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Wireless World

The Universal Language

IF circuit diagrams are the universal language of electronics it is only right and proper that they should have a standardized grammar. Without this, communication becomes difficult. On the other hand, it is unreasonable to expect all who use the same grammar to speak with the same accent.

We are delighted with the lively discussion in our correspondence colums resulting from L. H. Bedford's letter on circuit conventions in the April issue. It is a subject on which everyone feels justifiably entitled to express an opinion, and on which the views of the young technician can be as sensible and worth-while as those of the experienced and highly qualified engineer. But in all these letters there does not seem to be any serious disagreement on the basic grammar of circuit drawing—only on such things as wiring cross-overs and junctions, valve envelopes and resistor "squiggles". Whether one would describe these as matters of grammar or of accent is open to question. They are certainly important to the easy reading of circuit diagrams, but not so important, we feel, as the general layout, the spacing and grouping of component symbols, the use of easily recognized configurations—and even the relative thicknesses of lines.

Several correspondents have reminded us that there is a British Standard on circuit conventions. We agree that these recommendations are an excellent guide to the draughtsman. But it is unreasonable to expect that everyone should follow B.S.530 slavishly and make all circuit diagrams look alike—just as it is unreasonable to expect a Mancunian to sound like a Londoner. The point is, surely, that circuit diagrams are drawn for very different purposes and on very different media—technical reports in laboratories, servicing manuals for technicians, wiring diagrams for the work bench, technical journals for general publication—and each of these has its own particular requirements and limitations. For practical reasons, then, the actual techniques of presentation must differ also.

In our own case (and we are often under fire on this subject), besides the general requirement of clarity and easy reading we have problems of sizing, space limitation, balance of diagrams to text and making our diagrams acceptable to people who cannot be expected to know anything about B.S.530—Continental readers, for example. To cover new developments without delay it is often necessary to design new symbols: we cannot wait for the standardizing committees. In this way, in fact, *Wireless World* played a considerable part in developing the actual grammar of modern circuit symbolism from the old pictorial diagrams used in the early days of radio. We say this, not to pose as grey-beards, but to show that we have had a good deal of experience in evolving a system to suit the purposes of technical publication. We do not wish to impose this system on anybody else and we may well change it to keep in step with changes in electronics or technical journalism. A case in point is the transistor symbol (e.g., March, 1960, issue, p.110) on which one correspondent accuses us of being "the odd-man out". Even if we are the odd-man out, we feel quite justified in departing from the present convention (junction transistors looking like the now-obsolete point transistors) if it helps our readers and possibly has other advantages (e.g., May, 1960, issue, p.228).

Our critic on transistor symbols has a very good point, however, about the usefulness of redundancy in communicating information. This fact, if not already understood, has certainly been brought to attention by modern Communication Theory. We in the radio and electronics field therefore ought to take note of it, not only when providing the means of communication for other people, but when communicating amongst ourselves.

Third-party Messages

HAS the time come for a change in the regulations which the P.M.G. is empowered to make to protect the telecommunications monopoly which prohibits a listener, radio amateur or radio operator from passing on a message for a third party?

Legally, Bill Hayes, of the B.B.C.'s Aerial Radio Club, was breaking the law when he passed on to the police an appeal from a Moroccan amateur for drugs for the Agadir earthquake victims. So was the driver of a radio-equipped taxi who, seeing some act of violence, called his control room to notify Scotland Yard. Such acts should be not, even technically, against the law.

hi-fi

By P. P. ECKERSLEY, M.I.E.E., F.I.R.E.

He knows what's what, he knows hi-fi;
Is not a true Fidelity.
(Adapted)

WHAT a term! How can fidelity be high? Lack of it can stink to high heaven but that hardly justifies an opposite. Perhaps it is something raised up, usually in volume! But let that pass, "we know what we mean". In my young day we used to speak of quality, good and bad, or, if faithful is the code word, of faithful reproduction.

But do we know what we mean? I know that perfect reproduction would be that which caused a loudspeaker to create a field of sound around a listener's ear identical to that existing around the ears of an individual situated in the auditorium, studio, or whatever, where the reproduced sound originated.

The diagram of Fig. 1 helps the understanding of the definition and is an aid to an explanation why truly faithful reproduction, according to any means known to me, cannot be achieved.

For the sake of example we postulate an orchestra spread around one end of the auditorium and a microphone (M) facing it. This microphone is connected by a single channel to a loudspeaker (L) placed opposite to the listener, in the room where he listens.

Apart from any distortion that may be created by the transducers and in the channel connecting them the principle inherent artificialities, which militate against perfect reproduction (hi-fi to you) are:

1. The acoustics of the room in which the loudspeaker is situated are superimposed on those of the auditorium.
2. The source of the sounds impinging on the listener's ears is a point source, the sources of sound in the auditorium are spread over a relatively wide area.
3. A minor cause of distortion is produced because the microphone, not being the shape of a human head (and not having two ears) must in some degree alter the composition of the sound field from its form as it would be created around the ears of one listening in the auditorium.

Neglecting for a while the problem of superimposed acoustics (paragraph 1 foregoing) the artificialities of a point source of reproduction and a single microphone (as distinct from two ears) it has been suggested (and the suggestion taken up in modern equipment) that more faithful reproduction would arise by the use of so-called stereophony, consummated by the use of, typically, two microphones, two channels and two loudspeakers. Dr. Leakey has more than adequately discussed the possibilities in a recent article (April and May issues).

While it may be, and often is, claimed that two-channel reproduction is an improvement we must nevertheless appreciate that it cannot achieve the ideal of true fidelity.

I recollect, and this, though it is related to "binaural" rather than "stereophonic" listening, may be of some academic interest, that in the very early days of broadcasting, when we transmitted opera from Covent Garden, H. J. Round set up two microphones spaced feet apart, among the footlights, and connected each one to each earpiece of a two-earpiece headphone. It was remarked that as a singer moved across the stage parallel or at some angle to the line joining the microphone he (or she) appeared to us wearing the headphone to move not from side to side but in an arc above our heads. Thus if one kept one's eyes shut one looked upwards!

One of the more dramatic effects of stereophony is the verisimilitude of movement of a sound source. Properly located in relation to the loudspeakers the listener hears an aeroplane flying over his room diagonally or a speaker appears to move from side to side. Orchestra players, however, sit still, but it is claimed that two-channel broadcasting adds realism in the sense that, for instance, the fiddlers do appear to play to one side, the wood wind to another; is there a claim for depth?

Stereo Assortments

An American friend of mine, writes to me and starts a paragraph with the words "Why Stereo?" and goes on "Dr. Harry Olson wrote an interesting paper . . ." on "the psychological response to monaural" (sic Mr. Editor) "low-fi" (sic), "monaural hi-fi" (he is unrepentant) "with several spaced speakers . . . playing the same record; binaural fringe-channel two-speaker reproduction and "filled-in" binaural hi-fi, three channel, with speakers respectively playing the left-ear channel, the right-ear channel, and (at intermediate position for the speaker) the mixed left and right-ear channels.

"The results indicate successive improvements between each of these and the preceding but very unequal steps. The big jumps were to hi-fi and spaced speakers whether two . . . or single channel."

I envy Dr. Harry Olson, he must have had a lot of fun; I would join in it more thoroughly, however, were I better acquainted than I can be, without a sight of his paper, with the meaning of some of the terms he uses.

It is time for a confession—quite simply I do not find any real improvement between any single- and any multi-channel reproduction I have heard demonstrated and I hasten to say that many, whose powers of observation and whose integrity in expressing their opinions I respect, hold different views;

I must add that some equally competent people agree with me. There is, without doubt, a difference between the two systems but to me it is no more than a difference; it is not an improvement.

I would characterize this difference as giving one a feeling that the sound from two-channel reproduction is more diffused, it is fuller than when the single channel system is compared. But, with a limited number of observations, I have remarked this same improvement when two or more loudspeakers are energized from a single-channel source. Moreover I would say that those loudspeakers which are designed to be facing the corner of a room and are responsive to single channel energization give much the same effect. It is, I repeat, a difference that I observe, and a pleasing one in some instances, but it is still artificial, reminding one of reality rather than copying it.

No! What I believe is that the primary need in improving reproduction is not so much a perfect copy of the original but rather a result, limited in certain respects as it may be, which pleases because it is free from the intromissions of the several types of non-linearities, and is unaccompanied by extraneous noise.

Art and Artificiality

This is where I mount my hobby horse and discuss art and artificiality. There is some rather involved phrase implying that the object of the artist is to conceal art. It is doubtful if artists are objective, but if the sense of the statement is that art produces emotion in those who appreciate it without the means to this end being obvious (and certainly being artificial and distinct from realism) then one can agree with a supposed meaning.

When it is seen how a two-dimensional picture can represent a three-dimensional subject, or how in statuary without loss of the value as art, dimensions are shrunk or expanded below or above those of reality then the artificiality of these forms of art are its obvious characteristics. The artist paints not what he sees but from a sub-conscious which tells his hand to register the emotion a scene conjures in it. This is not realism but it can be good art. I must say, in passing, that it would help if some painters would issue a guide to the operation of their sub-conscious; it is not always easy to join in as it were. Is it, as a final example, necessary to call attention to the artificiality of the theatre and to its impact as an art?

This may seem to have wandered a long way from hi-fi, but surely not. Surely in broadcasting there is on the one hand an artist creating a programme and upon the other the person upon whom an effect is produced and between the two a medium, a means, indeed, an artificiality, namely the technique of "reproduction." In television, as in the film, it is again the two-dimensional image that creates a three dimensional impression; in sound it is more usually the point not the diffused source which stimulates the listener's sensibilities. And provided always that these artificialities are such as to convey reality without precisely reproducing it, and provided in so doing at least some of those who look or listen are moved, and provided, in other words, their sensibilities are awakened, what more is required?

But if the artificiality of reproduction has added to it the distractions of dissonances and the peevish introduction of irrelevant noise then its value as an art is at least reduced, in some cases destroyed. So in discussing hi-fi, I would count it of greater importance to consider chiefly the effect of the generation of harmonics, and combination tones and the presence of noise than what, in a cynical mood, I describe as the sales gimmick of stereophony.

In discussing the kind of distortion I have in mind it helps to consider the graphs of Fig. 2*. In this figure the ordinate represents pressure (a scale of decibels is also shown) and the abscissæ frequency on a log. scale. The upper full-line graph shows sound intensities at which the ear experiences pain, or "which stimulate the sensation of feeling"; the threshold of feeling is therefore the intensity at which the listener starts to experience painful sensations. The lower graph delineates the threshold of audibility, intensities less than those shown by the graph are inaudible. It is remarkable that the maximum pressure at the threshold of feeling is some 130dB greater than the minimum of audibility. The ratio of fortissimo to pianissimo of a symphony orchestra is of the order of 80dB. The contrast ratio of hi-fi reproduction is of the order of 40dB at maximum; if it were more faithful to the original with respect to contrast ratio pianissimo passages would be masked or spoiled by noise. Fi cannot be so hi as some would believe.

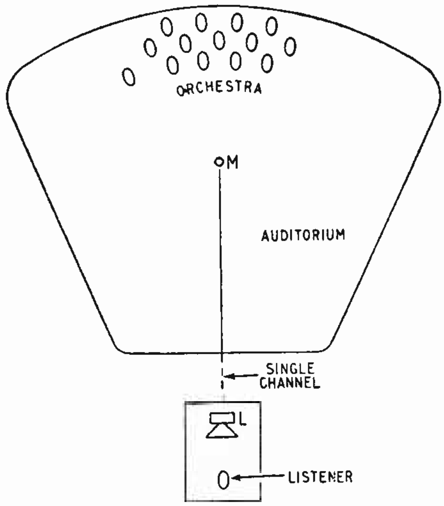


Fig. 1. Illustrating the obstacles to fidelity of reproduction.

The upper broken-line graph in Fig. 2 is drawn to illustrate the performance of a poor quality receiver; typically one designed for medium wave reception or perhaps one of those little snarlers that use transistors and pick up anything anywhere without visible means of aerial.

In drawing the graphs of Fig. 2 we have assumed "attenuation distortion," i.e. "distortion due to variation of loss or gain with frequency"; in jargon terms the frequency characteristic is not "flat." Another assumption, alas by no means unjustified, is that there is considerable mains hum (frequency 100c/s).

The lower dotted graph illustrates a contrast ratio

* Based on Fig. 70, p. 141 of "Speech and Hearing"—Harry Fletcher, (Macmillan and Co., 1929).

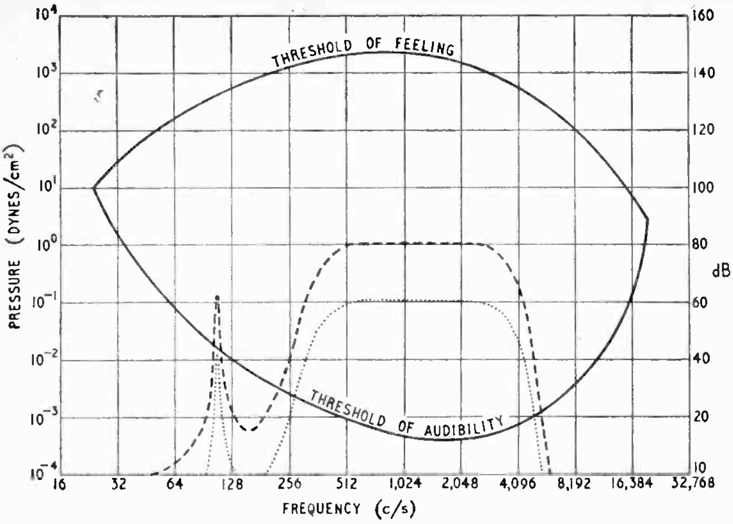


Fig. 2. Fletcher-Munson curves of the upper and lower limits of hearing, with superimposed (dotted) response curves of a poor-quality receiver at two different volume levels.

of 20dB, may be a pessimistic value, but not greatly so for medium-wave broadcasting.

We notice that the reproduction of the upper and lower frequencies varies with the volume knobs and this may explain, if it does not excuse, why the user of an inferior type of set turns up his volume. It is seen from Fig. 2 that as volume is increased so the frequency gamut is increased but now the middle frequencies must approach nearer to sensation level. The result may well be to overload the audio amplifiers with a consequent introduction of amplitude distortion "the lack of constancy of the r.m.s. value of the output of the system to that of the input at different amplitudes of the input," also of harmonic distortion "the production of harmonic frequencies at the output by the non-linearity of a network when a sinusoidal voltage . . . is applied at the input." In other words turning up the volume produces a harsh and unpleasing result marred by the introduction of spurious frequencies not existing in the original.

Noise and Bandwidth

It is also remarkable that as the volume is increased the bandwidth of reception is also increased and so any noise picked up is also increased—"the wider you open a window the more dirt that comes in." Maybe this noise is masked by the greater intensities of speech or music, while this is transmitted, but during quiet passages or during pauses noise is annoyingly audible.

Perfect quality would be represented by points lying within the lozenge-shaped area, indicated by the full lines of Fig. 2; it would demand a frequency characteristic, including the loudspeaker, which was flat between, say, 30 to 16,000c/s, freedom (to, say, 80dB) from harmonic or amplitude distortion and a contrast ratio without the introduction of noise of, say, 80dB.

There is another form of distortion which may or may not be audible, namely, phase distortion "distortion due to variation of the group velocity of the system with frequency" and, as explained later on, a distortion associated with a Doppler effect in the loudspeaker. There is also the effects due to hangover of oscillation of the loudspeaker diaphragm. We know that if the frequency characteristics of a system is flat then the group velocity of waves transmitted through it is constant; phase change is then proportional to frequency. If, however, the effects of reactance are present, causing a variation of the ratio of the output to the input of the system with frequency, then inevitably phase distortion appears. This is why some argue that the frequency characteristic of the amplifiers in a receiver should extend to, say, 100,000c/s and then fall off gradually. In common practice cut-off is allowed just above the highest frequency it is desired to reproduce. Whether this effect, other distortions being eliminated, is audible, I do not know.

The Doppler principle is that which makes the frequency of waves appear to change when there is a relative velocity between the wave source and the observer. Thus if a loudspeaker diaphragm is moving as a piston at a low frequency, and if it is simultaneously reproducing a higher frequency than there is, so far as the higher frequency is concerned, relative velocity between observer and source; the higher frequency is thus frequency-modulated by the lower. The degree to which the effect is audible is not known to me; it may well be negligible.

But there are more things in transducers and amplifiers than are dreamed of in some philosophies; flattening the frequency characteristic, as judged by audio oscillator and output volt-meter (electrical or acoustical) is a step on the way, but there are other side effects which this simple test cannot remark. For example, there is the hang-over of the diaphragm of a loudspeaker which, given a steep wave front, continues to oscillate long after the impulse which sets it in motion has died away. By the same token it will not immediately and therefore properly respond to a steep wave-front. These are effects which subtract from good quality by robbing music of its attack, its crispness, which when present is an engaging characteristic of good reproduction.

Obscure Distortions

There are other distortions which defy analysis; recounting an experience may illuminate my meaning.

A friend, whose judgment of quality is of a very high order, installed an allegedly hi-fi single channel radio-gramophone which, at first hearing, pleased him. The same impressive housing beautiful wood, discreet lid cushioning into place, contained tuner and turntable while a set of loudspeakers, contained in what might be described as a cupboard, radiated their output through an elegant grill.

As time passed my friend's satisfactions diminished until, thoroughly disillusioned, he decided to install a separate loudspeaker in substitution for those boxed in what I have described as a cupboard.

A change-over switch allowed a comparison. It only needed to be operated once to demonstrate excellent as compared with indifferently good quality. Incidentally, the single loudspeaker which gave the improved quality was one which faced into the corner of the room.

What can one conclude and what more when it is recounted that the substitution of the tuner and the gramophone pickup by others of different design made a further improvement? Perhaps all is not fi which is described as hi; except the latter abbreviation did truly qualify the cost of my friend's set.

I can hear my critics saying, "What after all have you said, that the elimination of harmonic, amplitude and phase distortion is essential? We hi-fi experts are quite aware of that."

I reply "Yes! But if you are why can someone buy an expensive hi-fi equipment and find it lamentably wanting and why do I and others feel that stereophony is no more than a gimmick, not a fundamental improvement?"

Another critic might exclaim, "Are you so simple as to neglect the cost factor? It's all very well to ask for a wide frequency gamut, amplifiers free from distortion, elimination of mains hum, but have you considered the cost?"

"I am," I reply, "quite aware of the cost factor and that is one reason why I have continuously and persistently (without making much impression) argued the merit of wire-broadcasting." Let me once more, in the light of the foregoing, point out its advantages with respect of reproduction.

Essentially, given a conductor, joining programme source and loudspeaker, the receiver can be simpler than when radio is used. In audio frequency technique the receiver is no more than a loudspeaker; if a carrier frequency method is essential, then the received level is not a few, but hundreds of millivolts and the receiver is consequently cheaper and gives better reproduction in spite of its decreased cost.

In sum, while I respect those who believe that stereophony represents a major advance in the art of reproduction, my own ears fail to notice more than a difference, not an improvement. I am not alone in this belief.

The greatest step towards hi-fi would be that which concentrated on removing distortions due to non-linearities and the effects of noise from the average receiver.

A wider application of wire broadcasting would be a major advance towards hi-fi. It would also perhaps be easier, because of its facility to provide more channels, to introduce stereophony with wire rather than radio broadcasting.

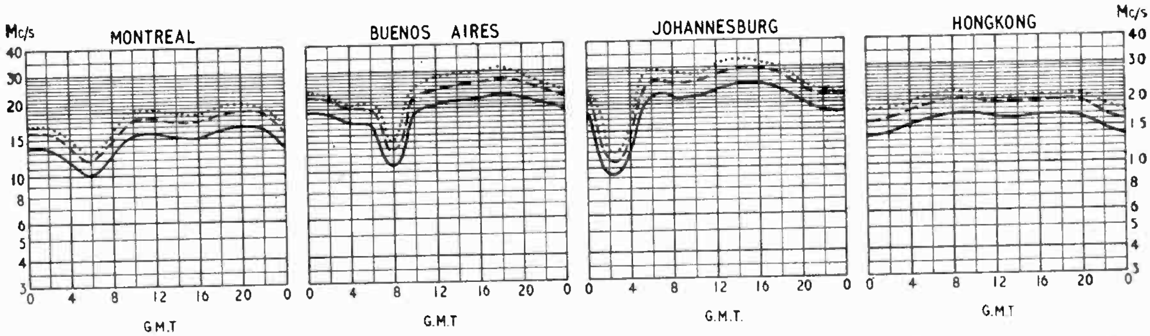
Excessive Volume

As a final and possibly "tantrumistic" contribution to the subject I must air a grievance. What is it that turns ordinary decent folk, once they get their hands on the steering wheel of a motor car or the volume knob of a loudspeaker into sadists demonstrably hating their fellow men? As one who suffers from my neighbour's ever-louder speaker, I pray that the designers of reproduction equipment should limit volume output and should not give the user the excuse to increase it by the limitation of the frequency characteristic. If I were in charge of a wire broadcasting system I would deserve the thanks of many, because I would make it impossible for the reproduced sounds to exceed a certain level. I am aware that a reduced level may subtract from realism, but then I deny the need for realism. I would and do accept limitations both of contrast level, frequency characteristic, and volume, but I cannot abide the invasion of spurious tones; I want clean reception and the crisp reproduction of transients.

Good quality, as I define it, at a lower volume than may be theoretically desirable is, as I prove whenever I listen, satisfactory, but the quality must be good quality, and the operator of the set, like me, a good neighbour.

SHORT-WAVE CONDITIONS

Prediction for June



•••••••••• 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 June.

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

Noise Level Measurement in Television

Method for Use When the Video Signal is Present

By L. E. WEAVER,* B.Sc., A.M.I.E.E.

THE following method of measuring the level of random fluctuation noise in a television signal was originally developed in response to a request within the BBC for an accurate and completely objective procedure for use with camera tubes, and in particular image orthicons. It has proved to give very consistent and accurate results, and for this reason it has for some time past been adopted as the standard method of test for the acceptance and maintenance checking of these tubes.[1]

Although such a measurement may seem to concern only a comparatively few specialists, in fact the manner in which the method operates, by taking advantage of certain characteristics of a television signal, is of much wider interest. It can also be applied to other random noise measurements in the television field.

Difficulty of Measurement

For the present purpose it is only necessary to explain that the principal difficulty in measuring this random noise level arises because these camera tubes can only operate while being scanned, so that their output signal always contains both scanning and random noise components. Even in the extreme case where the lens is capped and the synchronizing pulses are removed, the output signal still contains enough energy from the line and field components to frustrate any attempt to estimate the random noise by a direct measurement of the output level of the tube.

Evidently what is needed is some means for distinguishing clearly between the random noise and the signal components. The standard method hitherto achieves this by making use of the storage property of the eye and its ability to interpret patterns. The signal is displayed on a waveform monitor and the apparent or quasi peak-to-peak noise voltage is measured separately from the signal voltage by recognizing the difference in waveform. Unfortunately there is a degree of uncertainty inherent in this method which makes it inadvisable for the present purpose. For example, the conversion factor from quasi peak-to-peak to r.m.s. noise voltage, which is the quantity required for the signal-to-noise ratio, is given values ranging from 14 to 18 dB by various authorities.

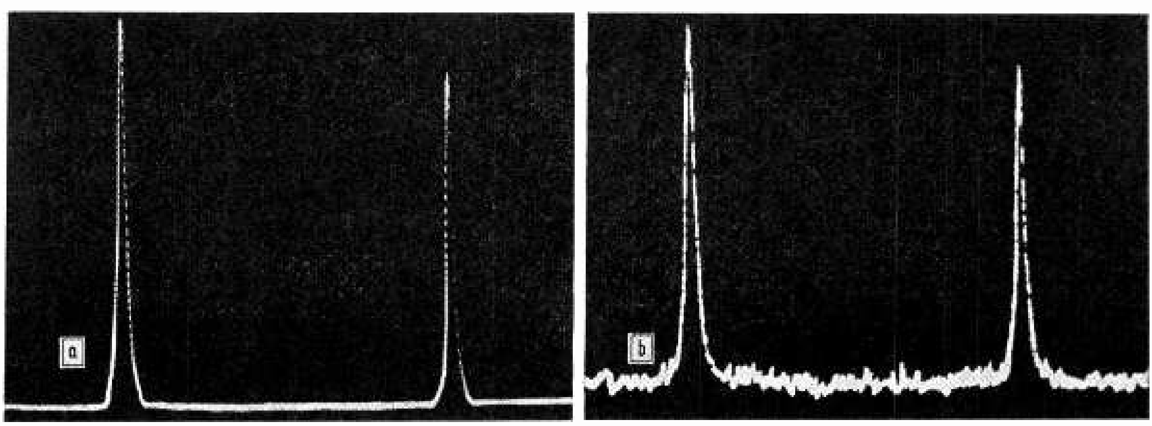
* British Broadcasting Corporation.

Nature of the Video Spectrum

The preferred method takes advantage of the difference in spectrum between the signal and the random noise components. It was shown by Mertz and Gray[2] more than a quarter of a century ago that the spectrum of a television signal is basically discontinuous, that is, in general the energy is almost entirely concentrated in the area immediately surrounding each line-frequency harmonic in the form of a rapidly decreasing series of sidebands, which originate from both the synchronizing information and the picture content. On the other hand, the spectrum of random fluctuation noise is inherently continuous, with the energy, on an average, distributed evenly over the spectrum.

This is well illustrated by Fig. 1, which shows two photographs of the same portion of the spectrum of a television signal comprising two adjacent line-frequency harmonics in the neighbourhood of 600 kc/s. Fig. 1 (a) corresponds to the original, almost noise-free, signal and (b) to the same signal but with added white noise. The resolving power of the apparatus was not sufficient to show the sidebands in detail, but their presence is indicated. The apparent erratic nature of the noise spectrum

Fig. 1. Portion of the spectrum of a television signal comprising two adjacent line-frequency harmonics: (a) original noise-free signal, (b) the same signal with added white noise.



between the harmonics is due to the fact that the sweep shows the conditions existing at a series of successive instants, and not the average condition over the area concerned.

This leads one to suppose that if it is possible to measure the energy in a narrow frequency band situated midway between two such line-frequency harmonics, the reading will be independent of the signal content and will, in fact, represent the noise power distribution with frequency in that region of the spectrum.

The simplest satisfactory way of making use of this principle in practice is shown in Fig. 2. A more refined version has already been described elsewhere[3] and an improved form of this is at present under investigation.

In the "measure" position of the switch the incoming video signal is connected through a fixed attenuator pad to the input of a communications receiver, which covers the video band down to 60 kc/s and is provided with a choice of bandwidths between 6 kc/s and 100 c/s. The input circuit has been modified to provide a good 75-ohm impedance, and the pad serves to prevent overloading the receiver. The audio output terminals are connected

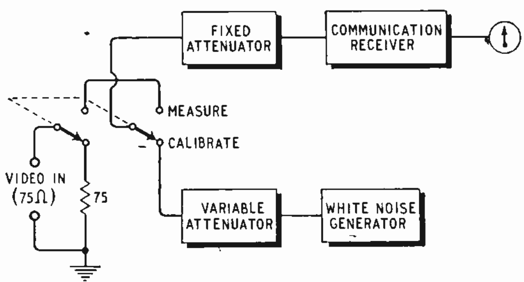


Fig. 2. Simplest technique for measurement of random noise level.

to a meter which reads a close approximation to r.m.s. values.

In the "calibrate" position of the switch the incoming signal is terminated and at the same time the receiver with its input pad is connected through a variable attenuator to a standard white-noise generator. This generator furnishes an accurately known and constant random noise power per unit of bandwidth.

Use of the Apparatus

With the switch in the "measure" position, the receiver is set to a convenient bandwidth, say 600 c/s. When it is tuned slowly through the region where a reading is required a series of sharp maxima corresponding to the line-frequency harmonics are shown on the output meter. The receiver is then tuned accurately to the exact minimum point midway between two such maxima, and the gain is adjusted until a convenient output reading is obtained.

The switch is next placed in the "calibrate" position and the setting of the fixed attenuator is varied until precisely the same reading is given by the output as in the previous instance.

When this has been achieved, the noise power per unit of bandwidth from the generator has been made the same as that existing at the point in the video spectrum where the measurement was made. If the random noise has a flat spectrum, then a knowledge of the generator constant and the attenuator setting are sufficient to enable one to calculate the total noise power in a 3-Mc/s band, and hence the r.m.s. noise voltage. If the noise spectrum is not constant a few more readings must be taken, in most instances three or four are sufficient, and the calculation is just a little more complicated but nevertheless still very simple.

The great advantage in calibrating the receiver with the standard white-noise generator lies in the removal of two important sources of error, the variations in the pass-band of the receiver and the behaviour to noise voltages of its diode detector. The adjustment to equality of output meter reading means that the noise powers per unit bandwidth are the same in the two instances, and the shape of the receiver pass-band is therefore quite immaterial. At the same time the detector is operating at the same level with applied voltages of the same nature, and consequently no correction is needed for this effect.

A Practical Example

Suppose that when noise with a flat spectrum is measured, the attenuator reading for equality of output level is found to be 20 dB. The reference generator furnishes a noise power of 20 μW per Mc/s. Now for a picture signal amplitude of 0.7 volt peak-to-peak in a 75 ohm circuit and 3 Mc/s bandwidth the random noise power distribution corresponding to a signal-to-noise ratio of 0 dB is easily found to be 220 μW per Mc/s. The actual ratio is therefore $20+10 \log_{10} 220/20$ dB= 30 dB to the nearest 1 dB. In practice the added 10 dB constant would be known in advance, so that the answer would be obtained without the necessity of calculation.

When the measured spectrum is not flat a small number of readings is taken. The fact that these are expressed in power per unit bandwidth makes it possible to use immediately one of the rules for approximate integration such as the trapezoidal rule, and the calculation then reduces to a quick and simple arithmetical operation. The details, if required, are given in reference[3].

This series of readings at different frequencies also gives the shape of the noise spectrum, which is a further useful piece of information. For example, when testing image orthicon tubes it is usual to present the camera with a standard test scene and to adjust the overall resolution of the camera with its control unit in a standardized manner. Since the noise spectrum of an image orthicon should itself be flat, the measured deviation from flatness is an accurate measure of the resolution of the tube itself under working conditions[1].

A small correction to the overall signal-to-noise ratio has to be made when the signal is blanked, since this process reduces the total random noise power without changing the noise voltages which are superimposed upon the unblanked portions of the waveform. With 405-line signals, 1 dB must be subtracted from the measured value.

There is a limit to the lowest signal-to-noise ratio which can be measured, which arises from the fact that the energy from the signal components in the region of measurement, although normally extremely small, is not in fact absolutely zero. The exact amount is a function of the subject matter of the picture signal, the frequency of measurement, and the time stability of the waveforms composing the synchronizing signal, so that it is impossible to give a single figure for the limiting signal-to-noise ratio measurable to a certain degree of accuracy. Further information and a curve are given in reference[3]. Very broadly, however, it can be stated that this limitation has not been found at all restrictive for the type of measurement for which the method is intended.

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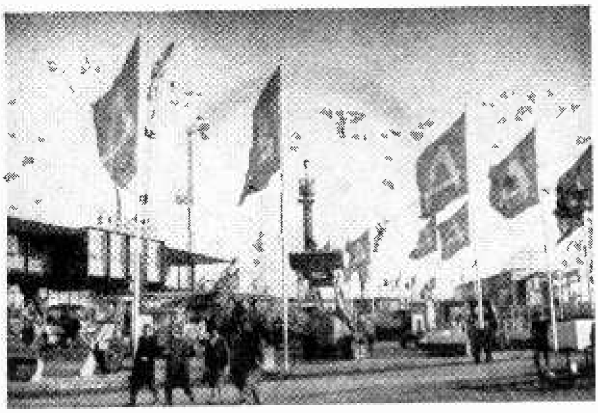
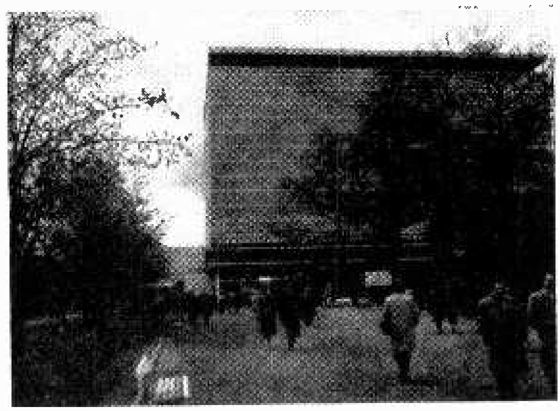
3. "The Measurement of Random Noise in the Presence of a Television Signal." L. E. Weaver, BBC Engineering Division Monograph No. 24, March 1959.





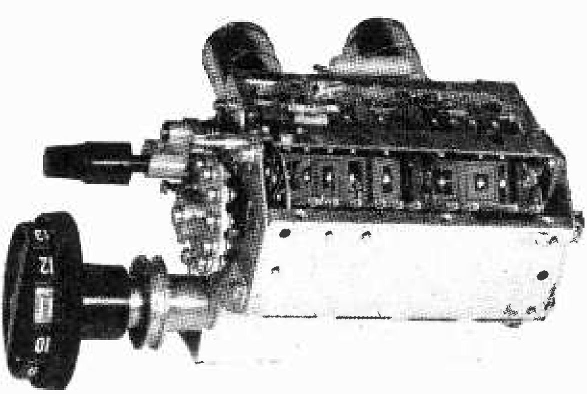
HANOVER FAIR

IF the radio and television sections seem to occupy an insignificant part of the 7 million square feet of this vast exhibition, they are nevertheless comparable in size with our annual and the German biennial special radio shows. Indeed, Hanover is regarded by many of the German radio manufacturers and their customers as the most important event of the year, and this applies particularly to those interested in portable and car radio receivers, for the Fair is invariably held at the beginning of the summer season.

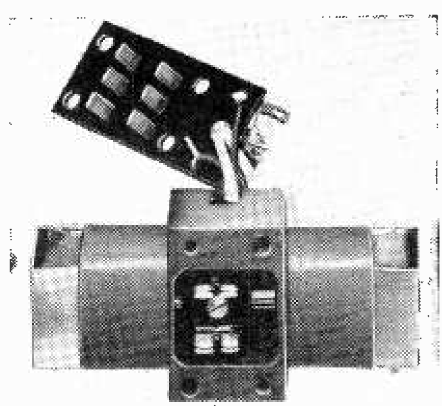
The valve has virtually disappeared from portable receivers and most of the new all-transistor models have provision for v.h.f. as well as medium and long waves. The introduction of a v.h.f. band has spread even to some personal portables, e.g., the Telefunken "Partner" (v.h.f. and medium waves) and Siemens RT10 (the latter with three wavebands). Although operating on medium waves only, the new Grundig "Mini-Boy" is the smallest transistor pocket receiver at present on the German market; it weighs 250gm (10oz) and measures 104×65×27mm.

The vogue of the dual-purpose car-radio/independent

Deutsche Philips "Memomatic" tuner with printed inductances and independently adjustable trimmer stops on each channel.



Band switching in some Nordmende sets is effected remotely by a miniature switch operated by an electromagnet, shown open to reveal sliding contacts.



battery portable first noted last autumn in London and Frankfurt is well established and has been strengthened by the introduction of the "Westerland" combination by Blaupunkt. In this an independent transistor portable with self-contained batteries is designed, as usual, to fit neatly into a recess in the car dashboard. When the set is pushed home an additional 4-watt output stage, feeding a larger loudspeaker also permanently installed in the car, is brought into operation. This auxiliary reproducer has its own separate bass and treble tone controls.

Although the promised second television programme in Germany is still delayed by organizational questions, for which satisfactory answers have not yet been found, it is confidently expected at the turn of the year (1960/61). One consequence of the delay is that set manufacturers have had to produce sets with provision for Band IV tuners which can be bought and fitted later on by customers who are reluctant to spend money so far in advance of fulfilment. To ensure that realignment will be unnecessary when the u.h.f. units are added, Blaupunkt are using a non-reactive bridge filter in the output from the mixer. This causes some loss of gain, so all new Blaupunkt models have 4-stage i.f. amplifiers.

"Fully automatic" operation is still obligatory in television sets which hope to sell in Germany, and contrast control by ambient light, as well as "automatic fine tuning" on both v.h.f. and u.h.f., are now common. The method adopted by Deutsche Philips in their "Memomatic" tuner for Channels 2-11 is to pay particular attention to oscillator stability and then to provide independently adjustable trimmer stops for each channel on the selector switch mechanism. These determine the setting of the trimmer through a rocker arm.

A neat method of band switching is used by Nordmende in some of their television sets, which not only eases design problems in the layout of the tuner unit but also provides for simple remote control. The switch slider is actuated by the armature of a solenoid in which there are two windings connected in series in the valve heater circuit. One or other of these coils is short-circuited by push buttons on the front panel or by switches in a cable-connected remote control unit.

The inexpensive Grundig television camera, mentioned last autumn in our report of the Frankfurt radio show, can now be obtained with a portable battery-operated radio link, working on 440-460 Mc/s. The range is stated to be 2km average.

Considerable prominence is being given in Germany at the present time to *störstrahlung*—radiated interference from TV tuner units, timebases, etc. With the coming of the second programme on Band IV the problem is appreciated as a serious one and is being so treated by the manufacturers, who are giving particular attention to the design of screening in tuning units and to the establishment of radiation measuring laboratories in order to be able to meet the requirements laid down by the German Post Office.

Television sets capable of receiving the four standards at present in use in Europe are now offered by Blaupunkt, Graetz and Telefunken.

Although the Hanover Fair is predominantly the shop window of German industry it is open to all and is gaining in international significance. It is gratifying to record that many British radio and component manufacturers were represented, either as individual exhibitors or as participants in the British Electronics Centre.

Nordwest Deutsche Rundfunk television studio and O.B. equipment installed adjacent to Hall 9 for the broadcast of special programmes relating to the Fair. These and other programmes were distributed by cable to exhibitors' stands.

Using the Simple Analogue Computer

SETTING UP THE INSTRUMENT TO REPRESENT A MECHANICAL SYSTEM

By G. B. CLAYTON*, B.Sc.

LAST month the author described the design and construction of a simple analogue computer that could be used for demonstration purposes in educational and other training establishments. As a suitable exercise in connecting up the computer to represent a physical system, consider the mechanical arrangement in Fig. 1. This consists of a mass M suspended in a viscous liquid by a light spiral spring.

It is required to determine the subsequent motion of the mass if it is displaced from its equilibrium position and then released. Let S represent the force required to produce unit extension of the spring (S being a measure of the " stiffness " of the spring) and let D be the viscous force per unit velocity acting on the mass. Let y measure the displacement of the mass from its equilibrium position.

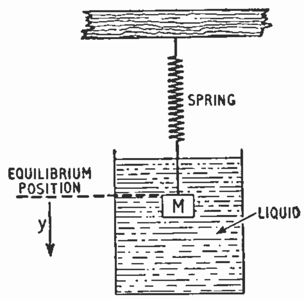


Fig. 1. Mechanical system to be represented on the analogue computer.

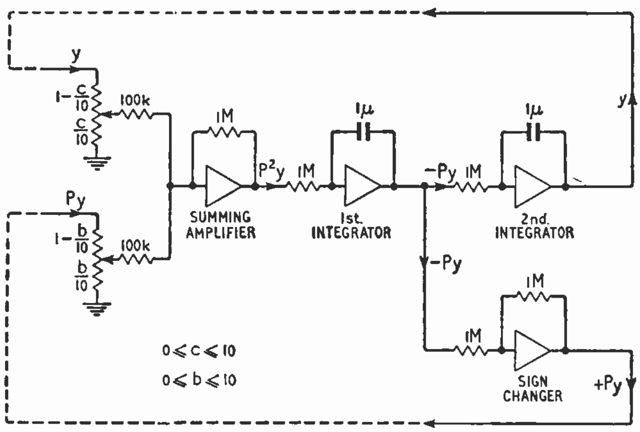


Fig. 4. Combination of Fig. 2 and Fig. 3 to form the complete computer set-up for solving the equation for Fig. 1.

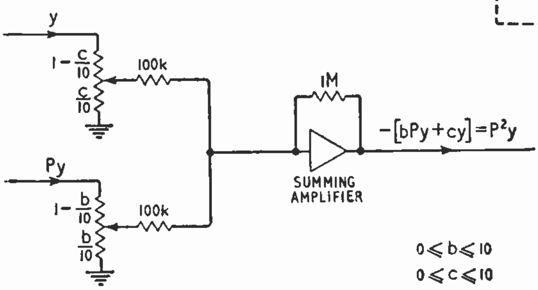


Fig. 2. The summing operation necessary in solving the equation for Fig. 1.

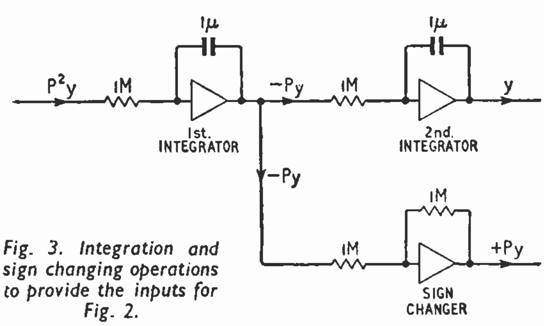


Fig. 3. Integration and sign changing operations to provide the inputs for Fig. 2.

The force acting on the mass will be

$$F = - Sy - D\frac{dy}{dt}$$

and the equation of motion of the mass will thus be

$$M\frac{d^2y}{dt^2} = - Sy - D\frac{dy}{dt}.$$

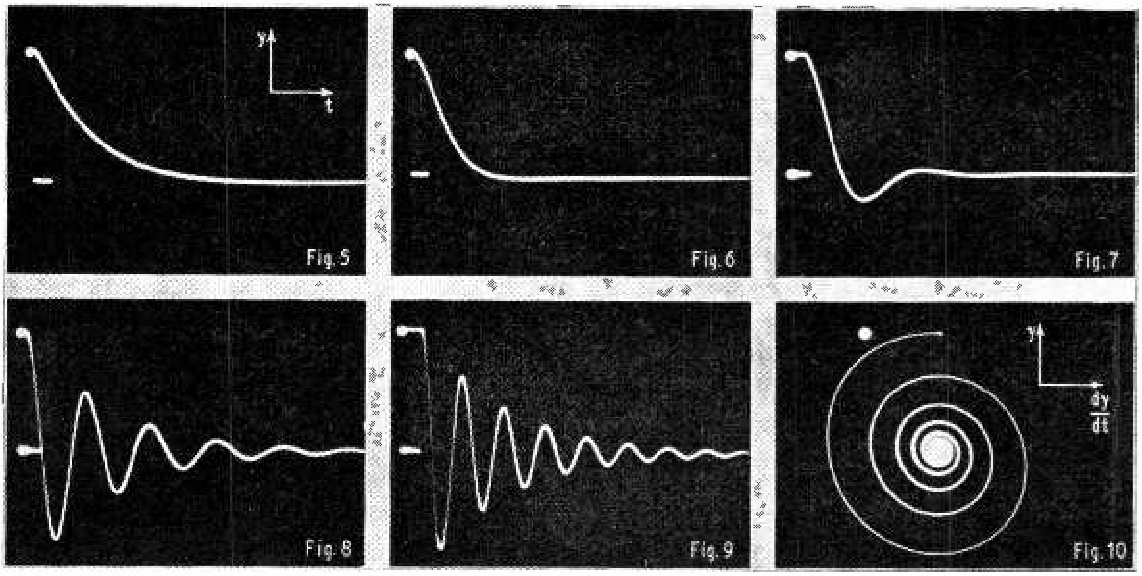
Rearranging this gives

$$\frac{d^2y}{dt^2} + \frac{D}{M}\frac{dy}{dt} + \frac{S}{M}y = 0 \text{ or } P^2y + bPy + cy = 0$$

where $P = \frac{d}{dt}.$, $b = \frac{D}{M}$, and $c = \frac{S}{M}$. Many physical systems may, in fact, be represented by a second order differential equation of this type, e.g. a damped galvanometer movement, or an LCR electrical circuit.

In order to solve the above equation it is first rearranged: $-(bPy + cy) = P^2y$. Terms bPy and cy are represented by voltages which are applied to the input terminals of a summing amplifier. This performs the operation of addition and multiplication by -1, and its output must therefore represent

* Liverpool College of Technology.



Figs. 5—10. Oscillograms of solutions of equations obtained using the analogue computer arrangement in Fig. 4.

P^2y (Fig. 2). The voltages representing Py and y are dependent on the value of P^2y and are obtained from P^2y by successive integrations.

P^2y is assumed to be known and is applied to the input of an integrator. The action of an integrator being essentially that of multiplication by $-1/P$, the output of this integrator gives $-Py$. A second integrator changes $-Py$ to $+y$ and a sign changing amplifier changes $-Py$ to $+Py$ (Fig. 3). The voltages representing Py and y are now available for application to the summing amplifier of Fig. 2, and the complete computer set up for the solution of the equation is shown in Fig. 4.

This circuit causes the variable voltages to change in exactly the same way as the physical variables that they represent. At the start of a computer run the integrator control switch is put in the "reset" position and a voltage representing the initial value of the displacement y is put across the capacitor of the second integrator. On switching to the "compute" position the integrators are placed in circuit and the computer run commences.

The oscillograms above are a record of some solutions obtained using the circuit of Fig. 4. Figs. 5 to 8 show the displacement y as a function of time for a constant value of the coefficient c but successively smaller values of the coefficient b. The coefficient b, which depends on the viscosity of the liquid, controls the damping of the motion; Fig. 6 corresponds to critical damping. Figs. 8 and 9 are solutions for the same value of b, but in 9 the coefficient c has been increased. This corresponds to an increased spring "stiffness" with a consequent increase in the frequency of oscillations, the damping remaining the same. Fig. 10 shows the displacement y as a function of the velocity $\frac{dy}{dt}$ for a damped oscillation. The recordings were made using an oscilloscope with d.c. coupled amplifiers, slow sweep facilities and a long-persistence screen.

Thanks are due to D. L. McCluskey who did most of the constructional work on the apparatus described last month.

B.B.C. HANDBOOK

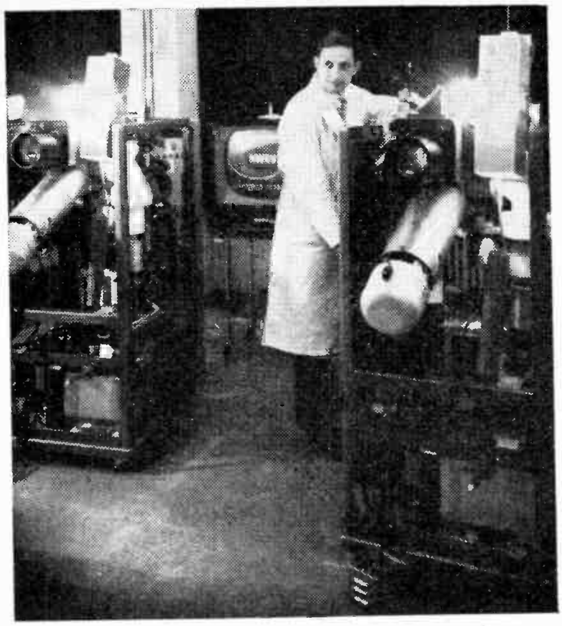
WITH the object of giving "a comprehensive and up-to-date picture of what the B.B.C. is and what it does," the Corporation publishes each year a handbook. The 1960 edition, like its predecessors, does just that. Although a considerable part of its 270-odd pages is devoted to programme matters, there is much of technical and general interest in the Handbook. Here are some points of interest culled from the section devoted to engineering activities.

"Approximately 50% of the programme output is recorded in advance. . . . During the year recordings were made on 108,000 disks and 24,000 miles of magnetic tape. . . . B.B.C. tape recording facilities include 241 static, 88 mobile and over 225 midget machines. There are also 68 static and 29 transportable disk-recording machines."

"While it may well be possible to build at great cost a loudspeaker or combination of loudspeakers, which in a specially arranged setting will be the ultimate in performance in the light of present knowledge, this is of little use to a broadcasting authority [for monitoring]. Here the need is for some hundreds of high-quality loudspeakers, all of which must have an identical performance within normal manufacturing limits. Since nothing meeting these requirements is available commercially, the B.B.C. has designed and produced its own loudspeaker system, including the design of a suitable cabinet."

It is interesting to see that the cost of running the television service in 1958/59 was £14M as against £11.1M for the domestic sound service and £5.9M for the external services. The percentage of each of these figures attributed to "engineering" is 33, 23 and 25, respectively. Of the total of £4.6M for television engineering, £775,086 was for the rental of Post Office lines.

LARGE SCREEN COLOUR TV



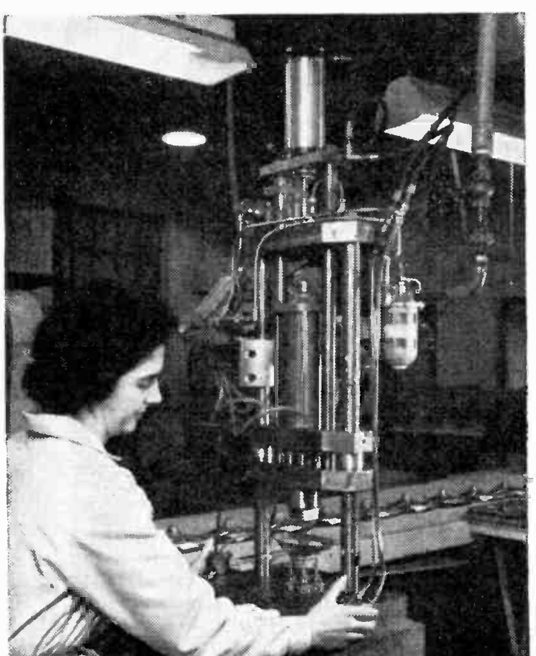
Eidophor projectors in process of manufacture.

THE Eidophor system for projecting television pictures on large screens has now been adapted for colour television, and recently we saw a demonstration of its capabilities for closed-circuit work at Belle Vue, Manchester, given by CIBA Clayton Ltd., the dye manufacturers. In the Eidophor projector (made in Switzerland by Gretag A.G., with the backing of CIBA, the Swiss chemical combine) light from a powerful xenon arc lamp is modulated by means of an oil film which is electrostatically deformed in the pattern of the television picture by a scanning electron beam. The deformations in the film actually modulate the light by refraction—by altering the angle at which the light is reflected from a concave mirror behind the oil film. An optical interception system (Schlieren system) in the path of the reflected light then causes the beam-angle variations to produce corresponding beam-intensity variations in the light emerging from the projector.

Adaptation to colour television has been achieved by using the frame-sequential system with synchronized rotating colour filters in front of the camera and projector. For the demonstration three image orthicon cameras were set up at CIBA Clayton's Technical Service Laboratories in Manchester and the signals were transmitted $1\frac{1}{2}$ miles by microwave link to Belle Vue for projection on a screen measuring 10ft × 7ft. The cameras were American types and the 525-line standard was used.

The advantage of the Eidophor system over c.r. tube projection systems is, of course, the greater brightness obtained by modulating a normal light source. This was very evident at the demonstration, although the pictures suffered a certain amount of spasmodic flicker. Definition was excellent for a large screen (there are no image registration problems with the frame sequential system) and the colour rendering was as good as the quality of the rotating colour filters.

Multi-Riveting Machine



A DOUBLE-ACTING air-operated press tool especially suitable for radio assembly work involving riveting of any kind has been introduced by Rhoden Partners Ltd., design and development engineers of 19, Fitzroy Square, London, W.1. It is shown in the illustration in use in the production of loudspeakers.

A feature of this machine is that it automatically feeds and punches a whole pattern of rivets in one operation and it is claimed that the squeezing action of the air-operated punches is less violent than mechanical impact operation as it produces little or no distortion in the immediate vicinity of the riveted parts.

The working cycle is as follows: the operator loads the parts to be riveted together on to the spring-tensioned location pins in the bottom bolster, then releases compressed air to the upper ram punch holder. For this latter operation two press buttons have to be operated simultaneously, one by each hand. This is a safety precaution. After the riveting operation is completed the rams rise automatically to the "ready" position. This sequence of operations takes about three seconds.

Power for the press is a single-phase (230-250V) a.c. supply for the rivet vibratory-bowl feeder, and an air supply of preferably 80lb sq in.

Rhoden multi-riveting machine.

WORLD OF WIRELESS

Trade and Production

FIGURES contained in the twenty-seventh annual report of the Radio and Electronic Component Manufacturers' Federation show that production of components during 1959 increased by over 20% compared with 1958. Total production for 1959 was about 2,400M components, worth £120M. On average this represents an output of one million components for each working hour.

Domestic equipment manufacture absorbed 43% of the total, an increase of 1.4% over 1958, professional equipment took 30.4% and 14.6% (– 0.9%) was exported. The remainder comprised a.f. equipment and military use, retail sales, etc. Exports of components returned £21.5M, compared with £20M in 1958.

The total value of parts and assembled equipment exported was £53.4M (+17.5%), the most significant increase being in professional equipment, which rose by 35% to £21M. The largest individual markets (up to November) for components continued to be Australia (£1.34M) and India (£0.96M) and for a.f. equipment the U.S.A. (£5.03M); but the largest increase, 50%, in sales over £0.5M was in Italy. Total exports to America top the list at £5.6M, a rise of 28.2% over 1958. Total audio exports, however, fell.

Imports to the U.K. rose to £20.3M from £13.5M in 1958. Biggest increase here was £2M, to £5.7M, for valves, tubes and parts; but imports of domestic receivers nearly trebled to £0.61M. Tape recorder imports were three times our exports and Great Britain now has an adverse balance of £3.8M with the Netherlands and W. Germany. The total deficit with the Common-Market countries was £2.7M and the credit with Outer Seven £1.2M.

New Post Office Director General

On June 1st Sir Gordon Radley, K.C.B., first engineer to be director general of the Post Office, retires after five years in office. He joined the Post Office in 1920 and was controller of research before being appointed engineer-in-chief in 1951. Sir Gordon, who was knighted in 1954 and was for some time chairman of the technical sub-committee set up by the Television Advisory Committee, was awarded the I.E.E. Faraday Medal in 1957 for his "outstanding contributions in the field of international communications and particularly in the development of long-distance, deep-sea telephone cables and their repeaters."

The new director general is Sir Ronald German, C.M.G., who entered the Post Office in 1925 and left in 1950 to become Postmaster General in East Africa, where he did much to develop the telephone service in that area. He returned to the British Post Office in 1959 as a deputy director general. Sir Ronald is succeeded as deputy director general by W. A. Wolverson, C.B., who entered the Post Office in 1928. In 1951 he was appointed commandant of the Post Office Residential Management Training Centre. He was more recently in charge of the Radio Services Department and since 1955 has represented the Post Office on the Council of the International Telecommunication Union.

Data Processing Expansion

THE Electronic Engineering Association, which represents the capital goods side of the industry and is now separated from the Radio Industry Council, is setting up more groups to deal with electronic data processing matters. The 1959 Annual Report of the E.E.A. reveals that in addition to the data processing executive committee formed in 1956 there are now two technical committees, on digital and analogue data processing respectively, with working parties on coding of punched paper tape, storage systems, input and output equipment, international data transmission, core stores, magnetic tape, single-purpose computers and on transistors and semiconductor devices for computers. In 1959 exports of electronic computers amounted to £1.75M, the total exports in the field of the E.E.A. being £28M. Recent achievements of the capital goods section of the industry are described in an illustrated annual review obtainable from the E.E.A.

Servicing Examination Problems.—The practical tests for entrance for the sound radio servicing certificate examination of the Radio Trades Examination Board on May 21st had to be postponed. This was because of "the difficulty of concluding a satisfactory arrangement with the patent holders" of the trainer-tester system introduced last year. This test has been deferred until the autumn when actual receivers will be used. Because of the problem of securing the necessary number of receivers, which are lent by manufacturers, it has been decided to restrict the practical course to candidates who succeed in the written papers.

The Paul Instrument Fund Committee have awarded a grant of £2,500, with the probability of further grants totalling up to £3,000, to Dr. J. H. Sanders, university lecturer and demonstrator in physics, Clarendon Laboratory, Oxford, for the construction of an optical maser; and another of £3,000 to H. W. Gosling, lecturer in the department of engineering, University College of Swansea, for the construction of an instrument for checking the stability of the standard ampere.

Institution of Electronics 15th annual electronics and instruments exhibition and convention is to be held at the Manchester College of Science and Technology from July 7th to 13th. It is again being organized by the northern division of the Institution and will include a manufacturers' section and a section devoted to scientific and industrial research. Complimentary tickets of admission to the exhibition and also details of the convention are obtainable from W. Birtwistle, 78 Shaw Road, Rochdale, Lancs.

Electronic Organs.—The first general meeting of the recently formed Electronic Organ Constructors' Society, of which Alan Douglas is president, will be held on May 28th at 2.30 in Room 45, Northern Polytechnic, Holloway Road, London, N.7. The secretary of the society, which has a membership of nearly 80, is A. Le Boutillier, 26 St. Catherines Road, London, E.4.

R.E.C.M.F.—At the annual general meeting of the Radio and Electronic Component Manufacturers' Federation on April 22nd, the following member firms (whose representatives' names are in parentheses) were elected to the council: Belling & Lee (N. Dundas Bryce), Garrard (H. V. Slade), A. H. Hunt (S. H. Brewell), Multicore Solders (R. Arbib), Painton & Co. (C. M. Benham), Plessey (P. D. Canning), S.T.C. (L. T. Hinton), Telcon Metals (G. A. V. Sowter) and Bakelite (G. J. Taylor). In addition Texas Instruments (D. Saward), Reliance Cords & Cables (C. H. Davis), and Morganite Resistors (J. Thomson) were subsequently co-opted to the council. Hector V. Slade and Dr. G. A. V. Sowter were re-elected chairman and vice-chairman, respectively, of the Federation.

B.R.E.M.A.—The new council of the British Radio Equipment Manufacturers' Association elected at the annual general meeting on April 29th consists of the following member firms whose representatives' names are in parentheses: A. J. Balcome (E. K. Balcombe), British Radio Corp. (F. W. Perks), Bush Radio (G. Darnley-Smith), E. K. Cole (W. M. York), Ferguson Radio Corp. (S. T. Holmes), G.E.C. (M. M. Macqueen), Kolster-Brandes (L. R. Tyne), Philips (A. L. Sutherland), Radio & Allied Industries (R. H. W. Pengelly), Rediffusion Vision Service (M. Exwood), Roberts Radio Co. (H. Roberts), and Ultra Radio & Television (E. E. Rosen). The new chairman of the association is A. L. Sutherland with W. M. York as vice-chairman.

Channel Islands TV.—The Television Act, which governs the I.T.A.'s operations, does not at present apply to the Channel Islands, but provision is made in the Act for its operation to be extended by Order in Council. If this is done, the I.T.A. plans to build a station, probably in Jersey, which will receive some of its programmes *via* the Authority's Devonshire station, due to be opened early next year. It is announced by the I.T.A. that if the Act is extended to the Channel Islands, they will offer the programme contract to Channel Islands Communications (Television) Ltd., which has recently been formed in Jersey.

"**Designers Guide**" is the title of an information sheet introduced by Mullard's Semiconductor Division to assist industrial designers to plan equipment in the knowledge that the semiconductors they specify will continue to be available when the equipment comes into production. It gives essential data on every Mullard transistor, rectifier and diode available. Readers wishing to receive "Designers' Guide", which will be issued three times a year, should write on their organizations' letter heading to: Semiconductor Division, Mullard Ltd., Mullard House, Torrington Place, London, W.C.1.

A radar training school is being established by Decca at the recently acquired site at Cowes Airport, Isle of Wight. Technical training courses of eight or ten months will be provided for the staffs of overseas Governments and authorities installing Decca civil or military radar systems. There will also be shorter courses of about six weeks for service engineers. The company already operates a technical training scheme at its service headquarters in London and a marine operational school at Blackfriars Pier, London.

"**Engineers in Communications**" is the title of a half-hour film surveying the research and development in telecommunications undertaken by Post Office engineers, which is now available for hire from the C.O.I. Central Film Library, Government Building, Bromyard Avenue, London, W.3. It costs 15s to hire and is considered particularly suitable for students.

Apprenticeship schemes offered by E.M.I. are outlined in a well-illustrated 32-page book "A Career in E.M.I. Electronics," which also deals with the group's various products. Career masters and others concerned with young people leaving schools and colleges may obtain copies of the book from the Group Personnel Department, E.M.I. Ltd., Hayes, Middx.

The Orkneys v.h.f. sound broadcasting station at Netherbutton, near Kirkwall, was brought into full-power service on May 2nd. Its directional aerial, giving a maximum e.r.p. of 25kW, radiates the B.B.C.'s three sound services on 89.3, 91.5 and 93.7Mc/s. A single-programme low-power transmitter has been in service on the site since December, 1958. Netherbutton picks up its programmes direct from the v.h.f. station near Wick, which in turn receives the programmes from the v.h.f. station at Meldrum, Aberdeen.

15,000,000 broadcast receiving licences were in force in the U.K. at the end of March. During the month the number of combined television/sound licences increased by 101,430 to 10,469,753. Sound only licences totalled 4,535,258, including 427,491 for sets fitted in cars. During the same period television licences in Holland rose to 640,000 and sound licences to 2,621,000.

H.P. and Hiring Restrictions.—Under new restrictions imposed by the Board of Trade on April 29th on the initial deposit and repayment period for hire-purchase and credit sales agreements (S.I. 1960, No. 762) a deposit of 20% of the cash price is now required on sound radio and television sets and gramophones. The period for repayment is limited to two years. Another Order (S.I. 1960, No. 763) stipulates that the initial payment on hiring agreements for these equipments is a quarter's hire charge.

Norway.—The official opening of the Norwegian television service has now been fixed for August 20th. At present experimental transmissions are radiated by a transmitter in the Oslo area, where some 14,000 licences have been issued. A second station, in Bergen is being introduced.

Armour Research Foundation of the Illinois Institute of Technology is acting as host for the fourth annual Joint Military-Industrial Electronic Test Equipment Symposium which will be held in Chicago on September 14th and 15th.

Two-year sandwich course in telecommunications, providing alternate 6-monthly periods in college and industry, commences at the South East London Technical College, Lewisham Way, London, S.E.4, on October 3rd. The London fee is £17 per year. C. W. Robson, head of the electrical engineering department, has also sent us details of a four- or five-year engineering sandwich course in which provision is made for specialization in communication engineering.

Technical books to the value of £200 are to be provided during each of the next seven years to the Holborn (London) Central Library under a deed of covenant presented by Philips Electrical Ltd.

Valve Dimensions.—Two new sections of BS448, specifying the base and bulb dimensions of the B5G/F and B7E/F sub-miniature valves with flexible connecting leads, have been issued by the British Standards Institution. They cost 2s each.

"**Hardwood Instrument Cases.**"—Because of the misspelling of the name of a resin glue in the footnote on p. 178 of our April issue some confusion might arise with Casein type glues which are not so suitable for hardwood gluing. The correct name is Cascamite.

"**Dynamic Side Thrust in Pickups.**"—Owing to a typographical error in this article in our May issue, the steady stylus displacement was given on p. 215, column 2, line 30, as 25×10^{-3}cm; it should, of course, be 2.5×10^{-3}cm. On page 216, column 2, at the end of line 39, "other" should read "outer."

Advance Components Ltd. have asked us to point out that the price of their TC1 transistorized counter, which was quoted on page 254 of our May issue as £425, is now £335.

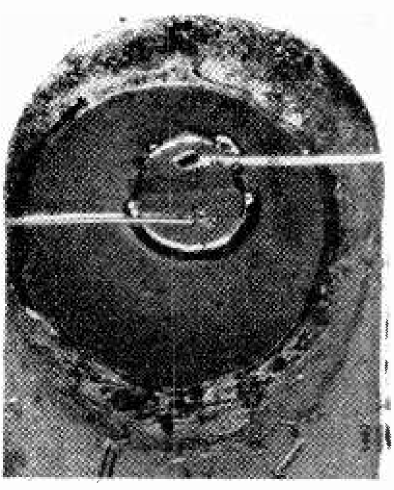
Heathkit Ham Transmitter Kit.—We regret that the price of the Model DX-40U on page 24 of the advertisements in our May issue, was given in error as £12 10s. The correct figure is £29 10s.

Royal Signals Institution.—Membership of the Royal Signals Institution, which has in the past been restricted to Officers of the Royal Corps of Signals, is now open to all ranks of the Corps, both past and present. Its object is to foster the professional and technical interests of the Corps by publishing a journal (at present bi-annually), arranging lectures, maintaining the Royal Signals museum and conducting an annual essay competition. Details of membership, for which the fee is 15s a year, are obtainable from Brigadier W. T. Howe, Royal Signals Institution, 88 Eccleston Square, London, S.W.1.

Twelve Scholarships to men wishing to study for the Radio Amateurs' Examination are being offered by 404 Signal Squadron (Press Communications), Army Emergency Reserve. The scheme is open to fit men between the ages of 18 and 40 who are prepared to enlist in the Squadron for three years. When they attend the annual 15-day camp (the only peace-time training) they will be given intensive courses in basic theory and morse. At home they will continue their theory studies by means of a free correspondence course in preparation for the 1961 radio amateur examination. Details are obtainable from Major J. A. Bladon (G3FDU), 28 Jack Lane, Davenham, Northwich, Cheshire.

I.E.E. On The Pipe.—The Institution of Electrical Engineers building is now permanently connected by a 5-Mc/s wide-band coaxial cable to the Post Office distribution network for television or other wide-band signals. The cable, which goes to the Gerrard exchange, was actually put in for the colour television relay from Paris reported on p. 287.

Stereophonic broadcasting using a time-multiplex pulse-amplitude modulation system for the transmission of two channels from one transmitter has been developed by Siemens & Halske AG., of West Germany. The system, which is compatible, is one of several being tested in Germany.



Portrait of a Mesa.—*The central section, to which the two wires are attached, is the raised plateau of semiconductor material which is characteristic of a mesa transistor. This specimen, magnified 53 times, is the Ferranti double-diffused silicon transistor ZT20, which has a cut-off frequency of 80 Mc/s. Its construction was described and illustrated in the March issue, p. 127. The two gold wires, one mil in diameter, are pressure-bonded to the base and emitter, while the metal tab supporting the main body of the semiconductor forms the collector connection. By mid-1960 production of these transistors is expected to be 25,000 per year.*

Personalities

J. A. Saxton, D.Sc., Ph.D., A.R.C.S., M.I.E.E., head of a division of the D.S.I.R. Radio Research Station at Slough for the past five years, has been appointed deputy director of the station. Dr. Saxton has been in the scientific civil service since 1938, when he joined the staff of the N.P.L. Radio Division. As already announced, the present director, **Dr. R. L. Smith Rose,** retires on September 30th, and is succeeded by **J. A. Ratcliffe.** Dr. Saxton has been responsible for carrying out a considerable programme on research in the propagation of microwaves over the ground and through the troposphere. He has twice served in the U.K. scientific mission in Washington and has been a U.K. delegate at many international scientific meetings. He is chairman of the U.K. national study group of the C.C.I.R. covering groundwave and tropospheric propagation.

Dr. J. A. Saxton

Prof. C. W. Oatley

C. W. Oatley, O.B.E., M.A., M.Sc., M.I.E.E., who since 1945 has been a Fellow of Trinity College, Cambridge, and University lecturer in electrical engineering, has been elected Professor of Electrical Engineering by the University. He will succeed **Professor E. B. Moullin,** who, as announced in our January issue, is retiring in October after occupying the chair since it was established in 1945. For twelve years prior to the war Professor Oatley was a member of the staff of the physics department of King's College, London, and for some time during the war was in charge of basic work on radar transmitters and receivers at the Radar Research and Development Establishment of the Ministry of Supply. He was chairman of the Radio Section of the I.E.E. in 1954/55 and is a member of the measurements and standardization committee of the International Scientific Radio Union.

J. Bell, B.Sc., F.Inst.P., deputy director of the G.E.C.'s Research Laboratories at Wembley, Middx., which he joined in 1929, has been appointed a director of the M.O. Valve Co., a subsidiary of the G.E.C. Mr. Bell, whose scientific work has been largely in the field of radio and radar transmitting valves, has been manager of telecommunications division of the laboratories since 1953.

P. J. Walker, president of the British Sound Recording Association for 1960/61, is managing director of Acoustical Manufacturing Co., of Huntingdon, which he formed in 1936. Mr. Walker, who has been responsible for most of the design and development of audio equipment made by his company, is also very well known as a lecturer on loudspeakers and high-quality reproduction. Readers will recall his articles in *Wireless World* on the electrostatic loudspeaker.

A. L. Sutherland, director of Philips Electrical, which he joined in 1933, and of Cossor Radio and Television since its acquisition by Philips, is the new chairman of the British Radio Equipment Manufacturers' Association. After war service in the Royal Artillery, in which he rose to the rank of major, and the Air Branch of the General Staff, Mr. Sutherland rejoined Philips in 1946 and managed the tungsten lamp department until being appointed commercial manager of the television and radio division in 1950. Six years later he was appointed to the board. Mr. Sutherland has represented Philips in B.R.E.M.A. for some years and has been vice-chairman of the council since 1957.

A. L. Sutherland.

J. F. Winterbottom.

J. F. Winterbottom, M.Sc., A.M.I.E.E., A.M.Brit.I.R.E., has been appointed chief engineer of Data Recording Instrument Co., of Ashford, Middx., which is associated with International Computers and Tabulators Ltd. Mr. Winterbottom was previously with the Motor Industry Research Association.

P. A. Charman, who joined Semiconductors Ltd. on its formation in 1957, has been appointed sales development manager and will be concerned with the company's technical information service. After ten years in the Electrical Branch of the Royal Navy and of the Royal Canadian Navy he was for two years with Philco (Great Britain), Ltd., where he set up a training equipment division.

Joseph Samuels, purchasing director of Winston Electronics, Ltd., Shepperton, Middx, for several years, has been appointed works director in charge of production. Before joining Winston Electronics in 1954, Mr. Samuels, who is 49, was for several years with Standard Telephones & Cables and later Sunvic Controls of A.E.I., Ltd.

V. P. Cole, who joined Grundig (Great Britain) Ltd. as sales manager in 1955, has been appointed sales director to the board. He started his career in 1917 as a wireless operator with Marconi's and during the last war he was with the Radio Production Executive of the Ministry of Aircraft Production.

James C. Pledger has been appointed technical director and chief engineer at the Coventry factory of Lexor Electronics Ltd. He succeeds **R. Grey,** who has taken an overseas appointment.

E. G. Wakeling, who joined Advance Components, Ltd., as general manager in February last year, has been appointed a director. He was formerly manager of the servo division of Elliott Brothers, Lewisham.

A. B. Clarke has joined Cossor Instruments Ltd. as sales manager. He was previously instrumentation sales manager of J. Langham Thompson Ltd., which he joined from the G.E.C. Applied Electronics Laboratories.

Cecil Dannatt, O.B.E., M.C., D.Sc., M.I.E.E., has been appointed vice-chairman of Associated Electrical Industries Ltd., with the special responsibility of co-ordinating both commercial and technical policy. Dr. Dannatt, formerly group managing director of Metropolitan-Vickers, has been group managing director of Associated Electrical Industries (Manchester) since it was formed earlier this year. He joined the board of Metro-Vick in 1947 as director and chief electrical engineer. Four years later he became assistant managing director and director of research and education. Dr. Dannatt, who is 63, and a director of a number of companies in the A.E.I. Group, was professor of electrical engineering at Birmingham University from 1940 to 1944.

H. West, M.Sc., M.I.Mech.E., M.I.E.E., assistant managing director of A.E.I. (Manchester) since last January, succeeds Dr. Dannatt as managing director. He joined Metropolitan-Vickers as an apprentice in 1918. In 1946 he was appointed assistant to the chief electrical engineer of the company; three years later he became chief electrical engineer, and was appointed to the board in 1951.

Peter Axon, O.B.E., Ph.D., M.Sc., A.M.I.E.E., managing director of Ampex Electronics Ltd., is now also managing director of Redwood City Engineering Ltd., the U.K. marketing subsidiary of Ampex International, S.A., of Fribourg, Switzerland. Dr. Axon joined Ampex Electronics Ltd., the organization's U.K. manufacturing subsidiary, last year from the Research Department of the B.B.C. where he had been engaged mainly in magnetic recording research and development since joining the Corporation in 1947.

D. H. Follet, M.A., Ph.D., F.Inst.P., keeper of the Department of Electrical Engineering and Communications in the Science Museum, London, since 1957, has been appointed director of the Museum. He succeeds Dr. T. C. S. Morrison-Scott, who has become director of the British Museum (Natural History). Dr. Follett joined the museum in 1937 as an assistant keeper in the department of physics. He was previously an industrial physicist.

OUR AUTHORS

D. Saull, who on page 306 discusses mains transformer design, is on the development engineering staff of a firm of instrument manufacturers, where he is mainly concerned with the design of a wide variety of transformers. Following war-time military service in radar, he served for eight years in the Police Force and then entered the Diplomatic Wireless Service in which he was engaged on technical security work. For several years immediately prior to joining his present company he was in the Plessey applications laboratory at Towcester.

L. E. Weaver, B.Sc., A.M.I.E.E., author of the article on the measurement of random noise in television receivers, is head of the measurements group of the B.B.C.'s Designs Department which he joined in 1955. Prior to joining the B.B.C. he was with Standard Telephones and Cables where in the transmission laboratory he was engaged on the design of multi-channel telephone systems and networks and was for some time leader of a group specializing in the design of terminal equipment.

John E. Robson, B.Sc., A.M.I.E.E., senior development engineer of Redifon's Communications Laboratory, Crawley, Sussex, contributes an article on the calculation of standing-wave ratio to this issue. After serving in Royal Signals from 1940 to 1946 he studied at King's College, Newcastle, where he graduated in electrical engineering in 1948 and then went into industry. For seven years prior to joining Redifon in 1959 he was with Waymouth Gauges, Ltd. He is 39.

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

By R. V. TAYLOR,
Assoc. Brit.I.R.E.

USE OF F.M. TUNER, A.F. AMPLIFIER AND POWER SUPPLY UNIT FOR MOBILE BROADCAST RECEPTION

THE B.B.C.'s v.h.f./f.m. services now cover all the major populated areas, and the greater part of the country is served by the 20 transmitting stations. In many areas medium and long-wave reception is not as satisfactory as v.h.f and, of course, the relatively short car-radio aerial is very inefficient at low broadcast frequencies. Many listeners now use v.h.f.-only receivers in their homes and would, no doubt, be satisfied with restriction to B.B.C. only on their car radios; especially in view of the freedom from interference given by f.m. Thus it seems only logical to use a v.h.f./f.m car-radio receiver.

Two difficulties arise when considering such an installation. The first, common to most car radios, is the provision of power supplies. Many modern cars use 12-volt positive-earthed batteries; thus valves must either have 12-volt heaters or be connected in series pairs. Also the positive earth may limit the choice of vibrator units.

The second apparent difficulty concerns the aerial. Only a vertical aerial could be kept reasonably clear of the car body and one would expect reception of horizontally-polarized transmissions on a vertical aerial to be unsatisfactory. Fortunately this is not so; a vertical quarter-wavelength rod fitted to the car roof (which will serve as a ground plane) has been found to provide a good signal in the service area of a v.h.f station. Such an aerial is usually omni-directional and is also suitable for direct connection by coaxial cable to the receiver input.

The principal requirements for a mobile v.h.f./f.m. receiver are met by most good f.m. tuners at present available, so the simplest method of obtaining v.h.f. car radio is to use a "standard" tuner and add a.f. stages and a power unit.

Tuner Requirements

The principal requirements of the tuner are:—

Sensitivity.—A figure of the order of 10μV input for effective limiting has been found to be adequate in most areas. Greater sensitivity is not an advantage, as in places where it would be warranted for domestic use a moving vehicle would pass through rapid variations of signal strength, the minimum values of which might be too low for satisfactory use. A tuner of 10μV sensitivity normally gives good reception or no reception at all, an ideal state of affairs where borderline operation may distract a driver.

Frequency Stability.—Naturally, retuning during the warm-up period is undesirable and automatic frequency control is a useful "extra." However, despite the variations of temperature and supply voltage which arise in a car, many tuners seem to be stable enough to operate satisfactorily.

Good a.m. rejection.—It is vital where signal levels are low and ignition interference, vibrator hash, and generator "whine" abound, that a good a.m. rejection factor should be achieved. Tuners having a limiter stage preceding a ratio detector, or two limiters and a Foster-Seeley discriminator, should be suitable.*

Automatic Gain Control.—Good a.m. rejection can be achieved by "dynamic" limiting, but a limiter of this type is not able to compensate for variations in signal strength. Thus a.g.c. is necessary and this may also help to hold constant the a.f. level when using a static type of limiter.

Free Tuning.—Switched tuning is unsuitable unless the receiver is to be used in the service area of only one station. A large-reduction tuning drive is, naturally, an aid to tuning.

A.F. Gain Control and Switch.—Some v.h.f tuners incorporate an a.f. gain control and a power switch. This is desirable as then only the tuner need be accessible from the driving position and the power supply and amplifier can be mounted elsewhere.

Many of the kits and ready-assembled tuners on the market satisfy these requirements with little modification, so the choice of "front end" for the receiver is largely a matter of size (both in regard to the pocket and the tuner).

Preparing the Tuner

For a 12-volt supply the valve-heater circuit will have to be re-arranged unless 12-volt valve equivalents are available. The simplest method is to connect the valves in series pairs, remembering that a shunt resistor will be necessary across the lower-current heater if valves of different heater-current rating are connected in series.

The heaters of the local oscillator and discriminator valves (if germanium diodes are not used for the latter) should be at the "earthy" side of their pairs. The extra wiring involved may cause instability. New leads should be run close to the chassis and kept away from signal wiring: extra decoupling may be necessary. Microphony, too, can be a problem, so this should be eliminated from the tuner before installation. Any leads or components likely to move under vibration should be secured. To ease servicing problems plug-and-socket connections for aerial, power supply, switch and a.f. output are desirable.

A.F. Stages

Most tuners provide an a.f. output of at least 0.3 volts at high impedance and the author finds that a power output of one to two watts is ample for use in a car—in most modern cars no more than 0.5W will be required. Thus a single-ended two-stage amplifier is adequate. Where space is limited a single triode-pentode valve (an ECL80 or ECL82, for example) could be used.

* *Editorial note.*—Readers are reminded of the excellent and simple limiter/discriminator described by J. G. Spencer on p. 492 of our November 1959 issue.

TABLE: SUITABLE OUTPUT VALVES

Valve	Bias Resistor (ohms)	Output Transformer Ratio for 3-Ω Load	Heater Rating		H.T. Current (mA)
			V	A	
6BW6 / 6V6	270	40 : 1	6.3	0.45	50
6J5 / 6C4	470	50 : 1	6.3	0.3 / 0.15	15
EL91	680	75 : 1	6.3	0.2	19
EL32	470	50 : 1	6.3	0.2	37
12A6	330	50 : 1	12.6	0.15	33

Transistors could be used with advantage in both the a.f. amplifier and power supply units. However, the intention was to keep down costs by using components available either from the "junk" box or the surplus market. Kits for both transistor amplifiers and power units are available, though, and the saving in battery drain through the use of transistors may be thought worthwhile. Also data sheets giving details of suitable 12-volt power units and a.f. amplifiers are obtainable from some transistor manufacturers.

Fig. 1 shows a circuit in which various combinations of valves may be used—a 6BR7 voltage amplifier and 6BW6 output stage are indicated. The a.f. input, from the tuner gain control (a screened lead is necessary), has connected across it a 1MΩ resistor to prevent the grid circuit becoming "open"

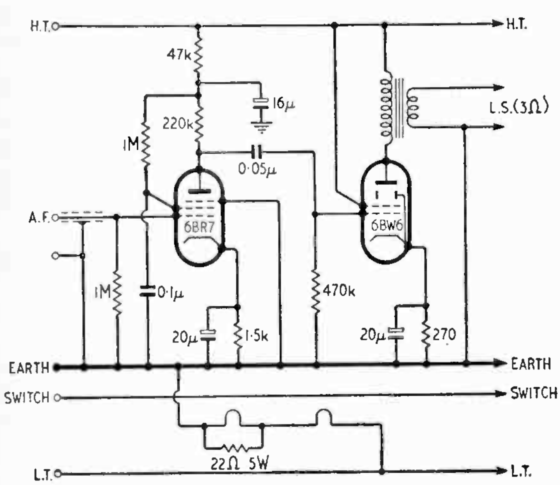


Fig. 1. Audio amplifier showing heaters connected for operation from 12-V battery. On 6V, heaters should be connected in parallel and 22-Ω shunt resistor omitted.

if the lead is disconnected. This first stage provides a voltage gain of about 140; it is thus capable of driving fully the least-sensitive output valve listed in the Table from a tuner output of as little as 0.15V. Octal-based near equivalents of the valves shown are 6SJ7 (V1) and 6V6 (V2) but a 43-Ω 2-W heater shunt will be required for the 6SJ7 instead of 22Ω.

An "economy" version of the a.f. unit, given in Fig. 2, is intended for use where space is limited and battery drain must be kept at a minimum. An output of over one watt is available, but distortion is higher than in the first circuit.

Other Possibilities.—If battery drain is the only consideration, a 6J5 or 6C4 may be used as an output valve. No heater shunt resistor is required with a 6SJ7/6J5, or 6BR7/6C4 combination.

Other pairs not requiring a shunt resistor for 12-V operation are EF86/EL32 and EF86/EL91. No change in component values, except heater shunt, need be made for any of the voltage-amplifier valves mentioned. Of course, a 12A6 and 12SJ7 or 12AT6 could be used with parallel-connected heaters on a 12-V supply. The Table gives further details of the valves suggested.

Layout of the a.f. stages is not critical; normal precautions should be taken to keep input leads away from the output and heater wiring.

Interconnections

The connection between tuner and a.f. unit will carry a.f., h.t., l.t. and leads to the switch thus, for convenience, plug and socket connections are a good idea, although it would be unwise to add a bulky socket to a compact tuner. Multiple earthing should be avoided and the outer braid of the screened a.f. lead must be connected to earth only at one point. It will thus require a separate pin on the plug. L.T., earth and, possibly, the switch leads carry high currents, and need conductors thick enough to keep the total potential drop within bounds—say a maximum of half a volt with a six-volt supply, and double that on 12V.

Connections from the a.f. unit to the power supply

Fig. 2. "Economy" a.f. amplifier requiring only 19mA at 220V h.t. Heaters shown wired for 12-V operation.

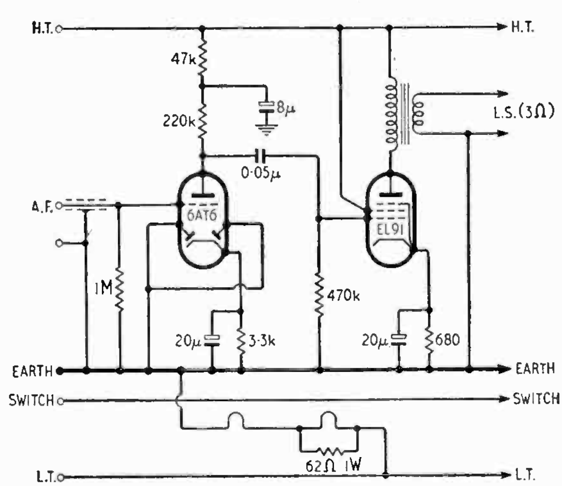
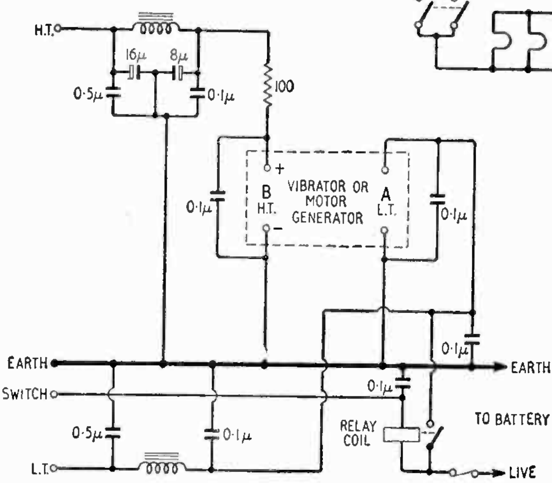


Fig. 3. (Below) Filter and switch circuits added to vibrator or motor-generator h.t. supply. If the h.t. unit has only three terminals its input polarity should match that of the car supply. Switch on volume control connects switch lead to earth in the "on" position.



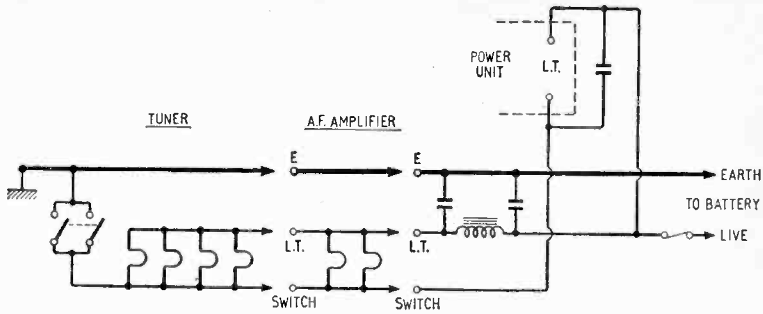


Fig. 4. Power switching without relay. The h.t. unit must be isolated from earth: i.e. there must be no d.c. earth connection in the unit. Switch lead may require filtering similar to l.t. lead.

should be made in the same way and a screened lead should also be used for the loudspeaker. The loudspeaker should be earthed only at the amplifier chassis (the earthy connection of the cathode-bypass capacitor for V2 seems to be the best place). All these measures are taken to avoid noise pick-up from the electrical-system currents flowing in the body of the vehicle; these may reach the loudspeaker, even when the receiver is switched off, if earth connections are made at several points on the car body.

Power Supplies

A variety of vibrator and motor-generator units are available on the surplus market. A vibrator is more efficient than a motor generator and is therefore kinder to the battery. Care must be taken to check that the polarity of the supply acceptable by the vibrator unit is the same as that used on the car, although some units are designed to be compatible, usually by a simple modification, with either polarity of supply. The h.t. current of both the tuner and the a.f. unit (see Table for values at 220V) must be added to give the total power required from the h.t. supply.

Fig. 3 shows the connections for a typical vibrator or motor-generator unit. The filters shown in the h.t. and l.t. leads should not be necessary where the unit has its own filters, but the additional capacitors will generally be required to reduce radiation or pick-up of noise by the leads. The l.t. choke may be made by winding about three yards of 14-s.w.g. enamelled-copper wire on to a 1-in long by ½-in diameter former. An ordinary smoothing choke rated at the full h.t. current is suitable for the h.t. filter.

The contacts of the switching relay must be capable of carrying in the region of 12A for 6-V operation or 5A on a 12-V supply. If a suitable type cannot be found on the "surplus" market a horn relay from a motor-accessory dealer would be suitable.

If the space available allows a compact layout, and leads between battery and power unit (via the tuner power-on/off switch) can be kept short (less than about six feet total) the relay can be dispensed with and the alternative circuit of Fig. 4 may be used. If the switch is incorporated in the tuner volume control it is advisable to connect in parallel the two halves of a double-pole type.

The lead from the power-supply unit to the car battery should follow the most direct route possible, passing through grommets where necessary to avoid chafing. Remember that the movement of the car may damage a heavy cable that is not securely fixed. The fused lead may be connected directly to the battery terminals; but if an "auxiliary" connection is provided (usually on the cut-out panel) this should be used in preference to the direct connection.

The author used a 7×4-in elliptical loudspeaker as space was available. Generally, the largest-possible loudspeaker with the highest-flux magnet will give the best results; but avoid damp or hot places or its life may be shortened. A large baffle area also helps.

Aerials

At v.h.f. a resonant aerial can easily be used. A quarter-wavelength vertical whip mounted at the centre of a sheet of metal is a simple and effective aerial. As long as the metal sheet extends for more than a quarter wavelength in all directions from the base of the aerial it will behave as a ground plane and the aerial will have an impedance of about 50Ω at its base (but 75-Ω coaxial cable is suitable). For Band II the sheet of metal must be at least five feet across its smallest dimension; a car roof is obviously ideal.

A 2-ft 6-in whip in the centre of a car roof thus makes a simple and effective aerial. Despite the apparently incorrect plane in which it is mounted, it will operate because the signal at or near ground level will have a considerable vertically-polarized component.

Details of easily constructed or adapted aerials are given in Fig. 5. Where a quarter-wave whip and ground plane cannot be used (for example, on a sports car) a coaxial dipole (each element 2ft 6in long) may be suitable. In most cases the lower ele-

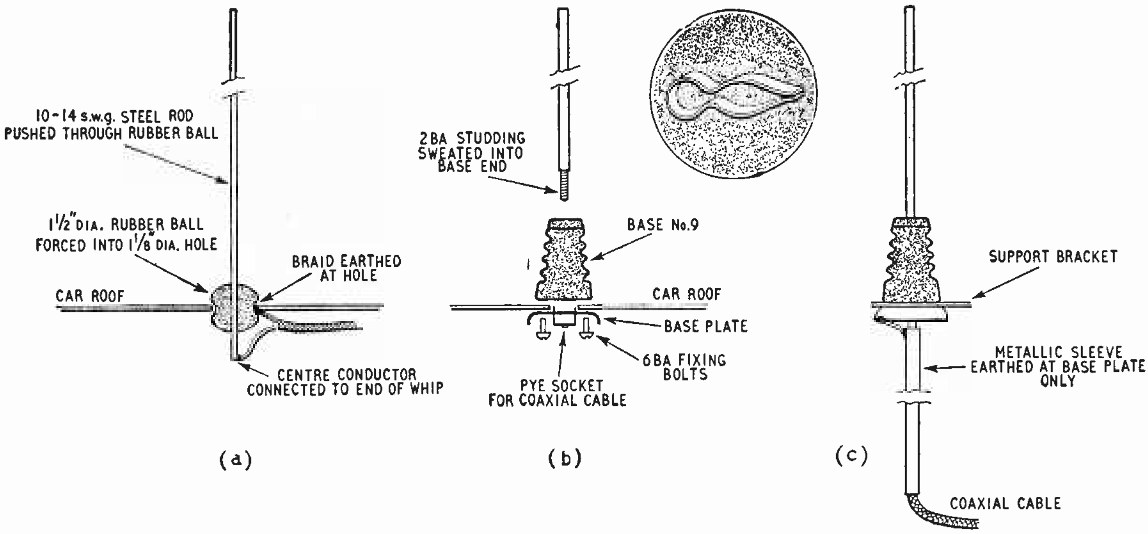


Fig. 5. Some methods of mounting the aerial: (a) uses rubber ball as insulator and (b) employs ex-Govt. aerial base. For cars with non-metallic bodies (c) shows a coaxial dipole. Sleeve can be formed from outer covering and braid from large-diameter coaxial cable. Aerial elements are about 2ft 6in long. (Inset). Cable clip to secure aerial feeder. Springy clip material enables " legs " to enter slot in bodywork, then open out to hold cable firmly.

ment will be close to the bodywork, reducing the efficiency of the aerial, but a good signal should still be obtained.

Feeder losses are negligible on the short run required in a car and the unbalanced aerial is better suited to connection to a coaxial cable than a balanced dipole. The normal telescopic car-roof aerial may be used as long as the outer braid of the coaxial cable is earthed effectively to the car roof at the aerial base.

The inset in Fig. 5 shows a cable clip for use in a slot in the bodywork. To avoid a loop in the receiver earthing it may be necessary to isolate the aerial-feeder "outer" at the tuner-input socket. This can be done by using a coaxial socket of the type employed on live-chassis television receivers. The sleeve (outer braid connection) of this socket is connected to the chassis through a 1,000-pF capacitor shunted by a 1-MΩ resistor. The resistor provides a leakage path for any "static" charges picked up by the aerial.

Mounting the Units

Of course, the tuner chassis must be insulated from the car body—if the tuner has rubber feet it may be stood on the parcel shelf. Strips of plastic-foam draught excluder stuck to the bottom of the tuner make a good substitute for rubber feet. Some form of insulated resilient retaining clips are also advisable. For the a.f. unit the same considerations apply as far as vibration and earthing is concerned—the units should be placed rather than mounted, but must be restrained from "wandering" due to the movement of the car.

The power-supply unit, as it is much heavier than the other units, must be firmly anchored. The vibrator or generator is likely to be noisy acoustically so it is best placed outside the passenger compartment, either in the boot or in the engine space. To prevent the transmission of noise by the bulkhead or body work, the unit should be fixed by bolts, passing through rubber grommets in its chassis and in the mounting holes in the car.

Conclusion

A receiver made up on the lines suggested should give good results in almost any part of the country. However, many apparently small points may have a noticeable effect on performance and a certain amount of trial and error is inevitable if the best results are to be obtained. A last word—don't forget that a separate licence is required for a car radio!

Foreign Body Locator, *developed by the University of Birmingham Department of Physics, will detect an object of about 1 cu. mm size at a distance of 1cm with an accuracy of better than 1mm. It uses a search coil in one arm of an R-L bridge, and the presence of a magnetic or metallic object causes an impedance change which unbalances the bridge (indicated by a meter reading and a variation in pitch of an audible note). A phase-sensitive detector indicates whether the object is magnetic or not.*

LONDON AUDIO FAIR

SELECTED EXHIBITS OF INTEREST

"THE mixture as before," only more so, might be said to describe the recent Audio Fair, since most of the changes from last year were continuations of trends which were already noticeable then.

One trend which had perhaps hardly begun last year but which was very noticeable this year was an increase in the number of imported foreign (and in foreign we hope we are allowed to include U.S.A.) exhibits.

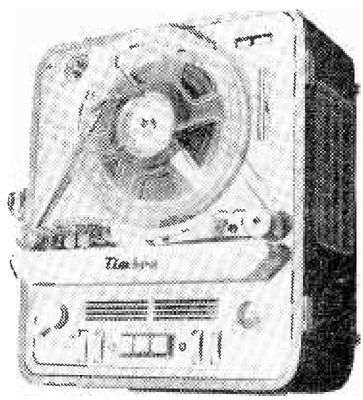
As before, while the main emphasis was on stereo, the main developments were in tape recording. This year, however, stereo has well and truly invaded the tape recording field, with stereo recording as well as replay facilities being offered in many of the new models and with the introduction of several new stereo microphones. Stereo microphones and tape recorders which can both record and replay stereo are thus now no longer the rarities they once were.

Four-track tape recorders are also now no longer a rarity, many of the new models coming into this category. As many as three such models were introduced by T.S.L.—the Harting HM8, the Korting and the Electron 9S/4K. All of these can also record stereo (as well as mono). Both the Korting and Harting HM8 use a transistor in the pre-amplifier to reduce hum and noise. In the Harting HM8 this transistor is not in its usual position before the first valve, but rather after it, this latter arrangement being claimed to allow better matching to the tape head.

Four- and two-track recorders, both of which used the same deck, were introduced by Multimusic (Reflectrograph). One unusual feature of this deck is that variable-speed fast forward and fast rewind are provided by a single control. This control consists of a potentiometer. The ends of the element are connected to the fast forward and rewind motors while the slider is connected to one side of the mains supply: the other side of the mains supply is connected to the other inputs to the motors. In this deck no idler wheels are used to drive the tape, the capstan being directly attached to the spindle of a synchronous "inside-out" motor. The rotor of this motor then acts as a flywheel to reduce fluctuations in the tape speed. Speed change is effected electrically. No pressure pads are used, the required close contact between the head and tape being produced by means of fingers bearing on the tape at each side of the head: a method being increasingly used nowadays. The signal-to-noise ratio is quoted as 50dB for the two-track model A; for the four-track model B this ratio is reduced to 45dB because of the narrower track width.

A stereo recorder shown by Ampex—the 970—has several unusual features. One of these is that the numbers of tracks used on record and replay can be different, since two-track heads are used to record and four-track heads to replay. Thus, while only two-track tapes can be recorded, both four- and two-track tapes can be replayed. Since the tape track positions are different for two- and four-track stereo tapes, and since the replay head gaps should lie centrally across each track for minimum crosstalk, the optimum head positions for minimum crosstalk are also different for replaying two- and four-track stereo tapes. This factor is allowed for in the Ampex 970 by making the position of the four-track replay head adjustable relative to the tape width—another unusual feature.

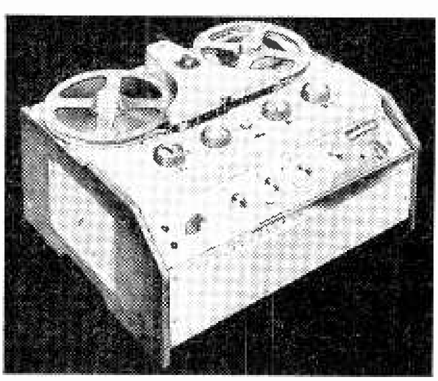
A very unusual feature of the two-track Timbra recorder shown by T.S.L. is that the two tape reels are

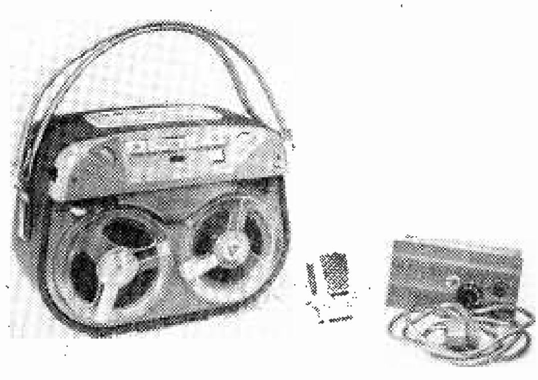


Timbra recorder showing reels in playing position one on top of the other.

placed one on top of the other. To raise the tape from one reel to the other it is first twisted through a right angle until it lies horizontally, then raised, and finally twisted back through a right angle. Impressive performance figures are quoted for this recorder: at the two provided

Multimusic Reflectograph 4-track recorder





Butoba battery/mains transistor recorder showing mains converter on right.

tape speeds of 3¾ and 1⅞in/sec the frequency responses are stated to be within ±2dB from 30 to 18,000c/s and 30 to 12,500c/s respectively, and the total wow and flutter less than 0.05% and 0.1% respectively.

An unusual facility of the Vollmer 120 tape deck shown by Chitnis is that the tape speed can be continuously varied from 1⅞ to 7½in/sec. This variable speed is obtained simply by driving the capstan flywheel by means of a rubber wheel which can be shifted along a shaft perpendicular to the flywheel axis. Even at the slowest tape speed of 1⅞in/sec, the wow and flutter is quoted as less than 0.1%. Space for up to six miniature Bogen heads is available on this deck.

Two new two-track transistorized battery tape recorders were shown—the German Butoba MT4 (distributed in England by Denham and Morley) and the Challen Minivox. In the latter recorder, although the high-frequency recording bias is provided by the transistors, permanent magnets are used for erasing the tape. Two magnets are used in an arrangement which is claimed to result in much less tape noise than is produced by a single magnet. The fast forward and rewind motors are designed so that the battery current does not increase when the tape is fast wound (at about 40in/sec). The tape is capstan driven in the usual way in both this and the Butoba MT4 recorder. In this latter recorder the tape drive motor speed is kept constant as the battery voltage falls by means of a transistor switched by a centrifugal governor. The wow and flutter is quoted as 0.3% at a tape speed of 3¾in/sec. Both high-frequency bias and erase are provided by two OC74 transistors in push-pull. A converter for operating this recorder from the mains is available.

TAPE

American Irish (Orr) tape was shown by Wilmex. The recording surface of this tape is polished so as to produce closer contact between the head and tape and thus improve the high-frequency response.

Pre-recorded four-track 7½in/sec stereo tapes produced by the United Stereo Tape group of American manufacturers were demonstrated by Ampex.

MICROPHONES

Stereo twin moving-coil cardioid microphones were shown by the Austrian firm A.K.G. (distributed in England by Politechna (London)), Chitnis, T.S.L. and Telefunken. In the Telefunken model the two moving-coil units can be rotated relative to one another or even separated altogether: in the other models the units are fixed at right angles to each other.

A close-talking high-quality ribbon microphone—the 4104—was shown by S.T.C. A ribbon microphone normally responds to the sound pressure gradient or sound velocity and the low-frequency response rises for close sound sources. In the S.T.C. 4104, however, for a person speaking from a controlled standard distance from the microphone set by a mouth guard, this rise in the low-frequency response has been eliminated to give an output which is flat within ±3dB from 60c/s to 10kc/s. Distant sound sources will then appear to have their lower frequencies attenuated by amounts which range from about 5dB at 1000c/s to 25dB at 60c/s. Since these lower frequencies form an important part of most background noises, the response to such noises is considerably reduced. Another feature of this microphone is that the responses to sounds from the mouth and nose have been carefully equalized.

A number of useful facilities are offered with Austrian A.K.G. moving-coil and condenser microphones (distributed in England by Politechna (London)). For example, in several of the moving-coil units the bass response can be usefully reduced to eliminate the normal rise when close talking. This reduction in the low-frequency response is usually produced simply by connecting a choke across the microphone. A variable polar response is offered for both the D30 and D36 moving-coil and C12 condenser microphones. Essentially this variable polar response is obtained by mounting two cardioid units back to back and combining a varying proportion of their outputs in or out of phase—in the case of the condenser unit by altering the relative magnitudes and polarities of the two polarizing voltages. Omni-directional and figure-of-eight responses, for example, are then obtained by combining the two cardioid responses in or out of phase respectively.

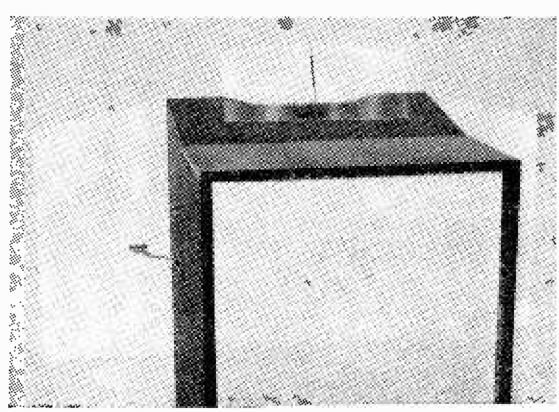
Many of the moving-coil units in the A.K.G. range have been given a cardioid response. This is done by combining the omni-directional sound pressure response of a diaphragm exposed on only one side to sounds with the figure-of-eight pressure-gradient response of a diaphragm exposed on both sides to sounds. Basically these microphones are thus constructed with the diaphragm enclosed on one side except for a release tube.

LOUDSPEAKERS

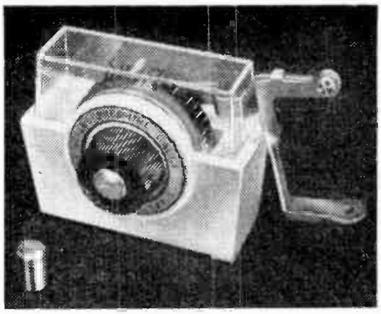
An interesting single-cabinet stereo loudspeaker system—the Acousta-Twin—was demonstrated by Lowther. In this system frequencies below 200c/s—which convey only a small part of the directional information—are combined together by loading the rear of each of the two loudspeakers via a cavity (to cut off frequencies above 200c/s) with two folded horns having a common mouth. Frequencies above 200c/s which are radiated from the front of the speakers are reflected both sideways and upwards by wedges at the top of the cabinet. Further reflections at the room walls and ceiling then produce apparent sound sources much further apart than the speakers themselves. The separation and height of the sound sources produced by the upward-directed portion of the sound can be modified if desired by tilting a Perspex reflector on top of the cabinet. When the speaker system is used for reproducing mono sound this reflector is turned round through 180° and can then be raised or lowered to reflect a variable proportion of the upward-directed sound forwards. A variable proportion of the sideways-directed sound can also be reflected forwards by rotating two hinged Perspex panels at the side of the cabinet. For reproducing stereo, these hinged panels should be flat against the wall.

A number of unusual loudspeakers and loudspeaker mounting arrangements were shown by the French

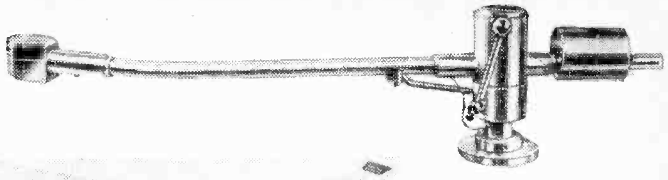
Below: Lowther Acousta-Twin stereo loudspeaker system.



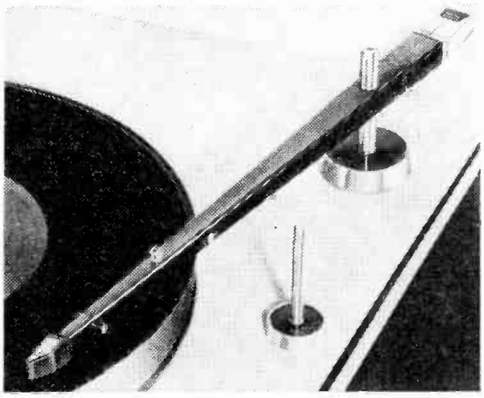
Above: A.K.G. stereo moving-coil cardioid microphone.



Garrard stylus pressure gauge showing check weight at front left.



Above: H.M.V. pickup arm and stereo cartridge.



Left: Shure pickup arm and stereo cartridge.

firm Teppaz whose equipment is distributed in England by Selecta Gramophones. For example, in their portable record players high-impedance crystal loudspeakers are used to reproduce frequencies above 3000c/s, and, in order to save space, the lower frequencies are reproduced by inside-out loudspeakers—i.e., loudspeakers in which the magnet is inside rather than outside the cone angle. These inside-out loudspeakers are mounted on flat lid baffles with the mounting deliberately made non-rigid. Moreover, both the front and back of these speakers are covered by grilles which are deliberately designed to impede the free flow of sound. The Teppaz Duo Dynamic enclosure has a long slit opening at its rear which leads to two expanding chambers terminated by hinged doors. By adjusting these doors the bass response of the system can be varied.

A recent modification to the Stantel column loudspeakers made by S.T.C. for sound reinforcement purposes is that they have been given a slight curvature in the vertical plane. This widens the high-frequency vertical polar response to the same width as the low-frequency vertical polar response.

A 10-in version of their well-known Dual Concentric loudspeakers—the IIILZ—was shown by Tannoy. In this new unit the high-frequency response can be altered by using a capacitor to shunt a variable fraction of a resistor in series with the horn-loaded high-frequency unit. Alternative speaker impedances of 4, 8 or 15Ω can be selected by means of an auto-transformer.

High-quality moving coil headphones with quoted responses from 30c/s to above 15kc/s were shown by A.K.G. (distributed by Politechna (London)) and Chitnis (the Beyer DT48). The low-frequency response of course depends on how airtight the earpiece to head joins can be made.

PICKUPS

A rather unusual arm is used in the American Shure Studio Dynetic pickup (distributed in England by Maunder). In this arm the vertical- and lateral-motion pivots are well separated rather than close together. The two vertical motion point pivots, being only about an inch from the head, carry little more than the head and head counterweight. The arm is balanced about the point and sleeve pivots for lateral motion so as to reduce interference by external vibrations and to avoid the need for levelling. The main arm counterweight is attached by means of a vertical strip embedded in a special damping material to reduce the effects of the low-frequency arm resonance. A magnet in the arm attaches it to its rest. This arm is straight, the offset angle necessary to reduce tracking error being provided in the head itself. This head uses a moving-magnet system, both mono and stereo versions being available. For the stereo or mono cartridge respectively the effective mass at the stylus tip is quoted as 1.3 or 1.25mgm and the compliance as 9×10^{-6} or 7×10^{-6}cm/dyne.

A high-quality stereo pickup and arm were shown by H.M.V. The pickup uses a variable-reluctance vertical-lateral motion system, the correct outputs for the standard 45/45 recording system being obtained by the usual method of summing (adding) and differencing (subtracting) the vertical and lateral outputs. The effective mass at the stylus tip is quoted as about 1mgm vertically or laterally, and the vertical and lateral compliances as 3.5×10^{-6} and 7×10^{-6}cm/dyne respectively. The arm is suspended on a single pivot, movement being damped by a viscous fluid. The counterweight is mounted asymmetrically to provide the sideways balance necessitated by the head offset. The head offset angle is adjusted to minimize the distortion produced by the angular tracking error rather than to minimize the tracking error itself. Minimizing the tracking error will not necessarily minimize the distortion since this is not only proportional to the tracking error but also inversely proportional to the distance from the record centre. A raising and lowering mechanism is also incorporated in this arm.

In the Mark II version of the Tannoy Vari-Twin stereo cartridge an extra pair of pole pieces has been added. These are cross-connected to the bottom two pole pieces so that any hum picked up by either of the bottom two pole pieces and induced in the coil wound on it is cancelled by the hum induced via one of the extra pole pieces. A hum reduction of the order of 20dB has been obtained in this way.

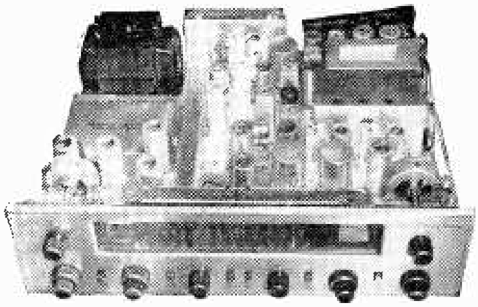
A new stylus force gauge—the SPG3—was shown by Garrard. This is graduated in ½gm intervals from 0 to 12gm. A 5gm check weight is provided. The stylus force is balanced via a lever against that of a spiral spring.

RECEIVERS

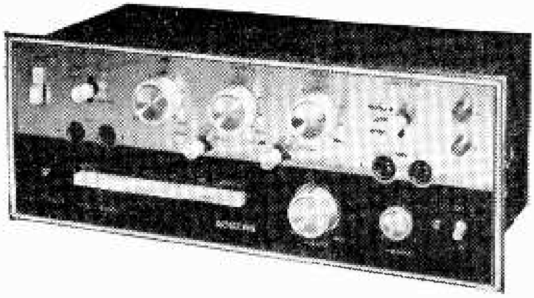
Two American models consisting of independent a.m. and f.m. tuners mounted on the same chassis for receiving suitable stereo transmissions were shown by Ampex and Wilmex. The Wilmex unit—the Fisher 202-T—is claimed to effectively limit f.m. inputs below 1μV, four i.f. and limiter stages being used. A stereo pre-amplifier and tone control unit is incorporated on the same chassis.

A new Chapman tuner—their S6BS/FM—is a combination of their older FM91 f.m. and S6BS a.m. tuners. Nine a.m. bands are provided, six being bandspread.

The range of Goldhorn transistor sets shown by Denham and Morley



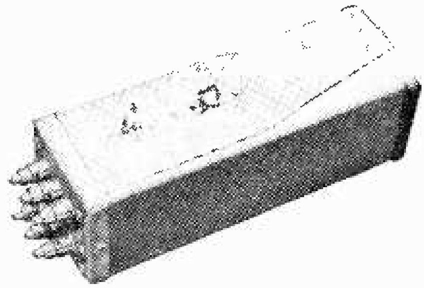
Above: Fisher a.m./f.m. stereo tuner and tone control unit.



Rogers stereo tone control unit.

includes the TK110 which can receive short waves down to 16 metres.

S.T.C. were showing a relatively inexpensive triple-crystal unit for use in f.m. receivers.



Right: Wellington Acoustic Laboratories transistor stereo pickup pre-amplifier.

AMPLIFIERS & PRE-AMPLIFIERS

Transistorized units seemed to be more common this year. Pre-amplifiers were shown by Cintel, Wellington Acoustic Laboratories, and Reslosound. The Reslo Transistor Coupler is designed for microphones with impedances from 30 to 1,000Ω and uses a common-base transistor circuit. Wellington Acoustic Laboratories showed two units for use with both high and low impedance pickups—one unit for mono and the other for stereo. The crosstalk on the latter—the Stereo Wal Gain—is claimed to be as low as −60dB at 1,000c/s and better than −50dB at 10kc/s. (Any capacitive coupling would tend to make crosstalk increase with increasing frequency.) Special features of the Cintel prototype unit are high- and low-pass filters cutting off at 18dB/octave from 30c/s and 7kc/s respectively.

A transistorized combined pre-amplifier and 15W (5% distortion) power amplifier on the same chassis —the BCS2429—was shown by G.E.C. In the pre-amplifier mixing of the signals from two 15 to 30Ω microphones and a high- impedance crystal pickup is possible. In the power amplifier the base bias of the driver and two output transistors can be adjusted to obtain the optimum performance. A prototype power amplifier shown by Cintel gave an output of 10W at less than 0.5% distortion.

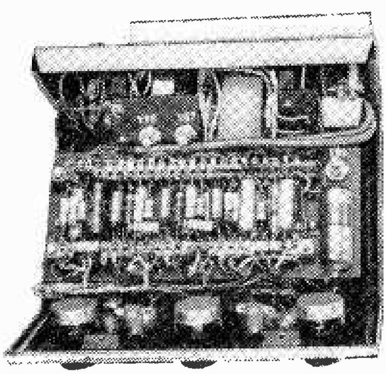
Turning now to valve amplifiers, for reducing stereo "hole in the middle" a variable output proportional to the sum of the two stereo signals and designed for feeding a central third speaker (third channel) is provided in the American Fisher X202 combined stereo pre-amplifier, tone control unit and 2×25W power amplifier shown by Wilmex. Variable crosstalk between the two channels can be artificially introduced in this unit so as to reduce the width of the overall sound field. Other unusual facilities in the Fisher X202 are controls for adjusting the bias and d.c. balance to optimum.

An unusual feature of a range of 30W (1.5% distortion) and 60W (3% distortion) portable combined pre-amplifiers and amplifiers designed by S.T.C. for use in public address systems is the provision of cathode-ray output level indicators. The output impedance is 333Ω for the AP30/2IP and AP30/3IP 30-W amplifiers and 166Ω for the AP60/3IP 60-W amplifiers. The signal-to-noise ratio for these amplifiers is as high as 54dB even at the maximum input sensitivity of 0.5mV (at 600Ω).

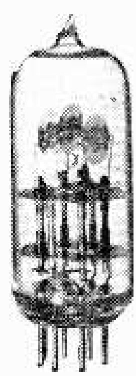
Special features of a very comprehensive stereo pre-amplifier and tone control unit shown by Rogers are a maximum sensitivity of 2mV, provision of as many as 18 inputs, 10 of which can have their sensitivities varied, a low-pass filter with variable slope and choice of three alternative cut-off points, a high-pass filter with two alternative cut-off points, and coarse and fine balance controls.

An American stereo amplifier balance indicator using a meter—the Kinematix SB-1—was shown by Wilmex. If an acoustic balance different from the amplifier balance is required and obtained, the indicator can be adjusted to re-indicate balance, and the same acoustic conditions for balance can then be readily reproduced.

A 25-W guitar amplifier combined with a 12-in loudspeaker—the Vibromajor—was shown by Grampian. A special feature of this is an amplitude modulation vibrato variable both in frequency and depth. The very high peak to mean ratio of the input signal necessitates an amplifier specification somewhat different from that for normal high fidelity. For example, the power requirements are somewhat higher, although a higher distortion—up to about 2%—is quite acceptable. The amplifier should have a smooth overload characteristic (i.e. less feedback than is usual can be employed) and not block or oscillate when overloaded.



Left: Underneath view of G.E.C. transistor combined pre-amplifier and power amplifier.



Right: S.T.C. triple-crystal unit for use in f.m. receivers.

Self-Balancing Push-Pull Circuits

2.—Practical Design Considerations

By D. R. BIRT*

(*Concluded from page 221 of the May, 1960 issue*)

FROM the discussion of general principles in last month's article, the requirements for the first stage of a practical amplifier are now fairly clear. We have seen that for good balance and low push-push gain, V_1 and V_2 should have a high g_m and large anode impedance. This suggests the use of pentode valves. However, there is an attendant disadvantage associated with the screen grid supply in this type of circuit, which may be of importance in the most critical applications. As may be seen from Fig. 8, the screen grids of V_1 and V_2 must be held at cathode potential as far as a.c. signals are concerned, and not at earth, to avoid application of one half the input signal to the common screen junction. This may be accomplished by decoupling the screen grids to cathode. However, when this is done, the screen dropping resistor appears effectively in shunt with the cathode impedance. A better plan is to substitute cascode stages for V_1 and V_2[12]. It is generally possible to achieve a higher gain in this way, and a screen grid supply is not required.

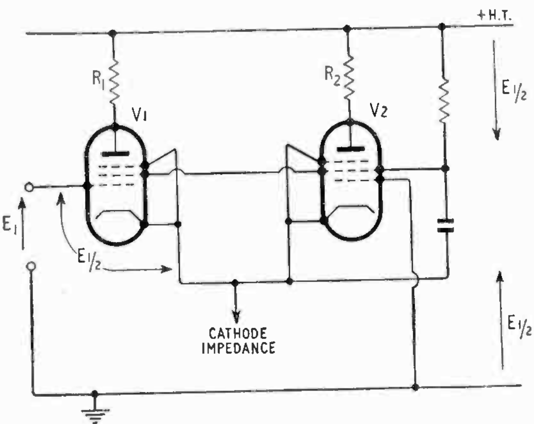


Fig. 8 Long-tailed pair using pentodes.

The grids of the upper triodes of the cascode pair require ideally to be at a constant potential relative to cathode. This is not a difficult problem, as we may decouple the grids to cathode, and make the grid feed resistor large.

Alternatively, a cross coupling arrangement can be used as shown in Fig. 9. The operation of this circuit is rather interesting. When a push-pull signal is applied, it can be seen that the drive to the upper triodes of the cascode pair is applied to both the grid and cathode, in antiphase. As far as the cathode circuit is concerned, this turns out to be equivalent to doubling the g_m of the upper valve, and therefore the cathode impedance is halved and the voltage

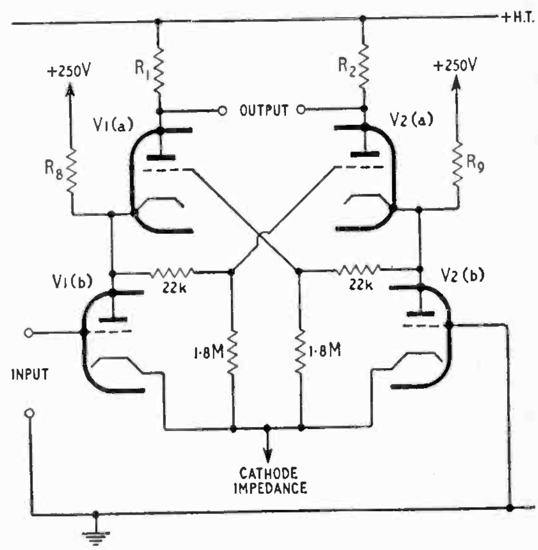


Fig. 9 Long-tailed pair using cascode stages with cross coupling.

gain to this point is halved. However, the grid-to-cathode voltage of each upper triode is the same as it would be in a conventional cascode amplifier, and the overall gain is similar.

If we now consider a push-push signal, we find that the signal voltages at the grid and cathode of the upper triodes are in phase, and of almost equal amplitude, so that the amplifier has less gain in this case.

The basic cascode amplifier may be improved by the addition of two resistors, R_8 and R_9 in Fig. 9[13]. This modification promotes a higher g_m in the lower triodes by reason of the additional anode current bled through R_8, R_9. The gain of each cascode stage is the product of the g_m of its lower valve and the anode load resistor of its upper valve. It would appear advantageous to operate the lower triode over the region of its characteristics where the g_m is highest. This implies working at a high anode current. In a conventional cascode amplifier, an increase in lower triode anode current increases the voltage dropped across the upper triode anode load resistor. In a driver stage, where we want a large output, we cannot tolerate this reduction of anode voltage as it reduces the available output voltage. Therefore we have to reduce the anode load resistance, and we find that what we gained on the "swings" of higher g_m we have substantially lost on the "roundabouts" by reducing the load resistance. In the modified circuit, however, current fed to the anode-cathode junction allows the anode current (and hence the g_m) of the lower triode to be greater

* Mullard Research Laboratories.

than that of the upper triode. The effective g_m is increased by this means without affecting the current in the load resistor, and it follows that there is an increase in gain over the conventional form of circuit.

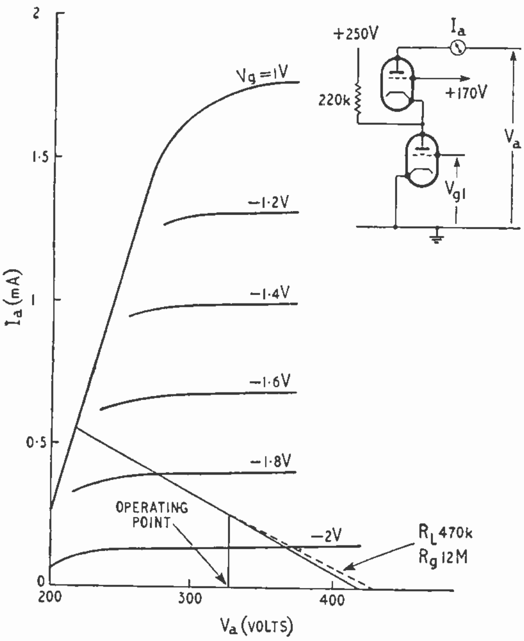
Having considered the general requirements of the circuit, it is now appropriate to consider particular requirements with respect to valve operating conditions. The first step is to plot the cascode characteristics of the double triode to be used. Fig. 10 shows the characteristics of an ECC83 plotted for an upper valve grid voltage of 170 volts. The characteristics are similar in form to those of a pentode, and it is a useful rule of thumb to take the knee voltage at a practical working current as being approximately equal to 120% of the potential of the upper triode grid. It is emphasized that, although these characteristics represent a fair average in respect of valves measured by the author, they are not necessarily those of a nominal valve.

The value of the anode load resistor may now be chosen. A high value will give a large gain, and the first limit is often set by the bandwidth requirements of the amplifier. It is necessary to ensure that the load is such that the operating point does not move into the knee region or beyond cut-off, under normal operating conditions.

In determining the operating conditions, one must bear in mind the fact that grid current may begin to flow at about -1.3 volts $V_{g}1$, and one must therefore ensure that the grid voltage does not normally approach this value. If supply voltages are subject to variation, allowance should be made to prevent an increase in distortion with a low h.t. voltage.

As an example, suppose the bandwidth required is 20 kc/s, and that the load presented by the following stage is 10 pF in parallel with 2MΩ. A load resistor of 470kΩ is suitable, and a loadline of the appropriate slope is drawn in Fig. 10. Fig. 11 shows

Fig. 10 Cascode characteristics of the ECC88 double triode.



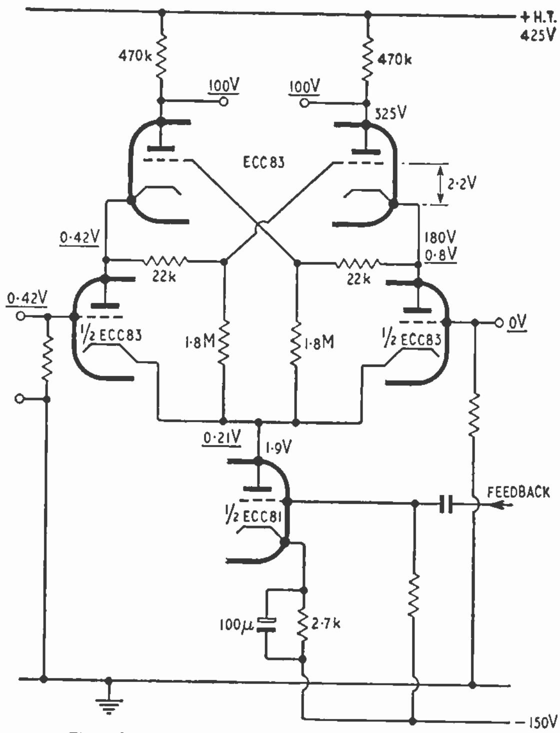


Fig. 11 Operating potentials of the cascode pair.

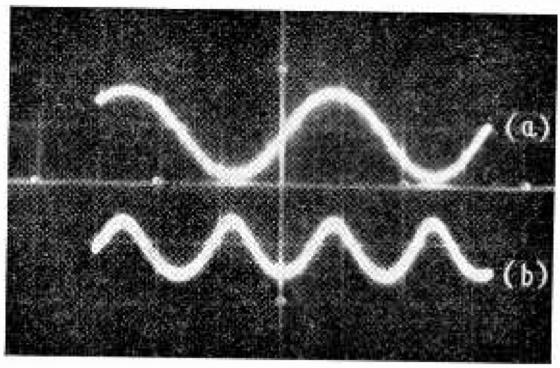


Fig. 12 Degree of balance in an experimental audio amplifier is shown by these oscillograms: (a) amplifier output voltage, (b) output stage cathode current.

the operating voltages. Figures underlined are peak-to-peak a.c. voltages relative to earth for a push-pull output of 200V peak-to-peak. The measured push-pull gain is some 500 times, and with feedback taken from a resistive divider connected between the output terminals, the push-push gain is -88 dB relative to the push-pull gain. Although a pentode is the ideal cathode impedance, the above figures demonstrate that it is frequently possible to obtain the required characteristics with a triode.

Experimental Audio Amplifier

An experimental 10-watt audio amplifier which utilizes overall push-push feedback has been built (and it is hoped to describe a development of this amplifier in a future article). The amplifier embodies

By adjusting the unbalance of the drive we can choose between zero even harmonics in the output, or zero fundamental component current in the h.t. line, at one particular signal level[9]; but Nature being as she is, we cannot have both, and either of the above conditions can only be achieved at one signal level!

We want to avoid the necessity of providing a balance control, and we would like our amplifier to remain balanced at all signal levels. It seems logical therefore to provide a push-push feedback loop enclosing the whole amplifier. This idea has been suggested by Offner[10] and is also covered by the Blumlein patent mentioned earlier. However, the idea does not appear to have been fully exploited. Overall feedback may be provided by a simple, but possibly novel, extension of Fig. 3 shown in Fig. 4. Neglecting for the moment even harmonic terms, any unbalance in the amplifier will produce an error voltage of fundamental frequency across the common cathode bias resistor R_7 which has an amplitude proportional to the degree of unbalance. The phase of the error voltage depends upon the direction of unbalance. This error voltage is reduced by the feedback loop acting via V3 grid. The important feature is that an excellent balance may be obtained which is not critically dependent on any component values. The degree of valve matching will not now affect the balance of the amplifier, but we shall see that it will influence the harmonic content of the output voltage.

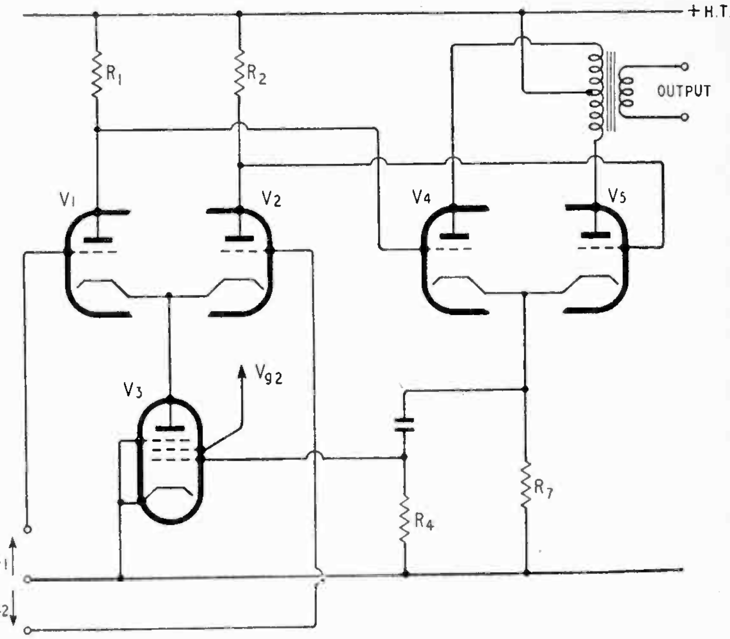


Fig. 4. Amplifier with overall push-push feedback.

Before discussing this, let us remind ourselves that in a push-pull amplifier even harmonic currents produced by the non-linearity of the output valves cancel by subtraction as far as the load is concerned but are present in the total h.t. current[1].

First, let us consider that V4 and V5 are matched, and therefore produce equal even harmonic currents. We know that these even harmonic currents add together to form part of the total h.t. current. Since this current flows in the common cathode bias resistor R_7, a harmonic voltage will be developed across R_7. The feedback loop reduces the amplitude of this sum of the even harmonics by a large factor. The push-pull connection prevents even harmonics from appearing in the output, in the usual way.

However, if the output valves are unmatched, it is likely that they will each contribute a different percentage of even harmonic distortion. Although we are able to reduce the sum of the even harmonics, in the limit to zero, we cannot avoid the fact that the difference between the amplitudes of even harmonics produced by each output valve is not zero. We shall therefore have some even harmonic content in the output of the amplifier, in this case.

Pentode Output Stage

So far it has been assumed that triodes have been used in the output stage. When this is the case the common cathode current is one and the same thing as the sum of the two anode currents, provided that the valves do not run into grid current. When V4 and V5 are pentodes, however, the cathode current is made up of the sum of the anode and screen grid currents. Thus by balancing the cathode currents, we have not necessarily ensured that the anode currents, and therefore the load currents, are balanced. With normal receiving valves, however, the unbalance introduced can only be very small, and may be neglected, provided that the valves are not operated to the extremes of their characteristics.

If in a particular application the screen grid current has a detrimental effect, or the valves draw grid current, a circuit of the form shown in Fig. 5 may be substituted. This arrangement has been simplified to illustrate a principle, rather than provide a working circuit. Naturally we would normally interpose cathode followers between the driver and output valves to supply the grid input power if the valves operate in grid current.

Here the anode currents as such are sampled, and feedback is maintained in the correct sense by changing the connections to V3. The new connections to V3 deserve some further explanation. Let us begin by considering the influence of the suppressor grid potential on the electron stream in the valve. If the suppressor potential is made sufficiently negative, electron flow to the anode ceases. However, the suppressor grid potential cannot influence the cathode current of the valve because it is prevented from influencing the electrostatic field in this region by the screen grid, which we shall assume to be at a constant potential with respect to the cathode. What, then, happens to the electrons we prevented from reaching the anode? The answer is that they alight on the screen grid. We may say therefore that the suppressor potential varies the partition ratio of the anode and screen currents. If the suppressor potential is negative, the greater pro-

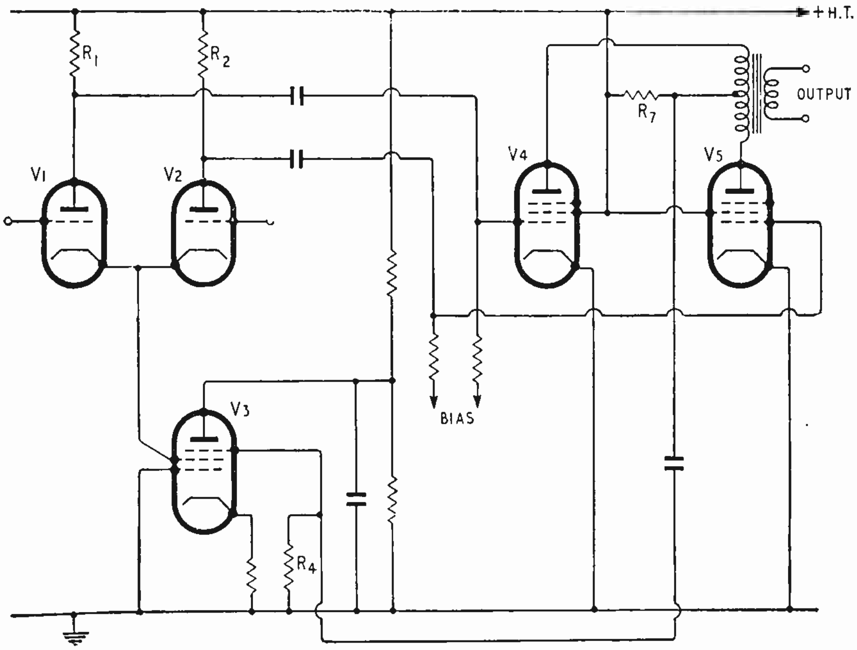


Fig. 5. Alternative feedback circuit

portion of current flows to the screen grid, and as we make the suppressor potential more positive, the greater proportion of current flows to the anode. If the total space current remains constant it follows that for a given change of suppressor potential the change in anode current $g_{m(g3\text{-}a)}$ is equal and opposite to the change in screen grid current $g_{m(g3\text{-}g2)}$. In a valve such as the 6AS6 this g_m is approximately 300 μA/volt. By connecting the valve in the manner shown in Fig. 5, an error voltage fed to grid 3 produces an in-phase error voltage at the cathodes of V1, V2. This is the condition required for the error voltage feedback to be negative.

Alternative circuits which are a combination of Figs. 4 and 5 may prove useful when there are several push-pull stages preceding the output stage. Where this is the case, particular attention must be paid to the coupling time constants, and also to the impedance of the h.t. supply in determining the stability of the loop.

Influence of Push-Push Signals

It has been briefly mentioned that the influence of push-push signals is important. This is particularly so, for example, in electro-encephalograph amplifiers. It is of interest to consider the extent to which the circuits described respond to these signals. Broadly they may respond in two ways. First, by providing a push-push output signal. Secondly, by converting an unwanted push-push input signal into a push-pull output signal‡.

Let us consider that the amplifier of Fig. 1 is connected to the receiving end of balanced line subject to electrostatic interference. This is a case where the unwanted signal appears in push-push at the two input terminals. Both V1 and V2 amplify the unwanted signal by equal amounts, so that there will be an amplified push-push interference signal at the output terminals. We may define push-push gain as the ratio push-push output voltage to push-push input voltage. We see that the circuit shown in Fig. 1 has a push-push gain which is equal to its push-pull gain. This is generally undesirable.

However, provided that the circuit is perfectly symmetrical the interference signal will not contribute to the voltage developed between the output terminals, and it is therefore convenient to say that the push-push rejection is infinite.

Now let us consider the circuit of Fig. 2; first, in respect of push-push gain. Because we are at present considering a linear system, we are justified in considering the behaviour of the circuit to the unwanted signal, without regard to the wanted signal. To this end, the amplifier may be represented in the simplified form shown in Fig. 6, where E_3 represents the unwanted push-push input signal. It can now be readily seen that R_3 provides negative current feedback in this case. The circuit of Fig. 6 bears a remarkable resemblance to a concertina phase splitter. Indeed we may use this similarity to tell us that if $R_2/2 = R_3$, the gain of the amplifier to the unwanted signal will be of the order of 0.9, which is low compared with the amplification of the wanted signal of 100 times. The inclusion of R_3, therefore, provides discrimination between push-pull and push-push signals by reducing the amplitude of the push-push output by negative feedback. This is not really surprising, because the balance error voltage we were considering earlier could be regarded as a push-push signal. In Fig. 2, if R_1 is equal to R_2 and V1 and V2 are identical, then once again the push-push rejection will be infinite. However, if R_1 is not equal to R_2 there will be a component of the interference signal in the output voltage between terminals OP_1 and OP_2.

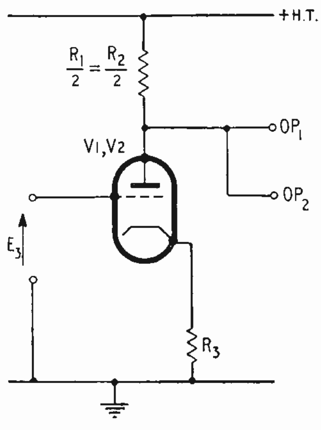


Fig. 6. Long-tailed pair equivalent for push-push signal.

‡ There is a further aspect of intermodulation between the push-pull input signal and the push-push input signal but this is beyond the scope of this article.

a modified cascode phase splitter of the type described above. The phase splitter precedes a Class A pentode output stage, and the push-push feedback loop is taken from the common cathode bias resistor of the output stage to the grid of a pentode forming the cathode impedance of the cascode pair. The degree of balance obtained with components of 20% nominal tolerance may be seen from Fig. 12. The upper trace displays the output waveform at an output of 11 watts. The lower trace shows the residual voltage across the output stage cathode resistor. This represents an alternating h.t. current which is predominantly second harmonic and which has an r.m.s. value of 500μA. This compares favourably with the peak anode current per valve, which is 120mA. Practical advantage of this feature is reflected in an extremely simple RC power supply, which may be used to feed a high-gain pre-amplifier simultaneously, without risk of instability; and a signal/hum ratio in excess of 60 dBm.

Finally, the author would like to thank many of his colleagues, and in particular K. W. Moulding and P. L. Mothersole, for encouragement and help in the preparation of this article.

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Causes of Low Outputs*

WHY AUDIO OUTPUT STAGES OFTEN DO NOT ACHIEVE THE EXPECTED PERFORMANCE

IN some valve manuals the data for most types of output pentode include a figure for the output power available at 10% total harmonic distortion. It is not always realized that this figure represents the power available *at the valve with the values of voltages, current and external anode resistance quoted.* Consequently, the values of output power actually obtained in practical equipment are often lower than those which seem, from the data, to be available.

The values of output power quoted in the manuals are usually given for fixed bias and screen-grid voltages because these closely represent the values actually available for speech or music reproduction. Where a cathode-bias resistor and/or a series screen-grid resistor are used, measurements with a continuous sine wave will show lower output powers than those obtained with fixed voltages. At full drive, the screen-grid current will be appreciably higher than without the signal. Therefore, if the signal is a sustained sine wave, the valve operating conditions will readjust themselves to an increased bias voltage and/or a reduced screen-grid voltage. During the reproduction of speech or music, the waveforms are complex and the sine waves are never sustained at full-drive amplitudes for a long enough time to affect the valve operating conditions.

If it is desired to know how much power is available at a certain level of distortion under speech or music conditions, the direct voltages between the various electrodes and the cathode can be measured and can then be maintained at these values by auxiliary supplies. As a rough guide, the output power measured with a sustained sine wave under cathode-bias conditions is approximately 10% less than that measured with a fixed bias voltage. A simple correction allowing for the effect of a screen-grid resistor cannot be given—it depends both on the value of the resistor and on the ratio of screen-grid current at zero signal to that at full drive.

The voltages quoted in the valve manuals are usually given with respect to the cathode, and should not be confused with the voltage between the h.t. line and the chassis. Usually, the actual anode voltage will be the h.t. line voltage less the voltages dropped across the primary winding of the output transformer and the cathode resistor.

Valve manuals usually give an optimum value of effective external anode load resistance, and the output power quoted is for this optimum value. At all other values of resistance, the output power will be lower. For single-valve operation, if the effective anode load resistance R_a is greater than the optimum value $R_{a(opt)}$, the anode voltage swing at a given distortion is almost independent of the value of R_a.

For a resistance less than the optimum, the anode current swing is roughly independent of R_a.

Therefore, for $R_a > R_{a(opt)}$:

$$P_{out} \simeq \frac{R_{a(opt)}}{R_a} \times P_{out(opt)}$$

and for $R_a < R_{a(opt)}$:

$$P_{out} \simeq \frac{R_a}{R_{a(opt)}} \times P_{out(opt)}$$

where P_{out} and $P_{out(opt)}$ are the values of output power corresponding to R_a and $R_{a(opt)}$ respectively.

One of the most common causes of mismatching is that the resistances of the primary and secondary windings of the output transformer and of the leads to the loudspeaker have been neglected. The effect of the resistance of the secondary winding and the speaker leads is to increase the secondary load resistance. The effect of the primary resistance R_a is twofold: it increases the external anode load resistance, and it influences the valve operating conditions in that it lowers the anode voltage and, hence, the optimum anode load resistance. The effective external anode load resistance R_a is given by:

$$R_a = R_p + n^2 (R_s + R_L)$$

where n is the transformer turns ratio, R_p is the

*This article is based on a report in **Mullard Technical Communications**, Vol. 4, No. 40 (August 1959).

resistance of the secondary winding and R_L is the secondary load resistance (including the resistance of the leads). Corrections to the optimum value of anode resistance can be made if it is assumed that the optimum value is roughly proportional to the anode voltage and the reciprocal of the anode current.

Practical Example.—Some time ago it was found that, in an amplifier which incorporated a single-ended EL84 audio output stage, the anode current was low with many samples of the valve and the output power delivered to a 7.5 Ω secondary load was only 2W instead of the 4.2W indicated in the valve manual. The h.t. line voltage in the amplifier was 250V, and the current in the output stage was 36mA. The relevant data, abstracted from the valve manual, are given below:—

V_a	= 250V
V_{g2}	= 250V
R_a	= 7kΩ
R_k	= 210 Ω
V_{g1}	= − 8.4V
I_a	= 36mA
P_{out} (D_{tot} = 10%)	= 4.2W

It was found that a cathode resistance of 210 Ω was used in the output stage of the amplifier. The actual screen-grid voltage (with reference to the cathode) was therefore only about 242V, which explained why the anode current was often low.

However, the loss in power resulted mainly from mismatching and the resistance of the windings of the output transformer. Measurements showed that the turns ratio of the transformer was 30.5 : 1, which transforms 7.5 Ω connected to the secondary winding into 7kΩ across the primary. However, the primary resistance was 700 Ω and the resistance of the secondary winding was 0.9 Ω.

The current of 36mA through the primary winding caused a voltage drop of 25V, so that the actual anode-to-cathode voltage was only 217V. At this voltage, the optimum anode resistance for an EL84 is approximately (217/250) × 7, or 6.1kΩ, and at this optimum value the output power would be (217/250) × 4.2, or 3.65W. However, the transformer, with its winding resistances and a secondary load of 7.5 Ω, presented to the valve an effective anode resistance given by:

$$R_a = 700 + (30.5)^2 (7.5 + 0.9)\,\Omega.$$

That is, the effective anode resistance in the amplifier was 8.5kΩ. The output power available from the valve at this optimum value is approximately (6.1/8.5) × 3.65, or 2.63W. There is, however, a loss of power of 0.47W in the resistances of the primary and secondary windings, so that the useful power delivered to the load is about 2.2W instead of the expected 4.2W.

Because the calculation of output power at an anode resistance different from the optimum is only approximate, and also because the transformer resistances were measured on a cold transformer, this value of 2.2W is in reasonable agreement with the output of 2W obtained with the amplifier. A small reduction in the cathode resistance, and the use of a different, though somewhat larger, output transformer (R_p = 305 Ω, R_s = 0.2 Ω, n = 28.3) resulted in an increase in output power to 3.5W delivered to a secondary load of 7.5 Ω.

Phonetic Alphabet

IT is understood that many hours were spent during the Geneva Conference discussing the merits and demerits of the various phonetic alphabets now in use, before adopting the one which has been used by N.A.T.O. forces and civil airlines since March 1st, 1956. It is a great improvement on the alphabet incorporated in the Atlantic City Regulations (1947), and will be used in international radiotelephony from May 1st next year when the Geneva Regulations come into force. However, even after that date stations of the same country may continue to use when communicating between themselves any other phonetic alphabet recognized by their own administration.

A	**Al**fa	Able	Amsterdam
B	**Bra**vo	Baker	Baltimore
C	**Char**lie	Charlie	Casablanca
D	**Del**ta	Dog	Danemark
E	**Ech**o	Easy	Edison
F	**Fox**trot	Fox	Florida
G	Golf	George	Gallipoli
H	Ho**tel**	How	Havana
I	**In**dia	Item	Italia
J	**Jul**iet	Jig	Jerusalem
K	**Ki**lo	King	Kilogramme
L	**Li**ma	Love	Liverpool
M	Mike	Mike	Madagascar
N	No**vem**ber	Nan	New York
O	**Os**car	Oboe	Oslo
P	Pa**pa**	Peter	Paris
Q	Que**bec**	Queen	Quebec
R	**Ro**meo	Roger	Roma
S	Si**er**ra	Sugar	Santiago
T	**Tan**go	Tare	Tripoli
U	**U**niform	Uncle	Upsala
V	**Vic**tor	Victor	Valencia
W	**Whis**ky	William	Washington
X	X-ray	X-ray	Xantippe
Y	**Yan**kee	Yoke	Yokohama
Z	**Zu**lu	Zebra	Zurich

We give in the table first the N.A.T.O./I.C.A.O. phonetics adopted at Geneva (with the syllables to be emphasized in heavy type), then the well-known Able-Baker-Charlie list, which is still used for working between British ships and British coast stations, and finally the cumbrous words approved at Atlantic City which will continue to be used for international working until the Geneva Regulations are introduced.

The first ten words of the new alphabet are also to be used for verifying the numerals 1 to 0 respectively, and the following four words for a comma, fraction bar, break sign and full-stop. When transmitting figures or marks they must be preceded and followed by the words "as a number" or "as a mark" spoken twice, e.g., the number 1960 will read: "as a number, as a number, Alpha, India Foxtrot Juliet, as a number, as a number."

This method of verifying numerals is not used by operators in British ships and coast stations. The G.P.O. "Handbook for Wireless Operators" gives the following rules for the pronunciation of numerals: 0, zero; 1, wun; 2, too; 3, thuh-ree; 4, fo-wer; 5, fi-yiv; 6, six; 7, seven; 8, ate; 9, niner. Each transmission of figures is preceded and followed by the words "as a number" spoken twice.

COLOUR TELEVISION FROM PARIS

DEMONSTRATION OF FRENCH SYSTEM AT THE I.E.E.

TECHNICAL history was made in a small way on the evening of 27th April, when colour television pictures were relayed for the first time from Paris to London. The occasion was a lecture at the I.E.E. on the Henri de France system of colour television, by R. Chaste and P. Cassagne of, respectively, the Compagnie Générale de Télégraphie Sans Fil and the Compagnie Française de Télévision, in which organizations the system has been under development. (C.F.T. is a subsidiary of C.S.F.) After the formal paper a demonstration was given, on colour and black-and-white receivers, of compatible colour pictures transmitted on the Henri de France system over a special relay network from the C.F.T. laboratories in Paris. The 625-line television standard was used and the programme material consisted of colour slides and colour films.

A 500-km television relay system was specially arranged for this occasion as a joint effort by the French P.T.T., British Post Office and B.B.C., and was described by W. J. Bray of the Post Office. It used a number of existing installations and some temporary stations. A temporary microwave link connected the C.F.T. laboratories to the P.T.T. establishment at the Tour de Meudon in Paris, from which the signals passed to Loos (near the town of Lille) on the permanent P.T.T. microwave relay system. From Loos they were transmitted to the Post Office radio station at Tolsford Hill, near Folkestone, by the permanent G.P.O./P.T.T. microwave link which normally serves for Eurovision and multi-channel telephony circuits.

The connection from Tolsford Hill to London was not made by the existing cables because these can only handle a bandwidth of 3Mc/s, whereas the 625-line colour signals require their normal 5Mc/s. Two temporary microwave links, connected in tandem, were therefore set up by the B.B.C., terminating at the Crystal Palace television station. From Crystal Palace the rest of the link-up to the I.E.E. was made by coaxial cable via Broadcasting House, the Post Office switching centre at the Museum telephone exchange and the Gerrard telephone exchange.

Characteristics of the System

Some readers may recall that the Henri de France system of colour television* has certain features in common with the American N.T.S.C. system, now operating in the U.S.A., but is distinguished by the sequential method of transmitting the chrominance (colour without brightness) information. It is a compatible system which transmits the brightness information in a wide band on the main carrier, so that it can be picked up by existing monochrome receivers as a black-and-white picture, and the chrominance information on a narrow-band sub-carrier. As in the N.T.S.C. system, the colour sub-carrier conveys two sets of chrominance information (called colour difference signals), but sequentially, on alternate lines, rather than simultaneously by an amplitude- and phase-modulation multiplexing process.

At the colour receiver the sequential colour information is turned into simultaneous form for display by a storage system based on a delay line. Thus the complexity of the synchronous detectors and associated circuits of the N.T.S.C. receiver is avoided, but a somewhat expensive delay line is required. The whole transmission system, unlike the N.T.S.C. one, is insensitive to spurious phase delays (as was demonstrated at the I.E.E. by the deliberate introduction of 40° of phase change in the incoming cable) and the receivers are inherently stable. On the other hand there is a loss of vertical colour definition, due to the line sequential method of transmitting the colour information, and a slight misregistration of displayed colour information, due to the fact that the storage causes colour information belonging to one line to be presented also on the next line of the frame (next-but-one of the picture).

Colour Receiver Design

Such points were brought out at the discussion following the lecture by various speakers, the majority of whom were critical of the Henri de France system but at the same time expressed their appreciation of the excellent demonstration and their admiration for the French authors' presenting a paper in a foreign country and in a foreign language. Regarding the receiver problem—which is certainly the main stumbling-block in the adoption of any system of colour television—it was generally felt that although the Henri de France receiver had the advantage over the N.T.S.C. receiver in fewer valves and less complexity, this was partly offset by the price of the delay line (about £6). In any case the price of receivers was largely controlled, not by these factors, but by the price of the colour c.r. tube.

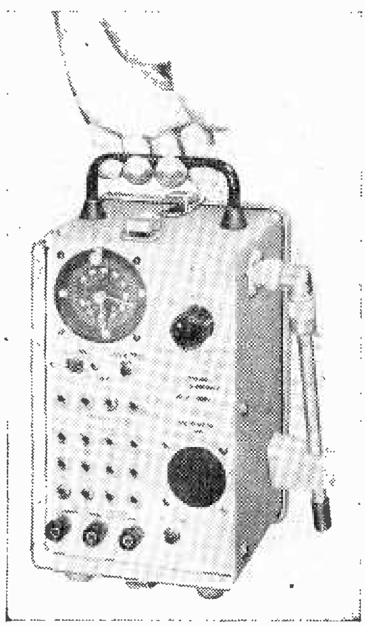
Recent work at C.F.T. has been aimed at reducing the cost and bulk of the delay line. Whereas it was originally a length of special coaxial cable, the present receiver uses a compact acoustical system based on multiple reflections inside a block of quartz to get the required path length. Other developments mentioned by the authors have been concerned with the reduction of noise visibility on the colour picture by the use of frequency modulation of the colour sub-carrier instead of amplitude modulation. With a.m. the system is somewhat worse than the N.T.S.C. system in this respect, having a threshold of noise visibility of about 7-8dB lower (both systems being worse than monochrome television). Demonstrations of pictures using the f.m. sub-carrier were in fact given at the I.E.E. Unfortunately the visibility of the f.m. sub-carrier on the picture is greater than that of the a.m. sub-carrier, but experiments are in progress to reduce this by trying sub-carrier frequencies specially related to the line scan frequency.

On the question of standards, one speaker reminded any members of the Television Advisory Committee present (in fact there were several) that the French had shown us colour television on 625 lines. Representatives of the B.B.C. and the French Centre National d'Etudes des Télécommunications put in heartfelt pleas for common international standards for colour television, saying that they had suffered enough already from different standards in monochrome!

* As described in our September 1957 issue, under the title "Sequential Colour Again."

Technical Notebook

Portable Time Standard, controlled by standard time transmissions, has been developed by Zenith in the U.S.A. It is a transistorized, battery-powered instrument, and is accurate to approximately ±16 seconds per year. A possible



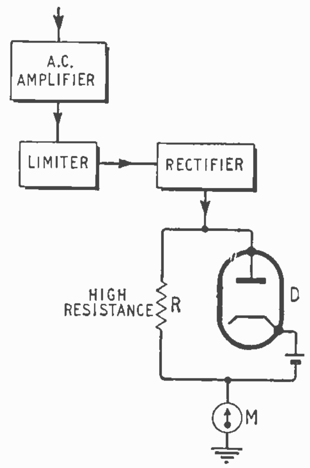
application is for precise time switching of recording instruments, telemetering transmitters, etc., in isolated areas. The instrument uses a transistor receiver—a crystal-controlled a.m. circuit—and is designed to receive the National Bureau of Standards station WWV, and other accurate sources of "seconds tick," at any of three frequencies, 2, 5 and 10Mc/s. The receiver output is fed to a circuit which filters out all information except the one-second "tick." This "tick" is applied to a pulse generator which gives a pulse of the required amplitude and duration to synchronize the electric clock (a type in which the balance wheel operates contacts for pulsing the mechanism). A "programme matrix," comprising a set of contacts utilizing the clock hands, is capable of providing a variety of switching time intervals for controlling external apparatus. An aural check of WWV signals is also incorporated.

Polymerization of Propylene (formula C_3H_6—the "next one up the chain" from ethylene, C_2H_4) by methods similar to those used to produce polyethylene, or polythene, result in a substance of very variable and not very useful properties. This variability is caused by the random placing of the "extra" CH_3 groups along the polymer molecule. However, research undertaken in Italy has resulted in the discovery of a new catalyst for the polymerizing process, a catalyst which enables the CH_3 groups to be aligned in a regular fashion. The result is a polymer of propylene with consistent and useful properties; in fact, it seems to possess most of the advantages of polythene and few of its disadvantages. Most valuable features of polypropylene for electronic purposes are its high melting point (170°C approx. compared with 108°C approx. for polythene), its hardness (Rockwell 90 to 95), small linear coefficient of expansion (11×10^{-5}cm/cm/°C) and high tensile strength (4,000lb/in²). In other respects it is broadly similar to polythene. Polypropylene is made in this country by the Telegraph Construction and Maintenance Company in the basic form of sheets from 0.020in to 0.375in thick, and it may be processed by all methods at present used with polythene (higher processing temperatures must, of course, be used).

Minute Sealed Switch, only 0.32in diameter by 0.44in long, has a breaking capacity of 3A at 28 volts (resistive load). Of welded stainless-steel

construction, the switch has a snap-action W-shaped blade operated by a push button, and the casing, before being hermetically sealed, is filled with an inert gas. The photograph shows the switch (made by Spencer Products Group, Texas Instruments, U.S.A.) against a background of aspirin tablets.

Balance Indicating non-linear amplifier forms part of audio-frequency current and voltage standardizing equipment developed by the Electrical Inspection Directorate. The standardization is carried out by means of thermo-junctions working at a fixed input current level. To avoid damaging or altering the characteristics of these thermo-junctions, the level must be set close to the fixed value before they are connected. This initial level setting is achieved to within 0.2% by means of a non-linear amplifier whose output is arranged to vary rapidly with the input when this input is near the required fixed value, but only slowly with the input otherwise. The output of the non-linear amplifier thus



provides a sensitive indication of when the input is near the required fixed value. The non-linear amplifier consists basically of an ordinary a.c. amplifier followed by a limiter and rectifier; across the rectifier output is connected a biased diode (D) in parallel with a high-value resistor (R) and in series with the output meter (M). At low input levels to the non-linear amplifier the biased diode does not conduct so that the output meter is fed from the high resistance. Thus the output meter reading increases only slowly with the input level at low input levels. Just below the fixed input level the biased diode suddenly starts to conduct and short circuits the high resistance feeding the output meter. Thus the output meter reading increases rapidly with the input near the fixed input level. At still higher input levels the limiter ensures that the meter reading again increases only slowly with the input level.

Elements of Electronic Circuits

14.—THE MILLER TIMEBASE

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

ONE of the most widely used linear timebase generators depends for its action on the Miller integrator circuit, in which negative feedback is introduced by an externally coupled capacitor between anode and grid. A single valve is used to control the charging and discharging of the timebase capacitor, which is initiated by switching pulses applied to the suppressor grid. It may be noted here that variations of this circuit (such as the "phantastron") differ in respect of the method of switching and the complexity of the associated amplifier circuit.

Before attempting to describe the operation of the circuit shown in Fig. 1 it will be necessary to understand what is meant by the Miller effect. First, let us consider a triode amplifier with gain=A, the valve developing its output voltage across a resistive load. As the anode voltage is 180° out of phase with the input voltage it can be shown that feedback to the grid is introduced by the inter-electrode capacitance C_{ga}. This has the effect of modifying the input capacitance of the valve, which can be written $C_{input}=C_{gk}+C_{ga}(1+A)$, the suffixes representing the respective inter-electrode capacitances. This increase in input capacitance, i.e., $A.C_{ga}$, is due to the Miller effect (named after its discoverer, J. R. Miller, in 1919).

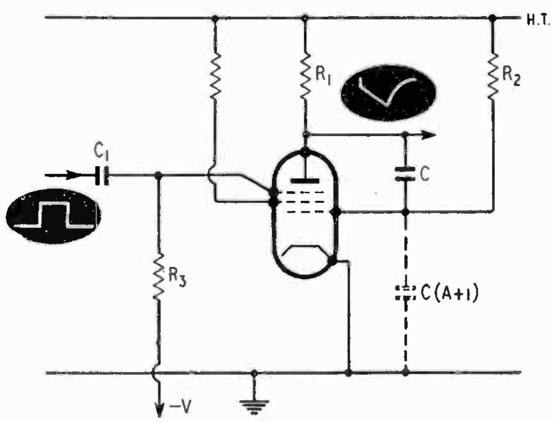


Fig. 1

A capacitor connected externally between the anode and control grid of a pentode amplifier will modify the input capacitance in a similar fashion, and this is the basis upon which the circuit shown in Fig. 1 operates. In this circuit the control grid is connected to a positive voltage source through a high-value resistor, R_2, and it is also connected to the anode via a capacitor, C. The grid circuit can therefore be regarded as consisting of a resistor R_2 in series with a capacitor C (A+1).

Referring to the waveform diagram in Fig. 2, the action of the circuit is as follows:—

Stage (a)

The suppressor is biased to a negative voltage via R_3 sufficient to prevent the flow of anode current, so that initially the valve is cut off as far as the anode is concerned, and V_a is at h.t. voltage. Grid current flows since g_1 is just above cathode potential (a few volts positive). C is charged practically to h.t. voltage.

Stage (b)

The action starts with the application of a positive-going square pulse to g_3. This is sufficient to cause anode current to flow. V_a falls and this drop in voltage is applied via C to g_1. As g_1 goes negative, less anode current flows; therefore V_a tends to rise. A state of equilibrium is eventually reached when

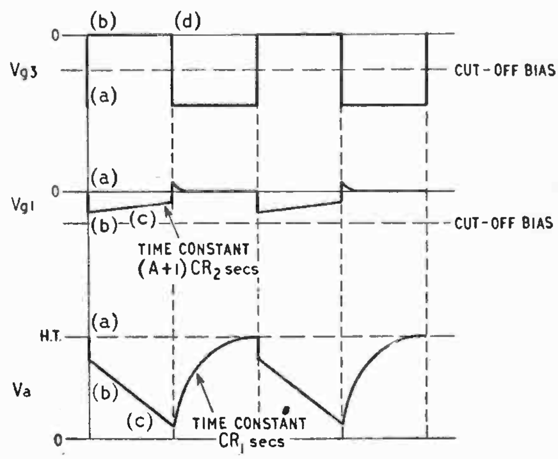


Fig. 2

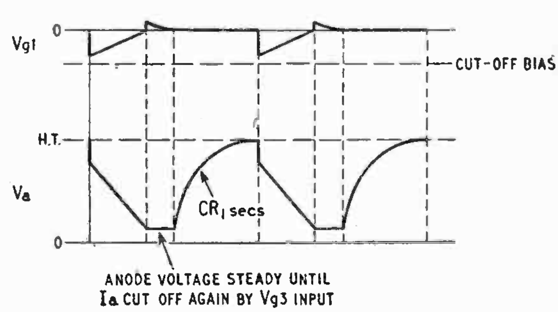


Fig. 3

the anode current is only just sufficient to cause a voltage drop in R_1 equal to the amount g_1 has gone negative from its original potential. V_{g1} is now negative and I_{g1} ceases.

Stage (c)

The side of C connected to g_1 is negative and as it is tied to h.t. via R_2 the h.t. voltage tries to charge it in the opposite direction through R_2. The voltage across C gradually falls. V_{g1} gradually rises and V_a consequently falls. The rate at which V_{g1} rises (V/CR volts/second in a CR circuit) is $\frac{V}{C(A+1)R_2}$ volts/second, where V is the h.t. voltage. The time constant is $(A+1)CR_2$ seconds. Note that C becomes $(A+1)C$ due to the Miller effect described above. V_a changes at A times the rate of change of grid voltage; therefore V_a falls at

$$\frac{V}{C(A+1)R_2} \times A \text{ volts/sec}$$

This can be written

$$\frac{V}{CR_2} \times \frac{A}{A+1} \text{ volts/sec}$$

Now if A is large (pentode amplifier) $A/(A+1) \simeq 1$. Therefore the rate of fall becomes V/CR_2 volts/sec, which is independent of the valve characteristics—an important attribute of this circuit. This is therefore the timebase sweep voltage.

Stage (d)

When the input square pulse ends, the suppressor voltage again cuts off the anode current and V_a rises, carrying V_{g1} with it until I_{g1} flows. C charges exponentially in the opposite direction through R_1 with time constant CR_1 (not $C(A+1)R_1$ as the Miller effect is now absent since the valve is not amplifying during this period). V_a finally reaches h.t. and the cycle of operation ceases.

If we make R_2 a smaller value, or if the square pulse which starts the action lasts long enough, the grid current region will be reached before the end of the period. This is illustrated in Fig. 3. V_a remains steady until the pulse on the suppressor ends and the recovery phase begins. Thus the slope of the timebase waveform can be altered by varying R_2.

Provided that A is large, the slope has been shown to be independent of the valve characteristics and also of the anode load R_1. The output impedance of the circuit is therefore low (approximately $1/g_m$). This means that the Miller timebase can develop its waveform with negligible distortion across quite low impedances.

Calculation of Standing Wave Ratio

Effects of the Terminating Load on Line of Known Characteristic Impedance

By *JOHN E. ROBSON**, *B.Sc., A.M.I.E.E.*

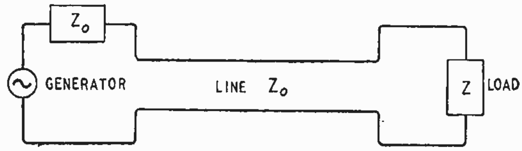
IT was the author's original intention to sub-title this article, " or how to do without a Smith Chart," but this would have seemed ungracious in view of R. A. Hickson's excellent series of articles on the subject.[1] However, the problem does arise in practice, and the main result obtained here is the outcome of a frequently recurring situation.

The essence of the problem is shown in Fig. 1. A transmission line of given characteristic impedance Z_0 is being driven by a generator, whose output impedance is taken as Z_0 also for the sake of simplicity, and is terminated in an impedance of value Z. What effect will this have on the performance of the system?

In an actual case, which does occur in practice, the generator of Fig. 1 is a source of signals in the frequency range 3 to 10Mc/s, the line is a coaxial cable for which Z_0 is 75 ohms resistive, and the terminating impedance Z is the input impedance of a level indicator or a receiver. The expression " the effect on the system " comes down to mean " the standing wave ratio," or " the return loss " caused by the impedance.

The Importance of Standing Wave Ratio.—In some previous treatments of the problem, the existence of standing waves was taken merely as an indication that all was not well at the far end of the line. Most probably, there was an amount of mismatch between the line and the load: in other words, the load was not exactly a pure resistance in value equal to that of the characteristic of the line. In fact, Hickson showed how a measurement of the magnitude and spatial distribution of the standing wave could be manipulated to provide a value for the terminating impedance. It is the purpose of this article to look at the problem from the other side; that is, to take a given impedance, and determine the standing wave ratio caused by it on a line of given characteristic impedance. This is the viewpoint of the transmission line engineer, who regards a standing wave as a bad thing in itself, being caused as it is by reflected power. The line has to be made " flat," and there are in general, many more than one

Fig. 1. Transmission line of characteristic impedance Z_0 driven by a generator and terminated in a load of value Z



*Redifon Ltd., Crawley.

junction at which reflection can take place. It is for this reason that the transmission line engineer works in terms of return loss, and here the author can do no better than refer to an earlier series of articles.[2] Another situation in which a high standing wave ratio is an inherently bad thing is that of a transmitter feeding an aerial via a transmission line. If the transmitted power is large, then dangerously high voltages can be developed across the line conductors, or even within the transmitter. Again, long before the danger point has been reached, the attenuation, or power loss in the line, has begun to rise quite steeply. In brief, the extra power losses at the high-voltage points on the standing wave pattern are not made good by the reduced losses at the low-voltage points.

Determination of Standing Wave Ratio.— Several measurement techniques have been evolved to determine the standing wave ratio, either by direct measurement or by calculation from a measurement of a related quantity. Thus, by means of a slotted line and probe, the electric field distribution along a line under given conditions of termination may be explored, and this will give the required quantity directly. Unfortunately, the line needs to be at least one half-wavelength long at the frequency of interest, and at 10Mc/s that would mean a line of some 47ft long.

Then the power flow in each direction along the line can be sampled, and two readings obtained which are proportional to the forward and to the reverse power flow. This technique is that of the Reflectometer, and " Cathode Ray " has recently illuminated it for us[3].

Finally, a kind of radar method can be used, in which signal pulses are sent off up the line, and the returns are displayed on a cathode-ray oscilloscope. This method is of wide application, though obviously the technique is fairly sophisticated.

A method will now be described in which a single impedance measurement is sufficient to allow of calculation of standing wave ratio.

Calculation from Impedance Measurement.— If the terminating impedance is purely resistive, and equal in value to the characteristic impedance of the line, then it is well known that no reflection of power will take place at the load. Everywhere along the line, the relationship $V = Z_oI$ will hold, including at the load itself. Now if the load is not equal to Z_o then that relationship cannot hold, and so some power is sent back. It is easy to see that if the load is purely resistive and of a different value from that of Z_o then there will be no phase change in voltages or currents, and the standing wave ratio will be given by $S = Z_o/R$ or R/Z_o. That fraction is chosen which makes S greater than unity, as the use of this convention appears to be increasing.

The next step is to consider the effect of a loading impedance which includes some reactance. For even if the resistive part of the load is equal to the Z_o of the line, the relationship $V = Z_oI$, which holds good for either wave on the line, cannot hold equally for a load in which $Z = R_o + jX$.

Consider now the situation as shown in Fig. 2. This illustrates part of the complex plane of impedance: in other words, two axes are drawn at right angles, the real, or resistive, and the imaginary, or reactive. With reference to these axes, points may be plotted which represent impedances. The two impedances actually shown are the terminating impedance $Z_1 = R_1 + jX_1$ and the characteristic impedance of the line Z_o. This is purely resistive, and so is represented by a point on the real axis.

Now the value of standing wave ratio at the load, due to the particular value of Z, can be denoted by S_1, and the question arises, do any other values of terminating impedance give rise to this same value, S_1? This question can be put another way; given any value of standing wave ratio, what shape will the curve be which passes through all the points on the plane with that value? The answer is, interestingly enough, a circle, and a quick derivation of this result is now given.

By definition, the standing wave ratio is:—

$$S = \left|\frac{1 + K}{1 - K}\right|$$

where K is the ratio of reflected voltage to forward voltage. Recalling that a phase change occurs for a

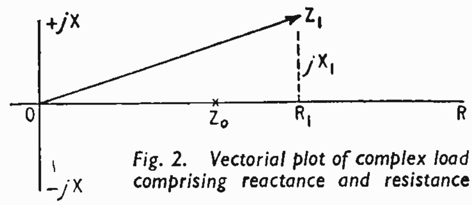


Fig. 2. Vectorial plot of complex load comprising reactance and resistance

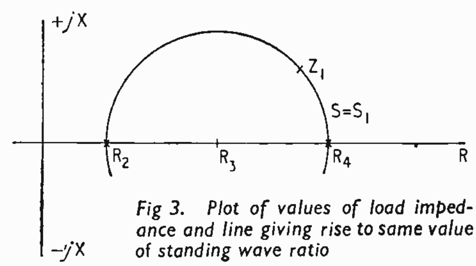


Fig 3. Plot of values of load impedance and line giving rise to same value of standing wave ratio

reactive load, it can be seen that K in general will be complex, that is, of the form $x + jy$.

This leads to:— $S = \left|\frac{1 + x + jy}{1 - x - jy}\right|$

and so:—

$$S^2 = \frac{(1 + x)^2 + y^2}{(1 - x)^2 + y^2}$$

After a little algebra this comes out to be:—

$$y^2 + x^2 - 2x\frac{S^2 + 1}{S^2 - 1} - \frac{1}{S^2 - 1} = 0$$

which is the equation of a circle.

Fig. 3 shows part of one such circle passing through the point representing the particular impedance $Z_1 = R_1 + jX_1$. In order to be able to describe this circle we need to know its centre and its radius, that is, to be able to determine the points R_2, R_3 and R_4 along the real axis. The points R_2 and R_4 are given by terminating loads of those values, and, it is to be noted, purely resistive in nature. Thus an earlier result can be used, and the value of standing wave ratio written at once as:—

$$S = \frac{R_4}{Z_o} \text{ and } S = \frac{Z_o}{R_2}$$

The reason for the inversion of one fraction is that

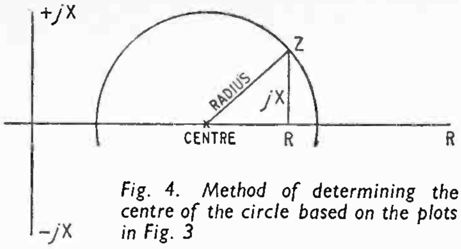


Fig. 4. Method of determining the centre of the circle based on the plots in Fig. 3

one value of resistance is greater than Z_o, and one smaller. Thus:—

$$R_1 = SZ_o \text{ and } R_2 = Z_o/S$$

The centre of the circle is R_3, and this is given by:—

$$R_3 = \frac{R_2 + R_1}{2}$$

which means that the circle has its centre at the point:—

$$\frac{SZ_o + Z_o/S}{2}$$

Again, the radius of the circle is given by:—

$$\frac{R_1 - R_2}{2} = \frac{SZ_o - Z_o/S}{2}$$

Finally, the line is terminated in any impedance $Z = R + jX$, and so the circle of constant standing wave ratio must pass through this point. This means that the distance from the centre to the point Z is equal to the radius of the circle. Thus there is a right-angled triangle shown in Fig. 4 whose sides are:—

$$X,\ R - \frac{SZ_o + Z_o/S}{2} \text{ and } \frac{SZ_o - Z_o/S}{2}$$

Applying Pythagoras gives:—

$$X^2 + \left[R - \frac{SZ_o + Z_o/S}{2}\right]^2 = \left[\frac{SZ_o - Z_o/S}{2}\right]^2$$

or

$$4X^2 + 4R^2 + S^2Z_o^2 + \frac{Z_o^2}{S^2} + 2Z_o^2 - 4RZ_o\left(S + \frac{1}{S}\right)$$

$$= S^2Z_o^2 + \frac{Z_o^2}{S^2} - 2Z_o^2$$

and, on solving for S, we have:—

$$S^2 - S\left[\frac{R}{Z_o} + \frac{Z_o}{R} + \frac{X^2}{RZ_o}\right] + 1 = 0$$

Applications of the Result.—The equation just arrived at is of great interest, and the author believes it to be original, never having seen that result stated in the literature. Its interpretation is straightforward: given a line of characteristic impedance Z_o, and a terminating load Z, whose components as measured on an impedance bridge are R and jX, then a value of standing wave ratio at the load will be observed, as given by the expression for S.

It would appear that, as the equation is quadratic in S, the two roots will give two differing values of S. That this is not so can be seen by noting that the equation is of reciprocal type, which means that if $S = \alpha$, say, is one root, then $S = 1/\alpha$ is the other. This follows from the well-known point in the theory of equations that the constant term is the product of all the roots taken singly, and the fact that the constant term in the equation for S is unity.

This result can perhaps be expressed more fancifully by saying that one root of the equation gives S in its British form, and the other root in American.

As an interesting check on the correctness of the approach, set the reactance term equal to zero; in other words, consider a purely resistive load of value R. Then the equation reduces to:—

$$S^2 - \left[\frac{R}{Z_o} + \frac{Z_o}{R}\right]S + 1 = 0$$

Here again the theory of equations helps, for the sum of the roots is the negative of the coefficient of S, and so the roots are obviously R/Z_o and Z_o/R Which is the correct value for the standing wave ratio under that circumstance.

Reverting to the general equation, it may well be that the measurement of the termination is in the form of parallel admittance components, and over the radio frequency range under consideration this is the more likely case. Then the unknown will be stated as $Y = G + jB$, and the line will have a characteristic admittance of Y_o. The equation then becomes:—

$$S^2 - \left[\frac{G}{Y_o} + \frac{Y_o}{G} + \frac{B^2}{Y_oG}\right]S + 1 = 0$$

and the conclusions are unchanged.

There is one particularly useful feature of the equation whenever normalized impedances, or admittances, are employed. The termination will then be written as:—

$$\frac{Z}{Z_o} = \frac{R}{Z_o} + j\frac{X}{Z_o}$$

or

$$Z' = R' + jX'$$

the primes denoting normalized values. With this in mind, the basic equation may be written at once as:—

$$S^2 - \left[R' + \frac{1}{R'} + X'\left(\frac{X'}{R'}\right)\right]S + 1 = 0$$

owing to the fact that the various ratios within the bracket are already normalized.

One final point concerns the actual solution of the equation. No explicit solution for S has been exhibited, as the author feels nothing is gained thereby. It is best to substitute actual measured values, and solve the resulting simple quadratic equation.

As an example; the normalized form of an impedance is:—

$Z' = 0.6 + j0.4$. Thus we have $R' = 0.6$; $X' = 0.4$ and $X'/R' = 2/3$. Substituting in the basic equation gives:—

$$S^2 - \left[0.6 + \frac{1}{0.6} + 0.4 \times \frac{2}{3}\right]S + 1 = 0$$

$$S^2 - 2.53S + 1 = 0$$

and

$$S = 2.04 \text{ or } 0.49$$

and it can be checked that these are reciprocal values.

REFERENCES

1 R. A. Hickson: "The Smith Chart," *Wireless World*, Jan., Feb. and March, 1960.

2 Thomas Roddam: "Return Loss": *Wireless World*, Nov. and Dec., 1957.

3 "Cathode Ray"; "The Reflectometer": *Wireless World*, March, 1960, p. 137.

LETTERS TO THE EDITOR

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

Negative Impedance

IN your May issue Mr. D. L. Clay has responded to my request to explain what he means by negative impedance, but he has still not convinced me that anything but confusion is to be gained by the concept. In an attempt to avoid the confusion invited by using "negative" in two different senses with reference to the same thing, he rules out the combination of a positive resistance and the reactance of a negative component, because it is unstable. On the same ground he must rule out the combination of a negative resistance and the reactance of a positive component. Since the latter is a commonly occurring one, its exclusion to suit Mr. Clay would be inconvenient.

He also appears to confuse dissipative losses due to the resistance of a reactor with the energy taken in by its reactance and returned in full during the same cycle.

Again, his use of the word "complex" in connection with impedance leaves one in doubt whether it is to be interpreted in its usual mathematical sense in that context or just as meaning "not simple."

I hope I am correct in interpreting his further remarks on phase difference as illustrating the worthlessness of any attempt to apply this concept to dissimilar waveforms.

Regarding Ohm's law and negative resistance: Mr. Clay said in his first letter "further explanation is wanted here." His second letter has convinced me that it is. But if I tried to compress it into a letter the confusion I appear to have created already might be worse confounded.

"CATHODE RAY"

Circuit Conventions

THE letter from Mr. Bedford (April issue) and your own comments on circuit conventions were interesting. The function of a circuit drawing is to convey information to the reader "unambiguously and without interference to thought sequences" of that reader. Is not the draughtsman's liability to error—on which the Editor appears to base his opinion—of very secondary importance?

On the other hand Mr. Bedford's mixing of X junctions (with a dot) and cross-overs (without) is indefensible. A dot omitted, or a slight merging of two ink lines and the whole meaning is changed.

In the diagrams in his letter in the April issue the loops may be acceptable to some, but more complex circuits may involve dozens—even hundreds— of "little bridges." They then become tedious to read and equally tedious and expensive to draw.

What is wrong with the recommendations of B.S.530? No X junctions, use only T junctions, and no looped cross-overs. If these sound conventions are followed the correctness of the drawing does not depend upon the presence or absence of dots and semicircles; it is more quickly drawn and traced and—most important—more easily read.

East Barnet, Herts. V. L. BUTCHER

WHILST congratulating Mr. L. H. Bedford on his prodigious achievements between the ages of four and five (April issue), may I, as a struggling technical author, advise him not to attempt any questions on circuit drawing which may crop up in his eleven-plus examination.

The recommendations of B.S.530 are not the perfect guide by any means but, if intelligently applied, they could make a very noticeable improvement to Mr. Bedford's Fig. 3.

However, I must side with Mr. B. (and with the B.S.I.) in deprecating the looped crossing, partly because of the time involved in drawing the wretched things.

To return to B.S.530, the requirements concerning T-junctions and crossovers are so sensible (even to a child of five), that it seems pointless to deviate from them. You see, Mr. Bedford, most diagrams have to be reduced photographically, and printed—often on inferior-quality paper—with ink which tends to spread. (Look what happened to your capacitors, Mr. B.!) It is thus quite possible to produce an accidental blob at an X junction.

I think most users of circuit diagrams would support my next point, namely that the inclusion of valve envelopes is of considerable value in identifying the separate stages in a complex circuit diagram. (How would you draw a gas-filled valve, Mr. B.?)

The following points come under the heading of "delicate points of style."

(1) If the Ω symbol is redundant in resistor values, the letter "F" is equally redundant in capacitor values (see B.S.530).

(2) The comma, such as appears in "5,000 pF" should *never* be used in circuit diagrams.*

(3) Those diodes are not "D," but "MR."

(4) Potentiometers are not "R," but "RV."

(5) If C26 is an electrolytic capacitor (as seems likely since the polarity is shown) it should be drawn as an electrolytic capacitor.

It would be interesting to submit Mr. Bedford's diagram to the Admiralty department which recently told me that resistors have four wiggles on one side and three on the other, and that anything else is not a resistor. (Probably Nelson drew his resistors that way.)

In conclusion, it may be relevant to point out that the majority of people concerned with the presentation of electronics diagrams blunder on, using B.S.530 as a guide, and (you may not believe this, Mr. Bedford), our readers understand us!

Belfast, 5. L. DENNIS

* We accept responsibility for this "error"—Ed.

YOUR correspondent, Mr. Bedford, seems to have forgotten that some degree of redundancy is essential to good communications. Looped connections, giving an absence of information, prevent the mind from wandering. In his diagram, Fig. 3 (April issue), is the cross at R23, R24, R26, C23, D2 really a junction, or did the ink flow? I stop to find out and communications are interrupted.

Similarly with the valve "bottle." The valve is the centre of a stage of the circuit; the circle is a spot-light and helps in rapid assimilation.

Adding pin numbers to valves has been tried and discarded: they clutter the diagram. If numbers for valves, why not for transformers and other sub-assemblies which cannot be found in a book?

The circuit is only of interest to the man who has never seen the junk before and has to find trouble quickly and to the engineer who has to make time to read the article. Anything to help and not hinder their efforts is worth while.

While I am writing, may I ask the *W.W.* not to be the odd-man out when drawing transistors (as, for example, in the March, 1960, issue, p. 110). Also, though a circuit with a negative supply at the top makes the transistor easier to us poor valve technicians, ought we not to start right with the positive at the top? Just one argument: with the negative supply at top, is a positive going pulse drawn downwards?

Bracknell, Berks. WALTER DALTON

"Ring Angels"

I SHOULD like to comment on "Diallist's" note on "Ring Angels" in the April, 1960, issue of *Wireless World*.

Expanding ring echoes of this kind were recorded as early as 1956 on radar equipment operated by the Meteorological Office at East Hill in Bedfordshire. They were recognized as being caused by birds. At various times since then seven different centres of ring echoes were recorded within a radius of 15 miles of the radar installation, and each one was found to be the site of a starling roost.

It is not difficult to see why these movements are seen as expanding rings. Starlings leave their roosts at around dawn in a series of "explosions," and the echoes appear as rings because their flight paths to their feeding grounds radiate outward in almost every direction from the roost with a surprisingly uniform flight speed. Sometimes the directions of flight are more limited, and then the echoes expand as arcs rather than as rings. A description and explanation of ring echoes were given by me in *Ibis*, the journal of the British Ornithologists' Union (Vol. 101, 1959, p. 201).

I think that few meteorologists will find support for the view that ring echoes are caused by "rapidly expanding thermal fronts in the upper atmosphere."

Meteorological Research Unit, W. G. HARPER
Great Malvern, Worcs.

[Since receiving the above letter from Mr. Harper, an article by E. Eastwood, G. A. Isted and G. C. Rider, of the Marconi Research Laboratories, Great Baddow, has been published in *Nature* (April 9th) describing further work to establish the correlation between "ring angels" and starling flights.—ED.]

Increasing Video Gain

FOR some time past I have felt dissatisfied with the performance of the single v.f. stage fitted to television receivers. In a fringe area, the low gain obtained is a serious disadvantage.

In my efforts to obtain an image free from "ringing" and "smearing" I have evolved the accompanying circuit for a high-gain v.f. amplifier.

The exact gain *in situ* proved unexpectedly difficult to measure, but appears to be of the order of volts × 120, and peak-to-peak output is 150 volts max. The cathode follower is connected in a manner calculated to give maximum d.c. protection to the c.r.t. in event of valve failure. The noise suppressor is highly efficient and does not affect the d.c. restorer.

The picture obtained is really beautiful, showing the 3 Mc/s (Test Card "C") lines with a minimum of ringing. (The exact amount of ringing is determined by the 500pF cathode bypass capacitor in the first stage.)

Peacehaven, Sussex. R. G. YOUNG.

Deeper Amplitude Modulation?

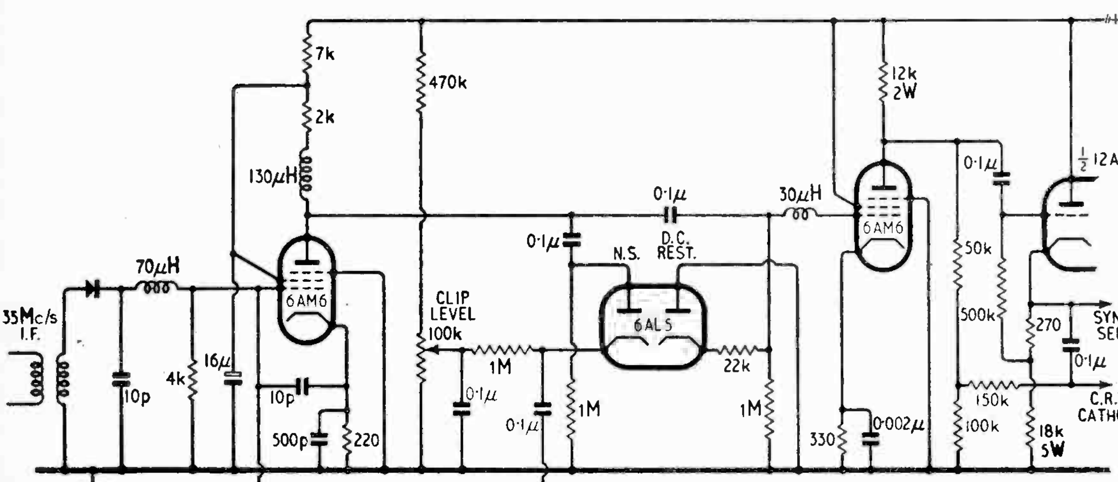
SOME time ago, when listening on my car radio in the London area, I noticed that the French 164-kc/s transmission appeared to be louder than the B.B.C. on 200 kc/s, but a check on the receiver a.g.c. showed that the B.B.C. had the stronger carrier. I assumed that the French were using more modulation than the B.B.C., and this was confirmed recently when I had a look at both carriers on a "panadaptor," which showed quite clearly that the French modulation, besides being considerably deeper than the B.B.C.'s, was also slightly clipped. The difference in quality was not immediately noticeable on a car radio, although it could be heard on hi-fi equipment, but this very slight loss of quality was easily offset by the great gain in intelligibility, and it occurred to me that now that the v.h.f./f.m. broadcasts are available to anyone expecting high-quality reception, the B.B.C. should adopt a higher percentage of modulation in its medium and long-wave transmissions and make them a little easier to listen to under marginal conditions, in a car or otherwise. From the amount of sideband splatter to be heard on the medium waves at night, most of the Continentals are already doing this without troubling unduly about their filtering! Another possibility is the adoption of single-sideband with carrier transmission, as used by the Voice of America on 173 kc/s.

I feel that the B.B.C. should make some sort of effort in this direction, since I find that more and more of my acquaintances, having good v.h.f. installations at their homes, listen on the medium- and long-wavebands only while in their cars.

Chichester. W. BLANCHARD

Economical High-gain A.F. Amplification

IN reply to Mr. Short's letter in the May issue, I would first like to apologise to him for quoting a gain of less than 200 for a "straight" pentode 6BW7 amplifier. The error arose due to having just written a reply to another correspondent who was contemplating using an EF86.



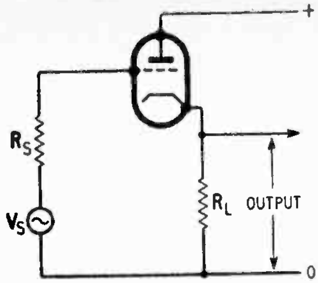


Fig. 1

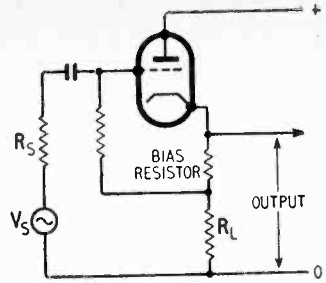


Fig. 2

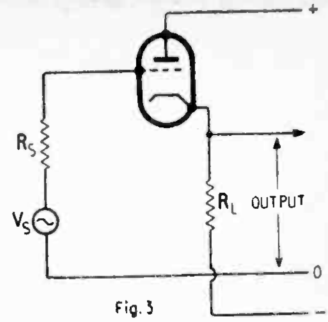


Fig. 3

I still feel, however, that 6dB loss in gain is a small price to pay in return for a stable high-gain amplifier which is not fussy about circuit layout.

With regard to Mr. Short's second point, I agree that the circuit that he shows (Fig. 1) has an output impedance that is independent of the input impedance for most practical purposes. It should be noted, however, that the output voltage is limited to a small amount due to the voltage drop across R_L providing the valve bias. For a 12AT7 valve operating with 250 volts on the anode at an anode current of 10 milliamperes, the correct operating bias is about 2·5 volts. This makes R_L equal to 250Ω. The peak output voltage will be in the region of 2·5 volts also and the output impedance will be less than $1/g_m$ ohms (180Ω) as R_L is in parallel with the output impedance of the valve itself. To give increased output voltage the circuit shown in Fig. 2 is normally used, this providing bias by feeding back only a small amount of the d.c. voltage across the cathode load. This, however, makes the output impedance of the cathode follower vary with the input impedance.

To overcome both difficulties, the circuit shown in Fig. 3 can be used if a negative supply is also available. This has the same advantage as Mr. Short's circuit in being d.c. coupled but can give a much greater output as the valve bias is developed automatically and is much less than the voltage drop in the load resistor R_L.

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

News from the Industry

A.E.I.—The consolidated profit and loss account of Associated Electrical Industries and its subsidiaries for 1959 shows an excess of income over expenditure of £16,972,609; just over £1M more than the previous year. After setting against this figure various charges, including nearly £5M taxation, the profit was £6,489,807 compared with £5.1M in 1958.

T.C.C. announce a group trading profit for 1959 of £769,980 which is a 45% increase on the preceding year. At the board meeting which followed the annual general meeting D. W. Aldridge resigned from the chairmanship and his place has been taken by W. C. Handley. The vacancy on the board has been filled by Dr. L. G. Brazier who is also director of research and education of B. I. Callender's Cables the parent company of T.C.C.

Ekco airborne weather radar is being fitted in the fifteen Boeing 707 airliners on order for British Overseas Airways Corporation. All B.O.A.C. Britannia and Comet 4 airliners are already equipped with Ekco radar.

Ampex.—According to figures issued by Ampex International, of Switzerland, there are now 65 of the corporation's Videotape recorders in use in Europe. Of this total 42 are in the U.K.

Fraser Electronics and Communications Ltd. has been set up by J. Fraser (until recently with Land, Speight and Company), and W. O. Buchanan, to act as Scottish agents for electrical and electronic manufacturers. They have premises at 1103 Argyle Street, Glasgow C.3 (Tel.: Central 9301).

Reynolds (Packaging) Ltd., of Alfred's Way, Barking, Essex, have constructed a dust-free air-conditioned room for the cleaning and packing of specialized equipment including electronic gear for guided weapons.

Mills & Rockleys (Production) Ltd. have announced three appointments in their printed circuits division. J. R. Atkinson has taken over production from A. K. Bullock who will concentrate on planning. T. L. Harcombe has joined the company from the G.E.C. and will be responsible for development and application engineering.

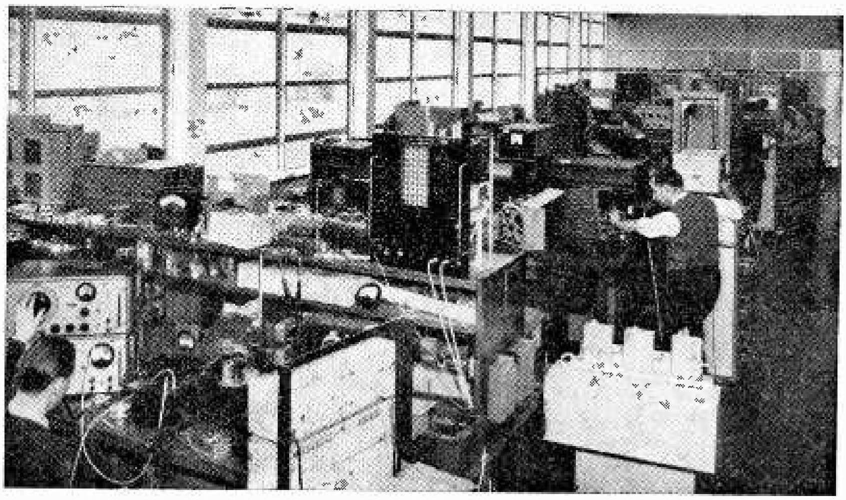
Transitron Electronic Corp., of Wakefield, Mass., have set up a European sales subsidiary, Transitron Electronic S.A., with its headquarters in Zug, Switzerland, and Offices in London, Paris and Münich. The London offices will be run by a new company, Transitron Electronic Ltd., of which D. P. O'Connell, formerly with British Electric Resistance Co., is manager.

Ferranti Ltd. have signed an agreement with Bendix Aviation Corporation for them to sell in the U.S.A. Ferranti machine tool control systems. Bendix, who made the initial move in the negotiations, will set up a computer centre in Detroit to supply magnetic tapes for the equipment.

Amplivox Ltd., of Wembley, Middx., has been awarded contracts by the General Post Office for the supply of miniature magnetic microphones and earphones for the new transistorized hearing-aid issued under the National Health Scheme.

Swiss made apparatus for the speedy insertion of soldering tags into printed circuit boards is being handled in this country by R. H. Cole (Overseas) Ltd., of 2 Caxton Street, London, S.W.1, who are agents for Kumag, of Zürich.

Grundig (Great Britain) Ltd. have extended the guarantee period for their tape recorders from six months to one year. This will apply to all guarantees registered on or after January 1st this year.



Communication systems laboratory at the new establishment of Standard Telecommunication Laboratories, at Harlow, Essex. This particular laboratory is used for investigations into television transmission by pulse code modulation. S.T.L., a wholly owned subsidiary of Standard Telephones & Cables, was formed in 1945 with laboratories at Enfield, to take over the advanced research and development work of S.T.C.

Direct TV Replacements, of 138 Lewisham Way, London, S.E.14 (Tel.: Tideway 6666) are now manufacturing their own replacement transformers for Ferguson television models 306T and 308T. This component is also used in H.M.V. models 1865 and 1869 and Marconiphone model VT153.

Miniature Electronic Components, Ltd., of St. Johns, Woking, Surrey, are producing under licence from Con-Elco, of California, a range of miniature trimmer potentiometers specially designed and developed for the guided weapon and aircraft industries. The range extends from 10 ohms to 50kΩ.

Precision Components (Barnet) Ltd. have moved from Barnet to Kabi Works, Cranborne Road, Potters Bar, Middx. (Tel.: Potters Bar 3444).

Precision Jigs Company Ltd., of 79 Caterham Avenue, Barkingside, Essex, has acquired a factory on the new industrial estate, Thetford, Norfolk.

Hagan Controls, Ltd., a member of the Plessey group, has moved to 14, Grosvenor Place, London, S.W.1 (Tel.: Belgravia 6382).

EXPORT NEWS

Tropospheric scatter link equipment is being supplied by Marconi's to Cable & Wireless (W.I.) Ltd. to establish a quadruple diversity u.h.f. link between the West Indies islands of Barbados and Trinidad. The system will carry six telephone speech channels and will be capable of enlargement to twelve channels.

Closed-circuit television equipment manufactured by E.M.I. Electronics has been installed in a Wall Street stockbrokers' office. The television system relays to large-screen monitors in seven offices a continuous picture of moving ticker-tapes giving stock market movements.

H.F. telecommunications equipment is being supplied to Turkey and Iran by Marconi's under a £225,000 order placed by H.M. Government as part of its programme of technical assistance to member countries of the Central Treaty Organization. The contract calls for the supply and installation of independent sideband telephone and multichannel telegraph circuits between Istanbul, Ankara, Teheran and London.

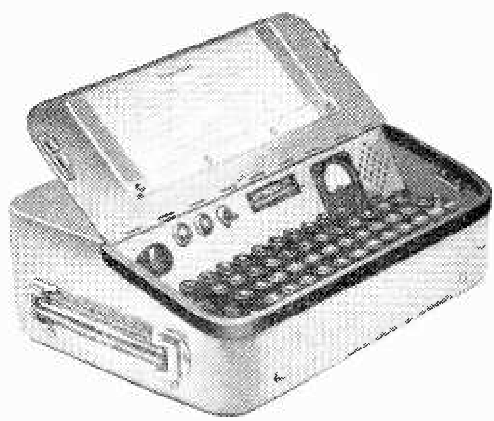
Telemechanics Ltd., who recently moved into new premises at Brokenford Lane, Totton, Southampton (Tel.: Totton, Southampton 3666), have appointed Conway Electronic Enterprises Reg'd., of Toronto, as their Canadian agents, and M. Rietveld, e.i., of Rotterdam, as agents in Holland.

Milan's first radio taxi service, comprising a fleet of 250 vehicles, is fitted with Pye equipment. The service was introduced at the opening of the Milan Fair at which the theme of the Board of Trade exhibit was "British electronics in the service of mankind."

Weather radar has been supplied by Decca to several U.S. television stations for their weather forecasting services. The radar pictures are transmitted to viewers while an announcer interprets the information.

Indian Agents.—Capital Industries, of 8, Kapurthala Road, Jullundur City, who have been established since 1925, want to represent a British manufacturer of radio equipment.

I.L.S. equipment is being supplied by Pye for Nairobi's new international airport.



The "Automorse" machine illustrated enables anyone without knowledge of the Morse Code to operate a telegraph communications system of either the wire or radio type. On depressing a key on the typewriter-like keyboard the machine automatically selects the correct Morse sequence of dots and dashes relevant to the figure, letter or other character marked on the key. Cams are not employed, the selection of dots and dashes being effected by an ingenious system of wiping contacts. The machine has a capacity of 180 characters per minute and it operates normally from 6V d.c. consuming 3A. It was demonstrated recently at the Norwegian Export Centre, 20 Pall Mall, London, S.W.1, and the makers are Automorse Ltd., Näktergalsgatan 6, Gothenburg, Sweden.

THE COSH AT WORK

By "CATHODE RAY"

PRACTICAL USE OF A HYPERBOLIC FUNCTION

LAST month we saw that plotting the equation $y = \sqrt{r^2 - x^2}$ gives us a circle of radius r, so long as x is confined to the range of values from $-r$ to $+r$. Certain ratios in this graph are very well known and useful; for example, x/r is called $\cos\theta$, y/r is $\sin\theta$, and y/x is $\tan\theta$, where θ is the angle of the radius from any point x, y, relative to the "3 o'clock" radius. Directly x goes beyond $\pm r$, y is the square root of a negative quantity, described by mathematicians as imaginary. An alternative form of the same equation, $y = j\sqrt{x^2 - r^2}$, is then more convenient. Just as in a.c. vectors we interpret

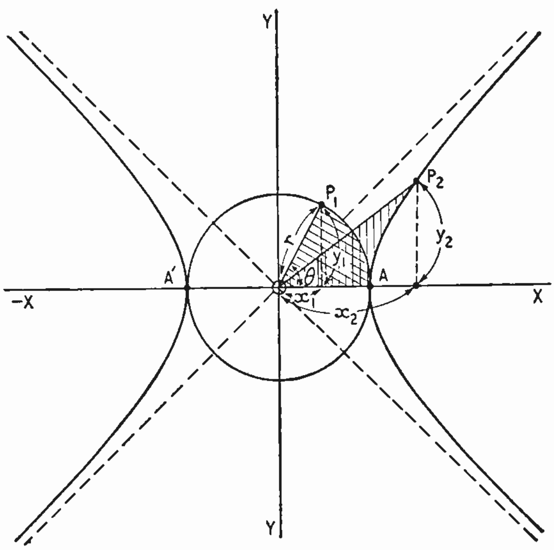


Fig. 1 Believe it or not, this graph all arises from Pythagoras— $x^2 + y^2 = r^2$. The circle part is mathematically real, and comes from values of x between $-r$ and $+r$. The hyperbolic parts can be plotted only after the factor j has been introduced, so are (by comparison) imaginary.

j as an instruction to break away at right angles into a new world that can only be imagined by single-dimensional x-axis beings, now we can interpret it as a break away from the two-dimensional plane of the paper on which our circle is drawn into a plane at right angles. Continuing to plot the equation there, we find the graph takes the form of a rectangular hyperbola. The complete graph of the equation therefore consists of the circle and two-part hyperbola, shown (without distinction between real and imaginary) in Fig. 1. P_1 is a typical point on the circle, x being less than r; namely, x_1. x_1/r is $\cos\theta$. To distinguish the ratios in the hyperbolic world, "h" is added to their names; so x_2/r is $\cosh\eta$. And if you ask to be shown η on the diagram, the best that can be done is to note that it is proportional to the shaded area AOP_2, just as the angle θ is proportional to the shaded area AOP_1. Although θ is the angle AOP_1, η is definitely not the angle AOP_2 or any other angle visible as the inclination of one line to another. It was to emphasize this very important point that I used separate symbols, θ and η; but both just stand for a number, and it may often happen that they are the same number.

Because both sets of ratios are derived from the same equation, requiring only j as a key for passing from one set to another, we have

$$\cos A = \cosh jA \qquad \cosh A = \cos jA$$
$$j\sin A = \sinh jA \qquad j\sinh A = \sin jA$$

Consequently the trigonometrical formulae for circular angles all have their hyperbolic counterparts, differing only by the appropriate power of j (j^2 being of course -1). For example:

$$\cos A = \frac{e^{jA} + e^{-jA}}{2} \qquad \cosh A = \frac{e^{A} + e^{-A}}{2}$$

$$e^{jA} = \cos A + j\sin A \qquad e^{A} = \cosh A + \sinh A$$
$$\cos^2 A + \sin^2 A = 1 \qquad \cosh^2 A - \sinh^2 A = 1$$
$$\cos(A+B) = \cos A\cos B - \sin A\sin B \qquad \cosh(A+B) = \cosh A\cosh B + \sinh A\sinh B$$

Now circles, and angles thereof, are involved in a great variety of practical activities, so we are familiar with the circular side of the picture. The very name hyperbola suggests something much more academic, and it is certainly not familiar to the great non-technical public. So the usefulness of hyperbolic functions is much less obvious than that of circular functions. Another thing: we usually have some warning, in the shape of an angle, that circular functions may soon appear; but hyperbolic functions have a way of cropping up suddenly and apparently inconsequentially, to the dismay of the reader. Last month's effort was intended to make clear what hyperbolic functions are, and we have just recapitulated. The next thing is to show how they can be used, by taking a simple example.

It is the familiar ladder arrangement, Fig. 2, in which the impedances Z_1 and Z_2 can be of any kind, usually pure resistances and/or pure reactances (or as close approximations to them as practicable). If both Z_1 and Z_2 are resistances—or both reactances of the same kind—we have an attenuator, treating all frequencies alike; if they are a mixture, we have a filter, the purpose of which is to discriminate between frequencies. When the number of stages or sections is even as few as two, it becomes a little

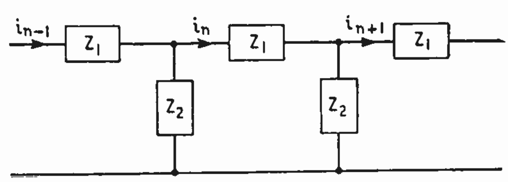


Fig. 2 General form of ladder network, made up of impedances in two sizes.

complicated to calculate it by ordinary circuit methods, and above two the paper work rapidly gets out of hand. However, if one can assume that the number of sections is unlimited—or alternatively that the chain is terminated by an impedance equivalent to an unlimited sequence—it becomes quite simple. The other necessary assumption is a signal source —a.c. or d.c.—somewhere to the left, to make current flow. The currents through the three Z_1 elements shown in Fig. 2 are named thereon. The current downwards through the left-hand Z_2 is obviously $i_{n-1} - i_n$, and that through the right-hand Z_2 is $i_n - i_{n+1}$.

The total voltage around any complete loop being necessarily zero, apply this principle to the loop formed by the two Z_2s and the middle Z_1. The clockwise voltage across the first Z_2 is $(i_{n-1} - i_n)$ Z_2; across the Z_1, $-i_nZ_1$; and across the second Z_2, $-(i_n - i_{n+1})$ Z_2. So

$$(i_{n-1} - i_n)\,Z_2 - i_nZ_1 - (i_n - i_{n+1})\,Z_2 = 0 \qquad (1)$$

Since every section is exactly the same as every other, the ratio of i_{n+1} to i_n is the same as that of i_n to i_{n-1}. Call it a, so that $i_{n+1} = ai_n$ and $i_{n-1} = i_n/a$. Substituting this in (1) we get

$$(i_n/a - i_n - i_n + ai_n)\,Z_2 - i_nZ_1 = 0$$

which can be divided throughout by i_n and Z_2 giving

$$a + \frac{1}{a} - 2 - \frac{Z_1}{Z_2} = 0 \qquad \ldots \quad \ldots \quad \ldots (2)$$

We are interested in a, because it is the input/output current (and voltage) ratio of each section; and the attenuation of any number of sections, m, is a^m. So the natural thing is to lick equation (2) into a shape giving a directly. It turns out to be a quadratic, and the answer is in the usual rather untidy form of the solution of a quadratic:

$$a = \frac{Z_1}{2Z_2} + 1 \pm \sqrt{\frac{Z_1}{Z_2}\left(\frac{Z_1}{4Z_2} + 1\right)} \qquad \ldots \quad \ldots (3)$$

There is nothing actually wrong with that, and it can be used for computing a, given the ratio Z_1/Z_2 and a good deal of time and patience if it varies with frequency and a is required over a wide band. The more sophisticated worker, being $e^x + e^{-x}$ conscious, notices with interest the $a + 1/a$ in (2) and wonders if there would be any advantage in putting a into the form e to the something. He, of course, is of the type who would in any case require attenuation to be specified in decibels or even nepers (which are to decibels as natural (base e) logs are to common (base 10) logs).* Now the attenuation in nepers is defined as the natural log of the input/output current ratio. If this attenuation per section is denoted by α, then, $\alpha = \log_e (1/a)$, which can also be written $1/a = e^\alpha$, or $a = e^{-\alpha}$. Substituting $e^{-\alpha}$ for a and e^α for $1/a$ in (2), and dividing throughout by 2, our smart worker gets

$$\cosh \alpha = 1 + \frac{Z_1}{2Z_2} \qquad \ldots \quad \ldots \quad \ldots \qquad (4)$$

a decidedly neater result than (3) and one that gives him the answer direct in nepers instead of needing a separate operation to convert into them from the plain ratio a. The coshes can simply be looked up in a table.

If you are thinking that seems too dead easy you may be partly right. Some queries can arise when the values of Z_1 and Z_2 have been filled in. So let us look into the various possibilities.

When Z_1 and Z_2 are both resistances, the procedure really is as simple as it looks. To convince the sceptics, let us work an example out both ways. Suppose Z_1 is $100\,\Omega$ and Z_2 is $250\,\Omega$ (or any two values in the same ratio, 0.4). Using equation (3) first, we find $a = 1.862$ or 0.538. As we are assuming the only source is on the left, i_n must be less than i_{n-1}, so a is less than 1, and the solution 1.862 can be eliminated. As one might reasonably expect, 1.862 is the answer for signals coming from the right, so for left-coming signals it is $1/a$, which may actually be a little more convenient for calculating the decibels. Either way, the impedance of every section being the same, this current ratio is equivalent to 5.4dB; and as 8.686 dB = 1 neper, that is 0.62 neper.

Now try equation (4). The right-hand side is clearly 1.2 and a table of coshes (or Fig. 3) shows that if $\cosh \alpha = 1.2$, α is 0.62. It's as easy as that.

Strictly, because of the symmetry of the cosh hanging-chain curve, α is ± 0.62, but since we know our attenuator can't amplify the signals put into it our common sense again tells us which answer is right: -0.62, denoting a loss.

Next, suppose Z_1 and Z_2 are reactances of the same kind—both inductors or both capacitors. The j and ω $(=2\pi f)$ cancel out in Z_1/Z_2, so we are left with the ratio of inductances or capacitances, which is a real number just like the ratio of resistances in the previous case. So it is just as easy, except that the impedance of the ladder varies with frequency, which is the reason that this kind of

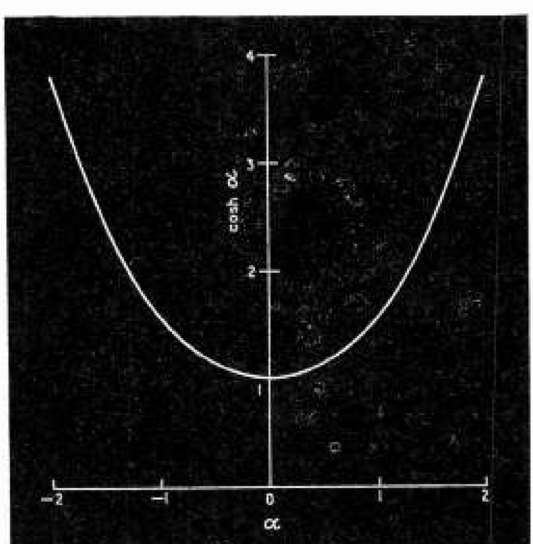


Fig. 3 Here, repeated from last month, is a cosh curve.

*Whereas decibels are power ratios expressed as common logs, nepers are current ratios expressed in natural logs. Current (or voltage) ratios can only be stated in dB on the understanding that both currents (or voltages) are in (or across) the same impedances. While the number of dB is correctly 10 $\log_{10}$ (P_2/P_1) where P_2 and P_1 are two powers being compared, powers in equal impedances are proportional to current (or voltage) squared, so the number of dB is then 20 $\log_{10}$ $(I_2/_1)$. The number of nepers is defined as $\log_e$ (I_2/I_1), and as $\log_{10}x = \log_e x/2.3026$, the number of dB is $20/2.3026 = 8.686$ times the number of nepers (always assuming the equal-impedance clause applies).

attenuator is seldom seen. The only example I can think of is the capacitance potential-divider sometimes used in the probe of a valve voltmeter, where a main object is to minimize the input capacitance.

We enter much the largest division of the subject when we pass on to reactances of opposite kind. Most filters use them. The vital feature is that a and α vary with frequency. So they have to be computed not once per filter but many times, and any short cut is that number of times more helpful.

Suppose Z_1 is an inductor and Z_2 a capacitor, both assumed devoid of resistance, as in Fig. 4. Then $Z_1/2Z_2$ in (4) is $j\omega L \times j\omega C/2 = -\omega^2 LC/2$. This not only varies as the square of the frequency, but is invariably negative, which will make us think a bit. For a start, it means that (except at zero frequency, when the filter does precisely nothing) according to (4) cosh α is always less than 1. But if we search Fig. 3 for a typical (or any) example we might as well look for an atheistic Pope.

For a hint of an escape from this impasse we can turn back to Fig. 1, where we see that x/r is a cosh when it is 1 or more and a cos when it is 1 or less. We know that a cos is a cosh of an imaginary quantity. There is no real value of a that makes $\frac{1}{2}(a + 1/a)$ less than 1; if one of the two terms in the brackets is less than 1, the other exceeds 1 by a greater margin, so their average is more than 1. But if instead of assuming a is equal to e^{α}, α being a real number, we consider the possibility of the index being imaginary, we can try $e^{j\beta}$. Since $\frac{1}{2}(e^{j\beta} + e^{-j\beta}) = \cos\beta$, we have as an alternative form of (4), for use when cosh α is " off the map,"

$$\cos\beta = 1 + \frac{Z_1}{2Z_2} \quad \cdots \quad \cdots \quad \cdots \quad (4a)$$

Until we are used to switching back and forth between a real world and (relative to what we have just left) an imaginary one, the transition may make us a little dizzy and in need of recovering our sense of direction. Fortunately there is always one point common to both worlds (A in Fig. 1), so let us pause on that threshold for a moment. From the hyperbolic point of view, it means that α—the attenuation in nepers—is zero. That is what we would expect, because cosh α can (from (4)) only be 1 when $Z_1/2Z_2$ is zero, which in our Fig. 4 case means zero frequency and a perfect straight-through connection. From the circular point of view, $\cos\beta = 1$ means $\beta = 0$. We could have chosen to call it cos α, to emphasize that it is basically the same quantity in both worlds, but it is rather more convenient to use a different symbol to indicate that in the circular world it is a circular angle. The physical interpretation of this is that instead of the attenuation, α, we are now going to have a phase shift, β. Our Fig. 4 filter at zero frequency obviously causes no attenuation and no phase shift, so is aptly represented by the common point A.

As the frequency rises, $-Z_1/2Z_2$ rises and makes cos β fall. That clearly indicates an increasing phase shift, which is what we get in an actual filter.

You will remember that there were two possible answers to the attenuation question, one representing movement away from the signal source and the other towards it, the first being a loss and the second an equal gain. In the same way there are two solutions to equation (4a); one a positive angle and the other an equal negative angle. Again, these represent what we find when we move away from or towards the source. Meanwhile, there is no attenuation. Two months ago we checked that $e^{j\theta}$ and $e^{-j\theta}$ represent vectors of variable angle but constant (unit) length.

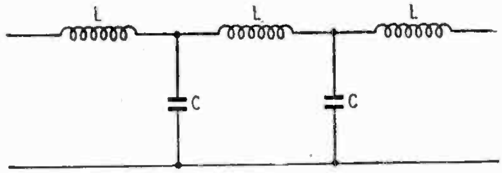


Fig. 4 A particular variety of Fig. 2—a low-pass filter.

The picture, then, is one of steadily increasing phase shift per section as the frequency of the signal entering the filter rises. Does it keep on doing this?

When the frequency is high enough to make $\omega^2 LC/2 = -1$, this cancels the 1 in (4a), so $\cos\beta = 0$ and $\beta = \pi/2$, or 90°. We are now half-way across Fig. 1, moving left. Doubling the frequency makes $\cos\beta = -1$, so $\beta = \pi$, or 180°. That brings us to A' in Fig. 1. What next? Do we keep on going round the circle, or is this another threshold to an imaginary world (for now we are in the circular world. it is the hyperbolic one that seems imaginary)? We can soon find out by increasing the frequency another step, making $\omega^2 LC/2 = 3$, for $1 - \omega^2 LC/2$, is then -2, and this is certainly not to be found in the table of cosines. Neither is it to be found in a cosh table or in Fig. 3. So where are we now? Completely lost, it seems!

Our mistake was being in too much of a hurry to get past A'. We should have paused there for a moment's reflection like we did at A. So let us go back to it. At that point there is still no attenuation, but a 180° phase shift, which means that the signal loses no strength in its progress down the filter but does reverse its polarity at every section. So, changing over once more to the hyperbolic or attenuation viewpoint, we can say that a is -1, which modifies (4) to

$$-\cosh\alpha = 1 + \frac{Z_1}{2Z_2} \quad \cdots \quad \cdots \quad \cdots \quad (4b)$$

This puts us back on to Fig. 3, and we can stay there indefinitely as the frequency rises. If you object that an infinitely large piece of graph paper would be needed, and that even cosh tables don't go to infinity, I would point out that if a is very large then $1/a$ is very small and can be neglected, simplifying (4b) to

$$a \simeq 2 + \frac{Z_1}{Z_2}$$

which in our example is $2 - \omega^2 LC$. The phase shift vector meanwhile sticks at 180°, represented by the minus sign in (4b).

Corresponding, then, to the abrupt mathematical change from circular to hyperbolic world as we pass through A', there is an abrupt physical change in the performance of the filter. At frequencies from zero to there, it doesn't attenuate the signal at all, but it does introduce an increasing phase delay.

Directly that delay equals 180° per section it sticks at that and attenuation begins, increasing with frequency. The change-over point is, understandably, called the cut-off frequency, usually denoted by f_c. We can easily find it for our simple Fig. 4 low-pass filter by remembering that the transition occurred when $\omega^2LC/2$ was equal to 2:

$$\frac{4\pi^2 f_c^2 LC}{2} = 2$$

$$\therefore \quad f_c = \frac{1}{\pi\sqrt{LC}}$$

Just for the fun of it let us plot the attenuation curve from (4b), choosing our frequency scale in multiples of f_c so as to make it applicable to any Fig. 4 filter. The result is Fig. 5. To put it in the form we expect for a filter curve I have drawn it upside down, and with α in dB rather than nepers.

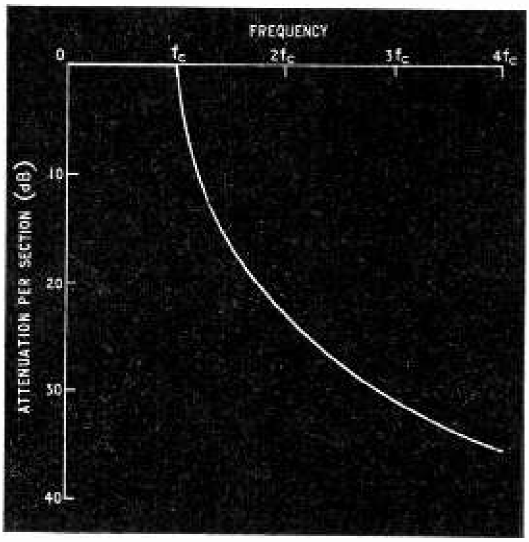


Fig. 5 Attenuation/frequency characteristic curve of Fig. 4, the frequency scale being in terms of the cut-off frequency f_c. From 0 to f_c there is a phase delay increasing from 0° to 180°; above f_c it remains constant at 180°.

We could do a high-pass filter in much the same way; the difference is that zero frequency is out at minus infinity on Fig. 1, and A is only reached at infinite frequency. And band-pass filters, with both Z_1 and Z_2 comprising both kinds of reactance as tuned circuits, are the same in principle, but of course $Z_1/2Z_2$ is a more complicated expression.

Having followed us so far, the earnest but inexperienced student may be disappointed, if not actually aggrieved, on being informed that the filters we have been considering are never used, or alternatively if they are used they don't work as hereinbefore described, because the conditions cannot be fulfilled. Quite apart from the inevitability of resistance, which smooths the sharp cut-off in Fig. 5, there is the awkwardness of having to provide an infinite number of sections, or an impedance equivalent thereto. This characteristic impedance Z_0, as it is called, has to vary in an extremely awkward manner with frequency. We went into the matter just over 10 years ago, and if you weren't with us then you can look it up somewhere, because it is outside our scope at present. To calculate it, the filter sections must be made symmetrical by dividing them either half-way along Z_1 to form Ts or down the middle of Z_2 to form πs. The Z_0/frequency curve for the Fig. 4 filter in T sections begins at zero frequency with a pure resistance equal to $\sqrt{L/C}$, curves downwards in a semicircle to reach zero at f_c, and after that is a pure reactance which rises indefinitely in a hyperbola. In fact, the curve is the same as P_1AP_2 in Fig. 1. The π form is even more awkward, going to plus and minus infinity at f_c. No practical load behaves like this.

If an ordinary resistance or reactance termination is used, the performance of the filter naturally departs considerably from that worked out here, and as one would expect from the general cussedness of things it is worse. So in high-class practice somewhat elaborated forms of filter are used.

The only simple basic combination of Z_1 and Z_2 we have not yet considered is resistance *and* reactance. There are practical examples in almost every radio receiver, Z_1 being resistance and Z_2 capacitive reactance. If we put $Z_1 = R$ and $Z_2 = 1/j\omega C$, equation (4) becomes

$$\cosh\alpha = 1 + \frac{j\omega CR}{2}$$

In this, the 1 is real and the $j\omega CR$ is imaginary. In other words, the total is complex. Switching over to cos avails nothing, because making the imaginary part real makes the real part imaginary and one is no better off. Neither cosh α nor cos β is sufficient by itself. There is both attenuation and phase shift at all frequencies, instead of these effects being segregated into their own frequency bands.

By means of a rather tricky bit of work, formulae have been found for cosh α and cos β separately, when $Z_1/2Z_2$ is complex and therefore has the general form $a + j\beta$:

$$\cosh\alpha = \tfrac{1}{2}\sqrt{(a+2)^2 + b^2} + \sqrt{a^2 + b^2)}$$
$$\cos\beta = \tfrac{1}{2}\sqrt{(a+2)^2 + b^2} - \sqrt{a^2 + b^2)}$$

These equations can obviously be used to calculate LC filters, taking account of resistance. But in our particular example, $a = 0$ and $b = \omega CR/2$, so the equations simplify to

$$\cosh\alpha = \sqrt{p+1} + p$$
$$\cos\beta = \sqrt{p+1} - p$$

where p is short for $\omega CR/4$.

Since $1 + Z_2/2Z_2$ can't be fully expressed as either cosh α or cos β (= cosh $j\beta$) when it is complex, you may be wondering what it *is* equal to. Cosh α + cosh $j\beta$? One can soon find, from the above equations, that that doesn't work out. Actually it is cosh($\alpha + j\beta$). The combination ($\alpha + j\beta$) is known as the propagation constant, the α part being the attenuation constant and β the phase constant. Or, if you rightly object that these things are not constant at all but vary with frequency, you will call them coefficients.

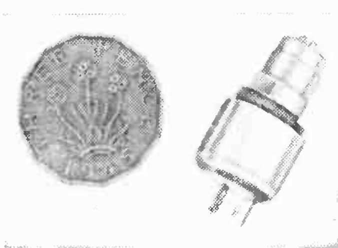
When one turns to transmission lines, hyperbolic and circular functions of complex variables arrive in a big way. That subject would be rather too much to bite off at this stage, but perhaps the foregoing introduction will help to make it more digestible when it does come.

Manufacturers' Products

NEW ELECTRONIC EQUIPMENT AND ACCESSORIES

Very Small Potentiometer

IN response to the growing demand for miniaturized components of all types, Plessey have introduced the Type L potentiometer. Measuring only 0.5in in diameter, it is housed in an aluminium case and the construction follows the well-tried Plessey practice of using a moulded carbon track with, in this case, a concentric metal track (silver loaded), the two being bridged by a moving contact mounted on an insulated carrier arm.



Plessey miniature Type L pre-set potentiometer.

Rating of the new potentiometer is 0.25W and the current range covers resistance of from 1kΩ to 2.5MΩ. A pre-set type only, with screw-driver slotted spindle, is available at present. The temperature range is −55°C to +85°C and a voltage limitation of 350 is imposed.

The makers are The Plessey Co. Ltd., Vicarage Lane, Ilford, Essex.

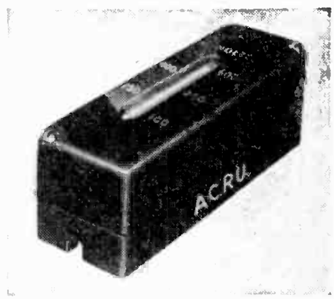
Transistorized V.H.F. Generators

R.E.E. TELECOMMUNICATIONS have recently introduced three new transistorized sine wave oscillators. Model A covers 40 to 70Mc/s and Model B 100 to 150Mc/s; Model C was developed for servicing v.h.f. mobile radio receivers and covers both 70 to 72Mc/s as well as 85 to 87Mc/s. In all three models the output can be amplitude modulated at 400c/s with a depth variable from 0 to 100%. Each model also contains attenuators which allow a maximum output level variation of 90dB down to approximately 1μV. An internal 6-V battery supply is used. Models A and B, which both cost £65, and Model C, which costs £70, are made by R.E.E. Telecommunications Ltd., Market Square. Crewkerne, Somerset.

R.E.E. Telecommunications single-band transistorized v.h.f. signal generator.

Potential-Indicating Lamps

THE Acru Electric Tool Manufacturing Co. Ltd. have introduced two neon lamps in which the length of the glow column depends on the current flowing through the lamp. Thus, with the normal high-value series resistors the lamps may be used to indicate applied potential. In the ⅜in diameter, 1⅞in long Type 93 (of "festoon" form) one electrode is in the form of a button at one end of the tube and the other extends along the tube: this is available also with a moulded housing containing either resistors appropriate for potentials from 60 to 250V (Type 103L) or 100 to 600V (Type 103H) a.c. The lamp is viewed through a calibrated slot in the cover. In another lamp (Type 98) the glow starts at the centre of the tube and extends towards the ends as the current increases.



Acru potential-indicating neon lamp and housing for 100-600V.

Other lamps in Acru's range include a snap-in one-hole-fitting type moulded in polystyrene and fluorescent-green types (only 7160V).

The address of the manufacturers is Acru Works, Demmings Road, Cheadle, Cheshire.

Printed Resistors

A FURTHER development in the printed circuit technique is a new printed resistor made as a separate component on a base material of paper. The specification of the paper used is; breakdown voltage 1.5kV, tensile strength 45lb/in; thickness 0.006in and upper temperature limit 150°C.

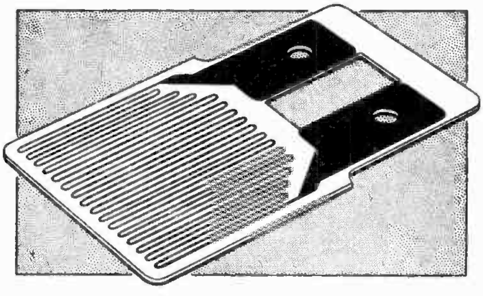
The resistance material can be either cupro-nickel, nickel-chrome or certain other alloys and the bond with the paper base is said to be so secure that it cannot be peeled off without destroying the component. Where complete insulation of the resistance is required the paper base can be bonded across the exposed face of the element.

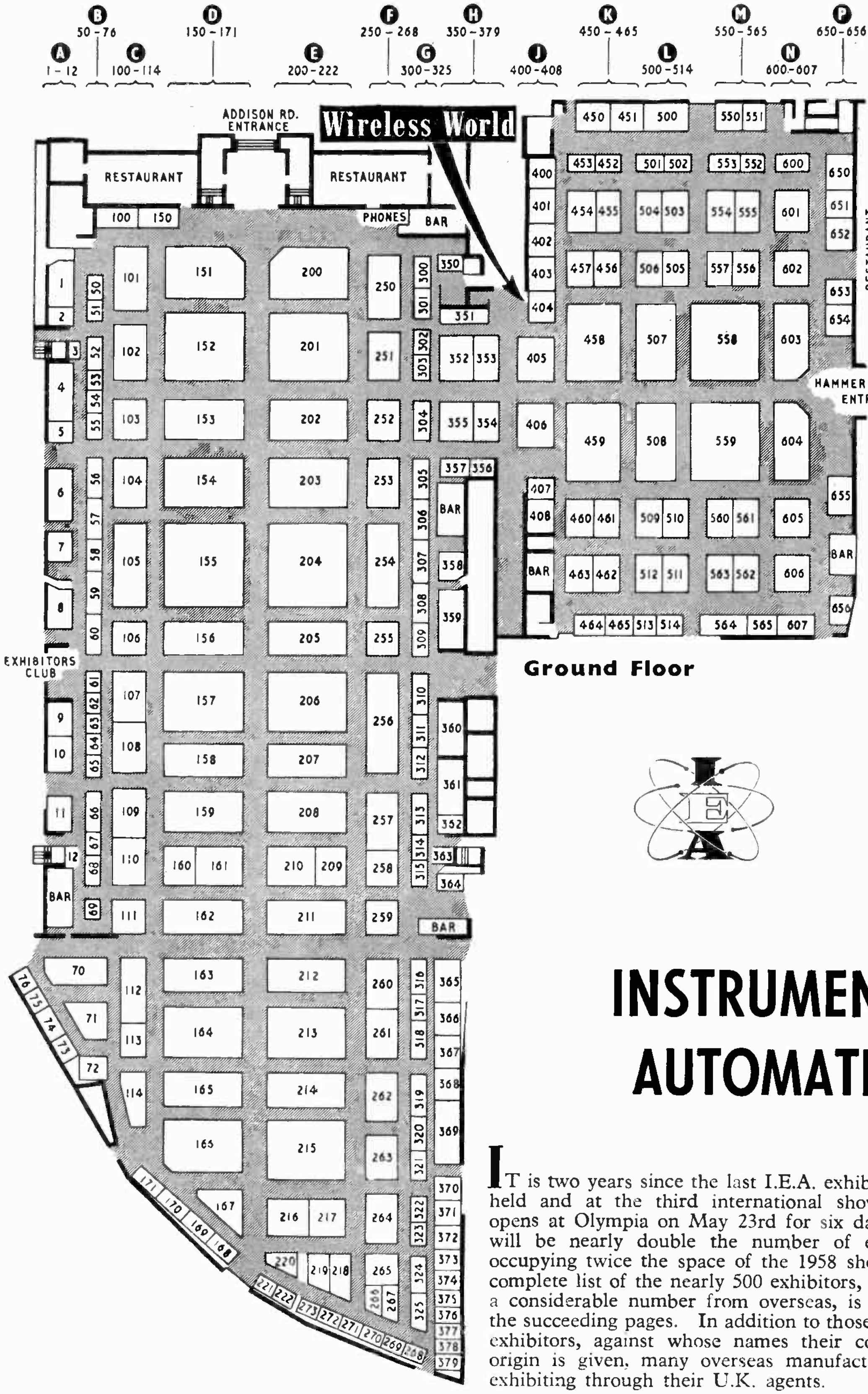
Among the applications for these resistors is where good heat dissipation is required in a restricted space, such as, for example, a contact-cooled mains dropper in radio and TV sets using the chassis as a heat sink.

These resistors are made to customers' requirements and the range of resistance can be anything up to 100Ω/sq in.

Further details can be obtained from Mills and Rockleys (Production) Ltd., Printed Circuit Division, Swan Lane, Coventry.

One of Mills and Rockleys' printed resistors. This resistance element measures approximately ⅝in square.

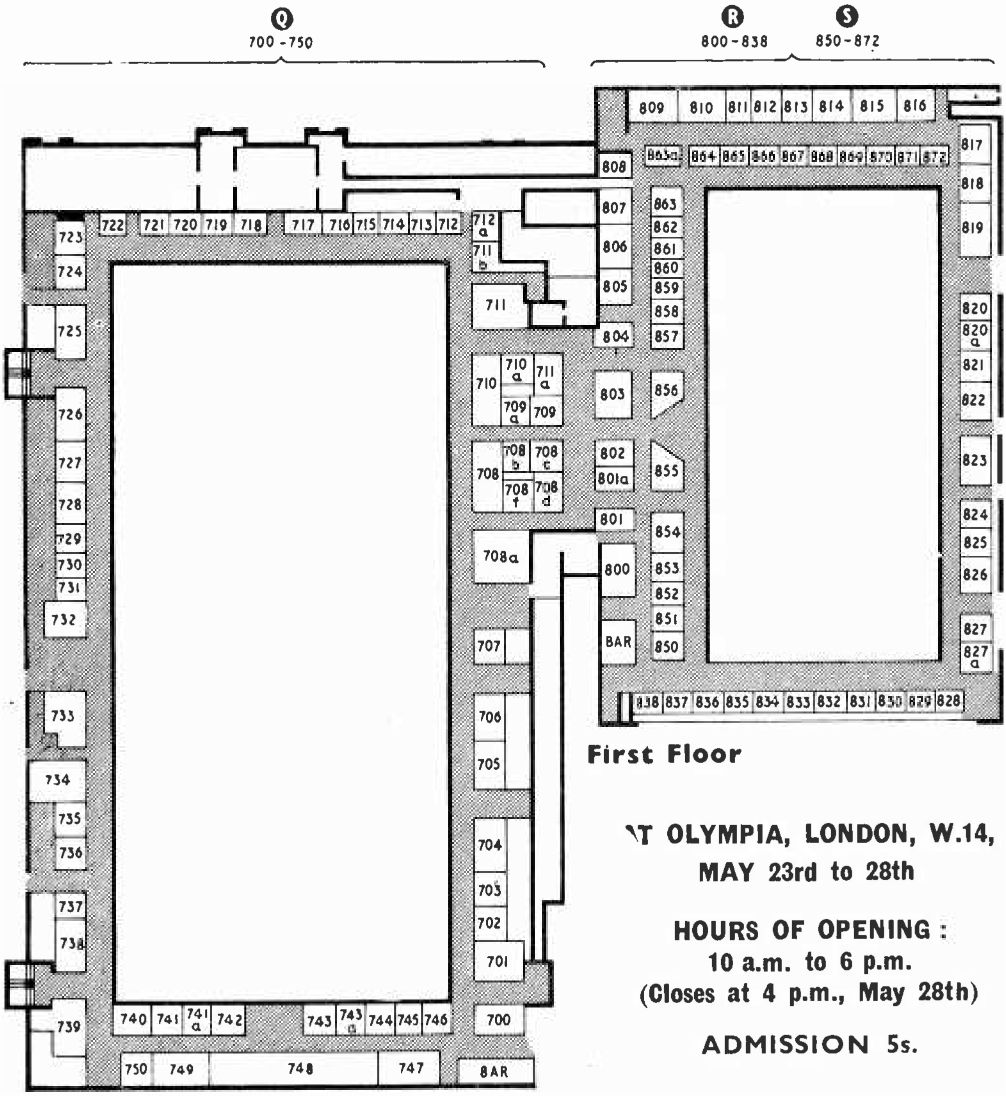




Ground Floor

INSTRUMENTS, AUTOMATION

IT is two years since the last I.E.A. exhibition was held and at the third international show, which opens at Olympia on May 23rd for six days, there will be nearly double the number of exhibitors occupying twice the space of the 1958 show. The complete list of the nearly 500 exhibitors, including a considerable number from overseas, is given on the succeeding pages. In addition to those overseas exhibitors, against whose names their country of origin is given, many overseas manufacturers are exhibiting through their U.K. agents.



First Floor

AT OLYMPIA, LONDON, W.14,
MAY 23rd to 28th

HOURS OF OPENING:
10 a.m. to 6 p.m.
(Closes at 4 p.m., May 28th)

ADMISSION 5s.

ELECTRONICS, AND EXHIBITION

In our next issue we hope to review some of the outstanding equipment shown at the exhibition which is promoted by the six industrial organizations listed below*.

Admission to the exhibition costs 5s. It will be opened by the Rt. Hon. Lord Mills at 11.30 on May 23rd, but on succeeding days will open at 10.0. The closing time is 6.0 except on Saturday when it will close two hours earlier.

For three days during the exhibition the Electronic Forum for Industry (E.F.F.I.) is holding a conference on "User Experience of Electronics." Each of the three sessions will cover a different field of application of electronics in industry. On the 24th the theme will be electronics in data processing; on the 25th, factory applications of electronics (chairman, Lt. Col. Sir John Eldridge) and on the 26th electronics in instrumentation and control (chairman, Viscount Caldecote). Each day's programme begins at 2.30.

This is the first full-scale conference organized by E.F.F.I., which consists of nine associations of manufacturers in or pertaining to the electronics industry, and the object quoted in the prospectus of the conference is: "To project to all users and potential users of electronics equipment the wide and varied scope of the electronics industry, and

* British Electrical and Allied Manufacturers' Association; British Industrial Measuring and Control Apparatus Manufacturers' Association; British Lampblown Scientific Glassware Manufacturers' Association; Drawing Office Material Manufacturers' and Dealers' Association; Electronic Engineering Association; and Scientific Instrument Manufacturers' Association.

to receive from them inspiration and guidance on new uses, and the improvement or modification of established application."

A fee of £1 11s 6d is being charged for each session of the conference and this includes admission to the exhibition and a report of the proceedings. Details are obtainable from the Honorary Secretary, E.F.F.I., c/o The Electronic Engineering Association, 11 Green Street, London, W.1. (Tel.: Mayfair 7874).

LIST OF EXHIBITORS

	STAND NO.
AAP-Allgemeiner Apparatebau GmbH, *W. Germany*	M565
A.B. Metal Products	F267
A.D.S. Relays	Q728
A.F.S. Developments	S861
A.K. Fans	S872
A.O.I.P. Mesures, *France*	R831
A.P.T. Electronic Industries	P650
A.T.E. (Bridgnorth)	F261
Advance Components	C107
Aircraft-Marine Products (G.B.)	N602
Airflow Developments	B66
Airmec	D162
Alexander Controls	G318
Allspeeds	R810
Alma Components	F268
Alto Instruments (G.B.)	R816
Ampex International S.A, *Switzerland*	S863a
Amphenol	K453
Analytical Measurements	G303
Anderton Springs	S850
Antiference	G321
Ardente Acoustic Laboratories	S865
Arrow Electric Switches	Q738
Associated Automation	D155
Associated Electrical Industries	D152 & E213
Astralux	Q711b
Audley Engineering Co.	K454
Aumann, Willy K. G., *W. Germany*	B73
Automation Progress	G314
Autronic Developments	Q715
Aviation, Ministry of	J406
Avo	D156
B & K Laboratories	E203
B & R Relays	R824
B.O.B. (Arundel)	R817
Bailey Meters & Controls	L507
Baird & Tatlock (London)	N603
Baldwin Industrial Controls	K463
Beckman Instruments	R805
Belling & Lee	D165
Bellingham & Stanley	G315
Beulah Electronics	S852
Black Automatic Controls	H359
Blackburn Electronics	Q710
Blakeborough, J. & Sons	F265
Boulton Paul (Aircraft)	B72
Bradley, G. & E.	Q743
Brannan, S. & Sons	B52
Braun, G., Publishers, *W. Germany*	F269
Bray, Geo. & Co.	Q731
Bribond	H368
Bristol Aircraft	B58
Bristol's Instrument Co.	D155
British Arca Regulators	R807
British Electric Resistance Co.	R801
B. I. Callender's Cables	R813
British Physical Laboratories	H351
British Power Transformer Co.	R801
British Rototherm Co.	Q729
British Sarozal	Q712a
British Scientific Instrument Research Assoc.	Q744
Brookhirst Igranic	D156
Brown, Neville, and Co.	H377
Brown, S. G.	H366
Bruce, Peebles & Co.	R802
Brush Crystal Co.	Q704
Bryans Aeroquipment	J400
Budenberg Gauge Co.	A4
Bulmers Business Machines	S864
Burndept	B68
Bush Beach & Segner Bayley	M561
Cambridge Instrument Co.	F259
Camlab (Glass)	G322
Carlo, Erba S.p.A., *Italy*	Q709
Carr Fastener Co.	R814
Casella, C. F., & Co.	K460
Cathodeon Crystals	G311
Cementation (Muffelite)	R838
Chapman & Hall	S862
Chemical Cutting Co.	R817
Clarke, H., & Co. (Manchester)	Q732
Cole, R. H. (Overseas)	B73
Coley Thermometers	Q708f
Colvern	Q723
Colyer & Southey	B75
Communication Systems	F261
Compagnie Francaise Thomson-Houston, *France*	Q708c
Connollys (Blackley)	R834
Constructors John Brown	H361
Control	A8
Correx Communications Equipment	R817
Cossor	E212
Coulter Electronics	Q743a
Counting Instruments	Q717
Coventry Controls	E222
Crompton Parkinson	C104
Crosby Valve & Engineering Co.	F253
Crouzet & Company, *France*	S861
Croydon Precision Instruments Co.	Q716
Cu-Ni-Craft	L500
Cuthbert, Ralph	G320
Data Recording Instrument Co.	G325
Dawe Instruments	Q727
Day, J., & Co.	B53
Daystrom	S852
DEAC (Great Britain)	R816
Decker's, R., Verlag, G. Schenk, *W. Germany*	F269
Degussa Hanau, *W. Germany*	M561
De Havilland Propellers	R730
Department of Scientific and Industrial Research	E214
Deutscher Innen-und Aussenhandel Elektrotechnik, *E. Germany*	Q748
Dewrance & Co.	M554
Diamond H. Switches	B64
Direct TV Replacements	S852
Dobbie McInnes (Electronics)	K452
Doran Instrument Co.	S858
Drayton Regulator & Instrument Co.	K455
Dubilier Condenser Co.	K461
Dynatron Radio	E208
E.M.I. Electronics	D166
E.M.O. Instrumentation	F251
Ekco Electronics	E208
Electran Coil Co.	Q711a
Electrical Development Association	F250
Electrical Remote Control Co.	F266
Electro Automat	S851
Electroflo Meters Co.	D155
Electrolube	S871
Electro-Mechanical Systems	D167
Electro Mechanisms	M563
Electronic Associates	R825
Electronic Components	Q714
Electronic Engineering	L502
Electronic Instruments	Q711
Electronic Machine Co.	R818
Electronic Technology and Data Processing	J404
Electronic Tubes	H373
Electronics & Automation (London)	R816
Electrothermal Engineering	G319
Elga Products	G304
Ellenberger & Poensgen, GmbH, *W. Germany*	Q746
Elliott-Automation	D155
Emeco Electronics Co.	R816
Enalon Plastics	H372
Endecotts (Filters)	B69
Engelhard Industries	N606
Engis	R819
English Electric Co.	E215
English Electric Valve Co.	E215
English Numbering Machines	H370
Epsylon Industries	D167
Equipment & Services	F266
Ericsson Telephones	D153
Erie Resistor	D169
Ether & Electro Methods	E205
Evans Electroselenium	A11
Everett, Edgcumbe & Co.	Q747
Ever Ready Co.	K465
Evershed & Vignoles	K453
Fairey Aviation	L503
Faraday Electronic Instruments	D154
Farris Engineering	D155
Ferranti	N604
Fielden Electronics	C110
Filhol, J. P.	R829
Fireye Controls Co.	Q726
Firth Cleveland Instruments	H353
Fischer & Porter	A10
Fisher Governor Co.	D155
Fleming Radio (Developments)	P652
Flexonics	M563
Floform Parts	F264
Formica	J403
Fortiphone	Q741a
Foster Instrument Co.	C111
Fox, P.X.	L514
Foxboro-Yoxall	E202
Furzehill Laboratories	Q721
General Controls	H375
General Electric Co.	E211
General Post Office	R823
General Precision Systems	M560
General Radio Co., *U.S.A.*	Q733
General Radiological	E209
Geyer, Christian, *W. Germany*	Q746
Gilbarco	G302
Glass Developments & Ultrasonoscope Co.	A3
Gloster Aircraft Co.	L508
Goodman, George	F264
Goodmans Industries	K462
Gordon, James & Co.	D155
Goring Kerr	Q736
Graticules	B62
Graviner Manufacturing Co.	R827
Griffin & George	R803
Grubb, Sir Howard, Parsons & Co.	P651
Grundy & Partners	S868
Guest Keen & Nettlefolds	F264
Guyson Industrial Equipment	Q742
Haddon, Thomas & Stokes	F264
Haddon Transformers	D170
Halden, J., & Co.	Q701
Hallam, Sleigh & Cheston	J408
Hall Harding	F256 & L505
Harper & Tunstall	M551
Harris Plating Works	H379
Harwin Engineers	L513
Hassett & Harper	R832
Hatfield Instruments and Balun	G305
Hawker Siddeley Group	L508
Headland Engineering Developments	Q745
Heathway Machinery Co.	H367
Heidenhain, Dr. Johannes, *W. Germany*	E218
Hendrey Relays	C113
Henry & Thomas	S869
Herbert Publishing Co.	D150
Heywood & Co.	N600
Hivac	F261
Holmes Bros. (London)	R806
Honeywell Controls	E200
Hughes International	G310
Hunt, A. H. (Capacitors)	M562
Hunt & Mitton	H357
Hunting Engineering	R830
Ide, T. & W.	H350
Ilford	B70
Imhof, Alfred	H360
Industrial Pyrometer Co.	L509
Inertia Switch	Q722
Infra Red Development Co.	P654
Institution of Electrical Engineers	R827a
Instron Engineering Corp., *U.S.A.*	Q705
Integra, Leeds & Northrup	D163
International Electronics	R811
International Rectifier Co. (G.B.)	Q739
Ionic Plating Co.	F264
Jobling, James A., & Co.	C112
K.D.G. Instruments	K457
K.L.G. Sparking Plugs	Q735
Kelvin & Hughes	F257
Kent, George	D159
Kovo-Foreign Trade Corp., *Czechoslovakia*	G306
Krizik n.p., *Czechoslovakia*	G306
Kumag A.G., *Switzerland*	B73
Kynmore Engineering Co.	R801a
Labgear	D154
Laboratory Equipment	G313

	STAND NO.
Lancashire Dynamo Electronic Products	E205
Langham Thompson Group, J	H364
Langley London	N601
Laurence, Scott & Electromotors	L510
Leach Corp., U.S.A.	D167
Leeds Meter Co.	J401
Leevers-Rich Equipment	R837
Levell Electronics	H363
Lewis Spring Co.	S867
Lintronic	B55
Lion Electronic Developments	L500
Livingston Laboratories	F254
Lloyds Bank	A9
Lodge Plugs	M553
London Electric Wire Co. and Smiths	B71
Loughborough Glass Co.	M556
Lucas, Joseph (Electrical)	Q743
Lyons, Claude	Q733
M.B.C. (Office Systems)	R822
M.C.P. Electronics	Q708c
M-O Valve Co.	E211
MSS Recording Co.	Q712
Magnetic Devices	J407
Mallory Batteries	P656
Marconi Instruments	D157
Markem (U.K.)	R835
Marrison & Catherall	R812
Marshall of Cambridge Electronics	B63
Mason, E. N., & Sons	E201
McMurdo Instrument Co.	D168
Measurement	E221
Mec-Test	Q740
Metaducts	R820a
Metal Detection	G233
Meterflow	D167
Metrix Instruments	E219
Micanite & Insulators Co.	L512
Microcell Electronics	C108
Midland Bank	Q734
Mine Safety Appliances Co.	Q718
Minerva Detector Co.	G309
Miniature Electronic Components	S854
Moncrieff, John	H356
Morbank	S860
Morgan Crucible Co.	K456
Muirhead & Co.	E207
Mullard	C102 & M559
Murphy Radio	E209
NSF	B57
Nagard	G312
Nalder Bros. & Thompson	C109
Nash & Thompson	F258
Negretti & Zambra	C105
Neoflex	F270
New Western (Eng.)	A6
Newmark, Louis	B74
Newmarket Transistors	G307
Newport Instruments	Q715
Nicolson, W. B. (Scientific Instruments)	N603
Norgren, C. A.	B61
Normalair	R826
Nottingham Thermometer Co.	L509
O.M.I. Instruments (G.B.)	R816
Oldenbourg, R., Verlag, *W. Germany*	F269
Oliver Pell Control	R809
Opancol	Q708b
Optical Works	H362
Otter Controls	Q741
Ozalid Co.	D151
P. & H. Engineering Co.	S866
Packaging Centre	Q749
Painton & Co.	B60
Palmer, G. A. Stanley	R816
Panax Equipment	S870
Panellit	D155
Parmeko	R804
Payne & Griffiths	H358
Peel, H. W., & Co.	H374
Pergamon Press	H378
Perkin-Elmer	J405
Permali	Q702
Phoenix Telephone & Electric Works	R817
Photoelectronics (M.O.M.)	A2
Planche, M., *France*	S861
Plannair	K464
Platon, G. A.	G317
Plessey Group	M558
Polypenco	Q709a
Precision Tool & Instruments Co.	M552
Process Control and Automation	G308
Pullin, R. B., & Co.	C103
Pye	D154
Pye, W. G., & Co.	D154
Quickfit & Quartz	C112
RCA Great Britain	Q708a
Racal	F260
Radiochemical Centre U.K.A.E.A.	H355

	STAND NO.
Radiometer, *Denmark*	J402
Rank Cintel	N605
Recorder Charts	A5
Reliance Cords & Cables	Q724
Reliance Manufacturing Co. (Southwark)	H376
Research & Control Instruments	D164
Richard Allan Radio	H371
Rivlin Instruments	R815
Roband Electronics	R808
Robinson D., & Co.	B76
Robinson, F. C., & Partners	B51
Rola Celestion	F271
Rotameter Manufacturing Co.	E210
Royal Worcester Industrial Ceramics	B54
Royston Instruments	R821
Rumburske Kovozavody, *Czechoslovakia*	G306
S.E. Laboratories	D167
SFIM (Great Britain)	M563
Salford Electrical Instruments	E211
Samson Controls (London)	E220
Sanders, W. H. (Electronics)	L506
Sangamo Weston	F263
Saunders-Roe	R826
Saunders Valve Co.	R828
Savage, W. Bryan	D154
Sciaky Electric Welding Machines	R833
Scott, James & Co.	Q703
Servomex Controls	F255
Shaw Moisture Meters	S856
Short Brothers & Harland	M557
Short & Mason	G301
Siemens & Halske AG., *W. Germany*	B73
Sierex	G324
Sifam Electrical Instrument Co.	S855
Smith & Nephew	L501
Smiths Aircraft Instruments	F257
Société D'Applications des Machines Motrices, *France*	B72
Solartron Electronic Group	E206
Southern Instruments	D158
South London Electrical Equipment Co.	B56
Sovirel, *France*	Q710a
Spear Engineering Co.	D171
Sperry Gyroscope Co	C101
Standard Telephones and Cables	K459
Stanley, W. F., & Co.	Q706
Stanton Instruments	G316
Stevens Manufacturing, Co., U.S.A.	Q746
Stonebridge Electrical Co.	S859
Stratton & Co.	K450
Submarine Signal Co. (London)	H366
Swartwout Co.	D155
Swift Levick & Sons	F273
Taylor Electrical Instruments	P655
Taylor Controls	D161
Techna (Sales)	Q746

	STAND NO.
Technicon Instruments Co.	P653
Technograph Electronic Products	K451
Telcon Metals	B59
Teledictor	C114
Telegraph Condenser Co.	L511
Telephone Manufacturing Co.	H352
Telequipment	S853
Tesla n.p., *Czechoslovakia*	G306
Texas Instruments	E216
Thermal Syndicate	C106
Thorn Electrical Industries	H369
Tinsley, H., & Co.	N607
Tintometer	A12
Torsion Balance Co., U.S.A.	Q719
Trist, Ronald & Co.	F262
Trumeter Co.	R836
Turner, Ernest, Electrical Instruments	C100
Turton Bros. & Matthews	Q720
20th Century Electronics	Q713
Tylers of London	A1
Ultra Electronics	H364 & R820
Unicam Instruments	D154
United Trade Press	G300
Vactric (Control Equipment)	M555
Veb Elektro-Apparate-Werke, *E. Germany*	Q748
Veeder-Root	S857
Venner Electronics	Q737
Vieweg, Friedr. & Sohn, *W. Germany*	F269
Walker, Crosweller & Co.	Q700
Waveforms	M550
Wayne Kerr Laboratories	E217
Webb, William A.	B50
Welwyn Electrical	S863
West, A., and Partners	F252
West Instrument	H354
Westinghouse Brake and Signal Co.	Q707
Westminster Bank	Q708
Westool	Q725
Whiteley Electrical Radio Co.	R800
Willy, Aumann K.G., *W. Germany*	B73
Williams & James (Engineers)	D160
Wilmot Breeden	Q708d
Winston Electronics	M564
Wire Products & Machine Design	B65
Wireless World	J404
Woden Transformer Co.	A7
Wolsey Electronics	S863a
Worcester Royal Porcelain Co.	H356
X-Lon Products	B67
Zeal, G. H.	L504
Zenith Electric Co.	F272

BOOKS RECEIVED

Basic Electronics, by Bernard Grob. Vol. 1 follows the order of topics presented in the first term's work of the technicians' training course at RCA Institutes, starting with elementary electricity and magnetism and ending with a brief insight into valves, transistors and radio frequency losses. It is to be followed by a second volume on Applied Electronics. Pp. 524; Figs. 383. Price 50s 6d. McGraw-Hill Publishing Co., Ltd., 95, Farringdon Street, London, E.C.4.

Proceedings of the National Electronics Conference, 1958 (Vol. 14). Illustrated record (99 papers) of the annual conference held at Hotel Sherman, Chicago, Illinois, covering all aspects of radio and electronics from antennas to automatic navigation and from audio to computers. Pp. 1074, profusely illustrated. Price $7.50. National Electronics Conference, Inc. 228, N. La Salle Street, Chicago 1, Illinois, U.S.A.

A Quality-Checking Receiver for V.H.F./F.M. Sound Broadcasting, by C. G. Mayo, M.A., B.Sc., M.I.E.E., B.B.C. Engineering Division Monograph No. 25, gives circuit diagrams and performance details of two alternative prototype receivers, designed, without compromise to give a high standard of performance. Pp. 15; Figs. 13. Price 5s. B.B.C. Publications, 35, Marylebone High Street, London, W.1.

Testing of Screened Enclosures, by J. Miedzinski, B.Sc., A.M.I.E.E. Methods of measuring insertion loss and its dependence on the details of experimental arrangements as well as on frequency and the construction of the enclosure. Pp. 27; Figs. 19. Price 24s. The British Electrical and Allied Industries Research Association, Thorncroft Manor, Dorking Road, Leatherhead, Surrey.

Insulation for Small Transformers, by J. H. Mason and C. G. Garton. Handbook for designers reviewing the factors influencing electric strength and life of insulation, methods of non-destructive testing and data on new materials. Pp. 93; Figs. 33. Price 37s 6d. The British Electrical and Allied Industries Research Association, Thorncroft Manor, Dorking Road, Leatherhead, Surrey.

Power Trans ormer Design

With Special Reference to Paper Interleaved Windings

By D. SAULL

THE development engineer in the electronic industry requires, from time to time, to design a power transformer for the equipment he is developing. The number of transformers he designs in the course of a year is usually relatively few; consequently it is necessary for him to become familiar with the "know how" of space factor, compensation, winding resistances, etc., each time.

In various technical journals are published graphs and charts for establishing space factor and gauges of wire, etc., but to date the writer has not come across any data which does not require some preliminary digesting before a start can be made.

The most common need in this industry is for relatively low-power mains transformers usually not in excess of 150VA. The writer's aim is to present a really easy, straight-forward method of design to cover six VA ratings, the first four applicable to equipment requiring valve heater supplies, and the remaining two for transistor power units of smaller physical size. The factors presented in the design data contained in this article are based upon practical results obtained from more than a hundred experimental transformers wound with terminal voltages to M.O.S. specification ($\pm 2\frac{1}{2}\%$ below 100V and $\pm 5\%$ above 100V).

The VA ratings referred to are 150VA, 100VA, 60VA, 35VA in the first group, and 20VA and 10VA in the second group.

The development engineer in the first instance requires to produce a transformer that will function in the equipment he is designing. His second need is to produce this transformer as a practical production winding which may be passed on to the drawing office without further modification. It must, therefore, be electrically and constructionally sound. It must not be a tight wind but must possess sufficient space tolerance to allow for variation in wire sizes ($\pm 10\%$ diameter $= 20\%$ cross-sectional area—wire manufacturers' tolerance).

Transformer windings may be layer wound on formers with end cheeks, or paper interleaved and wound on cheekless formers. This article is based upon the latter method. Cheekless-former windings lend themselves to better inspection during the winding process, it being very easy to detect a dropped down turn, which in the end cheek variety could not be detected and might result in a shorted

TABLE I—PRIMARY RATINGS

	100-150VA	60-100VA	35-60VA	25-35VA	10-25VA	8-10VA
Laminations (M.E.A.: Silcor 25) ..	60A	75A	75A	24A	101A	68
Stack size	$1\frac{1}{2}$in	$1\frac{1}{2}$in	1in	$\frac{15}{16}$in	$1\frac{1}{32}$in	$\frac{7}{8}$in
Window area	2.75 sq. in	2.375 sq. in	2.375 sq. in	1.42 sq. in	0.84 sq. in	0.644 sq. in
Primary turns per volt	3.56	4.42	6.68	7.83	7.4	10.5
Secondary turns per volt ..	3.81	4.76	7.15	8.4	7.9	11.2
Overall space factor	44%	46%	46%	48%	50%	50%
Area occupied by 250V primary winding	0.585 sq. in	0.624 sq. in	0.65 sq. in	0.363 sq. in	0.267 sq. in	0.194 sq. in
250V primary (Turns and wire gauge)	890t: No. 23 s.w.g.	1104t: No. 24 s.w.g.	1670t: No. 26 s.w.g.	1960t: No. 30 s.w.g.	1850t: No. 32 s.w.g.	2620t: No. 36 s.w.g.
Remaining area for h.t. and l.t. windings	0.955 sq. in	0.656 sq. in	0.63 sq. in	0.365 sq. in	0.153 sq. in	0.128 sq. in
6.3-V winding to fill layer	3.6A—7.2A 24t. 2×18 s.w.g.	4A—8A 30t. 15 s.w.g.	1.8A—3.6A 45t. 18 s.w.g.	0.5A—1.2A 51t. 22 s.w.g.	1A—2A 50t. 20 s.w.g.	—
5-V winding to fill layer	19t. 2×16 s.w.g.	24t. 2×19 s.w.g.	36t. 17 s.w.g.	42t. 21 s.w.g.	—	—
Former length	$2\frac{23}{32}$in	$2\frac{11}{32}$in	$2\frac{11}{32}$in	$1\frac{19}{32}$in	$1\frac{3}{32}$in	$1\frac{7}{32}$in

turn, or worse, a failure occurring early in the life of the transformer.

L.T. windings should be wound on first for two reasons:—

(1) They are wound with the thickest wire, and therefore form a good base on which to wind the thinner wire of the remaining windings.

(2) The l.t. windings carry the heaviest current, thus putting these windings on first results in a shorter mean-turn length. They consequently have a lower d.c. resistance and a better regulation percentage figure.

The l.t. winding should completely fill the available width, a bifilar wind can be used if a single winding at the required current capacity does not fill the layer. Current densities of these windings may be 1,500A or 2,000A per square inch.

A transformer design may call for four or more separate l.t. windings, perhaps two at 4A and two at 2A with a primary rating of the order of 150VA. In this case the 4-A winding should be wound on first, and the two 2-A windings wound side by side as a single layer with ¼in spacing at the centre between them. This saves valuable space which might well be required to allow a more generous wire gauge on the h.t. winding.

Where the occasion arises calling for a l.t. winding of low-current capacity (e.g. order of ½A) difficulty might be experienced in choosing a wire gauge to fill the layer. In this case, this winding may be wound on last, and placed centrally on the windings. Due to the low current value the voltage regulation would not be effected by the increased length of wire, and it would be convenient to operate the winding with a current density not greater than 1,000A per square inch.

The primary winding is wound on next with voltage taps as required, followed by the h.t. windings.

The choice of wire gauge for the h.t. winding should be as generous as possible to keep its d.c. resistance as low as possible. With full-wave rectification a good practical rule is to assume that each half winding will carry not less than an average of 0.7 of the d.c. output current, at a current density of 1,000A per square inch (this is not strictly true because a.c. current surges are in excess of the d.c. current and dependent on the rectifier used and the value of the reservoir capacitor—the 0.7 factor is a practical compromise).

Windings throughout the transformer should be in order of wire gauges, that is, the heaviest wire nearest the core, the lightest wire on the outside winding.

Table I sets out for easy reference the information required when designing a transformer. The space factor given is an overall figure and takes into account the former, insulation and wire tolerances. The space factor for a given lamination will remain reasonably constant for any gauges likely to be used at the respective VA rating.

Insulation throughout the transformer is as follows:—

(1) Three layers of Britain's (0.002in) tissue on the former.

(2) 2 layers of Symax (0.005in) between windings.

(3) One layer of Britain's tissue (0.002in) interleaving between layers throughout primary and h.t. windings.

(4) Two layers of Symax (0.005in) between layers of l.t. windings occupying more than one layer.

TABLE II

Dia.	T/in	T/in²	Current at 1,000A/in²	S.W.G.
0.131	7.6	57.8	12.9	10
0.119	8.4	70.6	10.6	11
0.107	9.3	86.5	8.5	12
0.095	10.5	110	6.65	13
0.083	12.0	144	5.03	14
0.0745	13.4	180	4.07	15
0.0665	15.0	225	3.22	16
0.0586	17.0	289	2.46	17
0.0505	19.8	392	1.81	18
0.0422	23.6	557	1.26	19
0.0382	26.1	681	1.02	20
0.0340	29.4	864	0.804	21
0.0300	33.3	1,110	0.616	22
0.0257	38.9	1,520	0.452	23
0.0237	42.1	1,770	0.380	24
0.0217	46.0	2,120	0.314	25
0.0197	50.7	2,570	0.255	26
0.0179	55.9	3,120	0.211	27
0.0163	61.3	3,760	0.172	28
0.0151	66.2	4,380	0.145	29
0.0136	73.5	5,400	0.121	30
0.0128	78.1	6,100	0.106	31
0.0120	83.3	6,940	0.0916	32
0.0112	89.2	7,960	0.0785	33
0.0102	98.0	9,600	0.0665	34
0.0094	106	11,200	0.0554	35
0.0086	116	13,500	0.0454	36
0.0078	128	16,400	0.0363	37
0.0070	143	20,400	0.0283	38
0.0059	169	28,600	0.0212	39
0.0055	182	33,100	0.0181	40
0.0051	196	38,400	0.0152	41
0.0047	212	44,900	0.0126	42
0.0043	233	53,300	0.0102	43
0.0039	256	65,500	0.0080	44

Table II sets out details of characteristics of enamelled copper wire for use with the design data given here.

Example of Practical Design———

(*a*) Tabulate the secondary VA ratings required:—

*LT*1. 5.0V at 2.5A = 12.5VA
*LT*2. 6.3V at 3A = 18.9VA
HT. 250–0–250V at 60MA = 15.0VA

Total = 46.4VA

Primary VA at 86% efficiency = 46.5/0.86 = 54VA.

(*b*) From Table I No. 75A laminations and a 1in stack is required.

(*c*) Windings (from Table I)
*LT*1. 36 turns of 17 s.w.g. En Cu wire.
*LT*2. 45 turns of 18 s.w.g. En Cu wire.

Space remaining for l.t. and h.t. = 0.63 sq in.
*LT*1. = 36/216 = 0,167 sq in.
*LT*2. = 45/392 = 0.115 sq in.

Total = 0.282 sq in.

Space remaining for h.t. winding = 0.348 sq in.

(*d*) Turns required for h.t. winding at 7.15 turns per volt = 7.15 × 500V = 3,576 turns.

(e) Choice of wire gauge = $\frac{\text{Number of turns}}{\text{Space available}}$ =

T/in² (turns per square in) = 3576/0.348 = 10,800 T/in²

(f) From Table II nearest gauge = 35 s.w.g. (55.4mA)
or even gauge No. 36 s.w.g. (45mA).

(g) Winding details would then be:—
*LT*1. 36 turns No. 17 s.w.g. En Cu wire.
*LT*2. 45 turns No. 18 s.w.g. En Cu wire.

Primary 230V, 1,533 turns
240V, 1,602 turns } No. 26 s.w.g. En Cu wire.
250V, 1,671 turns
H.T. 3,576 turns No. 36 s.w.g. (or 35 s.w.g.) En Cu wire tapped at 1,788 turns.

It will be seen that the time required to design a transformer from the given data should not be more than half an hour.

After the prototype has been tested in circuit, and any necessary modifications due to circuitry changes have been made the transformer is ready to be placed in production.

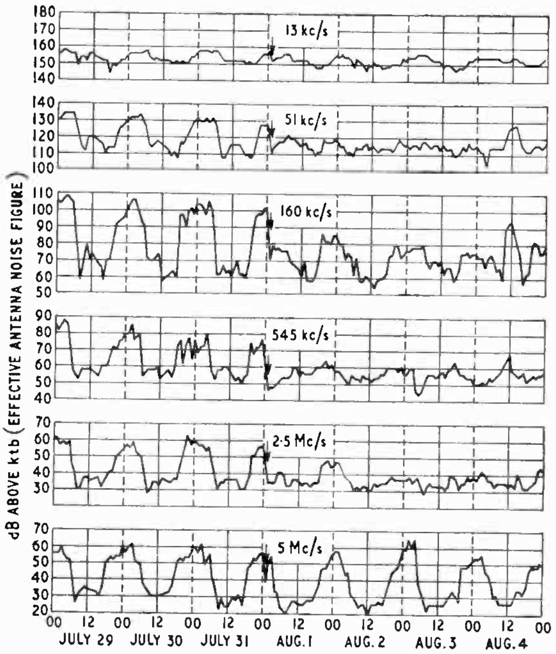
Nuclear Explosions and Radio Noise

EFFECT OF HIGH ALTITUDE BURSTS ON RADIO PROPAGATION

By *MICHAEL LORANT*

THE U.S. National Bureau of Standards recorded the changes in radio noise power that occurred when two high-altitude atomic explosions were set off over Johnston Island in the Pacific Ocean in August, 1958. The explosions appear to have had a pronounced effect on the radio noise as recorded at Kekaha, Hawaii. This recording station, located on the south-west coast of the island of Kauai, about 700 miles north-east of Johnston Island, is part of a world-wide chain of noise-recording stations supervised by the Bureau's Boulder (Colorado) laboratories.

Two bomb bursts occurred shortly after midnight on August 1 and August 12 at elevations estimated to be from 25 to 100 miles. Recordings were made of the received atmospheric radio noise power for a period before and after the first explosion. The usual diurnal pattern is evident on the graphs* during the three days prior to the blast, with the highest noise levels recorded at night and a rapid decrease in level between 0400 and 0800 local time. In the hour following the blast, however, the noise decreased by as much as 32dB (at some frequencies) at a time of day when it would normally be rising or holding steady. Recovery apparently occurred in a matter of hours at 13kc/s and 5Mc/s, but from 51kc/s through 2.5Mc/s a changed pattern is evident for several days, and records for August 5-11 indicate that a disturbed condition persisted until the second test on August 12. The after-blast effects on this date were similar to those on August 1, with abnormal noise conditions continuing on some frequencies until about September 1.



Graphs of radio noise power recorded at Kekaha, Hawaii, July, 29 to August 4, 1958. Time of nuclear explosion on August 1 indicated by arrows.

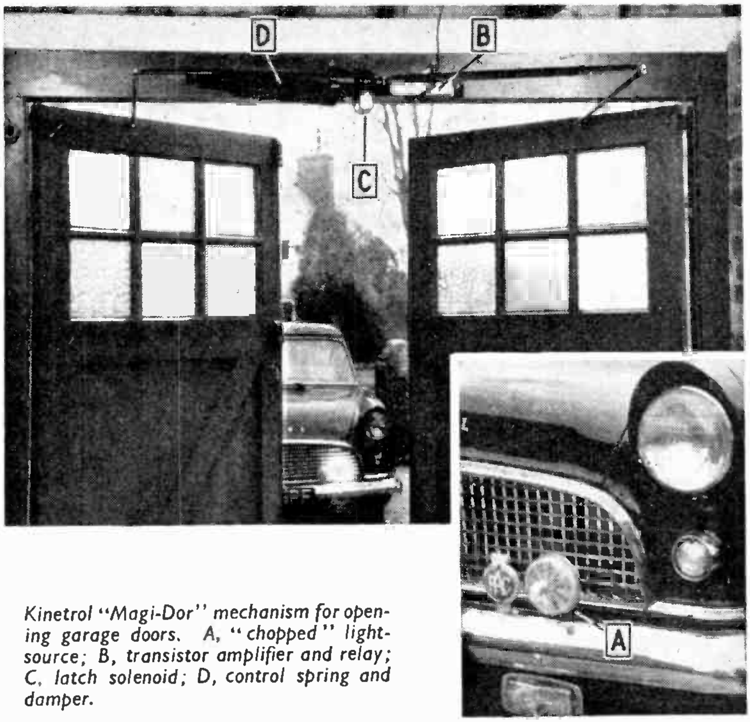
Because of the very low incidence of thunderstorms in Hawaii, most of the received radio noise is believed to be propagated from storms at a considerable distance. Thus, changes in propagation conditions are reflected more on the Kekaha noise records than at stations situated on large masses, where local and short-distance storm effects tend to mask changes in propagation.

It would appear likely that a highly ionized region was formed by the bomb explosions over Johnston Island and that this ionized region persisted for a period of at least several days after each test, causing greatly increased ionospheric absorption.

* The "effective antenna noise figure" is the mean noise power averaged over several minutes and is defined as the noise power available from an equivalent lossless antenna in decibels above the thermal-noise power available from a passive resistance. See "N.B.S. Radio and Ionospheric Observations During the I.G.Y." David M. Gates, *J. Res. N.B.S.* **63D**, July-August, 1959. p. 11.—Ed.

REFERENCE

"Effects of High-Altitude Nuclear Explosions on Radio Noise," by C. A. Samson, *J. Res. N.B.S.* **64D** p. 37 (Jan.-Feb. 1960).



Kinetrol "Magi-Dor" mechanism for opening garage doors. A, "chopped" light-source; B, transistor amplifier and relay; C, latch solenoid; D, control spring and damper.

TRANSISTORIZED DOOR CONTROL

IN a light-controlled garage door opening mechanism developed by Kinetrol Ltd., Trading Estate, Farnham, Surrey, the use of a photo-transistor followed by a transistor a.c. amplifier ensures that the device operates only with light interrupted within a specified range of frequency; it cannot be triggered by steady light or even by headlamps switched on and off by hand. The high-speed chopped light source necessary to actuate the mechanism is provided by a rotating shutter driven by a small d.c. motor incorporated in the transparent plastic lens of a small spot light mounted on the front of the car and controlled from the dashboard.

The photo-transistor is housed in a black moulding about 1 inch in diameter, screwed to the garage door frame. Saturation by ambient light is avoided by restricting the aperture of exposure. The alternating component resulting from illumination by the car's special lamp is amplified, rectified and applied to a P.O.-type relay with mains contacts which energizes a solenoid and releases the bolt latch. The doors, which are spring loaded, then open at constant speed under the control of a linear damping device.

We have had an opportunity of examining one of these installations, which operated reliably under daylight conditions at a distance of 20ft or less and seemed to us to be soundly designed and made.

The complete installation costs £39 10s.

CLUB NEWS

Birmingham.—John Savage, director of engineering of Collins Radio Company of England, is to give a lecture-demonstration on the new Collins series of s.s.b. equipment at the meeting of the Slade Radio Society on June 17th at 7.45 at The Church House, High Street, Erdington. Admission is by ticket only obtainable from the secretary, C. N. Smart, 110, Woolmore Road, Erdington. The subject to be discussed at the June 3rd meeting is entitled "Technical problems in sound and vision."

Bristol.—The third mobile rally to be organized by the Bristol Group of the Radio Society of Great Britain will be held on June 26th at Longleat House, near Warminster, Wilts. Details of the day's programme are obtainable from the secretary, D. F. Davies (G3RQ), 51, Theresa Avenue, Bishopston, Bristol, 7.

Mitcham & District Radio Society, which meets every Friday at 8.0 at The Canons, Madeira Road, now has four slow-morse tapes available for loan to members.

Prestatyn.—At the June 6th meeting of the Flintshire Radio Society, J. Thornton Lawrence (GW3JGA), secretary of the society, will give a talk on audio amplifiers. The meeting will be held at 7.30 at the Railway Hotel.

RANDOM RADIATIONS

By "DIALLIST"

"Things Great and Small"

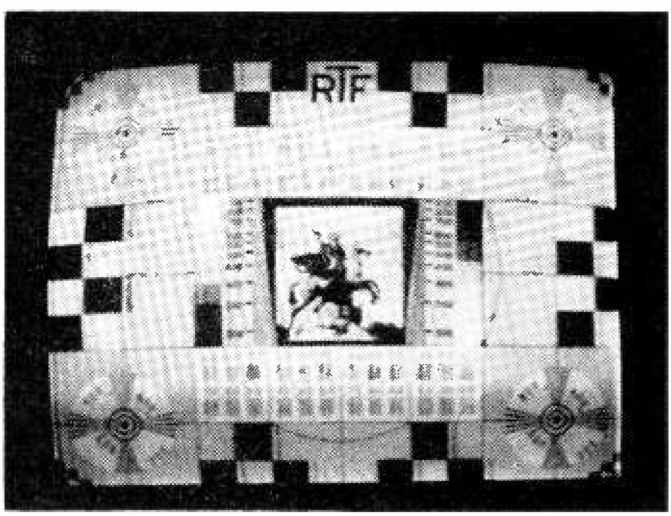
THE National Bureau of Standards and the International Committee on Weights and Measures of the U.S.A., have, I see, approved for general use four numerical prefixes which have been used for some time in Europe. They are tera (symbol T) = 10^{12}, giga (G) = 10^{9}, nano (n) = 10^{-9}, and pico (p) = 10^{-12}. Their adoption is most welcome, for it should help to clear up the confusion which terms such as billion (10^{12} with us, 10^{9} with the Americans) and trillion (10^{18} and 10^{12} respectively) have long been causing. I do think, however, that the names might have been more happily chosen. In the metric system the terms are based on Greek and Latin numerals; Greek as you go up from unity (deca-, hecto-, kilo-, etc.) and Latin as you go down (deci-, centi-, milli-, etc.) though there's a slip-up over micro-. The system worked splendidly until words for very large numbers had to be found.

Could be Better

The trouble is that neither the Greeks nor the Romans had any definite single words for quantities above 1,000 or for very small quantities. Hence names for the enormous and extremely minute numbers in use today had to be invented. The four prefixes in question aren't very good inventions because they don't suggest anything definite; they convey in fact vague suggestions of the enormous, gigantic, the dwarfish and the tiny. I can't see why terms such as hectomega (10^{8}), kilomega (10^{9}) and megamega (10^{12}) shouldn't have been chosen, with symbols hM, kM and MM, for the big numbers. As micro and micromicro have already made their Greek appearances among the tinies why not millimicro (mμ) for 10^{-9}? These prefixes would anyhow show definitely what they mean without any sort of vagueness.

819-line DX

FROM a Harrow, Middlesex, reader comes a most interesting account of a deliberate attempt made to receive French television programmes here. That it was a success you'll gather from the accompanying photograph of the R.T.F. test card on his screen. His firm, he writes, when faced with some knotty problems brought about by their expanding export market, decided to try to obtain direct reception from Lille. A modified British television receiver was used, with an 11-element Yagi mounted on the factory roof some 260-feet above sea level. I congratulate my correspondent most heartily and I hope that his success will induce others to try their hands at long-distance TV reception. In the U.S.A. and Canada it's quite a popular hobby—but the would-be DX-er is more luckily placed as all north American stations use the same standards.



Medium Waves Too

MY recent note on long-distance v.h.f. reception has also brought forth a letter from an enthusiastic night-owl reminding me that there are still those who are interested in long-distance medium-wave reception. Time was when there was no more enthusiastic night prowler on this band than myself and this sort of reception as a hobby is most rewarding in the way of thrills. I recall, for example, hearing a mysterious heterodyne on a German station at about 9.30 p.m. one winter's night. I left the tuning as it was and switched off, for I'd an idea about that heterodyne. At 2 a.m. or thereabouts, I switched on again and there almost on the same frequency was an American station. There can't be much doubt that its carrier had caused the heterodyne on Hamburg. If any readers who haven't gone in for this kind of exploration care to try it out on a good night, I'm sure they'll be rewarded. There is, of course, the Medium-Wave Circle, which publishes its own duplicated monthly newsletter "Medium Wave News." The January issue had a 6-page supplement of western hemisphere m.w. stations logged in the U.K. since 1951.

Entertainment by Line

THOUGH, as stated in the May *Wireless World*, the relaying of broadcast programmes by wire is nearly as old as broadcasting itself (relaying started in 1927 and broadcasting in 1922) there was in London and possibly in some other cities a wired entertainment service long before that. It was run by a company called, I think, Electrophone, Ltd. and I first came across it when shortly after the end of the first war (possibly in 1919) I was invited as a youngster to stay with some friends of my father's in London. To make use of the service you had to be on the G.P.O. telephone and to subscribe to Electrophone, or whatever its name was. This company paid half a dozen theatres and other places of entertainment, fees for the right to relay their entire programmes for a week or more. The subscriber's home was provided with a small square-topped table, at each side of which hung a set of earphones. You consulted the list for the current week supplied by the company, then called exchange and asked to be connected to the theatre of your choice. That done you turned a switch which connected the telephone wires to a small distributor box on the table. Four people could then listen to their hearts' content. There was, I recall, an arrangement, whereby, should a call come through for you, the operator at the exchange could break in and inform you. You then switched back to the telephone and took the call, returning when it was finished to the theatre.

V.H.F./F.M. Goes Ahead

WITH the opening of the Orkney v.h.f. sound transmitter on May 2nd, the B.B.C. completed one of the last stages necessary for full country-wide coverage by its three-programme network. Just how wise the B.B.C. was after the war in deciding to plump for v.h.f. for sound broadcasting is very clear to those who live near the south and east coasts and in other places where heterodyning, sideband splutter, and even virtual jamming too often occur on the medium and long waves. One's experience in East Anglia, for instance, is that with a moderately good receiver no station is of much use on the long waves except at odd times. On the medium waves the only B.B.C. programme fairly well received is the Home. Turning to v.h.f. is like going into another world—no interference, no fading, and always clear steady Home, Light or Network Three signals.

Electron Welding and Cutting

THE electron has long proved itself a useful ally when harnessed by the ingenuity of man to perform tasks for him. We're all familiar with its work in the valve and the c.r. tube. But recently new applications have been found for sharply focused, high-velocity electron beams. Two firms, in W. Germany and Switzerland, have, it is reported, developed methods of electron-beam welding for use on metals ordinarily very difficult to join satisfactorily. A similar beam is being used successfully for drilling tiny holes in metals and for cutting slots in steel plates up to one fiftieth of an inch in thickness. The metal pieces that can be welded, drilled or cut must, one imagines, be very small, for an electron-beam can't be sharply focused except in a vacuum chamber.

UNBIASED

By FREE GRID

Audio Fair

THE most obvious new thing at this year's Audio Fair was the presence of stereo tape recorders whereby you could make your own stereo recordings as well as play commercial tapes. Last year there was one such instrument shown but it was a prototype and not actually on sale.

Stereo tape recorders have, of course, been with us for some years but only very expensive super ones not normally intended for home recording.

There is one thing about these new instruments which was not stressed and which I think ought to have been, as several non-technical people to whom I spoke were under quite a false impression about the instruments. They imagined that by using one of them they would be able to "bottle" their favourite broadcast programmes *stereophonically*.

I had quite an argument with some people about it who imagined that it was only necessary to stand the two mikes in suitable positions in front of their sets or to take two feeds from the set to the "radio" input of the recorder. I explained that this would be quite impossible until the B.B.C. starts regular stereo broadcasting.

All this made me rather wonder if the new machines will be used as *recorders* for few people nowadays make their own music at home, although those that do will, of course, be able to record it stereophonically. Also, it will be possible for them to record the amateur theatrical performances in the village hall.

There was also one complete stereo machine which operated at the two speeds of 3¾ and 1⅞ i.p.s. I know that there are some commercial tapes recorded at 3¾ i.p.s., but most of them are 7½ i.p.s. I think that if I were paying 89 guineas—the price of this recorder—I should expect to have the 7½ i.p.s. speed. It would, in fact, seem to me to be rather a waste of money to buy a stereo machine at all if I could not have this "hi-fi" speed.

The Fair seemed as crowded as ever on the day I visited it. I understand the total attendance was approximately 32,000.

All the demonstrations at the Fair were as good, or bad, as might be expected when a couple of dozen perspiring people are packed in an hotel bedroom. But quite frankly I don't see what the industry can do about it short of building an exhibition centre incorporating demonstration halls.

The stereo demonstrations did, however, make me realize that listening conditions in the average home leave much to be desired. My suggestion is that the garages in new houses should be built primarily as listening rooms with soundproof walls and built-in loudspeakers. Then, when it is desired to do some serious listening, the family limousine could be backed out and some chairs taken in.

My suggestion is primarily made because of the terrific volume which, judging by the demonstrations, it is necessary to have nowadays. The neighbours simply would not stand for it. The size and shape of the garage would also enable domestic listeners to sit far enough back from the loudspeaker to get a proper perspective of sound if that is the correct expression to use; more especially for stereo listening.

Fiat Lux

IN the May issue, "Cathode Ray" tells us that he has forgotten the reason why a complete turning of an angle—or in other words a circle —is divided into 360 degrees. So have I, but I believe I am right in saying that the 60-cycle a.c. frequency in the U.S.A. is based on it. If so, maybe some American reader can lighten our darkness.

Bridal Larinometry

WE have all heard that "gentlemen prefer blondes" but this obviously cannot refer to Africa where blondes are conspicuous by their absence; at any rate among the native population. But even there men have their preferences, and it is a matter of common knowledge that among certain tribes "gentlemen prefer fat girls," in fact for a really outstanding specimen a father can command a price of many head of cattle from his would-be son-in-law.

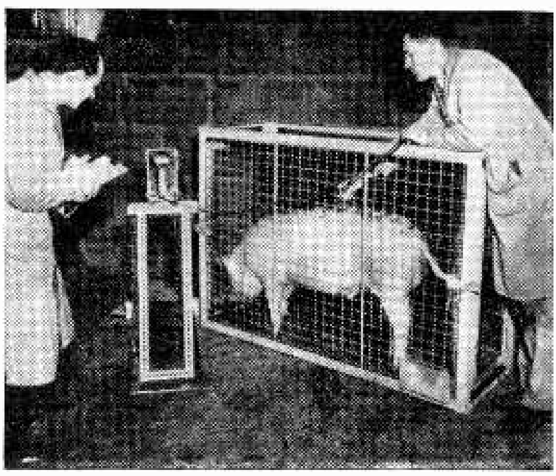
Hitherto a prospective African bridegroom has had to use the necessarily rather crude method of visual inspection when deciding whether one girl was fatter than another. But science has changed all that, as I have been reading in *Pulse*, the bulletin of technical development published by Kelvin & Hughes. An ultrasonic flaw detector is now being used to measure with great accuracy the thickness of body fat. It is true that the technique has not been developed specifically for the African marriage market, but for measuring the thickness of fat on a pig's back, such thickness being, strangely enough, important also in the porcine marriage market.

For this purpose, ultrasonic waves at a predetermined frequency of between 0.5 and 5 Mc/s are transmitted through the fat, and are reflected back at the boundary between the backfat and the lean muscular tissue. The time taken depends on various factors including the thickness of the fat. The measurement is read directly on the graduated scale of a cathode-ray tube.

This technique has, so it is said, already been used to obtain a "photograph" of a man's back muscles and vertebræ, and it is obviously but a step to apply it to performing a similar service in the fatty areas of a female African matrimonial candidate. One can visualize the live-wire salesmen of the firm hastily packing their bags and their portable larinometers.

It won't be long before a prospective African bridegroom will be able to demand the production of an ultrasonic chart by any girl offered to him; and double-crossing fathers-in-law will no longer be able to practise any Laban-like tricks in getting rid of their less attractive daughters.

It is obvious that there are many other uses for this fat-measuring setup, not the least being to let the surgeon know exactly the amount of fat he has got to cut through before he reaches the seat of the trouble.



An unusual use for a Kelvin Hughes flaw detector.