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Wireless World

How Many Councils?

"The formation of an Electronics Industry Council is announced in London by the Electronic Engineering Association, who, with the Radio and Electronic Component Manufacturers' Federation and a number of other bodies, has been discussing this for some time.

"The new Council will be concerned with electronic instruments, sound and television transmitters, radio communication equipment, radar and radio navigational aids, computers, industrial electronic control equipment and industrial television and the electronic components used therein.

"Its constitution will provide for the adherence of associations or federations of manufacturers concerned wholly or partly in the manufacture in the United Kingdom of electronic components, apparatus and equipment except for those used in the broadcast radio and television receiving industry and for public telephone services."

THIS news item impels us to redirect attention to the rift which appeared last year in the higher organization of our affairs when the E.E.A. decided to withdraw from the Radio Industry Council. As we see it, the situation at that time might be summarized as follows. Electronic engineering, which began as the application of radio-like methods and devices in fields other than communications, and was nurtured by the radio industry, had grown in stature until it equalled the domestic receiver industry in the gross value of its output and considerably exceeded it in the value of its exports. No doubt, like many a lusty youth, it thought its parents were at times dragging their feet when asked to support or partake in new adventures, and as often happens in such situations it finally decided to cut the apron strings and leave home. It is now flexing its muscles and proving its maturity and independence by forming a Council of friends of its own choosing.

But some of these friends, and in particular the R.E.C.M.F., still maintain close relations with both parties. Is there, in fact, any fundamental reason for the continued existence of two camps now that E.E.A. has asserted itself and, we hope, worked the hidden dissatisfactions out of its system?

Let us look a little more closely at the criteria which were advanced to differentiate the sheep from the goats when the breakaway took place last year. Essentially they were capital goods as distinct from consumer goods and entertainment as distinct from, let us say, utility.

Can a clear dividing line be traced on this basis? We think not. Television and sound broadcast transmitters are capital goods, but they also form an essential part of the domestic entertainment industry. Radar comes under the ægis of tha E.E.A., but in our view inexpensive radar sets in quantity production for small vessels are consumer durables and no more capital goods than television sets.

In announcing the formation of the "Electronics Industry Council," the E.E.A. specifically excludes manufacturers of public telephone equipment. But are not telephone exchanges looking to electronic rather than electromechanical methods for the future?

Why this tendency on the part of the E.E.A. to hive off sections of the industry? Surely it is as easy to find community of interest with those outside its fold as it might be to discover divergence among its present members and indeed between the sectional interests inside individual firms. There would seem to us to be fewer situations when common interest is likely to be evoked between the makers of radar equipment and broadcast transmitters than, say, between broadcast transmitter and receiver manufacturers. When any new system of transmitting stereo sound or colour television is being assessed the estimates of feasibility and cost of the receiver manufacturers are likely to carry more weight than those of the transmitter manufacturers. Already a community of interest between R.I.C. and E.E.A. (and presumably of E.I.C.) is admitted in negotiations involving frequency allocation and the siting of broadcast transmitters. Why must the Industry speak with two voices and expose a chink in its armour when opposed by skilful negotiators in matters affecting any part of its livelihood or the interests of its customers?

On the occasion of the initial split between R.I.C. and E.E.A. we took the view that the processes of association and dissociation are as fundamental to the growth of industrial organizations as they are to living organisms, and that such processes are often accompanied by growing pains. It is to be hoped that the phase of dissociation is now nearing its end and that the formation of the Electronic Industry Council in its present restricted form may be remembered as the turning point in the transition from dissociation to a wider association.

It may be a portent that Mr. L. T. Hinton, Chairman of the E.E.A., in speaking of the gross production of the Industry, was proud to give the figure of £475M, which includes the output of the makers of broadcast receivers and telecommunications equipment as well as the £200M accounted for by the capital goods side.

If B.R.E.M.A. and E.E.A. will stand together once again, and, with their many friends and relations, speak with one voice in all matters affecting the Industry, the title of its Council will be immaterial. But we hope the title will not be too long! In America there has always been only one association, which has remained cohesive while assimilating change. In 1957 its title had grown to the Radio-Electronic Television Manufacturers Association (R.E.T.M.A.), and would no doubt have added more letters as time went on had it not been then renamed the Electronic Industries Association (E.I.A.) to make it "more indicative of our expanding industry."

Further Thoughts on

Stereophonic Sound Systems

I.—RECENT EXTENSIONS OF BASIC THEORY

By D. M. LEAKEY,* Ph.D. (Eng.), B.Sc. (Eng.), D.I.C., A.C.G.I., Grad. I.E.E.

In a previous article [1,2] on stereophonic sound systems, experimental results were presented on which a practical stereophonic system could be based. Unfortunately, the results were rather limited and no theoretical justification was given. The purpose of the present article is to attempt to remedy this situation by briefly describing some of the results obtained during a more recent study of the subject†. Further accounts of the work can be referred to elsewhere [3, 4, 5, 6, 7]. A brief analysis of present day two channel stereophonic systems is also included.

Before describing the results, it is first necessary to define the more important terms used. This is best done with the aid of what will be called a component signal diagram. Consider a subject listening to a single source as shown in Fig. 1(a). Unless the sound source is directly in front or directly behind the listener, the time of arrival of sounds at one ear will be different from the time of arrival of similar sounds at the other ear. This difference is referred to as the interaural time difference and can be depicted on a component signal diagram as shown in Fig. 1(b). The time axis is shown as going from left to right and the signals represented as arrows spaced by the appropriate interaural time difference T_a. If the sound source is assumed to be at an infinite distance away from the listener, and the influence of the head on the sound field is neglected, then the interaural time difference is given by:

$$T_a = \frac{h}{v} \sin \alpha \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

h = separation of ears
v = velocity of sound.

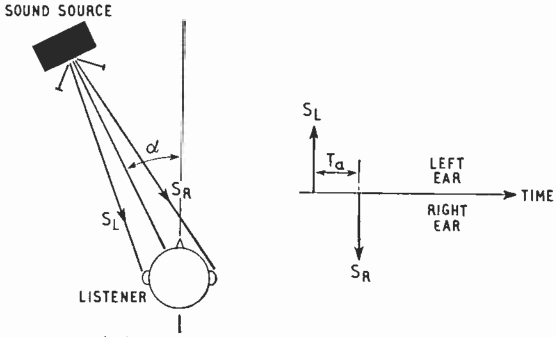
In practice this equality becomes only an approximation, but is still sufficiently accurate for most purposes. More accurate expressions can be derived if required, but unfortunately, as the accuracy is increased, the equations become more cumbersome to handle. Note that interaural time difference can only be defined relative to features which are common to the signals at each ear. Thus, if the signals had not originated from the same source, or virtually identical sources, T_a could not be defined.

Besides the arrival time difference of the sound at the ears, the sound level at one ear is liable to be different from that at the other ear. This difference is termed the interaural intensity difference and is most significant at the higher audio frequencies, where the shadowing effect of the head becomes appreciable.

Paired source listening is depicted in Fig. 2(a). If the sound sources are radiating independent sounds, a value of interaural time difference and interaural intensity difference can be assigned to each source separately, but little more. If, however, both sources are radiating the same sound, or practically the same sound, then further differences, termed interchannel differences, can be defined. In Fig. 2(b) is shown the component signal diagram for two sources, as shown in Fig. 2(a), radiating the same sound. Note that there are now effectively two signals to each ear, the "direct" signals A_L and B_R, and the "crossed" signals A_R and B_L, which are delayed by an amount T_a given by:

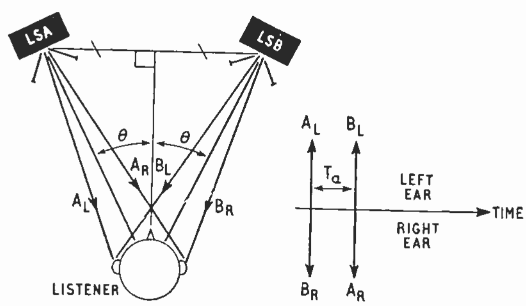
$$T_a \approx \frac{h}{v} \sin \theta \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

Three modifications to the diagram shown in Fig. 2(b) are important. Firstly, the effect of a difference in the signal levels from the two sources at the listening position can be illustrated as shown in Fig. 3. This difference is termed the interchannel intensity



(a) (b)

Fig. 1. (a) Single source listening. (b) Component signal diagram.



(a) (b)

Fig. 2. (a) Paired source listening. (b) Component signal diagram.

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†This article includes material taken from a thesis by D. M. Leakey approved for the Ph.D., University of London.

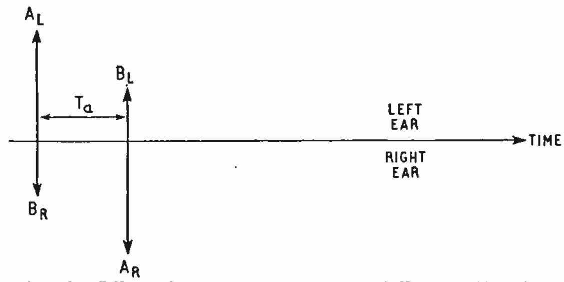


Fig. 3. Effect of interchannel intensity difference (A>B).

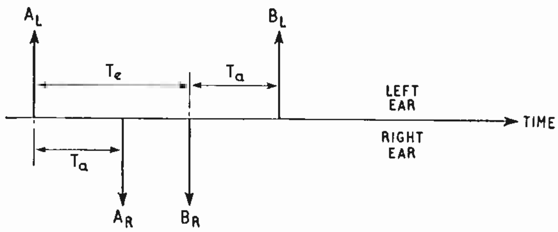


Fig. 4. Effect of interchannel time difference T_e.

difference and can be produced by adjusting the relative sound output levels from the sources. Note that an interchannel intensity difference does not produce simply an interaural intensity difference unless the "crossed" signals are absent. Secondly, there can be a difference in the time of arrival of similar sounds at the listening position from the sources. This difference is termed the interchannel time difference and can be represented as shown in Fig. 4. The time difference can be produced either by an electrical delay line, by staggered heads on a magnetic tape, or by actual movement of one of the loudspeakers radially away from the listener. The last method introduces an additional interchannel intensity difference. Again, an interchannel time difference does not produce only an interaural time difference unless the "crossed" signals are absent. The third effect is that due to a head rotation, that is, if the listener turns so that he is no longer facing the centre of the loudspeaker base line. The result of this movement is shown in Fig. 5. The new time differences T_M and T_N are given by:

$$T_M \approx \frac{h}{v} \sin\theta \cos\psi \quad \quad .. \quad .. \quad (3)$$

$$T_N \approx \frac{h}{v} \cos\theta \sin\psi \quad \quad .. \quad .. \quad (4)$$

where ψ = angle of rotation of head (+ve clockwise).

The approximations arise for the same reasons as those mentioned in connection with eqn. (1).

Other effects can be represented as combinations of the above three cases. For example, movement by the listener to an off-centre position produces an effective interchannel intensity difference, an effective interchannel time difference and an effective head rotation.

Although only two channel systems have been used to describe the terms employed, the system of representation is applicable to any number of channels. Reverberation and echoes can be represented as subsidiary sources with appropriate time delays, etc.

Throughout the article, almost exclusive use will be made of the term time difference, with little mention of the term phase difference. As has been stated previously[1], the term time difference has more direct application to normal complex sounds encountered in everyday life, whereas the use of the term phase difference is best limited to the more "ideal" waveforms such as single sine waves and other simple repetitive signals.

Test Procedure.—The experimental arrangement used was very similar to that employed previously[1], although the method of measurement was modified considerably[3,6]. Basically, the listener was asked to compare the position of the stereo sound image with the sound image produced by a single reference loudspeaker, which could be placed in any of the positions V1 to V7 as shown in Fig. 6. The reference and stereo sound images were presented sequentially and the same sound was used for both sources. The listener was asked to decide whether the stereo sound image appeared to the left or to the right of the reference sound image. Many results were taken for each listener and for a given reference loudspeaker position, but with various values of interchannel intensity difference. From the analysis of the resulting left-right judgments, the particular value of interchannel intensity difference, for which the stereo sound image position was coincident with the reference sound image position, was determined. The test was repeated for each reference source (V1 to V7) and for each of several listeners.

Interchannel time difference could be introduced by moving one loudspeaker away radially from the listening position as illustrated in Fig. 6. To compensate for the reduced sound intensity level at the

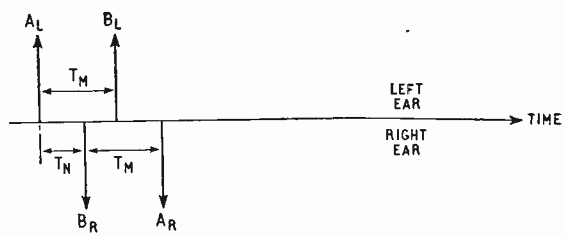


Fig. 5. Effect of head rotation.

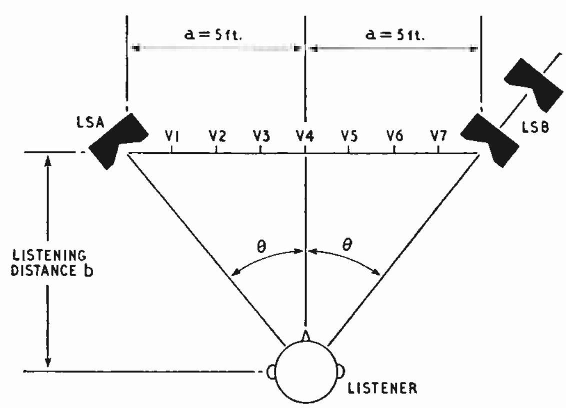


Fig. 6. Experimental arrangement showing method of introducing time difference.

listening position from the delayed channel, the gain of the amplifier in the delayed channel was suitably increased.

The types of sound used for the measurements included single- and two-component tones, wide-band speech, random noise, pulses, and speech, noise and pulses passed through octave wideband limiting filters.

Experimental and Theoretical Results.—The experimental results can be divided into two sections, as follows:

(1) Results obtained with the listener seated centrally. No interchannel time difference. Sound image controlled by interchannel intensity difference only.

(2) Results obtained with an interchannel time difference present, either as a result of off-centre listening, or as produced by radial movement of one of the loudspeakers.

Effect of Interchannel Intensity Difference Only.—In Fig. 7 is plotted a mean curve of sound image displacement against interchannel intensity difference, for low-frequency sounds in the range 250-500 c/s. The sounds used included band-limited noise band-limited speech, band-limited pulses, single-component tone and two-component tones. The general results can be summarized as follows. The sound image displacement, for a given interchannel intensity difference, was, to a first approximation, independent of the nature of the sound, the sound level, and of the listener under test. The results were, however, very sensitive to a small displacement

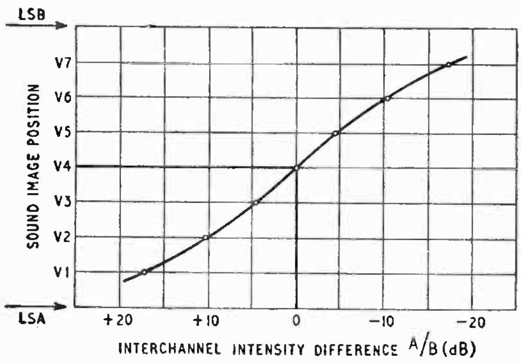


Fig. 7. Mean curve for sound image displacement with interchannel intensity difference. Low-frequency signals. Central listening position at a listening distance of 8ft.

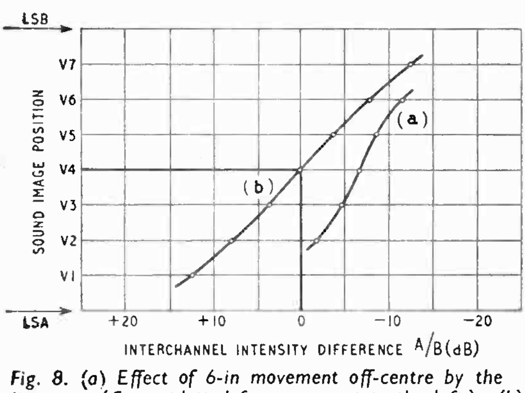


Fig. 8. (a) Effect of 6-in movement off-centre by the listener. (Curve plotted for movement to the left.) (b) Result obtained if listener only nominally central.

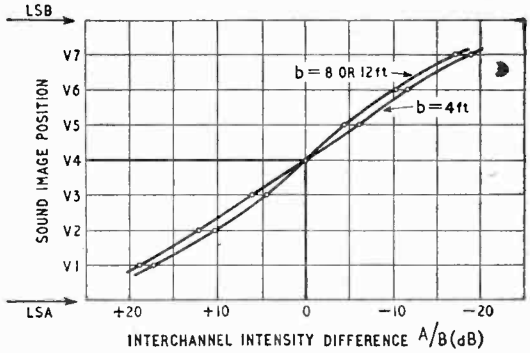


Fig. 9. Effect of variation of listening distance. (Note: curves for b = 8ft. and b = 12ft. are virtually identical.)

off-centre by the listener. The curve shown in Fig. 7 was for results when a headrest was in use, which limited side-to-side head movement. The result of a 6-inch head movement off-centre is shown in Fig. 8 together with a typical result obtained if the listener's head is only nominally central, but actually free to move randomly by quite a considerable distance off-centre. The curves in Fig. 8 were taken using band-limited noise. Different results are obtainable depending on the sound, the sound level, and the listener under test. Results which are independent of these factors, are obtainable *only* for "on-centre" listening.

The result of a variation in the listening distance is shown in Fig. 9. With small listening distances it was noted that the sound image appeared to become elevated to well above the level of the loudspeakers[4].

Theoretical expressions can be derived which are in reasonable agreement with the practical results[6, 7]. With reference to Fig. 3, the analysis for low frequency signals proceeds as follows. As shown in the Appendix, the two component signals, say at the left ear, can be considered to combine to form a single resultant signal, providing the component signal spacing T_a is small compared with the periodic time of the highest frequency component present. The resultant signal is in magnitude approximately equal to the sum of the individual components, but is in time delay relative to the first arriving component by an amount T_L such that:

$$T_L \approx \frac{B_L}{A_L + B_L} . T_a \quad \ldots \quad \ldots \quad (5)$$

The approximation becomes more correct as T_a is reduced. At the right ear a similar result is obtained. The single resultant is in magnitude approximately equal to the sum of the separate component signals, and is in time delay relative to the first arriving component by an amount T_R such that:

$$T_R \approx \frac{A_R}{A_R + B_R} . T_a \quad \ldots \quad \ldots \quad (6)$$

From eqns. (5) and (6) the value of the *interaural* time difference between the resultant signals at each can be calculated. To simplify the result, it is convenient to neglect the effect of the increased attenuation of the "crossed" signals relative to the "direct" signals, and to write:

$$A_L = A_R = A$$
$$B_L = B_R = B$$

With this approximation included, the resultant interaural intensity difference is zero, and the resultant interaural time difference becomes:

$$T_S = T_R - T_L \approx \frac{A-B}{A+B}.T_a \approx \frac{A-B}{A+B}.\frac{h}{v}\sin\theta \quad (7)$$

To calculate the position of the resultant stereo sound image, the interaural time difference T_s is equated with the interaural time difference that would be produced by a single source at an angle α, as given by eqn. (1). Hence:

$$\frac{h}{v}\sin\alpha \approx \frac{A-B}{A+B}.\frac{h}{v}\sin\theta$$

or

$$\sin\alpha \approx \frac{A-B}{A+B}.\sin\theta \quad .. \quad (8)$$

Although the agreement between eqn. (8) and the practical results is reasonable, the equation does not account for the apparent elevation of the sound image. Closer agreement, and an explanation for the apparent elevation, can be obtained if it is assumed that the brain is sensitive to interaural time difference and to the variation of interaural time difference with head rotation. This approach provides the modified result[6]:

$$\tan\alpha \frac{A-B}{A+B}.\tan\theta \quad .. \quad (9)$$

$$\cos^2\beta \approx \frac{A^2+B^2+2AB\cos 2\theta}{(A+B)^2} \quad .. \quad (10)$$

where β = angle of elevation of sound image.

The foregoing practical results apply only if the loudspeakers are driven in phase. If the connections to one loudspeaker are reversed, the stereo sound image no longer appears to move between the loudspeakers, but rather to move outside the loudspeaker base line. This is illustrated in Fig. 10 where the interesting modification resulting from a reversal of the listening direction is included. It is important to note that usually this effect is observed only with low-frequency signals, "on-centre" listening and in relatively echo-free conditions.

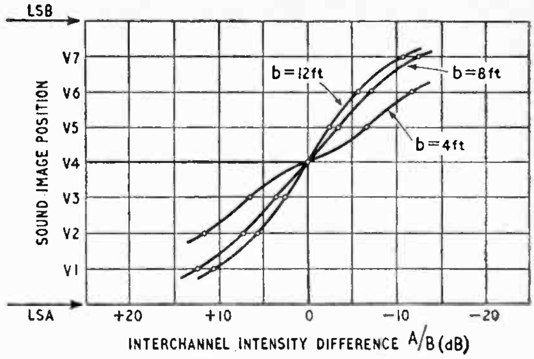
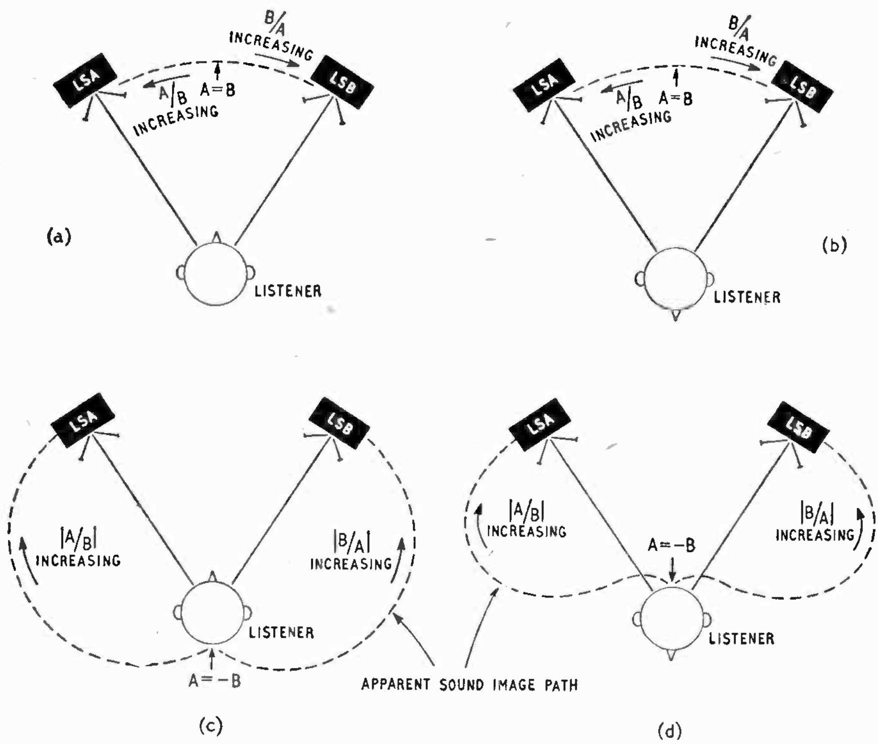


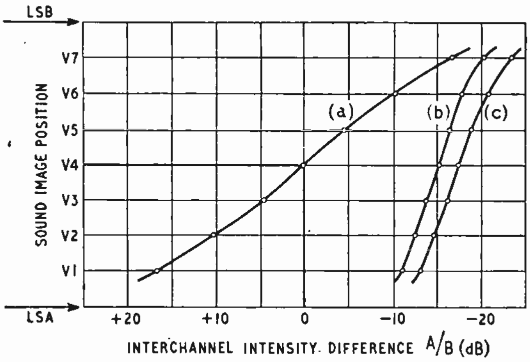
Fig. 11. Effect of interchannel intensity difference at high frequencies.

At high frequencies the curves shown for low-frequency sounds no longer apply. Again, however, the sound image displacement, for a given interchannel intensity difference is, to a first approximation, independent of the type of sound, and of the sound level, provided the sound is sufficiently complex. Single high-frequency tones give rise to results which vary widely and are not repeatable. However, five closely spaced tones do provide a sufficiently complex signal to produce similar results to band-limited speech, noise and pulses. The mean curves for high frequency complex sounds, band limited to 2 kc/s to 4 kc/s are shown in Fig. 11.

The analysis as previously described cannot be extended unmodified to include the high-frequency case, as, in general, the component signal spacing is not small compared with the periodic time of the highest component frequency present. However, at high frequencies, the analysis still assumes that the brain is sensitive to interaural time difference, but the time difference of interest is that of the slowly varying "envelope" function of the sound waveform, rather than that of the fine detail[5, 6, 7, 8]. The theory assumes that the fine detail of the component signals at an ear

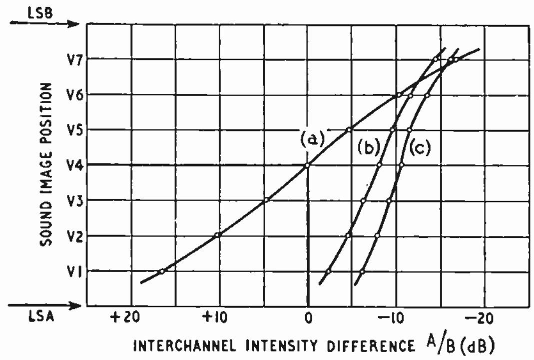
Fig. 10. Effect of interchannel intensity difference. Low-frequency signals. (a) and (b) Loudspeakers driven in phase. (c) and (d) Loudspeakers driven out of phase.





(a) ON-CENTRE LISTENING
(b) LISTENING POSITION OFF-CENTRE BY 2½ft TO LEFT
(c) " " " " 5ft " "

Fig. 12. Effect of off-centre movement by listener. Wide-band speech signal, b = 8ft.



(a) $T_e = 0$
(b) $T_e = 0{\cdot}9_1$ m sec (≡ 1ft) } CURVES DRAWN FOR DELAY IN RIGHT CHANNEL
(c) $T_e = 0{\cdot}8_2$ m sec (≡ 2ft)

Fig. 13. Effect of interchannel time difference. Wide-band speech signal, b = 8ft.

add on an r.m.s. basis. Again, by using the Taylor Expansion Theorem, a single resultant is derived such that in magnitude it is equal to the r.m.s. sum of the individual components, and is in time delay relative to the first arriving component by an amount T_L (or T_R) such that:

$$T_L \approx \frac{B_L^2}{A_L^2 + B_L^2} \cdot T_a \quad \ldots \quad (11)$$

$$T_R \approx \frac{A_R^2}{A_R^2 + B_R^2} \cdot T_a \quad \ldots \quad (12)$$

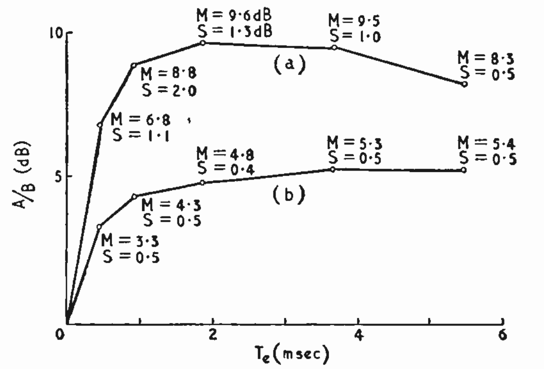
Due to the appreciable shadowing effect of the head at the head at high frequencies, the increased attenuation of the " crossed " signals cannot be neglected. Providing the listener is seated symmetrically with respect to the loudspeakers (as in Fig. 2), then it can be assumed that the increased attenuation of the " crossed " signals is the same. Allowing for this attenuation by including a factor " m " so that:

$$A_L = A,\ A_R = mA \ (m < 1)$$
$$B_R = B,\ B_L = mB$$

then:

$$T_S = T_R - T_L \approx \frac{m^2A^2}{m^2A^2 + B^2} \cdot T_a - \frac{m^2B^2}{m^2B^2 + A^2} \cdot T_a$$

$$\approx \frac{m^2(A^4 - B^4)}{(m^2A^2 + B^2)(A^2 + m^2B^2)} \cdot \frac{h}{v} \sin\theta \quad (13)$$



M = MEAN (dB)
S = STANDARD DEVIATION (dB) FOR 6 MEASUREMENTS { (a) ON SUBJECT 1 (b) ON SUBJECT 2

250 - 500 c/s BAND-LIMITED NOISE

Fig. 14

Figs. 14, 15 and 16. Examples of numerical equivalence between interchannel time difference and interchannel intensity difference.

Equating this time difference to that produced by a single source at an angle, gives the final result:

$$\sin\alpha \approx \frac{m^2(A^4 - B^4)}{(m^2A^2 + B^2)(A^2 + m^2B^2)} \cdot \sin\theta \quad (14)$$

If the increased attenuation of the " crossed " signals is neglected (i.e. $m = 1$) then:

$$\sin\alpha \approx \frac{A^2 - B^2}{A^2 + B^2} \cdot \sin\theta \quad \ldots \quad \ldots \quad (15)$$

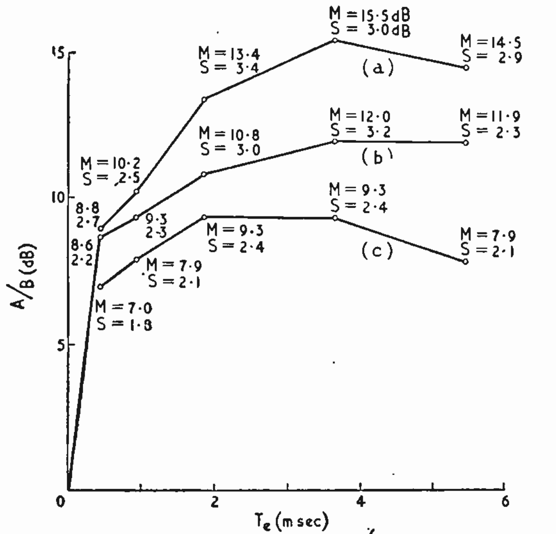
Equations (14) and (15) correspond with eqn. (8) in the low-frequency analysis. High-frequency equivallents to eqns. (9) and (10) can be derived, but the analysis is tedious and the result too cumbersome for normal use.

It will be noted that in eqns. (8) and (9) the sound levels from the loudspeakers occur only in the " squared " form. This would suggest that phase reversal of one channel would have little effect on the results. This conclusion is found to be correct, providing the listening angle θ is large, or the phase matching of the loudspeakers is poor. These conditions ensure virtually r.m.s. addition of the fine detail of the sound waveforms at the ears. With the listening angle θ small and with very accurately matched loudspeakers, the results tend to be similar to those obtained at low frequencies.

Effect of Interchannel Time Difference.—The effect of off-centre movement by the listener is illustrated in Fig. 12 for wide-band speech. The results are very dependent on the type of sound, the sound level, and the listener. Also, the sound image position becomes very badly defined, although consistent results can still be obtained for a given listener and a given sound at one level.

A simple computation indicates that in most cases the changes in the curves produced by off-centre movement are due largely to the effect of interchannel time difference thereby introduced. This can be seen by noting the similarity of the curves with those shown in Fig. 13, where the effect of introducing only an interchannel time difference is shown. The curve with no interchannel time difference is shown for comparison.

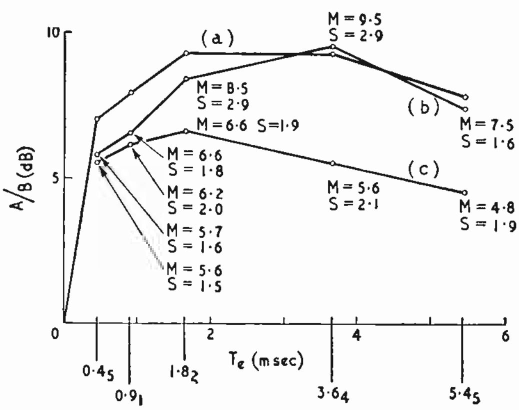
As the interchannel time difference is increased beyond about 2 millisec., the measurement tends to



M = MEAN (dB)
S = STANDARD DEVIATION (dB)

MEASUREMENTS ON 6 SUBJECTS: (a) WIDE-BAND PULSES (b) WIDE-BAND SPEECH (c) WIDE-BAND NOISE

Fig. 15



M = MEAN (dB)
S = STANDARD DEVIATION (dB)

MEASUREMENTS ON 6 SUBJECTS: (a) WIDE-BAND NOISE AS IN Fig. 15 (b) 250-500 c/s BAND-LIMITED NOISE (c) 2-4 kc/s " " "

Fig. 16

degenerate into deciding which loudspeaker is radiating the louder sound. Hence, although curves of the form shown in Fig. 13 can be plotted for any value of interchannel time difference, the significance of the results becomes increasingly uncertain as the interchannel time difference is increased. In view of this fact, the method of presenting the results is best modified as follows. If a given interchannel time difference is introduced, the sound image tends to move towards the time leading channel. By means of an opposing interchannel intensity difference the sound image can be returned to a central position. Hence an equivalence of the interchannel time difference with interchannel intensity difference can be defined. This equivalence, besides being of importance in the evaluation of stereophonic sound systems, is also of interest in the design of sound reinforcement systems.[9, 10]

For the present purposes, only interchannel time delays of up to about 5 millisec. are of interest, as beyond some 5–10 millisec. the impression of a single locatable sound image as distinct from some "etherial" source, is almost entirely lost. Some typical results for this type of measurement are shown in Figs. 14, 15 and 16. The general findings can be summarised as follows:

(a) For a given sound level and given listeners, the necessary interchannel intensity difference, to compensate for a given interchannel time difference, is very dependent on the nature of the sound, being greatest for sounds with transient characteristics, such as pulses, and almost zero for single component tones.

(b) For a given sound and given listeners, the necessary interchannel intensity difference, to compensate for a given interchannel time difference, is very dependent on the sound level above the ambient noise level, and decreases as the overall signal level above threshold decreases.

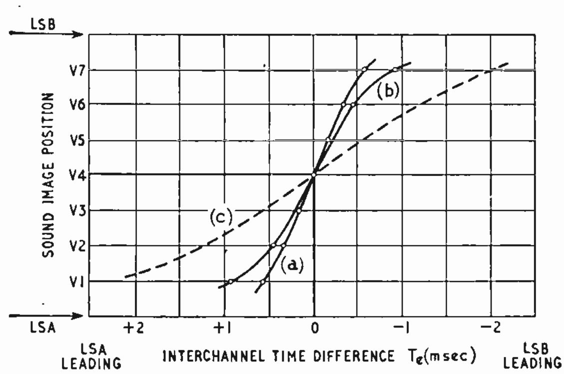
(c) For a given sound at a given level, the necessary interchannel intensity difference, to compensate for a given interchannel time difference, varies widely between listeners, although it appears to stay constant for a given listener.

(d) The equivalence is hardly effected by the listening angle θ especially for interchannel time delays of about 2 millisec. or more.

(e) The equivalence is virtually unaffected by a phase reversal of one channel especially for interchannel time delays of about 2 millisec. or more.

(f) The necessary compensating interchannel intensity difference reaches a maximum for a value of interchannel time difference of about 2 millisec.

It is important to note that the above equivalence is not the only possible one. Another equivalence arises as follows. The position of the stereo sound image can be controlled by interchannel time difference only as illustrated in Fig. 17. Unfortunately, the curve is rather uncertain as it depends on the sound level, the listener under test, and the type of sound. However, an equivalence can be postulated by equating those values of interchannel time and intensity difference for which the same sound image



(a) MEAN RESULT FOR 6 LISTENERS
(b) LIMIT INDIVIDUAL RESULT
(c) POSSIBLE RESULT IF MEASUREMENT CONDUCTED IN REVERBERANT CONDITIONS

Fig. 17. Movement of sound image by interchannel time difference. Wide-band speech signal.

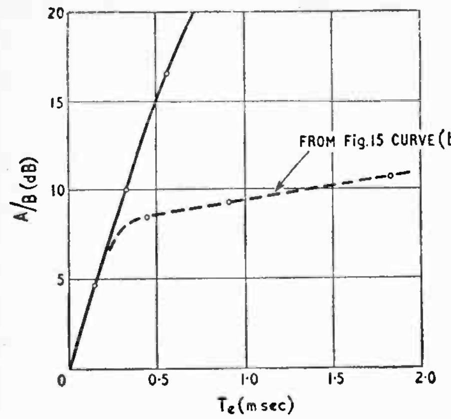


Fig. 18. Alternative interchannel time—intensity equivalence.

displacement is obtained[11]. This equivalence is very different from that previously defined as is shown in Fig. 18.

APPENDIX

With reference to Fig. 3, express the signals at the left ear as:

$$A_L f(t) \text{ and } B_L f(t-T_a)$$

where A_L and B_L are the amplitude terms, and f(t) represents any function of time. The resultant signal at the left ear S_L is given by:

$$S_L = A_L f(t) + B_L f(t-T_a) \quad .. \quad .. \quad .. \quad (16)$$

By the Taylor Expansion Theorem:

$$S_L = A_L f(t) + B_L f(t) - B_L T_a f'(t) + \tfrac{1}{2} B_L T^2{}_a f''(t) \ldots \text{etc.} \quad .. \quad (17)$$

Neglecting the terms involving $T^2{}_a$ and higher powers of T_a (this is reasonable providing T_a is small compared with the periodic time of the highest component frequency present), then:

$$S_L \approx (A_L + B_L)\left[f(t) - \frac{B_L}{A_L+B_L} T_a f'(t)\right] \quad .. \quad (18)$$

But $f(t) - \frac{B_L}{A_L+B_L} T_a f'(t)$ are the first two terms in the Taylor expansion of: $f\left[t - \frac{B_L}{A_L + B_L} T_a\right]$

Hence:

$$S_L \approx (A_L + B_L)\, f\left[t - \frac{B_L}{A_L + B_L} T_a\right] \quad .. \quad .. \quad (19)$$

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(To be concluded)

AUDIO FAIR

Exhibitors and Convention Speakers

A RECORD number of exhibitors are participating in this year's London Audio Fair which opens at the Hotel Russell, Russell Square, W.C.1, on April 21st for four days. As will be seen from the list of exhibitors below, there are a number of overseas audio manufacturers who have taken space. All but nine of the 74 exhibitors have booked rooms for demonstration purposes in addition to exhibiting in the main hall. The Fair is open daily from 11.0 to 9.0, but on the first day admission up to 4.0 is limited to the trade.

AKG (*Austria*)
Acoustical Mfg. Co.
Amateur Tape Recording
Ampex International (*Switzerland*)
Armstrong Co.
Audio Fidelity (England)
BASF (*Germany*)
B.B.C.
B.S.R.A.
Beam-Echo
Brenell Engineering Co.
British Ferrograph
Butoba K.G. (*Germany*)
Celestion
Challen Instrument Co.
Chapman (Reproducers)
Chitnis, Gopal (*Germany*)
Cole, E. K.
Cosmocord
Decca
Design Furniture
Dynatron
E.A.P. (Tape Recorders)
E.M.I. Records
E.M.I. Sales & Service
Electronic Reproducers
Fi-Cord
G.E.C.
Garrard Engineering
Goldring Manufacturing Co.
Goodmans Industries
Gramophone Co.
Grampian Reproducers
Grundig (Great Britain)
Hi-Fi News
Jason Motor & Electronic Co.
Leak, H. J. & Co.
Lowther Mfg. Co.
Lustraphone
M.S.S. Recording Co.
Minnesota Mining & Mfg.
Mullard
Multimusic
Orr Industries (*U.S.A.*)
Pamphonic Reproducers
Pye
Pye Records
Rank Cintel
Record Housing
Recording Devices
Redifon
Reslosound
Rogers Developments
S.T.C.
Shure Brothers (*U.S.A.*)
Simon Equipment
Specto
Sugden & Co.
Tannoy Products
Technical Suppliers
Telefunken (*Germany*)
Teppaz (*France*)
The Gramophone
Trix Electrical Co.
Truvox
Veritone
Vortexion
W. & N. Electronics
Walter Instruments
Wellington Acoustic Labs.
Wharfedale Wireless
Whiteley Electrical
Wireless Trader
Wireless World

Tickets admitting two to the Fair are obtainable free from audio dealers, exhibitors and *Wireless World*. Postal applications to this office for tickets should include a stamped addressed envelope.

The British Sound Recording Association is organizing a technical convention in conjunction with the Audio Fair. It opens on Friday, April 22nd with an evening meeting at 7.15 at the Royal Society of Arts, John Adam Street, W.C.2, at which J. Moir (Goodmans) will speak on sound radiation from loudspeaker cabinets. On Saturday the 23rd, there will be a whole day's meeting starting at 10.0 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1. At the morning session Peter Ford, honorary historian of the Association, will speak on the evolution of stereophonic techniques and Herrmann K. F. Juncke (Telefunken, Hanover) on progress in tape recording. In the afternoon from 2.0 G. D. Browne (Mullard) will read a paper entitled "A new system of stereophonic broadcasting" and Fritz Ph. Sippl (AKG, Vienna) will deal with new microphone developments. In the evening at 7.0 at the Tower, Hammersmith Broadway, London, W.6, a lecture demonstration on stereophonic sound in the cinema will be given by RCA (Great Britain). The registration fee for the convention for non-members is 10s. Applications should be sent to S. W. Stevens-Stratten, Greenways, 40 Fairfield Way, Ewell, Surrey.

At the Audio Fair the B.S.R.A. is organizing a display on the theme "Sound in the Service of Man."

Long-Distance Communication

Possible Use of Earth Satellites

By R. J. HITCHCOCK,* M.A., A.M.I.E.E.

ALTHOUGH the frequency allocation table in the new Geneva Radio Regulations covers nearly 40,000 Mc/s, little more than one two-thousandth of this is suitable for world-wide communications at present. With two relatively minor exceptions (long waves and ionospheric scatter) it is within the high-frequency portion of the spectrum, between 3 and 30 Mc/s, that the commercial operators, Armed Forces, broadcasting authorities, ships and aircraft stations of all nations must find allocations if they are to provide and maintain world-wide services by radio. For this, with the exceptions mentioned above, is the only portion of the spectrum where ionospheric reflections support long-distance propagation.

The astonishing growth in the number of world-wide telecommunication circuits since the end of the second world war has been partly due to a natural increase in consumer demands, viz. telex, customer-to-customer leased channels, etc., and partly to the decentralization of global communications following the emergence of new countries. This increase in the utilization of frequencies has had its greatest effect in the bands allocated to the Fixed† services and broadcasting. In the 50 kc/s between 9100 and 9150 kc/s (Fixed services) there were, in 1939, fewer than 40 registrations; by 1952 this number had grown to nearly 340, and by 1959 to over 540. Although there is less numerical congestion in the higher part of the h.f. band the proportional increase has been scarcely less startling. In the 15 Mc/s Fixed service bands, for instance, there are now 7 registrations for every one in 1939. This, however, is only part of the story, for in the last decade multichannel techniques have become commonplace in both telegraphy and telephony, and although such techniques offer much greater traffic-carrying capacities, they also demand greater bandwidths. Broad-band registrations, therefore, constitute a considerable portion of the present International Frequency List.

For the Fixed services in particular the process of finding a place in the spectrum has virtually degenerated into a struggle in which power and continuity of transmission are all important and, although some vestiges of order continue to be maintained through the International Telecommunication Union, it would be pure idealism to expect the spectacular from a body with no supra-national authority. In fact, so concerned were the delegates at the recent Geneva conference at the congestion in this part of the spectrum that they resolved to set up an international Panel of Experts with the task of devising "ways and means of relieving the pressure on the bands between 4 and 27.5 Mc/s." In drawing up this resolution the delegates were not unaware that the true effects of the congestion have yet to be seen. In fact, they will not be apparent until the next sunspot minimum, some three or four years hence, when a reduction in the reflecting properties of the ionosphere at higher frequencies will still further increase the congestion in the lower part of the h.f. band.

The question facing telecommunications operators, therefore, is how are long-distance services to be maintained and new ones provided for, if the only section of the radio-frequency spectrum *naturally* suitable to them is virtually saturated. At present, the answer is found by looking to systems other than radio and, in the Commonwealth in particular, great emphasis has been placed on the potentialities of the coaxial submarine telephone cable. Although expensive in initial capital outlay, and not immune from physical interruptions, such cables can provide numerous speech channels of far higher quality than can be obtained with conventional radio techniques where ionospheric propagation introduces distortion and fading. However, it is not intended here to discuss the relative merits of radio and cable systems, but to see how, when one radio resource is nearing exhaustion, a new one capable of carrying the vast world-wide traffic potential may be built up.

If the general propagation characteristics of the main radio communication techniques now available are considered in simplified relation to one another, it is evident that no single one is capable of meeting all the essential requirements.

Rough though the classification in Table I is, it is apparent that, with present techniques, range is only

* Cable & Wireless Ltd.
† A radiocommunication service between specified fixed points.

TABLE I
LONG DISTANCE COMMUNICATIONS

Technique	Range	Bandwidth	Reliability
H.F.	Yes	No	Insufficient
Line-of-sight v.h.f.	No	Possibly insufficient	Yes
Ionospheric scatter	Insufficient	No	Yes
Line-of-sight u.h.f.	No	Yes	Yes
Tropospheric scatter	Insufficient	Yes	Yes
s.h.f. etc.	No	Yes	Yes

obtainable when using frequencies below 30Mc/s and bandwidth on frequencies above 300Mc/s. Little can be done to increase available bandwidth in the lower frequency bands, and even if this were practicable the quality afforded by ionospheric propagation is probably inadequate for many future telecommunication needs. It is, therefore, towards increasing the transmission ranges at higher frequencies, where the ionosphere plays little or no part, that efforts must be directed. With propagation in this part of the spectrum limited to "line of sight" we must look for possible means of extending this to extend the communication range. Extra terrestrial relay points provide the solution.

Much has been said and written recently, particularly in the United States, on the use of earth satellites for world-wide communications, but it was in this journal nearly fifteen years ago that A. C. Clarke[1] first drew attention to the potentialities of such systems. Clarke, in fact, suggested what is still regarded by many to be the ultimate in communication satellites, one in 24-hour "stationary" orbit carrying both receiving and transmitting equipment. In the intervening years developments in rocket techniques and space conquest have produced other ideas, and it is proposed here to consider all such possibilities with their relative advantages and disadvantages from the communications point of view.

An extra terrestrial relay point may be either natural or artificial, active or passive. The first, of course, is the moon, and successful intercontinental transmissions, using that body as a passive relay point, have already been made. There are, however, obvious disadvantages. Not only does the great distance earth/moon/earth result in relatively high path losses and excessive transmission time for two-way telephony, but the moon's transit across the sky makes continuous transmission between any two earth locations impossible. The main advantage is, of course, that the moon is already in orbit—permanently we presume—and, therefore, the problems are confined to radio engineering rather than to space techniques and rocketry.

There are three general ways in which artificial satellites may be used to further communications:

(1) Storage in low-level orbits (active).
(2) Direct communication in higher orbits, say, 3,000 miles (active or passive).
(3) Direct communication in "stationary" or 24-hour orbits (active or passive).

[1] A. C. Clarke, "Extra-Terrestrial Relays," *Wireless World*, October, 1945.

Of these the simplest but probably the least potentially useful for the future is the first. Here the information is received and recorded by the satellite as it passes over one earth station and retransmitted as it passes over another. This is, so far, the only method to have been proved experimentally. It will be recalled that a "talking" satellite carried President Eisenhower's 1958 Christmas message to the world. A few watts from a non-directive aerial is all that is necessary to transmit the message to receivers on the ground and a few hundred watts on the ground is sufficient to interrogate the satellite. Although there is only limited enthusiasm for this particular technique it is worth recording that under the U.S. project "Courier" it is proposed to launch, in the course of the year, a 500lb storage or delayed action satellite with a capacity of twenty 100-word-per-minute teleprinter channels. The storage satellite is essentially a relatively low-level body and to achieve worth-while *direct* trans-oceanic communication, satellites at much higher altitudes would be needed. The second of the three ways, i.e., higher level orbiting offers this possibility.

With an orbit height of, say, 3,000 miles (an orbit time of 3 hours) a satellite would "see" a substantial part of the earth's surface, but communication between specific earth points could only be intermittent as the duration of visibility at any terminal would be little more than 30 minutes at the most. If, however, a sufficient number of satellites could be provided at this height a virtually continuous service over a 2,500-mile earth path could be achieved (Fig. 1).

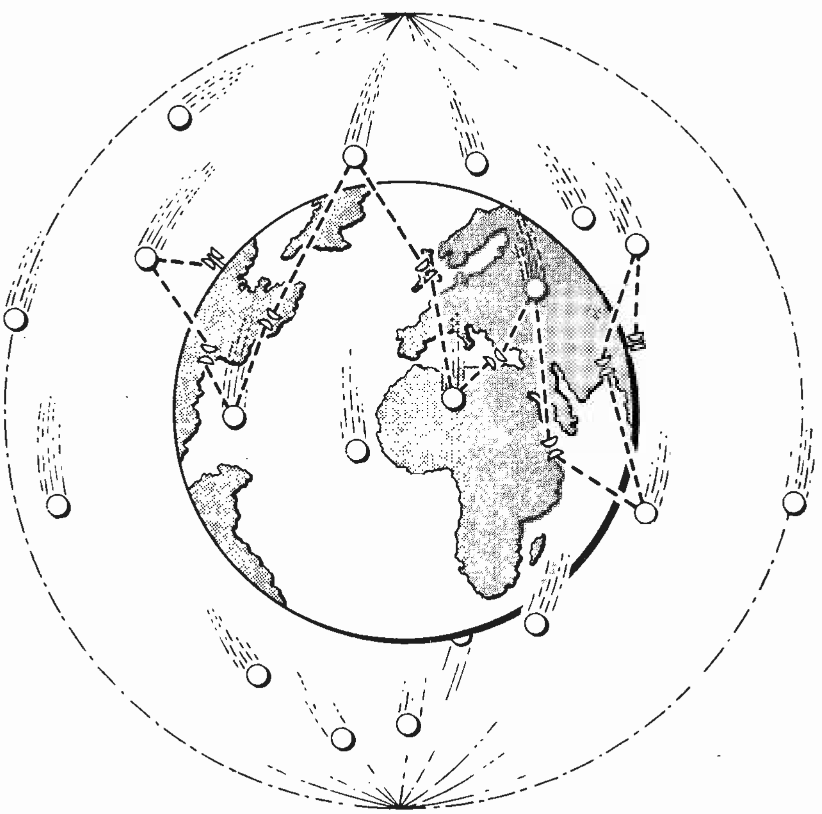


Fig. 1. Round-the-world communication by passive satellites in 3,000-mile polar orbits.

Theoretically, of course, such bodies could be either active, i.e., contain their own relay stations, or passive, acting merely as reflectors. To be economic any active system would need to provide linearity over a wide bandwidth and years of continuous operation.

Current hopes are therefore being placed in the passive system on which Pierce[2] has done much theoretical work. The simplest reflector is a metallized balloon and Pierce has calculated that, with 28 such bodies randomly spaced in 3,000-mile polar orbits, communication could be achieved over a transatlantic path between Newfoundland and the Hebrides with a continuity of service of 99.9%. The first experiments along these lines are also due to begin this year when, under U.S. project "Echo," a 100ft inflatable satellite of 0·0005in-thick Mylar plastic coated with vapour deposited aluminium will, it is hoped, be put into orbit.§

What are the advantages and disadvantages of such a system? In the first place the repeaters or relay points are themselves simple, as they carry no electronic equipment and should be capable of a relatively long life even in the face of micrometeorite perforations. While a passive orbiting system has the advantage of using less frequency space than an active one—and, of course, it might well be used by any number of organizations, each with its own operating frequency—it has the disadvantage that, compared with an active system, more powerful and complex ground stations equipped with large steerable aerials and maser amplifiers are essential. Furthermore, as each satellite must be found and tracked, these very large aerials would need to switch rapidly from one satellite to another if a continuous circuit were to be maintained. The most intriguing prospect, therefore, and the third of the possible methods, is the relay satellite which remains stationary, i.e., in 24-hour orbit, over one point of the earth's surface. The major problem facing such a system is that of attitude and altitude stabilization, for to be completely stationary relative to the ground a satellite needs to be 22,300 miles above the earth's surface and in a circular equatorial orbit. Theoretically, it could be either an active or passive body but, in practice, the latter technique would require a sphere several thousands of feet in diameter and weighing many tons. Although passive reflectors other than spheres may be developed, the relatively long transmission distances involved suggest that an active satellite carrying its own receiving and transmitting equipment would be preferable.

As to the number of such satellites required for world-wide communications, three equally spaced would be visible from some 98% of the earth's surface with the north and south limits of visibility at 62° of latitude for a 5° ground horizon (Fig. 2).

This, then, is the ultimate system and the one envisaged by Clarke 15 years ago. It has the one disadvantage that the transmission distance produces time delays of the order of a quarter of a second which would be noticeable, and possibly objectionable, in two-way telephony conversations. Such a system, however, would be ideal for providing other forms of world-wide broad-band communications, including, of course, television broadcasting.

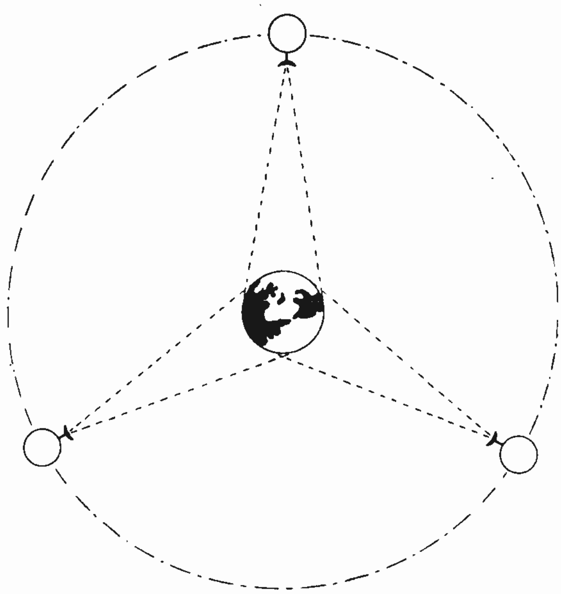


Fig. 2. World-wide communication by active "stationary" 24-hour satellites in equatorial orbits.

Having started with the frequency problems of the h.f. band it is probably fitting to make some mention, at this stage, of the frequency problems facing commercial communication satellite systems. From a propagation aspect the usable frequency range must be such as to avoid the effects of both the ionosphere and cosmic noise at the lower end of the spectrum, and of atmospheric absorption and radio noise from oxygen and water vapour at the upper end of the spectrum. This leaves a usable frequency range extending from approximately 1,000 to 10,000 Mc/s with the optimum, according to Pierce, between 2,000 and 6,000 Mc/s. Of equal importance is the question of allocations for practical satellite systems within the optimum band. For the first time the International Frequency Allocation Table includes allocations for space and earth-space systems, but as yet these are relatively narrow bands intended for research purposes only. However, one of the recommendations of the Geneva Conference was that a further Extraordinary Conference should be called in 1963 to examine the progress in space communications, and if necessary to make broad-band allocations for world-wide communications.

With the move towards very wideband and high-quality communication systems, long-distance operators, both civil and military, can no longer expect conventional h.f. radio to provide the medium of transmission. The future can only lie in the higher bands of the spectrum. The first break through into truly long-distance commercial u.h.f./s.h.f. propagation is likely to be achieved in the relatively near future with passive reflectors circling the earth in orbits of a few thousand miles allowing communication between interlinked ground stations. Finally, the ultimate system of stationary, 24-hour satellites with their own receiving and transmitting equipment acting as world-wide repeaters, navigational aids, etc., although obviously further away, is already in the project stage.

[2] J. R. Pierce and R. Kompfner, "Transoceanic Communications by Means of Satellites," *Proc.I.R.E.*, March, 1959.

§ As a prelude to this project balloons have been used as passive reflectors to relay transmissions from the Bell Telephone Laboratories, at Holmdel N.J., to the Massachusetts Institute of Technology.—Ed.

WORLD OF WIRELESS

Unfair Competition?

THE possibility that Government support for the reorganized civil aircraft industry, which has recently shown a tendency to diversify into electronics, might be construed as indirect and unfair competition with the established electronic industry, was mentioned by L. T. Hinton, chairman of the Electronic Engineering Association at their annual luncheon.

The principal guest, the Rt. Hon. Duncan Sandys, Minister of Aviation, in his reply, said that Government policy was to maintain an efficient capacity for aeronautical equipment production and that while it was not his policy to encourage airframe constructors to go into electronics, neither would he do anything to prevent them, provided that they did so at their own risk and expense. The Government's objective was to obtain equipment at the lowest cost, and this would determine the placing of contracts.

Technical Writing Awards

UP to six premiums of 25gn each are awarded by the radio and electronics industry each year for published technical articles to encourage a greater flow of material from within industry and thereby to make more widely known technical progress in this country. The scheme is now jointly sponsored by the Radio Industry Council and the Electronic Engineering Association, and the members of the present panel of judges are:—Professor H. E. M. Barlow, B. C. Brookes, P. D. Canning, A. H. Cooper, The Hon. John Geddes, F. Jeffery and Dr. R. C. G. Williams.

A total of 63 articles published during 1959 were submitted and premiums have been awarded to the following authors:—

A. E. Karbowiak ("Waveguide as a Long-distance Communication Medium," *Electronic Engineering*).

T. G. Thorne and J. A. Billings ("The Performance of Doppler Navigation Systems," *British Communications and Electronics*).

C. M. Cade ("Infra-red Navigation Aids," *British Communications and Electronics*).

R. Rowland ("Printed Circuits Applied to Broad-band Microwave Links," *Electronic Engineering*).

D. A. Wright ("Compound Semiconductors," *Electronic Engineering*).

R. J. D. Reeves ("The Recording and Collocation of Waveforms," *Electronic Engineering*).

A.P.A.E. Exhibition

MORE than twenty firms supported the exhibition of equipment which took place at the King's Head Hotel, Harrow-on-the-Hill, on March 9th. This was the occasion of the 10th annual luncheon of the Association of Public Address Engineers, at which the guest of honour was the Rt. Hon. Ernest Marples, Minister of Transport, who is the first recipient of the Association's Gold Microphone (donated by L. W. Murkham) for the "best microphone user of the year."

At the general meeting which followed, Haydon Warren was elected president for 1960. Mr. Warren, who is also hon. librarian of the Association and has many U.S. contacts, arranged an interesting historical collection of early p.a. equipment and literature from both sides of the Atlantic.

B.B.C. Income

UNDER a three-year agreement (1957-60) the B.B.C. receives annually 87.5% of the receiving licence revenue after the deduction of a sum by the Post Office for the service it provides in collecting licence fees and investigating interference. The remaining 12.5%, plus the £1 excise duty on the combined sound/television licence, is passed to the Treasury. There is a proviso in the agreement under which additional sums can be paid to the B.B.C., if the Treasury is satisfied that the income is "insufficient for the adequate conduct of the home services"*.

In response to representations by the B.B.C., the Treasury reduced to 7.5% the proportion of the licence income it is retaining in the financial year 1959/60 leaving 92·5% for the B.B.C. The P.M.G. announced in the House of Commons on March 11th that the Corporation's income will be still further increased to 95% in 1960/61 and in 1961/62 to 100% of the net licence revenue, that is, after the Post Office deduction and the Treasury's retention of the excise duty. The following figures, taken from the "B.B.C. Handbook 1960," show how the gross licence revenue of £42M in 1958/59 was apportioned—B.B.C. (£27M), Treasury (duty £9M, 12·5% retention, £4M), Post Office (£2M).

* External services are financed by grants-in-aid from the Treasury, which in 1958/59 totalled some £6M.

Receiving Licences.—During January the number of combined television/sound licences throughout the U.K. increased by 105,448, bringing the total to 10,219,867. Sound-only licences totalled 4,679,755, including 415,230 for sets fitted in cars. Recently announced figures for other European countries are: Holland: sound, 2,612,000; television, 610,000; and subscribers to wired services, 489,737. Norway: sound, 1,008,000; television, 10,000, although the Norwegian television service does not officially open until later this year.

Boston Television Relay.—Multisignals (Boston) Ltd. have put into operation a "wired aerial" service for television and v.h.f./f.m. in Boston, Lincs., serving initially some 700 subscribers. Using E.M.I. equipment, the installation is being extended to cover the major part of Boston. This is the first installation under the ægis of the parent organization, Multisignals Ltd., which is sponsored by three companies, Ekco, Thorn and Ultra, in co-operation with the R.T.R.A.

Standards for Audio Connectors have been published by the Audio Manufacturers' Group of B.R.E.M.A. in a free booklet entitled "Recommended Standard Practice for Plugs, Sockets & Connectors for use with Audio Amplifying Equipment." The suggested standards are designed to facilitate the interconnection of units made by different manufacturers and apply only to equipment in which the chassis is isolated from the mains by a double-wound mains transformer.

Home Construction.—Entries from non-members as well as members are invited by the British Sound Recording Association for this year's Home Constructors' Competition. Apparatus submitted for the competition should be associated with the recording and reproduction of sound, including appropriate test equipment. Exhibits will be judged on May 21st on the score of technical originality, suitability of purpose, design and finish. Application forms may be obtained from the B.S.R.A., 40 Fairfield Way, Ewell, Surrey.

Education and Training.—Reference was made at the annual luncheon of the Electronic Engineering Association to the formation of the Electrical and Electronic Manufacturers' Joint Education Board, which replaces what was previously known as the Electrical Industries' Education Board. The founder members are: B.E.A.M.A., B.R.E.M.A., B.V.A., E.E.A., R.E.C.M.F., S.I.M.A. and T.E.M.A. The secretariat is being provided by B.E.A.M.A. and Colonel B. H. Leeson has been elected chairman.

I.F.A.C.—The first international congress on automatic control will be held in Moscow from June 27th to July 7th under the auspices of the International Federation of Automatic Control. Twenty countries are participating and in all nearly 300 papers will be presented. Twenty-eight papers have been selected as the British contribution. They will be read again in this country in September. The U.K. delegation is to be led by John F. Coales, of Cambridge University, who is a member of the executive council of the I.F.A.C.

Moscow Exhibition.—Thirty-four British scientific instrument manufacturers are holding a collective exhibition in Moscow from June 18th to 29th. It is being organized by the Scientific Instrument Manufacturers' Association.

Electronic Equipment Reliability.—Methods of assessing and predicting the reliability of electronic equipment, as well as experience gained in the use of equipment, will be covered during a one-day symposium to be held in London on May 18th. Further details and registration forms are available from the I.E.E., Savoy Place, London, W.C.2.

Components and Materials.—Preliminary details of a conference on components and materials used in electronic engineering to be held next year from June 12th to 17th have been announced by the Electronics and Communications Section of the I.E.E. The scope of the conference falls under three main headings: (a) materials, their preparation, properties and applications; (b) components, excluding thermionic and semiconductor devices; and (c) assembly techniques.

Audio Shows.—Independent exhibitions are being staged by two manufacturers during the London Audio Fair (see page 160). Sound Sales Ltd. will be in the Club Room, Imperial Hotel, Russell Square, W.C.1, and Daystrom (Heathkits) at the Grand Hotel, Southampton Row, W.C.1.

B.V.A. and V.A.S.C.A. Move.—The offices of the British Radio Valve Manufacturers' Association and the Electronic Valve and Semi-conductor Manufacturers' Association have been transferred from Jermyn Street to Mappin House, 156-162 Oxford Street, London, W.1 (Tel.: Langham 8562).

"How Long Will a Transistor Live?"—In case it may not have been obvious from the footnote on p. 108 of this article in our March issue we would point out that the author, Ralph Brewer, is with the Research Laboratories of the General Electric Company Limited, Wembley, England.

E.E.A. Officers.—L. T. Hinton (S.T.C.), and **R. R. C.** Rankin (Mullard) have been re-elected chairman and vice-chairman, respectively, of the Electronic Engineering Association.

C. & G. Radio Society.—Group Captain E. Fennessy, C.B.E., managing director of Decca Radar, has been elected to succeed L. H. Bedford, C.B.E., of English Electric, as president of the City and Guilds College Radio Society.

Ferrites.—A course of six lectures on the principles and applications of ferrites is being given by J. Roberts, of Imperial College, at the Norwood Technical College, Knight's Hill, London, S.E.27, on Tuesdays at 7.0 from May 10th.

A three-day course dealing with semiconductors will be held at the Portsmouth College of Technology on May 26th, 27th and 28th. The lecturers are members of the staff of the G.E.C. Research Laboratories.

"Trader Year Book."—Features such as the buyers' guide, manufacturers' addresses, condensed specifications of current sound and television receivers and tape recorders, receiver i.fs, etc., which have been found to be invaluable for the radio dealer and serviceman, are retained and brought up to date in the 1960 edition of the "Wireless and Electrical Trader Year Book." A new section of 14 pages covering television and f.m. transmitters in the U.K. incorporates field-strength contour maps of B.B.C. and I.T.A. television stations. This 448-page reference book, which is published by Trader Publishing Co. Ltd., Dorset House, Stamford Street, London, S.E.1, costs 15s.

Scottish TV.—A permanent television transmitter at Thrumster, near Wick, Caithness, where temporary equipment has been in use since December, 1958, was brought into service by the B.B.C. on March 1st. It radiates in channel 1, using vertical polarization, and its directional aerial gives an e.r.p. of from 0.25 to 7kW, according to direction. On the same date a three-programme v.h.f. sound service was started from the same station. The transmitters radiate on 90.1, 92.3 and 94.5Mc/s with horizontal polarization. The directional aerial gives an e.r.p. varying from 0.1 to 10kW.

Radio Emergency Networks.—Dr. Arthur C. Gee (G2UK), the chairman of the Radio Amateur Emergency Network Committee in this country, is endeavouring to compile a world-wide list of emergency radio organizations to facilitate the work of the Red Cross in such disasters as have occurred recently at Mauritius and Agadir. Overseas readers are invited to send details of local organizations to Dr. Gee, c/o this office.

Personalities

E. D. Whitehead, M.B.E., B.Sc., M.I.E.E., has been appointed Director of Electrical Inspection in the Ministry of Aviation in succession to **Brigadier C. A. Zweigbergk** whose tour of duty in the Ministry ends at the beginning of April. Mr. Whitehead, who is 49, graduated from London University in 1930. After a few years in industry, first with G.E.C. and then Pye, he joined the Government service in 1937. In 1940 he began work on radar at R.A.E., Farnborough, and for five years from 1943 was technical assistant to the Director General of Communications Equipment. He then transferred to work on telemetry, and later (in 1952) became assistant director electronic component production in the Ministry of Supply. Since 1957 Mr. Whitehead has been in charge of a division of the Electrical Inspection Directorate responsible for the inspection of electronic equipment.

Sir Ian Jacob, K.B.E., C.B., director-general of the B.B.C. from 1952 until his retirement at the end of last year, has joined the board of Electric and Musical Industries, Ltd.

E. M. Whitaker, B.Sc., A.M.I.E.E., has joined A.E.I. (Woolwich) as assistant to the commercial director, J. W. Ridgeway. He joined B.T.H. at Rugby in 1931 as a school apprentice and in 1932 went to Leeds University for a three-year degree course in electrical engineering, after which he rejoined B.T.H. Since his demobilization in 1946 after war service with R.E.M.E., he has held various overseas appointments with B.T.H. and in 1958 became personal assistant to Lord Chandos.

K. R. Sandiford, B.Sc.(Eng.), has joined Hagan Controls, Ltd. (one of the Plessey group of companies) as general manager. Since 1954 he has been chief instrument engineer of the development and engineering group of the U.K. Atomic Energy Authority.

John Guy has been appointed chief planning engineer of Measuring Instruments (Pullin), Ltd. He was for 13 years with Sifam Electrical Instrument Co.

Captain Walter R. Wells, D.S.C., R.N., was recently appointed deputy chairman of the British Joint Communications and Electronics Board and deputy director of the Joint Communications Electronics Staff. He entered the Royal Naval College, Dartmouth, at the age of 13 in 1933 and after service at sea qualified in communications in 1943. From 1945 to 1947 he was Communications Officer to the First Destroyer Squadron. Capt. Wells held various staff appointments overseas and for two years from May, 1949, was on the staff of the Director of Radio Equipment at the Admiralty. He then became Staff Communications Officer, Far East Station, and for five years from 1953 served in the Admiralty Signal Division.

Brigadier J. D. Haigh, O.B.E., M.A., M.I.E.E., has been appointed divisional manager of Plessey's capacitors and resistors division at Swindon. Brigadier Haigh was, from 1939 until 1941, a radar instructor at the School of Anti-Aircraft Artillery. In 1946 he joined the Ministry of Supply where, until 1950, he was responsible for the development of Army radar equipment. In 1953, on his return to the U.K. from Singapore where he had commanded an Air Formation Signals Regiment, Brigadier Haigh rejoined the Ministry of Supply and in the following year was appointed Director of Electronic Research and Development. He joined the Plessey Company in 1958.

Brig. J. D. Haigh

A. P. Castellain

Alfred P. Castellain, B.Sc.(Eng.), A.C.G.I., D.I.C., chief engineer of A.E.I. Sound Equipment, Ltd. (formerly B.T.H. Sound Equipment, Ltd.) has been appointed an executive director whilst retaining his former position. Mr. Castellain, who was on the editorial staff of *Wireless World* in the early 1920's, was a lecturer in communications engineering at Queen Mary College, London, from 1924 to 1929. He joined Sound Equipment, Ltd., which later became B.T.H. Sound Equipment, in 1930 as its chief engineer. From 1941 to 1946 he was seconded to B.T.H., Rugby, for development work on 3-cm radar and in 1948 was put in charge of sound reproducer sales at Rugby. Mr. Castellain returned to London in 1956 as chief engineer, B.T.H. Sound Equipment. **Reginald Oulton,** acting secretary and general manager of A.E.I. Sound Equipment since 1956, has also been appointed an executive director. He joined Sound Equipment in 1934 and has been general manager since 1940. **Ernest V. Bowers,** M.B.E., formerly managing director, A.E.I. Sound Equipment, Ltd., has resigned from his executive duties to join A.E.I. Lamp and Lighting Co., but retains his directorship.

P. W. Blick, author of the article on page 169 describing a transistor tape recorder amplifier, has been on the research staff of Belling & Lee for the past three and a half years. Prior to joining Belling & Lee he was an apprentice with the Electrical Research Association at Perivale. He is 25.

G. C. F. Whitaker, who was assistant superintendent of the Admiralty Signal and Radar Establishment from 1952 until 1955 when he became Fleet Electrical Officer on the staff of the Flag Officer Commanding Reserve Fleet, has been appointed assistant controller of programmes (technical operations) for Associated-Rediffusion. He will be in charge of the company's engineering activities. Mr. Whitaker joined Associated-Rediffusion from the television broadcasting department of Central Rediffusion Services, Ltd. Prior to his retirement from the Royal Navy, he was on loan to the Royal Australian Navy as Director of Electrical Engineering.

C. O. Stanley, C.B.E., chairman and managing director of the Pye group of companies, is to have the honorary degree of Doctor of Laws (LL.D.) conferred upon him by the University of Dublin.

Major E. A. Stuart, T.D., Assoc.I.E.E., has joined Colben Electronic Engineering Co. (until recently Colben Radio and Engineering Co.), of Dartford, Kent, as a director. Retiring from the regular army (R.E.M.E.) in January he went to Canada where he has since been associated with E.M.I./Cossor Electronics, Ltd. Major Stuart was for some time adviser to the G.O.C. Pakistan Army and responsible for the technical control of radar and other electronic equipment being introduced for the Pakistan Forces. For three years immediately prior to his retirement he was Deputy Asst. Director Electrical and Mechanical Engineers (Radar) at the Headquarters of Eastern Command.

Air Commodore B. Ball, C.B.E., has been appointed Deputy Chief Signals Officer at Supreme Headquarters Allied Powers Europe (S.H.A.P.E.). Since December, 1956, he has been Command Signals Officer, Bomber Command. He was at one time Commandant and Chief Inspector of the R.A.F. Signals Division at Debden.

Group Captain J. A. Robinson, O.B.E., who since 1957 has been Senior Technical Staff Officer at Signals Command, R.A.F., has succeeded Air Commodore B. Ball as Chief Signals Officer, Bomber Command, and has been granted the acting rank of Air Commodore. From 1955 to 1957 he was Chief Signals Officer at Far Eastern Air Force headquarters.

Major General Sir William A. Scott, K.C.M.G., C.B., C.B.E., Director of Communications at the Foreign Office from 1955 until his retirement from the Army in 1959, has joined the board of Southern Instruments, Ltd. Sir William, who was knighted in the 1959 New Year Honours, was previously Director of Signals, War Office (1949-1952); Director of Weapons and Development, War Office (1952-1955) and was at one time during the war Chief Signal Officer to the 8th Army. Originally commissioned in the Royal Engineers he transferred to Royal Signals in 1920.

OBITUARY

Baden John Edwards, M.B.E., M.I.E.E., a director and at one time chief engineer of Pye, Ltd., which he joined in 1935, died on February 16th at the age of 47. For his war-time services, part of which was as an adviser to Bomber Command Headquarters on the applications of radar, he was appointed an M.B.E. in 1945. In 1953 Mr. Edwards became a member of the technical sub-committee of the Government's Television Advisory Committee.

James Nelson, M.I.E.E., Hon. M.Brit.I.R.E., who died on January 31st at the age of 78, was a founder member of the British Institution of Radio Engineers and was its third president. It was in a letter in the August, 1925 issue of our sister journal *Experimental Wireless* (now *Electronic Technology*) that he stressed the need for the formation of a "really technical society" for wireless men and proposed that it should be called the British Institute of Radio Engineers. For most of his professional career Mr. Nelson was associated with B.I. Callender's Cables, from which he retired in 1953.

Time Multiplex Stereophonic Broadcasting

NEW MULLARD SYSTEM

THE left and right stereo signals (after the usual pre-emphasis) are sampled alternately for half-cycle periods at a frequency of 32.5kc/s and the resultant complex signal used to frequency modulate a v.h.f. transmitter in the usual way in a new system developed by G. D. Browne of the Mullard Research Laboratories.

In the transmitting equipment (shown in Fig. 1), the pre-emphasized left and right stereo signals are sampled by multiplicatively mixing them with two 32.5-kc/s sine waves of opposite phases, alternate half cycles of each sampled signal removed by half-wave rectification (not shown) and the left and right sampled signal added together. A sine wave at 32.5kc/s, 90° out of phase with both the sampled signals, is also added at a low level. The resultant complex signal can be shown to be equivalent to the combination of the sum of the two stereo signals, a suppressed sub-carrier at the sampling frequency (double-sideband amplitude modulated by the difference between the two stereo signals), a sub-carrier at twice the sampling frequency (double-sideband amplitude modulated by the sum of the two stereo signals) and other modulated sub-carriers at still higher frequencies. All these higher frequencies above 80kc/s are filtered out and the final complex signal thus obtained is used to frequency-modulate the transmitter in the normal way.

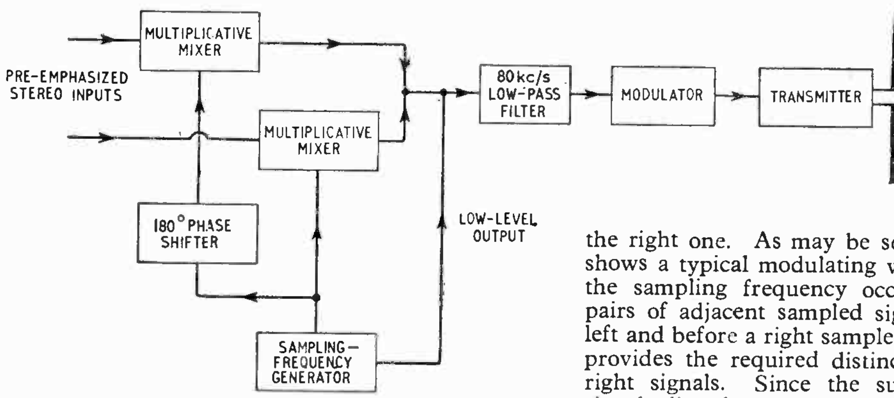


Fig. 1. Block diagram of transmitting equipment.

The receiver (see Fig. 2) follows normal practice up to the discriminator output. The low-level signal at the 32.5-kc/s sampling frequency is then separated out and used to phase lock an oscillator at this frequency. The output from this oscillator is phase-shifted by plus and minus 90° to form two further sine waves in phase with the sampled signals. These phase-shifted sine waves are then multiplicatively mixed with the discriminator output to recover the two stereo signals. Extra equipment needed at the receiver thus consists of one oscillator and two mixers, apart, of course, from the second audio amplifying chain and loudspeaker.

The low-level signal at the sampling frequency and 90° out of phase with the two sampled signals is added to avoid any ambiguity as to which stereo signal is the left one and which is the right one. As may be seen from Fig. 3, which shows a typical modulating waveform, the signal at the sampling frequency occurs between alternate pairs of adjacent sampled signals, i.e., only after a left and before a right sample or vice versa, and thus provides the required distinction between left and right signals. Since the sum of the two stereo signals directly modulates both the main carrier and also the sub-carrier at twice the sampling-frequency, this sub-carrier carries redundant stereo information. It is, however, retained both in order to avoid having to consume an appreciable fraction of the transmitter power in radiating a high-level signal at the sampling frequency and also in order to simplify the circuitry required in the receiver to synchronize the recovery of the stereo signals with the sampling process at the transmitter.

The normal transmitter deviation is not exceeded in this system, and adjacent-channel interference is very low. It is compatible in that a listener with

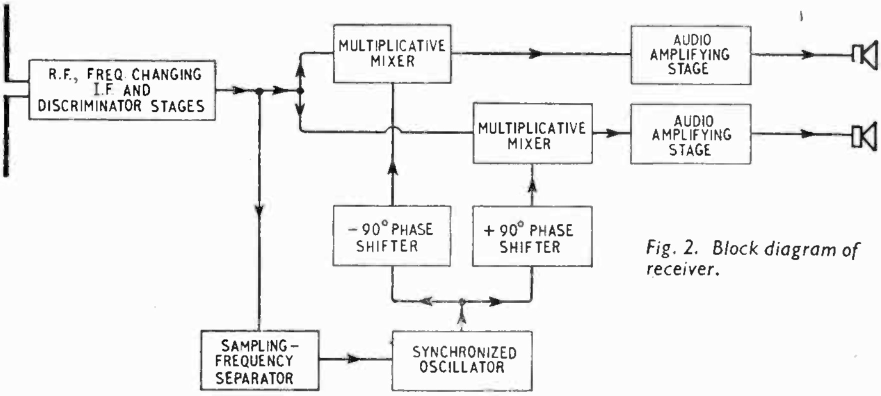


Fig. 2. Block diagram of receiver.

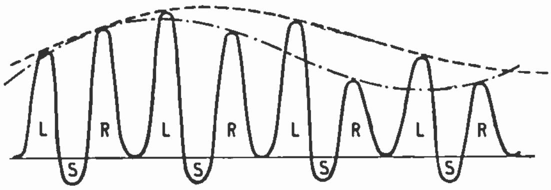


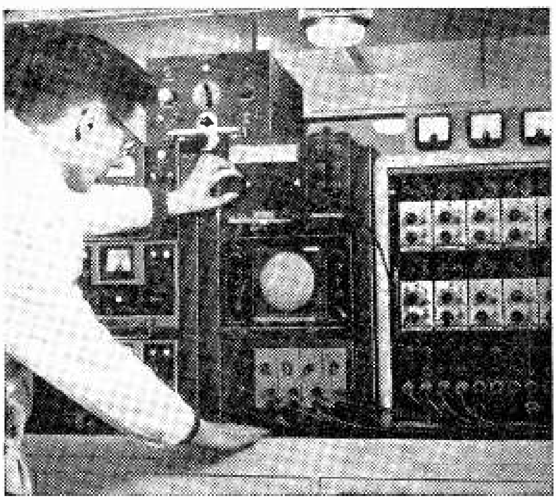
Fig. 3. Example of a typical modulating signal waveform: the left sampled-stereo, right sampled-stereo and sampling-frequency signals being indicated by the letters L, R and S respectively. The left and right audio waveforms are shown dotted. For clarity the audio signals have been shown sampled over only part of each half cycle. The rounding of the samples is produced when modulating frequencies above 80kc/s are filtered out.

an ordinary unmodified signal-channel receiver will obtain the sum of the two stereo signals, and reverse compatible in that a single-channel transmission will be reproduced by a stereo receiver in both outputs at the same level.

In this system the theoretical crosstalk is −45dB. This is low enough to offer possibilities of transmitting two independent signals. In all stereo systems, since the transmitter has to carry an extra signal, there is inevitably a loss of effective power. This produces a deterioration in the signal-to-noise ratio relative to the ratio obtained from a single-channel transmission and single-channel receiver. In this system this deterioration in the signal-to-noise ratio is different according to whether a single-channel or stereo receiver is in use and whether the transmission is single-channel or stereo. In the case of a stereo transmission and single-channel receiver this deterioration in the signal-to-noise ratio is 5dB, and in the case of a stereo transmission and stereo receiver the deterioration is 20dB. In the case of a stereo receiver and single-channel transmission the deterioration is normally 15dB, but in this case the deterioration can be eliminated by switching off the sampling-frequency oscillator in the receiver.

RADIO TELEMETRY CAR TESTING

WITH new mobile equipment developed by Armstrong Whitworth, physical factors such as stress, strain, pressure, vibration, temperature, etc., are continuously monitored at up to 23 different points on a vehicle while in motion, using strain gauges, force transducers, thermocouples and other familiar telemetering devices.



(Above) fixed station equipment; (right) mobile set.

The electrical outputs from these devices are sequentially sampled, amplified where necessary, combined and transmitted as a coded signal by u.h.f. radio to a laboratory or a fixed receiving station, which can be several miles away. Here the data is extracted from the coded signal in the same sequence as it was applied to the car's radio transmitter, monitored by a cathode-ray oscilloscope and permanently recorded for detail study. At the same time meter readings and graphs provide continuous information on the performance of the car and engine undergoing test to design staff technicians and enable advice or early warning of impending trouble to be radioed to the driver in the distant car.

In one of the illustrations is shown part of the complex monitoring and recording equipment installed at the fixed receiving point and it is obvious that no equipment as comprehensive as this could possibly be installed, let alone used effectively, in a car under test conditions.

Apart from the various transducers already mentioned all that has to be carried in the car is a small d.c. amplifier, sequentially sampling switch assembly, coding circuits and a compact u.h.f. radio transmitter. The second illustration shows the compact "black box" containing this equipment on the front passenger's seat.

The technique and equipment illustrated here were evolved in the electronic research department of Sir W. G. Armstrong Whitworth Aircraft Ltd., Coventry.

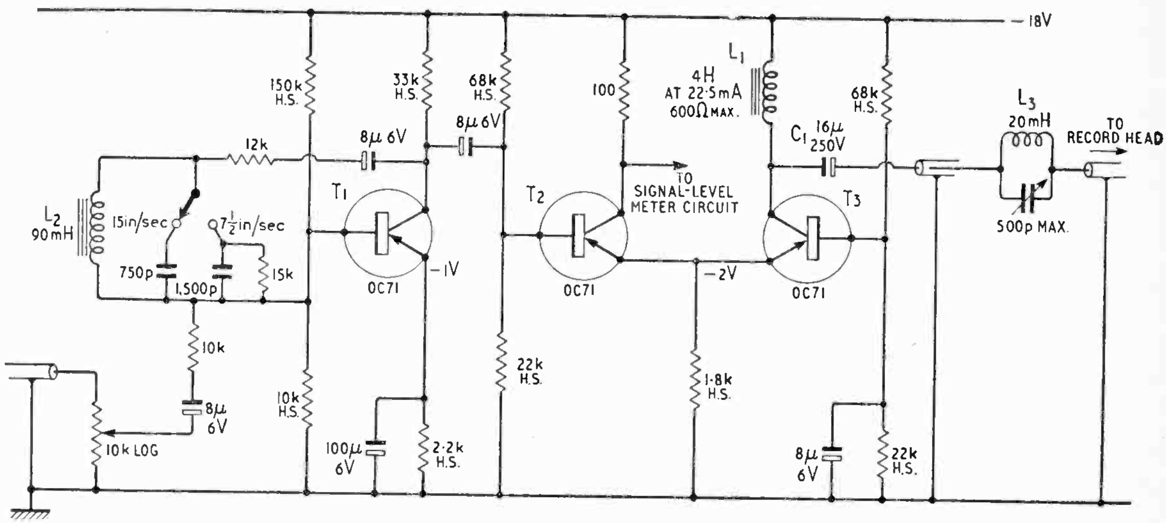


Fig. 1. Recording Amplifier. All resistors should be ±5%. The two 68kΩ and two 22kΩ resistors in the long-tailed pair circuit should be matched to within 5%. The 750pF and 1500pF capacitors should be ±5% and mica.

Transistor Tape Recorder Amplifier

PLAYBACK, RECORD AND BIAS CIRCUITS

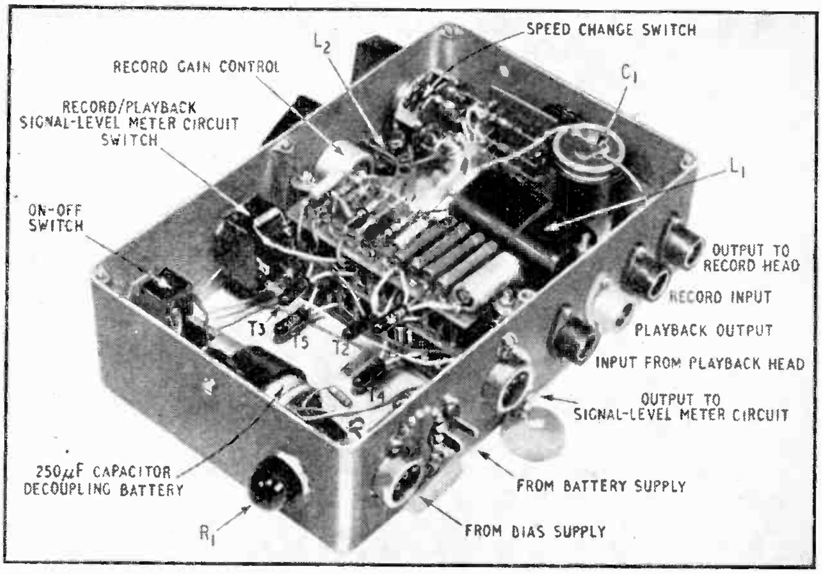
By PETER W. BLICK

MOST of the published transistor amplifier circuits for use with tape recorders have only been for bias oscillators and replay amplifiers. The recording section has been given very scant regard. This is probably due to the supposed difficulty in obtaining the constant-current source for the recording head. If valve practice is followed, this is no doubt true. A solution to this problem is given in this article. It departs from the usual valve practice in that the high-value resistor in series with the recording head is omitted. A detailed description is given in the section dealing with this part of the amplifier.

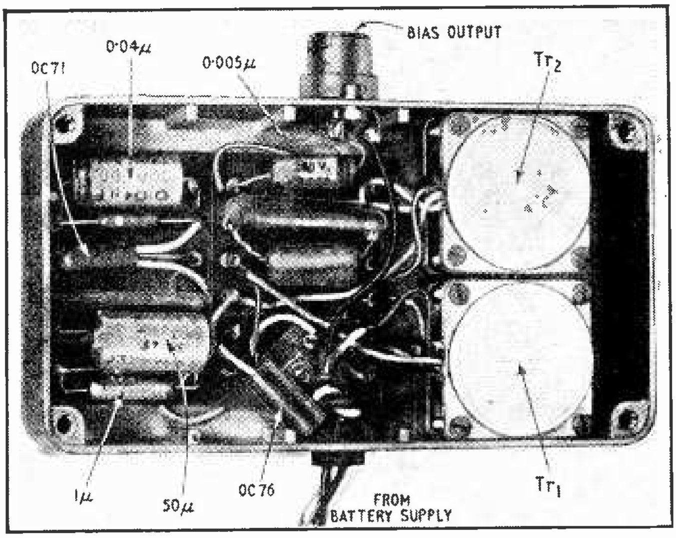
With a suitable tape deck and tape, high-quality results may be obtained, results which are in fact better than with valves. The tape deck used is a " Wearite " 2B/H, which is a three-head deck with tape speeds of 7½in/sec and 15in/sec. The record and replay chains are entirely separate. The tape used was the new B.A.S.F. LGS26 double-playing tape. The overall response obtained at 7½in/sec was flat within plus or minus 1.5 dB from 40 c/s to 14 kc/s and at 15in/sec flat within plus or minus 1.5 dB from 30 c/s to 18 kc/s. This good response is due partly to the fact that the tape is polished on the oxide side, i.e. a more intimate contact is obtained with the head gap. In fact the pressure pad on the playback head is not needed.

The whole amplifier together with a level meter consumes only 17 mA at 18 V on record and 7 mA on playback. The replay pre-amplifier gives an equalized output of the order of 50 mV, sufficient to drive a Mullard 5-10 amplifier to its full output.

The amplifier is stable over the temperature



Recording and playback amplifiers. (The bias rejection filter is separately mounted under the tape deck.)



Bias oscillator and amplifier.

range that is liable to be encountered in this country.

Recording Amplifier.—The purpose of this amplifier is to provide the recording head with a constant-current source and to compensate for losses in the head and tape at the higher audio frequencies.

As can be seen from Fig. 1, the last stage is a transistor T3 in the common-base configuration. This can have a high output impedance, in this instance several times higher than 20 kΩ, the head impedance at the highest audio frequency. The constant-current source is effective up to about 30 kc/s.

The collector load consists of the head and a 4H inductor L_1 in parallel. As the head is also inductive, a constant fraction of the constant current will flow via the head. At a low audio frequency the output capacitor C_1 together with the head and the inductor form a series-tuned circuit. The value of the capacitor must be large enough to place the peak outside the audible range, i.e. lower than 30 c/s. For example, with a 16 μF capacitor the rise at 30 c/s is about 1 dB. (This output circuit is the subject of patent application number 7512/59.) This capacitor must have a leakage current of less than about 0.3 μA to avoid polarization of the recording head. The last two transistors T2 and T3 form a direct-coupled long-tailed pair. An output from the first collector of the pair is used to drive the metering circuit. The high frequency pre-emphasis is obtained by frequency-selective negative feedback over the first transistor T1. The values of the feedback components vary with different speeds, heads and tapes. The sensitivity at 1 kc/s is such that 10 mV input is needed for 150 μA r.m.s. current in the head.

Playback Pre-amplifier.—The circuit diagram is shown in Fig. 2. The design is fairly straightforward but has one special point of interest. As is well known, the input impedance of a transistor in the common-emitter configuration is quite low, namely of the order of a few kilohms. This could cause quite a considerable reduction in the input current at high frequencies, because of the increasing head impedance with frequency. The first OC75 transistor T4 has some current negative feedback in the emitter. This increases the input impedance to about 18kΩ, giving a loss of about 3 dB at 18 kc/s, which can be easily compensated for.

Bass lift is obtained by applying negative feedback over the second OC75 transistor T5. The time constant at 7½in/sec is 100 μs and at 15in/sec is 35 μs. If any treble lift is needed on playback, the feedback may be reduced at the higher frequencies by by-passing it to earth. This can be accomplished by splitting the 5.1 kΩ and 1.8 kΩ feedback resistors and connecting capacitors from the junctions to earth. However, it has been found that with the B.A.S.F. tape and Wearite deck used there is no need for this treble lift.

Bias Oscillator.—This operates at 60 kc/s and, as can be seen from Fig. 3, it takes the form of a master oscillator followed by a power amplifier. This was chosen because it was easier to obtain the necessary frequency stability and controllable output than with a single transistor. The maximum output is about 150 mW, which is ample for most tapes. An erase oscillator is not included, but an output transistor may be driven from the 800-Ω bias output stage to give an output of about 1W.

In the bias oscillator it is of course necessary to tune the two transformers to the same frequency of 60 kc/s. A bias filter in the form of a parallel-tuned circuit is connected in series with the recording head lead.

Level Meter.—The circuit of Fig. 4 will indicate the peaks if a suitably-damped meter is obtained. The level meter may be switched to either the record amplifier or, for bias adjustment purposes, to the playback pre-amplifier. The 2.2kΩ and 33kΩ resistors at the input of the meter circuit are to reduce the signal level to give a suitable reading on the meter. They may need altering to suit different heads and tapes. The meter may also be used whilst the bias filter is being tuned.

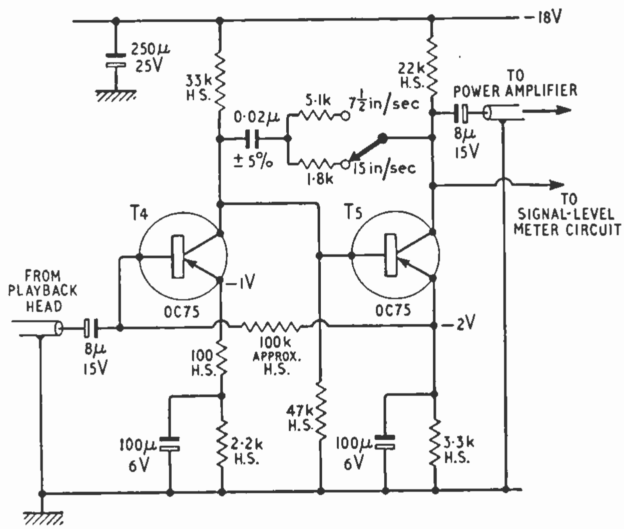


Fig. 2. Playback pre-amplifier. All resistors should be ±5%.

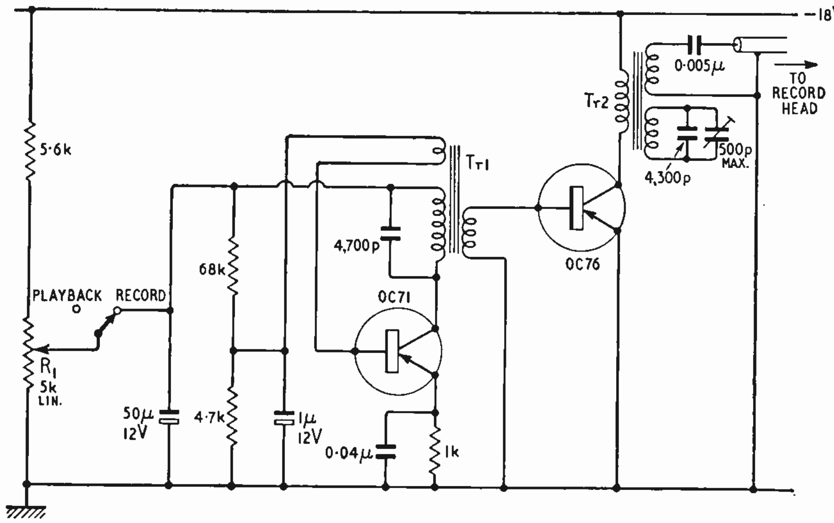


Fig. 3. Bias oscillator and amplifier. All resistors should be ±10%. The 4700 and 4300pF capacitors tuning the transformers should be ±5% and mica.

Setting-Up and Testing Procedure.—With the bias oscillator off and the heads disconnected, the d.c. conditions should be checked with an Avo Model 8 or similar meter if possible. The two OC71 transistors in the long-tailed pair T2 and T3 should be matched for base current at 1 mA collector current. The only resistor that may need adjustment is the 100 kΩ bias resistor for the first OC75 transistor T4 in the playback pre-amplifier. The voltages should be as indicated on the circuit diagrams.

Before connecting the recording head, the leakage current of the 16μF output capacitor C_1 should be measured. If it is greater than 0.3 μA at 18 V, then it should be re-formed for several hours at 250 V. The leakage current in the sample used in this amplifier was, after re-forming, 100 μA at 250 V. At 18 V it was too low to be measured on the 50 μA range of an Avo 8. It has shown no tendency to increase even after one year's use. On the Wearite deck it is possible to have the recording head earthed for all positions except record, so that if the function switch is not on record when the amplifier is switched on, the head will not become magnetized.

The heads are now connected to the amplifier and the a.c. tests may be performed. If a test tape is available, such as the E.M.I. Type TBT1, the playback pre-amplifier may be checked for conformity with the C.C.I.R. playback curve at 7½in/sec. Similarly, if a 15in/sec test tape is available, the playback characteristic can be checked at 15in/sec. The level meter cannot be used for these tests as it has a poor frequency response. The meter used for checking the frequency response should be linear over the whole of the audio-frequency band.

The bias amplifier transformer Tr2 should now be tuned to the same frequency as the oscillator transformer Tr1 by adjusting the 500pF trimmer until the output voltage shown by the level meter on record is a maximum. It may be necessary to detune the bias filter when making this adjustment.

The recording amplifier can now be checked. With the deck on record, but with the tape stationary and the bias set at maximum, the bias filter is adjusted for a minimum indication on the level meter.

The bias can now be set. With a 1 kc/s signal applied to the record amplifier the bias should be adjusted by varying the 5kΩ potentiometer R_1 to give maximum output on the meter on playback. The tape speed does not affect the result materially. The level for this and the following tests must be such that the output from the playback pre-amplifier does not exceed 10 mV.

The top peaked frequency for the head and tape used is 14 kc/s at 7½in/sec and 18 kc/s at 15in/sec. The amount of peaking needed can be determined by checking the overall response.

The noise level of this amplifier is very low and, to obtain full advantage of this, it is recommended that a bulk tape eraser be used. When an 18 V battery is used for the amplifier, there is no audible hum.

Winding Details for Inductors and Transformers.—All are wound with enamelled copper wire on Mullard Ferroxcube cores.

Recording amplifier

Treble-boost inductor L_2, 90 mH: 600 turns 38 s.w.g. on LA 42

Bias filter L_3, 20 mH: 100 turns 30 s.w.g. on 2 FX1073

Bias oscillator

Oscillator transformer Tr1:
- Tuned winding: 75 turns 32 s.w.g. } Side by side on LA2
- Output winding: 20 turns 30 s.w.g. }
- Feedback winding: 1 turn 24 s.w.g. }

Output transformer Tr2:
- Tuned winding: 75 turns 32 s.w.g. } Side by side on LA2
- Collector winding: 30 turns 26 s.w.g. }
- Output winding: 27 turns 30 s.w.g. }

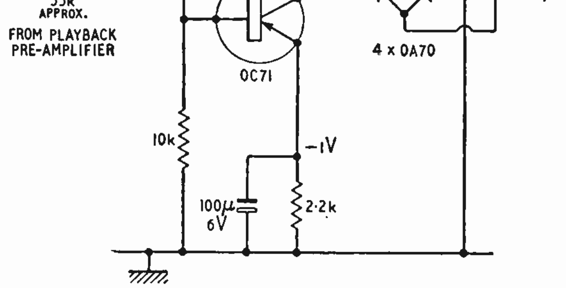


Fig. 4. Signal-level meter circuit. All resistors should be ±10%.

INTERNATIONAL COMPONENTS EXHIBITION

SOME IMPRESSIONS FROM THE 1960 SHOW IN PARIS

REGULAR visitors to the Salon International de la Pièce Détachée Electronique, now in its third year, have probably got used to the idea that it is as much an exhibition of test gear and audio equipment as of ordinary radio components. Such multiplicity of purpose is not, however, as confusing as it might seem, for the different sections are segregated in a very orderly fashion, and this, combined with the general spaciousness and airiness of the layout, makes the exhibition a pleasure to visit. This year the Salon was the biggest ever. There were over 400 exhibitors, including 60 or more non-French firms (it was also the 23rd French components show). An interesting innovation was the provision of a separate section for the international technical press. *Wireless World* was represented here, along with its European and American contemporaries.

Semiconductor devices are tending to overshadow valves now that transistors are showing themselves capable of operating at unexpectedly high frequencies, even up to the u.h.f. region. The French firm C.S.F., for example, were demonstrating a small portable transmitter which used an experimental germanium diffused-base "mesa" transistor to produce signals at 500Mc/s. This company also had silicon diffusion-type transistors with cut-off frequencies of 50-100Mc/s, and demonstrated their "Alcatron" field-effect device (July/August 1959 issue, p. 350) as the oscillator in a transmitter working at 110Mc/s.

The possibilities of using transistors for domestic television receivers are, of course, well known. It was, nevertheless, interesting to see, on the Thomson-Houston stand, a demonstration of a working 819-line television set which used transistors throughout (26 in all) except for one line deflection valve. It covered the band 174-188Mc/s and had a signal-frequency circuit consisting of an oscillator and mixer using tetrode transistors with 70Mc/s cut-off frequencies.

In the sphere of semiconductor power devices, several exhibitors had silicon diodes for rectification of up to 500mA for television-receiver h.t. supplies. C.S.F. showed a power transistor capable of carrying 2 amps which also had the remarkably high cut-off frequency of 10Mc/s.

As for the glassware on show, a great deal of interest was excited by a television cathode-ray tube announcing itself as having a 114° deflection angle—the Westinghouse 23FP4. It has a $23\frac{1}{2}$-inch screen, a depth of $13\frac{3}{4}$ inches and operates with an e.h.t. of 14kV. There were, of course, a good many examples of the 110° tube on view. One interesting development, exemplified by the Sylvania 23DP4 and others, was the use of an integral tinted glass protective panel sealed round the front face of the normal tube envelope. This eliminates the need for a separate protection panel and dust seal in television receivers. There are four glass mounting-lugs at the corners of this integral protection panel, intended for clamping to the receiver chassis.

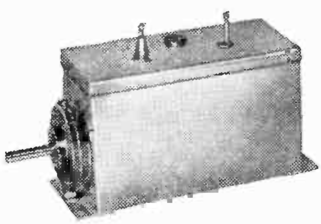
Amongst cold-cathode tubes, the Swiss firm Elesta had an interesting decade counter tube of miniature-valve size, the EZ10B, which was notable for its high maximum counting speed of 1Mc/s. It was a unidirectional type and contained hydrogen gas. On the same stand was a cold-cathode trigger tube, the ER21A, which could be directly powered by the 220-V a.c. mains supply and directly triggered by photocells, etc., thereby making possible very simple industrial control circuits. Other new Elesta trigger tubes, using molybdenum electrodes, were claimed to have expectations of life in excess of 25,000 hours.

The term "microminiature" now seems to be generally accepted and understood and there were plenty of components on show which fully justified this description. L.C.C. had a range of flat ceramic decoupling capacitors for 30V operation, of which the smallest measured only 1.5mm square and had a capacitance of 1,000pF. Slightly larger ceramic types had capacitances up to 2μF and measured only 25mm long and 12mm maximum diameter. One of the smallest variable capacitors (air dielectric) in the Salon measured 6mm cube. Displayed by Arena, it had a capacitance of 1.5pF and could be operated at up to 220V. Variable capacitors can be reduced in size for a given performance by replacing the air dielectric with liquid filling. National showed examples of this technique with capacitors from 50 to 2,000pF and working voltages from 4kV to 15kV, which were claimed to give a hundredfold advantage in size reduction. Control of the rotor through the sealed metal container is achieved by a magnetic drive system.

An unusual form of construction was the feature of a series of fixed tubular polystyrene capacitors shown by Capa. They are built round a rigid axial rod or wire which forms one connection and is used for mounting, while the other connection is a thin wire emerging at the same end of the cylinder. This system is intended for strength in conditions of vibration, and is designed for mounting on printed circuits.

Delay lines made in the form of small rods up to 100m long and 8mm diameter were displayed by Steafix. The ceramic rod has a metallized surface over which an insulated inductive winding is laid to give the distributed inductance and capacitance. They give a delay of 1μsec and have a pass band of 4Mc/s, with impedances of 1kΩ or 2kΩ.

The Société Orega specialize in making sub-assemblies, coil-packs, tuners, etc., for all types of domestic receivers. This year they offered a whole range of printed-circuit modules, completely tested and aligned, for transistor receivers—r.f., frequency changer, i.f. and audio units. Some of these incorporated a very neat miniature two-button wave-change switch, designed for pocket receivers. Another miniature item was an i.f. transformer of only 10mm diameter and a Q factor of 150. Orega, with other firms, also showed the flat-bar type of ferrite aerial, which has a space-saving advantage over conventional cylindrical rods in small receivers.



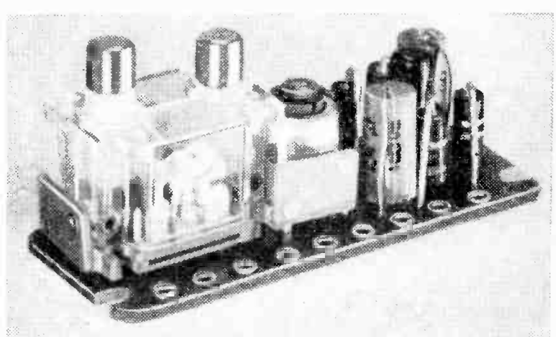
Left: Liquid-dielectric variable capacitor by National.

Below: Turntable by Dual with indicator for the weight of the arm (behind the right-hand control button).

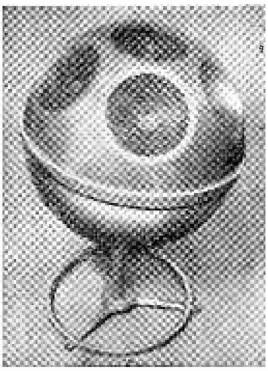
A particularly sensitive subminiature relay shown by Le Prototype Mécanique operates with a power of only 5mW and has a response time of less than 2msec. Its sealed container measures 25mm long by 10mm diameter. The sensitivity depends on the precise balancing of a cranked armature, which is actuated by magnetic pulls from opposite directions (from the centre pole of the solenoid and from the magnetic return path). The magnetic circuit is also carefully designed so that magnetic forces on the armature pivot cancel out; consequently friction during movement of the armature is reduced to a minimum. With an energization of 8mW the relay will withstand accelerations up to 30g. On the stand of C. P. Clare, relays with mercury-wetted contacts were demonstrated. The technique is notable for giving constancy of operating time, lack of contact bounce, and low and consistent contact resistance (25-50 milliohms range). Mercury is fed continuously to the contacts by capillary action from a reservoir of mercury under gas pressure.

Piezoelectric filters are, of course, well known for their high Q and sharp cut-off properties. Intermetall were showing filters of this type based on ceramic discs of zirconium titanate. Operating at frequencies in the region of 450kc/s, they have Q factors of about 400 and are notable for their small size and high stability with time and temperature. Working frequencies up to 1Mc/s are possible.

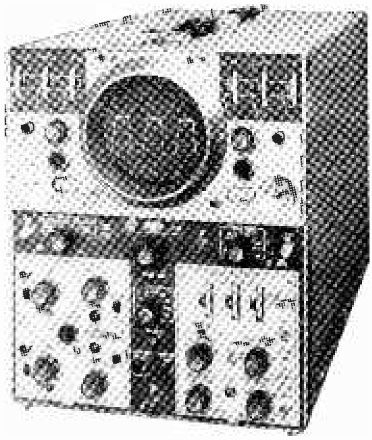
Looking at the wide range of gramophone turntables and pickups on view it was very noticeable that the Continental manufacturers had a definite category of equipment labelled "semi-professional". It lies, in fact, half-way between the professional transcription units and the ordinary domestic record changers in both quality and price. As an example the transcription unit shown by Thorens had a speed fluctuation of $\pm 0.07\%$, wow figure of 0.1% and turntable rumble of -40dB (N.A.R.T.B.), while their semi-professional model had corresponding figures of $\pm 0.12\%$, 0.2% and -38dB. Incidentally, Dual presented a new turntable with the unusual



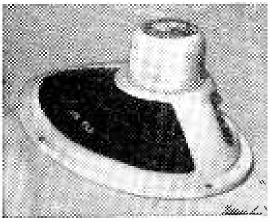
Transistor frequency-changer module (Orega) showing "Tom-Thumb" wavechange switch on the left and 10-mm i.f. transformer in the centre.



Left: The Gogny "sphère pulsante" loudspeaker.



Above: Du Mont oscilloscope with digital read-out.



Left: Audax loudspeaker with eccentric diaphragm.

feature of a pointer indicator which registers the weight of the pickup arm.

Stereophonic equipment was, of course, very much in the forefront. A new introduction from Philips is a four-track stereo tape recorder—that is, it provides two double tracks for stereo recording, or allows two single-channel programmes to be recorded simultaneously through the two 4-watt amplifier chains. There are three tape speeds and the frequency response on the highest speed (19cm/sec) extends to 20kc/s. A stereo microphone is provided, and two loudspeakers, one in the main unit and one in the detachable lid. Kodak, the film people, are now in the magnetic tape business and the examples on their stand included tapes as long as 4,000 ft.

Flat loudspeakers, with magnets and speech-coils inside their cones, seem very popular in France, and this year the Audax people had a new 7-inch model which achieved a depth of less than an inch (24mm). The magnet has a field of 8,000 gauss. This firm also displayed an eccentric loudspeaker—the driving unit being offset from the centre of the elliptical cone with the object of obtaining an oblique radiation of sound. The main application is in television sets. Another unusual configuration was the Gogny "sphère pulsante" which gives all-round radiation by grouping six small loudspeakers on the top half of a 10-inch diameter sphere.

Going to the other end of the sound reproducing chain, Brüel & Kjær showed a new condenser microphone, intended for measurements, with a diameter of only ½ inch. With sound waves impinging perpendicularly on the diaphragm the frequency response is flat within 2dB from 20c/s to 40kc/s. The microphone is normally fitted on the top of a tubular housing, which contains a cathode follower. Another new and small microphone, shown by Lem and measuring about 1-inch in diameter, was an omnidirectional electrodynamic type intended for reporting, and was fitted with a useful clip enabling it to be propped on a table or hung on the hand.

Outstanding in interest amongst the test equipment was a new oscilloscope by Du Mont which offers the unusual facility of digital read-out—that is, it enables voltage and time-interval measurements of the waveforms displayed on the screen to be presented directly on digital dials. The system is a kind of "electronic graticule" based on two movable light spots generated on the c.r.t. screen. One of them, the "index dot" is positioned at some suitable reference point on the waveform by a joystick type of control. The other, the "scaling dot" is then moved horizontally and vertically by two sets of controls until it is positioned on the part of the waveform to be measured relative to the reference point. The horizontal-movement controls (top right of picture) are digitally calibrated in microseconds, milliseconds and seconds, while the vertical-movement controls (top left) are calibrated in volts and millivolts. The two measuring spots are actually produced from a Lissajous figure generated by two sets of square waves, which are applied to the X and Y plates by time sharing with the normal X-sweep and Y-signal deflection voltages. A special facility is included for rise-time measurements.

The main idea of the digital read-out system is to save time and reduce the inaccuracies due to parallax, scale interpolation and other types of reading error which can occur with conventional oscilloscopes. The instrument is built on the plug-in unit principle, has a Y-amplifier response of 0-35Mc/s and generally offers all the normal facilities of a high-quality professional oscilloscope.

Another useful aid to reading c.r.t. traces was seen in the latest wobbulator-plus-c.r.o. for television frequencies shown by Ribet-Desjardins. It enables one to see the frequency at every point along the response curve by providing a continuous sequence of frequency markers along the sweep between 0 and 250Mc/s. The marker signals are at 1Mc/s intervals with multiples at 10Mc/s intervals. They are generated by a 10Mc/s crystal oscillator to which a 1Mc/s oscillator is coupled and locked. The 10Mc/s oscillator is deeply modulated with short, almost rectangular, pulses by the 1Mc/s signal, and the result is to generate a whole spectrum of signals, at ± 1, ± 2, ± 3Mc/s, etc., relative to the 10Mc/s oscillation and relative to all its harmonics. These marker signals are applied to the wobbulator circuit so that they appear on the response curve trace as a sequence of short vertical deflections—bigger ones for the 10Mc/s intervals than for the 1Mc/s intervals. The wobbulator has a saturated-ferrite frequency modulation system and will operate in the three bands, 0-80Mc/s, 80-160 Mc/s and 160-320Mc/s.

"Mobile-receiver Alignment Equipment," by J. F. Golding (February, 1960, issue, p. 75). The author has asked us to point out that, although some 100-kc/s channel spacing equipments are still in use, the channel spacing of 100kc/s ascribed in Table I to the police, fire and ambulance services, has been reduced officially to 50kc/s.

Elements of Electronic Circuits

12.—PRINCIPLES OF TIMEBASES

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

IN the next few articles we shall be dealing with some of the means of generating a triangular-shaped waveform, otherwise known as a sawtooth or linear waveform. Two of the principal uses are:

(a) The measurement of time intervals. The linear sweep is the most widely used timebase for display purposes.

(b) The derivation of other basic voltage waveforms. A rectangular wave is obtained by differentiation and a parabolic wave is the result of integration.

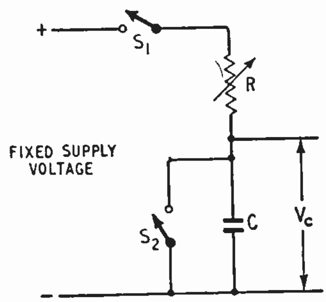


Fig. 1

Basic circuits for generating linear waveforms usually make use of the charging or discharging of a capacitor, ideally at a constant rate, e.g., the change in voltage across a capacitor from its value at $t=0$ is:

$$V_c = \frac{1}{C}\int_{t=0}^{t=t} i\,dt$$

where C is the capacitance in farads. If i is maintained constant $=I_0$, then $V_c=(I_0/C)t$, which represents a linear relationship between the voltage appearing across the capacitor and time.

The apparent complexity of some circuits is due to the precautions taken to ensure that a constant charging current is available to produce the required linearity. The capacitor may be charged or discharged in one of the following ways:

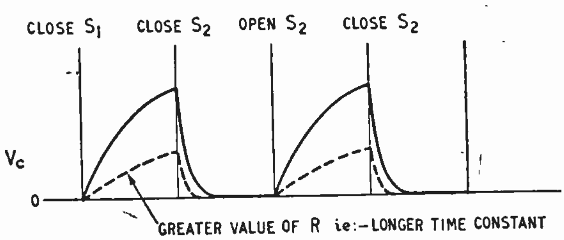


Fig. 2

(i) From a constant-voltage source through a series resistor. One arrangement uses a CR circuit in combination with a simple thyratron switch.

(ii) From a constant-voltage source through a pentode operated in the so-called "constant-current" region of its anode voltage/current characteristic.

(iii) From circuits employing both positive and negative feedback. The "bootstrap" cathode-follower type of circuit falls into this class.

(iv) From circuits employing negative feedback only. The family of circuits which depend for their action on the Miller effect come into this category.

Let us consider the operation of the circuit shown in Fig. 1. Assuming a constant supply voltage, with S_1 closed and S_2 open the capacitor C charges exponentially through R. Closing S_2 causes C to be short-circuited and to discharge rapidly. Opening S_2 enables C to charge once more, and so on, thus producing the waveform in Fig. 2.

Although the output waveform taken across C is an exponential sweep, if the first portion of the rise is made use of then an approximately linear sweep can be obtained. If the total time taken to generate the sweep is small compared with the time constant CR then the capacitor charging current will be nearly constant during the charging period. The best linearity with this type of simple circuit can be achieved by restricting the sweep amplitude to a small fraction of the supply voltage. In practice S_2 in Fig. 1 can be a thyratron operated by a switching pulse.

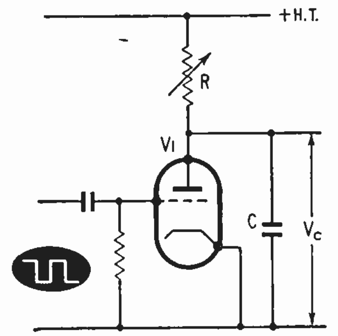


Fig. 3

Fig. 3 shows an alternative simple arrangement using a hard valve in preference to the slower operating thyratron. Initially V_a is low when the valve is

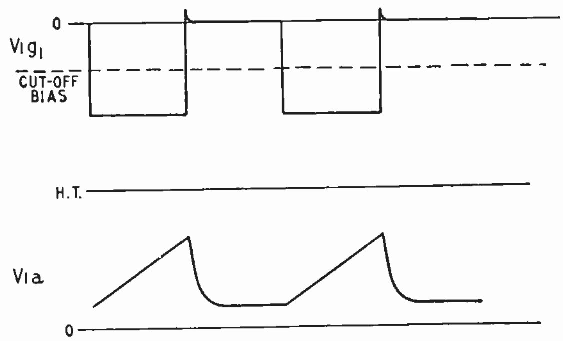


Fig. 4

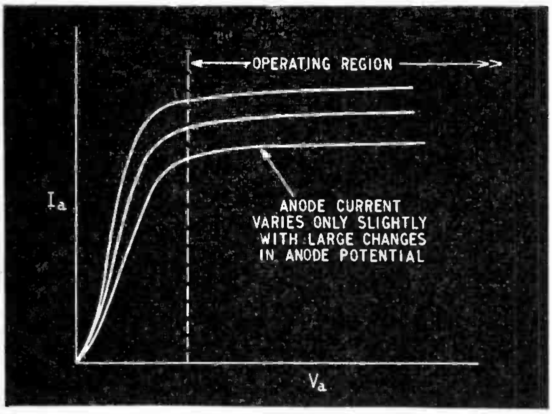


Fig. 5

conducting and C is charged to a low value. The square wave input to the grid of V_1 is clamped to zero (grid clamping) and the negative excursion cuts off the anode current. This would normally have caused V_a to rise to h.t. immediately, but due to the action of C charging through R, the rise towards h.t. is gradual. Subject to the limitations mentioned above, this rise can be made approximately linear. Fig. 4 shows the resultant anode voltage waveform.

We have seen that the voltage developed across the capacitor is proportional at any instant to the charge on the capacitor. If the charge increases linearly with time, i.e., the current flowing into the capacitor is kept constant, then the voltage across the capacitor will also increase linearly with time. In other words, if the timebase voltage is to be linear then the capacitor must be fed from a constant-current source.

A suitable constant-current device, as already mentioned, is a pentode operated above the knee of its I_aV_a characteristic, which can be substituted for the charging resistor R (see Fig. 5). It will be seen that at this operating point the anode current varies only slightly with large changes in anode potential.

Fig. 6 shows a typical constant-current pentode, the high anode impedance of which replaces R in Fig. 3. The cathode bypass capacitor has been

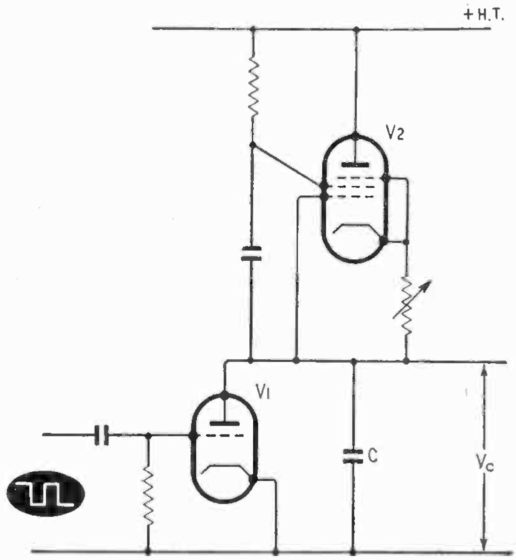
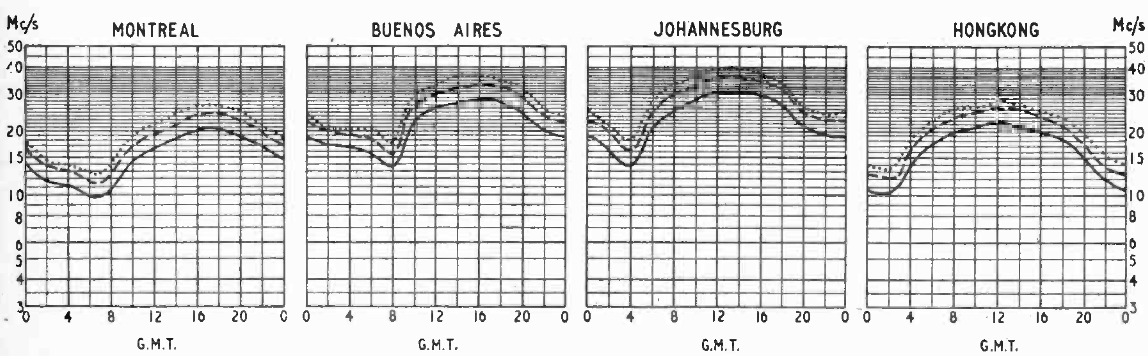


Fig. 6

omitted, thereby introducing current negative feedback, which serves to increase the effective I_a/V_a slope still further. The greater the slope resistance the closer is the approach to linearity of the voltage across the capacitor C.

SHORT-WAVE CONDITIONS

Prediction for April



•••••••••• 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

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 April.

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

Hardwood Instrument Cases

SIMPLE CONSTRUCTION USING MODERN GLUES

By *GEOFFREY I. LILLEY*

THE natural elegance of hardwood can impart to a well-made cabinet an impression of quality unparalleled by any other material. The arts of complex joinery and expert finishing are by no means easy to master; but the age of "plastics" has made possible the production of well-finished cabinet work with the minimum of special skill.

It is no longer essential to use dovetailed joints for carcass and box-frame construction. Where, previously, end-grain joints had to be avoided owing to their lack of strength, modern resin glues are capable of bonding firmly wood across any plane and, in fact, they have shifted the limiting factor in the strength of a wooden article from the glued joints to the wood itself. Modern synthetic finishes have made easy the production of a fine, lustrous surface.

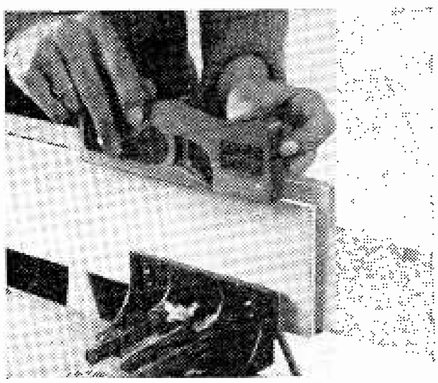


Fig. 1. Rebate plane in use.

One disadvantage of timber is its movement with changes in humidity. Contrary to the widely held belief, however well-seasoned a piece of timber may be, it will always exhibit this property of swelling and contracting: this, however, is no problem if the design is right. The golden rule is to avoid joints in which the grain of the two parts is mutually perpendicular across the width. This means in practice that, for instance, if a box lid is to be made, the wooden frame cannot be covered with a board of solid timber since the latter would always form a cross-grained joint with either the sides or the back and front. Plywood may be used for such an application, and the simple construction method outlined below incorporates the use of cloth-covered plywood panels which can, if necessary, be made detachable.

The timber used will depend largely upon personal preference, but it is advisable to use one of the more stable hardwoods such as agba, abura, or African mahogany. These are most often available in 1-in thickness, which can be deep-cut at the yard to give one piece about $\frac{1}{2}$-in thick, the other being about $\frac{3}{8}$in; these two thicknesses are convenient sizes for small-cabinet work. Some timber yards have sawn drawer-side material which is usually $\frac{9}{16}$-in thick. This is ideal for the present application and is sometimes available in fairly good widths.

The one tool required over and above the ordinary basic range of woodworking tools will be some form of rebate plane, a small model being preferable on account of its lightness and cheapness: Fig. 1 shows a plane of this type in use. To prevent any possibility of splitting when planing-off the waste wood from corner-joint rebates it is a good plan to bevel off the ends (using a chisel) down to the marked-out line. Alternatively with wide pieces of wood, it is often possible to plane towards the middle from both sides.

Method of Construction

The basic system of construction is to make the rebated joints at the corners and the front and back rebates for the panels all to the same depth (Fig. 2). Thus the housings for the front and back panels are simply provided. The width of the individual rebates is determined by what they are to accommodate. If the timber used is $\frac{1}{2}$-in thick, all rebates may be, say, $\frac{1}{4}$-in deep, and the top and bottom housings in the sides will be $\frac{1}{2}$-in wide. The front and back rebates will be the same width as the thickness of the panel material, and this will generally be either $\frac{1}{4}$in or $\frac{1}{8}$in.

Fig. 3 shows the parts of a simple square-shaped cabinet rebated for front and back panels. Of course,

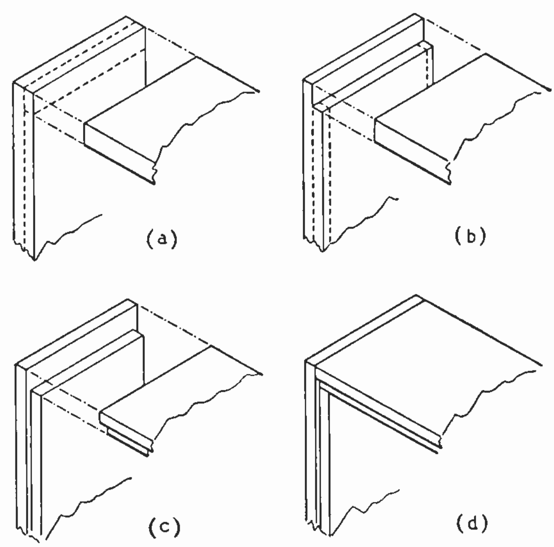


Fig. 2. Steps in construction of corner joint: (a) marking out for rebate, (b) end rebate cut to depth of top members (c) side rebates cut to receive panels and (d) assembled joint.

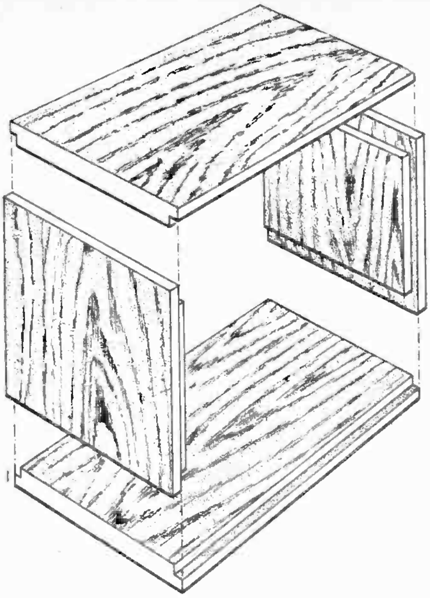


Fig. 3. Sides, top and bottom of case having inserted front and back panels.

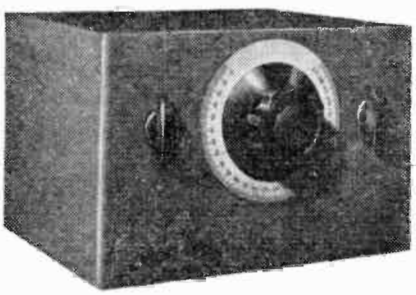


Fig. 4. Electronic timer unit using panels at top and bottom. Controls are mounted on wooden "side".

it would be a simple matter to change the proportions somewhat so that the plywood panels were at the top and bottom positions, then the "front" would be one of the hardwood sides. This is illustrated by the timer-unit cabinet shown in Fig. 4.

It will be noticed in Fig. 3 that the sides ready for assembly have a rebate cut all round. It is a good plan, therefore, to gauge in this rebate round all four edges before starting to cut. The end rebates are then marked in and cut first, as shown in Fig. 2(a), the other two rebates being cut afterwards.

Design Adaptations

This basic square-shaped cabinet may be adapted to a more complex design, such as that of the meter case shown in Fig. 5. Here the sides are shaped first and the other parts cut to fit. The top member, for instance, will be cut to the required width and rebated for front and back panels in the usual way. Although the front panel slopes, the top and bottom rebates need not necessarily do so; they may be cut square, the front edges being sloped off with the plane after assembly. It will be found in practice, however, that working with the rebate plane held at an angle will be hardly any more difficult than when holding it square, and the angle required may be judged very easily by holding one of the side members up against the work as a guide. The small, bottom, front wooden member seems to break the rules regarding cross-grained joints; this is permissible, however, in such a narrow piece as this.

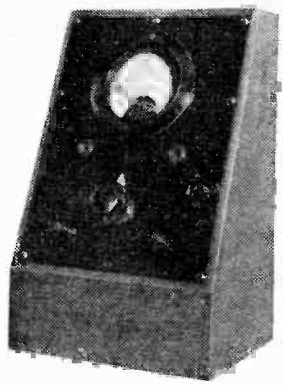


Fig. 5. Meter case with sloping front panel.

Assembly presents few problems, the frame being held with a G-cramp placed across the side members at top and bottom. Just two G-cramps should be sufficient even for the more complicated assemblies, for these will invariably be based upon a square frame which may be cramped up first, the other members being glued and pressed in place. Cramping every part is not essential when using resin glue[1] as it tends to fill any small gaps: provided each part makes a good press fit and will hold in place good joints are assured.

When the glue has set the panels may be fitted. The front panel may be of $\frac{1}{8}$-in metal or paxolin, in which case it would probably be easier to trim the joints of the wood members before assembly until the panel is a good fit in the recess. However, if the panels are made of plywood, they may be readily cut to size after the cabinet is made.

A very smart finish may be imparted to plywood panels by covering them with a grained leather-cloth, this being cemented down with a non-tacky type of rubber-resin adhesive.[2] The panel is then fitted to the cabinet with raised-head chrome screws, the holes and countersinks for these being made before the panel is covered with the leather-cloth.

Some workers may wish to finish off the wood surfaces of the cabinet with french polish, or perhaps one of the new plastics finishes that are available today. A good durable finish, which is easily applied and very attractive, consist of a few coats of a synthetic varnish[3], rubbed down with an abrasive paste. The varnish is wiped on with a cloth, rather than brushed, and very lightly rubbed down with fine sandpaper between coats. The final coat is rubbed down with fine pumice powder used wet, or even better, the ready-mixed rubbing paste sold for finishing brushing cellulose. This is used upon a small piece of baize or thick cloth wrapped over a small wood block. Care must be taken, of course, to keep the rubbing strokes in line with the grain.

After this process it will be found that a quick rub over with a wax polish will give the surface a final burnish and bring up a really good quality smooth gloss. Those who prefer the more subdued egg-shell finish, however, may leave this last stage out, for the surface left by the abrasive rubbing is very fine and quite suitable as a semi-matt finish.

[1] Two suitable resin glues are "Caseamite" and "Aerolite 306."
[2] Boscotex 5/S adhesive is obtainable direct from the makers, the B.B. Chemical Co. Ltd., Ulverscroft Road, Leicester.
[3] Valspar "Clear" is one such suitable varnish.

LETTERS TO THE EDITOR

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

Negative Impedance

IN HIS article in the February issue, "Cathode Ray" says that his subject is controversial—how right he seems when members of the I.E.E. argue and "Cathode Ray" and myself have differences of opinion.

Let us start with the definition of resistance, $R = E/I$. Then when a voltage is applied the current will flow in one of two directions giving I, R and power EI, or $-I$, $-R$ and $-EI$. The first case obviously applies to a passive positive resistance which absorbs power, the second to negative resistance which gives out power, and in which the current is the *same as in the first case except that it flows in the reverse direction*. By changing R to Z the above may apply word for word equally to an impedance, except that since the power flows alternatively into and out of an impedance the average power must be taken. The average power for a pure reactance is zero, and this is the boundary case between a practical positive impedance and a negative one.

If $Z = R + jX$, then $-Z = -R - jX$. Here then is Dr. Myers' negative reactance, and I expect that since writing the last section of his article "Cathode Ray" has realized that this is short for the reactance of a negative inductance or capacitance, e.g. $-jX = j\omega(-L)$ or $1/j\omega(-C)$.

These reactances act in the normal way except that the current flows in the reverse direction. In a circuit with steady cisoidal voltages and currents, a reversed current is equivalent to one 180° out of phase. In this case the current of a negative inductance is in phase with that of a positive capacitance, but this, it may be considered, is a confusing coincidence.

It may be shown by simple formulæ and diagrams that when a d.c. generator is connected to a series RL or RC circuit with normal components, the current changes rapidly at first and then becomes steady.

If both components are made negative, in each case, the current varies as before but flows in the opposite direction. If however one component only is made negative, the time constant becomes negative, and the current increases indefinitely. In these cases of transients the inductance never behaves as capacitance with any combination of positive or negative components. The above does not take into account any practical difficulties in simulating the negative components.

If the real part only of an impedance is negative, the impedance is equivalent to a negative resistance plus a normal impedance of which the resistance is zero.

In the section "Principles of Dependency", "Cathode Ray" limits the definition to cisoidal voltages and currents in order to find the phase angle for the equivalent impedance, but this is not necessary for ϕ is defined by

$$\cos\phi = \text{True Power}/\text{Apparent Power} = \text{True Power}/EI.$$

$\cos\phi$ is positive for leading or lagging ϕ, i.e. with the current in the first or fourth quadrant. With negative true power $\cos\phi$ is negative, which means that the current is in the second or third quadrant, i.e. it is reversed as we saw before.

In the text concerning Fig. 5 "Cathode Ray" applies "Ohm's Law" not to a resistor but to a generator. This gives a very peculiar resistor, for, apart from being negative, the resistance varies with current, and the back e.m.f. (or should it be forward e.m.f. for a negative resistance?) remains constant even when the current is switched off or reversed. It says in *W.W.* for August 1953, referring to the application of "Ohm's Law" to a circuit containing an e.m.f., "even a beginner would have to be rather dim to fall into the trap." "Cathode Ray" must have read that—he wrote it. Further explanation is wanted here.

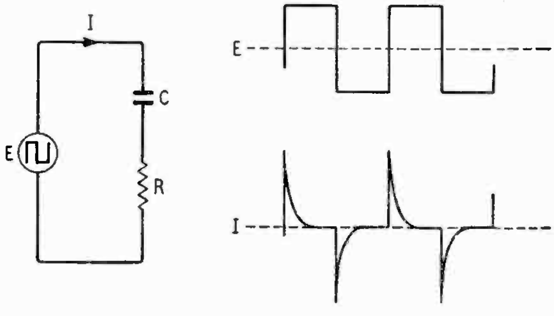
Binley, nr. Coventry. D. L. CLAY.

The author comments:

Mr. Clay has convinced me that it is time I wrote on the meaning of the word "negative". Meanwhile, I must repeat that the long-accepted understanding of "negative reactance" (which fits consistently into the larger subject of complex numbers) is the quantity which is set off vertically downwards in an Argand impedance diagram. Since the only passive circuit element that has negative reactance is capacitance, "negative reactance" normally means "capacitive reactance". It is true that with the aid of feedback amplifiers one can simulate negative inductance, and its reactance is also negative. Except perhaps in very specialized contexts, however, one would be wise to refer to it as "negative inductive reactance".

But the subject, after all, was impedance. If instead of retracing the ground of my penultimate paragraph Mr. Clay had explained to me what he or Dr. Myers means by negative impedance I would have been grateful. Is it any impedance in which both resistance and reactance are negative? Or only if the reactance involves negative inductance or capacitance? Is an impedance comprising negative resistance and negative capacitive reactance (i.e., the reactance of a positive capacitance) negative or positive? And how about a negative resistance and positive inductive reactance, involving negative capacitance? And, in any case, what is to be gained (except confusion) by whatever convention of this kind is adopted with regard to impedance, seeing that the signs of the real and imaginary parts are determined on quite different principles?

Mr. Clay seems to have a novel definition of phase angle: The phase angle (as commonly understood) between the cisoidal voltage and current having the same r.m.s. values and conveying the same true power as the voltage and current in question. But a glance at the current and voltage waveforms for the circuit shown,



in which CR is small compared with a period, will show that this "phase angle" (of the order of 80°) is not easily identifiable.

Whatever gave Mr. Clay the idea that I was applying Ohm's law to Fig. 5? Not only did I not say I was, but (lest anyone should mistake silence for consent) I added to the caption the exclamation ". . . resistance (not an ohmic one in this case!)".

"CATHODE RAY"

THE quotation "Omnis definitio periculosa est" (from Erasmus) which heads "Cathode Ray's" article on impedance in your February issue is very apt: all definitions are dangerous, because the question as to whether a particular idea is or is not a proper concept or vehicle of thought cannot be properly settled by mere information, or by appeals to establish custom or to definitions (as in "Cathode Ray's" article). It is necessary instead to review radically and critically ideas we have always known (or have thought we knew, and have taken for granted). Without such a fundamental, critical review our intelligence may be bewitched by the words or symbols used.

At least one can agree with "Cathode Ray" in condemnation of negative impedance, even if he regarded a certain letter to the *Journal I.E.E.* as incomprehensible. It will perhaps help the readers of *Wireless World* to appreciate the real point at issue if we simplify the subject under discussion somewhat, and consider, instead of "negative impedance", the notion of "negative" alone. The ideas involved should then be universally understood even by professors (for whom it is difficult to achieve the unbiased ignorance necessary for clear fundamental thinking).

We first meet the minus sign at school as equivalent to an order to reduce the number preceding the minus by the number following the minus, which is always less. If at this stage our teacher asks us to subtract 8 from 6, the correct answer is the natural one: it cannot be done. Robinson Crusoe, for example, could not have a debt or a minus quantity of any kind. The teacher may try to explain that a negative answer (like -2, the result of trying to subtract 8 from 6) implies a debt, or legally or socially agreed contract to deliver the corresponding positive quantity (here 2) at some future date. The more docile and obedient children simply accept this idea, but the more intelligent children are right to regard it as not simple, and accept it unwillingly. Indeed, the minus sign affixed to a result (as opposed to an item legitimately subtracted during the course of a calculation leading to a positive final result) is a mere social convention, devoid of inherent and independent capacity to exist as a logical concept.

On the other hand when the signs + and − are applied to spatial or geometrical relations, there is no difficulty: the sign + then indicates a move to the right (or up) while the sign − indicates a move to the left (or down) and the final result may have any direction relative to the origin. The directions of the axes are arbitrarily chosen, and are not essentially different from other directions. However, because numbers represented along (say) the x-axis and to the right of the origin can be handled in a manner very like the positive numbers of early childhood, we are apt to think that they are identical, whereas we should be careful to state the kind of universe in which we are working. Is the "positive" universe of Robinson Crusoe or the "geometrical" universe appropriate to the problem under consideration?

The obedient student tends to regard the ideas "minus" and "negative" as universally applicable and "obvious" concepts instead of only applicable where a "geometrical" universe is appropriate. Thus the adjective "negative" applied to mass, energy, horse, shilling, etc., is correctly regarded as a mere verbalism indicating that the quantity specified is to be subtracted.

The existence of the phrase "negative horse" does not imply that a corresponding physical entity exists in the world, or even that it could exist in any world. Likewise, negative resistance, negative inductance and negative capacitance exist only in the purely verbal sense of terms in a mathematical formula which will at some later stage of the calculation be subtracted from greater positive terms.

Kingswood Warren,
Surrey.

J. W. HEAD.

The author comments:

Having stated that fundamental, critical review is the only proper way of settling whether a particular idea is or is not valid, and that appeals to custom or definition are no good for this purpose, Mr. Head proceeds to demonstrate this point on the idea of "negative."

He begins by appealing to a definition of the meaning of the minus sign. I suppose if I raised a point of order here he would appeal to the other forbidden thing—established custom—by claiming that his definition is a widely accepted one. However, I don't want to be awkward so soon, so let it pass.

Having shown that according to this definition a negative quantity as an independent entity is an impossibility, he goes on to say that when a minus sign is applied to geometrical relations there is no difficulty. One might have expected that the fundamental and critical review on which Mr. Head was engaged would have caused him to boggle at the spectacle of something just declared to be impossible suddenly becoming not merely possible but devoid of difficulty.

Since he regards the minus sign as an instruction relating to numbers, presumably he would justify its geometrical application by regarding it as an instruction to subtract a number of units of length measured to the right (or upwards). If so, the reason one can be left with a negative answer in this case is that a zero has been arbitrarily fixed somewhere inside space. A sufficiently clear-minded review ought, however, to have shown that if this is allowed there is no difficulty with the school problems either. 0°C, for example, is a zero arbitrarily established inside the possible range of temperature, so -5°C is an actual physical (not geometrical) state. It would have been easy for Robinson Crusoe to have had a negative number of breadfruit for dinner, if he had established his zero level as the amount required to give him a pleasantly full feeling.

The distinction between Mr. Head's "geometrical" and "positive" universes, therefore, seems quite artificial and personal.

Mr. Head is good enough to say that one can at least agree with me in condemning negative impedance. But if his discourse on "negative" has any relevance, it is difficult to see why. He mentions resistance, but not impedance, among the things having no existence except as a term in a formula which will have to be subtracted from greater positive terms. From the context, however, it seems reasonable to assume that he would put it in the same class. Are we to infer, then, that negative impedance is permissible in the same sense? If so, his measure of agreement with me is very small.

I now give warning (but not in Latin) of another danger: that of the mathematician's armchair review. The basis of science is experiment and observation, before which many critical reviews have had to give way. Certain circuits have been observed in which the *net* resistance, at least for a brief time, is negative. There would seem to be no valid logical objection to students of such circuits making use of a parameter "facilitance" for negative resistance. Logically, negative facilitance would be classed by Mr. Head among the things existing only in the sense of temporary terms in a mathematical formula; nevertheless, in most circuits it would emerge as the final answer.

And how does electric charge fit into Mr. Head's philosophy?

Summing up: One is unlikely to disagree either with the meaning Mr. Head gives to the minus sign or with his immediate observations thereon. It is a pity he then fouls his own nest by bringing in a "geometrical universe" as an unexplained contradiction. And it is a pity he offers all this as a help to answering the question of negative impedance, dismissing with contempt the one thing on which it really turns—definition. As a mathematician he should know that signs and terms mean what they are made to mean, and that without established custom there would be chaos. There is general acceptance of what "negative resistance" means. There is not general acceptance of what "negative impedance" means, or that it has any meaning at all that is in keeping with related concepts.

Confusion does sometimes result from failure to dis-

(*Continued on page* 181)

tinguish between negative quantities and negative values. One often denotes the voltage of a valve grid relative to the cathode by the symbol V_g. It usually turns out to have a negative value. But one could define V_g as the negative voltage of the grid relative to cathode. In that case it would usually have a positive value. Other writers say: "Let $-V_g$ be the voltage of the grid relative to cathode." In that case too V_g is usually positive.

I understand Mr. Head to be making the proposition: "That in any self-contained system no non-geometrical quantity can have a net negative value."

The question I actually raised was what meaning, if any, can logically be given to negative values of the quantity "impedance." Certain American writers attach a defined meaning to them. I deprecated the practice on the ground of liability to clash with established practices. It is (*pace* Mr. Head) a question of definition and custom.

"CATHODE RAY."

A.F. Amplification

I WOULD like to clear up a few points that have arisen in correspondence in the March issue:—

First, I appreciate Mr. Tily's comments and agree that two pentodes with negative feedback will give similar results to the circuit I use. More components will be needed, however, and the cost of a pentode valve exceeds that of half of a double triode by an appreciable amount. With regard to the low phase shift obtained, this is restricted to 90°, as Mr. Tily correctly states, and enables feedback circuits of exceptional performance to be obtained*.

Regarding Mr. Short's letter, I have a suspicion that I did not state my case as clearly as I should have done. A triode in a conventional circuit can admittedly give a gain of some 40 times, but due to Miller effect the input capacitance will be over 100 pF (allowing for strays). This restricts the effective anode to earth impedance of the previous stage to less than 160 kΩ under which conditions the gain in V1 will be considerably less than 200 times.

I really cannot agree with Mr. Short on his figure of merit. If one is going to use such a unit then it should be on a logarithmic amplification basis. For instance, a cascaded amplifier of two valves each having a gain of 100 times and having 10 components would have a figure of merit of $\frac{100}{10} = 10$ per stage, but $\frac{100 \times 100}{20} =$ 500 overall. An amplifier that is 50 times cheaper per component, if you double its size, is certainly rather peculiar. The output stage *is* a cathode follower as it is driven on its grid between grid and earth as reference.

I do agree that its output impedance is not $\frac{1}{g_m}$ as might be expected, but this applies to all cathode followers driven from a high source impedance. I cannot agree that the input capacitance of the triode is increased due to action of the triode. The effective input capacitance is C_{ga} (between grid and earth) plus the very small effect of C_{gk} as in all cathode followers. The triode was treated as a bootstrap purely for convenience in explanation; it is still a cathode follower: a leopard does not change his spots just because you look at him from the other side!

With regard to the high gain-bandwidth comment of Mr. Short, I entirely agree you cannot do more than nature will allow.

Regarding Mr. Mansfield's letter, all I can say is that this particular circuit, or modifications of it, has been operating in no fewer than 10 pieces of equipment over the last four years with no valve failures. One answer to this point would be to raise the heater chain to about +50 volts which would even out the heater/cathode stresses to less than 100 volts in any valve, the cathode voltage of the triode being normally less than 120 volts above earth potential.

In conclusion, the author would like to state that in all the versions that have been used of the circuit (in oscillators and selective amplifiers as well as those described), it has always worked as it should, with never any trouble from parasitic oscillations, which is more than can be said for many two-stage amplifiers.

Bradford, 7. A. R. BAILEY
Bradford Institute
of Technology

* "Low Distortion Sine Wave Generator"—Arthur R. Bailey, *Electronic Technology*, February, 1960, p. 64.

I WAS interested to see the article on "Economical High Gain A.F. Amplification" in your January issue. I modified the circuit, given by E. Jeffrey (*Wireless World* Vol. 53, page 274, August 1947), to single-ended working, shortly after his article appeared, and have used it single-ended in an audio-frequency amplifier since then.

I communicated the circuit to a number of people in August 1948, and subsequently to several technical journals, but until now I have not known many show interest in the matter. I have been informed that the use of a pentode as anode load for a pentode amplifier valve was suggested by Vance. I saw an article many years ago where E.M.I. used a valve as anode load but this was complicated by a deliberate use of phase-shift to obtain reactive effects. I believe linear time constants have been obtained using a basically similar circuit. The low output impedance would have advantages in pre-amplifiers feeding into lines and when feeding some grid input circuits. The poor high-frequency response is a definite advantage with regard to stability in negative feedback amplifiers.

Allerton, Bradford. A. WOMERSLEY.

Circuit Conventions

AT the age of four I was taught to draw circuit diagrams as exemplified by Fig. 1. Even at this age it did not

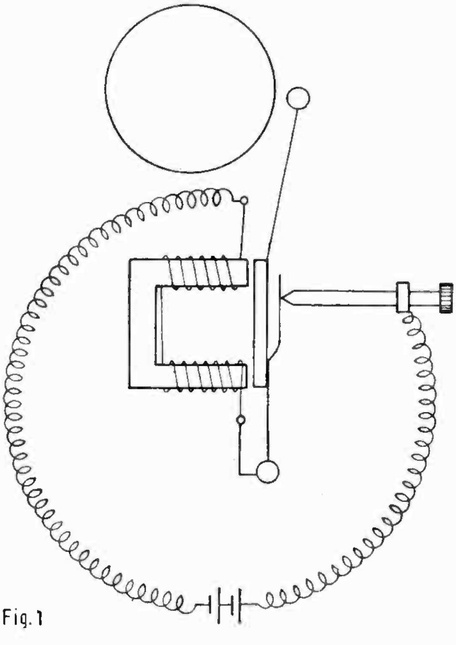


Fig. 1

take me long to appreciate that from the point of view of the circuit the literal depiction of the elegant green silk-covered wire, neatly helixed round a pencil, was not absolutely imperative. I was therefore glad when at the age of five I was taught the "straight wire and loop" convention now current in your journal, and it took me very little time to accustom myself to this new standard. Some years later, on being introduced to the

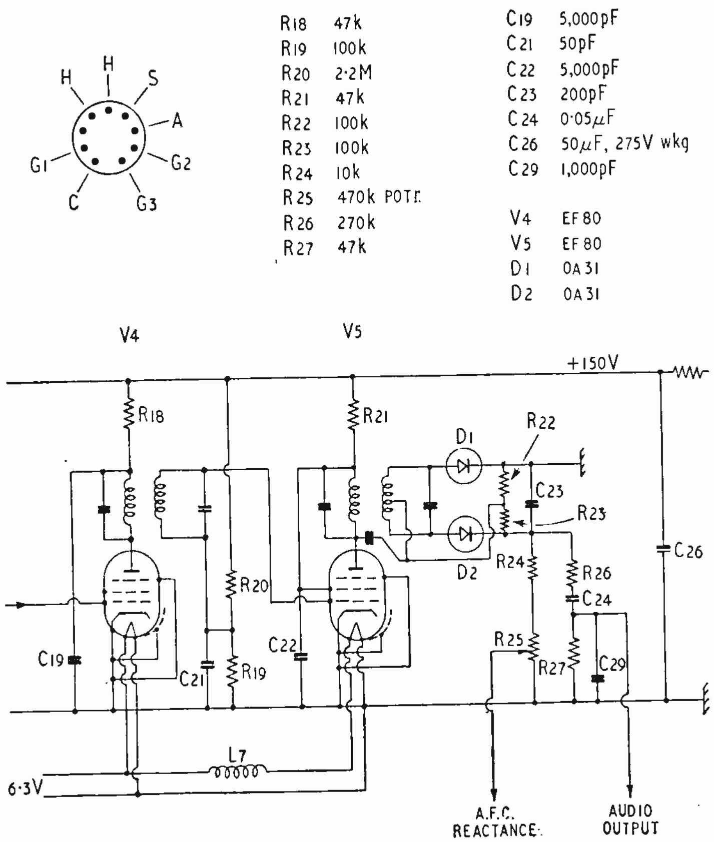


Fig. 2

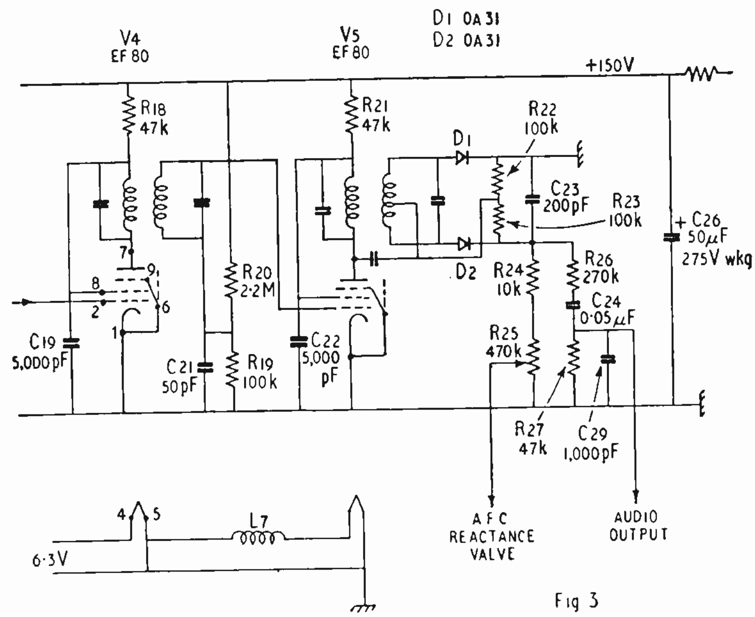


Fig 3

wiring diagram of a telephone switchboard, I made the acquaintance of the "straight through" wiring convention. I resisted this only so long as it took me to see that the loops would be nearly impossible to draw, and totally impossible to read. This major change of convention took me rather longer to absorb into the mental system; perhaps half an hour.

This somewhat frivolous preamble is only to indicate that a change of convention is not quite such a formidable proposition as is often supposed. When a "new" convention is notably superior it will be accepted easily enough; it only needs to be given the chance.

This letter refers primarily to the continuance in your journal of the "loop" wiring convention which I regard as indefensible. Perhaps I may be allowed to add my ideas on circuit conventions generally, all this belonging to the greater subject of "notation," which I have long learnt and taught to be "more than half the battle."

My thesis is that the composer of a circuit diagram should not work to a rigid and comprehensive book of rules but to a few cardinal principles freely interpreted. I suggest that the following are such principles:

1. Information should be so expressed as to be unambiguous, and to minimize interference to thought sequences.

2. Since a circuit diagram has much to express it should not be cluttered with redundant information.

3. Cross referencing is to be avoided whenever direct referencing is admissible.

In the light of these principles, consider the diagrams of Figs. 2 and 3 which express the same circuit with different conventions:—

(a) Fig. 2 uses the loop convention which infringes two of the principles. First of all (1) is infringed because the loops interrupt the mental process of following a straight run. Secondly, the loops infringe (2) because the loops show the *absence* of a join. To show the *absence* of something is redundant.

(b) There is a minor difference between Figs. 2 and 3 in the conventions for T junctions. Some standards favour a "blob" on T junctions. However the T junctions of Fig. 3 can have only one meaning, so the blob, essential at an X junction, is redundant at a T. Therefore I prefer the Fig. 3 convention, though I am prepared to regard it largely as a point of "style." (Another standard avoids the issue by "staggering" so as to use only T junctions.)

(c) We come now to the valve conventions. In the first place the envelope plays no circuit role, nor is it needed to "group" the valve elements. It is therefore redundant in a circuit diagram and should not appear. [Still less is an envelope required round a transistor.]

On the subject of pin numbering one must take into account the intended purpose of the diagram. If it is purely theoretical, i.e., if it is not in any sense a practical wiring diagram, the pin numbering is redundant and should be omitted. In any other case the pin numbering is preferably shown *directly;* not indirectly as in Fig. 2. Direct numbering is more easily possible when the superfluous envelope is omitted.

As a fine point, Fig. 3 omits the pin numbering on V5 because this is shown on the adjacent valve V4 of the same type. Principles (2) and (3) are here in conflict, and the choice is a delicate point of style.

If the above is accepted as a good philosophy of circuit drawing, then it would appear that the loop convention stands condemned. Its continuance in your journal would seem to imply uncomplimentary assessments of your readers; either that they are incapable of assimilating change, or that they are apt to wire with their soldering irons rather than with their brains.

Luton. L. H. BEDFORD

[We welcome Mr. Bedford's criticisms and acknowledge the force of his arguments against looped crossings, particularly in relation to complex wiring diagrams; but the telephone switchboard type of circuit does not often occur in this journal. Long experience has taught us that errors in draughtsmanship and checking are fewer when looped crossings are employed. The formation of the crossover loops is the *first* deliberate act when inking-in a pencilled circuit; further checks are imposed when ruling in the horizontal and vertical lines. In Mr. Bedford's method the fact that mental processes are *not* interrupted when drawing a straight run constitutes a potential source of error. The peppering of his circuits with dots would be the *last* act, which, things being what they are, must often be done against the clock with the blockmakers' messenger waiting to collect the finished product! (Incidentally, in Mr. Bedford's Fig. 3, which has been faithfully reproduced, his draughtsman seems to have given the pot too hard a shake over V5. There is also a mistake in the heater circuit, which does not occur in Fig. 2 where the *W.W.* convention is used.) With looped crossings and staggered junctions (which have long been the rule in *W.W.*) you have both belt and braces, and, strange as it may seem, they look nice—or so we think.—Ed.]

"Subjective" Colour Tests

IN reply to C. E. M. Hansel's letter (March issue) I should like to elaborate on the conditions under which Land-colours were obtained using a stereoscope. Rivalry between the two eyes was found to be troublesome. This was minimized by matching the intensities presented to the eyes by using an appropriate neutral filter (N.D.$\approx$ = 0.6) in the " white " path.

With most subjects it is only after viewing for some minutes that the colours become fully developed, but these are finally almost as saturated as in the normal Land arangement.

With inspection times of the order of 5-10 minutes, about 15 out of 20 subjects have reported the usual range of Land colours, the same object in each arrangement being given the same colour name by different observers. Reversal of the filters gives similar results to those reported with Land's usual arrangement.

On the other hand, when the inspection time was limited to 10 seconds it was found that only 2 out of a group of 30 students could see Land colours, although all had previously seen them in the usual projection arrangement.

Pictures of natural objects were used. These contain internal contours, such as shadows and highlights, which would be similar in both eyes. Such a pair of pictures might be expected to fuse (i.e. the internal process of combining the images as distinct from the external process of registration) better than a chart of test patches whose only contours are colour boundaries.

Although negative results are easily obtainable, therefore, these positive results would seem to rule out a purely retinal theory.

London, W.C.2. J. P. WILSON,
Information Systems Group,
King's College.

"Piped TV"

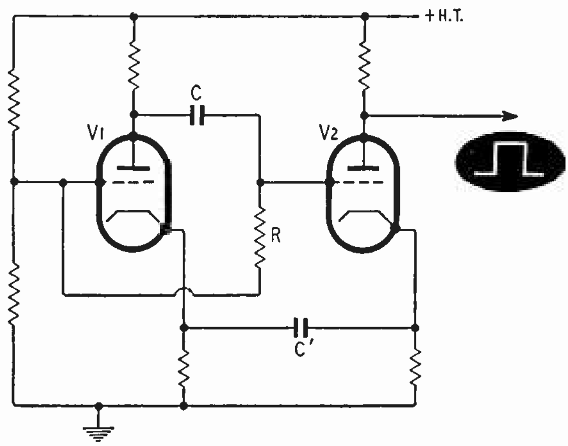
I WAS surprised to note the implication in the paragraph on piped television under " Random Radiations " in your March issue, that wired television systems of the kind operated by the Rediffusion Group require special receivers and do not allow the public a free choice in the selection of a television receiver. This, of course, is not the case. Some 35,000 ordinary television receivers supplied by manufacturers other than ourselves are at the present time connected to our wired television systems. There are two methods of connection: in the first and most popular, the front end of the receiver is replaced by an adaptor which takes the signal from our network and delivers it direct to the cathode ray tube and sync. separator of the receiver; in the second, which involves no alteration to the receiver, a separate unit mounted outside the receiver converts the carrier frequencies used on the network to frequencies in Band I which can be accepted by the unmodified aerial receiver.

Of course, if a member of the public wishes to secure the full economy which a system of sound and vision distribution, designed as an integrated whole, can provide, then he will select the receiver which has been designed as part of that system.

London, S.W.1. R. P. GABRIEL,
Rediffusion, Ltd.

Two-State Terminology

J. M. PETERS' article on "Triggered Two-state Circuits" in the February instalment of "Elements of Electronic Circuits" illustrates in Fig. 1 a cathode-coupled flip-flop or relay and *not*, as stated, a cathode-coupled multivibrator for which the basic circuit is:—



In this arrangement the charging and discharging of C' through the potential difference between cathodes mainly determines the period of oscillation in the freely-running state. This action bears little relationship to that of the cathode-coupled flip-flop where the period is partly determined by the time-constant of C and R (Fig. 1); in the multivibrator circuit this time-constant is normally made high compared with the natural period and is not connected with a cumulative action.

H.M.S. Ariel II, Winchester. S. J. WALTON,
C. V. F. C. VELEY.

The author comments:

I do not disagree with Messrs. Walton and Veley that the circuit (Fig. 1) is a flip-flop relay, but I still maintain that it comes under the general classification of multivibrators. It can be argued that any square-wave generating device, either freely-running or triggered, is a "multi-vibrator" because Fourier analysis will show the presence of harmonics up to at least the several hundredth. If the bias voltage applied to one valve of a multivibrator is made sufficiently negative the circuit then becomes a relay, the stable state being that in which the unbiased valve is conducting. To qualify for description under the heading "Triggered Two-state Circuits," the simple basic circuit of Fig. 1 had to provide a relay action. It was therefore necessary to arrange for the current flowing in V2 when V2 was conducting to be greater than that in V1 when V1 was conducting, so that V1 could be cut off by V2 (by the bias on R_k), hence requiring a positive grid pulse at V1 to continue the action. Asymmetry in the cathode circuit is all-important for this action.

The circuit given by your correspondents is only one type of freely-running cathode-coupled relaxation oscillator, square-wave generator or "multivibrator," which depends for its action on unequal cathode load resistors. The charging and discharging of C′ through the difference in cathode potentials determines the period of oscillation. I could draw the circuit of another form of freely-running cathode-coupled relaxation oscillator, also termed a cathode-coupled "multivibrator," while a third variation is the bootstrap circuit described in the February article.

J. M. PETERS.

Transistor Stopwatch

IN your November issue the author of "Transistor Stopwatch" states that the OCP 71 phototransistor in Fig. 3 is used as a photodiode. I disagree with this statement and maintain that it is being used as a transistor even though the base is "left floating."

When used in this manner, the light falling on the base of the transistor produces free electrons and holes in the base, the electrons so produced then act as the base current which is normally derived from an external signal source. The usual transistor action now occurs and an amplified version of this "light" current flows in the collector circuit. Therefore the device is being used as a transistor amplifier and cannot possibly be considered as a diode.

The phototransistor could be used as a photodiode by connecting either the base/emitter or the base/collector junction to a reverse bias supply. The light falling on the junction would then merely increase the reverse current.

Hounslow. R. O. BRADLEY.

THE following circuit of a simple electronic stopwatch using the integrating capacitor method may be of interest to readers, particularly in comparison with the pulse count method used by D. E. O'N. Waddington in his transistor model (*Wireless World*, Nov., 1959). The two methods form an interesting comparison of computational technique—the pulse method and integrating capacitor method representing the digital and analogue branches respectively. It is also interesting to note that the pulse count circuit was used to measure flight times of a projectile, and the circuit shown here is used extensively in practical dynamics measurements of velocity and distance-time relations in technical college classes.

The circuit is very simple, consisting of an Eccles-Jordan bi-stable switch controlled by miniature germanium photocells, a charging voltage gate, diode one-way gate, charging capacitor and valve voltmeter. Two ranges of time measurement are used, 0 to 0.05 sec and 0 to 0.5 sec. Practically all the parts required are to be found in the surplus Modulator Unit Type 67, and each unit has shown itself to be very reliable and virtually foolproof in the hands of often very inexperienced operators.

Duffield, Derby. D. M. MELLUISH.

CORRESPONDENCE on photographic timers fails to disclose the one fault of these devices. Unless the timing condenser is a plastic film type (at £2 a microfarad) the timing of the circuit may vary by as much as 20% in a few weeks, since this is the variation of ordinary paper condensers.

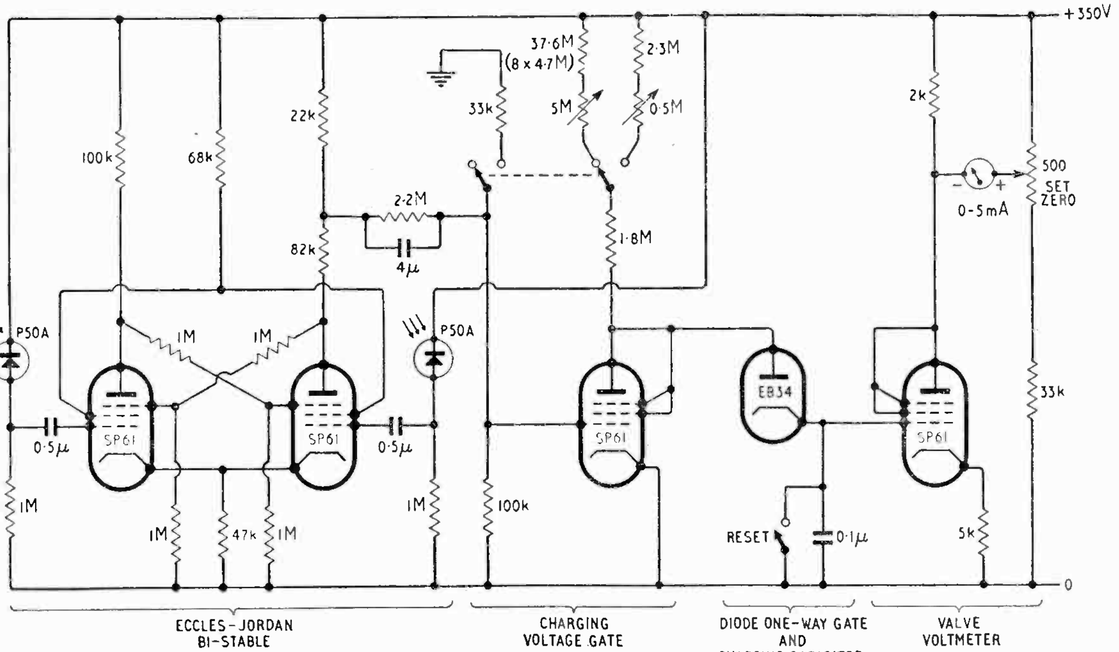
Plymouth. G. G. GARDNER.

Colour Codes

THE problem of wiring codes which do not conform to the usual British standard is capable of being solved quite simply. A legal prohibition of the importation of any equipment which does not conform to the British standard is all that is required, with a rider that the sale of any equipment already imported but not rewired to conform is also prohibited.

Marlborough. H. J. FENN.

[Electrical and radio equipment imported into other countries, for example, Canada and Sweden, must comply with their "safety" regulations.—Ed.]



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By "CATHODE RAY"

REGULAR readers (if any) who have noticed my fondness for terse titles will appreciate the above. I had thought of "e^{jx}", but decided that was needlessly long-winded for the purpose. (Like the Scot who, after three hours of silent fireside fellowship with his brother just back from Australia, so far forgot himself as to remark "Aye . . . .")

A recent leader in *The Times* contrasted mathematicians, who delight in tracing the perfect abstract relationships of their subject, with engineers, who work by "rule of thumb." I don't know if the Top Mathematician who wrote this was asserting that engineers are content to use logarithms or sliderules for their calculations without troubling to find out what a logarith is, and that they apply the formula $E(1-e^{t/CR})$ to plot the charging of a capacitor without knowing what e is (except perhaps that it = 2.71828 . . .) and why. Or whether his point was that the whys and wherefores of maths are outside the scope of engineers. There is probably a grain of truth in both, but I'm sure that few engineers are in fact content to use anything without at least trying to understand it, and those that are are bad engineers. For while it is true that they can make good practical use of logarithmic and exponential tables—and Bessel functions—without having the least idea of the principles involved, anything outside the memorized instructions would be completely beyond them. Even for strictly practical purposes one's aim should be to have such a grasp of mathematical principles and their inter-relationships as to see the easiest way—or at least a way—of tackling any new kind of problem.

Two months ago I mentioned that a unit vector (say in an a.c. vector diagram) inclined at any angle θ can be represented mathematically by $e^{j\theta}$, which is the same as $(\cos\theta + j\sin\theta)$. It was quite easy to explain and visualize the lengthier expression, but I excused myself from pursuing the subject of $e^{j\theta}$ any farther just then, on the ground of shortage of space. If you suspected the worst about that, please be more charitable in future, for here it comes!

There is perhaps some excuse for using $e^{j\theta}$ as a mathematical tool in blind faith rather than clear understanding. According to the ordinary rules, it appears to mean a very odd number (2.71828 . . .) multiplied by itself an imaginary number of times. That is not a very helpful or even intelligible concept. The fact that an "imaginary" number, distinguished by the label "j" ($=\sqrt{-1}$), is one measured vertically on graph paper, as distinct from "real" numbers which are measured horizontally, hardly clarifies the matter. Why on earth should a vector of *unit* length be based on 2.71828 . . .? Why should θ be rotated anticlockwise through a right angle (that being the accepted significance of j)? And how can one multiply together $j\theta$ factors, each equal to e? And, above all, how can one reasonably interpret the result as a unit vector inclined at angle θ?

Some books take the line of Humpty Dumpty and tell their readers that mathematical symbols mean just what they are made to mean. In other words, they are purely arbitrary. So they don't have to make sense. Certainly the choice of symbols such as π and e and = is arbitrary, and if they were all shuffled and dealt again it would make no difference provided all concerned remembered the changed meanings. But it doesn't follow that choice of symbols is unimportant. The object of practical maths is to eliminate as far as possible the need for thinking.

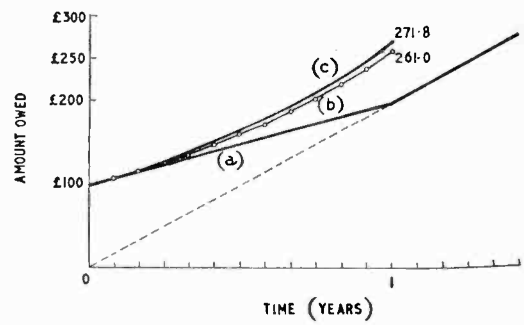


Fig. 1. Growth of a debt due to borrowing £100 at 100% per annum, when the interest is added (a) annually, (b) monthly, (c) continuously.

(That is not just mental laziness; the idea is to give the mind more time for constructive work.) If symbols are appropriate and easily remembered and universally used, that all helps. More important, the rules for their use should be consistent and free from exceptions.

For example, in accordance with the definition that a^n means the product of n factors each equal to a we have $a^2 = a \times a$, and $a^3 = a \times a \times a$, and $a^2 \times a^3 = a^5 = a^{2+3}$. In accordance with the same definition, a^0, a^{-1} and $a^{\frac{1}{2}}$ are nonsense. But the meanings that have been given to them are not just arbitrary; they are such as to be in the spirit of the definition by conforming to the same rules*. Thus, to obey the addition-of-indices rule, $a^0 \times a$ must be equal to $a^{0+1} = a^1 = a$, so a^0 must be 1. Similarly

*An example of a rule that does have exceptions, against which one must always be on guard, is $a/a = 1$; it fails when $a = 0$ or ∞.

$a^{-1} = 1/a$ and $a^{\frac{1}{2}} = \sqrt{a}$. But imaginary numbers won't mix with real numbers, so this direct approach fails to give meaning to $e^{j\theta}$. To work out for ourselves a satisfactory meaning, we shall have to go a surprisingly long way round and pass through some unexpected territory.

First of all—and this justifies the sweet simplicity of the title—what is the significance of e? Why should it crop up so often, even in such simple things as charging a capacitor from a constant voltage? That other ubiquitous number running to unlimited decimals — π — has a quickly explainable and easily appreciated meaning. But too often one is just told that e is the base of natural logarithms. So what?

The rate at which a lot of quantities vary is proportional to the quantities themselves. For example, if you borrow £200 at a certain rate of interest you have to pay twice as much as if you borrowed £100. In simple interest, the interest is paid as it falls due, so that capital remains constant. In natural events, however, the "interest" is continuously added, so the rate of increase itself increases accordingly; it follows the law of compound interest. Suppose someone (*you* would have more sense) borrowed from a rapacious money lender who charged 100% per annum compound interest. That would appear to mean that each year the amount owed would be multiplied by 2. At the end of the first year it would therefore be £200, and the rate of increase for the next year would be double, as shown by (a) in Fig. 1. But the lender might be more cunning and specify his rate of interest as 100%/12, or 8.3%, per month. So at the end of the first month a debt of £100 would have risen to £108.3. It would be multiplied by 1.083 every month, so after 12 months would be £100 × $(1.083)^{12}$, which is over £261. This figure is reached by a series of 12 straight lines (b), each 8.3% steeper than the last. If the money lender happened to be scientific as well as cunning, he would calculate his interest on the basis that it was being added continuously (c) instead of at monthly or any other finite intervals, and at the end of the year would demand £271.828, or £100 × e.

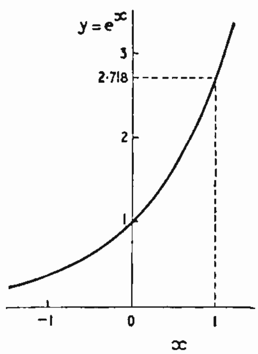


Fig. 2. The graph of e^x is the same as (c) in Fig. 1, divided by 100 to make it start from 1.

For that is what e means. Only of course it applies to *any* two quantities, one of which varies with respect to the other at a rate proportional to itself; not only money and time.

We arrived at a rough approximation to it (2.61) by dividing the rate of interest by 12 and applying it 12 times. In other words, we evaluated $\left(1+\frac{1}{n}\right)^n$ for $n=12$. The larger we make n, the nearer we approach a continuous curve and the value e. One method of getting as near e as we like or have time for is to use the binomial theorem to express $(1+1/n)^n$ as a series, with the result

$$e = 1 + 1 + \frac{1}{2} + \frac{1}{6} + \frac{1}{24} + \ldots .$$

$$\text{or} \quad 1 + \frac{1}{1!} + \frac{1}{2!} + \frac{1}{3!} + \frac{1}{4!} + \ldots .$$

where "$m!$" means the first m numbers all multiplied together. As the terms in the series dwindle very rapidly, only a few more are needed to give quite a close approximation.

In Fig. 1, the continuously-rising debt after 1 year is e times what it was at the start. The next year it is again multiplied by e, so after 2 years the total multiplication is e^2, and so on. So if y_0 is the original debt, the debt y after x years is y_0e^x. Fig. 2 shows a plot of e^x against x. Because (as we have seen) any number to the power 0 is equal to 1, the curve of any number to the power x would pass through the point $y = 1$ at $x = 0$. *But e is the only number for which the slope is everywhere equal to y.* Note, too, that the same principle works to the left, into the negative values of x. And that e^x has no negative values.

In these days I ought to be safe in assuming that anyone who might be interested in e would know that there is a special and very important place in mathematics for slope; it is usually designated by the composite symbol $\frac{d}{dx}$, meaning "differentiate with respect to x. So e can be defined by the equation

$$\frac{d}{dx}e^x = e^x$$

Now the method we have just used for approximating to e is available for e^x and gives

$$e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \frac{x^4}{4!} + \ldots$$

The rule for differentiating any power of x is to multiply by that power and reduce the power by 1. E.g., $dx^3/dx = 3x^2$. If we perform this operation on the e^x series we confirm that it is like the application of water to a duck's back. For the graph of any constant quantity is a horizontal line, so its slope is

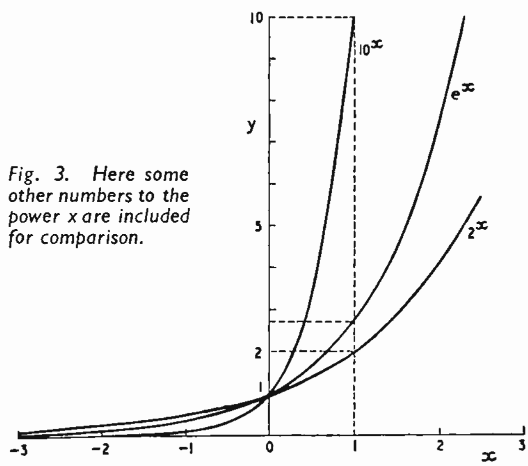


Fig. 3. Here some other numbers to the power x are included for comparison.

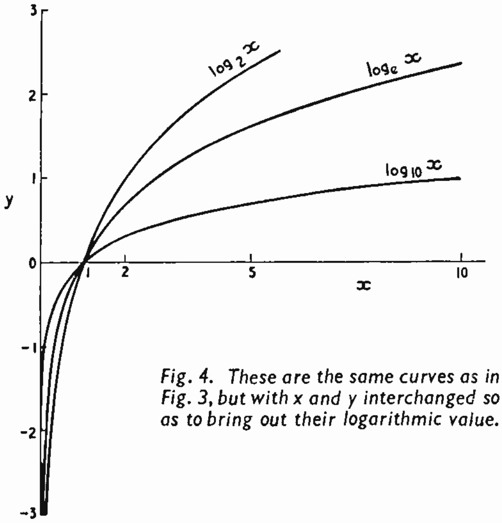


Fig. 4. These are the same curves as in Fig. 3, but with x and y interchanged so as to bring out their logarithmic value.

zero, and therefore 1 goes out; x reduces to 1; $x^2/2$ reduces to x; $x^3/6$ to $x^2/2$, and so on to infinity. The net effect is therefore nil.

Suppose, however, that we didn't know what the series for e^x was, or anything about $(1 + 1/n)^n$ or the binomial theorem. All we knew was that the slope of e^x was equal to e^x, starting at 1 for $x = 0$; and the rule for differentiating (i.e., finding the slope by algebra). Then, by guessing that a power series might exist for e^x, we could construct it. For the general power series is

$$a + bx + cx^2 + dx^3 + ex^4 + \ . \ . \ .$$

where a, b, etc., are unknown constants. Differentiating this we get

$$b + 2cx + 3dx^2 + 4ex^3 + \ . \ . \ .$$

and equating these two (in accordance with our definition of e^x) we find

$$b = a$$
$$c = b/2 = a/2$$
$$d = c/3 = b/2.3 = a/2.3$$
$$e = d/4 = c/3.4 = b/2.3.4 = a/3.2.4$$

So the series must be

$$e^x = a + ax + \frac{ax^2}{2!} + \frac{ax^3}{3!} + \frac{ax^4}{4!} + \ . \ . \ .$$

We still have to find a. For this we draw on that other fact about e^x which makes it so basic and simple—that its starting value (at $x = 0$) is 1. (Which of course is the same as saying that its starting slope is 1). Putting $x = 0$ in the above series, we find that a must be 1, and so we arrive by another route at the same series.

For the sake of comparison we might like to plot some other number to the power x; say 10, as in Fig. 3. Or, since digital computers are bringing the binary scale into prominence, 2^x.

Before leaving these graphs we should remember that there is an alternative way of looking at them. If y equals any number to the power x, then x is the logarithm of y to that number as base. Fig. 3 is therefore not only a selection of exponential curves (x being the common exponent or index) but also a selection of logarithmic curves to different bases. As such, Fig. 3 would normally be shown turned on its side, and left to right, with x and y interchanged, as in Fig. 4; but the curves themselves are exactly the same. Because we count in tens, the most convenient logarithms for ordinary arithmetical computation are to base 10. If we worked in the binary scale, our log tables would be to base 2. As one might guess from Fig. 4, there is a constant ratio between logs to any two bases, so it is quite easy to convert tables of common (i.e., base 10) logs to any other.

However, the only point that concerns us just now is why logs to base e have any special interest. If we turned a hill up on its end, what was previously a gradient of 1 in 3 would be 3 in 1. The distinctive feature of the e^x curve in Fig. 3 is that its gradient at the start ($x = 0$, $y = 1$) is the simplest possible—1 in 1. So turning it up on end makes no difference here. (The fact that it *looks* steeper is solely because I used different horizontal and vertical scales, to get the graph on to the page.) Elsewhere along the curve the slope has changed from e^x to $1/e^x$ ($= 1/y$), in the notation of Fig. 3. In Fig. 4, x and y have been interchanged, so the slope at any point is $1/x$. Therefore, in calculus symbols,

$$\frac{d}{dx} \log_e x = \frac{1}{x}$$

(The tendency nowadays is for "$\log_e x$" to be written "$\ln x$" where the n commemorates Napier, the inventor of logs to base e.) With any other base, the sweet simplicity of this formula is marred by a constant factor, usually with unlimited decimals.

In case the purely intellectual appeal of simplicity is not appreciated by all, I will now give one example—out of very many—of the importance of e in practice. Fig. 5 shows a capacitance C charged to voltage V. At zero time ($t = 0$) it is switched across a resistance R. The problem is to depict what happens to the voltage from then on, say by plotting a graph of v against t.

We already know that at $t = 0$, $v = V$. The charge on a capacitor is always equal to vC, so at

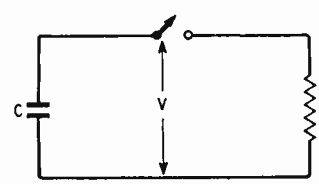


Fig. 5. Very simple capacitor discharge circuit, which is found to involve e^x.

that particular moment is VC. And the current, i, directly the switch is closed, is V/R. If it continued flowing at the same rate until the charge was exhausted, say at time T, then Ti = initial charge = VC. So

$$T = \frac{VC}{i} = CR$$

This product, CR, is well known as the "time constant" of the circuit; as we see from the dotted line in Fig. 6, it is equal to the time that would be needed to discharge C through R completely if the starting rate were maintained. But of course, it is not maintained. When C is half discharged its terminal voltage is V/2, so the current is half what it was, so the rate of discharge is halved. The slope

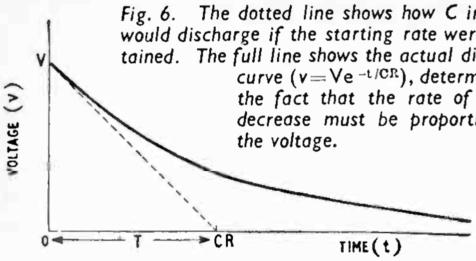


Fig. 6. The dotted line shows how C in Fig. 5 would discharge if the starting rate were maintained. The full line shows the actual discharge curve ($v = Ve^{-t/CR}$), determined by the fact that the rate of voltage decrease must be proportional to the voltage.

of the actual discharge curve is everywhere proportional to its height; i.e.,

$$\frac{dv}{dt} \propto v \text{ or } \frac{dv}{dt} = kv$$

where k is a constant. The discharge curve must therefore have the same shape as those in Fig. 3. Obviously the parts concerned are those that lie to the left of zero—the $-x$ region. If we want to keep things as simple as possible we shall choose the e^x curve, because a line having its slope at $x = 0$ would, if continued, rise from 1 to 2 at $x = 1$. It is clear that if produced in the opposite direction it would fall from 1 to 0 at $x = -1$. Fig. 6 shows that $x = -1$ corresponds to our $t = CR$. We can convert from our t scale to the $-x$ scale by dividing it by CR and reversing the sign. So $e^{-t/CR}$ is the basis of the curve, and this only needs multiplying by V to fulfil the starting condition:

$$v = Ve^{-t/CR}$$

The curve can be plotted from this, using a table of e^{-x} (though in practice it might be easier to manipulate it into the form $2.30 \log_{10}\frac{v}{V} = -\frac{t}{CR}$). If we haven't time for that we can at least note in passing that just as going from 0 to 1 in Fig. 1 multiplied the starting price by e, going from 0 to -1 (i.e., $t = CR$ in Fig. 6) divides it by e, so that at that point v is 0.368V. Similar methods can be used for showing that a capacitor charged from zero to V volts reaches 0.632V in the first CR seconds. The growth and decay of current in inductive circuits takes place in the same way. But we must press on if we are to reach our "imaginary" destination.

The first step in this trickiest bit of the journey, from "real" values of x in e^x to "imaginary" ones (e.g., $j\theta$), is to find series for sin x and cos x. You could do this quite easily but uncomprehendingly—by "rule of thumb"—by dipping into a mathematical textbook, pulling out the tool labelled "Maclaurin's Theorem," and following the instructions. Anyone who is familiar with this tool already is too mathematically learned to be reading this, so I assume you have never heard of it and will therefore be surprised to know you have begun to use it already—and comprehendingly, too, I hope. It is in fact, a continuation of the rather interesting method we used for e^x; namely, assuming that a converging power series exists, and successively getting rid of the first term by differentiating.

So we need to know what $\frac{d}{dx}\sin x$ and $\frac{d}{dx}\cos x$ are. If you don't know already, you can soon get a very good idea by drawing accurate sin and cos curves (one curve will do, if you move the starting line from zero amplitude for sin to peak amplitude for cos) and then drawing curves of their slopes. These slopes are measured in so much per *radian*, of which there are 2π in each 360°. The sin wave begins at zero but with positive peak slope, which measurement shows to be 1. At its peak its slope is zero. And so on, giving a curve which turns out to be the same as the cos wave. Similarly the slope curve of a cos wave turns out to be the same as an inverted sin wave. The results, are, then,

$$\frac{d}{dx}\sin x = \cos x$$

$$\frac{d}{dx}\cos x = -\sin x$$

Now tackle our assumed series:

$$\sin x = a + bx + cx^2 + dx^3 + ex^4 + \ldots$$

The value of a can be found at once by making $x = 0$. The series reduces to $0 = a$. Next, differentiate:

$$\cos x = b + 2cx + 3dx^2 + 4ex^3 + \ldots$$

Again put $x = 0$, making $\cos x = 1$, so $b = 1$. Differentiate again:

$$-\sin x = 2c + 6dx + 12ex^2 + \ldots$$

This gives $c = 0$. Once more:

$$-\cos x = 6d + 24ex + \ldots$$

This gives $-1 = 6d$, so $d = -\frac{1}{6}$ or $-\frac{1}{3!}$. And so we can go on indefinitely, finding the values of the constants in the general series and establishing that

$$\sin x = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \frac{x^7}{7!} + \ldots$$

and $$\cos x = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \frac{x^6}{6!} + \ldots$$

Park those for a few minutes while we go back to our exponential series, boldly making $x = j\theta$ and seeing where it leads:

$$e^{j\theta} = 1 + j\theta + \frac{(j\theta)^2}{2!} + \frac{(j\theta)^3}{3!} + \frac{(j\theta)^4}{4!} + \frac{(j\theta)^5}{5!} + \frac{(j\theta)^6}{6!} + \frac{(j\theta)^7}{7!} + \ldots$$

(Knowing what is to come, I have written down more terms than the bare minimum needed merely to make clear what the series is.) Now, since $j = \sqrt{-1}$, $j^2 = -1$, $j^3 = -j$, $j^4 = 1$, $j^5 = j$, and so on. Filling in these values, and sorting the sheep from the goats, we get

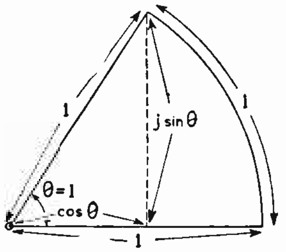
$$e^{j\theta} = 1 - \frac{\theta^2}{2!} + \frac{\theta^4}{4!} - \frac{\theta^6}{6!} + \ldots + j\left(\theta - \frac{\theta^3}{3!} + \frac{\theta^5}{5!} - \frac{\theta^6}{7!} + \ldots\right)$$

Taking a good look at the two series in store to make sure, we can do no other than write

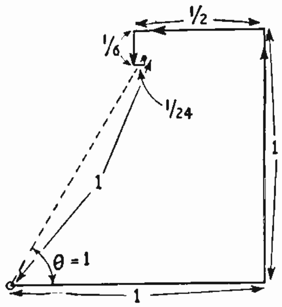
$$e^{j\theta} = \cos\theta + j\sin\theta$$

The first time this celebrated identity (Euler's) was put before us, without warning or explanation, it looked like the most outrageous of the six impossible things the Red Queen had schooled herself to believe by breakfast time. A useful abbreviation,

(*Continued on page 189*)



Left: Fig. 7. This shows how a unit vector, inclined at an angle θ, is equivalent to cos θ + j sin θ. But why should it also be equivalent to $e^{j\theta}$? In this example, for simplicity θ = 1 radian.



Right: Fig. 8. Here $e^{j\theta}$ (for θ = 1) is plotted term by term in its series and is found to give the same result as cos θ + j sin θ (Fig. 7).

perhaps, but quite arbitrary, and indeed unintelligible if considered literally. It was like a rabbit produced from a hat we knew to be empty. But now that we have been standing by the conjuror's side, as it were, examining all the steps leading to the sensational denouement, does it begin to make sense? And if not, can we point to where we lost touch?

Well, I think with a little graph sketching we can make sense of it all the way through.

With Fig. 1 in front of us the meaning of e is pretty clear, and it can even be visualized as an infinite coverging series, in which the first term (1) consists of the original "capital," the next (1) is the 100% "simple interest" increase in unit time, and the fractional terms give increasingly close approximations to the summit of curve (c), which represents continuous addition of "interest."

The meaning of e^x when x is a "real" number (even if it is negative or fractional) imposes no great strain on our credulity, for we are familiar with the fact that every time we raise the power of any number by 1 it means multiplying by that number. If anyone, lacking knowledge of the binomial theorem or faith in it, is dubious about the e^x series, he can check it for some easy value of x, say 2 or 3.

It is when x is made "imaginary" that we have to watch the conjuror very closely. For simplicity let us take as our example $\theta = 1$. The mathematical unit of angle is the radian, because that is the angle swept through when the moving end of a vector of unit length travels through unit distance (Fig. 7). Because the whole circumference of a circle is 2π times as long as its radius, 360° equals 2π radians, and 1 radian is about 57.3°. Fig. 7 also shows where the sine and cosine of θ come in, and how the inclined unit vector is equivalent to $\cos\theta + j\sin\theta$, j being (for the reason already noted) the standard instructions to reckon upwards instead of along to the right. Now let us follow the instructions given by the series for cos x, x being = 1:

$$\cos 1 = 1 - \tfrac{1}{2} + \tfrac{1}{24} - \tfrac{1}{720}, \text{ etc.}$$

That is to say, from the zero point in Fig. 7 move one unit of distance to the right along the horizontal axis, then back $\frac{1}{2}$, then forward $\frac{1}{24}$, and so on. Very soon we find ourselves settling down at the point we had already found by dropping the dotted vertical from the tip of the vector.

To do the same for $j \sin\theta$ we must obviously prefix every term in the series by j, which means that all our distances are measured up and down instead of along. When we have finished doing so, the net result is the dotted line.

And so, by making use of the series forms of cos x and j sin x, instead of looking up the values in tables in the usual way, our two-part journey takes us from zero to the upper tip of the inclined vector and thereby is vectorially equivalent to that vector itself.

Obviously this result would equally be achieved if we moved as instructed by cos θ and j sin θ terms alternately; i.e., 1 to the right, 1 up, $\frac{1}{2}$ to the left, $\frac{1}{6}$ down, $\frac{1}{24}$ to the right, $\frac{1}{120}$ up, $\frac{1}{720}$ to the left, and so on, as in Fig. 8. At the end—theoretically never reached, but with an ordinary sized pencil point reached in about six steps—we find ourselves 1 unit of distance from the start, inclined at an angle of 1 radian, as before. In carrying out this manoeuvre we were in fact (whether we realized it or not) using as our instructions the series for e^x, x being in this case $j\theta$ and the usual meanings given to j^2, etc., consistent with successive anticlockwise right-angle turns.

Now at last we can see how a power (*every* "imaginary" power, in fact) of 2.71828 . . . can equal 1. Because the expansion of e^x into a series, when x is "imaginary," involved periodical appearances of j, and these must be interpreted as instructions to move vertically, the length 2.71828 . . . is traversed in a sort of squarish snail-shell manner, and by a remarkable coincidence always lands us 1 unit of distance from the starting point, whatever the value of θ. By another remarkable coincidence our net angular movement is always equal to θ. It would be a good idea to try a few other values for θ. For instance, $\theta = 2$, as in Fig. 9. Note that this time the total

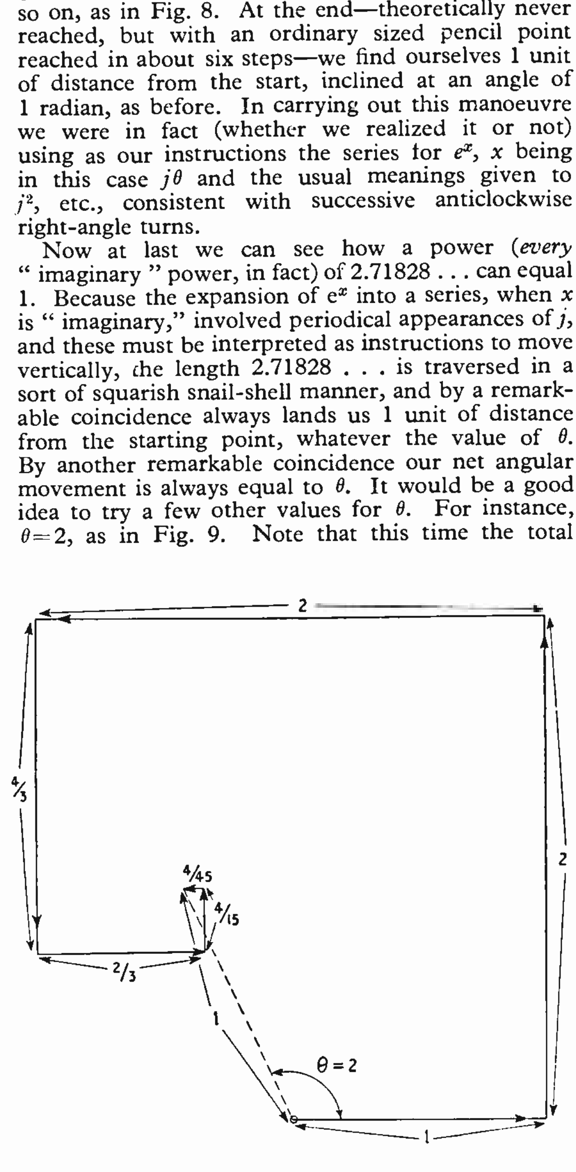


Fig. 9. This is the same as Fig. 8 except that θ = 2.

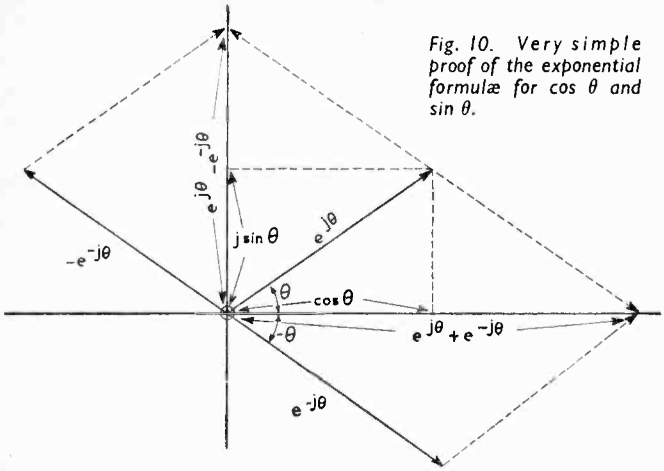


Fig. 10. Very simple proof of the exponential formulæ for cos θ and sin θ.

distance to be covered is considerably greater; actually, of course, e^2, which is about 7.39.

By now we ought to be able to visualize not only $e^{j\theta}$ or e^{jx} as a piece of still life but, having taken several successive values of x, see how a steadily increasing x represents a steadily rotating vector. That is why books on a.c. are full of $e^{j\omega t}$. A frequency f means f cycles (or complete revolutions) per second, or $2\pi f$ $(=\omega)$ radians per second; so ωt is the angle turned through in time t, and since time progresses steadily so does the angle. Therefore $e^{j\omega t}$ signifies a unit vector rotating steadily at f r.p.s. And $Ve^{j\omega t}$ means an alternating voltage v of the same frequency, and peak value V. An impedance (operator) **Z** of magnitude Z and phase angle ϕ can similarly be expressed as $Ze^{j\phi}$. Since the current $i = v/\mathbf{Z}$, it is $Ve^{j\omega t}/Ze^{j\phi}$, and by the usual rule for indices this is $Ve^{j(\omega t - \phi)}/Z$. (To save the printer it is sometimes written V exp $[j(\omega t - \phi)]/Z$.) This indicates that the phase angle of the current is less than that of the voltage; in other words, the current lags behind the voltage. Whenever vector quantities have to be multiplied and divided then, this e^{jx} form is very convenient.

It is also very convenient for working out all those standard trigonometrical formulae we usually have to look up in a book. We have already seen (in Figs. 8 and 9) that $\cos 1 + j \sin 1 = e^{j1}$, and $\cos 2 + j \sin 2 = e^{j2}$, and by the usual law for indices the latter is equal to $(e^{j1})^2$ and therefore to $(\cos 1 + j \sin 1)^2$. This is true in general, i.e.,

$$\cos nx + j \sin nx = e^{jnx} = (\cos x + j \sin x)^n$$

That, by the way, is known as de Moivre's theorem. Suppose we have forgotten the formulae for $\sin 2x$ and $\cos 2x$ in terms of $\sin x$ and $\cos x$. Using this theorem, we put

$$\cos 2x + j \sin 2x = (\cos x + j \sin x)^2$$

and multiply out the right hand side to give

$$\cos^2 x - \sin^2 x + j2 \cos x \sin x$$

As I said before, the real and imaginary parts never mix, so we can equate them separately and get

$$\cos 2x = \cos^2 x - \sin^2 x = 2 \cos^2 x - 1$$

$$\sin 2x = 2 \cos x \sin x$$

(I've done this in " x " so as not to puzzle the unsophisticated by introducing too many different symbols for angles, but for some reason unknown to me the books usually use A for any one angle and B for any other.) Perhaps you would like to practise the same technique to rediscover the formulae for $\sin(A+B)$, etc. The value of the exponential form $(e^{j(A+B)})$ in enabling one to use the adding-indices-for-multiplication law is particularly marked here. By now, in fact, I hope I may be allowed to take the usefulness of e as established. And I hope that any readers who, like me, tended to regard algebra, trigonometry, vectors, logarithms, etc., as separate subjects, pervaded by mysteries such as e^{jx} apparently decreed arbitrarily by remote mathematical high-ups, will find this unattractive vista of things that just had to be learnt giving place to a beautiful interlocking design, formed naturally by just following a few simple laws wherever they may lead.

Here, to end, is one final and very simple example. We have already seen, by expanding the terms into series, that $\cos x + j \sin x = e^{jx}$. Multiplying x by -1, we get $\cos(-x) + j \sin(-x) = \cos x - j \sin x = e^{-jx}$.

Adding these two together and dividing by 2:

$$\cos x = \frac{e^{jx} + e^{-jx}}{2}$$

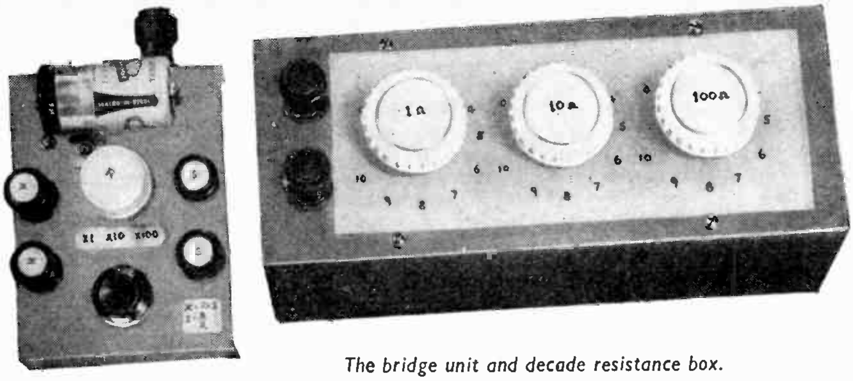
and by subtracting:

$$\sin x = \frac{e^{jx} - e^{-jx}}{2j}$$

These open up new prospects which we have no time to explore just now. The relevant point is that here again we have rather surprising results, and although they are derived from the e^{jx} equation by very simple and entirely lawful means, we may be excused if we feel we have to accept them by faith rather than by sight. However, sight also can be granted very easily by means of our vector diagrams. If, as in the right-hand part of Fig. 10, we add a $e^{-j\theta}$ vector to the $e^{j\theta}$ vector of Fig. 7 (" completing the parallelogram ") we clearly get $2 \cos\theta$. So the answer for $\cos\theta$ could hardly be more obvious! On the other hand, if we subtract $e^{-j\theta}$ (i.e., produce it in the opposite direction as $-e^{-j\theta}$) the answer is almost equally obvious. I can hardly believe that this demonstration is not in lots of books, but it is evidently not in nearly enough of them, because I have never seen it in any.

Television Society Awards

PREMIUMS for papers read at the Television Society's London meetings in 1958/59 have been awarded to the following: K. H. Smith, of A.E.I., receives the *Wireless World* premium for his paper " Design of Experimental Tuners for Bands IV and V Receivers "; E. Ribchester (G.E.C. Research Laboratories, Wembley), the E.M.I. premium for " Experimental Colour Receiver: Setting up and Adjustment "; D. Ingman (Young and Rubicam) the *Electronic Engineering* premium for " Advertising in Relation to Television "; B. Marsden (Associated Television) the Pye premium for " Master Control Room Techniques " and C. Grant-Dixon (British Amateur Television Club) the Mervyn pemium for " The Present Position in Amateur Television." The Mullard premium goes to Dr. K. Schlesinger (General Electric Co., New York) for his paper " A New Electron Gun with Low Drive Signals " published in the Society's *Journal*. For his colour television receiver exhibited at the Society's 1959 Exhibition, John Ware receives the T.C.C. premium.



The bridge unit and decade resistance box.

Simple Wheatstone Bridge

By H. B. DENT

Making an Inexpensive Resistance Measuring Set with a Potentially High Order of Accuracy

FOR some time past the writer has felt the need for means of measuring resistance with greater precision than that provided by the popular type of ohmmeter, but since the need was not pressing it was decided to try to make a reasonably high grade piece of apparatus without the expenditure of too much money.

Reviewing the various means of measuring resistance it was felt that a Wheatstone bridge would probably be the best for this purpose as it seemed to be the easiest to construct with the very limited resources available at the time. Actually apart from a few precision resistors and a meter or two there was little else that seemed likely to be of any use in making and calibrating a bridge. There was a quantity of Eureka resistance wire in assorted gauges so this decided the use of wirewound resistors throughout.

The prospect of producing anything in the nature of precision measuring equipment seemed very remote at first, but as more thought was given to the matter it seemed likely that a reasonably satisfactory piece of equipment might conceivably emerge, with a little care and some patience, which would be capable of measuring resistance from a fraction of an ohm up to 10kΩ or possibly 100kΩ with an accuracy better than 1% over most of this range.

The Wheatstone bridge is possibly one of the oldest systems for measuring resistance and it forms the basis of many modern impedance-measuring bridges. The versatility of the Wheatstone bridge cannot be denied, yet it is a simple piece of apparatus and this was a deciding factor in the decision to make up a bridge of this kind. Basically it consists of four resistance arms arranged symmetrically as in Fig. 1, with a constant voltage applied across one diagonal and a sensitive meter, such as a milliammeter or preferably a microammeter, connected across the other diagonal. The bridge is said to be balanced when no current flows through the meter and this condition obtains when $R_1/R_2=R_3/R_4$. Now if R_3 (usually denoted by x) is the unknown resistance to be measured, or adjusted, $x=(R_1/R_2)\,R_4$.

Since only the ratio of R_1 and R_2 need be known—their exact values are unimportant—it is only necessary to know the exact resistance of R_4 to determine the value of the unknown resistance x. By using a calibrated resistance for R_4, such as a decade resistance box, quite a wide range of resistance can be measured and adjusted with a fixed ratio R_1/R_2. But if these two, generally called the ratio arms of the bridge, can be changed to two or three accurately known ratios, then the usefulness of the bridge is considerably extended, even with quite a modest range of resistance at R_4. Decade ratios are the most convenient for R_1/R_2 as, with the bridge balanced, R_4 has only to be multiplied by the ratio in use to determine R_3. By arranging R_1/R_2 to be $\frac{1}{10}$ or $\frac{1}{100}$, resistance can be measured at R_3 which is $\frac{1}{10}$ or $\frac{1}{100}$ of the resistance provided by R_4. However it is not essential to introduce switching into the ratio arms because by merely changing over R_3 and R_4 the R_1/R_2 ratio, which hitherto provided a multiplying factor for the calibrated box, now provides a dividing factor of the same order.

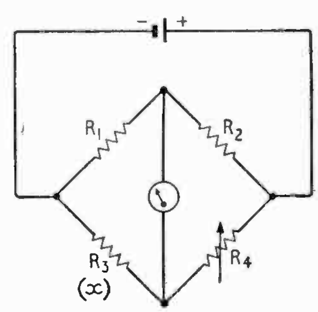


Fig. 1. Basic circuit of the Wheatstone bridge.

A lot of the preliminary work entailed in making the bridge could have been avoided by purchasing precision resistors for the ratio arms R_1 and R_2, and a few assorted precision resistors, for the purpose of calibrating a resistance of one kind or another for use at R_4. As it was particularly desirable to keep expenditure as low as possible it was decided to make do with the available parts, among which were precision resistors of 10Ω and 100Ω.

It was decided to make a decade resistance box for R_4, but not to incorporate it in the bridge, as it would also be useful for other purposes; likewise the meter was not included. Terminals would be used for connecting in these external items. Stripped of these items very little remains of the bridge, only R_1 and R_2, the ratio-arm switch, battery and its switch and six terminals are all that comprise the bridge unit, so even if it is used only very occasionally nothing of any value is permanently tied up (and so made unavailable for other purposes).

Three decades of resistance one each of 1-Ω, 10-Ω and 100-Ω steps were decided on for R_4. With R_1/R_2 ratios of 1 to 1 and 10 to 1 only, resistance of from 0.1Ω (theoretically) to 11.1kΩ can be measured on the bridge with the above three decades. Measurements to 0.1Ω have been made, the widest tolerance being 2% in a 1.5-Ω resistor (home bridge value) compared with a laboratory standard, but with one of 19.9Ω the accuracy was 0.2%, the same close agreement being achieved with a home-made (and adjusted) 100-Ω resistor. All these were, of course, wirewound.

Construction of the Bridge Unit.—The first step in the construction of the bridge unit was to make two very closely matched resistors for the ratio arms R_1 and R_2. This was effected by using a 52-in length of No. 36 s.w.g. double-silk covered Eureka resistance wire with the exact centre connected to the point A in Fig. 2 and the two outer ends to B and C respectively. The two sections can be wound, for convenience in handling, on a rod or strip of insulating material such as shown in Fig. 3. The temporary bridge (Fig. 2) comprised a 1.5-volt dry cell, resistor R_5 of 33Ω, a press-to-make single-pole switch S_1 and six terminals, two each for the meter, standard resistor R_4 and R_3 the resistor to be adjusted or measured. The resistor R_5 was included to limit the current through the bridge to a reasonable value, and, of course, R_1 and R_2.

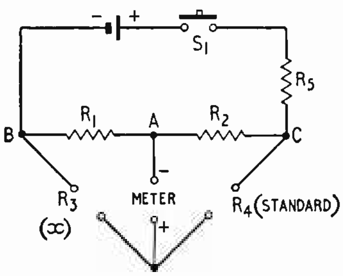


Fig. 2. Resistors R_1 and R_2 constitute a ratio arm, their exact values need not be known.

Ideally the balancing indicating meter should be a centre-zero type milliammeter or microammeter, but quite satisfactory results can be obtained with an ordinary 0-1mA meter with its pointer off-set slightly from the normal zero position. The usual "zero adjuster" should allow sufficient movement of the pointer. The writer used a meter of this kind for making the bridge described here.

The reason for using a 52-in length of No. 36 s.w.g. Eureka wire is that each half (26in) is approximately 10Ω and a bridge of this kind is most sensitive to small differences in any of its four arms when all four resistances are of equal value, or very nearly so. It was thought undesirable to assume that the measured lengths of wire for R_1 and R_2 provided two resistors of exactly the same resistance, although the resistances would be close enough to satisfy many requirements in a bridge of this kind. The aim was to achieve the highest possible accuracy throughout. So two new resistors of known close match were made. For this purpose a 10-Ω standard was used in the R_4-position and a 26-in length of No. 36 s.w.g. Eureka connected to the x terminals.

With the polarities of battery and meter shown in Fig. 2 the pointer of the meter will probably move *up* the scale when d.c. is fed to the bridge by closing switch S_1. This direction of movement would indicate that the resistance of x is higher in value than R_4 and it should be progressively shortened until a perfect balance is achieved. The conditions obtaining are now that $R_1/R_2=x/R_4$. If R_1 exactly equals R_2, x would equal R_4, but the assumption that $R_1=R_2$ is only based on measurement of the length of the wire in each, it has not been verified by any test so x might or might not exactly equal R_4.

The measured length of wire at x can be removed and wound on a former like Fig. 3 but with only two wire pigtails, one at each end. Those used by the writer for the 10-Ω resistors, and for this one also, were strips (often called cards) of Paxolin $\frac{7}{8}$in long, $\frac{1}{4}$in wide and $\frac{1}{32}$in thick. A winding length of $\frac{1}{2}$in between end pigtails is ample. When winding on the wire care must be taken to ensure that the exact length of wire found to give the required resistance (the amount that was finally between the two terminals x on the bridge) is wound on the card. The excess, or part of it, can be used to twist round the end pigtails. Only one end of the resistance wire should be soldered to its pigtail at this stage, the other not being soldered until a further check has been made on the bridge and any final adjustment effected.

Another resistor exactly like the one just described is also required, these two are to replace the temporary R_1 and R_2 resistors in the bridge as they have now served their purpose. The two new resistors may not be exactly 10Ω each, but if they have been carefully made they will be of equal resistance. Close matching of these two resistors is a vital factor in the bridge as the final overall accuracy depends entirely on the matching of these two resistors at this stage.

It will be useful to remember when adjusting resistors wound with No. 36 s.w.g. Eureka wire that a $\frac{1}{4}$-in length measures approximately 0.1Ω. Contact resistance at the x- and R_4-terminals can affect the accuracy of adjustment of these resistors (and all subsequent ones) so terminals must be screwed down securely. Likewise, similar precautions to keep contact resistance down to the minimum must be taken throughout the bridge circuit; No. 18, s.w.g. tinned copper wire, or heavier gauge if available, should be used and all soldered joints must be good ones, no "dry" joints!

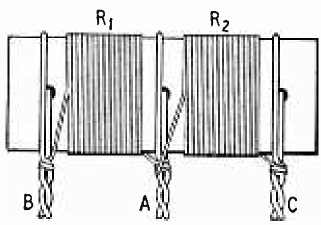


Fig. 3. Suggested method of constructing R_1 and R_2.

The two accurately matched resistors can now replace the temporary centre-tapped length of wire forming R_1 and R_2 and, with the bridge (still only in temporary form at this stage) now in a more satisfactory form for accurate measurement, attention can be turned to making up one of the resistance decades. A finalized form of the bridge cannot be made at this stage as R_1 and R_2 are still only "temporary" resistors. The final R_1 and R_2 have to be as close as possible to 10Ω and it is also required to provide one of 100Ω to make R_1 into a two-ratio arm as shown in Fig. 4.

If a 100-Ω standard is available it could be used for the multiplier, or a 100-Ω resistor made up using the 100-Ω standard in R_4 position of the bridge. For the present purpose it will be assumed that a 100-Ω standard is not available and while one could have been used in making the author's version of the bridge the temptation to use it was resisted primarily in order to explore the possibilities of constructing the equipment with only the one 10-Ω standard as the yardstick.

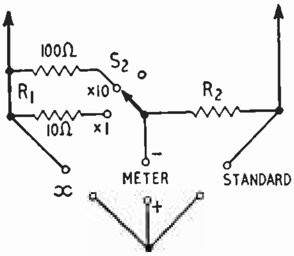


Fig. 4. By switching R_1 two or more ratios R_1/R_2 can be provided.

In all 12 resistors of exactly 10Ω are required and each can be made in the same way as already described for the latest R_1 and R_2 resistors. With R_1 now equal to R_2 the new resistors will be exactly equal to R_4, 10Ω with an accuracy which, if sufficient care is taken in adjustment, to about the same order as that of the standard. These are all wound on Paxolin cards as used for R_1 and R_2. When completed they can be "doped" with any good impregnating varnish, or shellac varnish which was the writer's choice.

Shellac varnish may be a little old fashioned but it is reasonably easy to obtain, or rather to make, since it consists only of flake shellac dissolved in methylated spirit.

The ten 10-Ω resistors can now be assembled on a single-pole 11-way rotary switch as shown in Fig. 5 and in the illustration of the finished box. A 12-way switch was actually used as an 11-way was not readily obtainable. They were small switches measuring only 1¼in in diameter, but any kind will serve. With the small switches used by the writer the three decades are housed in a box 8in. × 3½in. × 3½in made of ⅜-in thick oak with a $\frac{1}{16}$-in thick aluminium top plate on which the switches and terminals are mounted. Home-made scales, 0–10 for each decade, are marked on drawing paper and glued to the aluminium top plate of the box with "Durofix." If professionally made scales can be obtained with the switches they might be preferable, but the size of the box will then have to be adjusted to suit the scales. Likewise the small pointers on the knobs are home made, being cut from thin sheet brass and fixed to the underside of the knobs with 8BA screws, the knobs being drilled and tapped for the purpose. Knobs with pointers are however obtainable.

This 10-Ω decade with all 10 resistors in series was used as the standard for making the 100-Ω units for the 100-Ω decade. Eleven resistors are required, one for the multiplier in the bridge unit and 10 for the decade. Each 100-Ω resistor requires about 68in of No. 42 s.w.g. (d.s.c.) Eureka resistance wire. Since the resistance of different batches of wire may vary slightly for a given length a start can be made with 70in, later cut down to what is found to be the optimum for the wire used. The Paxolin cards on which these are wound measure 1in long, ⅜in wide and $\frac{1}{32}$in thick with wire pigtails at each end leaving a winding length in the centre of ⅝in. Procedure for making them is the same as for the 10-Ω resistors, but the fine gauge wire needs careful handling. For the record, No. 42 s.w.g. Eureka measures 0.672in (nominal) per ohm, so for a 0.5% resistance tolerance the length of wire on each resistor must be within 0.34in of the optimum length.

If the constructor has not had previous experience in making wire-wound resistors of this kind and to such close tolerances, a few early failures must be expected, but they should not be discouraging. It is essential for each unit to be as accurate as it is possible to make it.

The next job is to make the decade of 1-Ω units, but before embarking on this the bridge unit has to be put into correct form. Sufficient parts have now been acquired to justify making a final version of the unit. If the 10kΩ limit is acceptable the circuit arrangement of Fig. 4 will suffice, but if it is required to carry the measurements up to 100kΩ then a third multiplier must be added. Another switch could be embodied to switch R_2 from 10Ω to 1Ω but the writer preferred to switch R_1 only using a single-pole three-way switch for S_2 and fit a 1,000-Ω multiplier to give a 100 to 1 ratio. The 1,000-Ω multiplier will be dealt with later.

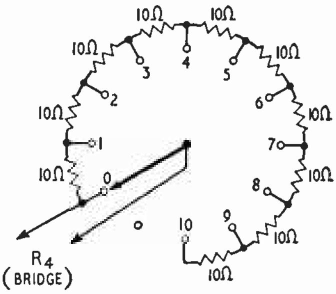
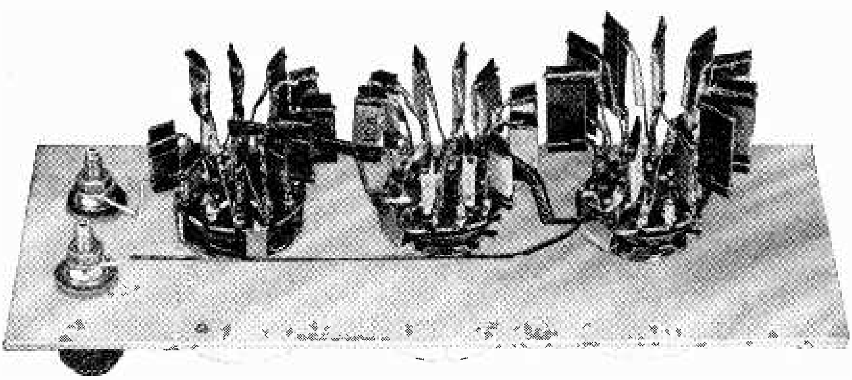
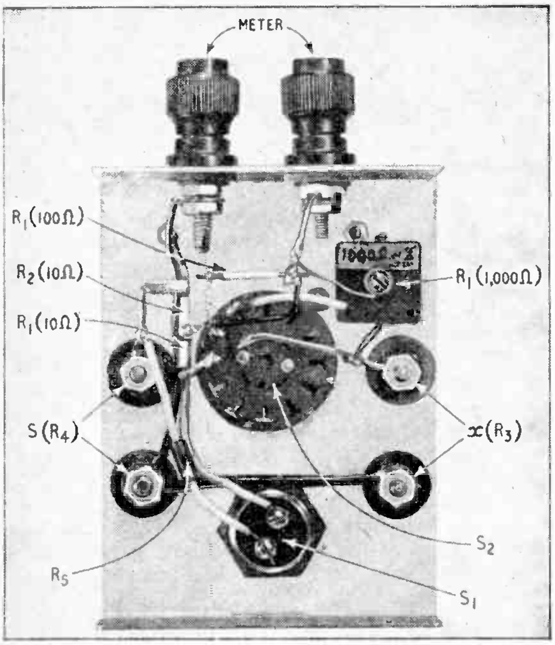


Fig. 5. Schematic arrangement of the completed 10-Ω decade.

As the lowest resistance standard available was 10Ω, adjustment of the 1-Ω resistors on the bridge required a R_1/R_2 ratio of $\frac{1}{10}$ and as explained earlier this can be achieved by changing over the positions of *x* and the standard R_4. The final version of the bridge takes the form shown in Fig. 6, with the various parts assembled on a small aluminium



The three resistance decades mounted on the underside of the aluminium top panel of its box.



Underside view of the bridge unit.

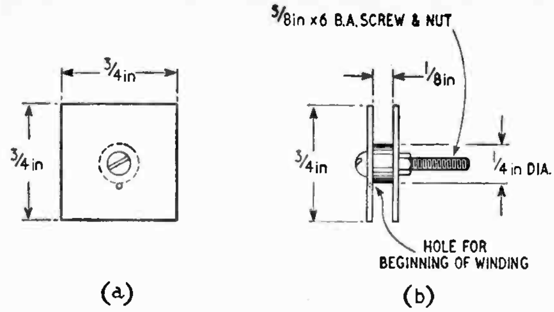


Fig. 7. Details of the bobbin for the 1,000-Ω ratio-arm resistor in Fig. 6.

chassis, or on the top plate of a box of suitable size and depth. How the bridge unit is made is of little consequence provided the precautions mentioned earlier are taken in its construction.

Now with the 10-Ω standard connected to the x-terminals of the bridge, the ratio switch S_2 set to ×10 (effectively × $\frac{1}{10}$), for the 1-Ω resistors a start can be made with 11in of No. 28 s.w.g. Eureka (d.s.c.) wire, connected to R_4 terminals. The procedure for adjusting them follows the same general lines as for the 10-Ω and 100-Ω resistors. The card on which they are wound can be the same size and type as that for the 10-Ω resistors ($\frac{7}{8}$in × $\frac{1}{4}$in × $\frac{1}{32}$in) and with a $\frac{3}{8}$-in winding space between the end wire pigtail connections. It is doubtful if an accuracy better than 2% to 3% can be achieved with the 1-Ω resistors using the method described here. Extra special care must be taken to keep terminal and switch contact resistance down to the absolute minimum otherwise quite large errors in adjustment of the resistance will be inevitable.

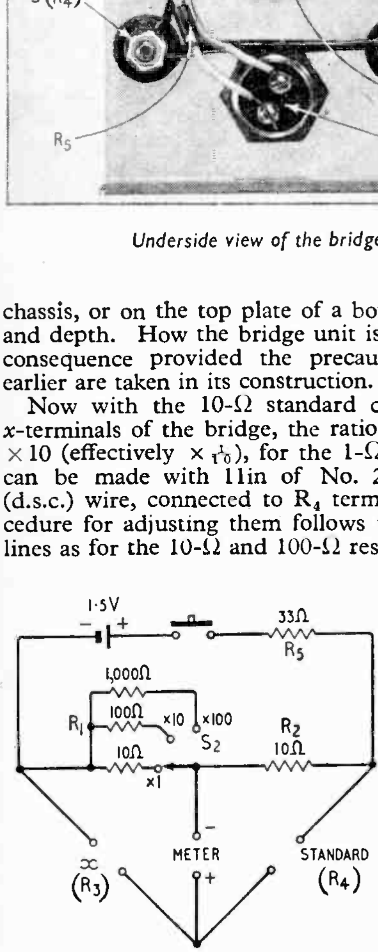


Fig. 6. Circuit of the complete bridge unit.

The 1,000-Ω resistor used by the writer for the ×100 multiplier position of R_1 Fig. 6, was wound random-wise on a small bobbin using No. 42 s.w.g. (d.s.c.) Eureka resistance wire. The bobbin consisted of two end cheeks $\frac{3}{4}$in square and $\frac{1}{16}$in thick separated by a centre boss $\frac{1}{8}$in long cut from a piece of $\frac{1}{4}$-in diameter Paxolin rod. A plastic knitting needle would serve just as well. All three are clamped together by a 6BA nut and screw, the latter $\frac{5}{8}$in long; the projecting part of the screw being used to secure the bobbin to the bridge chassis. A small hole was drilled for the beginning of the winding as shown in Fig. 7(b). There are several ways of providing re-inforcement for the lead-out wires when very fine wire, such as No. 42 s.w.g., is wound on a bobbin. One is to fold the wire lengthwise two or three times, twist the strands together and wind one or two turns of the reinforced part round the centre of the bobbin; another is to solder the fine wire to a heavier gauge of wire (copper wire) and also wind one or two turns of it round the centre boss. The writer favours the second mentioned method, but it is inclined to make the winding a little uneven. Very thin insulating paper, or something equivalent, must be wrapped over the soldered joint and corrosive-type fluxes must be avoided at all costs.

For 1,000Ω about 19 yards of No. 42 s.w.g. (d.s.c.) Eureka resistance wire is required, but as it is awkward to measure without getting the wire into a hopeless tangle (Eureka is a "springy" type of wire) it is best to take a chance and wind on 550 turns; an ordinary hand drill can be used if a winding machine is not available.

The whole of the 100-Ω decade was used as the "standard" for adjusting the 1,000-Ω resistor, the decade box having previously been assembled with its three decade switches and resistors and wired up as shown in Fig. 8.

It is often difficult to know where to obtain small quantities of wire and other items for home construction of apparatus. Eureka resistance wire in small quantities is obtainable from Post Radio Supplies, 33 Bourne Gardens, London, E.4. One ounce of No. 42 s.w.g. (bare) Eureka wire has a resistance of 23,013Ω so even allowing generously for waste half an ounce of this fine gauge wire would suffice, assuming such a small quantity is procurable. The larger sizes of wire are not so expensive so that discriminating purchase is not so important.

Most of the firms advertising components in this journal will be able to supply the switches, but the Paxolin sheet may be more difficult to obtain. The writer found some in one of the shops dealing largely in disposal equipment and materials, but there is no reason why one of the several brands of plastic sheet

(*Continued on page 195*)

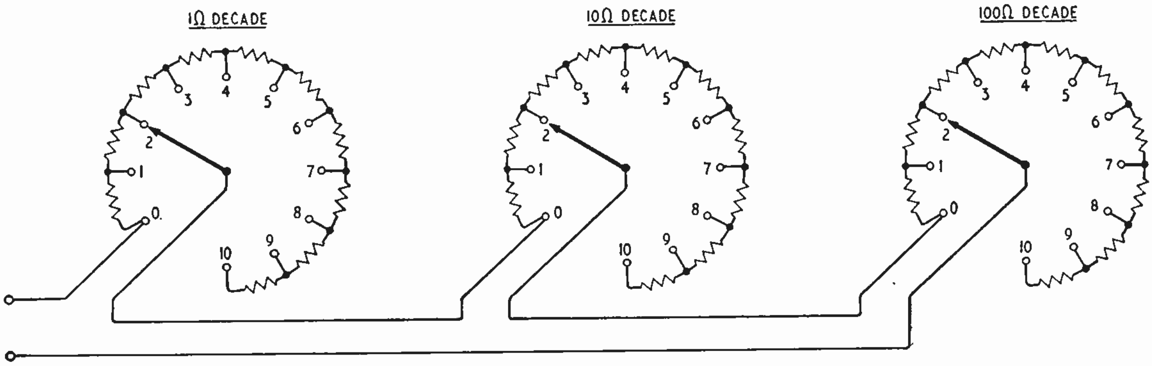


Fig. 8. Schematic arrangement of the completed three resistance decades.

sold for domestic uses should not be used. The only qualities required are toughness and good insulation to d.c. and if the decade box is ever to be used for a.f. purposes, good insulation to frequencies up to say 20kc/s, but as the resistors are not non-inductively wound the accuracy at a.f. might be questionable.

Commercial Literature

High Stability Resistors of the carbon film type. Ratings of $\frac{1}{4}$W, $\frac{1}{2}$W, $\frac{3}{4}$W and 1W with tolerances of $\pm 1\%$ and $\frac{1}{4}$W rating with tolerance of $\pm 5\%$. Details and price list in leaflets from Standard Telephones and Cables, Edinburgh Way, Harlow, Essex. Also a brochure on **Silicon Rectifier Stacks** consisting of silicon junction rectifiers mounted in cooling fins.

Rare Earth Products, in the form of pure oxides and metals, are now available from Johnson Matthey in larger quantities and at lower prices (15 elements from lanthanum, atomic number 57, to lutetium, atomic number 71). Booklet describing their properties from the firm at 73-83 Hatton Garden, London, E.C.1.

Mobile H.F Station for communications in the range 2-22Mc/s with an output of 350 watts p.e.p. Can be installed in a 1-ton truck and will give voice communication up to 70 miles (as well as telegraphy). Specification in a booklet from Marconi's Wireless Telegraph Company, Chelmsford, Essex.

R.F. Beam Tetrode, for power amplification up to 100Mc/s, high-speed pen recorders, and frame deflection for 110° c.r. tubes are three of the subjects dealt with in the November, 1959, "Radio & Electronics Review," a quarterly survey of products from A.E.I. (Woolwich), 155 Charing Cross Road, London, W.C.2 Also a leaflet on new **Transistors**—high-speed switching, high-voltage power and audio power output types.

Reflex Speaker Columns, suitable for stereo because of their small floor area of 17in × 10in. Also other speaker enclosures and equipment cabinets in an illustrated leaflet from Record Housing, N. & S.B. Field and Company, Brook Road, London, N.22.

Radar Developments.—A well produced and copiously illustrated booklet "The First Ten Years of Decca Radar" describing some of the important contributions to modern radar technique made by this company during the period 1949-59. From Decca Radar, Albert Embankment, London, S.E.11.

Switches and Signal Lamps.—A 60-page catalogue lists the complete range of products and contains blueprint diagrams with dimensions, etc., while an abridged 16-page catalogue lists the whole range without blueprints. From Arcolectric (Switches), Central Avenue, West Molesey, Surrey.

Components and Accessories, including aerials, receivers and sound reproduction equipment; a 1960 comprehensive illustrated catalogue of 127 pages listing the complete range from Home Radio (Mitcham), 187 London Road, Mitcham, Surrey; price 2s 9d including postage.

Crystal Marker Oscillator, a small transistorized unit weighing only 5½oz, including battery, is now available for a wider range of frequencies, from 500kc/s to 20Mc/s. Frequency stability on load is better than 0.01%. Leaflet from Labgear, Willow Place, Cambridge.

Electronic Stroboscopes, vibration measuring instruments, sound level and noise meters and analysers, and dynamic balancing equipments. Brief technical details in tabulated form on illustrated "summary leaflets" from Dawe Instruments, 99 Uxbridge Road, Ealing, London, W.5.

CLUB NEWS

Birmingham.—A 160-m mobile rally at Lickey Beacon, Rednal, is being organized by the South Birmingham Radio Society on April 3rd at 10.30. At the monthly club meeting on the 21st at the Friends Meeting House, 220 Moseley Road, T. R. Smith (G3BMN) and R. D. Franklin (G3ITH) will give a lecture on two-metre operation.

The month's meetings of the Midland Amateur Radio Society include a talk by Brigadier F. Jones on the G.P.O. subscriber trunk dialling system (7th); a talk entitled "Radio pictures of the sky" by K. Stevens, who has constructed his own radio telescope (19th); and a mobile rally (24th). The rally is being organized jointly with the Stoke Radio Society and will be held at the Trentham Gardens, Stoke-on-Trent.

Bradford.—D. G. Enoch (G3KLZ) will give a lecture on the development of television at the meeting of the Bradford Amateur Radio Society on April 26th. Meetings are held at 7.45 at Cambridge House, 66 Little Horton Lane.

Doncaster.—The South Yorkshire Amateur Radio Society meets on the 2nd Tuesday and 4th Thursday of each month at 8.0 at the Stag Inn, Dockin Hill Road. On April 12th there will be a general discussion on aerial systems and on the 28th W. Farrar (G3ESP), secretary of the Society, will discuss the radio amateur examination.

Leeds.—The theme of the meeting of the Leeds Amateur Radio Society on April 6th will be the radio control of models. The meeting will be held at 7.45 at the Swarthmore Education Centre, 4 Woodhouse Square.

Reading.—A lecture demonstration will be given to members of the Calcot Radio Society by a representative of Truvox on April 21st at 7.45 at St. Birinus Church Hall, Calcot.

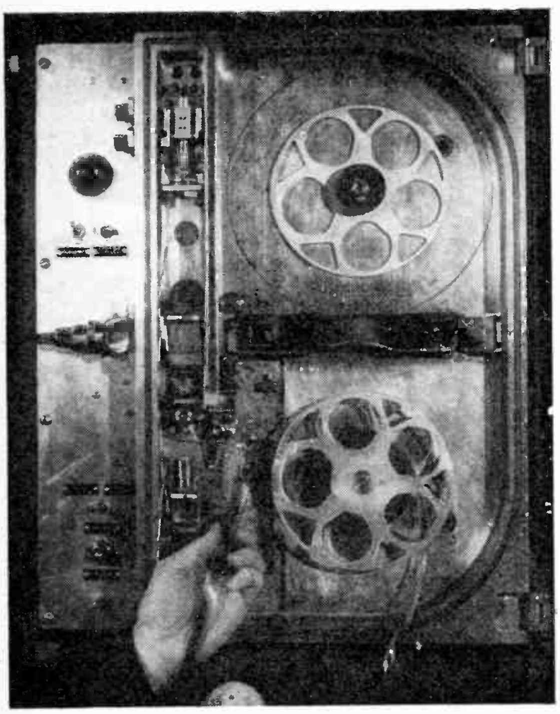
India.—The secretary of the recently formed Electronics Club, Trivandrum, S. India, has asked for back numbers of radio journals. His address is:—C. Pereira, The Electronics Club, Trivandrum, S. India.

Thermoplastic Recording

NEW SYSTEM WITH HIGH INFORMATION DENSITY AND HIGH PROCESSING SPEED

SIGNALS are recorded in the form of deformations of the surface of a special transparent tape in a new system developed by Dr. W. E. Glenn of the General Electric Company of America and described by him in the *Journal of Applied Physics* for December, 1959 (p. 1870).

In this system the tape is made up of three layers: a high melting point base similar to that used for

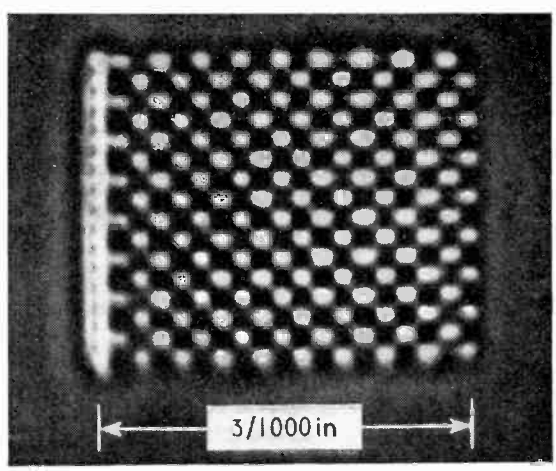


Thermoplastic recorder (G. E. of America).

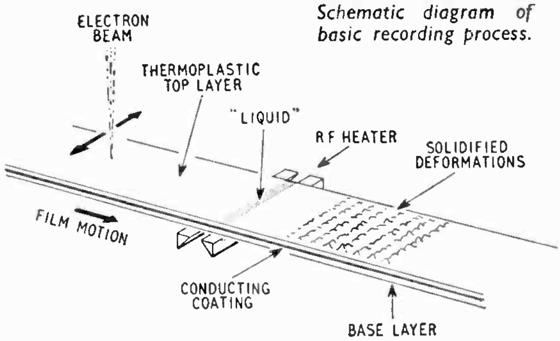
ordinary cinematograph film, an electrically conducting coating on top of the base, and a thin film of thermoplastic material on top of the conducting coating. The signal to be recorded is used to modulate the intensity of a fine electron beam in a vacuum so as to lay down a pattern of charges of variable density on the surface of the thermoplastic. The thermoplastic is then heated until it softens. The attraction between the surface charges and the conducting film then deforms the surface of the thermoplastic until equilibrium is reached between the surface-tension restoring forces produced by the deformations and the electrostatic deforming forces. Recorded deformations can be erased by heating the thermoplastic well above its melting point which also makes it conducting. This disperses the charges on the thermoplastic surface and surface-tension forces then resmooth this surface. R.f. heating can be used to erase, and local erasure in an area as small as a few mils square can then be made possible by confining the r.f. fields.

The recording tape is wound on and off spools as in an ordinary tape recorder. After the charges are laid down in a television-like raster by the electron gun, the tape passes over an r.f. heater. This induces currents in the conducting coating which heat the top surface layer of the tape for about the 10msec necessary to give the thermoplastic plenty of time to deform. After the tape has passed beyond the r.f. heater, the top layer of the tape then cools and the deformations are frozen in. The whole apparatus is continuously evacuated down to a pressure of about 0.1 microns.

One advantage of this recording system is that colour and black and white video signals can be recorded in such a way as to permit immediate visual reproduction by optical means. To permit such reproduction in colour, each signal is recorded in the form of four parallel deformations making up a small diffraction grating, and an optical system described by Dr. W. E. Glenn on p. 841 of the November, 1958, issue of the *Journal of the American Optical Society* is used. In this system, the light from a number of equally-spaced line sources is focused by a lens through the recording tape on to a number of equally-spaced opaque bars parallel to the line sources: any light which should happen to pass between the opaque bars is in turn focused by a second lens on to a viewing screen. Any grating deformations recorded on the tape will then diffract the light between the opaque bars through the second lens and on to the screen to form an image whose position corresponds to the position of the grating deformation and whose brightness cor-



Example of high information density thermoplastic recording. If the light and dark squares are taken to represent 0 and 1 on the binary number system, the recorded information density is 4×10^7 bits per square inch.



Schematic diagram of basic recording process.

responds to the amplitude of the deformations in the grating. The spaces between the opaque bars are made so small that they let through only one diffracted colour, the wavelength of this colour being determined by the spacing between adjacent deformations in the grating. By superimposing several grating deformations, a coloured image can thus be built up. To build up such images it is convenient to use one fixed and one variable colour rather than a three-colour system. Each grating is then recorded by means of a beam which is split in one plane into a number of equally-spaced side-by-side beamlets. The splitting is carried out by means of an extra grid between the normal accelerating anode and the tape, this grid being made slightly positive with respect to the anode. The exact potential difference between the splitter grid and the anode then determines the spacing between adjacent parts of the split beam, and thus also the spacing between adjacent deformations in the recorded grating, and thus in turn the reproduced colour. Black and white images can be obtained by broadening the line sources and enlarging the spaces between the opaque bars until the full range of visible light wavelengths is let through: the recording being then made in single lines. Electrical reproduction of recorded signals by means of normal flying-spot scanning techniques is also possible.

Another advantage of this system is that recordings can be made with a very high information density, values as high as 4×10^7 bits per square inch having been achieved. Video recordings have been made on a 0·1-in wide track with the tape running at only 5in/sec; this may be compared with effective tape speeds of at least several hundred in/sec necessary with ordinary magnetic tape for video recording.

Frequency Allocation Problem

Computation Methods Used in Trying to Solve America's Growing Navaid Congestion

By *MICHAEL LORANT*

THE U.S. National Bureau of Standards, at the request of the Federal Aviation Agency of the United States, is studying automatic computation methods for determining the best possible operating frequencies for radio transmitters used as " road markers " on air lanes. A network of such transmitters marks routes between cities by sending out signals which assist pilots in flying a straight-line course. The rapid expansion of commercial and military air operations makes it necessary to add a substantial number of new transmitters to this network each year. The locations of these transmitters are determined by technical and economic considerations. However, the choice of carrier frequencies constitutes a surprisingly difficult problem. Efforts to solve this problem are being carried out by L. Joel, G. M. Galler, and A. J. Goldman of the Bureau's Applied Mathematics Division.

The difficulties of frequency selection stem from the fact that transmitters with identical or neighbouring carrier frequencies must be spaced widely enough to prevent signal interferences. Furthermore, this must be accomplished within the scope of 100 discrete frequencies assigned to the F.A.A. However, not only is the " interference radius " of a transmitter large (approximately three times the radius its signal actually serves) but the number of transmitters in existence is already considerable and is increasing rapidly. For these reasons, allocating a frequency to a new transmitter without introducing any interference requires a laborious examination of many existing transmitters.

Such an allocation may, in fact, be impossible without changing the frequency of one or more existing transmitters. This, in turn, may create new interferences in the system and require alteration of the frequencies of still more transmitters. The insertion of a new transmitter into the network has sometimes required frequency changes at as many as 11 existing transmitters. Such changes are expensive and disturb the smooth operation of the system, since pilots must be informed of and become accustomed to the alterations. An additional requirement introduced into frequency allocation is therefore the limitation of the number of changes.

As the frequencies and transmitters (old and new) are finite in number, there is only a finite number of ways in which frequencies can be allocated throughout the network. This means that in principle the problem could be solved by examining all such network-wide allocations, rejecting those which lead to interference, and then selecting from the remainder one which allots the original frequencies to the largest number of existing transmitters. This procedure is impractical because the number of cases to be examined, though finite, is so enormous (exceeding 10^{2000}) that the investigation could not be carried out in a reasonable time even on the fastest electronic computer. What is needed is a systematic, rather than an exhaustive, procedure.

The Bureau's efforts toward such a procedure can be roughly divided into two categories, which may be called " *ad hoc* methods " and " model construction." The preliminary direction of the *ad hoc* activities was suggested by the fact that many new transmitters require changing, at most, one old transmitter. As a temporary aid to the Federal Aviation Agency and an introduction to the general problem, a routine has been devised to make such " easy " frequency allocations when possible.

The major activity in the " model construction " technique has been the examination of a procedure which reduces the frequency allocation problem to the maximization of a sum. Computational methods and computer programming codes, although not immediately applicable in this instance, are available for this general type of problem, and efforts are being made to adapt them for frequency selection.

Ad Hoc Methods.—The computer programme developed on an individual or *ad hoc* basis first evaluates for each frequency, f, the number n_f, of old transmitters which would be interfered with should f be assigned to the new transmitter. It then notes the identity, T_f, of the first such old transmitter (if $n_f > 0$). If $n_f = 0$ for some frequency, then the new transmitter can simply be given that frequency, f. If $n_f > 1$ for *every* frequency, then the new transmitter cannot be introduced without changes of at least *two* old transmitters. If $n_f = 1$ for some frequency, then the new transmitter and T_f are artificially " interchanged "; that is, T_f is treated as a new transmitter, the (original) new transmitter is treated as an old transmitter with frequency f, and the programme is applied to this artificial situation to see whether T_f can be assigned a frequency without any change elsewhere in the system. If this proves possible the routine is completed; if not, it is impossible to assign f to the new transmitter without the changes elsewhere, and so the programme moves on to the next frequency for which $n_f = 1$.

The computer routine can be extended to examine cases in which more than one old transmitter must undergo a frequency change. However, this provides at best an inefficient approach to the problem, since it is merely an automatic trial-and-error process with no facilities for taking advantage of the special properties of the system that a deeper analysis might uncover.

Model Construction.—In the procedure now being considered as a real solution to the overall problem, a variable X_{fT} is associated with each frequency, f, and transmitter, T. X_{fT} is interpreted as having the value 1 if the frequency is assigned to T and the value 0 if it is not. The requirement of no interference is readily expressed in this notation. If, for example, transmitters 1 and 2 are so close together that they cannot have the same frequency, then the conditions " $X_{f1} + X_{f2} \leqslant 1$ for all f " must be imposed. The equation " $\sum_f X_{fT} = 1$ for all T " expresses the fact that each transmitter is allocated exactly one frequency. If constants X°_{fT} are introduced which take the value 1 or 0 depending upon whether the old transmitter T does or does not have the frequency f, then the expression $\sum_{fT} X^\circ_{fT} X_{fT}$ (where the sum is over old transmitters only) represents the number of old transmitters left unchanged by the variable allocations denoted by the X_{fT}'s. The variables should therefore be chosen to maximize this sum, subject to the constraints described above.

The maximization of a linear function subject to linear equation and inequality constraints is the typical problem of a fairly new branch of applied mathematics known as " linear programming." Several computational methods and computer codes are already available for the solution of such " linear programmes." However, these standard codes are not usable for the frequency selection problem because their limitations are greatly exceeded by the numbers of variables (about 250,000) and constraint conditions (about 1,200,000) involved. Nevertheless, there is reason to believe that this difficulty can eventually be overcome by exploiting the special nature of the constraints to modify the standard linear programming codes.

The result of the research should be a considerable improvement in the rapid and accurate allocation of carrier frequencies to new Federal Aviation Agency transmitters.

Telephone Hearing Aid

WEARERS of hearing aids experiencing difficulty in using the ordinary P.O. telephone should be interested in a small attachment for the earpiece of the P.O. handset which gives considerable amplification of the received speech.

It is known as the Clarafon and as the illustration shows is the same diameter and shape as the earpiece and is just under $\frac{3}{4}$in deep.

It operates by magnetic induction, the thick moulded spike on the Clarafon houses a pickup coil and all sound currents flowing through the normal earphone bobbins induce corresponding voltages in the pickup coil by the resultant change in magnetic flux that normally operates the diaphragm. The voltages induced in the Clarafon pickup coil are amplified by three transistors, the amplified output being fed to an ordinary magnet telephone receiver occupying approximately the same position as the original earpiece.

The Clarafon is powered by two self-contained Mallory RM625 batteries, their estimated life being over 1,600 three-minute call periods. It incorporates a volume control and on-off switch, these two controls being the white projections visible on the side of the adaptor. After switching on the unit should be rotated round the earpiece in order to position its pickup coil in the strongest magnetic field. As the unit need not be removed except for replacing batteries re-positioning the pickup arm is only needed very occasionally.

The Clarafon is made by Multitone Electric Co. Ltd., 12-20 Underwood Street, N.1, and the price is £14 14s.

Multitone Clarafon P.O. telephone hearing aid.

A Brief and Not Too Informative Discourse on the Subject of

TECHNICAL WRITING

By JACK DARR*

NOT too long ago, P. P. Eckersley gave us some very sage advice about technical writing. Later, the Editor condescended to hold forth on the subject, together with some pertinent (and impertinent) comments by Mr. Waldron in the correspondence columns. Now that these capable and competent gentlemen have chopped down the tree, may I gather up a few chips for firewood? Just in case they missed anything let's briefly discuss some of the salient facts about the gentle art of technical writing, methods which they might have overlooked.

Really, there are a frightful lot of things that a good technical article must be: factual, informative, clear, educational (and brief: Editor). It should contain the maximum of information (in the minimum of words: Ed.) and must be authenticated most unimpeachably by numerous experiments. It must also be illustrated by numerous pictures. (Good sharp photos, please, and do send the negatives! Ed.) [I say, do you seem to hear a voice in the background? I seem to be getting a bit of interference from somewhere. Tropospheric skip, probably.]

Know Your Reader

The main object of all technical papers is the imparting of information. To do this, the basic facts must be couched in such language as to be readily comprehensible *by the group to whom the article is directed!* Here, the writer has his choice: he can write to the upper echelons: P. P. Eckersley, "Cathode Ray," Thomas Roddam *et al*; he can write to the larger mass of readers, gentlemen with engineering training and education, who can readily comprehend mathematical expositions, complicated diagrams, etc., or to a group of students, beginners (and me) to whom the subject is not thoroughly familiar as yet. By the proper use of long words, heavy mathematics, and complicated diagrams, it is quite possible to write a paper which cannot be understood by anyone except those to whom the subject is already quite familiar. To the bewildered reader who really needs the knowledge, it is completely incomprehensible! So, here we have our first problem: Communication! Your article must be "slanted," as the newspaper men say, toward the group you want it to reach. You must know to whom the message is to be addressed, so that it will reach its destination in understandable form.

I've several pet aphorism that might be tossed in at this point. These have been gathered over a period of many years from various editors. "Express; don't impress!"; this is what Mr. Eckersley meant when he spoke of "prancing." And a notably exact description that was, too. Another; "Wad some power the giftie gi'e us, to express ourselves so others could 'see' us" misquoted, but apt, I think. So, use language appropriate to the group to whom you're talking.

The technical writer does have one big thing in his favour: "'Vantage Number one, said the Bi-Coloured Python Rock Snake'": he is writing to a group who *want* the knowledge, (or they wouldn't be reading the bloomin' book in the first place!) and, therefore, are willing to take some pains to get the information out of it. So, make his task easier by getting the information over to him in as simple a manner as possible. Talk directly to him, and try to talk in his own tongue.

Don't be too verbose (Thanks! Ed.) but don't be *too* brief, either. In this connection, there is a story current among two-way radiomen here, concerning a pair of Latin-American gentlemen testing a radio system.

"Allo, Pedro, thees ees Pancho. Geeve me a short count, please. Over." "Allo, Pancho thees ees Pedro. One. Out!" So don't give your readers a "Mexican short-count" by trying to be too crisp or "snappy" in the style.

Speaking of style in technical writing (and this wasn't really intended to be in here, but inserted at the last moment, in direct contravention of all the principles I advocate, later on!) You'll find that there are really as many kinds of style as there are writers. Personally, I use two: what I've always called "Conversational," in which the writer is talking directly to the reader: this is derived from much experience in telling some of my many teen-age technicians how to do various things. I have found it quite effective in various lower-echelon textbooks, etc., for beginners. Contrasting to this is another, what one might call, "Modified Pedantic": this is "straight college textbook" with a few irreverent touches now and then. Still further up the ladder would be "Straight Pedantic," which is good readable college textbook, followed at the top by "Incomprehensible Pedantic": the style consisting of about seven words in English followed by three pages of Greek symbols!

I have an unshakable belief that there is a place for humour even in a dry technical article.

A wee touch of humour often lightens a heavy discussion, and in my opinion, makes the article much more "rememberable." (If I can't find a word that'll do what I want, I'll *make* one!) I know that *I* shall never forget Thomas Roddam's classic phrase about the "engineers paddling happily in their troughs"! ("Return Loss": *Wireless World*, November '57) See? I even remembered the author's name! Somehow, a humorous association seems to make the subject matter stick more firmly in the memory.

So, the essentials of a good technical article are: Clarity, Continuity (and Brevity: Ed.).

Neglecting the interruption, we shall continue. Clarity, we have just discussed. Now, let's work over the remaining feature: Continuity. We may assume that the potential scribe already has in his possession sufficient facts to enable him to give a valid exposition of the subject. A technical article consists mainly of a series of facts: laws, processes, applications, conclusions drawn from experiments, etc. In order to make the material readily com-

* Ouachita Radio-TV Service, Mena, Arkansas, U.S.A.

prehensible, these must be set down in a logical order: Facts A, B, C, etc., follow each other like sheep over a hurdle. It should, in my opinion, have an order something like this: introduction, statement of purpose, material used, processes, and conclusions drawn from same. The whole article, in fact, should resemble a series circuit. At this point, the aspirin consumption among writers rises rapidly. Despite all precautions, Fact H *will* crop up in the final draft, nestling coyly between Facts B and C!

Creator and Critic

There are several methods used by technical writers to cope with this. Personally, I use the "Hobson-Jobson" method. This consists of sitting down to the typewriter with several fresh packs of cigarettes, a pot of strong coffee and a grimly determined look, and writing down as rapidly as possible without regard to grammar or spelling every possible pertinent fact that I can dredge out of my unwilling brain. Hew to the line and let the split infinitives fall where they may!

From the resulting hodge-podge, the various statements, assertions and incontrovertible facts are sorted out, and rearranged in some sort of order. This, too, is but a preliminary: the result is then rewritten, and rechecked for continuity of thought. At this point it is a good idea to tuck the dog under one arm, whistle for your gun, stuff the manuscript into your hip pocket, and head for the woods. Find a suitable stump, and sit thereupon for a period sufficient to permit consecutive thought. Read the ms. (mess? Ed.) (Quiet! D.) and try to criticize it. Incidentally, it is always impossible to be completely objective about one's own work, so don't feel too badly if it still looks good to you.

An alternative to this is the "abandonment method." After finishing the first or second rough, place the whole thing firmly upon a convenient shelf, and forget all about it for a period of about a week. (A disadvantage of this method is that during the waiting period, one usually finds that someone else has had the same idea, written and sold an article to the magazine on the same subject! This happened to *me* on this one!) However, if the mental telegraph isn't working and the idea is still valid, get it out and see if it still looks as good to you as it did upon completion. If so, make a fair copy of it, on pristine white paper, liberally margined, and double-spaced, to provide space for sarcastic editorial comments (*Well!* Ed.), stuff it in a suitable envelope, and bung it into the nearest post box. There will now ensue a waiting period of indeterminate length, while Editor and Staff chew over the unfortunate ms, to see if it is suitable for inclusion in their august journal.

We might close with a few observations of the genus Scribus Technicalis, gleaned from looking over my own shoulder, and from watching a few of my confréres at work. There are two distinct species of T-writers, which may be identified by their methods of preparing the subject material. They can be divided into Mumblers and Jotters, with the inevitable sub-phyla having mixed characteristics of each class.

The Mumbler goes about for a period of roughly two weeks prior to the launching of an article, with a preoccupied look on his face, muttering under his breath, to himself. He is reminding himself of certain points which he must remember to include in the finished paper. This often causes him to be looked upon askance by normal members of his community, until his habits are understood.

The Jotter, on the other hand, mistrusts his own memory (and with very good reason, too). He writes everything down on odd bits of paper, and squirrels them away on his person. When actual production begins, these are unearthed, deciphered, and included in the finished product. There are two distinct drawbacks to this method, and, remember, I speak from actual experience. The first hazard is the laundry. When the Wife decides that our absent-minded friend's linen has gone quite long enough (and, truthfully, he is prone to getting a bit grubby about the collar and cuffs!), she is quite apt to sequester it without his knowledge, and pop it into the washer. So, sad to say, full many an important contribution to the world's technical literature has vanished down the drains in a soggy wad of wood pulp.

The last, and most heart-rending of all, is the inability of the author to translate his own notes! (And once again I speak from bitter experience!) A whole mass of vital statistics has vanished into the Limbo of such cryptic notations as "Fzll turnspike mst be vshtrd" and "Mss cap's shd be tnd wth fzzlbat xpal!"

Words are tricky things; they have a dreadful habit of meaning one thing and saying another. In addition to the methods discussed above, there is always the possibility of the "Inadvertent Howler." This is a sort of technical Irish Bull, and crops up in the most amazing places. Here are a few examples of meaning one thing and saying another.

A certain U.S. company with a well-deserved reputation for excellence and clarity in its technical writing came up with this not long ago: "This progress would not be possible without the intense interest in learning new things that you electronics technicians have!" (Why should they want to know what new things we technicians have?)

Our very favourite item, and one which I shall always remember for its sheer purity of thought and simplicity, was unearthed long ago in an instruction book for a mechanical phonograph, or juke box. At the bottom of a long list of troubles and their causes and repairs, this came up. The item was the slipping of a small gear, or something, and the suggested cure was, brief and very much to the point, "Find cause and repair!"

Technical Authorship

FOR what is believed to be the first time in this country a responsible and qualified body, *viz*, the City & Guilds of London Institute, is holding examinations in technical authorship. They are being held in May and are the culmination of a long period of planning between the Institute and the Technical Publications Association. The two papers to be set aim at testing candidates' knowledge of the principles and practice of technical authorship and their skill in technical writing and editing.

The principal objects of the T.P.A., which now has a membership of just under 300, are: "To promote the advancement and improvement of technical publications techniques . . . and to promote and maintain a recognized status for its members." Its offices are at 46, Brook Street, London, W.1.

News from the Industry

English Electric Group, which includes the Marconi group, English Electric Valve Co., Napier and Son and a number of overseas subsidiaries, announces a group profit in 1959 of £3,433,759, which was over £400,000 above the previous year's figure. The diversity of interests of the twenty-five or so companies in the group is shown in a 28-page illustrated brochure "English Electric Activities 1959-1960."

Marconi Group, which includes Marconi's W/T, Marconi Marine and Marconi Instruments and a number of overseas companies, made a net profit of £411,470 in 1959 compared with £431,783 the previous year. The net profit of the Marine company was £264,624, compared with £222,039 in 1958. The Instrument company, which had a record turnover last year, is building an additional factory of 30,000 sq ft at the St. Albans works.

Metal Industries Group, which includes Igranic, Avo and Taylor Instruments as well as a number of companies in the engineering and metal industries, has acquired Lancashire Dynamo Holdings, Ltd. It will be recalled that E.M.I. withdrew their offer for the stock of Lancashire Dynamo.

Relay Exchanges Ltd.—A 50% increase in the group's trading profit as compared with the previous year is shown in the preliminary figures for 1959. The group net profit was £1,068,701 compared with £391,276.

Regentone Group.—Reference is made in the annual report of the chairman of Lloyd's Packing Warehouses (Holdings) Ltd. to the activities of its subsidiary, the Regentone group. Both the turnover and the profit of the group, which manufactures R.G.D., Regentone and Argosy receivers, were "the highest in the history of the company."

Radio Rentals Ltd., who, through their 220 branches in the U.K., rent sound and television sets, record a net group profit, after taxation, of £1,098,616—an increase of £293,958 on 1957/58. Mains Radio Gramophones Ltd., of Bradford, a subsidiary, manufactures all sets handled by the group.

Simmonds Aerocessories Ltd., of Treforest, South Wales, a member of the Firth Cleveland Group, have formed a company in Western Germany in association with Mecano-Bundy, G.m.b.H., of Heidelberg, for the manufacture and sale of Spire Speed Nuts and other fastenings. The new company will be known as Mecano-Simmonds G.m.b.H., with headquarters in Heidelberg.

Anglo-American Agreement.—Marconi's W/T Co. and Hermes Electronics Co. (formerly Hycon Eastern Inc.), of America, have concluded an agreement providing for general technical collaboration between their two companies in the field of point-to-point communications. Each company will act as agents and licensees for certain equipment manufactured by the other.

Tektronix.—It may not be generally known that for the past fifteen months Tektronix Inc., of Portland, U.S.A., have been assembling oscilloscopes in Guernsey, C.I. A resultant saving in freight has enabled their agents in this country—Livingston Laboratories—to make about a 3% reduction in price.

A.E.I.—A new product department devoted to semiconductors has been set up within the A.E.I. radio and electronic components division. The semiconductor department's sales office is at 155 Charing Cross Road, London, W.C.2. The sales manager is F Szekely

Heathkits.—Direct TV Replacements, Ltd., of 138, Lewisham Way, London, S.E.14, are now marketing a range of test equipment which is basically constructed from Heathkits. The instruments are being marketed under the name Beulah Electronics.

Belling & Lee have reorganized their sales department into two divisions—industrial and domestic. Both divisions come under the jurisdiction of the sales director, E. A. Taylor, and each has two assistant sales managers. These are: Industrial Division: R. M. Prevett (internal) and R. W. Elliott (field); Domestic Division: L. R. Dunlop (internal) and H. J. Walters (field).

DEAC (Great Britain), Ltd., was formed last year to produce in this country the Perma-seal hermetically sealed re-chargeable nickel-cadmium cells manufactured in Germany by DEAC. The first types to go into production at the factory established at Altona Way, Buckingham Avenue, Trading Estate, Slough, Bucks., is the range of "button" type cells. They will be marketed by G. A. Stanley Palmer, Ltd., Maxwell House, Arundel Street, Strand, London, W.C.2, who will continue to handle those German-made cells which are not yet manufactured in this country.

Muirhead's have produced a tape recorder for the storage at relay stations of facsimile signals for re-transmission when immediate relaying is impracticable. By recording a 1,000 c/s standard frequency (from a Muirhead tuning fork) on the lower tape track at the same time as recording the facsimile signal on the upper track, the speed of the tape on replay can be synchronized with the original recording speed.

Aveley Electric.—With the formation of the new Avel-Toroid division of Aveley Electric, Ltd., of South Ockendon, Essex, A. C. Green becomes works manager, J. R. Erskine chief engineer, and S. J. Arliss production engineer. R. S. Mattin has assumed responsibility for all toroidal winding machine sales and service, and handles general sales enquiries for sub-contract toroidal winding. A. J. Cornwell, who has been with the company since 1955, has taken charge of the Technical Services Department, which is responsible for service and overhaul of all Rohde & Schwarz and other similar equipment distributed by Aveley Electric.

Transistor Television Set.—This prototype portable television set with an 8-in tube and using twenty-three transistors and fourteen diodes is soon to be marketed in Japan by Sony Corporation. Monthly production initially will be about 1,000 sets which it is planned to increase to 10,000 in about a year. The set, weighing 11-lb and measuring $6\frac{1}{4}$x8x$8\frac{3}{4}$ inches, will sell at about $200.

Canberra.—Tannoy have supplied the sound installation for the 45,000-ton P. & O. liner *Canberra*, the largest turbo-electric passenger ship to be built in Britain. Each of the 1,000 or more cabins has provision for receiving either a broadcast programme or a programme originating in the ship's control room. Marconi's are providing the ship's radio-communication equipment and are also installing multi-standard television equipment which will permit the relaying to cabins and public rooms of programmes from countries employing either 405, 525 or 625 lines. There will also be a closed-circuit TV system aboard.

Shure Brothers, the American manufacturers of microphones, pick-ups, etc., have appointed J. W. Maunder, of 95 Hayes Lane, Beckenham, Kent, as their representative in this country.

Tellux Ltd., and **Perihel Ltd.** (members of the K.G. Holdings group of companies) are moving from 146 New Cavendish Street, London, W.1, to the factory premises at 44 Brunel Road, London, W.3, occupied by their associated company, W.S. Electronics, Ltd. (Tel.: Shepherds Bush 0333).

R.E.E. Telecommunications Ltd., of Crewkerne, Somerset, have appointed J. H. V. Stephens, previously with Standard Telecommunications Laboratories, as technical manager. G. E. Webster, formerly with Panda Radio, is export manager.

A new service depot at London Airport has been opened by Marconi's W/T Co. to replace the temporary one previously in use. The engineer-in-charge is J. W. Grandey, and the address: Marconi's Service Depot, Sections A & B, Building 201, No. 1 Maintenance Area, London Airport, Middx (Tel.: Skyport 1039).

Solus-Schall Ltd., have transferred their sales, administration and accounts departments to County Building, Honeypot Lane, Stanmore, Middx (Tel.: Wordsworth 4300). The service department is continuing for the time being at 15/18 Clipstone Street, London, W.1 (Tel.: Museum 5080).

McKellan Automation Ltd., of 122 Seymour Grove, Old Trafford, Manchester, 16, agents for a number of instrument manufacturers, have formed an associate company, Automac Ltd., which is undertaking instrument repairs, installation and maintenance work previously carried out by the parent company. The address of Automac is Throstle Grove Works, Great Egerton Street, Stockport, Cheshire (Tel.: Stockport 6767). G. M. P. McKellen is managing director.

The Pye Group has acquired 50,000 sq ft of buildings in the Sheerness Dockyard which will be used for additional production space.

EXPORT NEWS

Computers, data processing equipment, scientific and industrial instruments, automation systems and closed-circuit television manufactured by E.M.I. Electronics, is to be marketed in the U.S.A. by Fairbanks Whitney Corp. of New York. The company will also manufacture some E.M.I. equipment under licence.

Field trials of a new Decca Navigator receiver for use in South Africa, where atmospheric conditions are exceptionally bad, were undertaken last November by the South African Council of Scientific and Industrial Research. Decca Navigator have now appointed as their representative in the Union Brigadier H. G. Willmott, C.B.E., who until his retirement a few years ago was Air Chief of Staff in the South African Air Force.

True-motion radar (Type TM909) is being supplied by Decca for four new cargo vessels under construction in France for the Compagnie des Messageries Maritime. Decca are also supplying river radars (Type 215) for eleven inland waterway tankers owned by Esso Tankschiff Reederei, G.m.b.H., of Hamburg.

Italy's new intercontinental airport at Fiumicino is to be equipped with a Marconi 500-kW 50-cm radar (Type S.264A/H), together with two display systems (comprising eleven display units), microwave radar link and ancillary equipment.

Television O.B. Unit.—E.M.I. Electronics have received an order from Elektroimpex, Budapest, on behalf of the Hungarian broadcasting authority, for a television outside broadcast unit. It will be equipped with four Image Orthicon cameras. Two O.B. units, each with three cameras, have recently been supplied to the Australian Broadcasting Commission.

Radio-telephone transmitter-receivers.—Some of the 500 R/T transmitter-receivers ordered from Pye Telecommunications for installation in Mexico are for the extension of the existing Public Correspondence system and others for private radio-telephone services. Pye have already supplied over 3,000 mobile units to Mexico.

Surveillance radar for the new international airport being built at Belgrade, has been ordered from Cossor. Duplicate 10-cm transmitters with four display consoles are being supplied.

Airborne v.h.f. communications equipment to the value of 1M Swiss francs has been ordered from W.S. Electronics, Ltd., by the Swiss authorities.

A six-month tour of factories, research establishments, government organizations and technical colleges on the Continent is being undertaken by a new mobile showroom and demonstration unit of Marconi Instruments.

Marine apparatus, including the "Escort" true-motion and "R.M.S." radars, is fitted in A.E.I.'s new mobile radar unit, which is on a five-month demonstration tour of Western Europe.

APRIL MEETINGS

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

LONDON

4th. I.E.E.—"V.H.F. sound broadcasting: subjective appraisal of distortion due to multi-path propagation in f.m. reception" by R. V. Harvey at 5.30 at Savoy Place, W.C.2.

5th. I.E.E.—"Thermistors — their theory, manufacture and application" by Dr. R. W. A. Scarr and R. A. Setterington at 5.30 at Savoy Place, W.C.2.

7th. Brit.I.R.E.—"The work of the B.S.I. in relation to the radio and electronics industry" by H. A. R. Binney at 6.30 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

7th. Society of Instrument Technology.—"The electronic computer as a unit in an automatic electronic data processing system for missile trials" by W. C. J. White and D. L. Overheu at 7.0 at Manson House, 26 Portland Place, W.1.

8th. I.E.E.—Symposium on data handling and display systems for air traffic control at 5.30 at Savoy Place, W.C.2.

8th. Television Society.—"Video tape in action" by R. H. Hammans (Granada TV) at 7.0 at the Cinematograph Exhibitors' Association, 164 Shaftesbury Avenue, W.C.2.

8th. Junior Institution of Engineers.—"The atomic clock" by Dr. L. Essen (N.P.L.) at 7.0 at Pepys House, 14 Rochester Row, S.W.1.

12th. I.E.E.—Medical Electronics Group discussion on "Aids for the blind" opened by Lord Fraser of Lonsdale (St. Dunstan's) and Dr. R. L. Beurle (English Electric Valve Co.) at 6.0 at Savoy Place, W.C.2.

13th. Brit.I.R.E.—"Guided weapon control" by F. R. J. Spearman at 6.30 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

21st. Brit.I.R.E. Medical Electronics Group.—"Nerve impulses from stretch receptors in muscles" by Dr. J. G. Nicholls at 6.30 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

22nd. I.E.E.—Discussion on "Broadening university courses" opened by Professor H. E. M. Barlow at 6.0 at Savoy Place, W.C.2.

22nd. B.S.R.A.—" Sound radiation from loudspeaker cabinets " by J. Moir at 7.15 at the Royal Society of Arts, John Adam Street, W.C.2.

23rd. B.S.R.A.—Audio Convention at 10.0 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

25th. I.E.E. Graduate and Student Section.—" A survey of microwave techniques for the transmission of speech and vision " by K. C. Kao at 6.30 at Savoy Place, W.C.2.

26th. I.E.E.—" An experimental transistor-controlled component selection and testing machine " by T. C. Cardwell, J. R. W. Smith and G. H. King at 5.30 at Savoy Place, W.C.2.

27th. I.E.E.—" Henri de France colour television system " by R. Chaste and P. Cassagne at 5.30 at Savoy Place, W.C.2.

27th. Brit.I.R.E.—" Electronics in oceanography " by M. J. Tucker at 6.30 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

28th. British Computer Society.—" Automation and uncertainty " by Stafford Beer (United Steel Co.) at 2.30 at the Northampton College of Advanced Technology, St. John Street, E.C.1.

28th. I.E.E.—" Radar observations of birds and 'angels' " by Dr. E. Eastwood at 5.30 at Savoy Place, W.C.2.

28th. Brit.I.R.E.—Discussion on the Education Committee's report entitled " The education and training of the professional radio and electronics engineer " at 6.30 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

ABERDEEN
8th. I.E.E.—" Engineering education in the technical universities in Western Germany " by D. B. Welbourn, Professor D. B. Spalding and G. L. Ashdown at 7.30 at Robert Gordon's Technical College.

BIRMINGHAM
13th. A.S.E.E.—" Electronics in industry " by R. J. F. Howard at 7.30 at the Birmingham Exchange and Engineering Centre, Stephenson Place.

BOLTON
4th. A.S.E.E.—" Servo speed control of d.c. motors " by J. Bailey (A.E.I., Manchester) at 7.45 at the Railway Hotel, Trinity Street.

CARDIFF
28th. British Computer Society.—Symposium on auto codes at 6.30 at the Small Shanlon Lecture Theatre, University College.

CHELTENHAM
29th. Brit.I.R.E.—" The application of semiconductor devices in power supplies " by D. D. Jones at 7.0 at the North Gloucestershire Technical College.

COVENTRY
6th. I.E.E.—" High-capacity s.h.f. radio transmission systems " by H. D. Hyamson at 6.30 at the Technical College.

DUNDEE
7th. I.E.E.—" Engineering education in the technical universities in Western Germany " by D. B. Welbourn, Professor D. B. Spalding and G. L. Ashdown at 7.0 in the Electrical Engineering Department, Queen's College.

EDINBURGH
5th. I.E.E.—Faraday lecture on " Electrical Machines " by Professor M. G. Say at 7.0 at the Heriot-Watt College.
13th. I.E.E.—" High-current-density thermionic emitters: a survey " by A. H. W. Beck at 7.0 at the Carlton Hotel, North Bridge.

FARNBOROUGH
20th. I.E.E.—" Machine translation of languages " by Dr. A. D. Booth at 6.15 at Farnborough Technical College, Boundary Road.

GLASGOW
12th. I.E.E.— " High-current-density thermionic emitters: a survey " by A. H. W. Beck at 6.0 at the Royal College of Science and Technology.

KIDSGROVE
11th. I.E.E.—" Silicone transistors —their manufacture and fields of application " by Dr. J. T. Kendall at 7.0 at the English Electric Co.

LIVERPOOL
7th. Institute of Physics.— " New techniques in electron and X-ray microscopy " by C. W. Oatley at 7.0 at the University.

MANCHESTER
14th. Brit.I.R.E.—" The measurement of human performance " by H. Woolf at 6.30 at the Reynolds Hall, College of Technology, Sackville Street.

MIDDLESBROUGH
21st. Institute of Physics.—" The Jodrell Bank telescope " by H. A. Prime (Brush Electrical Engineering Co.) at 6.30 at the Cleveland Scientific and Technical Institute.

NEWCASTLE-ON-TYNE
13th. Brit.I.R.E.—" The development of electronics in the North East " by J. Bilbrough (chairman, N. E. Section) at 6.30 at the Institution of Mining and Mechanical Engineers, Neville Hall, Westgate Road.

PLYMOUTH
7th. I.E.E.—" A new cathode-ray tube for monochrome and colour television " by Dr. D. Gabor, P. R. Stuart and P. G. Kalman at 3.0 at Plymouth " B " Generating Station, Prince Rock.

PORTSMOUTH
6th. I.E.E.—" Modern ferromagnetic materials " by Professor F. Brailsford at 6.30 at the College of Technology.

STONE
22nd. I.E.E.—" The application of transistors to line communication equipment " by H. T. Prior, D. J. R. Chapman and A. A. M. Whitehead at 7.0 at the Duncan Hall. (Joint meeting with Institution of Post Office Electrical Engineers.)

SWANSEA
14th. I.E.E.—" Electronic applications in a modern steelworks " by J. K. Edwards at 6.0 at the Conference Room, S.W.E.B. Showrooms, The Kingsway.

WEYMOUTH
7th. I.E.E.—" Sound reproduction " by D. E. L. Shorter at 6.30 at South Dorset Technical College.

RANDOM RADIATIONS

By "DIALLIST"

Le Serviceman

VERY few suggestions of an alternative to "serviceman" (see February issue) have reached me from readers. One, writing from Johannesburg, tells me that the local term is "radiotrician," though "teletrician" hasn't yet appeared, as there is no TV service in South Africa. He wonders if wireless-troubleshooters are known as radiotricians anywhere else. I can't answer that one, though I've never come across the word before. None of the men whom I consulted had the faintest objection to being styled a serviceman; which was just what I'd expected. There's certainly nothing derogatory about the word, which exactly describes what they do. Most sound radio and television dealers advertise "sales and service." The people who do the selling are rightly known as salesmen; servicemen then seems just to fit those who provide the service. By the way, I've recently come across *le serviceman* in a French magazine, so the term seems to have found acceptance on the other side of the Channel. I'm all for plain rather than fancy terms: you can call a good rider a horseman; but to speak of him as an equestrian rather suggests the circus.

Transistor Life

THE article "How Long Will a Transistor Live" by R. Brewer, of the G.E.C. Research Labs., at Wembley, in the March issue of *Wireless World*, fascinated me and no doubt many readers too. All sorts of answers have been offered, but this is the only one I've seen which is based on a controlled test extending, so far as it has gone (for I imagine it will be continued) to 20,000 hours. One American physicist has spoken of transistors which will run for a century, but I don't think we've got quite that far yet, undoubtedly we shall do so as improved methods of manufacture and of "doping" in particular are developed; but that's likely to take a little time. Brewer's curve for the change of median value of β during a test of 20,000 hours is particularly interesting. It shows that following the nose-dive at the start the percentage of the initial median β value steadies up after the first thousand hours and then falls gradually until the 8,000 hours point is reached. And then comes a surprise; the value *rises* during the next 3,000 hours. Then comes another small dip, followed by a rise, another dip, a further rise at 16,000 hours and then almost steady readings until the 20,000-hour mark is reached. It's all so very unlike the life-curve of a valve, for there's none of that maintained or, more likely, accelerating deterioration.

Electronics and Honey

THE most surprising applications are being found for electronics. Who'd have thought, for instance, that it could do anything to help the beekeeper? Nevertheless, it can and a gadget called the Apidictor is now doing valuable work in many parts of the world. E. F. Woods, of the B.B.C. Engineering Division, is a knowledgeable and enthusiastic beekeeper and it was his work, in collaboration with E. F. Birch, a Post Office engineer, which led to the production by Wayne Kerr Laboratories of the instrument. One of the problems of beekeeping is swarming, which may take place at any time during the summer. Before there's to be an exodus the inhabitants hum with a peculiar sound for at least fifteen days. This Apidictor responds to the frequency of this sound and so gives the beekeeper advance warning of a swarm and makes unnecessary the opening of the hive and the search for queen cells which would otherwise have to be done every 9 or 10 days from about mid-April to mid-July.

Ring Angels

YOU may remember that some months ago I mentioned one type of radar "angel" which was undoubtedly caused by birds. Something over a year ago a new kind, known as the ring angel, made its appearance. This starts as a spot of light on the screen, but it quickly spreads outwards in the form of concentric rings exactly like those seen when a stone is dropped into a calm pond. The expansion is rapid: the rings travel outwards at speeds between 25 and 50 miles an hour. Such angels occur only in the half hour immediately before or after sunrise. For many months now the phenomenon has been investigated by radio engineers at the Marconi Research Establishment at Great Baddow. About 70 places in south-east England have been identified as repeated but irregular centres of such displays. So far no quite satisfactory explanation has been found. Birds have again been suggested as the cause; but flocks leaving the roosting places don't spread outwards in circles. The most likely suggestion, which still remains to be proved, is that these angels are caused by rapidly expanding thermal fronts in the upper atmosphere.

V.H.F. DX at Aylesbury

A LONDON reader writes that he is very envious of the regular reception in Aylesbury of French and West German v.h.f./f.m. stations reported in my notes in February. He asks how it's done: is some very special form of tuner used, or is the secret in the aerial array? Perhaps my Aylesbury correspondent will be kind enough to let him into the secret. It may well be that Aylesbury is a particularly favourable spot for v.h.f. DX reception, for I recall that when I lived in Hertfordshire at a place about a dozen miles from Aylesbury I often picked up distant f.m. transmissions. The aerial then in use was just the simplest of single half-wave dipoles, oriented on Wrotham. Admittedly my home was on the 500-ft contour line above sea-level and the aerial, mounted on a chimney stack, was a good 30-feet above the road; but the tuner wasn't designed specially for sensitivity.

Not Good Enough

A WEEK or so before this was written a friend remarked, "I still can't get that wretched valve." As he hadn't mentioned that he was short of one, I asked him to tell me more—this is the sad story he unfolded. He has a 17-inch television set of well-known make, now a little over three years old, which had broken down five weeks before. The dealer found that a valve had gone phut; he hadn't that particular type in stock, but ordered one the same day. The set remained out of action, for he'd not been able to get delivery of the valve. I'm sure you'll agree that this sort of thing just isn't good enough. The makers of the set (a large and important firm) should surely have stipulated when the contract for its valves was placed that replacements should be readily available for a reasonable number of years. I imagine that they did so, for disappointments of this kind do not help future sales. Apart from that, did the dealer not consult a valve data book to make sure that there wasn't a substitute of another make? I don't yet know. But one thing I'm sure of is that this kind of thing happens rather too often.

UNBIASED

By FREE GRID

Laurels and Lolly

NEARLY every daily journal reported an alleged television novelty in the Furniture Exhibition held at Earls Court in February. In this show five different people, who were said to be experts in the business, were given the task of re-furnishing a couple of old-fashioned rooms within the limits of budgets ranging from £100 to £2,000. The expert who was responsible for the £1,000 effort was the one who had the brainwave which caused all the newspapers to burst into songs of praise.

His jack-pot-hitting idea was to place a TV set in the fireplace, which, in these days of central heating, fewer people are using. It is, of course, a thoroughly sound idea from all points of view as I myself thought when I first put it forward in these columns, complete with illustration, 14 years ago, in March, 1946. Technically it is the ideal position for a television set because the aerial lead can go straight up the flue to the dipole on the chimney stack.

Since we are all creatures of habit and tend to sit around the fireplace, even if there is no fire, it is obviously also the correct place for a TV set from the viewing aspect. I only wish I could share some of the laurels and the lolly which came the way of the Earls Court designer for this old idea of mine. But I have thought of a way of improving it which I will mention here in the hope of helping other designers.

It will be realized that people sitting at each side of the fireplace would get a rather distorted view of the television picture. My idea is to avoid this by designing a television set with three screens set at an angle of 120 degrees to each other. This would mean that the front of the set would be shaped like half a hexagon. In these days of wide-angle tubes the relatively short necks could, by a bit of wangling, be prevented from fouling each other. Three tubes in the same cabinet could, of course, all share the same power pack and other ancillary equipment.

A further improvement would be to place a specially shaped electric fan-heater under the set in the place normally occupied by the ash tray. If it did nothing else it would prevent our getting cold feet in some of the horror plays that we sometimes see on the screen.

My 1946 fireplace TV brought up to date.

The Telegraphone

THOSE of you who, like myself, date back to the days of the first world war, may recollect "The Exploits of Elaine," a series of detective stories by Arthur B. Reeve, published in 1915. The book was sufficiently famous to be made into a serial film for the silent cinema of the early 'twenties.

In looking through this book again recently I found (p. 180) a very convincing account of the *modus operandi* of the magnetic recorder. Its invention is rightly ascribed to Poulsen who seems to have intended it for recording telephone conversations; hence the name "Telegraphone." The date of Poulsen's invention was, I find, 1898 although that is not mentioned in the book.

The antiquity of Poulsen's invention reminds me that only six years later in 1904, the first radar patent was taken out by Hulsmeyer. Owing to the fact that valves and transistors were, as Shakespeare puts it, still hidden in the womb of time, there was not much that either Poulsen or Hulsmeyer could do to bring their respective inventions to full fruition. Even in 1915, although the valve was on the map, it would have been difficult to make a really worthwhile magnetic recorder and I am surprised that such a detailed description is given in this book of 45 years ago.

Down with Dials

A FEW weeks ago I was astonished to read in the pages of *Electrical Review* a suggestion that cyclometer-type meters, instead of the multi-dial type with which we are all so familiar, be fitted into our houses for recording electrical power consumption. The writer mentioned that he had advocated this previously, and that an effort is to be made in influential quarters to get the Eastern Electricity Board to make the change.

Now *Electrical Review* certainly would not allow its reputation to be endangered by putting forward irresponsible views or suggestions. The reason for my astonishment is that when I made this very same suggestion in these columns some years ago, I was sternly taken to task by knowledgeable correspondents—some of whom were members of the electrical industry—who pointed out the error of my ways.

My correspondents reminded me that all types of meter are power-consuming devices, and it is the consumer who pays for the power required to work the meter. For that reason the Board of Trade imposed a definite limit on the power which a meter could be permitted to consume. It was furthermore pointed out to me that the reason why the cyclometer-type meter was barred was that its power consumption, unlike that of the multi-dial type, exceeded the permissible limit. The Board of Trade's powers in this matter are today vested in the Ministry of Power but surely this old consumer-protecting restriction has not been thrown overboard?

In view of what is said in *Electrical Review*, it is, I think, reasonable to suppose that in recent times either the cyclometer-type meter has been redesigned so that its power consumption is within the permissible limit, or this limit has been raised in order to bring it within the fold. In this latter case, of course, it would mean that the supply authorities are now allowed to dip still deeper into our pockets. If neither of my suppositions is correct can anyone give me the correct information?

Sirkit and Condewit

WHY is it that some electricians and radio servicemen persist in pronouncing conduit as condewit? They have a perfectly good example of the correct pronunciation in the word circuit. They never call that a sirkewit; or do they? I have even heard electrical engineers, and others who ought to know better, speak of condewit.