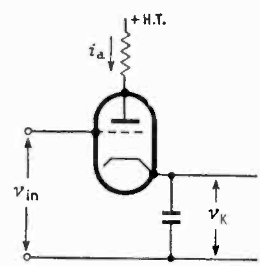


Fig. 3

LETTERS TO THE EDITOR

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

Stereo Broadcasts

I HAVE listened with interest and enjoyment to the B.B.C.'s series of experimental stereo broadcasts.

Presumably the original intention of these tests was to assess the relative merits of stereo and mono reproduction. This task has recently been made more difficult by the use of a TV sound a.m. transmitter for the right-hand channel. This inevitably produces a marked difference in the signal-to-noise ratio of the two channels. Similar performance from each channel can only be provided by using two similar transmitters or, preferably, one transmitter using a multiplex system.

In the meantime the case for stereo has been amply demonstrated by the gramophone record industry. After a somewhat shaky start they are issuing and selling vast numbers of stereo discs to a public which is obviously no longer in any doubt.

Now that the burden of proof has been lifted from the B.B.C., surely they could demonstrate a single-transmitter method of stereo broadcasting. The Mullard system (with its crosstalk 45dB down) seems to have much to recommend it, including the facility of radiating two separate programmes from a single transmitter.

Now seems the ideal time to start regular stereo transmissions from a single transmitter in each B.B.C. region. If this is not possible surely we could have an initial pilot scheme operating from Wrotham only, as was done during the f.m./a.m. controversy.

Saffron Walden, Essex. M. S. GOTCH.

Television Standards

MR. BANTHORPE (Oct. 1960 issue) advocates a change of field frequency from 50 c/s to 60 c/s for the purpose of reducing flicker The price to be paid would include an increase of bandwidth and a loss of the mains-hold feature as already mentioned by Mr. Banthorpe. But American experience shows that telecine and telerecording process become more involved and give inferior performances under those conditions. Once a field frequency has been reached which is sufficiently high to enable rapid movements to be depicted satisfactorily, then it would appear logical to achieve freedom from flicker by selection of afterglow time.

Mr. Heffernan, in the same issue, claims that "a real advantage . . . is gained in getting one's peak aerial power in the blacks and the all-important synchronizing pulses." Has Mr. Heffernan forgotten that an unmodulated carrier contains no intelligence and that a voltage change from 0-3 produces just the same signal as a change from 7-10?

Mr. Charles Rogers (Nov. 1960 issue) writes of the bandwidth needed for equal horizontal and vertical definition. Concentrating first on the word "needed," is this not putting the cart before the horse? A *suitable* number of lines is incidental to the bandwidth *available*. It is the bandwidth which is the raw material and which costs money, lines do not. There is no single correct relationship, and discussion* has shown that the country's experts disagree strongly amongst themselves as to what is the *best* relationship, their opinions covering wide ranges.

As for equal horizontal and vertical definitions, I suggest that there is no such condition. If there are l lines in a picture, then the number of different vertical heights which images may have is l. But images may be shown with an infinite variety of horizontal lengths. In the vertical plane an image may take up one of l positions. In the horizontal plane it may take up one of an infinite number of positions.

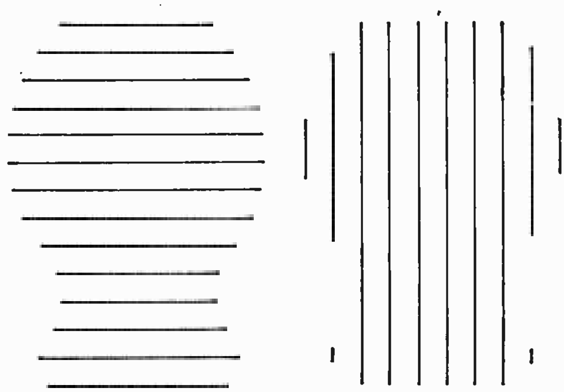
It has been known for at least a decade that the conventional relationship, usually expressed in cart-before-horse fashion as

$$f_{max} = Al^2f_p/2$$

gives, when transposed, a number of lines which is too small. The Television Advisory Committee's recommendation for increasing vertical definition to a greater extent than horizontal definition merely recognizes this fact.

I believe that the *logical* approach to this problem is to determine the *available* bandwidth, and with a multi-standard camera channel, limited to this bandwidth, to select that number of lines which gives the most pleasing results. This, of course, has been done, but it is surprising how old ideas stick. This is probably because the subject makes a neat (but very misleading) examination question.

I believe that the fallacy of the conventional equation can be demonstrated in the following manner:—



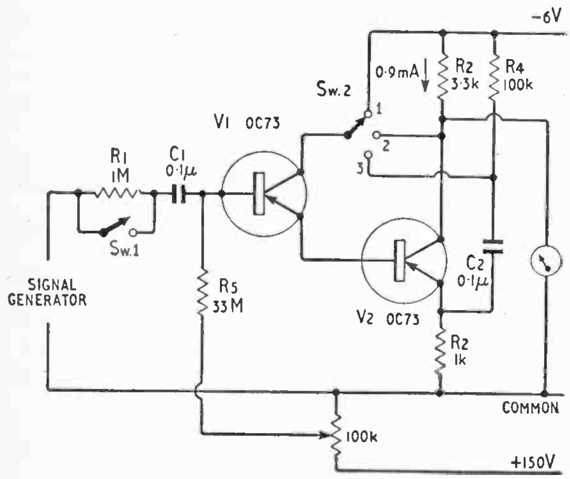
I reason that if this equation were valid, then the definition of an image would be governed by the sum total of the line lengths that lay within the boundaries of the image of an object, irrespective of whether they coincided with the major or the minor axis of an elongated image. The above sketches are of the *same* object drawn in these two different ways.

Sutton, Surrey. R. C. WHITEHEAD.

(* See, for example, "Relation Between Picture Size, Viewing Distance and Picture Quality," L. C. Jesty, *Proc.I.E.E.*, Part B, No. 23, Vol. 105, Sept. 1958.)

Transistorized Wein Bridge Oscillator

THE use of the super-alpha pair as the input stage in the article in your August 1960 issue has already provoked considerable comment, but one feature of the arrangement has been misrepresented by Mr. F. Butler and overlooked by subsequent correspondents. On page 388 he says that the super-alpha stage is an emitter follower directly coupled to a common-emitter stage, the collector of the emitter follower being taken to the collector of the common emitter stage and not the supply rail. He then says: "The principal effect of this change is to place in series with the collector circuit of the first transistor the whole output voltage developed across the load resistance. This voltage is opposite in phase to the amplifier input voltage and constitutes a large series negative feedback signal. The effect of this [feedback] is to cause a further increase in the already high input resistance . . ." Surely the effect of this feedback is to reduce the input



resistance, for, when the collector voltage of an emitter follower is reduced, an increase in the input current is required to maintain the emitter current constant. Thus the stage appears to have a resistor connected between base and emitter, the value using hybrid parameters, being $(B + 1)/h'_{22}$. By using the super-alpha stage this resistor is connected between input and output of the pair and thus appears as if it were across the input $k + 1$ times smaller, k being the stage voltage gain. At high frequencies the collector to base capacitance shunts the input still further, an effect which is $k + 1$ times greater with the super-alpha stage than with the conventional arrangement.

Using the circuit shown a set of measurements was made with the same two transistors throughout. With Sw2 in position 1 the circuit is that of an emitter follower driving a common-emitter stage, in position 2 the super-alpha stage results, and in position 3 the collector of V1 is connected so that it closely follows the input voltage. The input impedance is measured by inserting R_1 in series with the input and observing the change in the output voltage.

At 100 c/s the change of Sw2 from position 3 to position 2 reduces the input impedance from 1.6 to 1.3MΩ. This gives $(B + 1)/h'_{22}$ as 30MΩ (very approx.) and hence if $B = 30$ (and experiments show that B is maintained at very low currents) $1/h'_{22} = 1$MΩ, which is much higher than the value at normal currents.

At 3 kc/s changing from position 3 to position 1 reduces the input impedance from 1.4 to 0.8MΩ. This gives the collector to base capacity of V1 as 5½pF.

At 3 kc/s changing from position 3 to position 2 reduces the input impedance from 1.4 to 0.17 megohms. This gives the collector to base capacity as 7½pF, i.e. larger at the lower collector voltage, which seems reasonable though both values of the capacitance are smaller than the value at normal currents.

A table setting out the input impedance of the three circuits at various frequencies is shown below

	Frequency (kc/s)	0.1	1.0	3.0	10	30	Sw 2
Input impedance in megohms	Conventional circuit	1.6	1.4	0.8	0.19	0.05	1
	Super-alpha	1.3	0.6	0.17	0.045	0.02	2
	Collector "lifted"	1.6	1.6	1.4	0.5	0.07	3

The technique of lifting the collector of an emitter follower is used in Application Report No. 6 of Texas Instruments. Here a d.c. amplifier is described with an input impedance of 200MΩ.

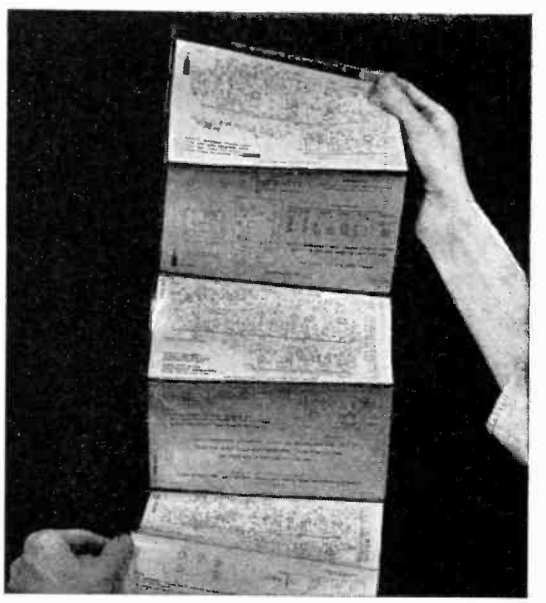
Barnet, Herts. J. C. A. TALBOT

The author replies:—

Mr. Talbot has drawn attention to what in some circumstances may be a fundamental defect of the super-alpha transistor pair. I accept his conclusion that the effect of feedback from the collector load is to reduce the input impedance of the first stage and not to increase it as I stated. Nevertheless, from Mr. Talbot's tabulated figures it is clear that at low frequencies the input impedances of the three circuit arrangements he describes are all of the same order of magnitude but that, partly because of collector-base capacitance, the input impedance of the super-alpha circuit falls off more rapidly with an increase in frequency than is the case with the other two circuits. It turns out, quite fortuitously, that this characteristic is acceptable in the present case because, on any given frequency range, the Wien bridge network has its lowest impedance at the highest frequency. Thus we have in effect an amplifier of variable input impedance driven from a source of variable output impedance and any mis-match is of little practical consequence. Naturally the effect of collector capacitance is much worse in the case of audio-frequency transistors than it is for h.f. or v.h.f. transistors in which this capacitance is very small. If outputs extending up to 100 or 200 kc/s are desired it would be advisable to use transistors with alpha cut-off frequencies in the range 30-100Mc/s.

I have a copy of the excellent Texas Instruments Application Report referred to by Mr. Talbot, but it was issued after my paper was written. It is possible that their techniques for designing transistor circuits of very high input impedance might have applications in the R-C oscillator field but, if carried to extremes, these techniques become too elaborate to incorporate in a simple piece of apparatus.

F. BUTLER.



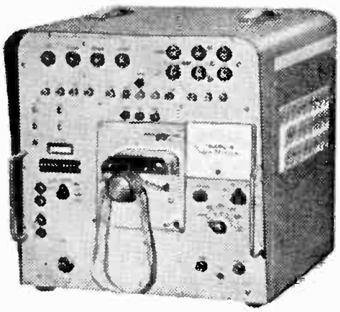
***P.V.C. holders** have been produced by Bush Radio to protect the miniature circuit diagrams which they now issue to dealers for the servicing of television and sound receivers.*

MANUFACTURERS' PRODUCTS

NEW ELECTRONIC EQUIPMENT AND ACCESSORIES

Automatic Circuit Tester

THE American Lavoie Laboratories' "Robotester" can test to any one of four alternative tolerance limits the resistance and a.c. or d.c. voltage between any two of up to 250 test points at a rate of about 80 tests per minute.



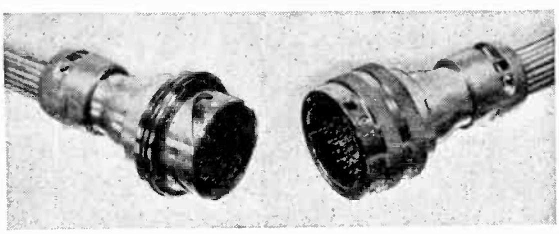
Lavoie Laboratories "Robotester" automatic circuit tester.

The tolerance limit as well as the resistance or voltage to be tested are individually set for each test by means of a punched tape which is fed into the Robotester. If a fault is found the machine automatically stops until switched on again, and at the same time the measurement accuracy can be checked. Alternatively, an additional unit can be attached which automatically records the fault and then restarts the tester. It is claimed that with this instrument on production runs final test times can be shortened by about 80%. The Lavoie Laboratories' Robotester costs £2,850 and is distributed in this country by Metrix Instruments Ltd., of 54 Victoria Road, Surbiton, Surrey.

Versatile Multi-pin Connectors

A NEW range of aluminium-cased, multi-pin connectors, the Mark 6, is now available from The Plessey Company. These connectors embody many singular features and they also accommodate a considerably greater number of contacts than other Plessey connectors of similar size.

Mark 6 connectors are available in four sizes with a fixed and free unit in each; both units are obtainable with either plugs or sockets and are easily convertible to coupler units. A silicone-rubber moulding forms the insulator and fully shrouds individual contacts, cable joint and a portion of the cable dielectric.



The new versatile Mark 6 Plessey multi-pin connector.

Insulation resistance between contacts and earth throughout is greater than 10^{4}MΩ at 500V.

The voltage rating is 1kV r.m.s., irrespective of contact class, at ground level, reducing to 350V at 70,000ft, or under equivalent conditions. Current ratings range from 5A to 12A and the connectors are satisfactory for operation in ambient temperatures between −55°C and +155°C.

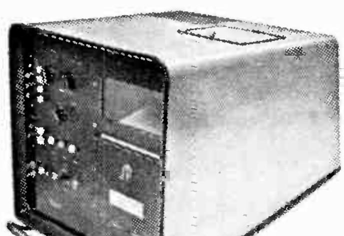
Contacts are silver-plated brass and socket inserts are designed to give equal mating loads irrespective of the length of engagement.

These new connectors can be used in four alternative positions by merely varying the position of the bayonet couplings. This feature prevents mis-coupling to wrong units and also prevents mis-mating. The connector is designed to meet the major performance requirements of British Military Specifications EL1987 and DEF5321, and American Military Specifications MIL-C-5015D and MIL-C-26500 (U.S.A.F.).

A special high quality connector with nickel-plated housings and gold-plated contacts is available to special order. Further details can be obtained from The Plessey Co., Ltd., Ilford, Essex.

Multi-channel Oscillograph

THE new Savage and Parsons Type RG32-12/15 multi-channel oscillograph has a response of up to 1000c/s at a sensitivity of 7.5mA/cm. Eight alternative paper speeds from 5in/min to 150in/sec can be used, and a well-defined trace is obtainable at writing speeds of 12,000in/sec. Up to 200 feet of paper can be recorded at any one time and this can either be run continuously or alternatively automatically stopped after 2, 5, or 10 feet have been used. Identification of each channel every two feet irrespective of the paper speed is provided by a sequential interruption of each trace. The signals are obtained from mirror galvanometers and the traces developed spontaneously within a few seconds by using ultra-violet sensitive paper. The magnet block carries fifteen galvanometers but some of

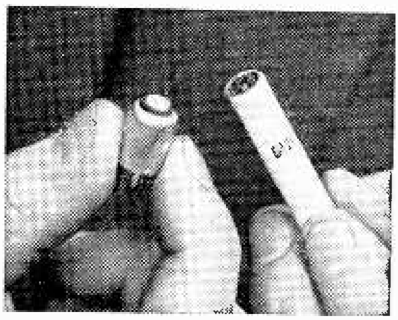


Savage and Parsons Multi-Channel Oscillograph.

these will usually be used as time markers or, connected to the mains, as a reference frequency. The cost of this oscillograph is in the region of £1,200, the exact value being obtainable on application. It is manufactured by Savage and Parsons Ltd., of Watford, Herts.

Sub-miniature I.F. Transformers

A TRULY sub-miniature transformer, the "Fidis," which measures only ⅜in in diameter and ⅝in high, is being produced in France primarily for use in pocket-



Orega "Fidis" sub-miniature i.f. transformer compared in size with a cigarette.

sized transistor receivers, but it has, also, applications wherever space is strictly limited. The base soldering pins are positioned so that the transformer can be used in printed circuits.

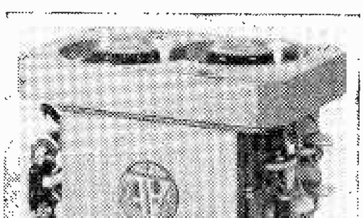
Despite its diminutive size it is fully screened and the "Q" of the windings is claimed to be of the order of 150.

Further details can be obtained from the French company Orega, 106, rue de la Jarry, Vincennes (Seine) France, a subsidiary of the Compagnie Générale de Télégraphie Sans Fil of Paris.

Transistor DC/DC Converters

RECENTLY introduced by Aveley Electric is a range of transistor converters supplying h.t. voltages from 6V to 24V batteries. A special feature of the Avel converters as they are called, is the use of toroidally-wound transformers on H.C.R. square-loop type magnetic cores, together with bifilar windings to ensure accurate balance and fast switching of the transistors with over-shoot voltages kept to a minimum.

The converters, which are available with ratings of 5W to 120W, provide normally 300V d.c. output with intermediate tappings of 200V and 250V. Adequate protection is provided to prevent damaging the transistors by inadvertently reversing the polarity of the input or by other wrong connections.



Chassis of a typical Avel transistor DC/DC converter made by Aveley Electric.

Shown in the illustration is one of the basic units employed in the converters, the massive chassis block forming a heat sink for the transistors. This basic unit can be fitted in a variety of housings to meet users' requirements. By duplicating and triplicating the basic units in a single housing higher power, or voltage, outputs and/or multiple voltages are readily obtainable.

The basic units are very compact, the chassis, or heat sink, measuring only 3⅛in × 2¼in with height dependent on output rating. In a 45-Watt unit, for example, this is about 3in.

Further details can be obtained from Aveley Electric Ltd., South Ockendon, Essex.

Television Aerial Isolator

TO the Egen range of components has now been added an aerial isolator, Type 364. It isolates the aerial on a.c./d.c. television receivers and is a single compact rugged unit which complies fully with the individual requirements of BS415. Insertion loss is very low and its

Egen television aerial isolator.

electrical specification ensures maximum performance at all frequencies envisaged for domestic receivers.

It is completely co-axial with full screening of the inner conductor. The series inductance of the feed-through capacitor in the outer conductor is exceptionally low, which is a desirable feature. Feed-through capacitors in both conductors are each 470pF. They are tested to 3,000V d.c.

Provision is made for direct mounting to the receiver chassis or to a separate bracket and the isolator can be supplied with any required length of coaxial cable for connection to the receiver input circuit. The external socket accepts a standard coaxial plug to R.E.C.M.F. specification. The makers are Egen Electric Ltd., Charfleet Industrial Estate, Canvey Island, Essex.

Transformer Kits

THE introduction of a range of transformer kits comprising a stack of laminations, a bobbin and fixing clamps where appropriate, will come as welcome news to many concerned with the construction of a prototype iron-cored transformer, and these also include home constructors.

Fifteen sizes and three different lamination materials, Silcor, Radiometal and Mumetal respectively, are available and prices for single kits range from 9s 3d to 15s 6d in Silcor, 9s 3d to 63s 9d in Radiometal and 9s 6d to 93s in Mumetal. Further details and prices for quantities are obtainable from The Belclere Company Ltd., 171 Cowley Road, Oxford.

New Plastic Foil Capacitors.—The following corrections should be made to the report on the Tropyfol capacitors on page 616 of the December issue. The largest capacitance in the 400V range is 0.47μF. The 125V type measuring 4.5 × 12mm is a 0.01μF capacitor while the 13 × 24mm capacitor of 1μF is a 125V type.

Iron-Cored Coupling Transformers

With Particular Reference to the Design of Iron-Cored A.F. Components

BY D. SAULL

A TRANSFORMER is like the conjunction in English language—it correctly joins two or more individual circuits together; e.g., a microphone to the input of an amplifier, one stage of an amplifier to the next stage, an amplifier output to a speaker or transmission lines, etc. And for each particular application a transformer must usually be specifically designed. The range of such designs is therefore very large.

The block diagram in Fig. 1 shows the family tree, as it were, illustrating some of the many uses to which transformers may be put in electronic circuitry. If the reader pauses to consider that a complete book could be written on the subject matter of any one application—say pulse transformers—it becomes evident that a single article in a journal could not possibly cover the complete subject of transformers.

The purpose of this article is, therefore, most certainly not a comprehensive study of impedance matching transformers; neither is this article intended to be read by transformer designers. No, its purpose is to aid the engineer, whose mind is centred on the equipment he is designing and from which he does not wish to be deviated, to reach a starting point if he is obliged to get down to designing his own transformer. Alternatively, to assist the engineer to call up his requirements if he is fortunate enough to possess the facility of a transformer design department to supply his needs. For these reasons, the author intends to generalize in his statements to avoid entering into details, which would defeat the purpose of this article.

Before leaving the reference to a transformer design department, it may be worth explaining the value of such a department to a firm employing a fair number of design and development engineers. It can be shown that the average transformer design time for a transformer design department, over a period of time, is half to two thirds the average time taken when individual design and development engineers design their own transformers. This is a money-saving consideration for readers in a managerial position in industry to ponder.

The reason for this shorter design time, claimed by transformer design departments, is twofold. First, although the transformer designer is no more skilled than the development engineer, and perhaps even less skilled, he has the advantage of constantly designing transformers and so learns the short cuts; whereas the development engineer is called upon only infrequently to design transformers. Secondly, one design frequently assists another design, and often a transformer is a modification of a previous design; a transformer design department has records of the work carried out but—in the case where separate designs are done by various engineers—Fred doesn't know what George is doing.

As the subject matter of this article is not intended to be "the management of industry," let us press on with transformer design.

A transformer is basically a number of turns of conducting wire wound round a block of iron. If two such windings, consisting of any number of turns, are wound round any block of iron and an a.c. signal is applied to one winding some form of a.c. signal will appear across the second winding. What relation the output signal will bear to the input signal, in this case, is anyone's guess. And, perhaps, here we come very near to the heart of the subject.

As was said earlier, a transformer correctly joins together two or more electric circuits. It may serve to connect a low-output impedance microphone to the high impedance grid circuit of a valve, or the high-output impedance of a valve to the low-input

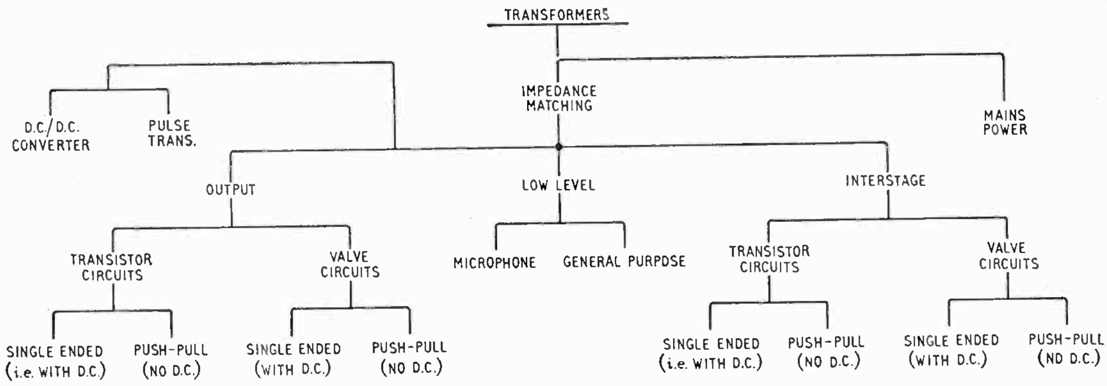


Fig. 1. Transformer family tree showing some of its numerous applications

impedance of a speaker. Whichever the case, if the transformer is ideally designed, each circuit will be correctly terminated and the respective circuits do not know that the transformer is there at all—like the broody hen and the china egg. However, the china egg is cold to sit upon, and the practical transformer is not ideal, having losses, phase shift, etc.

How near to the ideal may the engineer expect to get? The problem is rather like a tug-of-war contest with perfection on one end of the rope and costs on the other. The road to perfection leads to higher grade transformer laminations, larger lamination sizes, and longer development time; factors which may be expressed in terms of £, s, and d.

So a compromise must be made; and usually the engineer is obliged to specify the lowest standards that he can tolerate. The maximum insertion loss

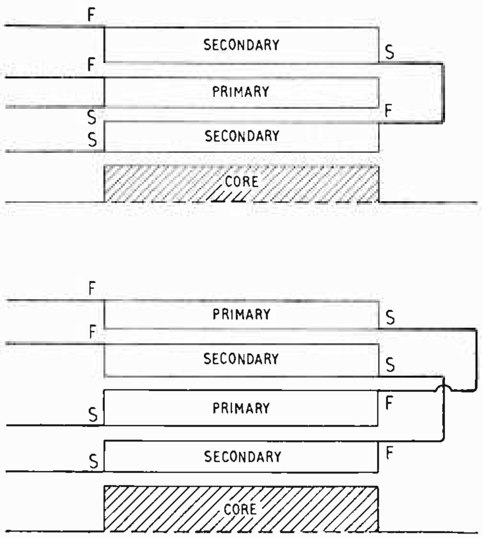


Fig. 2. Two methods of sectionalizing windings

and harmonic distortion, together with the minimum frequency response, that is acceptable to the engineer, must be specified.

A transformer functions electrically the same whatever its application, and its design is a compromise of a number of variables. For one application insertion loss is an important factor, for another it is of little importance; the same applies for winding d.c. resistance, leakage inductance, etc.

Perhaps the easiest method of reaching a compromise between perfection and costs is to examine the merits of the various lines of action that the engineer may take. The author will, therefore, try to take the reader briefly, in turn, through the practical considerations required for the design of each transformer application illustrated in the family tree in Fig. 1. But, before passing on, it might serve well to discuss some of the various grades of transformer irons available, the methods of winding, and three different ways of assembling the laminations.

Winding Methods.—There are two main methods of winding transformers, (*a*) paper interleaved layer winding on a cheekless former and (*b*) layer winding without interleaving paper on a former with end cheeks.

In the author's opinion, type (*a*) is more suitable for the larger variety of transformer, e.g., the output transformer of a high-quality 10-watt a.f. amplifier. The figures for overall space factor and the turns-per-inch-squared quoted in the Tables 1 and 2 of the article "Power Transformer Design," published in the June (1960) issue of Wireless World, will hold good for this application. Type (*b*) should be employed in the smaller variety of transformer for the reason that, when interleaving paper is employed, the thickness of the paper becomes comparable with the diameter of the winding wire used. For this smaller variety, an overall space factor of 30 to 35%, which includes the former, should be assumed.

Flux Gradient.—The flux density across the window area of the laminations is not constant due to the increasing length of the iron path; if the lines of flux are compared with the rings of water ripple surrounding a stone thrown into a pond, this idea becomes more evident. This flux gradient increases the leakage inductance. To reduce the leakage inductance the primary winding may be split into two or more sections and sandwiched between the secondary windings. The result of so dividing the primary winding into sections unfortunately increases the capacitance between windings. This capacitance may in turn be reduced by separating the primary and secondary windings by several layers of interleaving paper. Further sectionalizing and reversing the direction of the windings, but connecting the windings in the same magnetic sense, results in improved characteristics; Fig. 2 illustrates two possible methods.

A compromise must be arrived at to obtain the required results. For the above considerations, the number of turns on the primary winding should tend towards a minimum, which suggests in order to maintain the required primary inductance, that a core material with as high a permeability as possible—consistent with costs—should be employed. The latter applies particularly to low level transformers.

Grades of Iron.—Commencing from the lowest, in permeability and cost, the following list of core materials will give an approximate guide to the respective applications:

(*i*) *Silcor 25;* 0.014in and 0.020in thickness—1% silicon content.

(*ii*) *Silcor 107;* 0.014in and 0.020in thickness—3½% silicon content.

(*iii*) *"C" Cores;* 0.002in to 0.013in thickness—cold rolled grain-oriented silicon steel—may be worked at 30% higher flux densities than (*i*) or (*ii*).

These first three grades are suitable for use in output transformers employed with higher-power, good-quality a.f. amplifiers. For this application, it is better to have a large core of cheaper material than a smaller core of the higher, more expensive, grade material such as Radiometal or Mumetal.

"C" cores are particularly adaptable to such uses due to their shorter mean magnetic-path length and higher permeability, and may be conveniently worked at 5×10^3 gauss. This material saturates at

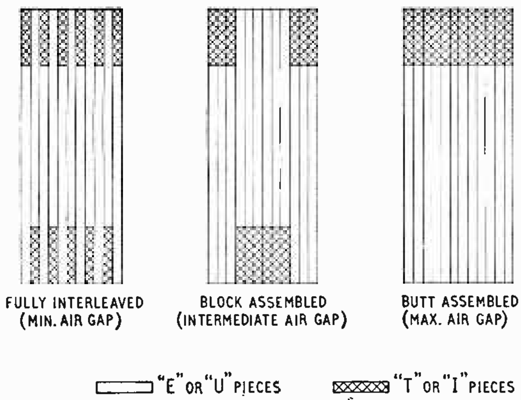


Fig. 3. Methods of assembling core laminations.

a higher value of d.c. component, which is worth bearing in mind when designing transformers carrying d.c. The range of sizes obtainable extends down to small sizes suitable for interstage transformers with a d.c. component.

(*iv*) *Radiometal* lies between silicon steel and Mumetal, and may be worked at flux densities twice that for Mumetal, but does not have as high a permeability as the latter material.

(*v*) *Mumetal.* The use of this material, with its high permeability, makes possible the design of miniature transformers for transistor circuits and transformers of smaller size with high primary inductance and low leakage inductance. The material saturates at low values of d.c. and is, therefore, not suitable for applications where a d.c. current is present. However, where the d.c. is of low value, and the primary inductance is not high, this material may be used, i.e., transistor a.f. interstage transformers.

Average Permeability:

Silicon Steel—350

Radiometal—1,600

Mumetal—15,000

Turns Reduction for a Given Inductance:

$$\frac{\text{Radiometal}}{\text{Silicon Steel}} = 2.14 \text{ to } 1$$

$$\frac{\text{Mumetal}}{\text{Silicon Steel}} = 6.8 \text{ to } 1$$

$$\frac{\text{Mumetal}}{\text{Radiometal}} = 3.3 \text{ to } 1$$

Methods of Assembling Laminations.—Fig 3 illustrates the three main methods of assembling the laminations to produce various degrees of effective air gap in the iron core.

Low-Level Transformers.—A low-level transformer is one which is used to couple two circuits where the power available from the primary circuit is of a small order, i.e., milliwatts. Such applications might be a microphone transformer, a transformer connecting a 600-ohm signal generator to a 20-ohm load, a moving-coil meter transformer to extend the current measuring range, etc.

The first consideration might be a low insertion loss, which calls for a low-loss, high-permeability type of lamination—Mumetal or Radiometal—the author's choice would be Mumetal. The second consideration is frequency response; the third consideration, closely related to frequency response, is second harmonic distortion.

Low Frequencies.—The distortion in a transformer at the lowest frequency is dependent upon the maximum operating flux density, and falls off sharply with frequency increase.

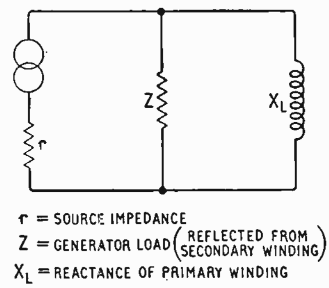
The frequency response at the lowest frequency is dependent upon the value of shunt inductance of the primary winding. Fig. 4 illustrates how this fall off at the lower frequencies arises, and the table gives practical values.

High Frequencies.—At high frequencies the leakage inductance and the capacitance of the windings increases the frequency fall-off. A well-designed low-level transformer may have a frequency response of from 20c/s to 100kc/s. The design problems of such a transformer might be listed as follows:

(*a*) High primary inductance.
(*b*) Low leakage inductance.
(*c*) Low flux density—order of 600 gauss.
(*d*) Low winding capacitance.
(*e*) Low d.c. resistance—dependent upon application.

Factors (*a*) and (*b*) plus (*d*) work in opposition because by increasing the number of turns, to in-

Fig. 4. Equivalent transformer primary circuit.



crease the primary inductance, the leakage inductance increases proportionately (i.e., leakage inductance and primary inductance are both a function of the square of the number of turns). The capacitance of the windings also increases.

Increasing the stack size increases the primary inductance but does not reduce the leakage inductance to the extent that might at first be expected, due to the increased mean turn length of the windings.

The answer lies in using core materials of high

Table

At flux density = 600 gauss		
X_L equal to	Total % harmonic distortion	Frequency fall-off
6R	0·3	
4R	0·4	
2R	0·7	1dB
R	1·7	3dB

permeability—hence a very good reason for using Mumetal. Radiometal follows some little way behind—if the purse strings are tied.

The tighter the specification, the greater the time taken to produce the completed design. The designer is fortunate indeed if he produces the finished transformer at the first attempt. The procedure is more likely to result in a first-off version to be tested and the shortcomings noted. This is where the transformer design department again has the advantage—the second-off and final design, in this case, will be the modification to a previous near design.

Making a Start.—The required primary inductance should first be calculated from $\omega L = R$, $2R$, $4R$ or $6R$ according to the permissible distortion at the lowest frequency to be reproduced (see table).

The next step is the choice of lamination size, which, unless a direct selection can be made based on previous experience, must satisfy the two following equations:—

(*i*) $$N^2 = \frac{L \times 10^8 l}{3.2 \times A \times \mu}$$

(*ii*) $$B = \frac{E \times 10^8}{28.6\ fNA}$$

Where:

μ = Initial permeability.
L = Henries.
A = Cross-sectional area of the core in sq in.
l = Mean magnetic path length in in.
N = Number of turns.
f = Frequency (lowest).
B = Flux density (order of 600 gauss).
E = Applied maximum voltage when the transformer is in circuit.

Having selected a suitable lamination size, the number of primary turns required should be evaluated from equation (*i*) and then a check made using equation (*ii*) to ascertain that the flux density is not in excess of 600 gauss.

The secondary turns are then evaluated from:—

$$\text{Turns ratio} = \sqrt{Z_1/Z_2}$$

where Z_1 and Z_2 are the input and output circuit impedances.

When a sample transformer has been wound it should be tested for frequency response. This may be done with the aid of a signal generator and a valve voltmeter. The transformer should be correctly terminated in a resistive load and the voltage appearing across the primary winding at A (see Fig. 5) should be adjusted, with the aid of the valve voltmeter, to be that which will appear across the winding when the transformer is connected in circuit. Fig. 5 illustrates the circuit required for testing such a transformer with a turns ratio of 2 to 1. The valve voltmeter is then connected across the secondary B and the voltage noted. This procedure is repeated in steps throughout the frequency range for which the transformer is designed. A frequency response graph is then plotted and the insertion loss evaluated.

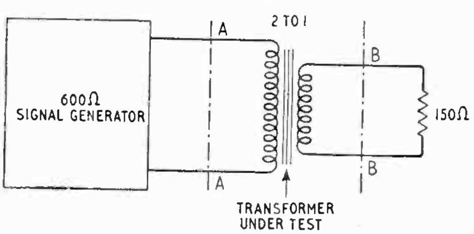


Fig. 5. Arrangement of circuit for testing a transformer

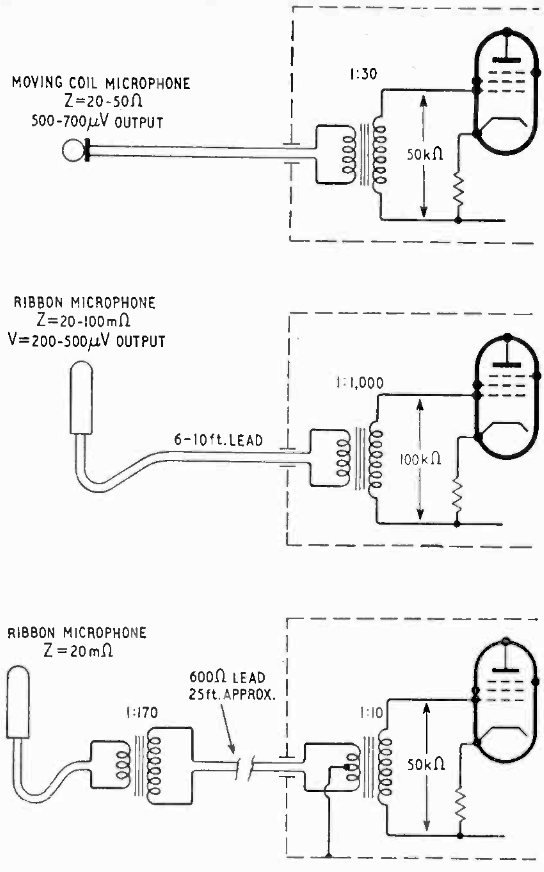


Fig. 6. Matching microphone to input of amplifier

Frequency fall-off at the low-frequency end calls for an increase in primary inductance; frequency fall-off at the high frequency end is due to either leakage inductance or winding capacitance. The latter factors may be identified by connecting a small capacitor across the secondary winding and if the fall-off in frequency response does not increase at this end the trouble is leakage inductance—if it does fall off more sharply, then the trouble is capacitance. The alterations necessary to improve these short-comings have already been discussed earlier in "Flux Gradient."

Microphone Transformers.—The low-impedance ribbon and moving-coil type microphones require a matching transformer to connect the low-impedance of the microphone to the high-impedance grid circuit of the first amplifier valve.

Fig. 6 illustrates these two types of microphone matching. The transformer windings are wound for Radiometal or Mumetal laminations.

To reduce hum pick-up when the transformer is mounted in the amplifier, narrow "U" laminations are used, the induced hum voltage cancelling out in the coils wound equally on either limb. The secondary winding is usually wound with fine wire—order of 50 s.w.g.—the high d.c. resistance being unimportant in this application. The windings of the secondary may conveniently be six separate bobbins, three on either limb of the "U" laminations; the primary consisting of thin copper strip.

Fig. 7 shows a suitable transformer of turns ratio 1 to 1,000; the secondary is made up of six bobbins each of 1,000 turns and the primary consists of 6 turns of thin copper strip.

Fig. 7(b) shows the direction of the winding and the resulting magnetic polarity due to the signal current at any instant. It will be seen that, although the two sets of coils are connected to be additive in inductance, the coils on each limb produce magnetic fields that are in opposite directions in plan view. Hence a magnetic field, caused by hum, would produce a hum voltage equal and opposite in polarity in the windings on either limb. The narrow "U" laminations are used to ensure that both sets of coils are in a field of equal hum flux, which might not be so if the limbs were spaced well apart.

Output Transformers.—This type of transformer covers a very wide range and could not be dealt with fully in an article of this nature. They do, however, fall into two main groups, those for push-pull operation and those for single-ended operation. The former have no d.c. component in their windings whereas the latter may have.

For medium power a.f. amplifiers, ordinary silicon irons function quite well. For higher power a.f. amplifiers, in the order of 20 to 30 watts, it is an advantage to use "C" core laminations.

A good rule-of-thumb guide to lamination size is the weight of the core in lb should be 0.17 times the output watts of the amplifier and the volume in cubic inches should be 0.7 times the output watts of the amplifier. For good fidelity these figures should be doubled.

The maximum flux density of operation should not exceed 5 kilogauss for a reasonable distortion factor. The calculations for primary inductance are the same as under "Low-Level Transformers."

When the primary windings carry a d.c. component it may be necessary to increase the effective air gap in the core by block or butt method of assembling the laminations.

The frequency response of output transformers is a similar consideration to the factors effecting interstage transformers.

The permeability of the core will vary with applied signal level—thus the frequency response will normally extend lower as the signal level is increased.

When a transformer is connected to a source of zero impedance there is no voltage drop incurred by the magnetizing current. As in the practical case there is source impedance, a voltage drop will occur due to the magnetizing current; since the magnetizing flux is not by any means a sine-wave for an input sine-wave current, due to the B/H curve, distortion resulting from the out-of-phase magnetizing current occurs.

The ratio of $\omega L/R$ (where R is the resultant of anode and load resistances in parallel) should be kept as low as possible consistent with other requirements. The d.c. resistance of the primary, and of the reflected secondary, windings may be regarded as part of the source impedance for this purpose. Further to this consideration, the maximum flux density should be restricted to the straight part of the B/H curve. Fig. 8 illustrates these principles.

Interstage Transformers for Class A and Class B Working.—The amplification of the stage at mid-frequency is very nearly equal to the product of the

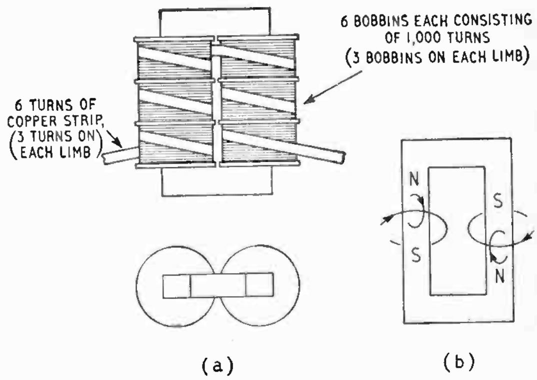


Fig. 7. Hum pick-up by microphone transformer minimized by an "astatic" form of winding using both limbs of a "U"-shaped core. (a) shows practical assembly and (b) the direction of winding

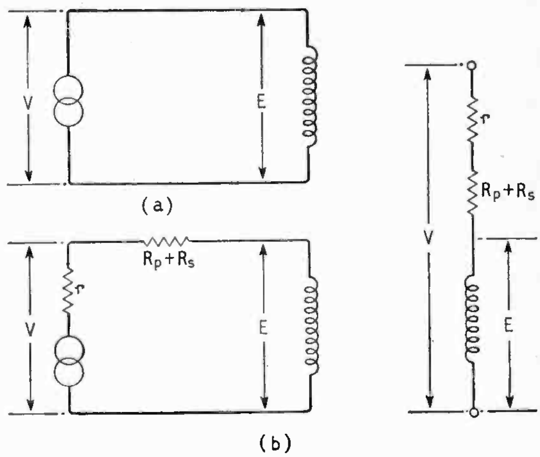


Fig. 8. Output transformer equivalent circuit; (a) no source impedance V = E; (b) with source impedance and resistance of windings. Magnetizing current a function of frequency and load current

amplification factor of the valve and the turns ratio of the transformer.

The gain falls off at low frequencies due to the decrease in the reactance of the transformer primary winding. At frequencies at which $\omega L = R$ the response will fall off 3dB; at frequencies $\omega L = 2R$ the response will fall off 1dB.

The leakage inductance and shunt capacitance of the transformer, in conjunction with the anode and the winding resistances, form a low-Q resonant circuit. The gain will fall off sharply above this resonant frequency. This resonant frequency may be varied by altering the value of the leakage inductance or the winding capacitance.

Transistor Output and Interstage Transformers.—These transformers may be wound on very small Mumetal laminations. Because the impedances associated with transistors are small compared with those for valves, primary inductances are of a low order—e.g. 250 to 500 millihenries.

Pulse Transformers.—It is not intended to more than mention this type of transformer in passing except to say that, due to the wave shape of the pulses the transformer is required to pass, the harmonic content may reach high frequencies. Trouble is frequently experienced when the leakage inductance resonates with the winding capacitance producing unwanted spikes.

To minimize this effect, a copper screen may be placed between the primary and the secondary windings and the screen connected to an earthy point in the circuit. This screen consists of one turn of 0.002-in copper foil interleaved with paper to prevent a short-circuited turn.

D.C./D.C. Transistorized Converters.—Toroidal cores are usually found most efficient for these types of circuits, particularly when the VA output is of a small order. However, transformers utilizing medium grade silicon-iron laminations can be designed for this application which are fully satisfactory for VA ratings in excess of 6VA, working at frequencies up to 1,000c/s.

Ferrite materials are also employed for circuits operating at several kc/s where, due to the low value of smoothing components at this frequency, the overall size of the complete apparatus may be kept small.

The nature of the converter circuit requires that saturation of the core is reached twice in each cycle of operation. The use of silicon-iron laminations therefore restricts the frequency of operation. The iron losses in the core are the chief losses in this type of circuit—hence a minimum VA rating for a high efficiency working is fixed by the relation between total losses and the output VA. Since this type of equipment is mostly used working from storage batteries, efficiencies are important.

Although the subject matter in this article is, of necessity, very briefly dealt with it is hoped that it will serve some use to the engineer, even if only as a pointer to select a starting point from which he may approach his objective, and to the management in the electronic industry in illustrating the advantages of setting aside a department, however small, for the specific purpose of designing transformers.

HI-FI P.A.

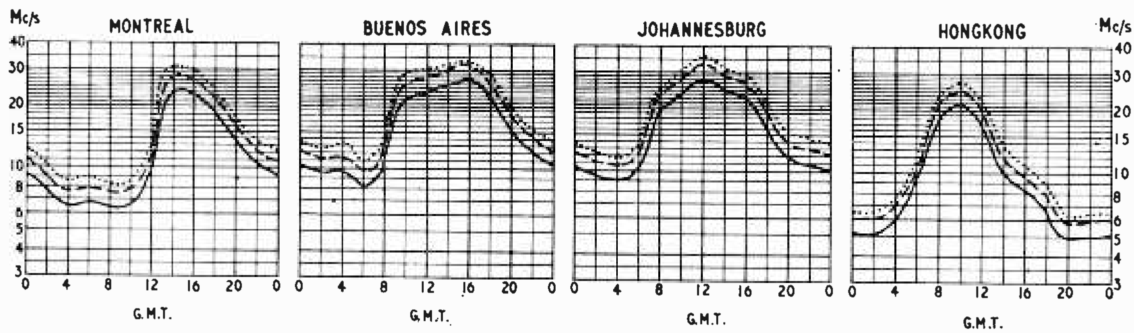
READERS who visited the National Radio Show and were impressed with the quality of reproduction on the B.B.C. Gramstand may be interested in the following brief details of the installation:—

The requirements were for high-quality public address coverage over a large area to feed a standing audience of up to 1,500 at one time. Anything less than high quality would not have served the purpose because the main output from this exhibit was commercial records which nowadays employ such "gimmicks" as close-balance, pre-emphasis, accentuated reverberation and frequency correction which would be lost on the normal type of public address system.

Six high-quality monitoring loudspeakers of a type normally used in control rooms and control cubicles and known as the LSU/10 were sited at strategic points round the audience area. The loudspeakers, mounted on plinths so that the sound output was not baffled by people standing in front of them, were built into the auditorium walls and in pillar casings.

Basically, the construction of an LSU/10 loudspeaker consists of an acoustic cabinet with a vented enclosure containing a large unit with a 15-in cone carrying a 3-in speech coil. The middle and high-frequency unit is mounted concentrically with the large unit and has a light domed aluminium diaphragm, $1\frac{3}{4}$-in diameter, attached to a speech coil of the same diameter. There is an additional tweeter unit separate from the main loudspeaker units to extend further the top frequency response. The 10-watt amplifier feeding the speaker units is also contained in the cabinet.

SHORT-WAVE CONDITIONS *Prediction for January*



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 January.

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

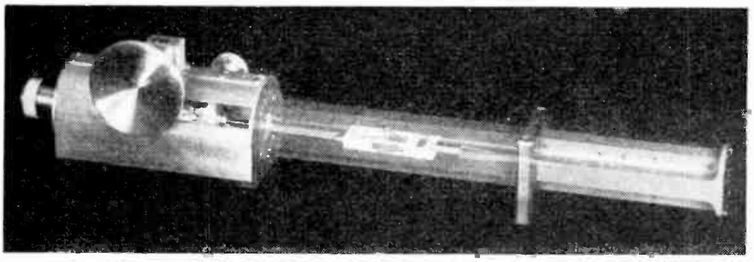
•••••••••• FREQUENCY BELOW WHICH COMMUNICATION SHOULD BE POSSIBLE FOR 25% OF THE TOTAL TIME

— — — PREDICTED MEDIAN STANDARD MAXIMUM USABLE FREQUENCY

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

TECHNICAL NOTEBOOK

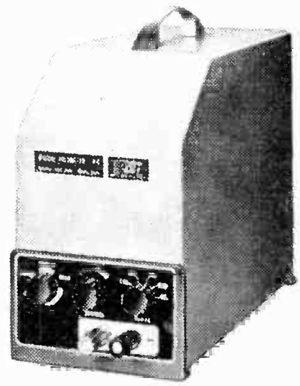
Adjustable Waveguide Termination recently developed at the U.S. National Bureau of Standards has two moving parts: a short-circuiting plunger and a resistive vane. The double-exposure illustration shows the plunger and vane positioned inside a rectangular waveguide.



Independent mechanical controls are provided for rotating the vane, longitudinally sliding the vane relative to the short circuit, and sliding the entire termination assembly along the waveguide. In operation, the resistive vane reflects some energy back towards the signal source. The remaining energy is either partially absorbed by the vane or reflected by the short circuit back towards the signal source. The relative phase of the reflections from the vane and short circuit can be altered by varying the distance between them. The amount of energy reflected by the short circuit depends upon the amount left unabsorbed by the vane, and this can be varied by rotating the vane.

New Transistor Manufacturing Technique developed by Bell Telephone Laboratories reduces switching times and collector resistances of diffused-base transistors by factors of more than ten. Diffused-base transistors require a collector region of relatively high resistivity in order to attain a low capacitance and high voltage breakdown. A lightly-doped collector region is thus used, and ideally this should only be about 0.1 mil thick. However, if the collector wafer were made as thin as this, it would be extremely difficult, if not impossible, to handle mechanically. Thus a collector thickness about thirty times greater is normally used, although increasing the collector thickness increases both its resistance and also, through carrier-storage effects, the transistor switching time. Thinner collector regions can, however, be made and utilized by growing them on a low-resistivity heavily-doped mechanically supporting wafer. When the thin collector film is a direct extension of a single-crystal supporting wafer it is said to be "epitaxial". Diffused-base transistors have been made at Bell Telephone Laboratories on epitaxial layers of both germanium and silicon and have shown the improvements to be expected from a thinner collector region. For example, the switching time in a typical circuit was reduced from 200 to 20 mμsec and the collector series resistance was decreased by a factor of more than ten.

Digital Voltmeter using a stroboscopic technique is being imported into this country from America by Scientific Furnishings Ltd. of Poynton, Cheshire. In this voltmeter the 250 indicating numbers are registered on a drum which is rigidly coupled to the spindle of a potentiometer. This potentiometer has a standard voltage developed across it and its spindle is rotated at 1500 r.p.m. so that its wiper generates a sawtooth voltage. This sawtooth voltage is continually compared electronically with the unknown voltage so as to fire a stroboscopic lamp whenever the sawtooth and unknown voltages are equal. For a fixed input voltage the stroboscopic lamp will thus be fired at corresponding points on each ramp of the sawtooth waveform, so



that the same number on the drum will be illuminated by each flash of the lamp. A slowly-varying input voltage will be indicated by a slowly varying number, and interpolation between two partially-visible numbers will give a measure of a voltage between these two numbers. Alternatively, only the nearest number to the actual voltage can be indicated. This is done by making use of an additional set of pulses produced as the numbers pass a phototransistor.

JANUARY MEETINGS

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

LONDON

4th. Brit.I.R.E.—"Automatic techniques in civil air line communications systems" by W. E. Brunt at 6.30 at the London School of Hygiene, Keppel Street, W.C.1.

5th. Institution of Mechanical Engineers.—Discussion on "The reliability of mechanical engineering parts of data processing systems" at 10.30 at the Institution, 1 Birdcage Walk, S.W.1.

5th. I.E.E.—Hunter Memorial Lecture on "The application of electronics to the electricity supply industry" by Dr. J. S. Forrest at 5.30 at Savoy Place, W.C.2.

9th. I.E.E.—"Recent research in thermionics" by Dr. G. H. Metson at 5.30 at Savoy Place, W.C.2.

10th. I.E.E.—"Precision measurement" by G. H. Rayner and A. Felton, with supporting papers, at 5.30 at Savoy Place, W.C.2.

11th. Brit.I.R.E. — "Multi-layer switching devices" by Dr. G. F. Taylor at 7.15 at the London School of Hygiene, Keppel Street, W.C.1.

12th. Radar and Electronics Association.—"Programme circuits on telephone plant" by G. Stannard at 7.30 at the Royal Society of Arts, John Adam Street, W.C.2.

13th. Television Society.—"A wide range standards converter" by E. R. Rout and R. F. Vigurs at 7.0 at the Cinematograph Exhibitors' Association, 164 Shaftesbury Avenue, W.C.2.

19th. Brit.I.R.E. — Symposium on "Alpha numeric displays" at 6.30 at the London School of Hygiene, Keppel Street, W.C.1.

20th. Institute of Navigation.—"Presentation of height information in aircraft" by A. Stratton and K. R. Honick at 5.15 at the Royal Geographical Society, 1 Kensington Gore, S.W.7.

20th. B.S.R.A.—"Modern electrostatic microphones" by F. W. O. Bauch at 7.15 at the Royal Society of Arts, John Adam Street, W.C.2.

20th. Junior Institution of Engineers.—"Radio investigations of the solar atmosphere" by J. Heywood at 7.0 at Pepys House, 14 Rochester Row, S.W.1.

23rd. Institute of Physics and Physical Society.—"Some new applications of radar" by Dr. E. Eastwood at 6.0 at 47 Belgrave Square, S.W.1.

24th. I.E.E. — Discussion on "Machine-tool control" opened by Dr. E. H. Frost-Smith at 5.30 at Savoy Place, W.C.2.

25th. I.E.E.—"Generation and amplification in the millimetre wave field" by W. E. Willshaw at 5.30 at Savoy Place, W.C.2.

25th. Brit.I.R.E.—"Noise correlation measurements" by K. R. McLachlan at 6.30 at the London School of Hygiene, Keppel Street, W.C.1.

26th. Television Society.—Fleming Memorial Lecture on "Behind the eye" by Prof. D. M. MacKay at 7.0 at the Royal Institution, Albemarle Street, W.1.

BIRMINGHAM

2nd. I.E.E.—Discussion on "Broadening university courses" opened by Dr. H. E. M. Barlow at 6.30 at the James Watt Memorial Institute.

13th. Society of Instrument Technology.—"Controls associated with flying" by Capt. A. M. A. Majendie at 7.0 in the Lecture Theatre, Byng Kendrick Suite, Gosta Green College of Technology, Aston Street.

18th. Television Society.—"Video recording" by J. Southgate at 7.0 at the New Physics Lecture Theatre, the University.

23rd. I.E.E. — "Applications of microwaves" by Prof. A. L. Cullen at 6.0 at the James Watt Memorial Institute.

BRISTOL

20th. Institute of Physics and Physical Society.—"The physicist and the technologist in industry" by G. W. Warren at 7.0 at the College of Science and Technology.

CARDIFF

11th. Brit.I.R.E.—"The measurement of ionizing radiation" by R. G. Wood at 6.30 at the Welsh College of Advanced Technology.

CHESTER

26th. Society of Instrument Technology.—"Satellite instrumentation" by Dr. R. C. Jennison at 7.0 in the Lecture Theatre, Associated Ethyl Co., Oil Sites Road, Ellesmere Port.

EDINBURGH

11th. Brit.I.R.E—"A survey of microwave valves" by C. R. Russell at 7.0 at the Department of Natural Philosophy, the University, Drummond Street.

17th. I.E.E. — "Applications of microwaves" by Prof. A. L. Cullen at 7.0 at the Carlton Hotel, North Bridge.

24th. I.E.E.—"The changing face of electronics" by W. E. J. Farvis at 7.0 at the Carlton Hotel, North Bridge.

EVESHAM

16th. I.E.E.—"Magnetic recording of TV programmes" by H. E. Farrow at 7.30 at the B.B.C. Training School, Wood Norton.

FARNBOROUGH

17th. I.E.E.—"Modern ferromagnetic materials" by Dr. F. Brailsford at 6.15 at the Technical College.

24th. Brit.I.R.E.—"Masers and parametric amplifiers" by Dr. W. A. Gambling at 7.0 at the Technical College.

FAWLEY

6th. Society of Instrument Technology.—"Electronics and instrumentation in the glass industry" by J. R. Beattie at 5.30 at the Administration Building, Esso Refinery.

GLASGOW

12th. Brit.I.R.E.—"A survey of microwave valves" by C. R. Russell at 7.0 at the Institution of Engineers and Shipbuilders, 39 Elmbank Crescent.

16th. I.E.E.—"Applications of microwaves" by Prof. A. L. Cullen at 6.0 at the Institution of Engineers and Shipbuilders, 39 Elmbank Crescent.

LEEDS

26th. I.E.E.—Faraday Lecture on "Transistors and all that" by L. J. Davies at 7.0 at the Town Hall.

LIVERPOOL

18th. Brit.I.R.E.—"Microminiaturization" by H. G. Manfield at 7.0 at the Adelphi Hotel.

23rd. I.E.E.—"Cybernetics" by Prof. J. C. West at 6.30 at the Royal Institution, Colquitt Street.

MALVERN

26th. Brit.I.R.E. — "Stereophonic broadcasting" by G. D. Browne at 7.0 at the Winter Gardens.

MANCHESTER

10th. I.E.E.—"Radio communication in the power industry" by E. H. Cox and R. E. Martin at 6.15 at the Engineers' Club, Albert Square.

11th. I.E.E. — "The ultrasonic microscope" by Dr. C. N. Smyth at 6.15 at the Engineers' Club, Albert Square.

17th. I.E.E.—"A universal non-linear filter, predictor, and simulator, which optimizes itself by a learning process" by Prof. D. Gabor, Dr. W. P. L. Wilby and Dr. R. Woodcock at 6.15 at the Engineers' Club, Albert Square.

24th. I.E.E.—Faraday Lecture on "Transistors and all that" by L. J. Davies at 7.30 at the Free Trade Hall.

MIDDLESBROUGH

4th. I.E.E.—"The Fylingdales early warning station" by D. R. Evans at 6.30 at the Cleveland Scientific and Technical Institution.

NEWCASTLE-UPON-TYNE

9th. I.E.E.—Hunter Memorial Lecture on "The application of electronics to the electricity supply industry" by Dr. J. S. Forrest at 6.15 at the Neville Hall, Westgate Road.

11th. Brit.I.R.E.—"The applications of photo-multipliers in industry and research" by J. Hambleton at 6.0 at the Institution of Mining and Mechanical Engineers, Neville Hall, Westgate Road.

16th. I.E.E.—"Precision measurement" by G. H. Rayner and A. Felton, with supporting papers, at 6.15 at the Rutherford College of Technology, Northumberland Road.

19th. Society of Instrument Technology.—"Recent advances in photo-electronic instruments" by H. Loebl at 7.0 in the Conference Room, Roadway House, Oxford Street.

NOTTINGHAM

19th. Society of Instrument Technology.—"The electrical synthesis of music" by A. Douglas at 7.15 at Nottingham & District Technical College, Burton Street.

SHEFFIELD

4th. I.E.E.—Christmas Holiday Lecture on "Colour television" by Dr. R. Feinberg at 3.0 at the City Hall.

18th. I.E.E.—Hunter Memorial Lecture on "The application of electronics to the electricity supply industry" by Dr. J. S. Forrest at 6.30 at the Memorial Hall, City Hall.

SOUTHAMPTON

4th. I.E.E.—"The planning and economics of telecommunication plant" by C. J. Stubbington at 7.0 at the University.

10th. I.E.E.—Discussion on "New semiconductor devices" at 6.30 at the University.

WEYMOUTH

12th. I.E.E.—"Electronic aids to banking and commerce" by Dr. R. Feinberg at 6.30 at the South Dorset Technical College.

WOLVERHAMPTON

11th. Brit.I.R.E.—"An equipment for automatically processing time-multiplexed telemetry data" by N. Purnell and T. T. Walters at 7.15 at the College of Technology.

18th. Institution of Production Engineers.—"The application of electronic computers to production control" by B. L. J. Hart at 7.0 at the College of Technology, Wulfruna Street.

CONFERENCES AND EXHIBITIONS

Latest information on forthcoming events both in the U.K. and abroad is given below. Further details are obtainable from the addresses in parentheses.

LONDON

Jan. 16-20	**Physical Society Exhibition** (Exhibition Secretary, 1 Lowther Gardens, S.W.7.)	R.H.S. Halls
Mar. 8	**Public Address Exhibition** (A.P.A.E., 394 Northolt Road, South Harrow, Middx.)	King's Head, Harrow
Mar. 21-25	**Electrical Engineers Exhibition** (A.S.E.E. Exhibition Ltd., Museum House, Museum Street, W.C.1.)	Earls Court
Apr. 5-7	**Electrical Contacts Symposium** (The Institute of Physics and the Physical Society, 47 Belgrave Square, S.W.1.)	Brunel College
Apr. 6-9	**Audio Festival and Fair** (C. Rex-Hassan, 42 Manchester Street, W.1.)	Hotel Russell
Apr. 20-21	**Television and Film Techniques Convention** (Television Society, 166 Shaftesbury Avenue, W.C.2.)	Savoy Place

Apr. 20- May 4	**Engineering, Marine, Welding and Nuclear Energy Exhibition** (F. W. Bridges & Sons, Grand Bldgs., Trafalgar Sq., W.C.2.)	Olympia
May 30- June 2	**Components Exhibition** (R.E.C.M.F., 21 Tothill Street, S.W.1.)	Olympia
June 12-17	**Components and Materials used in Electronic Engineering (Conference)** (I.E.E., Savoy Place, W.C.2.)	Central Hall
June 21- July 1	**INTERPLAS, International Plastics Exhibition and Convention** (*British Plastics*, Dorset House, Stamford Street, S.E.1.)	Olympia
July 7-29	**Soviet Trade Fair** (Industrial & Trade Fairs Ltd., Drury House, Russell Street, W.C.2.)	Earls Court
Sept. 6-8	**Microwave Measurement Techniques Conference** (I.E.E., Savoy Place, W.C.2.)	Savoy Place
Oct. 4-12	**Computer Exhibition and Symposium** (E.E.A., 11 Green Street, W.1.)	Olympia
Nov. 8-10	**Non-Destructive Testing in Electrical Engineering (Conference)** (I.E.E., Savoy Place, W.C.2.)	Savoy Place
Nov. 13-18	**Factory Equipment Exhibition** (Industrial & Trade Fairs Ltd., Drury House, Russell Street, W.C.2.)	Earls Court

FARNBOROUGH

Sept. 4-10	**Farnborough Air Show** (Society of British Aircraft Constructors, 29, King Street, London, S.W.1.)	

NEWCASTLE

Feb. 28- Mar. 2	**North East Electronic Engineering Exhibition** (Secretary N.E.E.E.E., c/o N.E.I.D.A., 9 Eldon Square, Newcastle-upon-Tyne 1.)	

OXFORD

July 5-9	**Communications and Space Research Convention** (Brit. I.R.E., 9 Bedford Square, London, W.C.1.)	

OVERSEAS

Jan. 9-11	**Reliability and Quality Control Symposium** (R. Brewer, G.E.C. Research Laboratories, Wembley, Middx.)	Philadelphia
Feb. 15-17	**International Solid State Circuits Conference** (J. J. Suran, General Electric Co., Syracuse.)	Philadelphia
Feb. 17-21	**International Components Exhibition** (Fédération Nationale des Industries Électroniques, 23 rue de Lubeck, Paris XVIe.)	Paris
Feb. 20-25	**International Symposium on Semiconductors** (Fédération Nationale des Industries Électroniques, 23 rue de Lubeck, Paris XVIe.)	Paris
Mar. 9-14	**International Hi-Fi and Stereo Exhibition** (Fédération Nationale des Industries Électroniques, 23 rue de Lubeck, Paris XVIe.)	Paris
Mar. 20-23	**I.R.E. National Convention** (Dr. G. K. Teal, I.R.E., 1 E.79 St., New York 21.)	New York
Apr. 30- May 9	**German Industries Fair** (Schenkers Ltd., 13 Finsbury Square, London, E.C.3.)	Hanover
May 2-4	**Electronic Components Conference** (I.R.E., 1 E. 79 St., New York 21.)	San Francisco
May 9-17	**Measurement, Control, Regulation and Automation Exhibition and Conference** (MESUCORA, 40 rue du Colisée, Paris 8.)	Paris
May 19- June 4	**British Trade Fair** (Industrial & Trade Fairs Ltd., Drury House, Russell Street, London, W.C.2.)	Moscow
May 22-24	**National Telemetering Conference** (I.R.E., 1 E. 79 St., New York 21.)	Chicago
May 22-24	**Global Communications Symposium** (I.R.E., 1 E. 79 St., New York 21.)	Chicago
May 23-25	**Large Capacity Computer Memories Symposium** (Miss J. Leno, Office of Naval Research, Washington 25, D.C.)	Washington
June 26- July 1	**International Measurement Conference** (Prof. J. F. Coales, The University, Cambridge.)	Budapest
June 28-30	**Joint Automatic Control Conference** (Dr. R. Kramer, M.I.T., Cambridge 39, Mass.)	Boulder
July 16-22	**Medical Electronics Conference** (Dr. H. P. Schwan, School of Electrical Engineering, University of Pennsylvania, Philadelphia)	New York
Aug. 1-12	**International Sydney Trade Fair** (Industrial & Trade Fairs Ltd., Drury House, Russell Street, W.C.2.)	Sydney
Aug. 22-25	**Western Electronics Show and Convention** (Wescon, 1435 LaCienega Blvd., Los Angeles.)	San Francisco
Aug. 25- Sept. 3	**German Radio Exhibition** (Berliner Ausstellungen, Charlottenburg 9, Berlin.)	Berlin
Sept. 11-15	**International Cybernetics Congress** (International Association of Cybernetics, 13 Rue Basse-Marcelle, Namur, Belgium.)	Namur
Oct. 9-11	**National Electronics Conference** (N.E.C., 228 N. LaSalle St., Chicago.)	Chicago

RANDOM RADIATIONS

By "DIALLIST"

Good Shot, Sir

JUST how electronic translating machines work I don't know; but work they certainly do, as is shown by the number now in use. There's no polished prose about their translations, which are more or less literal. Their vocabulary is necessarily somewhat limited, but they undoubtedly serve a most useful purpose by making books and articles understandable to people who don't know a word of the language in which they're written. Sometimes the machine is completely baffled by words which aren't in its vocabulary; but it always has a shot—and a pretty good one too as a rule. One machine kept on writing "water sheep" in the course of a translation on which it was engaged. The words occurred again and again. At first their meaning was dark to the mind of the would-be reader. Then light dawned. What it had been trying to set down was "hydraulic ram"!

Tiros II

THE latest American satellite, Tiros II, started to do useful work very soon after it had been launched. One of its jobs is to televise pictures of cloud formations back to earth and this it is doing most satisfactorily. It travels in an almost circular orbit a little over 400 miles aloft and enables a kind of weather forecast map to be made for all the areas within its range. It will thus become possible to track hurricanes with great accuracy. The satellite, besides carrying two television cameras, also has seven infra-red detectors for measuring the heat reflected from the earth, which again provides information about the gathering and the advancement of severe storms. The chief of the U.S. Weather Bureau says that information such as Tiros II sends to earth could have saved thousands of lives lost in the recent tidal waves in Pakistan. This satellite is the forerunner of the complete weather system "Nimbus" which is planned for 1962.

Underwater TV

ONE of the many interesting items shown at the recent Industrial Photographic and Television Exhibition was the latest model of the Marconi-Siebe Gorman underwater television camera. It can be so adjusted that it is almost weightless and can be carried by a diver, but it can also be lowered from the surface. The camera will be used by the North of Scotland Hydro-Electric Board chiefly to examine the big protective grilles (some 120ft below the surface) which prevent young salmon and other fish being carried into the turbines. Experiments have shown that at considerable depths and in water that is far from clear the TV camera can "see" a good deal better than a diver. The equipment will also be used for investigating fish life and behaviour in the various lochs. Closed-circuit TV has already become an invaluable aid to many branches of science and industry and new uses are always being found for it.

Scaring 'em Off

STARLINGS are a major menace on aerodromes used by jet planes. A recent appalling crash was almost certainly caused by their being sucked into the intakes of the engines and another disaster was averted by the presence of mind of a pilot who saw flocks of them as he was taking off and switched off his engines. Feathers and bits of starling were later found in the intakes. How to get rid of starlings is a real problem and so far it has proved baffling. A new approach to finding a solution is being made by the Ministry of Aviation in conjunction with the Trix Electrical Company. It consists in making hi-fi recordings of the alarm calls of starlings and other birds which frequent airfields and transmitting them from strategically placed loudspeakers. It is said to have given very promising results during the experimental stages. And it's not only aviation people who are interested in large-scale bird scaring. Farmers, fruit growers and others who suffer from damage to their crops would have a ready welcome for a system proved to be successful. And so, one imagines, would authorities in London, Birmingham and other cities in which huge flocks of starlings arrive to roost every evening.

TV in N.Z.

AT the moment I think I'm right in saying that New Zealand has only one television station in action, the 500-W experimental transmitter in Auckland. Three others, though, should be at work early this year. These are to be 5-kW stations at Christchurch, Wellington and Dunedin. All the equipment, except the aerials, which are to be supplied by the New Zealand Broadcasting Service, will be made in this country by

Marconi's. It's going to be a difficult task to cover the whole of that mountainous country as the system grows and it'll certainly take some time to complete.

Talking Books

OURS is, I believe, the first country to introduce books recorded on tape for the blind. An entirely novel feature of the new Talking Book machine being introduced by the National Institute for the Blind is a tape cassette containing two spools mounted one above the other and also housing and protecting the playback head. Half-inch tape is used, the 18 tracks recorded on it provide up to 20 hours of playing time. Near the end of each track the user is warned and all that he has to do to start on the next track is to turn over the cassette and press a button. And there are safety devices to prevent damage. The new tape equipment will gradually replace the disc machines now in use. Assistance in installing and servicing the machines is needed from volunteers in most parts of the country. Any reader who is able and willing to give it should write to: E. Read-Jones, Manager, Nuffield Talking Book Library for the Blind, Mount Pleasant, Alperton, Wembley, Middx. Offers will be most warmly appreciated.

A Long Time Coming

IT appears that we are to adopt the metric system for some purposes, at any rate. The old and quite outdated apothecaries' weight, with its scruples and drams and that sort of thing, is to be replaced fairly quickly by the metric system of weights. Scientists have, of course, largely adopted metric methods already and they're widely used in wireless. No one would now dream of expressing a wavelength in yards, feet and inches. But we've been as a country a very long time in making up our minds to discard our antiquated weights and measures in favour of the more sensible system. Some of our units are just nonsensical: why, for instance, are there 112 lbs in a *hundred*weight? I suppose that originally it deserved its name by consisting of 100 pounds; then the extra twelve were added for good measure. Now that they're about to adopt decimal coinage in the Antipodes I hope we shan't be long in following their lead. The metric system would save an immense amount of the time spent now in intricate calculations.

UNBIASED

BY "FREE GRID"

Exhibitiana

I HEAR the organizing committee is already holding meetings to discuss plans for the 1961 National Radio Show. If the committee has not advanced too far with its plans, I do hope it will consider making an innovation which I think would be welcomed by many.

My suggestion is that in addition to the individual exhibitors' stands, to which we are all accustomed, there should be special stands on which is grouped equipment of a like kind by all exhibitors. Thus I should like to see a stand on which there was nothing but tape recorders of all makes, another stand where there were shown all the available transistor midget sets, and so on.

At present if anybody wishes to examine the various types of tape recorders or other things before making a choice, it is necessary to go to umpteen stands which may be widely separated. It is, in fact, necessary to use tooth and claw, or at any rate, elbows and umbrella, to fight one's way through dense crowds of people who seem to have come to the show with the sole purpose of getting in the way of those who, like myself, have come with a serious purpose.

A splendid example of the usefulness of the grouping of exhibits in the manner I suggest was shown in the pages of our associate journal *Amateur Photographer* in its report of the world-famous biennial Photokina exhibition at Cologne. Although none of the stands at this exhibition were actually grouped in the manner I have suggested, the Editor of *Amateur Photographer* considered the interests of his readers by treating the stands as though they were so grouped. Thus, instead of a stand-to-stand report, he gave what I will call a group-by-group one.

Doubtless I shall be told that at Earls Court there is no room for these "group" stands. That is, of course, utter nonsense as can be seen from the accompanying photograph I myself took of one of the empty spaces in the gallery at last year's show.

[Logically, "Free Grid's" scheme would require additional floor area comparable with that at present allocated to firms' stands. Anything very much less would call for selection (by whom?) of representative exhibits. —Ed.]

Unwitting Offence

WE are often told that ignorance of the law is not a good defence if one is charged with a breach of it. But I have sometimes wondered if that would hold good in all circumstances. The thing which has brought this matter to my mind once more is the case recently reported in the Press of a young lady driving her invalid chair who, late at night, found her vehicle stuck in the mud in a rather lonely spot.

Because of a disability she was unable to get out of the chair and so was faced with the possibility of spending the night in this position. She remembered what she had been taught in the Girl Guides and endeavoured to attract attention by sounding on her electric horn the international distress signal in morse. She naturally expected the sound to reach the ears of some passer-by.

What actually happened was that her signals appeared as long and short flashes on the screen of a television set in a house not very far away. After a time the viewers realized that what they saw was a deliberate signal and when they went outside the house to consult the neighbours they could hear the actual sound of the horn although its signals were very faint.

The lady's rescue was obviously due to the fact that the radio signals she unwittingly sent out were picked up. Even had she known that the mechanism of the electric hooter formed a short-range spark transmitter, and had deliberately used it as such, it is hardly likely that any proceedings would have been taken against her, although it would certainly have been a technical offence as she had no transmitting licence.

Personally speaking, this incident has taught me a lesson and I intend to make provisions for the connection of my horn mechanism to my car-radio aerial so that I can send out a signal for help if I ever break down on a lonely road in evening broadcasting hours. I think that by making this provision I shall be guilty of establishing a radio transmitter even though I never have occasion to use it. I shall await with interest the service of a summons.

It is high time, I think, that all cars were equipped with short-range transmitters and all A.A. and R.A.C. 'phone boxes with receivers and other apparatus to enable an emergency call to be put through to the nearest depot of the motoring organizations. I have bitter memories of having to walk over two miles one stormy night to the nearest 'phone box after I had broken a half-shaft.

I Smell, You Stink

THE words in the title of this note are, of course, those used by Dr. Johnson when he was trying to teach good English to somebody who seemed to think that the verb "to stink" was merely a cacophonous vulgarism for "to smell." As the good doctor explained, the first verb in my title could only be used of the person at the receiving end of an olfactory system, and the last verb only of the person at the transmitting end.

I mention this as I think it is high time we had another Dr. Johnson to rebuke the B.B.C. for the misuse of words which it permits its announcers to make. For instance, the word "nostalgia" used to mean homesickness but the B.B.C. announcers—and in particular the ladies—seem to have changed all that. When they use the adjectival form of it, as they so often do, they seem to regard it as a synonym for reminiscent, sentimental, or half a dozen other things.

There are many other instances of this sort of thing, and I don't think Dr. Johnson would have allowed the B.B.C. the same poetic licence which he granted to Shakespeare. As the good doctor is no longer with us, could not A. P. Herbert or Eric Partridge be persuaded to undertake the task of preparing for us a dictionary of B.B.C. misusages.