Wireless World

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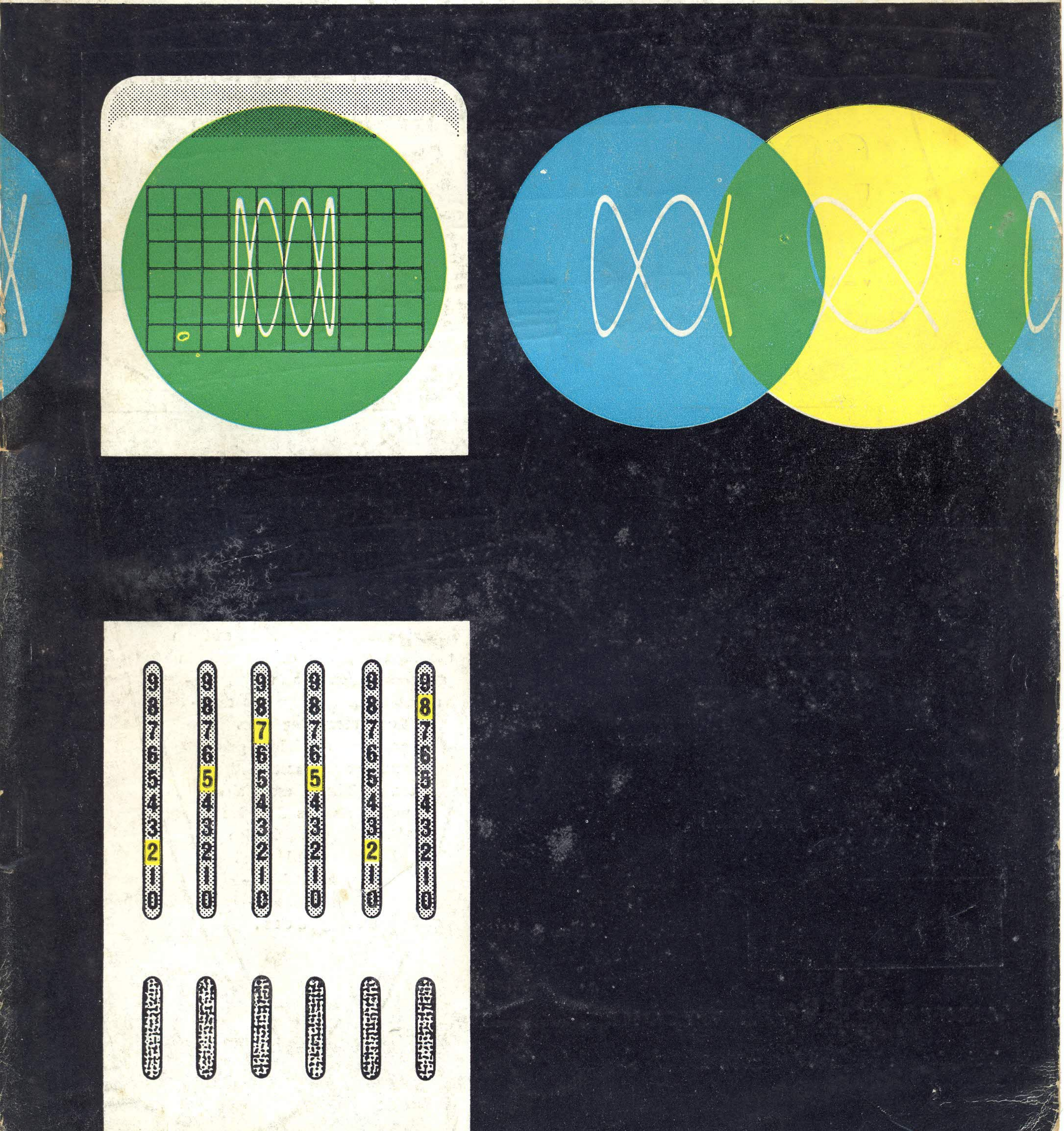

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DECEMBER 1961

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Over the Hump

THIS month the 60th anniversary is being celebrated of one of the most famous and, let us face it, controversial events in the history of wireless communication. It was in December, 1901, that Marconi announced that he had been able to receive at St. Johns, Newfoundland, the succession of triple dots sent out by the 20-kW spark station at Poldhu on a daily schedule from 3 p.m. G.M.T. onwards. The signals were heard at 12.30 p.m., 1.10 p.m. and 1.20 p.m. local time on 12th December and again less distinctly on the following day. On the 14th December Marconi abandoned further experiment owing to the weather, cabled the news of his success to his Company and informed the Press.

The whole project had been carried through under a certain amount of stress—of time (in order to ensure priority over possible rivals) and of weather. Widespread gales had brought down the original Poldhu aerial and a smaller temporary aerial had to be used; the balloons and kites used instead of tall masts at St. Johns had proved to be well nigh unmanageable in the winds then prevailing, and the variation of capacitance with the pitching of the kites prevented the use of the latest syntonic (tuned) receiver. The experimenters did have, however, a variety of sensitive coherers (detectors). These included "microphone" types consisting of loose carbon granules or a mixture of carbon dust and cobalt filings (Marconi's own formulation) and a sensitive self-restoring type, due originally to Tomassina and later used by the Italian navy, in which a globule of mercury was contained between carbon and iron electrodes. All these were used in series with a battery and a telephone earpiece—a far more sensitive arrangement than the earlier "tapper" coherer, relay and morse inker.

The news which Marconi gave to the world was received with astonishment and by his competitors with incredulity. But his confidence was unshaken. Within three months he had set out to repeat the experiment, this time on board the s.s. *Philadelphia*, outward bound, using this time the syntonic receiver and the self-restoring Italian navy coherer. In daylight signals from Poldhu could be received only up to 700 miles, but at night messages were recorded on tape up to 1,550 miles, and the letter S signals up to 2,099 miles.

So the scientific sceptics, whose calculations of diffraction over a curved surface had predicted failure of any attempt to span the Atlantic, were refuted. The Canadian Government was sufficiently confident to advance £16,000 for a transmitting station at Glace Bay and by successive increases of wavelength and power during the next year or two good contact was established at night, but it was not until the summer of 1905 that reliable signals were recorded at Poldhu from Glace Bay, with both stations in daylight. Eventually the Clifden station took over the transmission from this side of the Atlantic and a limited public telegraph service was opened in October, 1907, and an unlimited service from February, 1908, continued until the Clifden station was burnt down in 1922.

Looking back to that boisterous day in 1901, with our present knowledge of radio propagation and of the trials and difficulties which followed, we must be grateful for the fluke which gave Marconi the optimism and courage to persist. He was extremely lucky. No one then knew that daylight was the worst time to conduct such experiments, but this "mistake" was offset by the fact that he could not have chosen a better year than 1901, which was at sunspot minimum, or a better month of that year, when the absorbing D layer of the ionosphere was to all intents and purposes non-existent. The difficulties in repeating the initial success could be partly accounted for by the rise in sunspot activity in the following years and it was probably not until increasing absorption had been overtaken by the rate of increase of powers and wavelengths, that the fruits of the 1901 experiment were safely gathered.

To commemorate the anniversary the Science Museum, South Kensington, is arranging an exhibition of early Marconi apparatus which will be on view from 13th December to 25th January, and on the 12th December the Cornish Group of the R.S.G.B. in conjunction with the Newfoundland Radio Club are planning to exchange messages on the amateur bands between Signal Hill and Poldhu. This is a most imaginative gesture, and we congratulate all concerned in advance on what will undoubtedly be a successful and enjoyable event. Would it be asking too much to suggest that on a future occasion, near sunspot minimum, they endeavour with the permission of the P.M.G. to repeat the contact on some wavelength between 1,000 and 2,000 metres, using at the receiving end all the modern techniques, but making the transmitted power as near as can be estimated to that of the original Poldhu? It is unlikely that the powers that be would take kindly to a 20-kW spark but might be lenient towards a temporary c.w. transmitter of equivalent and therefore lower spectral power level. The results would be illuminating and would, we think, give added force to Sir Oliver Lodge's assessment of Marconi's achievement that "it constituted an epoch in human history on its physical side, and was itself an astonishing and remarkable feat."

OPEN LETTER TO

THE PILKINGTON COMMITTEE

Dear Committee

CONCERNED as you are to advise about the future of our broadcasting service you will doubtless have looked closely at its past. And having done so you may have concluded that the technical means by which broadcasting is consummated has been a dominant factor in determining the ends to which it has been put. Assuming this is an agreeable conclusion then it follows that the future of broadcasting will be shaped, in large measure, by the available technical facilities. The acceptance of this important generality should excuse the intromission of one who was a Founding Father of the B.B.C. and who, *circa* 1925, as the B.B.C.'s first Chief Engineer, planned a technical system for programme distribution which accorded with the ideological policies laid down by Lord Reith.

The creation of the B.B.C. was not, as some have pompously stated, "a wise measure of sociological planning" it was in fact a means to solve an intractable technical problem. The original demands from private enterprise to be given channels for the purpose of advertising greatly exceeded the number which could be used simultaneously without mutual interference. In these circumstances it was decided to grant a monopoly to one organization which was ordered to do broadcasting "to the satisfaction of the Postmaster General." This organization was to be known as the British Broadcasting Company, later on it became the British Broadcasting Corporation.

A strange beast this B.B.C.! By civil service, out of compromise, tended in its youth by rich uncles, handed over in adolescence to public trustees, obedient to a constitution which defies a basic principle of democracy, it yet became the fervent supporter of free speech; strongly opposed to radio advertising yet making large profits through a publications department, sailing on "heedless of the gulls screaming round its mast," and as sensitive to criticism as a newly fledged debutante, the B.B.C. (may it live for ever!) is quintessentially British; and it came into being solely because of the limitations of communications technology.

Is a Monopoly Desirable?

But the B.B.C. no longer enjoys a complete monopoly; to the great sorrow of many sincere folk commerce has taken over part of the service (television) and is now insinuating its persuasions to have a similar control over a parallel sound-broadcasting service; it is up to you to recommend what to do, whether to give or to withhold.

In this connection you are in my opinion asked to answer an unanswerable question, namely, is a vicious principle justified by an admirable practice? The vicious principle is that which gives a single authority control over a powerful medium of propaganda, the admirable practice is demonstrated by the way the B.B.C. performs its duties.

But suppose that technical advances have abolished the channel shortage, what then! It might be said that, in these circumstances, the justification for the B.B.C. no longer exists and private enterprise might just as well take over. Assuming the abolition of channel shortage I am sure that the abolition of the B.B.C. would be an altogether retrograde step; while the B.B.C.'s institution was fortuitous its demonstrations have earned it a respect which should ensure its continuance.

It is of course possible and moreover, in my opinion, essential to preserve the B.B.C. but not necessarily by a continuance of its sound-broadcasting monopoly. It is my belief that freedom, in all its implications, is more important than the certainty of its abuse; the price of liberty is high but worth paying. If the channel shortage could be abolished or alleviated then broadcasting could be refreshed from more and more contrasted sources and would therefore match the pattern of liberal democracy more closely than it can today.

Criteria for a Democratic Service

When, some 35 years ago, I was acting as the authority's first Chief Engineer, I laid down certain principles and, with the limited means at our disposal, did my best to see them put into practice. These principles, which I consider to be sound even today, were that the transmission service should be planned so that

(1) everyone receiving the programmes should be assured of a reproduction of them free from interference;

(2) the quality of reproduction, in its faithfulness to the original, should, given a good receiver, be capable of reaching a high standard;

(3) that the listeners (in today's set-up the viewer as well) should be given a wide range of choice between contrasted types of programme. This implies that the claims of minorities are of paramount importance.

It may be of some interest to examine today's broadcasting service in the light of these principles.

Interference

As to clear reception, reception that is free from interference, my own experience makes me say that while there is a vast improvment now that the v.h.f. service for sound broadcasting has been instituted the very fact that quality has greatly improved makes the occasional unwanted noise and variabilities that accompany reception the more annoying. Passing motors too often cause plucking fingers to tweak my loudspeaker, passing aeroplanes pulse-modulate reproduction, a local electric motor sometimes imposes a whine while the mains hum drugs the ears. I use a low-priced receiver, which I suppose is typical of that used by a majority and so my judgment is not that of the high-fidelity enthusiast which could well be more favourable. I do not own a television set but often, by courtesy of friends and relations, watch the programmes. From time to time I am annoyed by the sudden intrusion of snow storms blotting out the picture; it could all be better, it has all been worse.

Quality of Reproduction

Still making it quite clear that I get my reception of sound programmes by the use of a low-priced receiver I would say that the quality of reproduction, while it gives a potent reminder of music in the original does not allow critical judgment of performance. Speech is clear and, apart from occasional interference and continuous hum, the latter being no fault of the sender, all reproduction has a silent background.

The small screen of a television set is its handicap. Because of its more comprehensive technical characteristics the larger cinema screen and the associated tricks of loudspeaker placing and conditioning makes a contrast to television in its more convincing effects upon an audience. This is not to say that television is necessarily second rate, it is to say that its technical limitations impose a greater strain upon the producer to get his effects than were more abundant facilities available.

Range of Choice Between Programmes

Coming to my third principle, that demanding a greater number of and a greater contrast between the character of programmes, it seems to me that the present lack of choice and the consequent failure to cater for minorities, in anything like the degree I would favour, constitutes the major criticism of the existing set-up.

There is a large and respectable body of opinion which denies the justification for the wide range of choice that I believe to be desirable. Strange, is it not, to hear the same voices deploring the shrinking of the provincial press and at the same time denying the need for local broadcasting? The liberal mind is often open but, when it receives an impression, it is inclined to snap shut and not let go; like those flowers which catch flies. It is wrong to assume that an increase of facility must imply an increase of futility; it can also favour serious causes. Those likely to turn up a scornful nose at what they consider would be the vulgarities which would invade a more provident technical system of broadcasting will be more likely to welcome the suggestion to increase the time given to, for instance, educational programmes. My occasional overhearing and overseeing these programmes has convinced me of their value and, believing as I do, that the most important aim of present day sociological organization should be in furthering education, in the full meaning of that term, I therefore believe that the provision of more channels and their use for education would be a major contribution to the community's eventual health and happiness.

The B.B.C. has given us a fine example in catering for a minority by its institution of the Third Programme, but it is sad that lack of channels makes it necessary to use the Third Programme wavelength for other purposes. Not that these other purposes are inferior, they too cater for minorities, but if only there were more channels there would be no reason to dilute one type of programme by another and another by one.

Is it not true that there is constant compromise with respect to the demands of Welsh cultural bodies to possess an exclusive channel for their use, and is it not desirable that they should?

The vulgarities which would doubtless invade other channels would seem to me to be an inevitable consequence of satisfying a majority. Why baulk the fact that the majority is not cultured and why not see that the problem of making it more appreciative is much deeper than shoving "cultchar" at it? The way to abolish the gutter press is to abolish the gutter, not the press.

Summary of Desirable Characteristics

Summarizing the examination of contemporary practice in the light of my three principles shows that interference, while not a serious matter, too often dilutes the pleasures of looking and listening, that the quality of reproduction given by an ordinary set, while adequate, leaves a good deal to be desired and that the range of contrasted types of programmes available for choice is woefully limited. Thus we could make an embracing summary by saying that what is needed is the provision of not only more channels but channels relatively clear of interference to which are coupled receivers which do more justice to the potentialities of good quality, inherent in the transmission, than do the average types in use today. How to achieve these aims demands some clear thinking.

Wire Broadcasting

It is obvious that the use of conductors (wire networks) to join the output from microphone (or camera and microphone) to the household receiver has potential merit. Interference can be virtually done away with, aeroplanes cannot modulate waves passing in conductors, induced voltages from domestic machines are of such relatively low intensity as to be dominated by the wanted signals, while the authority responsible for the design and maintenance of the receiver can assure the user good quality reproduction. A further merit of the use of wires is that the number of channels that can be made available is certainly greater than that provided by radio as it exists today. These are purely technical advantages; there are contrasting disadvantages.

Objections to Wire Broadcasting

Concerned only with technical issues the disadvantage of the use of conducting networks for the dissemination of programmes is that the wires will not reach economically beyond the confines of a densely populated area. Concerned with commercial vested interests there is opposition to wire broadcasting by those who profit from the manufacture and sale of radio receivers.

If for no other reason than that portable sets and car radios cannot be served by the wire it would be plain silly to consider shutting down the radio senders. This must set a limit to the oppositions of vested interests, but without doubt it persists. Perhaps it may be lessened by the popularity of the transistor portable.

But some of the arguments advanced against wire broadcasting demonstrate in their futility how fearful its opponents can be. When I was proselytising wire broadcasting a serious writer, whose strictures were published in a respectable technical journal, argued how dangerous it was to suggest setting up a system which could be so easily seized by a dictator, or a would-be one. This argument neglected the point that a pirate radio station could be far more widely heard than transmissions through wires and that once a dictator had power it would not only be the broadcasting services that he commandeered. And as to the use of radio receivers to pick up encouraging messages from abroad, if the country were enemy-occupied it is certain that jamming would be used if the occupying authorities thought it to be worth while.

Use of the Electric Power Network

R. E. H. Carpenter and I devised, *circa* 1930, a system for diffusing sound programmes through the electric power network. Fortunately for the Trade, it was found that an Act of 1882 forbade the practice, and in a Parliamentary debate Members demonstrated their loyalty to vested interests and refused to repeal the Act. So much for the liberty of inventors.

I see from your terms of reference that you, as a committee, are required to consider the use of wires for disseminating programmes. Well! Well!

Use of the Telephone Network

It was suggested, *circa* 1930, notably by the British Post Office, that the telephone network could be used for distributing programmes. The frequencies of the carrier waves injected into the network were to be within the long-wave band, i.e. those used by radio senders such as Droitwich, Hilversum, Paris. The reception would be available on an ordinary radio set equipped with a long-wave switch which was plugged into the network. It would appear that the Italian authorities already have such a system.

The limitations of the scheme are, of course, that it is available only to telephone subscribers. I should think also that if the subscribers' telephones were served by open-wire conductors that there would be severe interference from long-wave senders of telegraph signals but I am prepared to be wrong. Also, of course, the quality of reproduction would be typical of the ordinary radio set.

Overlapping in the Absence of Planning

The fact that the wire broadcasting method is chiefly practicable in urban areas makes one ask if it is reasonable to deny a facility to some because it cannot be given to all. The Corporation understandably considers it as a duty to spread its radio service throughout the territory for which it is responsible, but it is questionable whether this practice need be carried so far as to cause overlapping and, therefore, in a national sense, unnecessary expenditure. In recognizing this problem I suggest in my summing up, the formation of a technical committee of all the talents to plan a national system of programme distribution, taking into account local conditions and modern technology.

Potentialities of Centrimetric Wave Broadcasting

In contrast to the use of wire networks to increase facility it may be of interest to consider a scheme, impractical, perhaps, but worth describing, relying upon the use of centimetric-wave radio. The telecommunications engineer will agree, other problems inherent in the scheme assumed solved, that the use of centimetric waves to carry programmes would allow the simultaneous diffusion of enough programmes to satisfy the most importunate desire for increased facility. The basic problem would be to avoid shielding, meaning the casting of radio shadows by buildings, hills and so forth. There is an analogy with light. A single source of light suspended above a densely populated area would illuminate some parts but cast shadows in others. A canopy of light over the whole area would disperse the shadows and create a uniform illumination everywhere below it. Centrimetric waves would not, to their advantage, cast such clear-cut shadows as light, but the analogy is a fair one.

According to my suggestion a number of senders, transmitting centimetric waves, would be installed on high buildings, towers, hills and high ground, and would thus spray the houses of an urban area with their radiations. The sending aerials would comprise a number of half-wave types interconnected by folds of conductors not contributing to radiation and would be extremely efficient. Only the receiving aerials would be directional, looking like pudding basins and oriented to catch the strongest signal; they would be coaxially connected to the householders' receiving sets. These aerials would be less conspicuous than those picking up television transmissions today.

Interference would be negligible and quality of a high standard. The simplicity of the senders would make it practicable to leave the installation unattended as is successfully done with more complex equipment.

The disadvantage of the scheme, assuming that the effects of shielding could be wholly overcome (which is doubtful) is that the area over which the signals would be received would be limited to urban areas. But as I read the last sentence it struck me that we need not be too pessimistic about rural areas; on a clear day and standing on the heights of hills and mountains it is surprising how far one can see. Centimetric waves penetrate fog and rain and so the analogy of sight need not deny the practicability of the suggestion to serve rural as well as urban areas by these very short waves. There would be shielding everywhere but in what degree? The experts will give you the answer.

The adoption of centimetric waves would, of course, mean radical and costly changes to our present-day transmission system; perhaps in time the medium- and long-wave stations might be shut down leaving only those using v.h.f. to serve portables and car radios.

It is said, moreover, that there are more important uses for centimetric waves than their employment in the broadcasting service—one can guess what these more important uses might be and feel that in a sane world. . . . But the world is not, in some aspects, sane.

Television—Lines and Colour

On other issues the future of television and recommendations about lines and colour must engage your attention—I saw a comparison of pictures using 405 and 625 lines. My impression was that there was a distinction without much difference. It would seem to me to be advisable to recommend the 625-line system for no better, but no worse reason than that the majority of other systems throughout the world use the greater number of lines—export and all that.

And colour! No sane person would argue that, other things being equal, the introduction of colour to television would be anything but desirable. But other things are not equal and should make one pause.

I was particularly struck by the implication of a polemical question put to me by an American engineer: "Would you," he asked, "pay two to three times more to see a colour film than you would to see a black and white?" I said, "Certainly not" and so drew the obvious conclusion that it was not worth paying two or three times the cost of a normal type of television receiver to get colour reproduction. If it cost no more to produce colour the debate would hinge upon the quality of the picture, but in the circumstances the cost factor is dominant.

Eckersley's Law

In spite of the dominance of the cost factor I go further in questioning the advisability of setting up a colour transmission service in what I consider to be the present inadequate state of its development. I cite Eckersley's law defining an enjoyment factor. The law is that the product of the value of two numerics one proportional to the fidelity of reproduction and the other to the intrinsic interest in the matter reproduced is equal to a constant. Thus delight in the fidelity of reproduction of a dull programme compensates precisely for its dullness; conversely the outpourings of transcendental talent, or the demonstrations of dramatic interest, heard through distortion, has an enjoyment constant of equal value to that derived from "dull" multiplied by "hi-fi."

The impact of an exciting programme can be considerable, colour or no colour, and if the colour is of poor quality it subtracts from not adds to excellence. I have seen silent films in black and white which have stirred far more emotion in me than the most orchidaceous all-talking, all-singing, all-dancing affairs the impact of which is made by exuberance and elaboration. "The play's the thing" and one's sensibilities can be awakened by simplicity allied with taste without need for adventitious aids. Putting aside considerations of cost and quality the potential delights of witnessing a colour television broadcast from, for instance, the Chelsea Flower Show can be sympathetically appreciated but, as I see it, the result, in present-day colour, would be an oleographic horror; I would not pay an extra penny piece to see it. So let us wait a while, wait for technical developments reducing cost and improving quality.

These views will be unpopular but may perhaps seem the sounder when my critics are confronted by a dealer whispering the cost of a colour receiver.

In my view the efforts expended in developing colour television would be better devoted first to increasing the area of the television screen. While agreeing that there is a practical maximum to screen size I feel it has not yet been reached. I have listened with respectful attention to theories about subtended angles related to distance separating viewer and picture and have been told that a bigger screen viewed at a larger distance gives no better impression than a smaller looked at from a lesser distance, but I remain unconvinced. Has it not been said that it can be proved from a law of aerodynamics that a bumble bee cannot fly but the bee, not knowing the law, goes on flying?

Improvements in television technology, namely, colour and larger screens demand a wider sideband. Thus my basic plea for more channels, if accepted, would imply a wider total spectrum to contain all broadcast transmissions. If this spectrum were wide enough then there would be room not only for more but for wider channels; and centimetric waves would provide this wider spectrum.

A Committee of All the Talents

Have I by now succeeded in drawing a single thread of argument through the warp and woof of my discursions? Have I convinced a reader that the potentialities of broadcasting have not yet been fully realized because of the restrictions of its technology? The sheer weight of tradition has so far confined the service within narrow limits and deprived it of a full exhibition of its powers. And if restriction has been inherent in tradition can we dismiss tradition and discover a way to expand the technical means at our disposal so as to give a new stimulus to broadcasting?

Had I my way I would attempt to gather together a technical committee of all the talents and ask it to frame a plan capable of giving a majority of listeners a multi-programme service.

The basic difficulty in achieving a plan is the rivalry of vested interests be they of prestige or profit. I see the B.B.C. is anxious to demonstrate an ability to provide local programmes and estimates that it will cost £30,000 a year to stir the blood of Bournemouth. Would not a local committee be the right authority to provide occasional local programmes and get the money to run them from local advertising? This in passing, but as an example of rivalry rather than combination.

Is it necessary to be so tender about vested interests be they of commerce or prestige? To form our technical committees we have bodies skilled in installing and running wired systems; the Independent Television Authority could surely subscribe ideas, the B.B.C. stands in its integrity as the most experienced body concerning all aspects of broadcasting, the Post Office could add its quota of experience in the linking of studio output with transmitter input; in sum could not a combination of authorities frame a national plan of broadcasting to provide a wider range of programme distribution than exists today?

Conclusions

In all I have said the principle that liberty is of paramount importance rules my thinking. That its abuse is often nauseating is obvious but for the sake of principle must be tolerated. The B.B.C. sets an admirable example and because it must choose it must also refuse; without selection it would be formless. I doubt very much whether a continuing insistence upon uplift lifts up anything, but I passionately support the B.B.C.'s policy. But there are other policies; let us benefit by them as well.

Open up the channels then and let the flood of opinion, the phases of art, the dichotomies of politics, the shocks of minority opinion be diffused to the public and broadcasting will be the greater for it. But find the best advice how to achieve these ends technically.

Yours sincerely,

P. P. Eckersley

BEGINNINGS OF THE B.B.C.

The History of Broadcasting in the United Kingdom: Vol. I.—The Birth of Broadcasting. By Asa Briggs. Pp. 425+xiii; 50 illustrations. Oxford University Press, Amen House, Warwick Square, London, E.C.4. Price 42s.

This is the first volume of a projected series on the history of broadcasting which will carry the story up to the ending of the B.B.C. monopoly in 1955. The present book covers the background, origins, organization and administration of the service up to the end of 1926, when the British Broadcasting Company became the Corporation.

In writing this volume Professor Briggs has drawn on much unpublished material, including Lord Reith's diary. He has produced a highly detailed and extremely well-documented study which puts order into the confused and confusing story of how broadcasting started.

Even before the B.B.C. was formed at the end of 1922, opposition had come from every conceivable quarter; the press and news agencies, the Services, the entertainment industry, the gramophone companies and others voiced their objections. The opposition "displayed a remarkable variety of fears and prejudices". Just as America had "blundered into chaos", so, it seemed, "British broadcasting was to be forced into a strait jacket". Highly restrictive rules were either proposed or put into effect at various stages; for example, the ban on controversy and on the broadcasting of news which had not already been published in the press. Hours of transmission were severely restricted and frequent breaks in programmes were required.

There were money troubles as well. The Company was "arbitrarily and inequitably financed", partly by a share of the licence fees and partly from royalties on receivers sold by member-firms. But "piracy" was widespread; for this the public was not entirely to blame, as there was great confusion over the different forms of licence, particularly that for home constructors.

In the face of all these difficulties a lesser man than the first General Manager might well have given up the struggle. "Reith did not make broadcasting, but he did make the B.B.C." He emerges from this book, not as the ruthless autocrat of popular fancy in the mid-1920's, but as the skilful, patient and resilient negotiator and administrator who set the pattern for the public corporation while the B.B.C. was still a commercial company.

If Reith (ably backed on the technical side by P. P. Eckersley, the B.B.C.'s first chief engineer) emerges as the hero of the book, it is pleasing to observe that Prof. Briggs finds no real villain, though clearly he considers the Post Office control to have been at times rather heavy-handed. Of the radio-electric companies who put up the money at the start, he says: "For bearing [the risk of initiating a broadcast service] the 'Big Six' received no concessions. Together they made up a monopoly, but it was a monopoly which enjoyed no monopoly profits and few monopoly privileges. It was the Post Office who did best financially out of the deal".

H. F. S.

"RADIO AND ELECTRONIC LABORATORY HANDBOOK"

THE widening sphere of activities encompassed by the term "radio experimenter" is reflected in the title of the seventh edition of this very popular work. "Radio and Electronic Laboratory Handbook," by M. G. Scroggie, B.Sc., M.I.E.E., is a completely revised and enlarged version of the earlier editions. The no-nonsense approach is retained, and although the discussion is as thorough and complete as in many more self-consciously "long-haired" books, the treatment is considerably more lucid and unobscured by jargon than is usually the case.

The author discusses the setting-up of an experimental laboratory, with suggestions for the choice of relevant instruments. The latest types of measuring instruments are described, with many references to commercial products, and several circuits for items of test gear are included. A chapter on the provision and use of standards is followed by discussions of the measurement of circuit parameters, equipment characteristics and signal measurements, at all frequencies up to v.h.f. The recording, examination and interpretation of experimental results are dealt with, and an extremely comprehensive, 80-page reference section contains most of the information that one never seems to be able to find when it is wanted. New sections include those on digital equipment, and the testing of semiconductors and f.m. receivers.

The book is published for "Wireless World" by Iliffe Books Ltd., and costs 55s.

TECHNICAL NOTEBOOK

New Distortion Criterion discussed in an article under this title by E. R. Wigan in the April and May 1961 issues of *Electronic Technology* is that the subjective unpleasantness of a distorted sound is assessed from the rate of deviation (with time) of the distorted sound from what the listener considers to be a normal undistorted sound. If we interpret this criterion simply as the rate of change of the difference between the distorted and undistorted signals, the unpleasantness should increase both with signal frequency and amplitude and both these effects were confirmed (the latter indirectly). The effect on the criterion of the listener's opinion of normality was shown by presenting him with a distorted background. This he took to be normal, thus reducing the subjective unpleasantness of other more distorted sounds. When, with an unknown language, very little opinion of normality was possible, listeners found it very difficult to make any assessment of the distortion. By changing the background, the memory time for such impressions of normality was found to be of the order of four seconds. A subjective grading of unpleasantness suggested that this was proportional to the square of the rate of deviation from normality. A suggested mathematical criterion which is consistent with these and other results is $C_t = n^2(p_n - t)\%$ summed for all terms from $n=2$ onwards for which $p_n > t$, where n is the harmonic number, p_n the percentage amplitude of the nth harmonic compared with the undistorted signal, and t the just audible percentage harmonic distortion (under the conditions of the experiment). The rate at which the individual terms decrease due to a finite t can be found by comparing signals of different bandwidth. In this way the minimum audible 500c/s distortion was estimated as 0.3%.

Fire and Water, especially salt water, are two of the classic elements which are usually regarded as fatal to electronic apparatus. But this is not necessarily true, as has been recorded in the February 1961 issue of the American *Naval Research Reviews*. The first step in the process is the immersion of the equipment which has been damaged by fuel oil, smoke and tars from fires or salt water in an emulsion of chemicals containing a hydrocarbon solvent (to remove the "greasy" substances) and water (to dilute and carry away the salt water). A surface active agent holds the solvent and water in emulsion until an oil-fouled surface is contacted when the solvent is released. Ultrasonic agitation is employed to "scrub" the apparatus and, when primary cleaning is complete, the emulsion is flushed away either by a water sprayer or again by ultrasonic agitation in an immersion tank.

The majority of the flushing water is then blown out by oil-free compressed air and the remainder is removed by a water-displacing compound. This either physically displaces the water or, in deep interstices, combines with it to form a substance known as an azeotrope, which has a lower boiling point than water and, when it evaporates, carries off the water with it. A drying period in a warm "oven" completes the process and the water-displacing composition leaves behind a corrosion- and moisture-resistant film. More than 90 per cent of equipment damaged by fire but not actually burned in the U.S.S. Constellation is being recovered satisfactorily by this rehabilitation process.

"Aperture Distortion" occurring in television systems causes lack of sharpness in the picture: the effect is due to the finite width of the camera spot "gradually" moving across a black-white boundary and so "slowly" changing the output signal from black through grey to white. This is corrected by electronic artificial sharpening of transitions, but usually the technique is applied only to the higher frequencies, that is, those representing vertical transitions. In *Journal of the S.M.P.T.E.* for June 1960 W. G. Gibson and A. C. Schroeder suggest correction for the effect of the aperture in the vertical direction, i.e. on horizontal edges.

Correction is achieved by deriving a "detail" signal by subtraction of adjacent lines from each other (thus leaving only the change that has occurred between the lines), and this signal is mixed with the original signal so as to reinforce the transition. Naturally, this involves the delaying of whole lines of the picture so that the detail signal can be derived and used: quartz-crystal mechanical lines are used, operating at about 30 Mc/s.

The technique does not suffer from some of the defects inherent in correction for vertical edges: for instance, the signal-to-noise ratio is not markedly degraded. Also it has the advantage that it can be used on a composite signal (including colour) so that only one unit is required for all signal sources at a station. The authors hold out the hope that the system may help to reduce the "lininess" of images by compensating at the transmitter for a display-tube spot expanded in the vertical direction.

First Colour TV Receivers available for sale from the Zenith Radio Corporation in U.S.A. use a new colour demodulator system. This employs two "sheet-beam" valves (Type 6JH8) which have, additional to the usual valve structure focus, accelerator and deflector electrodes and two anodes. The electron beam, controlled in intensity by the first grid, is forced into flat or sheet-like form by the focusing section and speeded up by the positive potential on the accelerator. Potentials applied to the deflectors switch the beam from one anode to the other.

For colour demodulation two colour-difference signals, R-Y and B-Y, are applied to the control grids of the two valves. These signals are, of course, on the 3.58 Mc/s sub-carrier and are in phase-quadrature (90° difference) with one another. The deflector plates are energized from the local oscillator synchronized with the "burst," or colour phase-reference, signal, the R-Y stage with a direct push-pull output, and the B-Y with a push-pull quadrature output. Thus the beams modulated with the colour difference amplitudes are switched from one anode to the other of the sheet-beam valves, so giving outputs which are of opposite polarity. The four outputs consist of B-Y and R-Y signals direct and two "negative" signals, from which G-Y is obtained, for application to the c.r.t. control grids. The luminance or Y signal is applied to the c.r.t. cathode. The use of the sheet-beam valves saves two waveform inverter stages which are otherwise necessary to obtain the G-Y signal.

Meter Relay—the MagTrack—introduced by the Weston Instrument Division of Daystrom increases the normally rather low contact pressure produced between a moving meter pointer and a fixed contact pointer both by attaching to the pointer a soft iron bead which is attracted by a magnet attached to the fixed pointer, and by means of a second aiding coil (suitably wound on the same frame as the measurement coil) which is energized on contact. The magnet provides sufficient force ($\approx$30 mgm) to break through any insulating film which may have accumulated on the contacts and the additional pressure ($\approx$2 gm) provided on contact by the aiding coil moves the flexible contact to provide a wiping action.

I.T.A. Plan for V.H.F. and U.H.F.

EXPANDING THE TELEVISION SERVICE AND CHANGING LINES WITHOUT DUPLICATION

THE Television Advisory Committee in their 1960 report emphasized the importance "of planning the use of Bands IV and V (and when the time comes the re-engineering of Bands I and III) from the start as an integrated whole." They also stated (paragraph 32) "If 625-line standards were adopted for the higher bands then eventually they would need to be introduced into Bands I and III in order to achieve a single standard. We [the Committee] consider that such a changeover is capable of achievement given a long-term programme in which the aim and phases are made clear to all concerned and as a consequence have the full co-operation of the broadcasters, the viewers and the radio industry."

The drafting of a detailed plan did not come within the terms of reference of the T.A.C., but there has subsequently been no lack of proposals and counter-proposals from various authorities and from industry. Some of these have been quite complex and have involved the starting of a third service in Band III, duplication of the existing services in Bands IV and V and an eventual reshuffle of these services between u.h.f. and v.h.f.

The Independent Television Authority, while not dissenting from the T.A.C. recommendations for an eventual change to 625-line standards, has in the past advocated delay in its adoption, until a scheme could be evolved which, as it was one of the first to point out, avoided "the absurdity that, if we changed the national line system, we must approach the point at which we have emptied our best television frequencies in Bands I and III of all television." It now puts forward a scheme which permits an early start of new programmes on 625 lines (which it now positively endorses as desirable for the future), which avoids any transfer of the two established national services from Bands I and III and which gives a practicable interpretation of the T.A.C. recommendations.

The I.T.A. proposals contained in a pamphlet "405:625. A plan for changing to 625 lines while retaining v.h.f. transmission" issued last month are basically as follows (and we quote):

So that we may continue to use the v.h.f. bands with their substantial advantages and avoid the duplication of services, the Authority proposes for consideration that there should be designated a "405-625 transition period," during which existing 405-line sets would wear out physically. This period would last for seven to eight years. At the end of the period, all transmissions would become 625-line, and all 405-line transmission would cease. This change would take place on an "appointed day." During this transition period, the following arrangements should be systematically introduced:

(i) At all the existing v.h.f. transmitting stations of both the B.B.C. and I.T.A., "shadow" plant, consisting of new transmitters and aerials arranged for 625-line operation on their appropriate new v.h.f. channels, should be installed. This would enable the two existing services to be switched simultaneously and without interruption to 625-line transmission on the appointed day.

(ii) There should be placed on sale from the start new dual standard receivers capable of 625-line reception in v.h.f. and u.h.f., and also capable of receiving the existing services as they are today transmitted. It should be the plan that these dual standard receivers, by the normal process of replacement, should have supplanted the existing 405-line v.h.f. receivers by the appointed day.

(iii) As early as possible, the planning and building of a national network of u.h.f. stations should begin, and arrangements be made for the introduction area by area of one or two new programmes on 625 lines. The network of u.h.f. stations should be progressively expanded to give as much coverage as possible, making the best pace that proved practicable.

The I.T.A. point out that the pace will be governed by the success or otherwise of acquiring sites for the thirty or more u.h.f. stations, additional to those on existing v.h.f. sites, which will be needed to give national coverage. It is estimated that nine of these lie within the boundaries of National Parks and at least five more near areas of natural beauty. These are difficulties which face any extension of the television services into Bands IV and V.

Advantages claimed for the I.T.A. proposals are:

(i) The superior v.h.f. bands are retained in permanent use without interruption for two of the national services.

(ii) The temporary duplication of two services, with the formidable waste of capital, revenue, and manpower involved, is avoided. New v.h.f. transmitters and aerials must, of course, be installed at the existing v.h.f. stations to provide the "shadow" equipment eventually to be used to take over and transmit the present two services on 625 lines on their new v.h.f. channels, but this provision is far less costly than the transfer of these services to a u.h.f. network of stations, only some twenty main v.h.f. stations for each of the present two programmes needing to be so equipped compared with the sixty-four main u.h.f. stations required to give approximately the same coverage.

(iii) The permanently heavier running costs of an all-u.h.f. transmission system are avoided, and so is the liquidation of the v.h.f. stations.

(iv) Duplicated transmissions require standards conversion, which further degrades the picture quality of the already lower grade 405-line service, and this degradation is also avoided.

(v) The transition to 625 lines could be achieved much more quickly, perhaps in half the time, for the termination of 405-line transmission would not have to wait for the completion of coverage by the u.h.f. 625-line transmissions. The shadow plant could be installed comfortably within seven or eight years. It is difficult to see how the building of the u.h.f. network could take less than twelve to fifteen years.

(vi) The new type of dual standard v.h.f.-u.h.f. receiver produced during the transition would be basically similar to those required by Continental and

Commonwealth countries, so their export would be assisted. The 405-line facility would simply be left out for export and finally, after the switch to 625 lines, it would be left out for the home market as well.

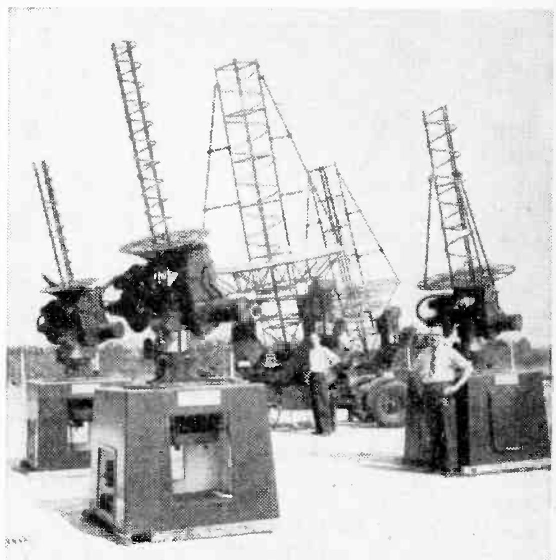
The design of the proposed new British receiver and the sequence of events in the changeover plan are envisaged in the following terms:

It is, of course, an essential part of the plan for retaining v.h.f. for the main British services that the standard receiver becomes and remains a v.h.f.-u.h.f. set if there are also to be u.h.f. services. The method of transition here proposed requires the incorporation of a small but essential additional piece of equipment in the new dual standard receiver. Over and above its ability to receive, or be converted to receive, the new 625-line u.h.f. services, the new set must also be capable of receiving, or of being converted to receive, the present two services when, on the appointed day, they are switched to 625 lines on their new v.h.f. channels. Provided that the parameters (the vision-sound carrier spacing, the width of the vestigial side-band, the polarity of vision modulation and the choice of frequency or amplitude modulation for the sound channel) adopted for the 625-line transmissions in both v.h.f. and u.h.f. are the same, this addition is both easy and cheap to provide, the cost being in terms of shillings rather than pounds. It involves no more than the equipment of the normal v.h.f. turret tuner with two additional "unchristened" channel positions, marked "X" and "Y," not initially fitted with coils. During a period of a year or more before the appointed day for changing the present two services to 625 lines on their new v.h.f. channels, local dealers would progressively clip in to these "X" and "Y" positions the coils or "biscuits" needed for the two new 625-line v.h.f. channels to be used in the area of the set. The task of the dealers would be eased by arranging for the "shadow" 625-line transmitters to radiate trade test transmissions on their new v.h.f. channels each morning, instead of the 405-line transmitters as at present, this practice being put into operation in all areas a year or so in advance of the appointed day. This is no new process for dealers. They have already experienced it several times on a smaller scale for, when the I.T.A. has opened new transmitting stations, many thousands of so-called multi-channel sets in the new area needed coils to be clipped in to unequipped positions on their v.h.f. turret tuners to enable them to receive the new channel. In these areas the dealers were able to accomplish this task in a few weeks, but no one will wish to underestimate the careful and efficient planning, by manufacturers and dealers alike, necessary to repeat the process on a national scale. Indeed, the feasibility of the plan rests on this particular operation. It would be a substantial alleviation that all receivers sold a few years before the appointed day would already have had their "X" and "Y" positions fitted with the necessary coils by the manufacturers, for the new channels would by then have been made known to them.

Whatever method of transition is chosen, it is little use to pretend that the complications will not be painful for the broadcasters, the manufacturers and the public alike. Equally, whatever method is chosen, the operation will be expensive. These considerations make it all the more important that, when the end is reached, it should be the ideal end, and not the second best end, shortsightedly determined by the choice of what might seem the easiest way out during the transition. History already contains a bitter lesson for us. Our present dilemma is the direct result of the great technical catastrophe of sixteen years ago, when television broadcasting was resumed on 405 lines at a time when refined line systems were perfectly feasible. The choice of the relatively coarse line system with which we are already technically dissatisfied then seemed the easiest way out. It will now cost many millions to correct matters. It would be tragic to fall into a second error by finding ourselves, at the end of the period of transition, with a broadcasting system that was still technically defective. If we are to make the change at all, we should steadily ask what it is we wish to have in the end, and we should accept whatever transitional complications are necessary in order to reach it. This end, it is the argument of this present paper, is a 625-line broadcasting system making full and continuous use of the v.h.f. bands, in which the two main services have been uninterruptedly contained.

We do not go all the way with the I.T.A. in condemning the restarting of television in 1946 on 405 lines. Nor are we convinced that the advantages of a change now to 625 lines will outweigh the disadvantages of the "expensive and painful complications" which will bear heavily on all concerned—not least on the public. It is true that we might have adopted a higher standard in 1946, but we could not have been expected to guess that the figure of 625 would be the one to find favour. If any other standard than 405 had been adopted it would have been the American 525, the only other higher standard then in the running.

Whatever may be the final conclusions about our line standards, we have no doubts about the desirability of extending the television services by the provision of more channels, the case for which has been so ably stated by Capt. Eckersley elsewhere in this issue. This will certainly cost a lot of money, and if the need for larger pictures and a higher line standard are part of the bargain, then there can be little doubt that the I.T.A.'s latest proposals provide the best solution so far advanced.



FRAME-GRID AERIALS?—These five helical aerials have been designed by Cossor Radar & Electronics and are for use by the War Office at the Guided Weapons Trials Establishment on the coast of Anglesey. They will operate in the frequency range 100—400Mc/s employing circular polarization and will be for telemetering missiles.

AIRBORNE HOMING SYSTEM

USE OF A PHASE-SHIFTING NETWORK

BY H. M. BOYLE,* B.Sc., A.Inst.P.

THE principle of measuring phase difference to provide direction finding information is well known. A new method for achieving the measurement was developed by Johnson and Beresford of R.A.E. in 1952 and is covered by British Patent No. 787,894. It involves the use of a phase-shifting network between two aerials used for the reception of the transmission on which it is required to home. Subsequent developments by the Plessey Co. have used the phase-shifting network principle in airborne homing equipments but the associated circuitry, both of the phase-difference measurement and of the equipment as a whole, has been much simplified and is described below.

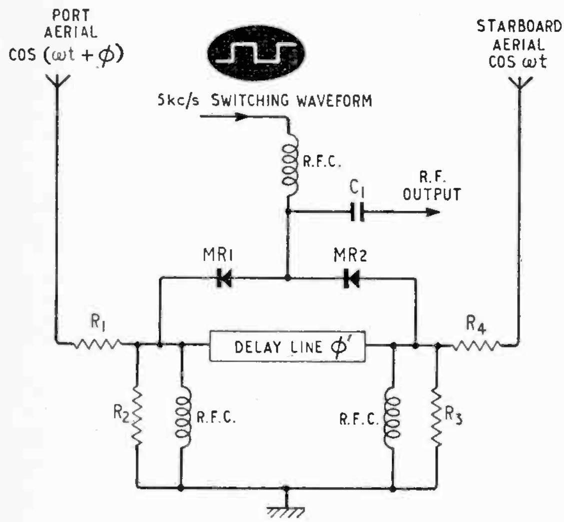


Fig. 1. Circuit for modulating a receiver carrier to provide homing information

The method of phase measurement takes the following form, the circuit being shown in Fig. 1. The diodes MR1 and MR2 are made to conduct alternately by the application of a low frequency switching waveform. The r.f. output can therefore be expressed as:

$\cos(\omega t) + \cos(\omega t + \phi + \phi')$— Diode MR2 conducting .. .. (1)

$\cos(\omega t + \phi') + \cos(\omega t + \phi)$— Diode MR1 conducting .. .. (2)

where ω refers to the carrier frequency of the received transmission, ϕ is the phase delay of the signal at the port aerial relative to that at the starboard aerial and ϕ' is the delay contributed by the phase shift network. This results in a square wave modulation of the carrier at the switching frequency and at a depth depending on ϕ. When $\phi = 0$ the two expressions above are equal and the modulation depth is zero. For any other value of ϕ, positive or negative, the modulation depth will increase, and the modulation is in phase, or in anti-phase, with the switching waveform according to the sign of ϕ. Thus the phase difference has been transformed into a modulation of the carrier and homing information provided. This can be seen by expanding expressions (1) and (2) above:

$$\text{i.e. } 2\cos\frac{(2\omega t + \phi + \phi')}{2}\cos\left[-\frac{(\phi + \phi')}{2}\right] \quad (3)$$

$$\text{and } 2\cos\frac{(2\omega t + \phi + \phi')}{2}\cos\left[-\frac{(\phi - \phi')}{2}\right] \quad (4)$$

These can be rewritten as:

$$A\cos\left[\frac{(\phi + \phi')}{2}\right] \quad \ldots \quad (5)$$

$$\text{and } A\cos\left[\frac{(\phi - \phi')}{2}\right] \quad \ldots \quad (6)$$

For negative values of ϕ expressions (5) and (6) may be written as:

$$A\cos\frac{(-\phi + \phi')}{2} \quad \ldots \quad (7)$$

$$\text{and } A\cos\frac{(-\phi - \phi')}{2} \quad \ldots \quad (8)$$

which become:

$$A\cos\left[-\frac{(\phi - \phi')}{2}\right] = A\cos\frac{(\phi - \phi')}{2} \quad (9)$$

$$\text{and } A\cos\left[-\frac{(\phi + \phi')}{2}\right] = A\cos\frac{(\phi + \phi')}{2} \quad (10)$$

These expressions are (5) and (6) reversed and the phase of the modulation is therefore changed for negative values of ϕ.

For completely satisfactory operation of this circuit in the u.h.f. band (225-400Mc/s) several points were investigated and a summary of these, and their solution, is now outlined.

It can be seen that it is essential to maintain the symmetry of the circuit, so that the indication of heading zero is not affected. At these frequencies, lead inductance and stray capacitance assume major importance and it was with a view to controlling these and maintaining symmetry that a "block" form of assembly was adopted. This method has the added advantage that the block acts as its own

* The Plessey Co. Ltd.

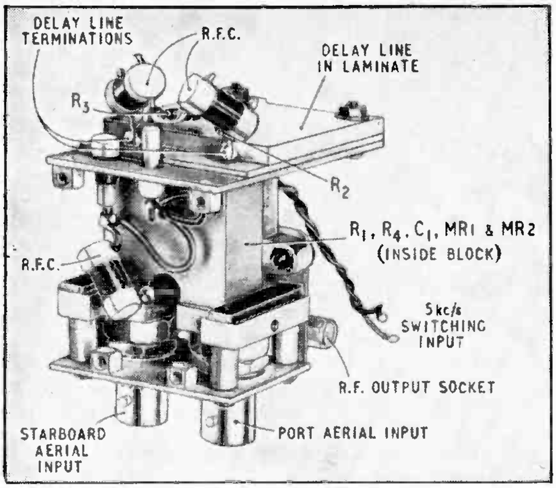


Fig. 2. Practical assembly of the circuit in Fig. 1

jig during assembly. Briefly, the resistors R_1 and R_4 and the diodes MR_1 and MR_2 are mounted in holes bored in a block of aluminium, the hole dimension being chosen to give an air-spaced transmission line, in association with the components and their leads, to give optimum performance over the band. The delay line consists of a brass horseshoe embedded in a dielectric of glass fibre laminate and spaced by the dielectric from the ground plane (the aluminium block) to give the required characteristic impedance. The assembly is shown at Fig. 2.

The choice of diode in itself constituted a major problem at the time (1956). The requirements are low forward resistance and high back impedance. The Transitron T19G diode was chosen finally, having a mean forward dynamic resistance of 6Ω and a minimum back impedance of 400Ω (capacitive). Germanium diodes were found more suitable than silicon because of their lower cut-on voltage in the forward direction, which eases the requirements for the switching waveform. Failure to cut the diode on quickly will result in " holes " in the carrier at 10kc/s, which were considered undesirable.

The choice of ϕ and ϕ' is affected by a number of factors, but in practice the aerial spacing was chosen to be 20 cm, which gives ϕ a value of approximately 96° at 400Mc/s at 90° heading. The delay ϕ' was chosen as 13.6 cm, giving 65° at 400Mc/s.

Some points of interest are worth noting before leaving this part of the circuit.

The switching frequency, although uncritical, is chosen to be approx. 5.0kc/s, which is outside the normal audio pass band of the associated receiver.

The circuit introduces a certain r.f. loss which is of no importance except in areas of weak signal. If it is desired to restore the signal to its previous level, an r.f. amplifier of good noise figure must be incorporated. This was done in one of the Plessey developments, the amplifier being tunable and controlled by the associated transmitter-receiver.

It should be noted that the circuit in no way affects the normal intelligence on the carrier and that only very heavy modulation will affect the homing function, resulting in a loss of homing sensitivity.

The complete system is shown in Fig. 3. The 5kc/s modulated carrier is passed into the associated receiver for demodulation. The demodulated 5kc/s square wave is taken out via a stage provided specifically for the purpose and passed back to the Homing Unit, where the signal is fed to a phase sensitive bridge. The 5kc/s switching waveform is also applied to the bridge, via a delay, to compensate for the phase delay suffered by the signal waveform in passing through the receiver. The resulting d.c. ouput is proportional to the amplitude of the signal wave form (provided that the signal waveform is small compared with the switching waveform) and of a polarity depending on the sign of ϕ. The d.c. output is applied to a Standard Service I.L.S. Indicator (Type 7 or 9024) for display in the pilot's cabin.

The Homing equipment derives its power supplies from the associated receiver and is controlled by the receiver's control unit. The power requirements are small, being 0.37A at 28V for heater supplies and approx. 12mA at 225V h.t.

It can be seen that having chosen ϕ' to be satisfactory at 400Mc/s, the phase delay introduced by the delay line is less at 225Mc/s. In addition, the fixed spacing of the port and starboard aerials means that for a given heading error, the value of ϕ is also less at the lower frequencies than at the high. Thus there is an inherent change in homer sensitivity (d.c. output versus heading error) over the band. Since it is desirable to have a sensibly constant output for a particular heading, regardless of operating frequency, a potentiometer has been fitted to the receiver, controlled by the frequency setting elements of that receiver. This potentiometer is used to control the gain of the 5kc/s signal amplifier in the Homing Unit, as the carrier frequency is varied.

It should be borne in mind that the system just described is not necessarily restricted to the u.h.f. band, although modifications to the delay line length and the aerial spacing would be required.

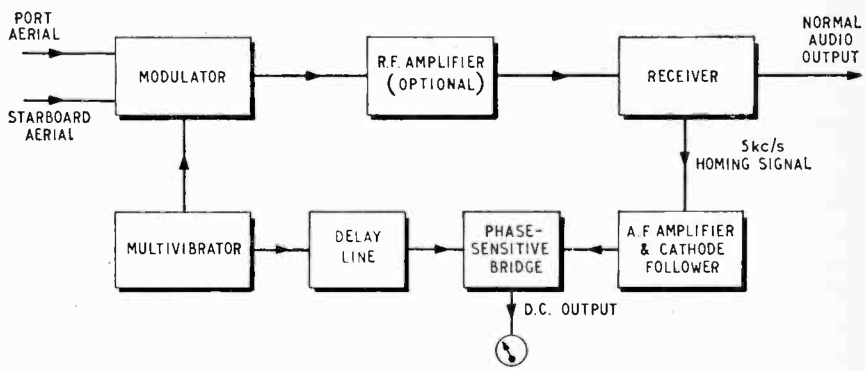


Fig. 3. Block diagram of homing system

WORLD OF WIRELESS

I.E.E. and Electronics

THE scheme put forward some months ago by the I.E.E. for the reorganization of the Institution to give a stronger emphasis to its "electronics" activities has now been approved by its members. Privy Council permission has to be sought but, in the meantime, plans are going ahead for the introduction of the scheme next October.

The present four Specialized Sections (Measurement and Control, Electronics and Communications, Supply, and Utilization) will be replaced by three Divisions: (i) Electronics, (ii) Power, and (iii) Science and General. Each Division will work through about ten relatively specialized Professional Groups. The number and scope of these groups "can be modified quickly to reflect any change of emphasis in the technological scene."

Dual-Standard TV in Eire

TELEFIS EIREANN (Irish Television Service) as already announced will ultimately adopt the 625-line television standard and their first two stations will therefore be equipped for both 405- and 625-line transmissions. They have placed a £175,000 contract for four 625-line television transmitters and associated equipment with the Pye Group. At two of the Eire stations, at Mount Kippure, near Dublin, and at Truskmore Mountain in Co. Sligo, a "combining unit" will be used to allow radiation of 405- and 625-line transmissions simultaneously from a "dual standard" aerial. The other two 625-line equipments ordered are for stations at Mount Leinster, Co. Carlow, and Mullaghanish Mountain, Co. Cork. Proposed date for the commencement of 405-line programme transmissions from the television station at Kippure is December 31st. Test transmissions are being radiated in Channel 7 with horizontal polarization, between the hours of 11.30 a.m. and 1 p.m., also from 3 p.m. to 5 p.m. and 6.30 p.m. to 7 p.m.

"Random Radiations"

THIS is the first issue since January 18th, 1935, in which "Diallist's" contribution "Random Radiations" has not appeared. As a result of ill health, and at his own request, he has felt obliged to relinquish the task of sustaining this regular feature.

As some readers may know, "Diallist" is the pen name of Major R. W. Hallows, M.A.(Cantab.), M.I.E.E., who, in addition to his regular contribution to *Wireless World*, has also frequently written under his own name. One of his special interests is batteries, and he was, for some 30 years, European consultant to the Burgess Battery Co. Inc.

Throughout the war Major Hallows, who is 76, was in the Royal Artillery and was for some time Chief Instructor, Radar, at the 6th A.A. Group School. He is the author or joint author of a number of books, including "The Oscilloscope at Work," "Introduction to Valves" and "Radar Simply Explained."

Pay TV Tests?

A PLEA to the Postmaster General for a licence to allow relay undertakings to conduct an experimental field test of Pay TV by wire was made by Barry King, chairman of the Council of the Relay Services Association, at the Association's annual luncheon on November 14th, at which Miss Mervyn Pike, Asst. P.M.G., was principal guest. Miss Pike had herself referred to the potentialities of Pay TV in her speech. The number of homes in this country served by wire television systems is now over 500,000; about 95% of all subscribers to television and sound relay systems in the U.K. are served by members of the Association.

Instruments for Export

SOME 150 delegates, representing over 70 scientific instrument manufacturers and a number of Government research establishments, attended the tenth annual convention of the Scientific Instrument Manufacturers' Association at Eastbourne from November 15th-18th. The theme was "export." After the opening session, which was addressed by Sir Charles Fitton, past president of the Institute of Export, and representatives from the governments of the U.S.A., Sweden and Australia, the delegates were free to attend the meetings of the three specialized panels (technical, marketing and economics) which ran concurrently.

The first session of the technical panel was addressed by G. W. A. Dummer, of the Royal Radar Establishment, on the subject of design for export. By way of introduction he mentioned that 6·3% of all equipment delivered to the R.R.E. under contract was outside tolerance or not working. Manufacturers may be interested to learn that the results of the R.R.E.'s specialized tests on a variety of apparatus are readily available.

Other sessions of the technical panel dealt with the "requirements of the overseas user," "problems of overseas manufacture" and "after sales service."

B.B.C. Portsmouth Exhibition.—The B.B.C. is staging a public exhibition at the Guildhall, Portsmouth, from November 29th to December 2nd, from 12 noon to 10 p.m. daily. B.R.E.M.A. are supporting the show and nineteen manufacturers will be exhibiting their radio and TV receivers. The B.B.C. is to relay TV and sound programmes direct from the Guildhall and the f.m. signal from Rowridge will also be provided for demonstrating radio.

I.T.A. Selkirk Station.—A temporary 200ft mast at the Independent Television Authority's Selkirk station will come into operation at the beginning of December. A permanent 750ft tower is being built which it is hoped will become operational not later than March 1962. The signal radiated from the temporary mast will be on Channel 13, vertically polarized, and e.r.p. will be 4kW, to be increased to 25kW when the permanent mast is used.

Microwave Valves Conferences.—September 1963 has been chosen as the date for a Conference on the Design and Use of Microwave Valves and an associated scientific exhibition, which is being organized by the Electronics and Communications Section of the Institution of Electrical Engineers. It will be held at Savoy Place, London, W.C.2. The next in the series of international conventions on microwave valves is to be held at The Hague, Holland, from September 3rd-7th, 1962. The I.E.E. also announces that a Conference on Components in Microwave Circuits will take place in London in September 1962.

Radio & Television Servicing.—The report on the servicing examinations held in May by the City and Guilds of London Institute and the Radio Trades Examination Board records that of the 2,068 candidates who sat the intermediate written exam. 1,108 (53.6%) passed. The 1960 figures were 560 entrants, 336 (60%) passes. Of the 717 who took the final examination in May 285 (29.8%) got a first class and 367 (51.2%) second class pass. This is the first year of the combined sound radio and television syllabus.

Radio Amateurs' Examination.—The Standard of papers submitted at the examination, conducted by the City and Guilds in May, "showed a welcome improvement over that of last year", says the report. A total of 1,251 entered and 866 (69.2%) passed compared with 1,274 and 699 (54.9%) in 1960.

The Physics of Semiconductors is the subject of an international conference, which is to be held at the University of Exeter from July 16th-20th, 1962. It is being organized under the auspices of the International Union of Pure and Applied Physics by the Institute of Physics and the Physical Society, 47 Belgrave Square, London, S.W.1. Provisional programmes and application forms may be obtained from the Administration Assistant at the aforementioned address.

The F.B.I. and its Japanese counterpart, Keidanren, are to make efforts "to realize at an early date a freer flow of trade between the two countries by progressively reducing and ultimately eliminating import restrictions and conducting orderly marketing, and to promote economic co-operation and technical links between the two countries by encouraging closer contact and fuller understanding between the industrialists of both countries." Following a visit by Sir Norman Kipping, Director-General, and J. R. M. Whitehorn, Deputy Overseas Director, the Federation has published a report entitled "A Look at Japan." Copies, price 10s, are available from the F.B.I., at 21 Tothill Street, London, S.W.1.

Domestic Receiver Design.—Papers of particular interest to those in the "entertainment radio and television industry" are being sought for the I.R.E. Chicago Spring Conference on Broadcast and Television Receivers, arranged for June 18th and 19th. Offers of papers, including a 50-100-word summary, should be sent to Al Cotsworth, Zenith Radio Corporation, 6001 West Dickens Avenue, Chicago 39, Ill., as soon as possible.

Television in South Africa will not arrive for at least another five years owing to the heavy cost of installation, stated Dr. P. J. Meyer, chairman of the board of the South African Broadcasting Corporation, on his return from a two-month trip abroad to study radio and television techniques.

The B.B.C. has placed an order for ten Marconi 250-kW short-wave transmitters which use vapour-cooled triodes made by the English Electric Valve Company. The new transmitters form part of a re-equipment programme for the B.B.C.'s External Services transmitting stations; six will be installed at the Woofferton station, which is used to relay the Voice of America, and two each at Daventry and Rampisham, Dorset.

U.S.S.R. Academy of Sciences were hosts to Professor T. Kilburn and Dr. D. B. G. Edwards of the University of Manchester, when they travelled to Moscow recently to deliver a series of lectures on the Ferranti Atlas electronic digital computer. Ten lectures were given altogether, over a period of five days, to an audience of technologists and engineers at the Institute of Precise Mechanics and Computing Technique in Moscow. Discussions showed that the Russians have a different approach on the general philosophy of computer design. Their policy is to build separate machines for scientific and data processing applications, and they are putting a great deal of effort into the development of faster storage and other components.

Colour Television test transmissions on 405 lines from the Crystal Palace transmitter were restarted by the B.B.C. in October. They are conducted from 1600 to 1630 on Mondays to Fridays. A simplified explanation and also a detailed specification of the system employed are available from the Engineering Information Department, Broadcasting House, London, W.1. The detailed specification is given on Information Sheet 2202/2.

The Scottish Electrical Training Scheme, launched some six years ago to train executives for the member firms in Scotland, has made outstanding progress, reports J. S. Hastie, of Scottish Cables Ltd., current chairman of directors. He said the 119 graduates and students attending the recent fifth annual conference was the highest figure since the start of the scheme, and it was planned to encourage volunteers for higher advanced courses to qualify graduates for the top posts in the industry and a start would be made shortly on an advanced mathematics course to meet this need. S.E.T.S. also plans to train one overseas student each year, returning him to his own country to work, as a gesture to the electrical industry abroad.

Westinghouse Schools Training Course.—A further "Introduction to Industry" training course will be held by Westinghouse at their Chippenham Works during the week January 8th-12th inclusive. This is for sixth-form boys taking G.C.E. "A" level examinations in science subjects in 1963. Applications should be addressed to the Personnel Superintendent, Westinghouse Brake & Signal Co. Ltd., Chippenham, Wilts., by December 1st.

Norwood Technical College, London, S.E.27, is introducing the first of two six-lecture evening courses on transistors on January 16th. The first course covers fundamentals and the second, beginning on February 27th, applications. The fee for each course is 10s.

Medium-wave DX.—A "set listening period" from 0100 to 0300 G.M.T. on December 2nd has been arranged by the group of DX enthusiasts which issues the monthly duplicated news sheet "Medium-wave News". Reports of long-distance reception will be welcomed by K. Brownless, 7 The Avenue, Clifton, York, who edits the news sheet.

WHAT THEY SAY

Component Research.—"It is perhaps not widely known that the British Electronics Industry spends out of its own resources a greater percentage of its gross turnover [on reasearch and development], approximately 12%, than any other industry in the United Kingdom." —*A. F. Bulgin, president of R.E.C.M.F., at the opening of the Stockholm component exhibition.*

Problems for Pilkington.—"Never in the long history of committees and commissions have so many problems been compressed into so few words."—*Miss Mervyn Pike, Assistant P.M.G., referring to the terms of reference of the Pilkington Committee at the Relay Services Association luncheon.*

Personalities

Sir Gordon Radley has succeeded **Lord Nelson of Stafford** as chairman of Marconi Instruments, Marconi Marine, and English Electric Valve Company and has also been appointed deputy chairman of Marconi's W/T Company. Lord Nelson has also retired from the chairmanship of Marconi's W/T and is succeeded by his son the **Hon. George Nelson.** Other appointments to the Boards of the subsidiaries of the English Electric Company include:— **F. N. Sutherland** as deputy chairman and **Dr. E. Eastwood** as a director of Marconi Instruments; **P. L. de Laszlo** as deputy chairman of E.E. Valve Co.; and **D. P. Furneaux** as managing director designate of Marconi Marine in succession to **R. Ferguson** who retires at the end of the year.

J. H. Westcott, B.Sc., D.I.C., Ph.D., M.I.E.E., who is 41, has had the title of Professor of Electrical Engineering in the University of London conferred on him in respect of his readership at Imperial College. Dr. Westcott, after post-graduate research on servo-mechanisms at the college and at the Massachusetts Institute of Technology, joined the Government scientific service in 1942 and was for some time at what is now R.R.E., Malvern. He was on the Control Commission for Germany in 1945/6. Dr. Westcott, who is chairman of Feedback Ltd., of Crowborough, Sussex, was responsible for the setting up of the control systems laboratory at Imperial College which he joined in 1950.

R. J. Hitchcock, M.A., A.M.I.E.E., consultant to Cable and Wireless where he was for some time engaged on radio-frequency allocations and radio propagation problems in general, has recently visited the Bell Laboratories in America to study the problems of satellite communications. Mr. Hitchcock, who has represented C. & W. at many international conferences and is a member of several study groups of the C.C.I.R., has contributed articles to *Wireless World* on various aspects of international telecommunications. He is a member of the committee set up by C. & W. to consider "what part, if any, the company should take in the provision of satellite relays." The committee is presided over by **H. C. Baker,** a director, and among the eight members is **P. A. C. Morris,** who is in charge of the company's radio propagation section.

John V. Dunworth, C.B.E., M.A., Ph.D., F.Inst.P., A.M.I.E.E., the new deputy director of the National Physical Laboratory, was throughout the major part of the war working on the development of radar; first with the Admiralty and later with the Ministry of Supply at R.R.E. He succeeds **Dr. G. G. Macfarlane,** who, as announced recently, is going to Malvern as director of R.R.E. Dr. Dunworth, who is 44, graduated at Cambridge University in 1937 and did post-graduate research under Lord Rutherford. After the war he returned to Cambridge to take up his Fellowship at Trinity College and was appointed a demonstrator in physics in the Cavendish Laboratory. He joined the Atomic Energy Research Establishment in 1946, and since 1959 has been deputy director of the Atomic Energy Establishment, Winfrith.

R. E. Fischbacher, B.Sc., A.M.I.E.E., has been appointed an assistant director of the British Scientific Instrument Research Association which he joined in 1957 as head of the Electronics Department. Educated at the Royal College of Science and Technology, Glasgow, and the University of Glasgow, Mr. Fischbacher served for 12 years in the Admiralty Signal and Radar Establishment as a member of the Royal Naval Scientific Service before joining the B.S.I.R.A.

Air Comdre. A. G. P. Brightmore, M.Brit.I.R.E., Director of Electronics Research and Development (Air) in the Ministry of Aviation, and **Air Comdre. F. E. Tyndall,** B.Sc., Director of Radio at the Air Ministry, have exchanged posts. Air Comdre. Brightmore, who is 53, has been in the Ministry of Aviation since 1958 having previously served for two years as chief signals officer of the 2nd Tactical Air Force. At one time he commanded No. 3 Radio School, R.A.F., at Compton Bassett, Wilts. Air Comdre. Tyndall, who is a member of the Post Office Frequency Advisory Committee, has been in the Air Ministry directorate of radio since April, 1959. He is 48.

Frank Poperwell, Assoc.Brit.I.R.E., who recently joined the Derritron group of companies as technical sales supervisor, has now been appointed general manager of Reslosound Ltd. (a member of the group). Prior to joining the group a few months ago he was with the G.E.C. for 35 years where he was technical supervisor of the Sound Equipment Division. **L. W. Murkham,** founder of Reslosound recently sold his interest in the company to the Derritron group.

C. J. Salvage contributes to this issue a constructional article on a transistor communications receiver which he designed for use with a 6-band miniaturized transmitter. He is a keen s.s.b. amateur transmitter (his call is G3HRO) and in 1956, using his own s.s.b. equipment, participated in the first six-continent R/T link-up on 20 metres. The receiver described, and its associated transmitter, was awarded first prize at the National Mobile Rally at Woburn Abbey in September. Mr. Salvage is chairman of the Aquila Radio Club of the Inspection Branch of the Ministry of Aviation where he has been employed since 1940.

T. H. Whitaker, who has been with Cossor Radar & Electronics since 1957, is going to New Zealand early next year to supervise the installation of eight meteorological radars, three of which will be on the islands of Fiji, Funafuti, and Rarotonga. He will also instruct staff of the N.Z. Civil Air Administration on the handling and servicing of the equipment. Mr. Whitaker, who is 32, was trained as a radar mechanic in the R.A.F.

T. H. Whitaker

W. P. Raffan

W. P. Raffan, B.Sc., A.Inst.P., has been appointed head of the newly formed Solid State Division of 20th Century Electronics. He was formerly with Rank Cintel where, during the past three years he has been engaged in the development of solid state devices.

Eric K. Cole, C.B.E., M.Brit.I.R.E., has resigned from the position of deputy chairman of British Electronic Industries Ltd. (the holding company formed on the merger of Pye and Ekco a year ago) and also from the chairmanship of E. K. Cole Ltd. and its subsidiaries, which include Ekco Electronics Ltd. and 20th Century Electronics Ltd. Mr. Cole, who was elected an honorary member of the Brit.I.R.E. in 1959 "in recognition of his services to the radio and electronics industry and profession," founded the company bearing his name in 1926 when he was 25. He was appointed a Commander of the Order of the British Empire in 1958. The chairman of B.E.I. is **C. O. Stanley**, chairman and managing director of the Pye Group.

C. J. Maurer, B.Sc.(Eng.), A.M.I.E.E., of Romford, Essex, and **W. T. Warnock**, A.M.I.E.E., A.M.Brit.I.R.E., of Stone, Staffs., both Post Office engineers, have received the Insignia Award in Technology from the City and Guilds of London Institute (C.G.I.A.). Mr. Maurer joined the Post Office Engineering Department in 1939, where he returned in 1946 after war service as a radar mechanic in the R.A.F. He is now an executive engineer and for the past six years has been working on the introduction of "international subscriber dialling". Mr. Warnock, who joined the Post Office in 1933, has been on the staff of the P.O. Central Engineering Training School at Stone since 1958, where he is now deputy principal.

News from Industry

Associated Television has formed a new wholly owned subsidiary, Planned Holdings Ltd., to integrate the technical and marketing resources of all the firms in its Planned Group of companies. This new company will be responsible for the future development of the Group into the field of sound and music services. Member companies of the Planned Group are Planned Music Ltd. (Muzak background music system), Planned Communications Ltd. (line networks) and Planned Equipment Ltd. (Audiomatic automatic audio-visual selling and communication system). J. B. C. Bennett, B.Sc. (Eng.), A.M.I.E.E., has joined the board of Planned Music Ltd. D. Humphriss and H. F. Mould, who were until recently in the Sound Equipment Section of the G.E.C., have joined the Planned Group of companies. Mr. Humphriss is regional liaison engineer and Mr. Mould public address engineer.

G.E.C. Telecommunications Group.—Two new operating companies, G.E.C. (Telecommunications) Ltd. and G.E.C. (Electronics) Ltd., have been formed by the General Electric Company to take over the activities of its Telecommunications Group. Co-ordination and direction of these companies will be undertaken by a newly formed holding company, G.E.C. (T. & E.) Holdings Ltd. O. W. Humphreys has been appointed executive chairman of the holding company and chairman of the two new operating companies. W. A. C. Maskell is director of the holding company, C. Riley director and general manager of G.E.C. (Telecommunications) Ltd., and R. J. Clayton director and general manager of G.E.C. (Electronics) Ltd. Brigadier John Clemow has been appointed engineering director of the latter company. The headquarters of G.E.C. (Telecommunications) Ltd. will be at G.E.C. Telephone Works, Coventry, and of G.E.C. (Electronics) Ltd. at Union Works, Wembley.

Cossor Board Appointments.—As a result of the purchase of A. C. Cossor Ltd. by Raytheon Company, of Massachusetts, U.S.A., the following have been elected to the board of A. C. Cossor:—Charles F. Adams, chairman of the board of Raytheon; Richard E. Krafve, president of Raytheon; and Dr. Carlo L. Calosi, vice-president of Raytheon. Raytheon have already announced their intention of preserving the identity of the Cossor Group. Major-General Sir Miles Graham continues as chairman and James S. Clark as managing director.

English Electric in France.—A new company, La Compagnie Continental D'Equipements Electriques (C.E.E.) has been formed by the English Electric Company and the French firm, Les Exploitations Electriques et Industrielles, to manufacture electric and electronic control equipment for France and the Common Market countries.

Plessey—A.T.E.—Ericsson Merger.—Completion of the merger between the Plessey Co. Ltd., Automatic Telephone & Electric Co. Ltd., and Ericsson Telephones Ltd., has been effected, and it is announced that A. F. Roger, A.T.E. chairman, and Sir Harold A. Wernher, chairman of Ericcson, have been appointed to the Plessey board of directors.

Decca Record Company's group net profit for the year ended March 31st is £1,249,229 as compared with £1,260,729 for the previous twelve months. Consolidated trading balance was higher at £3.7M (£3.4M), but exports, including £1.4M (£2.3M) to the U.S. and Canada, were lower at £7.1M (£8.1M).

International Rectifier Corporation.—Consolidated sales and earnings for the year to June 30th show a sales increase of 11% over the previous twelve-month period, and a profit margin of 7.4% after taxes. The Corporation, with headquarters at El Segundo, California, U.S.A., has a 50% share in International Rectifier Co. (Great Britain) Ltd. with Metal Industries Ltd. having a similar interest.

Solartron Sold To Schlumberger.—Firth Cleveland have sold for just under £2M their 56.7% holding in the Solartron Electronic Group to Schlumberger of Houston, Texas, who themselves were linked recently with the American Daystrom company. Firth Cleveland acquired their controlling interest in Solartron two years ago. Schlumberger has other interests in electronics and instrumentation both in the U.S.A. and Europe.

Console *of the 34-channel sound mixer manufactured by Pye for the Elstree Studios of Associated Television. In addition to providing mixing facilities for studio microphones it also provides echo effects and talk-back facilities.*

S.I.M.A. Delegation to Italy.—In 1960, only 8% of the scientific instruments imported into Italy came from the U.K. compared with 35% from west Germany and 21% from the U.S.A. In an effort to remedy this a delegation of the Scientific Instrument Manufacturers' Association of Great Britain visited main Italian cities recently to discuss marketing problems and to collect information on the instrument needs of Italian research programmes and industry.

Cambridge-C.G.S. is the title of a new company formed jointly by Cambridge Instrument Co. Ltd. and Istrumenti Di Misura, C.B.S. Located at Casoria, near Naples, the company will initially manufacture instruments based on Cambridge designs. English members on the board of Cambridge-C.G.S. are Dr. P. Dunsheath, H. C. Pritchard and W. E. Lamb.

T.C.C.—Sprague Exchange.—The Telegraph Condenser Company and the American Sprague Electric Company have recently agreed to a mutual exchange of technical "know-how," whereby the two organizations will share their research and manufacturing experience. T.C.C. are the sole distributors in the U.K. for Sprague products.

Raytheon Company are to acquire all of the assets of Rheem Semiconductor Corp., a subsidiary of Rheem Manufacturing Company, at Mountain View, California.

Marconi Cameras For ITN.—Four Marconi Mark IV television cameras ordered by Independent Television News are now in use at the ITN headquarters in Television House, Kingsway. This is part of a general re-equipment of ITN's facilities to enable them to carry out more ambitious programmes. The installation has been designed by ITN's own engineering staff and will be their first use of 4½in image orthicon cameras.

Hudson Electronic Devices Ltd., who specialize in the design and manufacture of v.h.f. radio-telephone equipment, have received an order from the Home Office, worth nearly £30,000, for 200 of their Type AM112 mobile 15-W equipments to be used by the Police. This follows a similar order last year.

E.M.I. Electronics Ltd. have been awarded a £30,000 contract by the Independent Television Authority for the installation of a 450ft tower and aerial array in Jersey, Channel Islands.

I. S. B. Transmitters.—Marconi's are to supply to the Admiralty a large number of 500-W m.f./h.f. independent sideband communication transmitters of a new type, NT204, which embody continuous tuning from 240kc/s to 24Mc/s. Value of order is about £90,000.

Manchester Minicabs have been equipped with Storno-Southern f.m. transistor radio telephones. A 25-W base station at Gorton feeds a standard centre-fed dipole aerial mounted on an 80ft mast, and ranges of up to 30 miles are being obtained.

British Communications Corporation, a subsidiary of Radio & Television Trust, has recently obtained a large contract for the supply of v.h.f. transmitter/receivers Type A.40 to the British Army.

Pickering Cartridges.—Goldring Manufacturing Company, of Leytonstone, London, E.11, advise that they are now marketing certain items of the American Pickering range of audio equipment in this country. These include the Unipoise 198 integrated arm and cartridge and a selection of Pickering cartridges.

Walmore Electronics Ltd., of 11-15 Betterton Street, London, W.C.2, have been appointed by Siemens & Halske A.G., west Germany, as U.K. representatives for their transmitting and special receiving valves.

Metal oxide film resistors developed in the U.S.A. by Corning Glass Works, are being manufactured in the U.K. by Jobling and marketed by Electrosil Ltd., of Colnbrook By-Pass, Slough, Bucks. The latter company was formed recently by Corning in association with James A. Jobling & Co. Ltd.

Tape heads manufactured by Wolfgang Bogen G.m.b.H. of Berlin, previously available through Gopalco Ltd., are now obtainable from R. H. Cole (Overseas) Ltd., 2 Caxton Street, Westminster, London, S.W.1. (Tel.: Sullivan 7060), who have been appointed sole U.K. agents. Components made by Bogen include mono and stereo heads for domestic tape recorders, erase heads and a range of single and multiple heads for professional applications.

ETEL Sales Move.—Electronic Tubes Ltd. advise that the sales and technical information office of their Instrument Cathode-Ray Tube Division is now at 80 New Oxford Street, London, W.C.1 (Tel.: Langham 0800).

New Telephone Numbers.—The Gresham Lion Group of Companies, Gresham House, Hanworth, Middx., advise their new number is Feltham 3655. (The telephone number of Gresham Transformers Ltd. continues as Feltham 6661.) Mullard Equipment Ltd., Crawley New Town, Sussex, have had their number changed to Crawley 28787.

Ampex Great Britain Ltd., which is responsible for the sales of Ampex equipment in the U.K., has moved to 72 Berkeley Avenue, Reading (Tel.: Reading 55341).

Dawe Instruments Ltd. have moved from Harlequin Avenue, Brentford, to Western Avenue, Acton, London, W.3 (Tel.: Acorn 6751).

Lee Products (Gt. Britain) Ltd. have transferred from Longford Street, N.W.1, to new offices at 10-18 Clifton Street, London, E.C.2 (Tel.: Bishopsgate 6711).

OVERSEAS TRADE

1962 Near East International Fair is to be staged in Tel Aviv, Israel, from June 5 to July 5, when Western visitors will find the opening times a little strange. They are 4 p.m. to midnight except on Saturdays, when they will be sunset to midnight. Electrical, cooling, heating and radio and TV products will be exhibited in a wide range of merchandise. British participation is being organized by Industrial & Trade Fairs Ltd., Commonwealth House, New Oxford Street, London, W.C.1.

Marconi's were responsible for equipping Ghana's new external broadcasting station, with its four 100-kW transmitters capable of world coverage. Marconi's have also been awarded a contract by the Ghana Posts & Telegraphs authorities for the supply and installation of a twin-path v.h.f. multichannel radio-telephone system to link the Volta river dam area with Accra, the capital. The carrier equipment will be provided by the Automatic Telephone & Electric Company.

W. G. Pye Get Russian Order.—Following an enquiry received at the British Trade Fair in Moscow this year, an order for industrial pH measuring, recording and controlling equipment worth £15,000 has been obtained by W. G. Pye & Co. Ltd. from the official U.S.S.R. buying agency, Mashpriborintorg.

Danmarks Radio, the Danish state broadcasting service, has placed an order with E.M.I. Electronics Ltd. to supply four 4½in image orthicon camera channels for use in the Copenhagen studios.

The Royal Malayan Navy has selected Decca True Motion marine radar for the six new fast patrol craft now on order from Vosper's.

Transistor High-Fidelity Pre-Amplifier

By R. TOBEY, M.A. and J. DINSDALE, B.A.

COMPREHENSIVE INPUT/EQUALIZING CIRCUITS, TONE CONTROLS AND FILTERS

IN the following article details are given of the design of a pre-amplifier, incorporating all the usual facilities, for use with the transformerless transistor power amplifier described in last month's issue.

This pre-amplifier may also be used with sensitive valve power amplifiers, such as the Mullard 510, when compactness, complete absence of hum and (with suitable transistors) improved signal-to-noise ratio, are required.

A two-stage circuit (Fig. 1) conforming fairly closely to standard valve practice, is used. The first stage provides equalization by frequency-selective negative feedback, and a wide variety of inputs may be catered for. The second stage is an adaptation of the well-known Baxandall tone control circuit, giving an ample range of control of both treble and bass by negative feedback. High- and low-pass filtering is also provided, again by the use of negative feedback.

Input Equalizing Stage.—The basic circuit is shown in Fig. 2. Any equalization curve consisting of slopes not exceeding 6 dB per octave may be produced by a suitable choice of components R_1, R_F, C_1, C_2. A typical curve is shown in Fig. 3.

The value of R_F sets the current sensitivity of the stage, and R_1 sets the input impedance (equal to R_1) and hence the input voltage sensitivity. Where maximum input sensitivity is not required, the equalizing networks may be derived directly from those used in valve circuits, but using component values suitable for transistors. Fig. 4 and Table I give typical values for the most usual applications.

This approach, however, does not lead to the best exploitation of transistor characteristics, since the transistor is a current-operated device, and the lower the input impedance which can be used, the greater the sensitivity. When used with low-output magnetic pickups and tape heads, valve pre-amplifiers are arranged to have an input impedance which places the L/R integration beyond the audio pass-band. For example, for a 500-mH pickup, most manufacturers specify an input impedance of at least 68kΩ, giving attenuation starting around 20kc/s. Greater sensitivity can be produced from a transistor pre-amplifier by using a lower impedance,

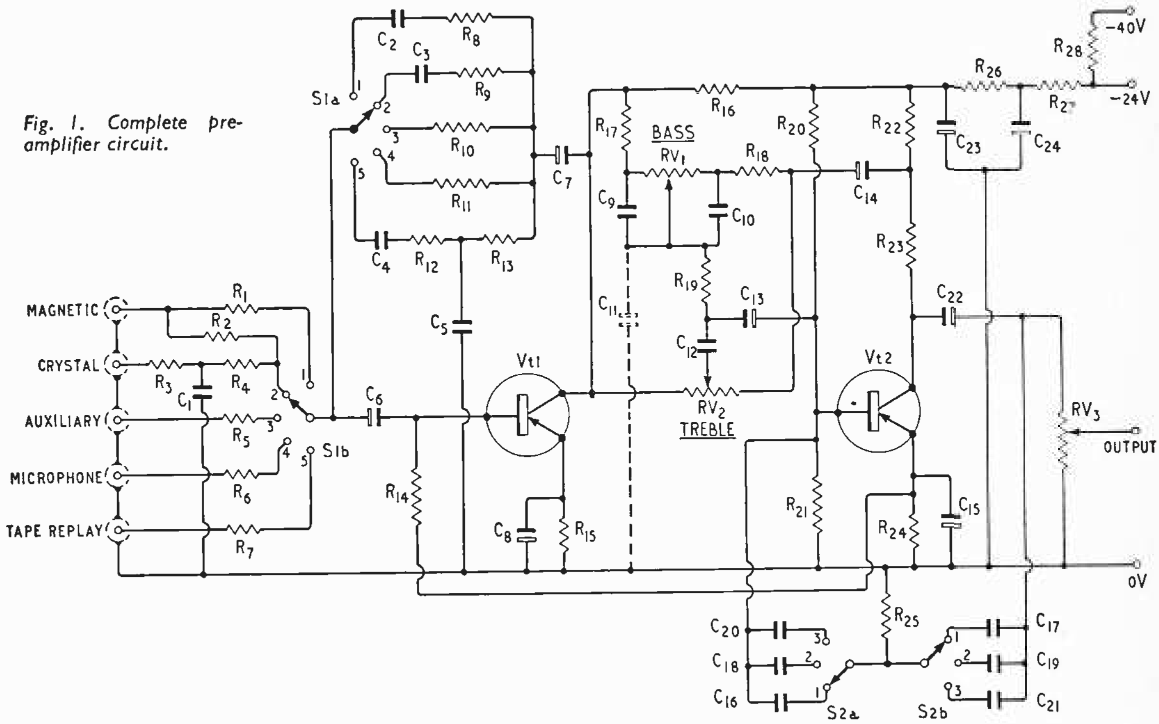


Fig. 1. Complete pre-amplifier circuit.

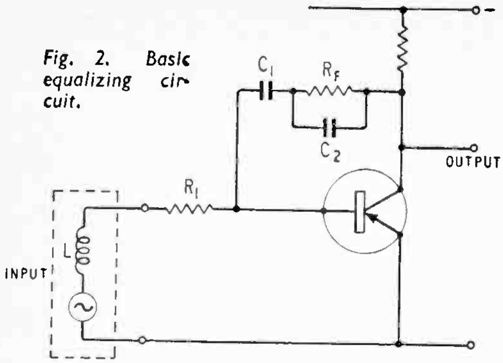


Fig. 2. Basic equalizing circuit.

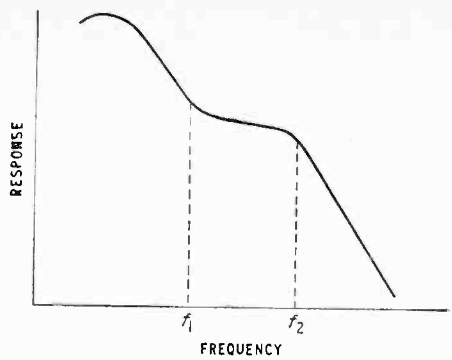


Fig. 3. Response given by equalizing circuit of Fig. 2. $f_1 = 1/2\pi C_1 R_F$ and $f_2 = 1/2\pi C_2 R_F$ or $R_1/2\pi L$.

Table 1

Component Values for Pre-Amplifier (Figs. 1, 4, 8)

Resistor	Value (kΩ) All Resistors are ¼W, 5%	Capacitor	Value (F) and Working Voltage
R 1	3.9	C 1	2,000p
R 2	5.6	C 2	5,000p
R 3	47	C 3	0.01μ
R 4	47	C 4	0.01μ
R 5	100	C 5	8,200p
R 6	1	C 6	10μ 12V wkg
R 7	1	C 7	2μ 25V wkg
R 8	47	C 8	100μ 6V wkg
R 9	39	C 9	0.1μ 5%
R10	33	C10	0.1μ 5%
R11	180	C11	0.01μ 5%
R12	18	C12	0.01μ 5%
R13	12	C13	25μ 12V wkg
R14	22	C14	2μ 25V wkg
R15	2.7	C15	100μ 6V wkg
R16	10	C16	1,000p
R17	3.3	C17	1,000p
R18	3.3	C18	2,000p
R19	3.3	C19	2,000p
R20	39	C20	5,000p
R21	10	C21	5,000p
R22	1	C22	5μ 12V wkg
R23	2.2	C23	50μ 25V wkg
R24	1.5	C24	50μ 25V wkg
R25	2.7	C25	5,000p
R26	2.7	C26	1,500p
R27	2.7	C27	0.01μ
R28	6.8	C28	1,000p
R29	47	C29	2,000p
R30	180	C30	100μ 6V wkg
R31	220		
R32	100		
R33	22		
R34	47		
R35	62		
R36	47		
R37	33		
R38	150		
R39	47		
R40	2.2		
R41	2.2		
R42	1.8		
R43	1.5		
R44	1.5		
R45	3.9		
R46	0.33		
RV1	50 lin		
RV2	25 lin		
RV3	10 log		
RV4	5 lin		

and a value can be chosen in conjunction with the inductance of the input source which gives part of the required equalization characteristic.

For example, the standard l.p. characteristic calls for de-emphasis above 2kc/s which can be produced by feeding a 500mH-pickup into 6.8kΩ-resistor. The bass emphasis required during the playback of tape may also be produced in this way. The complete circuit diagram (Fig. 1), together with Table 1, give component values for the most widely used types of equalization, assuming in the case of the magnetic pickup and tape head, an inductance of 500mH, which is the value most commonly used. For other inductances the input resistance should be changed to keep the same L/R ratio. The performance of the record equalizing networks is shown in Fig. 5.

If it is desired to use the same equalizing networks for non-inductive pickups (e.g., a crystal pickup), the treble de-emphasis must be provided at the input. In Fig. 1 this is done by R_3 and C_1.

Tone Controls.—The tone-control circuit gives a mid-frequency gain set by the values of R_{22} and R_{23},

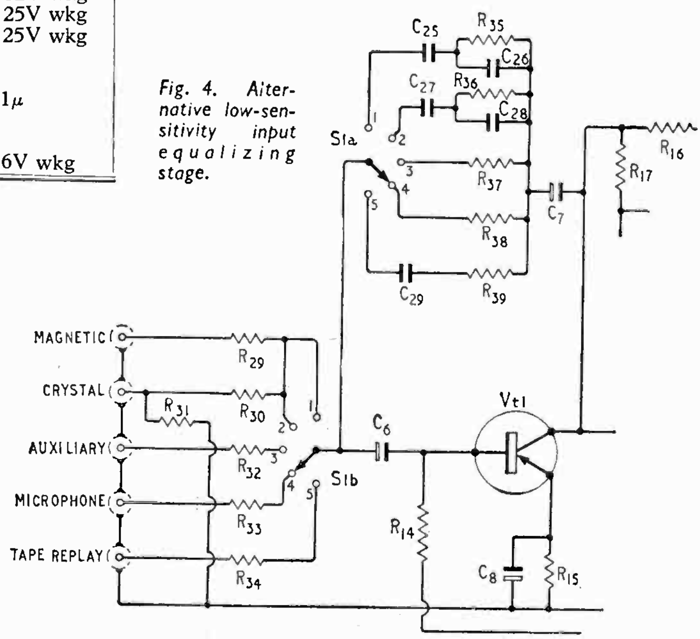


Fig. 4. Alternative low-sensitivity input equalizing stage.

a stage gain of about three being convenient. For a fuller description of the operation of this type of circuit the reader is referred to the original article (by P. J. Baxandall in the Oct. 1952 issue of *Wireless World*). The tone-control characteristics of the pre-amplifier are shown in Fig. 6. A different form of the treble characteristics, giving less severe control of the highest frequencies, is shown dotted, and these may be obtained by removing C_{11}. Without C_{11}, the "star" formed by R_{17}, R_{18}, R_{19} is equivalent at high frequencies to a "delta"-connected configuration of resistors which shunts each portion of the treble control, giving additional feedback and feed forward of current to the virtual-earth point (Vt 2 base). C_{11} earths the centre-point of the star at high frequencies and eliminates the shunting effect, hence allowing the treble control to operate as expected.

Filters.—The pre-amplifier can be designed to give a frequency response extending well outside the audio band, but in practice this is often an embarrassment. Many wide-range pickups produce peaks of considerable amplitude at frequencies above the audio band, which can give rise to audible intermodulation effects; also the modern trend to stereo pickups with their high vertical output, and small speaker enclosures giving little loading of the extreme bass, may make high-pass (or rumble) filtering a necessity. The slope of attenuation of frequencies above and below the audio band given by the filters varies with the setting of the corresponding tone control (see Fig. 6), since both filtering and tone control are achieved by feedback around the same transistor. The maximum boost position of the tone control gives the greatest slope of the corresponding filter. This ensures maximum discrimination against frequencies outside the audio band, when they would otherwise prove most objectionable.

The low-pass filter shown in Fig. 1 is provided by R_{25} and C_{16} to C_{21}. Although two passive R-C lags would have the same ultimate slope of 12dB per octave, the circuit of Fig. 1 has a sharper turnover. In theory this circuit would tend to peak below the turnover frequency, but in practice the finite output and input impedances of the transistor, in conjunction with the values used, prevent this happening.

The switch is normally in position 1, giving a turnover frequency of 20 kc/s, while positions 2 and 3 (with turnovers at 10 and 6 kc/s respectively) may be used to deal with programme material such as worn shellac discs or a.m. radio.

A smooth roll-off of frequencies below 20c/s is provided in the pre-amplifier, and below 40c/s in the power amplifier described in last month's issue. In the pre-amplifier (Fig. 1), the d.c. base current for Vt 1 is supplied from the top end of the emitter by-pass capacitor of Vt 2, so that increasing negative feedback via R_{14} results as the frequency is lowered. The input stage of the power amplifier is also arranged to give increasing feedback below 40c/s.

The overall characteristic of the filters is shown in Fig. 7.

Stereophonic Version.—The circuit diagram of part of one half of a stereophonic version of the pre-amplifier is given in Fig. 8. RV_4 is the channel-balance control, which forms part of the potentiometer R_{22}, R_{23} in Fig. 1. Rotation of this control

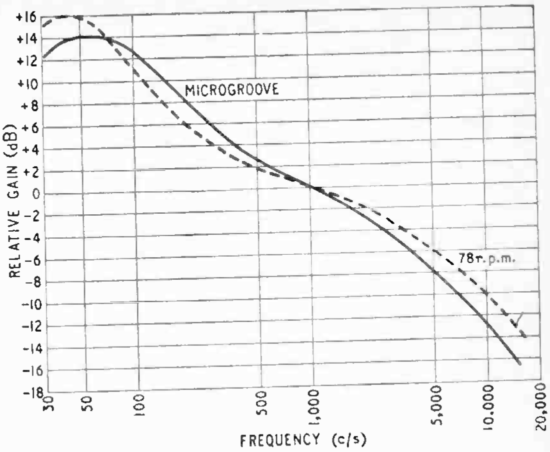


Fig. 5. Response of record equalizing circuits of Fig. 1 (magnetic pickup input).

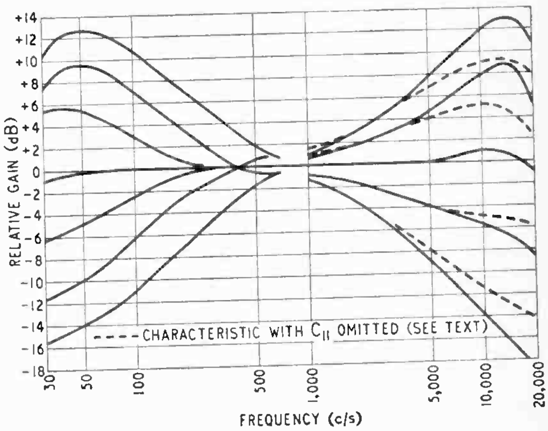
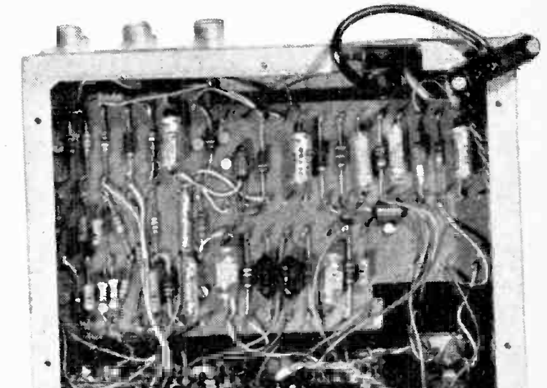


Fig. 6. Tone control characteristics with (full lines) and without (dotted lines) C_{11}. The low-pass filter was switched to 20kc/s.



One channel of the pre-amplifier viewed from the top (power amplifier and screen removed).

increases the gain of the tone-control stage of one channel, and decreases that of the other channel, hence correcting for any slight out-of-balance in other parts of the equipment. A difference of ±3dB in gain between channels is catered for. Gross differences in channel sensitivity, such as might by produced by using amplifiers and speakers of different types in the two channels, should be eliminated by an attenuator in the most sensitive channel.

In the prototype, switched tone controls and a single position low-pass filter were used, for the sake of compactness.

Transistors.—The transistors used in the pre-amplifier should have as high a gain as possible (greater than 80 at 1mA), to ensure close agreement between the theoretical and practical operation of the circuits. Suitable types for both Vt 1 and Vt 2 are the OC44, OC75, GET874, GET113 or XA102, but this list is merely a guide, and is by no means exhaustive. Two low-gain transistors as a "*super-alpha*" pair might, however, be used instead of one high-gain transistor, with appropriate changes of

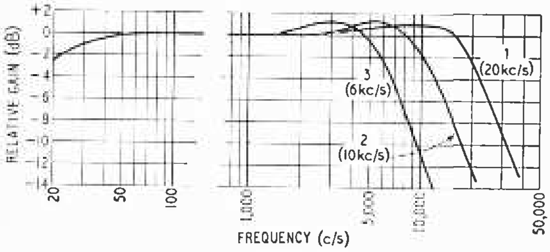


Fig. 7. Characteristics of high- and low-pass filters.

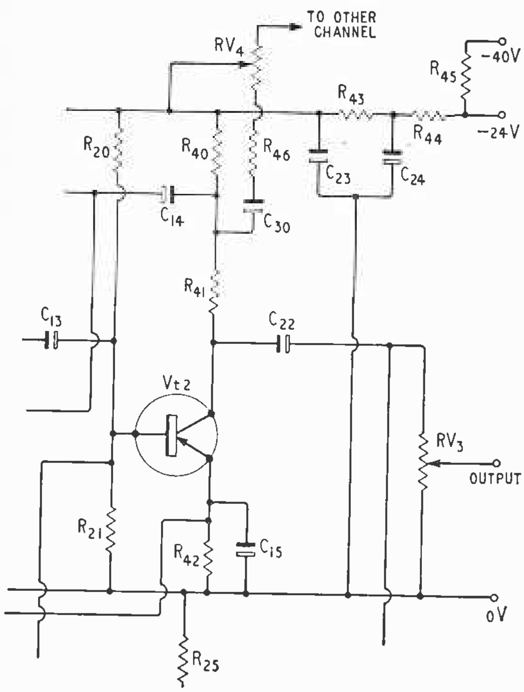
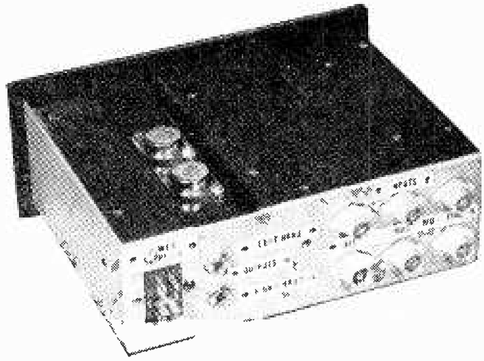
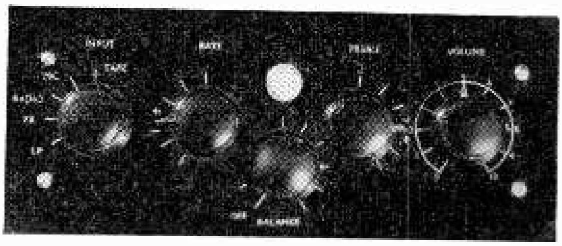


Fig. 8. Part of one half of stereophonic version of pre-amplifier.



Rear view of stereo pre-amplifier and power amplifier showing one pair of power output transistors.



Front panel of stero power amplifier and pre-amplifier.

biasing resistors. (For a discussion of the *super-alpha* pair see, for example, p. 388 of the article by F. Butler in our Aug. 1960 issue.)

The noise factor of the first transistor determines to a large extent the noise produced by the overall equipment. Though most transistors have proved satisfactory in this application, the occasional specimen may be found which is not, since large variations of noise factor exist between different transistors even of the same type. The signal-to-noise ratio is 70dB with the tone controls level, or 60dB with maximum treble boost.

Power Supply.—The pre-amplifier is designed to work off a nominal 12-volt supply but it will tolerate supply variations between 9 and 15 volts. When the pre-amplifier is being used with a valve power amplifier, the negative voltage required by the pre-amplifier may be conveniently supplied by a dry battery, since the current drain of 2½mA is small enough to ensure very long battery life.

When compared with a valve pre-amplifier, the transistor pre-amplifier has less capacity to tolerate over driving, since the voltage swing which can be accommodated within the circuit is limited by the lower supply voltage. The present design will not significantly distort signals corresponding to 20dB above those needed to give full output from the power amplifier, which gives a reasonable margin of safety. However, inputs requiring a sensitivity much less than the design values (see Tables 2 and 3) should be attenuated at the input, rather than by having the volume control turned right down.

Layout.—The layout is not critical though normal commonsense precautions should be observed. When the power amplifier and pre-amplifier are mounted in close proximity, a screening plate must

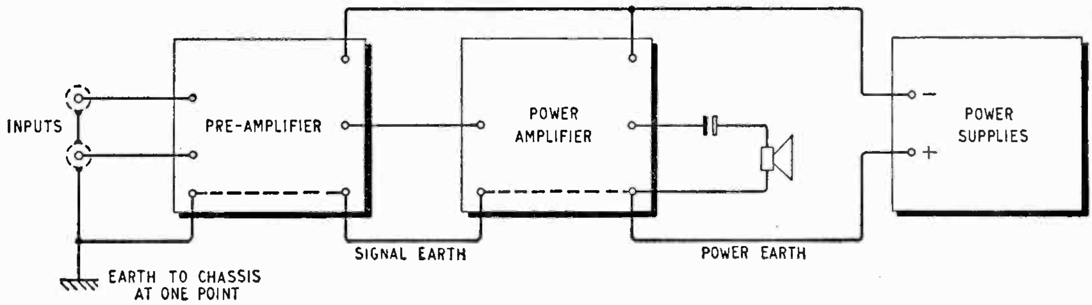


Fig. 9. Earthing diagram of pre-amplifier and associated equipment.

be used to prevent coupling between the output of the power amplifier and the input of the pre-amplifier, which may be troublesome at high frequencies, especially when treble boost is applied. The low-pass filter also helps to prevent trouble from this source.

The photographs show one channel of the pre-amplifier, and two views of the completed prototype stereo version. This was built up on a chassis 8in × 3in × 7in. The pre-amplifiers were built up on fibre-board with terminal pins. By arranging the layout of components and wiring in such a way that no wires cross each other, it is very easy to transfer the layout to a printed circuit form of

TABLE 2
Input Data for Fig. 1

Switch Position	Function	Sensitivity (mV at 1 kc/s)	Input Impedance (kΩ)
1	Microgroove	Mag 5 Xtal 100	6 100
2	78 r.p.m.	Mag 8 Xtal 150	7.5 100
3	Auxiliary	150	100
4	Microphone	1.5	1
5	Tape replay 7½in/sec	2.5	1

TABLE 3
Input Data for Fig. 4

Switch Position	Function	Sensitivity (mV)	Input Impedance (kΩ)
1	Microgroove	Mag 25 Xtal 100	47 100
2	78 r.p.m.	Mag 30 Xtal 120	47 100
3	Auxiliary	100	100
4	Microphone	4	22
5	Tape replay 7½in/sec	30	47

assembly. The boards for the stereophonic version were made of opposite hands to facilitate connections to the controls.

The importance of correct earthing, owing to the high currents flowing in the output stage, was stressed in the previous article (Fig. 9).

In conclusion, this article shows that in domestic high-fidelity apparatus, transistors can give just as good results as valves.

(In the article on the transistor power amplifier in last month's issue, in line 11 of the left-hand column of p. 568 R_{10} should read R_9.)

Characteristics of Whole Stereophonic System

Output power	10 watts per channel.
Frequency response	45c/s to 20kc/s within 3dB.
Total harmonic distortion	0.25% at 10 watts output.
Signal-to-noise ratio (at 10W output)	70dB (with controls level) 60dB (with max. treble boost).
Negative feedback in power amplifier	60dB.
Power requirements	Version 1: 40 volts d.c. at 800mA (max) or 150mA (average) for 10 watts in 15 ohm speakers. Version 2: 24 volts d.c. at 1.6A (max) or 300mA (average) for 10 watts in 3 ohm speakers and 24 volts d.c. at 500mA (max) or 100mA (average) for 3½ watts in 15 ohm speakers.
Controls	Input Selector (Microphone, Radio, Tape, l.p., 78 r.p.m.), Treble, Bass, Filter, Volume, Balance.
Size	8in × 3in × 7in.
Weight	3lb 2oz.
Maximum ambient temperature	40°C.

"Guide to Broadcasting Stations"

NEW edition of the *Wireless World* book "Guide to Broadcasting Stations" lists 500 v.h.f. sound broadcasting stations and 250 TV stations in Europe with an e.r.p. of 5kW and over. Completely revised this 13th edition includes, as usual, details of all European long- and medium-wave broadcasting stations and over 2,000 s.w. transmitters throughout the world which are listed both geographically and in order of frequency.

Tables covering standard time, wavelength-frequency conversion and the international allocation of call signs, are included in the new Guide, which costs 3s 6d (by post 4s).

"ALL-BAND" TRANSISTOR COMMUNICATIONS RECEIVER

By C. J. SALVAGE, (G3HRO)

Design Suitable for Mobile Use

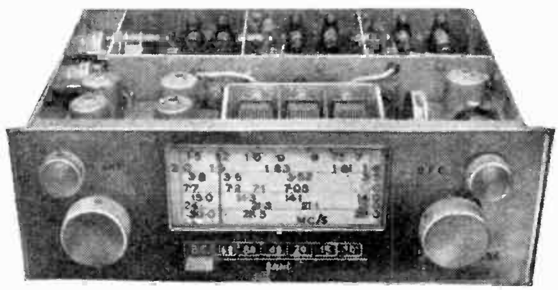
THE introduction of transistors has opened a new field to the amateur constructor and now the "drift" types have made possible the construction of an all-band all-transistor communications receiver. The set described here was designed primarily as a car radio and operates in the broadcast and six amateur bands. A b.f.o. is included for reception of s.s.b. and c.w. transmissions.

Circuit

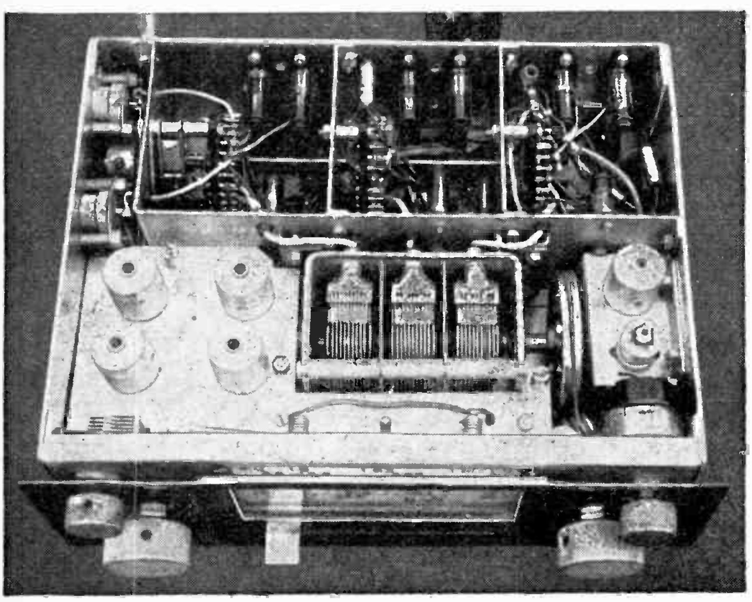
As can be seen from the circuit diagrams (Figs. 1, 2 and 3) the line up follows closely that of a conventional communications receiver using valves.

R.f., Mixer and Oscillator Stages.—The aerial circuit has seven coils, either tapped at a suitable position from earth or bearing a coupling winding to give an input impedance of approximately 50Ω, as the receiver is designed to operate from a whip aerial. The broadcast-band coils L_1, L_8 and L_{15} in the aerial, r.f. and oscillator sections are tuned by the 310-pF three-gang capacitor C_1, C_2 and C_3 giving a coverage of 1.5-0.7Mc/s. For the amateur bands 22-pF fixed capacitors C_4, C_{10} and C_{11} are switched in series with the main 310-pF tuning capacitors in order to provide the necessary bandspread. The capacitive dividing circuit C_5 and C_6 provides an impedance match to the base of V1 (OC171) the r.f. amplifier. V1, V2 and V3 are supplied from the 6-V Zener-diode (Mullard OAZ203) stabilizing circuit via the 470-Ω resistor R_{10}, thus reducing the operating voltage to 4. No useful purpose is served by raising the supply above this value which was found to be the optimum working point for all bands. High values for decoupling capacitors are necessary as all the circuits are of low impedance compared with the corresponding valve circuitry.

I.f. Amplifier.—The output from the mixer stage (V3), at a frequency of 470kc/s, passes to the i.f. amplifier (Fig. 2) which employs three stages. Two stages of amplification can provide sufficient gain if the d.c. supply is increased; but the extra stage was added in order to increase selectivity as the i.f. transformers have only one tuned winding, the secondary being untuned and providing an impedance step-down to match the base of the i.f. transi-



Above: Front view of tuner showing slider control for band switch below dial. Travel of switch "tab" is about two-and-a-half inches.



Left: Plan view of "tuner" unit. Chassis and compartments are 18s.w.g. aluminium; at top of photograph are, left to right, aerial, r.f. and oscillator compartments each containing seven coils. I.f. transformers are bottom left with b.f.o. stage to right of tuning capacitor drum.

stors V4, V5 and V6. Transformer T_4 has a secondary winding designed to match the detector diode (OA70) which supplies the a.g.c. to V5 and the demodulated signal for subsequent audio-frequency amplification. I.f. neutralizing feedback is provided by the R-C network connected to Pin 1 of each of the i.f. transformers (C_{23} and R_{16} with T_2 etc.).

First A.f. Stage.—The audio output from the 5kΩ potentiometer RV_2, which forms the volume control, is taken to the first a.f. amplifier. The receiver up to this point is all included in the main chassis; the loudspeaker, second and final push-pull a.f. stages are all mounted on a separate panel which is conveniently placed adjacent to the main "tuner" chassis.

Beat-frequency Oscillator.—A b.f.o. stage is included foı reception of s.s.b. and c.w. transmissions. Now a drawback of transistors, especially

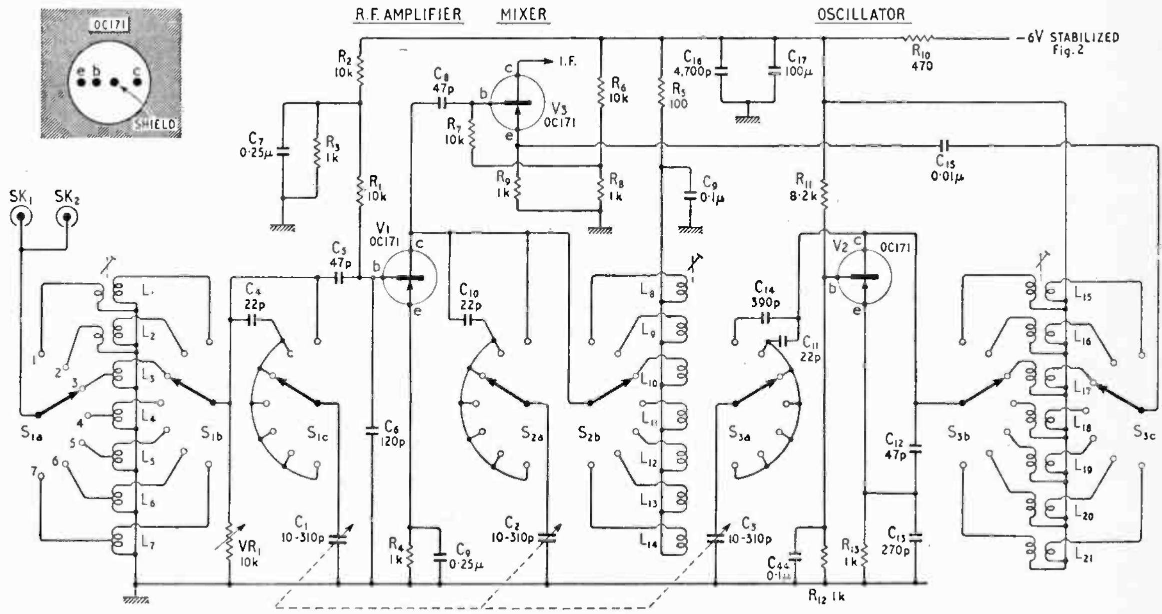
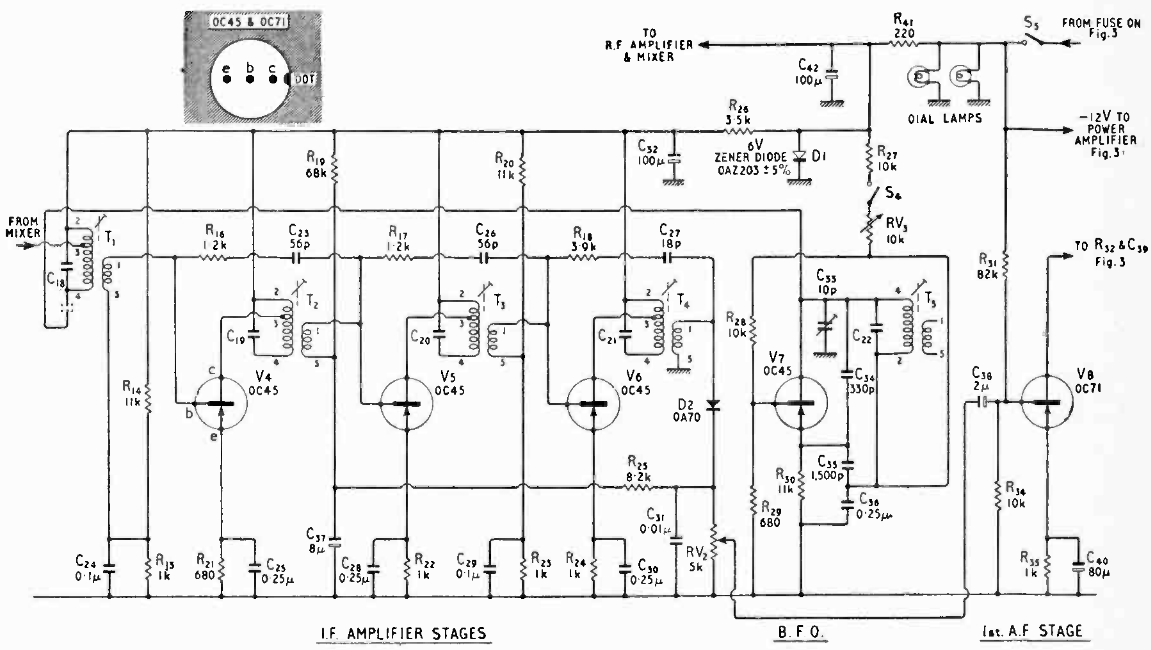


Fig. 1. R.f., mixer and local-oscillator stages. $\frac{1}{8}$-W resistors are used.

Fig. 2. I.f., detector, b.f.o. and first a.f. stages. Note that b.f.o. coupling to Pin 4 of T_1 first i.f. transformer, is by "stray" capacitance. $\frac{1}{8}$-W resistors are used.



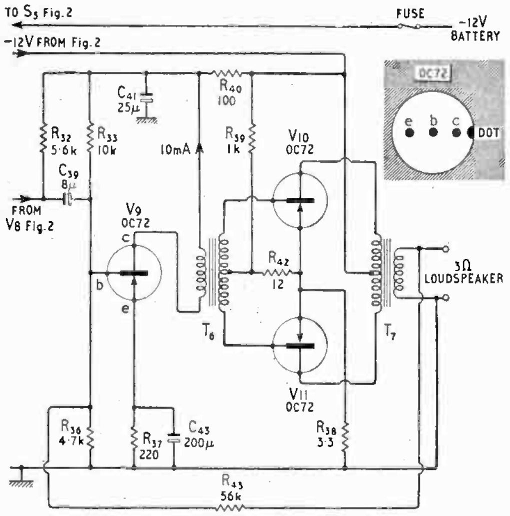


Fig. 3. Power amplifier unit.

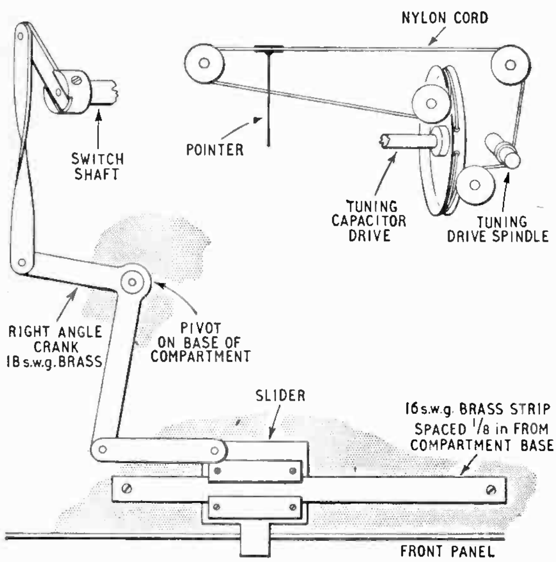
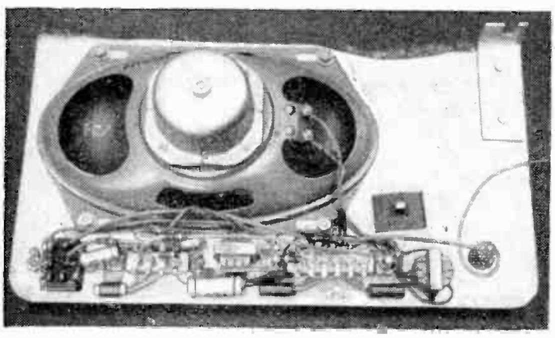


Fig. 4. Arrangement of tuning drive cord and levers actuating band switch from slide on front panel.



Back of loudspeaker and power amplifier panel. Fuse for power supply is at extreme right. First a.f. stage collector resistor and coupling capacitor to driver transistor are connected to socket at extreme left.

in oscillators, is that they are sensitive to supply-voltage variations. This, however, can be used to advantage here and adjustment of the rheostat (RV_3, 10kΩ) in series with the supply to V7 can provide sufficient change of frequency for upper or lower sideband reception of s.s.b. signals or c.w. operation. C_{33} (a 10-pF trimmer) allows fine pre-setting of b.f.o. frequency. The coupling from the b.f.o. to the i.f. amplifier is provided by a lead running from the "hot" end of T_5 to a point near Pin 4 of the first i.f. tranformer T_1.

Construction & Layout

As will be seen from the photographs the set was designed for fitting into a recess that is normally provided for a broadcast receiver in a car and, as this space is different in different cars, no exact dimensions have been given. The versatility of the receiver makes it very suitable for mobile operation.

The front view of the receiver shows the general lay-out of the front panel. The large knob on the left is the a.f. gain control RV_2, with the on-off switch S_5 incorporated, and the small knob near it is the r.f. gain control RV_1. The tuning control is the large knob on the right and a cord drive transfers the motion to the tuning capacitor. The small knob adjacent is for control of the b.f.o. (RV_3) and is ganged to the associated b.f.o. on-off switch S_4. The sliding band switch can be seen under the dial, which is lit by two low-consumption lamps (12V, 50 nA).

The plan photograph shows the two aerial sockets (top left) with the three screened compartments to the right for aerial, r.f. and oscillator coils. Holes for the adjustment of the cores of coils in the second row near the tuning capacitor are located between the coils at the rear of the compartment. The eight-pole seven-way switch used for band selection is operated by the sliding control whose motion is transferred to a right-angled crank fastened to the base of the compartment. In turn the crank transfers the motion to an arm on the rotating spindle of the band-change switch.

The switch itself is a nine-position type, two positions remaining unused, of three banks of three poles each. The small space available and the need for a very smooth mechanical action indicated that something rather different from the ordinary type of wavechange switch was wanted: thus a "Winkler" type switch made by Painton was used.

The small aerial trimming capacitor, shown on the left near the i.f. transformers, has now been replaced by the 10-kΩ potentiometer RV_1 and provides r.f. gain control. This control was incorporated as it was found that cross modulation occurred when receiving a very strong signal. The b.f.o. coil T_5 is to the right of the tuning capacitor and next to it is the trimmer C_{33}.

The layout of the output panel and speaker is simple, with the amplifier ranged along a tagstrip. The socket for connection to the main tuning unit is to the left of this strip. V9, the driver transistor, and its associated transformer are on the left with the two push-pull output transistors (V10 and V11) and their output transformer to the right, feeding into the 3-Ω loudspeaker. Negative feedback is

(*Continued on page 629*)

supplied from the secondary of this output transformer *via* the 56-kΩ resistor R_{43} to the base of V9. All resistors are of $\frac{1}{4}$W rating in this section.

Performance

The set has a sensitivity of 1μV on the lower frequency and on 10 and 15 metres this falls to 5μV. The power consumption is about 150mA at 12V for normal reception, increasing to 400mA at full output. Even this current can be conserved when used with transmitter as the whole set is switched off in the transmit condition, rather than, as with a valve receiver, leaving the heaters running. A separate switch for the dial lamps would be worthwhile for dry-battery operation.

Components Specifications

Coils.—All coils are wound on "Neosid" Type 358/8BA formers 0.3in. dia., with Grade 900 cores.
(Neosid Ltd., Stonehills House, Welwyn Garden City, Herts.).

Coil	Band	Aerial
L1	Broadcast	180μH, wave-wound (about $\frac{3}{16}$in wide) with 40 s.w.g. d.s.c. wire: coupling coil 15 turns close-wound adjacent to main coil, 30 s.w.g. d.s.c.
L2	160 metres	90μH, wave-wound (about $\frac{3}{16}$in wide), 40 s.w.g. d.s.c.: coupling coil 10 turns close-wound adjacent to main coil, 30 s.w.g. d.s.c.
L3	80 metres	76 turns, close-wound, 38 s.w.g. enamelled (en.), tapped 7 turns from bottom.
L4	40 metres	28 turns, close-wound, 36 s.w.g. en., tapped 5 turns from bottom.
L5	20 metres	19 turns, close-wound, 30 s.w.g. en., tapped 5 turns from bottom.
L6	15 metres	12 turns, close-wound, 30 s.w.g. en., tapped 2 turns from bottom.
L7	10 metres	8 turns, close-wound, 30 s.w.g. en., tapped 1 turn from bottom.
		R.f. Amplifier
L8	Broadcast	200μH, wave-wound (about $\frac{3}{16}$in wide), 40 s.w.g. d.s.c.
L9	160 metres	100μH, wave-wound (about $\frac{3}{16}$in wide), with 40 s.w.g. d.s.c.
L10	80 metres	80 turns, close-wound, 38 s.w.g. en.
L11	40 metres	32 turns, close-wound, 36 s.w.g. en.
L12	20 metres	21 turns, close-wound, 30 s.w.g. en.
L13	15 metres	14 turns, close-wound, 30 s.w.g. en.
L14	10 metres	10 turns, close-wound, 30 s.w.g. en.
		Oscillator
L15	Broadcast	120μH, wave-wound (about $\frac{3}{16}$in wide), 40 s.w.g. d.s.c.: coupling coil, 15 turns close-wound adjacent to main coil, 36 s.w.g. d.s.c.
L16	160 metres	80μH, wave-wound (about $\frac{3}{16}$in wide), 40 s.w.g. d.s.c.: coupling coil close-wound adjacent to the main coil, 36 s.w.g. d.s.c.
L17	80 metres	55 turns, close-wound, 38 s.w.g. en., tapped 8 turns from bottom.
L18	40 metres	28 turns, close-wound, 36 s.w.g. en., tapped 8 turns from bottom.
L19	20 metres	14 turns, close-wound, 30 s.w.g. en., tapped 5 turns from bottom.
L20	15 metres	8 turns, close-wound, 30 s.w.g. en., tapped 4 turns from bottom.
L21	10 metres	5 turns, close-wound, with 30 s.w.g. en., tapped 2 turns from bottom.

All coils are covered with polystyrene cement to secure turns.

I.f. Transformers.—T_1, T_2, T_3 and T_5 are identical and are "Weymouth" Type P50/2CC. The detector transformer T_4 is "Weymouth" Type P50/3CC. C_{18} to C_{22} inclusive are supplied as part of the transformer.
(Weymouth Radio Manufacturing Co. Ltd., Regent Factory, Weymouth, Dorset.).

Band Switch.—Painton "Winkler" Type AS/3P/9/33 three-pole wafers, nine-position, make-before-break, three-bank with Type "A" spindle
(Painton & Co. Ltd., Bembridge Drive, Kingsthorpe, Northampton.)

A.f. Transformers.—Details of these are given below; but if home design and construction is not contemplated Radiospares Type T/T1, ratio 1 : 1, is satisfactory for T_6 and Type T/T2, ratio 6.6 : 1, for T_7.
(Radiospares, Ltd., 4-8, Maple Street, London, W.1.)

T_6 Turns ratio 2 : 1+1
Primary inductance 1H
Primary resistance 20Ω
Secondary resistance 10Ω (each half).

T_7 Turns ratio 3.2+3.2 : 1
Primary inductance 50H
Primary resistance 1.0Ω (each half).
Secondary resistance 0.2Ω.

Commercial Literature

Controller-Indicator is a moving coil meter movement, with its pointer moving between two parallel plates, one plate being divided into sections. If the two plates are compressed, a circuit is made between one plate and whichever section of the other is under the pointer. Applications are alarms, recording and control, and many variations on the basic form are available. The equipment is part of the Canadian Bach-Simpson range of instruments, including testmeters, panel meters and engine-testing equipment, now marketed by Aveley Electric, Ltd., South Ockendon, Essex.

Chopper Type D introduced by Ericsson is capable of handling signals down to 10μV. Minimum noise pick-up is achieved by terminating the coil and contact leads at opposite ends of the unit. Units are supplied to work at 40-60c/s, but can be adjusted to operate at any frequency up to 100c/s. The standard coil is for 6.3V at a resistance of 500Ω. Full details from Ericsson Telephones, Ltd., 22 Lincoln's Inn Fields, London, W.C.2.

Universal C/tan δ Bridge by Siemens and Halske offers measurement of capacitance from 10pF to 2000μF at charging currents up to 1000A (with shunts). Direct reading of capacitance and loss factor is provided and there is provision for recording readings of crest voltage, loss angle and $\Delta C/\Delta$. Details from R. H. Cole (Overseas), Ltd., 2 Caxton Street, Westminster, London, S.W.1.

Phase-sensitive Voltmeter is described in a leaflet from Theta Instrument Corporation, 520 Victor Street, Saddle Brook, New Jersey. The instrument is panel-mounting and takes the form of a cylinder 5-in long, 3-in in diameter. Sensitivity 1mV f.s.d., frequency response 60 c/s-20 kc/s.

Position Control system—the EMICON B100—is described in a leaflet from E.M.I. Electronics Ltd., Industrial Division, Hayes, Middlesex. The system will control machines driven by electric or hydraulic motors, Ward Leonard controls or a.c. motors with clutches. Details are given of peripheral equipment for use with the system.

Components in the wide ranges made by Bulgin are listed in a new 174-page catalogue (No. 202) from A. F. Bulgin and Co. Ltd., Bye Pass Road, Barking, Essex.

Integrator Series 5300 is the subject of a leaflet from Electromethods Ltd., Coxton Way, Stevenage, Herts. The integrator, driven by the company's low-inertia integrating motor, employs a lamp and photocell with a rotating shutter to produce pulses. Motors are available to work at voltages between 1.5V and 24V.

Paralleling Transistors

AUTOMATIC DRIVE CURRENT EQUALIZATION

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

ALTHOUGH very high power transistors are now becoming available it is still quite common practice to use paralleled banks of smaller units in amplifiers and inverters designed to give a large power output. Parallel operation of small transistors has special advantages when the equipment is required to operate at high frequencies since the cut-off frequency of most high power units is unacceptably low. Matched pairs of power transistors can be supplied on demand by most manufacturers, but the provision of larger groups calls for special selection and this may delay delivery or result in increased costs. Replacements cannot be supplied to match earlier samples. When using unmatched transistors it is good practice to equalize the driving currents by the use of external resistance large enough to swamp the variations of input impedance of the individual units. The virtue of this technique is that it tends to linearize the driving currents as well as ensuring strict equality. Its drawback is that it is wasteful of driving power.

A recent paper[1] has shown how transformers of novel and unusual construction may be used to supply nearly equal currents to a number of loads of different, variable or ill-defined impedance. The author describes two distinct types of transformer which are equally effective in securing the desired equality of drive currents. In the simpler type the leakage inductance is rather larger than in a normal transformer which tends to reduce the operating bandwidth and may be objectionable on other counts, e.g. transient response. The second form of construction employs multiple cores with both individual and common windings. Good characteristics are thus assured but at the expense of increased production costs.

In power engineering it is frequently required to operate rectifiers in parallel and to provide some automatic means of load sharing between them. The usual way of doing this is to make use of small centre-tapped reactors or auto-transformers and the idea is readily adaptable for use in transistor power amplifiers or inverters.

Load Sharing by Tapped Reactors.—Fig. 1 shows an alternator of e.m.f. E supplying power to the unequal load resistances R_1 and R_2 through a centre-tapped reactor. Each half-winding has an inductance L with mutual inductance M between the windings. In practice an iron core is used and the windings are so closely coupled that M is virtually equal to L.

The action is best understood by first considering the case of equal load resistances. From the symmetry of the circuit it is clear that the input current to the reactor centre-tap will split so that each load resistor carries half the total current. The reactor core magnetization produced by current in one half-winding is exactly cancelled by that due to the oppositely directed current in the other half-winding. The net core flux is zero and no voltage appears across the outer ends of the reactor windings. On the other hand, if the reactor currents are unbalanced due to the use of unequal load resistances, there is an incomplete cancellation of core flux and the residual flux changes result in the induction of an e.m.f. in the windings of such a polarity as to cause an increase in the current in the high impedance arm of the network.

It is not difficult to determine the exact ratio of the two currents (see Appendix). Using the notation in Fig. 1 it can be shown that :—

$$i_1/i_2 = \frac{R_2 + j\omega(L + M)}{R_1 + j\omega(L + M)} \quad \ldots \quad (1)$$

For close-coupled windings L = M and :—

$$i_1/i_2 = \frac{R_2 + 2j\omega L}{R_1 + 2j\omega L} \quad \ldots \quad (2)$$

Provided the choke reactance is much larger than the load resistances it is clear that the current ratio is almost unity. In general, the two currents are out of phase but the phase difference is negligible in the case where the choke reactance is substantially larger than the load resistances.

It is instructive to look at the circuit of Fig. 1

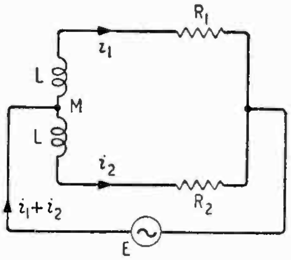


Fig. 1. Equal current division using centre-tapped reactor.

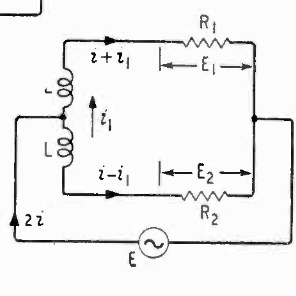


Fig. 2. Alternative treatment of Fig. 1.

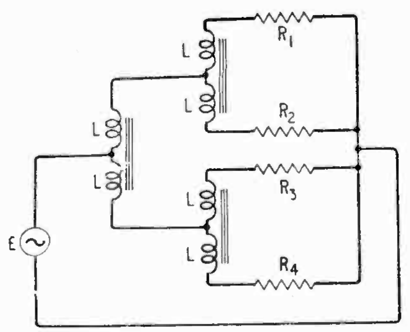


Fig. 3. Extension of current-sharing principle.

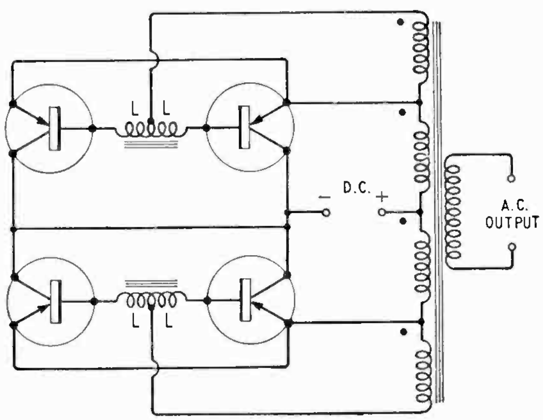


Fig. 4. Inverter using parallel push-pull circuit.

from a slightly different point of view. This has been redrawn in Fig. 2 in which a circuit current $2i$ is shown dividing equally at the reactor centre-tap. The current unbalance due to unequal load resistances is represented by a fictitious make-up current i_1 which adds to i in the low impedance arm and subtracts from i in the other. This of course calls for a reactor current i_1 flowing in the direction shown. The magnitude of this current i_1 depends on the choke reactance and on the net voltage between the outer choke terminals. In turn, this is the difference in the voltage drops across the two load resistors. If the choke is of high inductance it is clear that a large difference of voltage across the two resistances will be required to cause a significant current to flow. This is the unbalance current i_1.

A mathematical study of the arrangement of Fig. 2 leads to exactly the same conclusion as before and to the same expression for the current ratio $(i + i_1)/(i - i_1)$.

By making use of additional centre-tapped reactors it is possible to supply nearly equal load currents to 4, 8, 16 or, in general, 2^n different load impedances. The principle is shown in Fig. 3. At each stage of division the actual current to be handled becomes smaller and smaller so that finer gauges of winding wire may be used as the working current becomes smaller.

Construction of Reactors.—In most applications the tapped reactors will only be required to equalize the currents in moderately unbalanced loads. The working currents will seldom exceed one or two amperes and quite small magnetic cores are adequate. To provide maximum inductance with minimum physical size it is worth using cores of high grade magnetic material. Grain-oriented silicon-steel C-cores are suitable for high power 50 c/s equipment but for other applications it may be preferable to choose nickel alloy laminations of the HCR type.

As regards the windings, close magnetic coupling is best achieved by two-ply, bifilar winding, the two half-sections being connected series-aiding. To do this involves connecting the start of one winding to the finish of the other and regarding the junction as the centre-tap. The two free ends then become the outer terminals.

The wide variety of requirements makes it impossible to give useful winding specifications. In any event the design tolerances are very wide. As a rough guide it will be found that a few hundred turns of wire wound on a core with a cross-section about half an inch square will be adequate for most audio-frequency applications. For use in high frequency inverters it is sufficient to wind a few dozen turns of wire on a very small core, say about ¼ inch square section.

Practical Circuits.—Fig. 4 shows a typical d.c.-a.c. inverter circuit using four transistors in parallel push-pull. Two centre-tapped reactors serve to equalize the base drive currents. For simplicity, the normal starting-bias circuits have been omitted, but any standard arrangement can be incorporated.

The output stage of a typical Class B audio amplifier is shown in Fig. 5. Here again, the tapped reactors ensure equal base currents in the paralleled transistors. Finally, a full-wave rectifier circuit is illustrated in Fig. 6.

In all three cases two separate equalizing reactors have been shown. In the rectifier circuit both reactor windings may be placed on a single common core with suitable inter-winding insulation. With minor reservations, this technique is permissible in audio

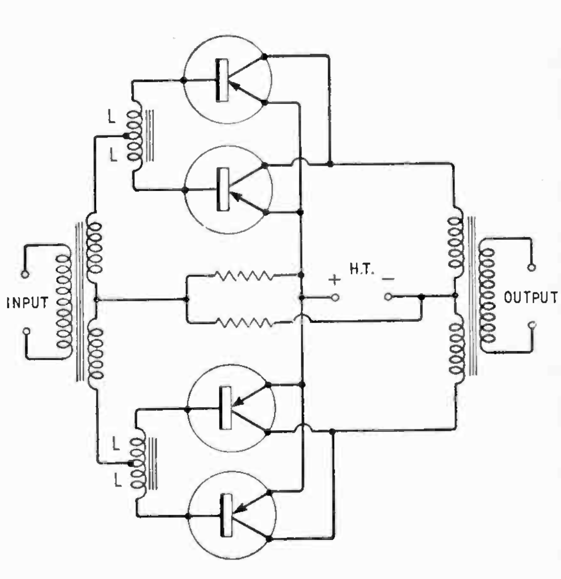


Fig. 5. High power class-B audio amplifier.

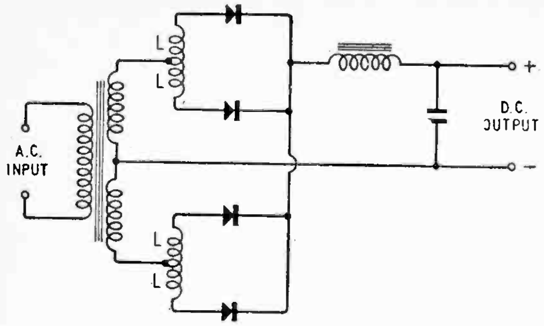


Fig. 6. Rectifier unit with current-equalizing reactors.

amplifier and inverter circuits. If a common core is used it may be found that current-sharing is imperfect near the cross-over point where the instantaneous driving currents are low. This disadvantage is not important, since the current division becomes more exact as the drive amplitude increases and the peak currents will be accurately equalized.

Conclusion.—The provision of small, simple and inexpensive reactors allows the use of unmatched transistors in paralleled groups. There is no degradation in the performance of equipment using them and few if any circuit modifications are called for. Such reactors are extensively used in high power rectifier circuits and are ideally suited for use with germanium or silicon rectifiers which can then be operated in paralleled groups without de-rating.

Reference

[1] H. G. Bassett, "Novel Transformer Suitable for the Parallel Operation of Current Driven Devices," *Radio and Electronic Components*, March, 1961, p. 129.

APPENDIX

From Fig. 1,

$$E = (R_1 + j\omega L)i_1 - j\omega M\, i_2,$$
$$= (R_2 + j\omega L)i_2 - j\omega M\, i_1,$$

Hence:—

$$\{R_1 + j\omega\,(L + M)\}i_1 = \{R_2 + j\omega\,(L + M)\}i_2.$$
$$\therefore \frac{i_1}{i_2} = \frac{R_2 + j\omega\,(L + M)}{R_1 + j\omega\,(L + M)}.$$

For a reactor with close-coupled windings L = M so that:—

$$\frac{i_1}{i_2} = \frac{R_2 + 2j\omega L}{R_1 + 2j\omega L}. \qquad \ldots \quad (1)$$

From Fig. 2, total choke inductance (end to end) is L + L + 2M, with L = M. Thus, total inductance = 4L.

$$i_1 = \frac{E_1 - E_2}{4j\omega L},$$

where $E_1 = R_1\,(i + i_1)$,

$E_2 = R_2\,(i - i_1)$.

$$\text{Current ratio} = \frac{i + i_1}{i - i_1} = \frac{1 + \frac{i_1}{i}}{1 - \frac{i_1}{i}}$$

$$= \frac{R_2 + 2j\omega L}{R_1 + 2j\omega L}, \text{ as before.}$$

The impedance seen by the source voltage E is $Z = E/(i_1 + i_2)$. Again taking M = L,

$$Z = \frac{R_1 R_2 + j\omega L\,(R_1 + R_2)}{R_1 + R_2 + 4j\omega L} \qquad \ldots \quad (2)$$

Some special cases are:—

(a) L = O so that $Z = \frac{R_1\,R_2}{R_1 + R_2} = \frac{R}{2}$ if $R_1 = R_2 = R$.

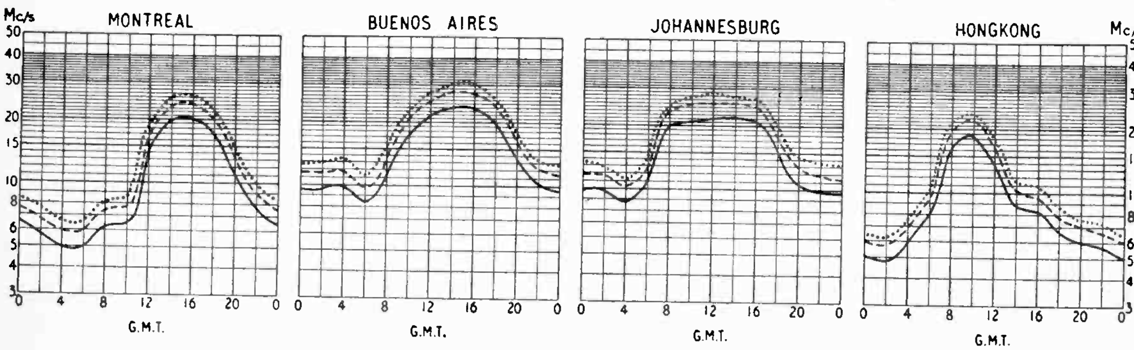
The load impedance is simply R_1 and R_2 in parallel.

(b) $L = \infty$, $Z = \frac{R_1 + R_2}{4}$,

(c) $R_1 = R_2$, Z = R/2 and is independent of L.

SHORT-WAVE CONDITIONS

Prediction for December



•••••••••• 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 December.

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

NEW TELEVISION VIDEO OUTPUT BEAM TETRODE

MAZDA 6F28

The 6F28 is a screened high slope frame grid beam tetrode for use in television video output stages. High peak current is available, enabling adequate video drive to be provided for the cathode ray tube with anode loads down to 4700 ohms; this low value of load eases the problem of HF video compensation.

This type has identical characteristics to the tetrode in the 30FL12 triode-tetrode combination.

Heater Voltage (volts)	V_h	6.3
Heater Current (amps)	I_h	0.3

TENTATIVE RATINGS AND DATA

Maximum Design Centre Ratings

Anode Dissipation (watts) ..	$p_{a\,(max)}$	2.5
Screen Grid Dissipation (watts) ..	$p_{g2(max)}$	1.3
Anode Voltage (volts)	$V_{a(max)}$	250
Screen Grid Voltage (volts) ..	$V_{g2(max)}$	250
Heater to Cathode Voltage (volts rms)	$V_{h\text{-}k(max)\ rms}$	150*

*Measured with respect to the higher potential heater pin.

Inter-Electrode Capacitances†(pF)

Input	c_{in}	8
Output	c_{out}	2.5
Control Grid to Anode	$c_{g1\text{-}a}$	0.03

†Measured in fully shielded socket without can.

CHARACTERISTICS

Anode Voltage (volts)	V_a	180
Screen Grid Voltage (volts) ..	V_{g2}	180
Anode Current (mA)	I_a	10
Mutual Conductance (mA/V) ..	g_m	12.5

TYPICAL OPERATION AS VIDEO AMPLIFIER

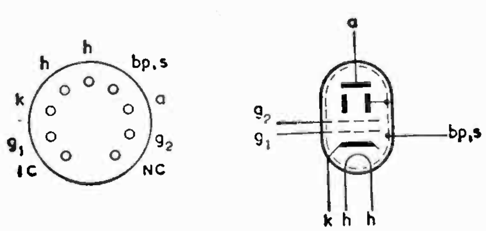
Allowance must be made in circuit design, not only for component variation, but also for valve spread and deterioration during life. Values of peak anode current, for an average valve when new and at the assumed end of life point for any valve, are as follows:—

	V_a (V)	V_{g2} (V)	V_{g1} (V)	I_a (mA
Average New Valve	70	180	−1	40
Assumed End of Life Condition ..	60	180	−1	25

Mounting Position: Unrestricted

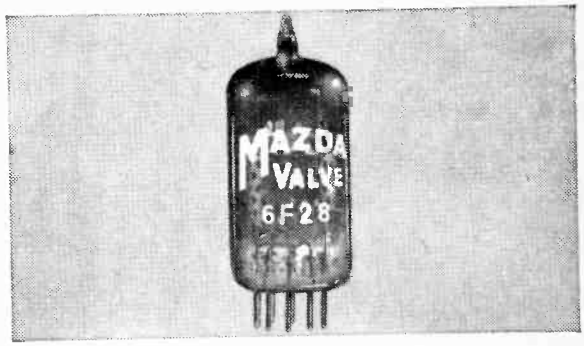
Base: B9A (Noval)

Connections

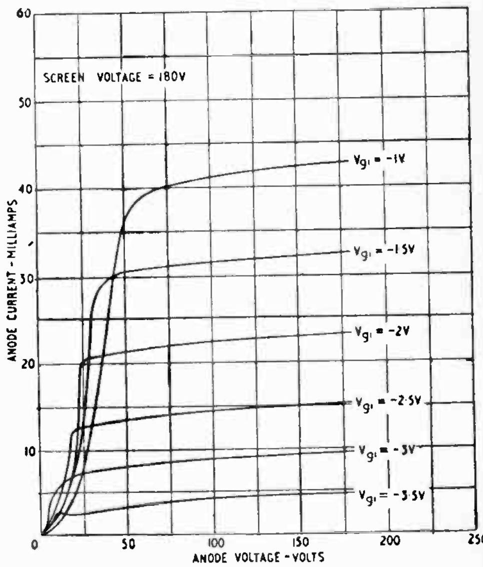


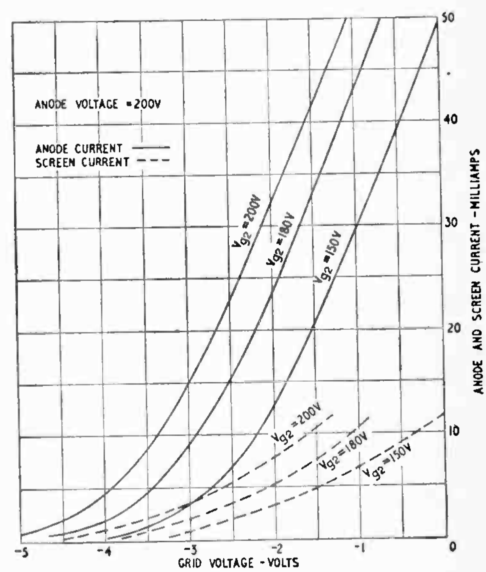
MAXIMUM DIMENSIONS (mm)

Overall Length	56
Seated Height	49
Diameter	22.2



Tentative Characteristic Curves of Mazda Valve Type 6F28





Thorn-AEI Radio Valves & Tubes Ltd.

155 Charing Cross Road, London, W.C.2
Telephone: GERrard 9797

MAZDA

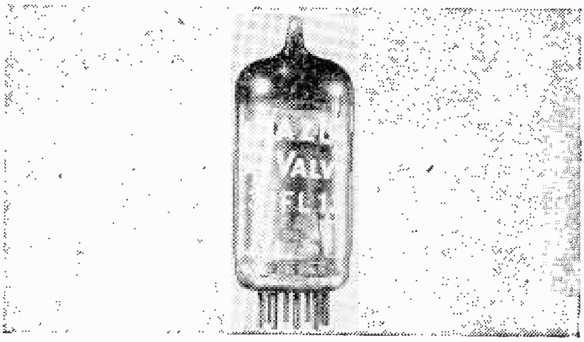
NEW TRIODE TETRODE FOR SYNC SEPARATOR CIRCUITS

MAZDA 30FL13

The 30FL13 consists of a high slope tetrode with frame grid construction and a general purpose triode for use in television sync. separator circuits. The short grid base and high slope of the tetrode enable good pulse limiting to be obtained with the anode load resistance directly connected to the HT line and a fairly high screen voltage.

The triode has identical characteristics to the 6/30L2.

Heater current (amps)	I_h	0.3
Heater voltage (volts)	V_h	10.0



TENTATIVE RATINGS AND DATA

Maximum Design Centre Ratings

		Triode	Tetrode
Anode Dissipation (watts) ..	$p_{a(max)}$	1.5	1.5
Screen Grid Dissipation (watts)	$p_{g2(max)}$	—	0.5
Anode Voltage (volts) ..	$V_{a(max)}$	250	250
Screen Grid Voltage (volts) ..	$V_{g2(max)}$	—	250
Heater to Cathode Voltage (volts rms) ..	$V_{h-k(max)rms}$	150*	150*

*Measured with respect to the higher potential heater pin.

Inter-Electrode Capacitances†(pF)

		Triode	Tetrode
Input	c_{in}	2.3	10
Output	c_{out}	2.0	2.6
Control Grid to Anode ..	c_{g-a}	2.4	0.04
Grid Triode to Grid 1 Tetrode	c_{gt-g1}	0.003	
Anode Triode to Anode Tetrode	c_{at-aq}	0.012	
Grid Triode to Anode Tetrode	c_{gt-aq}	0.004	
Anode Triode to Grid 1 Tetrode	c_{at-g1}	0.008	

†Measured in fully shielded socket without can.

TETRODE CHARACTERISTICS

Supply Voltage (volts) ..	V_b	200	
Anode Load Resistance (kΩ) ..	R_a	4.7	
Screen Grid Voltage (volts) ..	V_{g2}	80	
Control Grid Voltage (volts) ..	V_{g1}	−0.6	−1.5
Anode Current (mA)	I_a	4	0.1

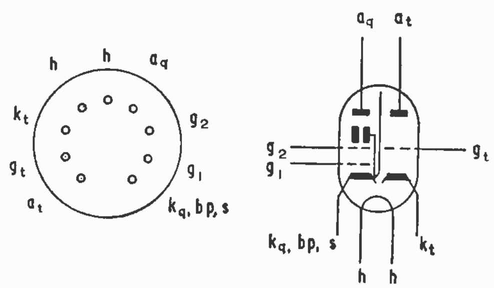
TRIODE CHARACTERISTICS

Anode Voltage (volts) ..	V_a	150
Anode Current (mA)	I_a	10
Mutual Conductance (mA/V)	g_m	3.7
Amplification Factor	μ	18

Mounting position: Unrestricted.

Base: B9A (Noval).

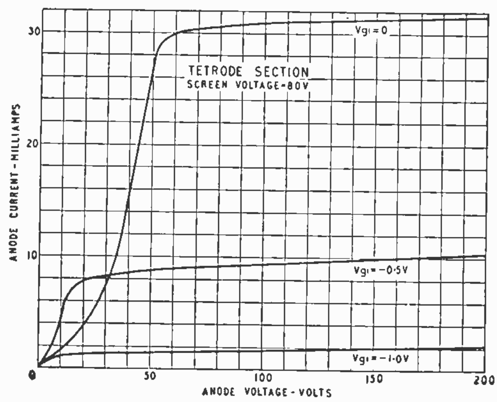
Connections:

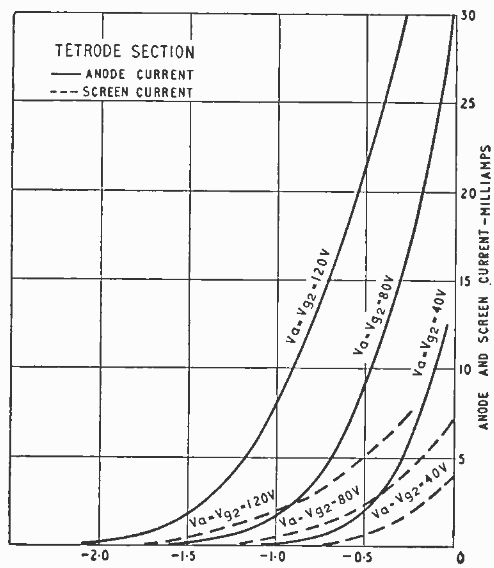


Maximum Dimensions (mm)

Overall Length	56
Seated Height	49
Diameter	22.2

Tentative Characteristic Curves of Mazda Valve Type 30FL13





MAZDA COMMERCIAL DIVISION

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MAZDA

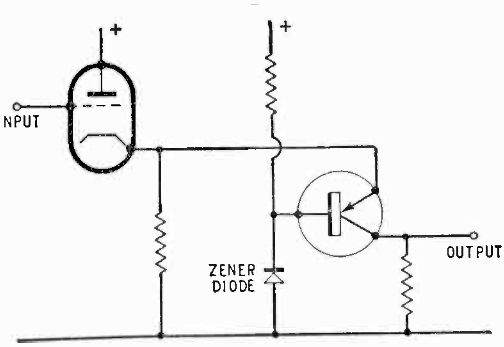
LETTERS TO THE EDITOR

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

Hybrid Amplifiers

THE accompanying circuit which appeared in the *Hewlett-Packard Journal* for April, 1961, is interesting. This hybrid is used in the X and Y amplifiers of an oscilloscope to provide high gain with a bandwidth of 22 Mc/s. The designers point out that the circuit is useful in a direct-coupled amplifier, since the difference in the steady voltage levels at the input and output is only 3 volts, compared with 60 volts for an all-valve circuit. As a result, the power supply can be simplified, and heater-cathode potentials can be kept low.

My article on hybrid amplifiers was written in January, and since then the cost of transistors has dropped



considerably For example, the Texas Instruments 2G301, an r.f. transistor with a cut-off frequency of 6 Mc/s and a current gain of 60, is listed at under five shillings. This is less than the price of a triode valve, so hybrid circuits should now be a more attractive economic proposition. The intrusion of transistors into mains television receivers reported in *W.W.'s* Radio Show Review seems to confirm this.

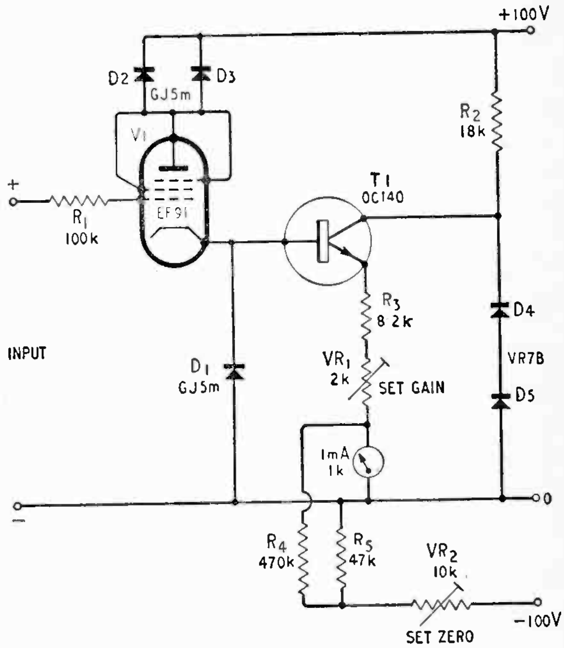
Croydon. G. W. SHORT.

IN your October issue, G. W. Short has analysed two of the many connections possible with a valve—transistor combination. In my work, a requirement arose for a high-impedance amplifier with good linearity for measuring the voltage stored on a 0.1μF capacitor, without discharging the capacitor unduly. The voltage range was 0-10V, and the amplifier was required to drive a 1000-ohm load at up to 1mA. A hybrid amplifier has proved ideal for this, using the common-anode plus common-collector combination.

In a simple cathode-follower circuit, low grid current can be obtained by operating the valve at low anode voltage and low cathode current. This results in poor linearity, but this can be improved by operating the valve with a constant cathode current. A germanium junction diode, operating in its reverse current direction, is a suitable cathode load, and the circuit is completed by an emitter follower driving the output load.

The accompanying diagram shows the practical circuit. The only additions necessary to the basic circuit are zero setting arrangements and the use of components R , D2 and D3 to protect the transistor in the event of the input voltage exceeding about 12V. Diodes D2 and D3 are operating on the reverse part of their characteristic and limit the valve anode current under abnormal operating conditions.

The linearity obtained with the circuit was $\pm 0.1\%$ of



maximum input and the input current was less than 10^{-10} amps over the range 0-10 V.

No attempt was made to compensate the circuit for temperature changes and the voltage drift referred to the input is therefore rather large. This has not proved troublesome for the 0-10 V range chosen.

The work described in this letter is published by permission of the Director, Central Electricity Research Laboratories.

Leatherhead. A. E. T. NYE.

Safety of Life at Sea

THE Ministry of Transport announced in August that as from 1st September, 1961, direction-finding facilities from British coast radio stations would be suspended. While these services offered by the coast stations have not been patronized to any appreciable extent, the ability of a wireless station to take the bearing of a transmission is a facility that should not readily be withdrawn.

That it is not the desired intention of the Post Office, who staff and operate the stations, to curtail this facility seems apparent from the reservation of a four-acre site for direction-finding aerials at the new Ilfracombe radio station and also from their action in resiting the aerials at Humber Radio within the past few years.

At a coast station the M/F watch, on 500 kc/s, is conducted by the Post Office for the Ministry of Transport, who pay for the service. This is considered to be a non-commercial activity. The direction-finding equipment consists, the present tense is used, of large triangular loop aerials erected at a site about half a mile away from the station. The loops are unscreened and are centrally supported from a wooden pole. The site for the direction-finder aerials has to be on suitable elevated ground well clear of buildings, trees, wire fences and overhead lines. Long term preservation of the site is usually secured by the Post Office becoming the landowner of surrounding territory that then may be leased for agricultural use. At the operating position, which is manned by the operator listening on 500 kc/s, there is a radiogoniometer and a receiver that can be switched at will to either the radiogoniometer or a receiving aerial. A.g.c. is automatically removed from the receiver when it is connected to the radiogoniometer. At frequent and regular periods throughout the day bearings are taken on other coast stations and by this means the operational efficiency of the system is checked.

The prime purpose of radio apparatus on board ship and of the coast radio stations is the safety of life at sea. In the past it has always been the automatic action of an operator at a coast station to take a bearing of a distress signal on 500 kc/s; most often this information is unnecessary but occasionally it has proved of great value and assistance in guiding rescue craft to the location of the distress. Information of this kind is generally only required when weather conditions are foul and only one transmission is made from the vessel in distress. The Ministry of Transport notice, issued from St. Christopher House, states " . . . there is not sufficient demand for navigational purposes to justify the retention of the service, and the needs of ships in distress are met by other methods." What these methods are is not stipulated.

What could they be? Bearings taken by other vessels? This is unlikely to happen if only one call is made from the station in distress because ships at sea do not normally keep watch on a D/F receiver and circumstances can arise, as was the case in the rescue operations subsequent to the foundering of the *Princess Victoria* in January 1953, when the search vessel is unable to take a reliable bearing owing to the extreme yawing of the vessel. Additionally, transmission of the distress message may occur when the ships' operators are not on watch, or the direction finder may be in the chartroom. Bearings provided by naval stations? These stations have not contributed directly in such operations in the past and it does seem unlikely that the D/F facilities would be transferred to the Service at this stage. The use of other modern aids to navigation? If a ship runs aground it would appear that these aids had failed and that it is uncertain of its position. How, then, is assistance to be directed to it promptly?

It seems that the cost of maintenance of these installations, compared with the revenue for the particular service rendered, is considered to be out of proportion. Another factor of influence will be that, in recent years, other countries have abandoned this service; not, however, countries with strong maritime interests. That the facility is not required for navigational purposes is not disputed; but it should be retained for distress purposes and even extended.

The D/F system just abandoned worked in the band 410 to 500 kc/s. This was, perhaps, its greatest disadvantage because the majority of ships using the coastal waters about the United Kingdom, fishing and home-trade vessels, are fitted with radiotelephone equipment that operates in the band 1,625 to 2,850 kc/s. D/F coverage in this band would be difficult to provide over the entire coastal area unless the facilities of the Coastguard Service were linked into the scheme. The segregation of marine communication into two bands without ready means of contact from one band to the other has, in the past, hampered rescue work; the most recent instance of this nature occurred after the collision involving the *Crystal Jewel* in the English Channel. It is peculiar that a modern ocean-going vessel cannot communicate directly with a lifeboat or coastal vessel that is coming to its assistance. The Merchant Shipping (Radio) Rules, 1952, make no provision for circumstances like these. Would it be unfair to hint that there seems to be a lack of complete assessment of practical conditions?

If the measures taken by the Ministry are unable to prevent accidents taking place, at least all facilities should be provided for rescue operations; and while it is not anticipated that they will in any way rescind their decision, the usefulness of permanent D/F installations, capable of reception over a wide frequency range, should not be overlooked. Who could help the crew of an aircraft in a rubber dinghy in the North Sea at 0130 G.M.T.? German coast stations, Dutch coast stations and, we are told, "other methods," but not British coast stations.

South Shields. A. T. FERGUSON.

Hearing High Frequencies

MR. MAWSON'S conclusion (November issue), that the most acceptable type of radio receiver for the elderly is one which has plenty of built-in top cut, would indicate that at high frequencies not only does the absolute level of hearing threshold increase with age but that also the absolute level of the threshold of pain reduces with age.

This would account for the often observed phenomena that such persons are the first to reach for the top cut and/or filter controls in reproduced music.

Many eminent elderly musicians, however, although ardent top-cut fans at home, make no complaint about the top from a live orchestra, even sitting in the middle of it. Can it be that with the experience of advancing years one becomes more discerning and thus less prepared to accept the imperfections which most transducers exhibit at high frequencies?

Huntingdon. P. J. WALKER.

Telemetry

I WAS pained to read in your November issue of the abuse of the word "Telemeter." A magazine with as much influence as yours should realize that some confusion will arise from its use.

Unless action is taken, followers of the noble science of measurement at a distance will become identical in the public image with gas company inspectors, and will have to coin a new word to cover their activities. I leave suggestions to Mr. F. Grid. I can only think of "Slotelly" for them.

One group will have to change. We have got classical justification and we got there first.

Cambridge. S. H. SALTER.

[While we sympathize with our correspondent's point of view, we think that "abuse" is perhaps too strong a word. After all the coins *are* measured, and at a distance from the company's headquarters.—ED.]

Degrees of Definition

THE suggestion in your November editorial, to use the word "Mark" in distinguishing different degrees of television, is astonishing.

Present day use of "Mark . . .", by individuals or commercial firms, suggests adherence to a style which became familiar to many in war time, or alternatively a snobbish attempt to suggest that the items referred to have a large "official" backing.

In the early days of multiple production, mainly in the gun industry I believe, when designs were modified for improvements or economies, it was found convenient to put on a distinguishing number, letter or other mark. When referring, in writing, to such distinctions, to avoid referring to "Gun II" or "Tank III," the reference became Gun or Tank "MARK II," sometimes abbreviated to "Mk. II." For consistency the word "Mark" or its abbreviation was then added on the articles themselves. Incidentally not all Armament and Government work makes use of the "Mark" system. I met it first as a curiosity of another branch when connected with Naval work in the early 1930's.

For a system to distinguish different standards of television definition, I suggest "Definition I," etc., for it will always be necessary to note that definition is referred to and the word "Mark" is superfluous. Subsequently in a single article, abbreviation to "I," "II," etc., would be reasonable. It is interesting for comparison to note that there seems no tendency to further abbreviate "Band I," etc., no matter how often repeated.

As the editorial also refers to "hair-splitting" about "service," it might not be wise for me to go on and list some of the ways in which "service" is used portmanteau fashion, like "thingamajig" to cover careless lack of discrimination.

However, as an engineer I like to avoid quibbling which is liable to waste time, like redundant reference symbols.

London, N.W.6. W. G. EALY.

Electronic Music

SINCE it is not possible in a short article to outline fully the artistic or manipulative techniques necessary to extract real value from electronic music, I append some references which readers will find useful. Mr. Judd, in his article in September, did not give sufficient credit to the father of *musique concrète*, Pierre Schaeffer, or his colleagues Olivier and Pierre Messian, whose musical knowledge enabled the art to be launched.

The same applies to the monumental work of Prof. W Meyer-Eppler and his colleagues Herbert Eimert, Fritz Enkel and Karlheinz Stockhausen, at Cologne. The immense amount of research into musical notation, composition, and apparatus for electronic music research cannot be fully appreciated without reference to the literature cited below.

Radcliffe-on-Trent. ALAN DOUGLAS.

Schæffer, P. "A la Recherche d'une Musique Concrète." Edition du Seuil, 1952.

Poullin, J. "Son et Espace." Editions Richard Masse, 1954.

Moles, A. "Les Machines à Musique." Editions Richard Masse.

Moles, A. "Studium und Darstellung des Complexen Tones in der Musikalischen Akustik. *Funk und Ton*, 1953.

Bernhart, J. "Deux Applications de la Notion de Distortion Spatiale." *L'Onde Électrique*, No. 304, July, 1952.

Articles in the special number "*Elektronische Musik*," Vol. 6, No. 1/2, 1954, of *Technische Hausmitteilungen des Nordwestdeutsche Rundfunks*.

TUNED COUPLED CIRCUITS

USE OF MAXIMUM POWER TRANSFER THEOREM

By B. J. AUSTIN

THE theory of tuned coupled circuits is a straightforward example of elementary circuit analysis and is adequately treated as such in many text books. However, in view of the importance of such circuits, it seems worth while to review the situation in a way which focuses attention on the underlying physics, not on the algebraic manipulations.

The purpose of the article is not, then, to carry out a complete analysis of the circuit of Fig. 1. This would be unrewarding and without much interest. Instead, let us try to see just why tuned coupled circuits behave as they do. In particular, let us attempt to explain, from basic physical principles, the observation that the secondary current I_2 can never be made to exceed V/2R, however large the coupling M may be. Familiarity with this fact may detract from its striking character, but could we, on a first acquaintance with the problem, merely write off such strange behaviour as accidental? Would we not contrast the docile increase of I_2 with M, up to the critical value V/2R, with its stubborn refusal to increase beyond this point, and begin to suspect the workings of a hidden law? Of course we would, and this article is intended to show how well-founded our suspicions would have been. Any of our readers who have read the subtitle will know that the law involved is one about maximum power transfer.

First of all, we must know what the Maximum Power Transfer theorem states. Imagine that we have a voltage generator V with internal resistance R. We connect, in turn, load resistances of various values and measure, in each case, the power which is dissipated *in the load*. The theorem then simply states that this power is greatest when the load resistance is equal to R, the internal resistance of the generator. The reader will be able to show that the maximum power available for dissipation in the load is then $V^2/4R$, corresponding to a current of V/2R. The theorem applies to steady or alternating voltage generators and, if necessary, it could be extended to include generators having complex internal impedances. We will not require this extension.

The theorem is still valid when the load is separated from the generator by a tangle of L's and C's. Indeed, in this situation, it is more flexible since it is possible to "match" any value of load resistance to the generator by means of a suitable lossless coupling network. The network must be chosen so that the generator "sees" a load equal to R, while the real load thinks that the generator has an internal resistance equal to itself. Fortunately, the second half follows from the first, so that we can forget about it. A well-known example of this technique is the matching of a loudspeaker coil

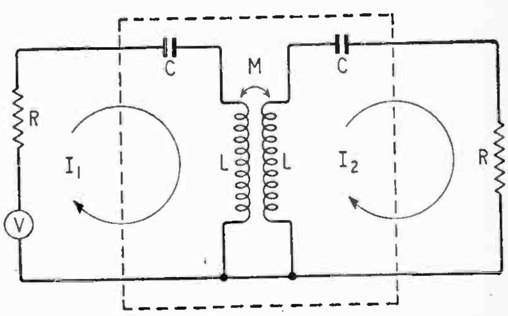


Fig. 1. Basic tuned coupled circuit. The dotted box contains a network which couples a "load" to a "generator".

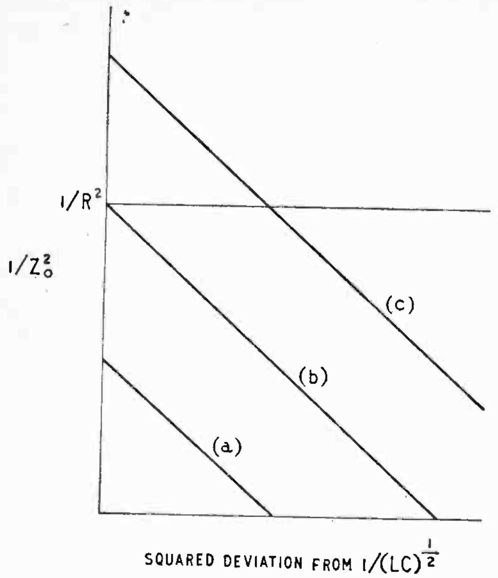


Fig. 2. Squared deviation from $1/(LC)^{\frac{1}{2}}$ plotted against $1/Z_o^2$ (for high-Q circuits). Graph (a) is for small M, when $1/Z_o^2$ never reaches $1/R^2$ (undercoupling), (b) is when $1/Z_o^2$ just reaches $1/R^2$ (critical coupling) and (c) is for large M (over coupling).

(resistance 15 ohms, say) to a power output valve (internal resistance 5000 ohms, say) by a transformer with a suitable turns ratio.

To see the application to tuned coupled circuits, let us view the circuit of Fig. 1 in an unusual way. Let us think of the resistance R in the primary as the internal resistance of the generator, and the secondary resistance as a load. Of course, this is an artificial dodge because the R's are inseparably bound up with the transformer, and, anyway, we are not using the tuned circuits merely to dissipate power in the secondary. These objections are not fundamental however, so we may lay them aside. Our problem is to find the condition for greatest secondary current, which amounts to finding the condition for maximum power dissipation in the "load". The properties of the coupling network are in this case frequency dependent, and we are seeking the frequencies at which a load R connected to the output terminals gives rise to a resistance R at the input terminals. (The point here is that the resistance "seen" at the input must be the same as the internal resistance of the generator, i.e. also R.)

At first sight, this problem may seem quite impossible to solve, but actually it can be done. At least, it is always possible to find an *impedance* (called Z_o) which, when connected to the output terminals of a symmetrical four-terminal network, causes the input impedance to be Z_o as well. Z_o is called, among other things, the iterative impedance, and it is a concept much used in some branches of circuit theory (e.g. the theory of filters). We need not worry about this, but merely remark that our problem is to find the frequencies at which the iterative impedance of the coupling network is equal to R.

It can be shown (and this stock phrase hides quite a lot of algebra) that in our case Z_o is given by:—

$$1/Z_o^2 = -[\omega C - 1/\omega(L+M)][\omega C - 1/\omega(L-M)] \quad (1)$$

Hence, the frequencies at which the secondary current is a maximum are the solutions of:—

$$1/R^2 = 1/Z_o^2 = -[\omega C - 1/\omega(L+M)][\omega C - 1/\omega(L-M)] \quad (2)$$

The reader may be tempted to feel that this is the end. After all, we have only to find what frequencies satisfy equation (2) for any given values of the parameters (M in particular), and we have the frequencies at which the load power is a maximum, and hence the secondary current is greatest. Disappointingly enough, we have not quite finished, since it is not always possible to satisfy equation (2). This is most easily seen by reference to Fig. 2. A word of explanation about this figure is in order here. The abscissa is plotted in terms of the squared frequency obviation from the centre frequency i.e. from $1/(LC)^{\frac{1}{2}}$. Thus each point to the right of the origin represents *two* frequencies, one above and one below the centre frequency. Negative points have no meaning. When plotted against this variable, for high Q circuits, the graph of $1/Z_o^2$ is practically a straight line in the region which concerns us.

For a given value of M, $1/Z_o^2$ is greatest at the centre frequency (remember that negative values of the abscissa are not allowed). If the highest value attained is less than $1/R^2$, as will happen if we make M sufficiently small, we will not be able to find a solution of equation (2). This is, of course, the situation known as "undercoupling". The secondary current has a single maximum at the centre frequency (i.e. where matching is most nearly achieved). The current is always less than V/2R since we can never have the theoretical maximum power transfer.

If we make M large enough, we arrive at the situation called "overcoupling". We now have the line representing $1/Z_o^2$ rising above $1/R^2$ at some real (positive) abscissa value. Hence we will have *two* solutions of equation (2) and thus two frequencies at which I_2 is a maximum. We can now see that the value of these maxima will be V/2R, for all values of M greater than the critical value. Thus, the obstinate refusal of I_2 to exceed V/2R can be seen to be a consequence of the maximum power transfer theorem.

At last we have reached the end of the road. It may seem that an undue amount of effort has been expended to arrive at rather meagre scraps of information, especially as the method cannot be extended to include the case of unequal primary and secondary resistances. We could, however, have worked out one more detail, namely the critical value of M, but this is left as an exercise for the reader.

CLUB NEWS

Bexleyheath.—W. J. Green (G3FBA) will give a talk entitled "Bandspreading HRO Coils" at the meeting of the North Kent Radio Society (G3ENT) on December 14th at 8.0 at the Congregational Hall, Clock Tower, Bexleyheath, Kent.

Birmingham.—The subject for discussion at the December 1st meeting of the Slade Radio Society (G3JBN) is d.f. developments. Meetings are held on alternate Fridays at 7.45 at Church House, High Street, Erdington, Birmingham, 23.

Bradford.—"The development of time measurement" is the title of the talk to be given by W. Barton at the December 12th meeting of the Bradford Radio Society. The club headquarters are at Cambridge House, 66, Little Horton Lane, Bradford, 5, where meetings are held at 7.30. Instruction for junior members is given at 7.0.

The D.C. Feedback Pair

A USEFUL TRANSISTOR AMPLIFIER CIRCUIT

By G. W. SHORT

THE circuit shown in Fig. 1 has several virtues. Not the least is economy: it gives good temperature stability with fewer components than the conventional one (Fig. 2(b)). It is useful in low-level audio stages, and it lends itself to negative feedback arrangements.

It has been called the transistor d.c. feedback pair,

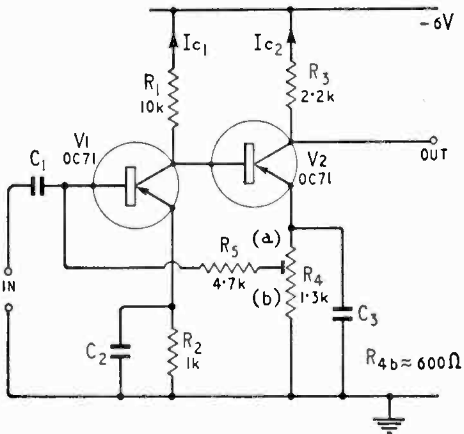


Fig. 1. Transistor d.c. feedback pair.

because it contains two transistors in a d.c. feedback circuit. The operation is complicated. Interested readers can look up reference (2) which contains a full circuit analysis. But they are warned that the formulæ are so complex that they mean very little to ordinary mortals.

A rough qualitative picture of what happens can be arrived at without any mathematics. Suppose that, as the result of a temperature change, there is a change in the base current of V1. The increment of base current is amplified by V1, which causes phase inversion as well. Part of the amplified increment is passed to V2, where it is further amplified, and finally a portion is fed back to V1 via R_5. Since there is no phase reversal in V2, which is a common-collector circuit as far as this feedback is concerned, the overall feedback is negative.

What about the temperature drift of V2? Assuming that ambient temperature, not the heat of internal power dissipation, is the controlling factor, then both transistors will be subject to the same temperature fluctuations. Their collector-base leakage currents (I_{cbo}) will drift in the same direction. Since there is phase inversion in V1, its amplified drift current appears at the base of V2 in opposite polarity to V2's own drift current. Thus some cancellation of V2's drift takes place. In practice, with two similar transistors, the drift in V2 is overcompensated by V1. As the temperature increases, the collector current of V2 decreases.

The behaviour of a practical circuit is shown in Fig. 3. This compares the performance of the d.c. feedback pair with the more conventional arrangements of Fig. 2. The same transistor was used for V1 and for the two conventional arrangements, and the operating current at room temperature was arranged to be the same in each case. A water bath was used to control the temperature: the transistor envelopes were immersed for about three-quarters of their length.

Simplified Circuits:—The d.c. feedback pair can be simplified by connecting the emitter of V1 straight to " earth ", and increasing R_5. This has

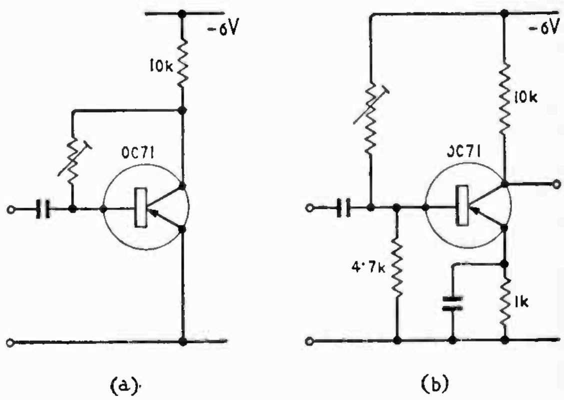


Fig. 2. Conventional temperature-compensated circuits; (a) with shunt feedback, (b) with emitter resistor and base bias potentiometer.

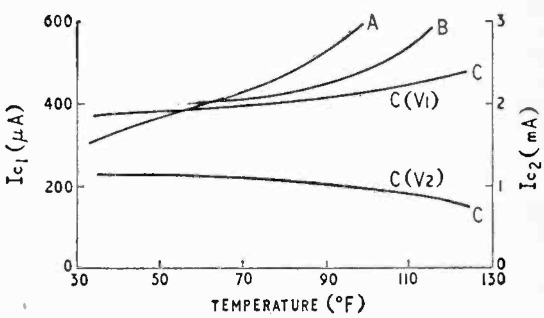


Fig. 3. Variation of collector current with temperature. Curve A refers to the circuit of Fig. 2(a), Curve B to that of Fig. 2(b), and Curve C to the d.c. feedback pair of Fig. 1.

the advantage of getting rid of R_2 and C_2. (It also increases the input impedance of V1 slightly, but this is hardly important, since R_5 can usually be made at least twice as big as the input impedance of the transistor V1 itself.)

Two simplified circuits are shown in Fig. 4. The first one (Fig. 4(a)) is applicable when the input is connected through a capacitor. The second (Fig. 4(b)) has too low an input resistance for this (in the particular set-up investigated by the writer, $R_{4(b)}$ was only about 30Ω) but it can be used with transformer input-coupling, as indicated.

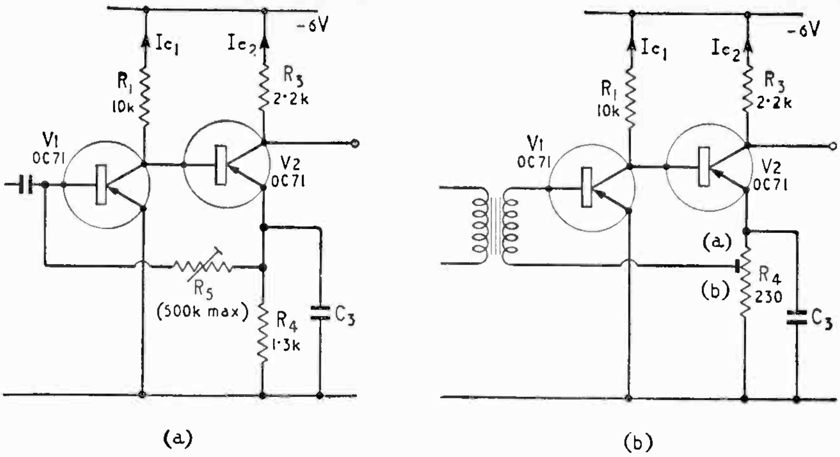


Fig. 4. Simplified feedback-pair circuits.

The temperature responses of these circuits are compared with that of full circuit in Fig. 5. The immediate conclusion is that the Fig. 4(a) type of circuit is no good: in this particular instance it is worse than the simple circuit of Fig. 2(a). In fact the trouble with this particular circuit was caused by an over-large R_4, which in turn made necessary an over-large R_5. For good stability, R_5 should be as small as possible.

Measurements taken on the circuit of Fig. 6, in which R_5 is reduced to 4.7kΩ, are shown in Fig. 7, along with those of the full circuit for comparison. The simpler circuit gives quite a good performance. ($R4_{(b)}$ was 37Ω.)

In general, then, all the variants of the d.c. feedback pair can be made to provide good enough temperature stability for use in domestic equipment, at any rate in a temperate climate. We shall now review some specific applications of the circuit.

Low-Level Input Stages.—Transistor noise can be serious in audio work. In order to minimize it, the transistor should be operated at a low current. In addition, the collector voltage (V_{ce}) should be kept small, though this is not so important as low current.

The temperature-stability curves show that the feedback-pair circuit is a good one for this application. The current in V1 is low and fairly constant, so that the transistor can be operated at a low voltage without the risk of "bottoming" at the higher temperatures. The OC71 is not conspicuously good from the point of view of noise. A special low-noise transistor such as the Mullard AC107 should give less noise, and also less temperature drift: its base leakage current is an order of magnitude less than that of the OC71. It would be reasonable to use an OC71 in the second stage, where noise and I_{co} are less important.

Negative Feedback.—The d.c. feedback pair behaves also as an a.c. feedback circuit at frequencies at which the capacitor which decouples the emitter of V2 has an appreciable impedance. The effect of this feedback is twofold. It reduces the input impedance of the amplifier as a whole, and it increases the input impedance of V2. Both effects can cause a reduction of gain as the frequency decreases. The magnitude of this "bottom cut" depends on the signal-source impedance and on the size of the collector load of V1. If the signal source has a very high impedance (constant-current drive) then the input current divides between the base of V1 and the feedback resistor R_5. Under these conditions the maximum amount of bottom cut is obtained. Note, however, that the process does not go on for ever. As the frequency is reduced, a stage is reached at which the reactance of the V2 emitter-decoupling capacitor becomes so great compared with the emitter resistance (R_4) that the feedback is virtually independent of frequency. The response then levels out again.

If the amplifier is driven from a low-impedance source (constant-voltage drive) the overall feedback has no effect. There is still the local feedback, however. The input impedance of V2 increases as the frequency is reduced. If V2 were driven from a source with a very high impedance, its base current would be unaffected, and there would be no bottom cut. In fact, the source impedance is the collector load of the first stage in parallel with the output impedance of V1, and it is unlikely to be very high compared with the input impedance of V2. The latter becomes approximately βR_5 at very low frequencies.

As in all transistor circuits, the two effects can-

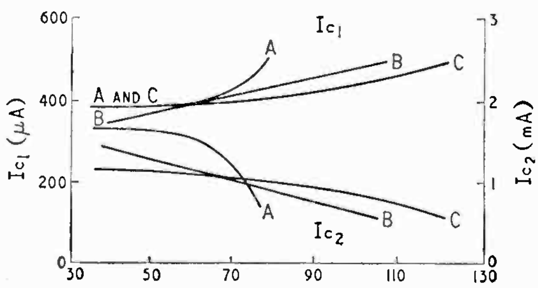


Fig. 5. Temperature performance of various feedback-pair circuits. Curve A refers to the circuit of Fig. 4(a), Curve B to Fig. 4(b), Curve C to one like Fig. 1, but with R_5 = 10kΩ.

not be completely separated. The output impedance of V1 is influenced by the signal-source impedance, for instance. But in typical audio circuits the signal-source impedance has only a small effect on the output impedance of V2. One can then get an idea of the effect of the second type of feedback by taking frequency response using a constant-voltage source.

Measurements on a practical circuit showed a low-frequency fall-off of about 5dB per octave with constant-voltage drive, and 8dB per octave with constant-current drive. These values were obtained when the capacitance C_3 was big enough to bypass the second emitter more or less completely above about 10 kc/s. If, on the other hand, C_3 is so small that it only begins to bypass the second emitter at frequencies near the upper cut-off frequency of a normal amplifier, a compensation effect occurs, and the frequency response is improved. In a particular instance, a 0.005μF capacitor doubled the bandwidth of the amplifier compared to that when *no* capacitor was used, the gain remaining almost the same.

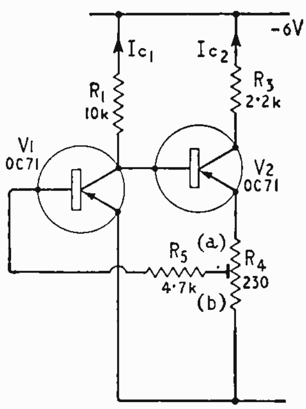


Fig. 6. Improved version of Fig. 4(a). By fixing R_5 and adjusting R_4 to obtain the right operating conditions the resistance in the base circuit of V1 is kept fairly low.

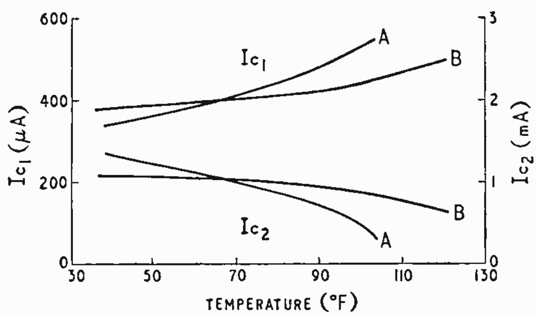


Fig. 7. Temperature performance of Fig. 6 (curve A) compared with full feedback-pair circuit with R_5= 10 kΩ.

Tape Recorder Equalization.—Readers may remember an article in the December, 1958, issue in which P. F. Ridler[3] showed that the circuit of Fig. 8 produced playback equalization for a tape recorder. In this case the inductance was that of the playback head, which was 500 mH.

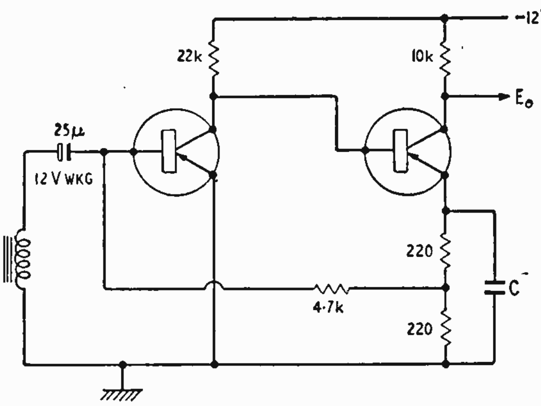


Fig. 8. Ridler's tape-recorder playback equalization circuit.

In tape-recording, two effects occur which modify the frequency response—a bass cut and a top cut. The bass cut arises simply because, as the frequency is reduced, the rate-of-change of flux at the playback head is reduced. The result is a bass cut of 6dB/octave. The top cut arises from more than one cause.

If the response of the recording amplifier is flat, and the recording *current* is constant, then, because of the low-frequency effect, the voltage induced in the playback head by the moving tape is proportional to the frequency. The lower the frequency, the lower the voltage, other things being equal. If, as is usual, the playback head is worked into a high-resistance load, so that it acts as a voltage generator, l.f. boost is necessary somewhere in the system.

If, however, the playback head is connected to a load with such a *low* resistance that it can be considered a short circuit, the output *current* does not fall off as the frequency is reduced. It remains constant. The reason is simple. The voltage induced in the head falls with frequency, as before. But the impedance of the head also falls, since the head is an inductor. These two effects cancel one another, and the output current is not a function of frequency.

Thus, in principle, the need for l.f. equalization can be avoided. The system fails if there is an appreciable amount of resistance in the circuit, either in the winding of the playback head or in the load. While a common-emitter transistor has a lowish input resistance (say 1 kΩ), this is by no means a short-circuit. The l.f. *current* response is 3dB down when the total resistance is equal to the reactance of the head. Assuming a 1 H head, then for a loss of no more than 3dB at 30 c/s the total resistance of winding and load must not exceed about 200Ω. While the winding resistance of the head may be less than 200Ω, the input resistance of a common-emitter transistor is much greater. One must either use a common-base transistor, or artificially reduce the input resistance of a common-emitter circuit. Since the feedback pair does this for us if we omit C_3, and since negative feedback brings other advantages, it is reasonable to use the feedback pair in equalization circuits.

The mechanism by which the equalization works is then as follows. The input resistance of V1 is unaffected by the feedback. What the feedback

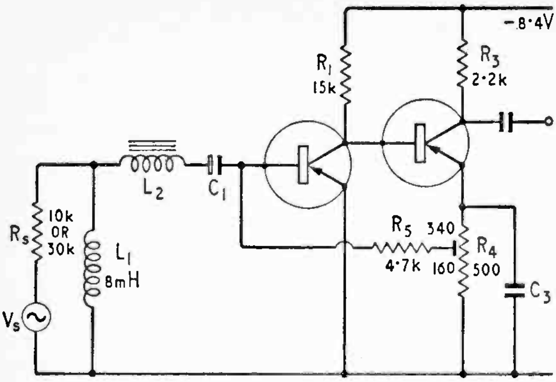


Fig. 9. Test circuit for playback equalization.

does is to make R_5 look smaller to the signal source, so that the input current mostly flows through R_5. If the amount of feedback is the same at all frequencies, the ratio in which the input current is shared by V1 and R_5 remains constant. (By reducing the feedback at high frequencies, one can produce top lift. With reduced feedback, R_5 looks more like its real value, and V1 gets more current from the source.)

The Mullard OC71 transistors used by the writer had a higher current gain than the transistors used by Ridler (about 50, compared with 30). In addition, the supply voltage available was less than Ridler's (8.4 V compared with 12 V). These factors prevented the use of an exact copy of Ridler's circuit. The one actually used is shown in Fig. 9. No test tape was available, so instead of using a tape recorder to generate an input voltage proportional to frequency, the effect was simulated by the method suggested by Murray.[1] This is to force a constant signal current through a small inductance (L_1 in Fig. 9). At low frequencies, R_s was 10 kΩ, and above about 1 kc/s it was 30 kΩ. In each case the condition $R_s \gg \omega L_1$, which is necessary if the current is to approach constancy, is satisfied, since L_1 is only 8 mH. (It might be mentioned that hum pick-up by L_1 and L_2 was somewhat troublesome at first, but was eliminated by carefully orienting the two chokes.)

Measurements were made using two different components for L_2. One was a choke of 800 mH, with a zero-frequency resistance of 70 Ω, and the other was an actual tape head of 200 mH inductance with a resistance of 100 Ω. The results are shown in Figs. 10 and 11. To begin with, the frequency response of the amplifier itself was measured; i.e., without any chokes at all. This is shown by the curve in Fig. 10 labelled $L_1 = L_2 = 0$, $C_3 = 0$. In theory, exact l.f. equalization is obtained using the full circuit with $C_3 = 0$, and this is borne out by the measurement. Note, however, that when the tape head has an appreciable resistance compared with its reactance, the system fails at really low frequencies (Fig. 11, 200 mH, 0 μF).

Referring again to Fig. 10, it can be seen that, by including C_3, and so reducing negative feedback at high frequencies, a rising response is obtained. This is used by Ridler to compensate the h.f. losses of the head. With his particular circuit, he found a distinct peak at the h.f. end. Such a peak is beginning to appear in the Fig. 10 curves. If the gain of the amplifier is much higher, it can oscillate at the peak frequency. Ridler's remedy for the peak of inserting a low resistance in series with C_3 stops this and gives the designer additional control over the h.f. response.

The effect of changing C_3 is to shift the response curves bodily. The slope remains nearly the same (about 6dB per octave). This suggests that, simply by switching in different capacitors, one might change the equalization to suit different tape speeds. The amount of equalization is sufficient to compensate

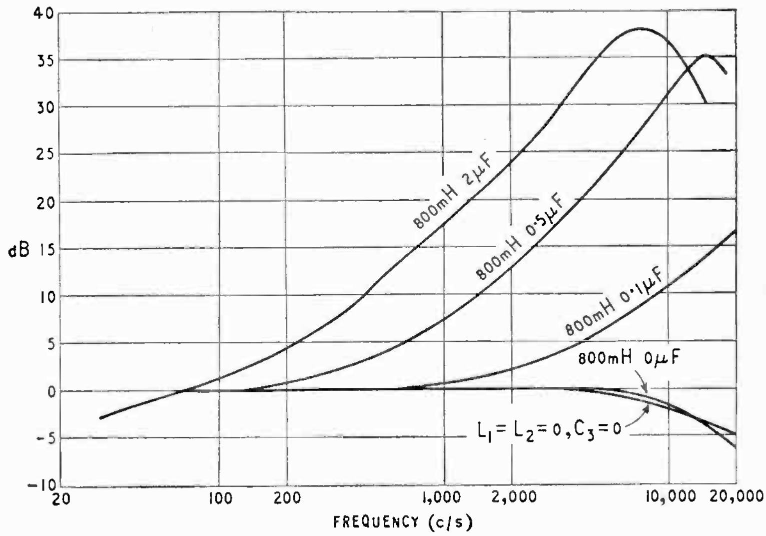


Fig. 10. Response of test circuit with simulated high-impedance playback head (800 mH). The capacitance values refer to C_3.

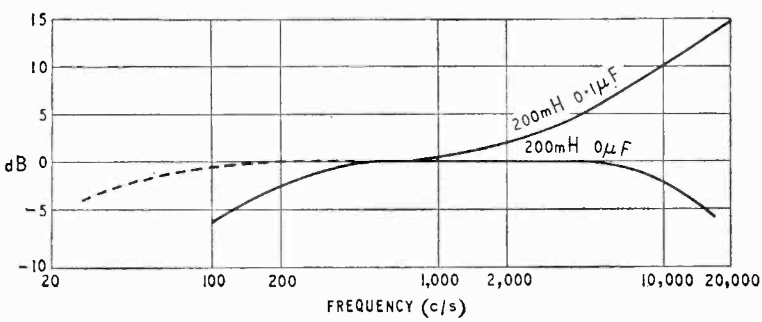


Fig. 11. Response of test circuit with low inductance head (200 mH, 100Ω d.c. resistance). The dotted curve shows how the l.f. response was restored by connecting 2kΩ in series with 0.5μF across the collector load of the first transistor.

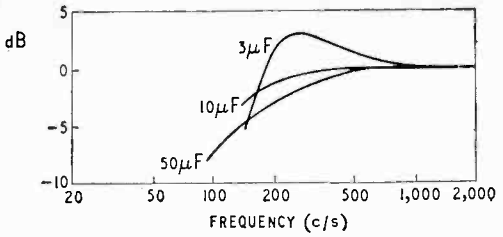


Fig. 12. Effect of C_1 on the low-frequency response of the test circuit, using the low-impedance tape head.

the l.f. tape loss completely. No pre-emphasis of low frequencies should be required when recording. If, as is probable, the same amplifier has to be used for recording and playback, one might wish to take advantage of the full gain for recording purposes. All one needs do to get it is to switch a large capacitor across the second emitter resistor—say 100μF. This will remove negative feedback at all significant frequencies. On the other hand, one might not need the full gain. The opportunity then presents itself of using some high-frequency pre-emphasis by leaving a small capacitor across the second emitter resistor. By suitable choice of values it should be possible to use the same capacitor during recording and playback and end up with a flat overall response.

The bass loss due to the head winding-resistance can be compensated, at the expense of gain, by connecting a series RC network across R_1. The effect of 2kΩ and 0.5μF is shown by the dotted curve in Fig. 11. With $C_3 = 0$, the shape of the h.f. response was unaffected, but with $C_3 = 0.1\mu$F the h.f. lift at 10 kc/s was reduced by about 4dB. Partial l.f. compensation can be obtained by selecting a value for C_1 which resonates with L_2 near the l.f. end of the response curve. The effect is shown in Fig. 12. As the resonant frequency is reduced, the circuit Q falls, and there is no peak in the response.

High-Impedance Input.—If the feedback loop is broken, the impedance looking into the break is high. This can be useful if one has a high-impedance signal source which must not be loaded appreciably by the amplifier. One then connects the signal source in place of R_5.

The input impedance can be measured by means of the circuit of Fig. 13. In this, there is no d.c. feedback, because to measure the impedance it is necessary to alter R, and this would upset the static conditions if R were carrying the base current of V1. With $R = 0$, apply an input signal big enough to produce a sizeable meter reading. Then adjust R so that this reading is halved. R is now the same as the input impedance. It can easily be a few hundred kilohms. An a.c. feedback pair along the lines of Fig. 13, but preferably with proper temperature stabilization of V1, may be useful when the signal source is a crystal pickup or crystal microphone. It is, of course, arguable that it may be just as good to use a straightforward amplifier without a.c. feedback and connect the crystal device to the input in the ordinary way, but with a series resistance big enough to provide an adequate load. For all the writer knows, this arrangement may be satisfactory. There is, however, one apparent virtue in doing it the other way. If the signal source is in the feedback path, the amount of feedback is controlled by the source impedance. As the latter decreases, the frequency response improves. This appears to work out the right way for crystal transducers, since their impedance falls as the frequency is raised.

Some evidence is provided by the following test results. The circuit used was like Fig. 9, but without the inductors, R_5, or C_3. V1 was biased by a resistor from base to the collector supply, and set up with $V_{ce} = 1$V. The input was applied between the emitter of V2 and the free end of C_1. The input resistance was over 500 kΩ. When the input signal was applied from a low-impedance source in series with 1000pF (this simulates a crystal device) the output was 3dB down at 250 c/s and 16 kc/s.

Conclusion.—Now that the writer has shown, to his own satisfaction, at least, that the d.c. feedback pair is a useful circuit, he will attempt to parry the inevitable question. If a feedback pair is good, why not a feedback triple, or quadruple? Let me say right away that circuits with d.c. feedback over three stages exist (Fig. 14). Readers can look up details in Reference 4. But there are a couple of snags. One

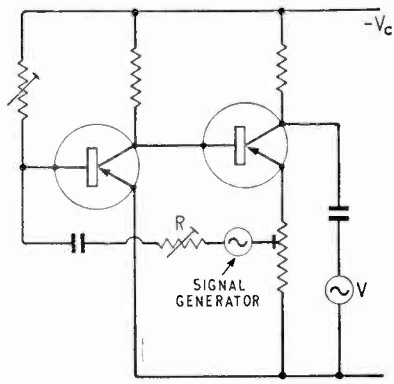


Fig. 13. Circuit for measuring imput impedance, looking into the feedback loop.

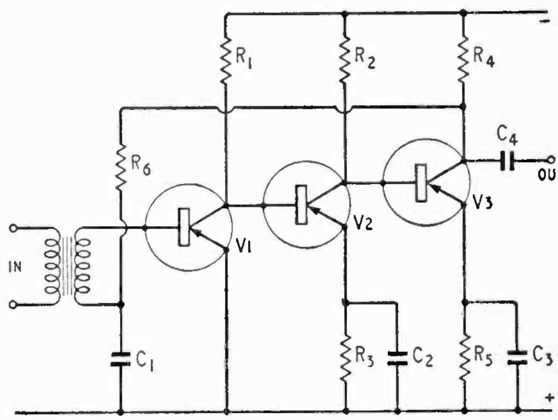


Fig. 14. D.C. Feedback Triple. In one variant, all the emitters are returned to earth directly.

is that, with germanium transistors, the temperature drift may be so great that the third transistor bottoms as the temperature rises. The point is that, with three stages, the drift of the first transistor gets amplified rather a lot before it reaches the third transistor, and may overload it. It's all right with silicon, but hardly with germanium transistors. Before readers who are familiar with Reference 4 rush to get pen and paper to write me rude letters, let me say that two of the germanium transistors in the three-transistor direct-coupled hearing aid described in it are not operated on the linear part of the V_c–I_c characteristics, but below the knee.

The other snag is that negative feedback over three stages isn't always practicable. If audio transistors are used, internal phase shifts may turn the amplifier into an oscillator if one attempts to apply a substantial amount of feedback. However, this objection is less valid if transistors with cut-off frequencies in the r.f. region are used, as for example in the amplifier described by R. C. Bowes in the July issue.

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[1] J. S. Murray, "Transistors Bias Stabilization," *Electronic and Radio Engineer*, May, 1957.

[2] S. D. Berry, "Transistor Amplifiers for Sound Broadcasting," *B.B.C. Engineering Monograph No.* 26, Aug., 1959.

[3] P. F. Ridler, "Transistors Tape Pre-amplifier," *Wireless World*, Dec., 1958 (correspondence, March, 1959).

[4] "Mullard Reference Manual of Transistor Circuits," pp. 165-6 and pp. 268-270.

BOOKS RECEIVED

Audio Biographies, by G. A. Briggs. With the collaboration of 64 of his contemporaries and friends the author has penetrated the façade of "hi fi" and explored the background, the upbringing and the motives which drive and sustain those who practise the art of sound recording and reproduction, either as professionals or amateurs. Quite apart from the human interest and the entertaining wit of the author/editor there is a wealth of technical information which should be invaluable to present and future historians. Pp. 343; Fig. 113. Wharfedale Wireless Works Ltd., Idle, Bradford. Price 19s 6d.

Printed Circuits, by J. M. C. Dukes. The book provides the background knowledge necessary for the engineer to undertake the electrical and mechanical design of printed-circuit assemblies at all frequencies up to the microwave region. A useful chapter contains design information for printed inductors, capacitors and resistors, and the bibliography is extensive. Pp. 228; Figs. 91. Macdonald and Co. (Publishers), Ltd., 16, Maddox Street, London, W.1. Price 40s.

Two-Way Radio, by Allan Lytel. A comprehensive, practical book on the theory and installation of voice-modulated radio-communication systems. The two main types of modulation, f.m. and a.m., are compared, and the later methods of amplitude-modulation such as single-sideband working are described. Information is given on power supplies, test equipment and servicing, and a chapter on selective-calling is included. Pp. 291; Figs. 277. McGraw-Hill Publishing Company, Ltd., McGraw-Hill House, 95, Farringdon Street, London, E.C.4. Price 74s.

Brimar Valve and Teletube Manual No. 9 is the latest in the series of manuals published by the Brimar Commercial Division of Thorn-A.E.I. Valves and Tubes, Ltd., Rochester, Kent (formerly Brimar Division of S.T.C.). Costing 6s, the new edition incorporates data on many new devices (including bonded-faceplate television c.r.ts) and has a tabular section listing characteristics of obsolete and obsolescent valves. Circuits included in this edition encompass a.f. amplifiers from 1.5 to 75W output, a crystal-controlled f.m. receiver and an R-C a.f. oscillator.

The Advance Science Master's Handbook, compiled by Ivan L. Muter. Intended to help the science teacher concerned with electricity and electronics. The first part of the book contains reference material and basic theory, while the second section is a set of nearly fifty experiments and demonstrations ranging from elementary a.c. theory to pulse circuits. Experiments to illustrate the nature of sound and wave motion are also included. Pp. 124; illustrated. Advance Components Ltd., Roebuck Road, Hainault, Ilford, Essex. Free to science teachers; otherwise available at 12s 6d.

Dictionary of Electronics, by Harley Carter. A cross-indexed, illustrated dictionary. Appendices contain lists of graphical symbols, colour codes and other tabulated data. Pp. 337; illustrated. George Newnes, Ltd., Tower House, Southampton Street, Strand, London, W.C.2. Price 35s.

Elsevier's Telecommunication Dictionary, compiled by A. Visser. Nearly ten thousand words and expressions are arranged in alphabetical order, using English as the base, with translations in five languages set out underneath. Following the main table, alphabetical lists of the terms in each language are given, and each term is linked to the main table by a reference number. The languages given are German, Spanish, French, Italian and Dutch. Pp. 1011. D. Van Nostrand Company, Ltd., 358, Kensington High Street, London, W.14. Price £7 7s.

The Mobile Manual For Radio Amateurs. Selected articles on mobile radio equipment, taken from past issues of "QST." Articles on s.s.b. equipment are included, and there is a complete section on portable and emergency units. Pp. 282. Profusely illustrated. American Radio Relay League, Inc., West Hartford 7, Connecticut, U.S.A. Price $2 (in U.S.A.), $3 (elsewhere).

Communications (Progress of Science Series), by Charles A. Marshall. Affords the younger reader an overall view, in non-technical language, of the field of telecommunications, including radar and television. A chapter on careers is included. Pp. 64; Figs. 19; plates 28. Phœnix House, Ltd., 38, William IV Street, Charing Cross, London, W.C.2. Price 9s 6d.

Sensitometric Control in Film Making, by L. J. Wheeler. Describes the system of sensitometry used to control the continuous processing of films used in B.B.C. Television news programmes. Pp. 22; Figs. 14. A B.B.C. Engineering Monograph. B.B.C. Publications, 35, Marylebone High Street, London, W.1. Price 5s.

Shortwave Propagation, by Stanley Leinwoll. Directed at both the amateur and the engineer, the book presents the basic principles of propagation on short waves, with chapters on circuit analysis and the preparation of m.u.f. curves. Mathematics are avoided wherever possible. Pp. 151; Figs. 75. John F. Rider (Publisher) Inc. Available from Chapman and Hall, 37, Essex Street, London, W.C.2. Price 36s.

Sound Recording Works Like This, by Clement Brown. An introduction to the subject for the layman, which describes in an unselfconscious way the working of all types of equipment, both domestic and professional. Pp. 62; Figs. 60. Phœnix House, 10-13, Bedford Street, Strand, London, W.C.2. Price 9s 6d.

Radio-Frequency Measurements

2.—LISSAJOUS FIGURES AND COUNTING TECHNIQUES

By R. BROWN

THE low difference frequency which is the output from some of the comparison systems has to be measured. A quick check through some of the standard textbooks reveals an almost bewildering number of ways in which such a measurement can be made. Many of the techniques described, however, seem now to be of only historical interest, and there seems to be only one or two of these methods of measurement in current use.

Lissajous Figures

By far the most common method is the one based on the use of Lissajous figures. This is an extremely accurate method, and it is one which calls for no other test equipment than the oscilloscope and a low frequency oscillator. It is a comparison method, the basic set up of which is shown in Fig. 9a.

The frequency to be measured (f_2) is fed to the "Y" plates of the oscilloscope, the "X" plates of which are fed from a reference oscillator (f_1). A figure will be traced on the oscilloscope, and the shape of this figure will depend upon the ratio of the frequency of f_1 to f_2.

The simplest case is where $f_1 = f_2$, and the shape the figure will take can be found with the aid of Fig. 9b. Here f_1 is represented by the equation

$$X = A \sin \theta \qquad (7)$$

and f_2 is represented by the equation

$$Y = B \sin (\theta + \alpha) \qquad (8)$$

where α is the phase difference between f_1 and f_2.

The two vectors in Fig. 9b, being of the same frequency will rotate at the same speed, and the figure is constructed by marking off the projection of the rotating vector B on the vertical axis—this represents Y in equation (8)—and marking off the projection of the rotating vector A on the horizontal axis—this represents X in equation (7).

The shape will vary with the phase difference α. In Fig. 9b this is 45°: when the two signals are in phase the ellipse of 9b closes to a straight line, broadening out again to an ellipse, and then to a full circle as the phase angle increases through 45° to 90°. This is shown in Fig. 10a.

The procedure when measuring the frequency of f_2 is simply to adjust the frequency of the reference oscillator (f_1), until a stationary figure is obtained on the oscilloscope screen. f_1 and f_2 are then equal, and their frequency can be read off the reference oscillator tuning dial. This should be known with sufficient accuracy, for most commercial oscillators are accurate to within about 1 %, and if the frequency being used is, say, 100 c/s the error will only be one cycle, and this is one cycle error in the measurement of the high frequency signal. So if the high frequency signal were say, 10 Mc/s this one cycle would amount to one part in 10^7.

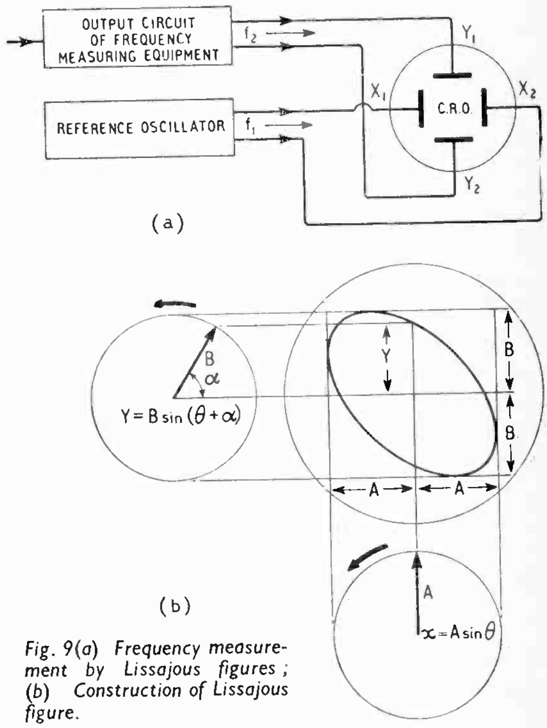


Fig. 9(a) Frequency measurement by Lissajous figures; (b) Construction of Lissajous figure.

Where the two frequencies f_1 and f_2 are fixed, and differ by only a fraction of a cycle, as is usually the case when checking fixed frequency oscillators against a standard oscillator for example, a stationary pattern will not be obtained. The phase angle between the two frequencies will slowly change, the rate of change depending upon their frequency difference. The figure on the oscilloscope screen will thus be of the form shown in Fig. 10, but it will change from a straight line, to an ellipse, then a circle and so on as the phase difference changes. If Fig. 9b is redrawn with vector Y say, rotating slightly faster than vector X and the results repeated as the phase difference increases from 0° to 360° it will be seen that the rate of rotation of the figure is equal to the frequency difference between f_1 and f_2. Frequency difference of as small as a cycle every few minutes can be measured in this way. It is not necessary to use an oscilloscope to time these slow rotations of the Lissajous figures; some quite simple device such as a magic eye tuning indicator can be used.

So far we have only considered the case where f_1

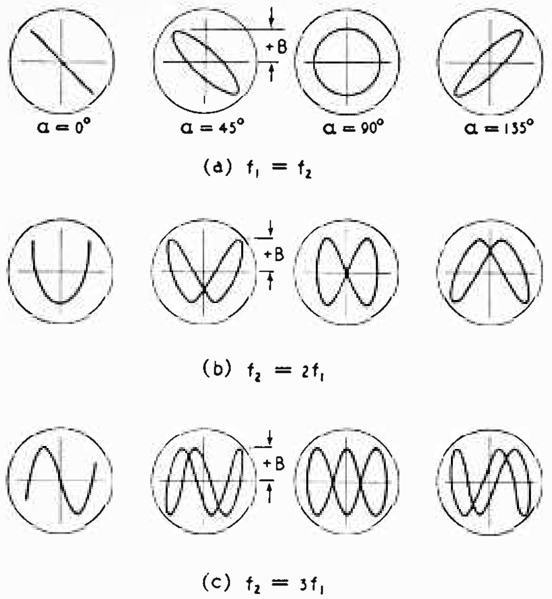


Fig. 10a, b, c. Some standard Lissajous figures.

is equal to, or very nearly equal to f_2. It is often more convenient, however, to have f_1 a sub-multiple, or a multiple of f_2. Stationary figures will be obtained when the ratio of f_1 to f_2 is 2 : 1, 1 : 2, 3 : 1, 1 : 3 etc. Examples of some of these figures are shown in Fig. 10b and 10c. They are all constructed in a similar manner to which Fig. 9b was constructed. Frequency ratios of four, five, six and higher can also be displayed; the figure becomes very complex with high ratios, however, and a ratio of six is about the highest that can be easily distinguished.

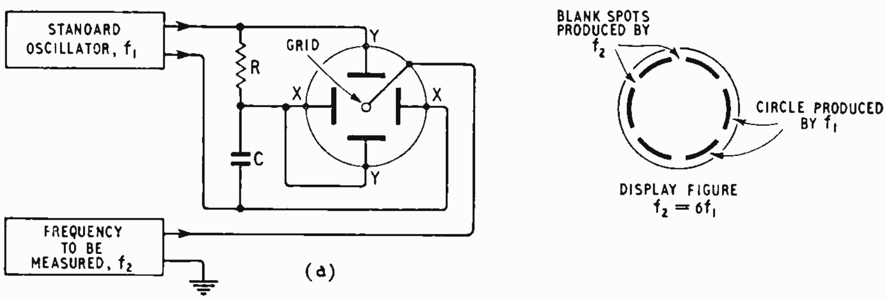
From Fig. 9b these intersections can only occur when Y = +B, i.e. from (10) when

$$\sin(p\theta + \alpha) = 1 \quad \ldots \quad (11)$$

i.e. when $p\theta + \alpha = \pi/2, 3\pi/2$ etc. .. .. (12)

Now the figure has a period of 2π. That is, the figure will be traced out once as θ goes through 360° (one revolution of the vector X). When p=1 there will be only one value of $p\theta + \alpha$ lying between 0° and 360°, and so the curve will intersect with the line +B only once. When p = 2 there will be two values of $p\theta + \alpha$ lying between 0° and 360°, and the curve intersects with the line +B when $\theta = \frac{\pi}{4} - \frac{\alpha}{4}$ and when $\theta = \frac{5\pi}{4} - \frac{\alpha}{4}$. In the same way when p = 3 there will be three values of $p\theta + \alpha$ lying between 0° and 360°, and the curve will intersect with the line +B when $\theta = \frac{\pi}{6} - \frac{\alpha}{6}$, when $\theta = \frac{5\pi}{6} - \frac{\alpha}{6}$ and when $\theta = \frac{9\pi}{6} - \frac{\alpha}{6}$. And so on for high values of p.

As has been said the highest frequency ratio p that can be easily distinguished, at least by people who don't spend the whole of their lives looking at Lissajous figures, is about six to one. One way of viewing high frequency ratios is by connecting the lowest frequency to both the 'X' and 'Y' plates, and the higher frequency to the grid or cathode of the cathode ray tube so that it intensity modulates the beam. The lower frequency signal is connected to the tube via a resistance-capacitance phase shifting network as shown in Fig. 11a. The 'X' and 'Y' plates will thus have connected to them signals of the same frequency, but which have a large phase difference, approaching 90°. Hence an ellipse, which is very nearly a circle, will be displayed on the oscilloscope. The time taken to



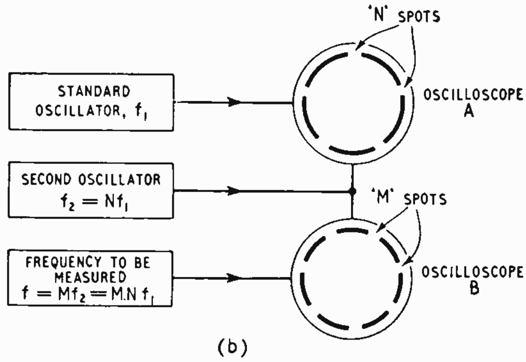


Fig. 11 (a). Determining frequency ratios up to 50:1. (b) Determination of frequency ratios greater than 50:1.

An important rule for determining the ratio of f_2 to f_1 can be found from these figures. Examining the three left-hand figures of each frequency ratio, that is the figures in which the go and return traces are separate, it can be seen that the number of times the curve intersects with the line +B is the same as the frequency ratio. That this must be so may be seen from the following:—

Let f_1 be represented by

$$X = A \sin\theta \quad \ldots \quad (9)$$

as before, and let f_2 be represented by

$$Y = B \sin(p\theta + \alpha) \quad \ldots \quad (10)$$

where p is the frequency ratio f_2/f_1

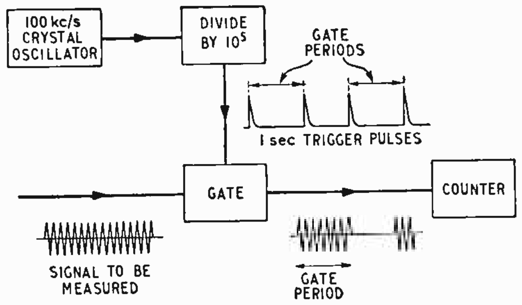


Fig. 12. Digital frequency meter—the counter displays frequency directly.

display the figures once will, as before, be the period of one cycle of the low frequency. The high frequency signal, which is being used to intensity-modulate the tube will shut off the beam on the peaks of the positive or negative half cycle (depending upon how it is connected). The result will be to produce a figure of the form shown in Fig. 11b, a broken circle. Since the circle is being displayed once for every cycle of the low frequency the number of blank spots must be equal to the ratio between the two frequencies.

As with Lissajous figures a stationary figure will only be obtained when one frequency is an exact multiple of the other. When the frequency is close to, but not an exact multiple the pattern will rotate slowly. Using this method frequency ratios of up to 50 : 1 can be determined. Much higher ratios can be determined by using a second oscillator, whose frequency need not be accurately known, and a second oscilloscope. This is shown in Fig. 11c.

A number of other similar comparison techniques use an oscilloscope,[18] and stroboscopes are also used to measure low frequencies.

Counter-type Frequency Meters

Frequency measuring techniques based on counters are being increasingly used. Where the accuracy required lies between about one part in 10^4 and one part in 10^6 the use of counters is becoming almost universal. This is largely because of the extreme simplicity of operation of the counter-type frequency meter.

A simple arrangement is shown in Fig. 12. The signal to be measured is connected to the input of the counter via a gate. When the measurement is to be made a trigger pulse is used to open the gate. The counter starts to count the individual cycles of the signal being measured; after one second a second trigger pulse closes the gate, and the counter stops counting. There will thus be displayed on the counter the number of cycles in one second of the signal being measured—that is its frequency. This count is usually repeated automatically. One small snag with this arrangement is that while the count is being made no information is presented to the operator, and conversely when the count is being displayed no information can enter the counter. This can be avoided if the counting and display sections are separate and if a memory device is included.[19] The memory system holds a count and displays it continuously while the new count is being accumulated. At the end of each counting interval the new count is transferred to the display in a very brief time—100μs in a commercial instrument. Thus the frequency is displayed practically continuously and the counter is collecting information on the frequency also almost continuously.

The trigger pulses, since they determine the width of the gate, must occur at accurately known intervals of time. A 100 kc/s crystal oscillator is usually the basic standard for determining this, the one per second trigger pulses being obtained by successive division of the 100 kc/s signal.

The highest frequency that can be measured is limited by the speed of the counter. In commercial instruments it is usually one megacycle or ten megacycles.[20, 21]

Any frequency within the range of the counter can, however, be measured simply by connecting it to the input of the counter, no adjustments being required.

To measure frequencies above the top limit of the counter, heterodyne techniques can be used. A suitable arrangement is shown in Fig. 13. The

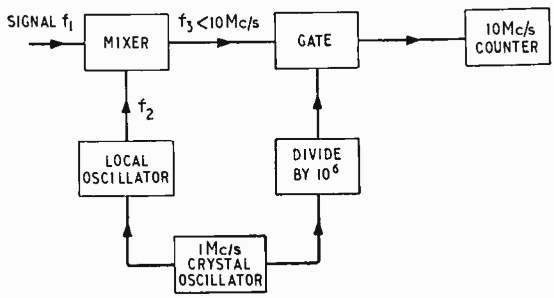


Fig. 13. Measuring frequencies above the upper limit of the counter by means of a heterodyne unit.

local oscillator can be locked, at 10 Mc/s intervals in the case of a 10 Mc/s counter, to the harmonics of the crystal oscillator. If the frequency to be measured was, say, 26 Mc/s, the local oscillator would be tuned to 20 Mc/s and locked to one of the crystal harmonics. The local oscillator output is then mixed with the signal in the mixer, and the difference frequency, 26 Mc/s—20 Mc/s = 6 Mc/s, is passed on to the counter and displayed.

With this sort of arrangement the signal frequency is given by the sum of the local oscillator frequency, and the frequency displayed on the counter. Some adjustment is now necessary when making measurements, but once the local oscillator has been set up any frequency over a 10 Mc/s band can be measured without any further adjustment.

This type of frequency meter suffers from two types of error. There is first of all the effects of an error in the standard 100 kc/s frequency which produces errors in the gate period. When using a heterodyne system, however, the local oscillator frequency will also be in error, and this error will add to the error in the gate period. If the 100 kc/s signal was for example slightly high, the gate period would be shorter than it should be. The local oscillator frequency would then be higher than it should be, causing the difference frequency to be low. The error in the standard frequency would thus result in low difference frequency and a short gate period. It is shown in the appendix, however,

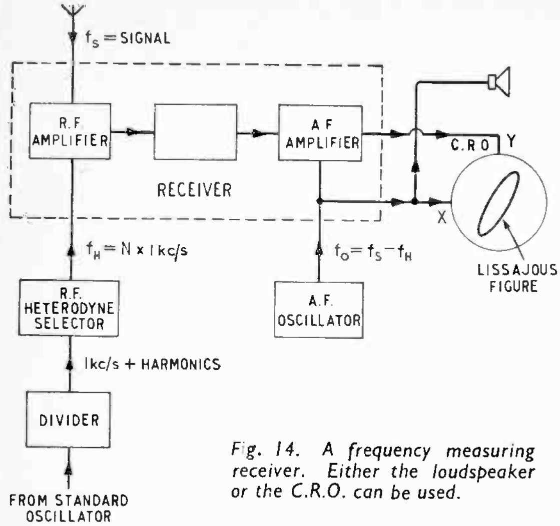


Fig. 14. A frequency measuring receiver. Either the loudspeaker or the C.R.O. can be used.

that the total error can never be greater than the error in the local standard.

The second source of error, and this is peculiar to counters, is what is called gate error. There is no direct relationship between the signal being measured and the trigger pulses that open the gate; the point in time when the trigger pulses arrive can be at any point on the signal waveform. Whether or not the first cycle is counted will depend upon what point on the waveform the gate opens, and an error of ± 1 digit is possible.

This error is the same, one digit, whatever the length of the gate period, so its effect can be considerably reduced by lengthening the gate period. A ten second gate can be used, for instance, and if the frequency being measured was, say, 10 Mc/s, then 10^8 cycles would be counted in the gate period and the gate error of one digit would then be equivalent to only 1 in 10^8. The displayed count must then be divided by ten, of course, and this does rather increase the possibility of errors due to misreading.

Counters with much higher counting rates seem to be just around the corner, and counter-type frequency measuring systems using computer techniques have also been described.[22]

Frequency Measuring Receivers

Errors due to misreading are always a possibility with frequency measuring systems, particularly the more sophisticated ones. Where readings have to be taken over a long period this can become a serious problem, and special care has to be taken with the design of the operating controls and read-out sections.

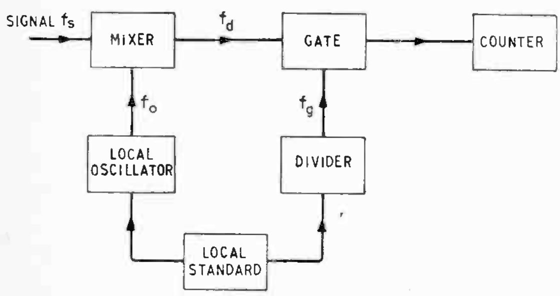
A technique which while covering a wide frequency range is almost free of misreading errors is the frequency measuring receiver. A simple type is shown in Fig. 14. The receiver, a conventional one, is tuned accurately to the signal to be measured. The heterodyne oscillator is then tuned until it is set to a frequency corresponding to the nearest whole number of kilocycles below the frequency to be measured, the accuracy of the oscillator setting being checked against the harmonics from the 1 kc/s multivibrator.

The heterodyne note produced in the receiver output will thus be below 1 kc/s. The output from

(*Continued on page 647*)

APPENDIX

That the total error can never be proportionately greater than the error in the local standard when using a counter in a heterodyne set-up can be seen in the following way. Any error in the local standard will cause the frequency of the local oscillator to



be in error and the gate interval to be in error. Suppose this error is a small fraction e, and the nominal local oscillator frequency is fo, then the possible limits of the local oscillator frequency will be

$$f_o' = f_o(1 \pm e) \quad \ldots \quad (1)$$

The difference frequency f_d between the local oscillator frequency and the signal frequency f_s will, therefore, be somewhere between the limits

$$f_d = f_s - f_o(1 \pm e) \quad \ldots \quad (2)$$

Next consider the effect of the error in the local standard on the gate interval. If f_g is the nominal gate frequency then the actual gate frequency will vary between the limits

$$f_g' = f_g(1 \pm e) \quad \ldots \quad (3)$$

But the gate time interval t_g' is given by $1/f_g'$.

Hence

$$t_g' = \frac{1}{f_g(1 \pm e)} \quad \ldots \quad (4)$$

For a frequency f_d counted for a time interval t_g the counter display will be N where N is given by $f_d \times t_g$, and the actual indicated count will vary between the limits

$$N = f_d t_g (1 \mp e) \quad \ldots \quad (5)$$

The indicated frequency N/t_g will thus vary between the limits

$$f = N/t_g = f_d(1 \mp e) \quad \ldots \quad (6)$$

The actual indicated value of the signal frequency f_s can now be found by adding the nominal value of the local oscillator frequency to this, or

$$f_s = f_o' + f_d(1 \mp e)$$

Substituting for f_d in equation (2) we get

$$f_s = f_o + [f_s - f_o(1 \pm e)](1 \mp e)$$
$$= f_s \mp ef_s + e^2 f_o$$

If we ignore the second order terms, which we can do since e is normally a very small fraction, then the limits of error in the measurement are given by $\mp ef_s$.

an audio oscillator is then mixed with the heterodyne note, and the audio oscillator tuned until it zero beats with the heterodyne note. The reading of the audio oscillator tuning plus the reading of the heterodyne oscillator tuning then gives the signal frequency.[23]

A counter can be included in the receiver to further increase the simplicity of operation, and one such arrangement is shown in Fig. 15. A receiver covering the desired range in 1 Mc/s bands is used. If the frequency to be measured was, say, 6.3 Mc/s, the receiver would be switched to the 6 Mc/s band, and tuned to 6.3 Mc/s. The range switch will have caused the first local oscillator to be locked to the 50th harmonic of the standard, that is to 5 Mc/s. The signal is mixed with this to give a difference frequency of 1.3 Mc/s. The output from a variable frequency oscillator, covering 900 kc/s to 1.9 Mc/s, is mixed with this, and the oscillator tuning is set to give an accurate difference frequency of 100 kc/s. This tuning is checked by comparing the 100 kc/s difference frequency with the standard 100 kc/s using Lissajous figures. The variable oscillator output at 1.2 Mc/s is now mixed with the 9th harmonic of the 100 kc/s standard to produce a 300 kc/s difference frequency which is displayed on the counter. The frequency of the signal is thus given by the frequency range in use, 6 Mc/s, and the counter reading, 300 kc/s, as 6.3 Mc/s.

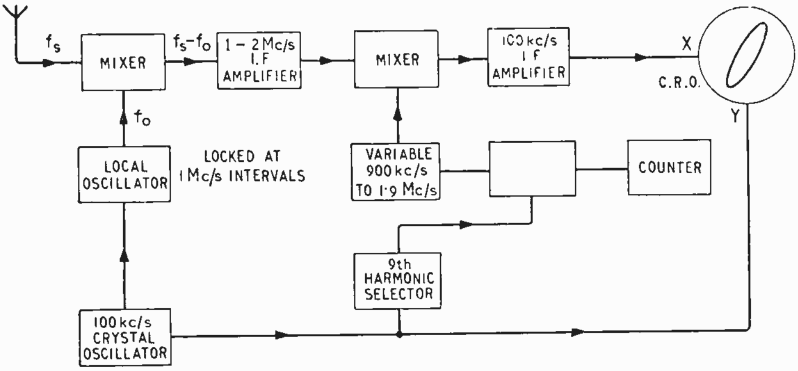


Fig. 15. A frequency measuring receiver using a counter.

Practical counter type frequency measuring receivers are usually more complicated than this; but despite the high inherent accuracy of such a system frequency measurement is no more difficult than tuning the receiver to the signal to be measured. Quite an improvement on some of the earlier high accuracy systems where a training period of anything from three to six months was usually required.

References

18. F. R. Stansel, "An Interpolation Method for Setting Laboratory Oscillators", *Bell Laboratories Record*, 1940, Vol. 19, p. 98.

19. "A Frequency Counter with a Memory and with Built-in Reliability", *The General Radio Experimenter*, Vol. 35, No. 5, p. 3, May 1961.

20. D. W. Bissett, "10 Mc/s Electronic Counter Type TF 1345", *Marconi Instrumentation*, Vol. 7, No. 5, p. 133, 1960.

21. A. S. Bagley, "A 10 Mc/s Scaler for Nuclear Counting and Frequency Measurements", *Hewlett-Packard J.*, Vol. 2, p. 1, October, 1950.

22. J. Stevenson, "Digital Rate Synthesis for Frequency Measurement and Control", *Proc. I.R.E.*, December 1959.

23. J. Treeby Dickenson, "International Monitoring", *Wireless World*, Vol. 59, p. 422, Sept. 1953.

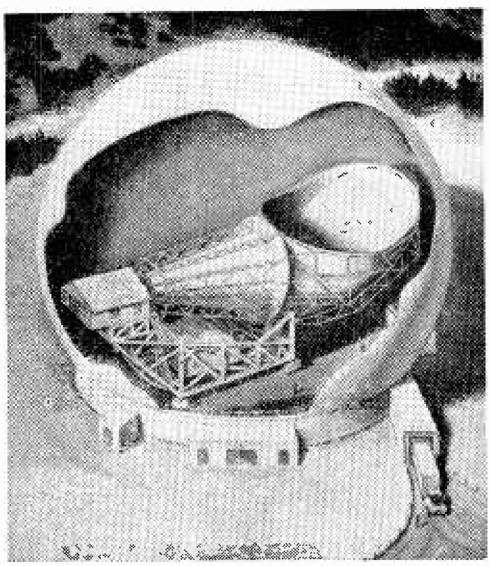
HORN RADIATOR

ON a 1,000-acre site near Rumford, Maine, U.S.A., Bell Telephone Laboratories is installing what is said to be the world's largest horn aerial as part of a new experimental space communications station. The 250-ton steel and aluminium structure will be a rotating aerial—177ft long, 94ft high, and will be protected from the weather by an inflated spherical cover, or radome, 210ft wide, 161ft high.

The huge horn will rotate on two concentric circular tracks on the ground. It will also "roll" about its horizontal axis so that it can follow a satellite from low to high angles of elevation.

Carried around on the structure with the horn will be two "houses" for equipment including a travelling-wave maser.

The radome will be supported by air pressure of one tenth of a pound per square inch greater than the outside atmospheric pressure. It will be anchored to the top of a 14-foot wall that will encircle the base of the aerial. Double doors provide an "air lock" to avoid losing pressure.



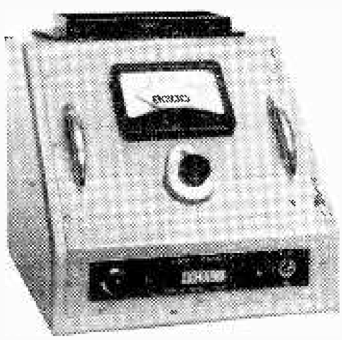
Cut-away drawing of the Bell horn radiator inside its radome. Eventually five such structures may be built on the Rumford site.

MANUFACTURERS' PRODUCTS

NEW ELECTRONIC EQUIPMENT AND ACCESSORIES

Capacitance-Type Moisture Meter

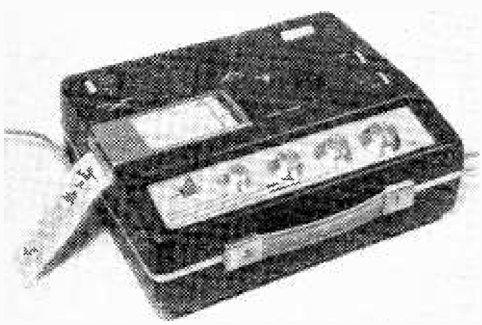
SIMPLICITY of operation is afforded by the single knob control of the "Varsity" moisture meter, in which the capacitance method of measurement is employed at a frequency of 100 Mc/s. Readings are obtained by noting the combined readings of a 10-turn calibrated control and a moving coil meter. The meter reading can be converted to moisture content by means of a graph or a transparent scale placed over the meter. The instrument is fully stabilized for mains variations of 190V-260V. Details are obtainable from Shaw Moisture Meters Ltd., Rawson Road, Westgate, Bradford.



Shaw "Varsity" moisture meter. Material sample is placed in 2,000cm³ container on top of the instrument.

Direct Writing Recorder

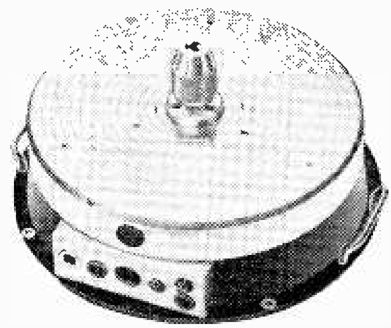
A SINGLE-CHANNEL recorder, the R.1, with a choice of two writing systems, is announced by Devices Ltd. Either a hot stylus on heat-sensitive paper using rectilinear co-ordinates, or an ink pen on curvilinear co-ordinates may be used, and any of six paper speeds can be selected. The sensitivity is 0.5V/cm or with pre-amplifier 0.5 mV/cm, giving a linear excursion of 5 cm. A differential feedback amplifier is employed, and the frequency response of the complete instrument is 0-65 c/s (−3dB). Full details of the instrument, which uses transistors throughout, may be obtained from Devices Sales Ltd., 13-15 Broadwater Road, Welwyn Garden City, Herts.



Devices R.1. recorder, with hot stylus unit in use. This may quickly be interchanged with an ink pen system.

Polar Recording Turntable

IN conjunction with level recorder Type 2305, the Brüel and Kjaer turntable Type 3921 enables directional measurements to be made on aerials, microphones, loudspeakers, etc., and the results automatically recorded on polar co-ordinate graph paper. The item under test may be either bolted to the table by means of the threaded holes provided, or may be mounted centrally in the chuck. The specimen can be provided with power or signals via a slip-ring arrangement below the table. Full details are obtainable from B. and K. Laboratories, Ltd., 4 Tilney Street, Park Lane, London, W.1.

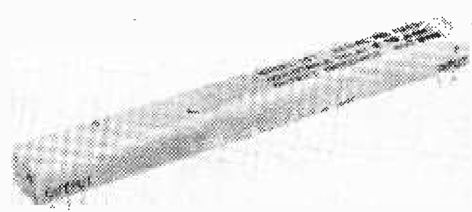


Brüel and Kjaer polar recording turntable.

Adjustable Delay Line

VARIABLE magnetostrictive delay lines with delays between 2 μsec and 20 μsec are announced by Sealectro. The unit is contained in a hermetically sealed steel case, and adjustment of the delay is by means of a single screw. The maximum pulse repetition rate is 500 kc/s, with a pulse width of 1 μsec. Input and output impe-

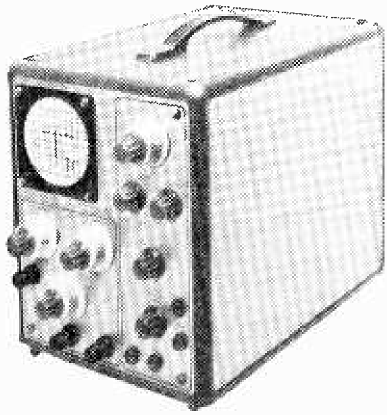
Sealectro Deltime Type 157 variable delay line. Adjustment screw is at left-hand end.



dances are 400 ohms and insertion loss is 45 dB. A complete description can be obtained from Sealectro Corporation, Hersham Factory Estate, Walton-on-Thames, Surrey.

Inexpensive Oscilloscope

ALTHOUGH marketed at the very low price of £36, the Model 381 general-purpose oscilloscope is capable of a high performance. The Y-amplifier has a band-



Dartronic Model 381 oscilloscope.

width of 0-9 Mc/s, a rise time of 40 nsec. and a sensitivity of 100 mV r.m.s./cm. Input impedance is 1 M and 20 pF. The timebase speed is from 0.55 μsec/cm to 0.15 sec/cm and the waveform is made available at the front panel. Accessibility for servicing is assured by the sensible construction; the top, bottom and side panels are removable, and most of the circuitry is mounted on two vertical panels. The instrument is made by Dartronic Ltd., 3, 5 and 7 Windmill Lane, London, E.15.

Sensitive Millivoltmeter

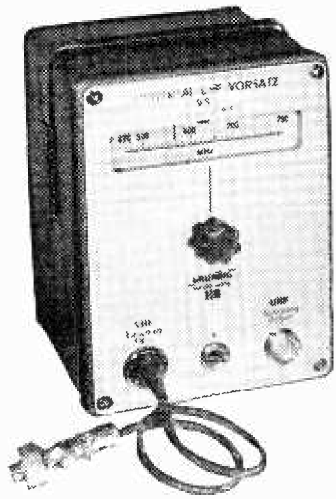
ALTERNATING voltages from 300μV in the range 100c/s to 900Mc/s may be measured by means of the Airmec Type 301. Measurement of direct voltages may be made in the range 100μV to 10V.

Airmec millivoltmeter Type 301.

The amplifier is direct-coupled throughout, stability being achieved by the use of chopper. A semiconductor rectifying probe allows the use of a simplified attenuator which needs no frequency-compensation. The input impedance is 5MΩ on d.v. ranges and when measuring alternating voltage varies from 120kΩ+2pf at 100kc/s to 3kΩ+2pf at 200Mc/s and above. Fluctuation of reading with ±10% mains variation is less than ±1.5% on all ranges. Full details are obtainable from Airmec Ltd., High Wycombe, Bucks.

Wobbulator Attachment

TO extend the coverage of currently-available sweep-frequency generators to the Bands IV and V region, Grundig have introduced their VS-2 u.h.f. converter. The output of the existing generator is set to 55Mc/s and applied to the converter, where it is mixed with



Grundig VS-2 u.h.f. converter for wobbulators.

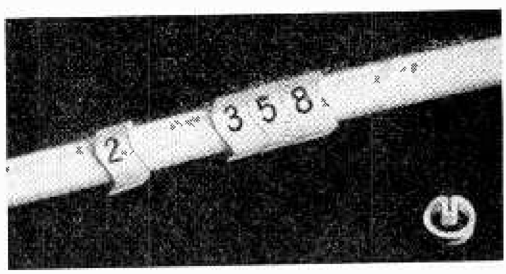
the output of a u.h.f. oscillator. The resultant signal covers the range 460-795Mc/s and the level is −13dB on the output of the sweep frequency generator. Input and output impedances are 60Ω unbalanced. The converter costs £30, and is available from the British distributors, Wolsey Electronics, Ltd., Cray Avenue, St. Mary Cray, Orpington, Kent.

Cable Identifier

DESIGNED for application without tools, the Helagrip is a flexible p.v.c. sleeve supplied in sizes to fit cables of $\frac{1}{8}$-in to $\frac{7}{16}$-in dia. The indented edge of the sleeve prevents adjacent pieces twisting relative to each other, and the special section prevents sliding. The sleeving is supplied partially cut in lengths of identical coding (A-Z, 0-9).

Further details may be obtained from Hellermann, Ltd., Gatwick Road, Crawley, Sussex.

"Helagrip" cable identifier.



DECEMBER MEETINGS

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

LONDON

4th. I.E.E.—Discussion on "Backward waves in waveguides" opened by Dr. P. J. B. Clarricoats, R. A. Waldron and G. H. B Thompson at 5.30 at Savoy Place, W.C.2.

6th Brit.I.R.E.—Discussion on "Possible uses of computers in medical diagnosis" opened by Dr. A. D. Booth at 6.0 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

8th. Institute of Physics and Physical Society.—"Electron microscopy in Japan" by T. Mulvey and Dr. M. Whelan at 2.30 at 47 Belgrave Square, S.W.1.

8th. Television Society.—"Remote control operation of television cameras" by H. C. Nickels at 7.0 at the Cinematograph Exhibitors' Association, 164 Shaftesbury Avenue, W.C.2.

11th. I.E.E. Graduate and Student Section.—"The professional engineer and an expanding industry" by G. S. C. Lucas at 6.45 at Savoy Place, W.C.2.

12th. I.E.E.—"Diversity reception and automatic phase reception" by L. Lewin at 5.30 at Savoy Place, W.C.2.

12th. Institute of Physics and Physical Society.—"Integrated electronics" by Dr. W. J. Granville at 5.30 at 47 Belgrave Square, S.W.1.

14th. Brit.I.R.E.—Symposium on "Constant luminance colour television" including papers by I. J. P. James and W. A. Karwowski, W. N. Sproson, A. V. Lord, K. Hacking and G. F. Newell at 6.0 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

14th. Radar & Electronics Association.—"Loudspeaker enclosures" by J. Gough and Prof. F. Landgrebe at 7.0 at the Royal Society of Arts, John Adam Street, W.C.2.

15th. Television Society.—"The 'Nev-Eye' vidicon camera" by N. S. Rutherford at 7.0 at the Cinematograph Exhibitors' Association, 164 Shaftesbury Avenue, W.C.2.

15th. B.S.R.A.—"Problems in telephone transmission" by D. L. Richards at 7.15 at the Royal Society of Arts, John Adam Street, W.C.2.

18th. I.E.E.—"Large microwave steerable aerials for communication with artificial earth satellites and space probes" by F. J. D. Taylor at 5.30 at Savoy Place, W.C.2.

20th. I.E.E.—"Satellite instrumentation" by Dr. R. L. F. Boyd at 5.30 at Savoy Place, W.C.2.

ARBORFIELD

11th. I.E.E. Graduate & Student Section.—"Design of service equipment" by B. W. Norman at 7.0 at the Unit Cinema, 3(Tels.) Training Bn., R.E.M.E.

BIRMINGHAM

4th. I.E.E.—"The banana-tube display system—a new approach to the display of colour-television pictures" by Dr. P. Schagen at 6.30 at the College of Technology. (Joint meeting with the Institution of Post Office Electrical Engineers.)

8th. Society of Instrument Technology.—"Instruments in clinical chemistry" by N Crawford and "Electronics in surgery" by R. Lightwood at 7.0 at the College of Technology, Aston Street.

12th. Institute of Physics and Physical Society.—"The observation of radio stars" by Dr. P. F. Scott at 6.30 at the Midland Institute.

14th. Brit.I.R.E.—"The R.R.E. radio-telescope interferometer" by H. Gent at 6.15 at the Electrical Engineering Department, The University.

BRADFORD

5th. I.E.E.—"The potentialities of artificial earth satellites for radiocommunication" by W. J. Bray at 6.30 at the Institute of Technology.

BRISTOL

14th. Society of Instrument Technology.—"The atomic clock" by Dr. L. Essen at 7.30 at the Department of Physics, the University.

20th. Brit.I.R.E.—Annual general meeting of the South-Western Section followed by "Transistors in transmitters and communications receivers" by D. C. Carey at 6.0 at the School of Management Studies, Unity Street.

CAMBRIDGE

12th. I.E.E.—"The banana-tube display system—a new approach to the display of colour television pictures" by Dr. P. Schagen at 8.0 at the Cavendish Laboratory, Free School Lane.

CARDIFF

6th. Brit.I.R.E.—"Microwave valves" by R. W. White at 6.30 at the Welsh College of Advanced Technology.

CHELTENHAM

1st. Brit.I.R.E.—"Electronic telephone exchanges" by J. F. Hesketh at 7.0 at the North Gloucestershire Technical College.

EDINBURGH

5th. I.E.E.—"Precision Measurement" by G. H. Rayner and A. Felton at 7.0 at the Carlton Hotel.

13th. Bri.I.R.E.—"Jodrell Bank" by J. B. Wilson at 7.0 at the Department of Natural Philosophy, The University, Drummond Street.

FARNBOROUGH

7th. I.E.E. Graduate and Student Section.—"The synthesis of speech for communication purposes" by H. L. Chesters at 6.30 at the Technical College.

FAWLEY

1st. Society of Instrument Technology.—"Applications of transistors and diodes" by D. Osborne at 5.45 in Room 4a, Administration Building, Esso Petroleum Co.

GLASGOW

4th. I.E.E.—"Precision measurement" by G. H. Rayner and A. Felton at 6.0 at the Royal College of Science and Technology.

14th. Brit.I.R.E.—"Jodrell Bank" by J. B. Wilson at 7.0 at the Institution of Engineers and Shipbuilders, 39 Elmbank Crescent.

GRANGEMOUTH

21st. Society of Instrument Technology.—"Instrumentation of space vehicles" by Dr. A. E. Roy at 7.0 at the Leapark Hotel, Bo'ness Road.

LEICESTER

6th. Brit.I.R.E.—"Transistors in computers and control equipment" by P. James at 6.45 at the University.

12th. I.E.E.—"Altitude control of earth satellites" by B. Stewart at 6.30 at the Lecture Theatre, E.M.G.B. Showrooms, Charles Street.

LINCOLN

7th. I.E.E.—Discussion on "Semiconductors for light-current engineering" opened by L. Rushforth at 7.30 at the E.M.E.B. Showrooms, 191 High Street.

LIVERPOOL

4th. I.E.E.—"Simulation of intelligence" by Prof. D. M. MacKay at 6.30 at the Royal Institution.

13th. Brit.I.R.E.—"Nuclear power station instrumentation" by M. W. Jervis at 7.30 at the Walker Art Gallery.

14th. Society of Instrument Technology.—"The versatility of the electronic potentiometer" by F. W. J. Howard at 7.0 at the Merseyside and North Wales Electricity Board Industrial Centre, Paradise Street.

18th. I.E.E.—"Education of an electrical engineer" by Prof. M. R. Gavin and "The place of formal study in the post-graduate training of an electrical engineer" at 6.30 at the Royal Institution.

MAIDSTONE

7th. I.E.E.—"Electronics in the postal mail services" by G. P. Copping at 7.0 at the "Wig and Gown."

MANCHESTER

6th. I.E.E.—"Generation and amplification in the millimetre wave field" by W. E. Willshaw at 6.25 at the Engineers' Club, Albert Square.

7th. Brit.I.R.E.—"Radar for civil aviation purposes" by K. F. Slater at 7.0 at the Reynolds Hall, College of Technology.

NEWCASTLE-UPON-TYNE

4th. I.E.E.—"Planning and installation of the sound broadcasting headquarters for the B.B.C.'s Overseas and European Services" by F. Axon and O. H. Barron at 6.15 at the Rutherford College of Technology, Northumberland Road.

13th. Brit.I.R.E.—"Masers and parametric amplifiers" by Dr. T. H. Wilmhurst at 6.0 at the Institute of Mining and Mechanical Engineers, Neville Hall, Westgate Road.

18th. I.E.E.—"Heaviside—his life and work" by Prof. R. L. Russell at 6.15 at the Rutherford College of Technology, Northumberland Road.

PORTSMOUTH

13th. I.E.E.—Discussion on "Silicon controlled rectifiers" opened by R. J. Alexander, J. P. Birchenough and R. Thompson at 6.30 at the C.E.G.B. Offices, 111 High Street.

SHEFFIELD

13th. I.E.E.—"Millimetre waves" by Dr. J. Allison at 6.30 at the University.

SOUTHAMPTON

12th. I.E.E.—Discussion on "High speed measuring techniques in the nano-second region" opened by B. H. Venning and D. Grollet at 6.30 at the University.

WEYMOUTH

1st. I.E.E.—"The banana tube" by Dr. P. Schagen at 6.30 at the South Dorset Technical College.

WOLVERHAMPTON

6th. Brit.I.R.E.—Symposium on "New electronic techniques in non-destructive testing" at 10.0 at the Wolverhampton and Staffordshire College of Technology.

UNBIASED

By "FREE GRID"

In Old Bohemia

AMERICANS often claim to be far ahead of us Europeans—and in particular of us Limeys—in the various activities of life, and in many cases they are, of course, quite justified in their claims. For instance, in some of their big cities, their buildings and their crime statistics are much higher than anything we can boast of.

However, it is mostly in matters of applied science that the Americans claim to be so far ahead of us, and here again they are fully justified. What European state, for instance, can boast of having had, since 1890, an electric chair for the administration of what they call "electrocution" but which we old-fashioned grammarians prefer to call "electrocussion"? I believe that American doctors are as out of date as we are when they speak of "concussion," rather than of "concution."

But there is one instance of applied science where the U.S.A. is twenty years behind Europe, as Mr. Kenneth Greenberg, writing to me from the city of sudden and violent death, has made quite clear by sending me a cutting from the October 1957 issue of the American journal *Popular Mechanics*.

This cutting has an illustration of an American ambulance fitted with a radio transmitter which turns all traffic lights red for a few seconds to give it a clear passage as it speeds on its way.

Mr. Greenberg quite rightly sends this cutting to me to refute the statement I made in the September issue of *W.W.* that the idea had never been put into use. But my statement was all wrong, and it is all the more blameworthy in that I had forgotten that in the issue of Dec. 2nd, 1937—nigh on a quarter of a century ago—I myself reported in these columns that I had seen this idea in use in a European city. I can only hang my debowlered head in shame at forgetting my own words, and thus misleading my readers.

I did not mention the name of the city but unless my memory has let me down again it was in the city of Good King Wenceslas that I saw this sight.

If any of you are so ignorant that you don't know the name of the land over which Good King Wenceslas ruled, and the name of his capital city—still unchanged today—in which he did his looking out on St. Stephen's Day, I do not consider it my duty to enlighten you. Ask any of the children who sing carols on your doorstep this Christmas.

"I can only hang my debowlered head in shame."

Diary Data and Dates

I AM very gratified to see in the "*W.W.* Diary" for 1962 that the pages in which we record our daily doings have been kept as free from printed matter as possible. Thus the Editor has kept his hagiographical information to a minimum, only including saints' days and other ecclesiastical information where they coincide with quarter days and half-quarter days.

In the non-diary pages I was a little surprised to see that the terminating sigma (ς) had been omitted from the Greek alphabet, but I suppose the reason is that it has no symbolic significance. I suppose, too, that a similar reason, namely lack of usefulness, causes the omission on the page of abbreviations of r.d.f., to denote what we now call radar. I think it is a pity that this was ever allowed to be superseded by the American name of "radar," but it is too late to alter it now.

I was very pleased to see the page of some historic wireless dates. I notice that the adjective "some" is used in the title, but even so I wonder why some dates were omitted. The omission which dismayed me most was the date when the cavity magnetron was invented.*

It is made quite clear in the Diary that G.M.T. is used throughout but I think it is carrying accuracy a bit too far when the time of the Titanic disaster is reduced to G.M.T. from local meridian time, thus causing what I regard as the wrong date of 15th April, 1912, to be given for the event which I, and all others who personally remember the disaster have always regarded as occurring on 14th April. It occurred at 11.40 p.m. local meridian time on Sunday, 14th April, but as the ship's longitude was 50° 14′ W it would be just after 3 a.m. G.M.T. on 15th April.

* An almost impossible task. It was developed over a period of many months, but on outstanding date was February 21st, 1940, when, to quote Sir Robert Watson-Watt, "the new device was successfully operated."—Ed.

Forty Years On

ALTHOUGH it is only three months since the British National Radio Show closed its doors, preliminary plans for the 1962 show are already being discussed. I think, therefore, I had better remind the organizers that next autumn we shall be celebrating not only the fortieth anniversary of the first radio show, held in the old Horticultural Hall in 1922, but also the fortieth anniversary of the beginning of broadcasting itself; at any rate of regular broadcasting in this country from 2LO.

I hope these anniversaries will be celebrated in some way at the show next August but we don't want merely a static museum showing a few sets that were on sale in 1922. Of course a museum section could form a part of the exhibition; there is, at any rate, plenty of room for it in the vast open spaces of which I complained in 1960 and which were again in evidence at the last show.

In order to celebrate these two anniversaries I think it would be a good idea for the B.B.C. to combine with receiver manufacturers to bring home to people how excellent is the quality of 1962 compared with that of 1922, not only on the technical side but on the entertainment side also. I am not trying to decry the pioneers of 1922, but, of necessity, they were venturing into a new field of entertainment altogether, and their efforts were naturally somewhat amateurish compared with today's polished standards.

Could not the B.B.C. arrange to give a programme or two of the type we used to get in 1922. I wonder if there are any recordings available. If such programmes were fed through 1922 sets, present day listeners—including youngsters of 40—would know what we had to put up with in those far off days.

Senescent Senescience

I MUST accept with becoming grace the rebuke administered to me by Mr. K. W. Mawson of the Royal Eye & Ear Hospital, Bradford (Nov. issue), concerning remedial measures necessary to combat the hearing defects of the ageing. It is quite clear to me that I have advanced further along the road of senescence than I had supposed, without a corresponding increase in my senescience.