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Transistor Reliability

IN theory a transistor should last for ever. There is nothing obviously expendable in it as there is in the hot cathode of a valve. The crystal lattice of the solid-state semiconductor remains, under normal operating conditions, a fixed framework through which electrons and holes circulate under the influence of applied fields to and from the external connections of the device. Although the charges associated with individual atoms may change temporarily, and the current carriers may leave with greater energy than that with which they entered, there is no net gain or loss of material, and the chemical nature and physical arrangement of the atoms remain unchanged.

We said "in theory" and "under normal operating conditions." In practice, of course, transistors sometimes fail and in the early days failures were frequent and of many kinds. Indeed there grew up a whole descriptive pathology of transistor diseases such as "sleeping sickness" leading to "slow death" or "sudden death." Some of these were peculiar to the first point-contact transistors and were accounted for by mechanical disturbance of the contact wires. In junction transistors most of the early troubles were due to contamination of the outer surface, particularly by moisture, which gained access, in spite of encapsulation in plastic, through incomplete bonding with the leads or the slight bulk permeability of the best synthetic resins then available. Silicone greases and varnishes in conjunction with low-temperature glass seals or cold metal-welding techniques have since mastered the moisture problem.

Given sound mechanical construction to ensure freedom from catastrophic failure through breakages at the lead-out connections and with the flanks safely guarded from surface contamination, deterioration or failure can only occur on the main fronts of the transistor action. Could a breakdown occur as the result of penetrating radiation, for example, cosmic-ray particles? All the evidence is against this as a significant possibility. Irradiation by gamma rays has caused failure in germanium transistors in 5 seconds, and in 30 seconds in silicon, but the failure was due primarily to surface effects and not to bulk effects involving the crystal structure*.

The worst enemy of the transistor is temperature, which is in effect vibration of the crystal lattice. If this becomes too severe dislocations may occur and the distribution of impurity atoms, so essential to the proper functioning of the junctions, may be permanently disturbed. Whatever the explanation may be, the fact remains that the performance deteriorates as temperature increases, and the deterioration may be permanent if the maker's recommended junction temperatures are exceeded. On the other hand, if the circuit conditions are such as to ensure a conservative rating, there seems no reason to doubt that the life expectation of a transistor may well be 50 to 100 times that of a valve and that it will outlive many of the components with which it is associated.

Space Experiments

NOW that argument in Parliament and in the Press about the propriety of accepting a lift in an American "satellite vehicle" has subsided, it is gratifying to learn that matters have been settled and that the first launching of a satellite from a "Scout" four-stage solid-fuel test vehicle is scheduled for the latter part of 1961. It is even more gratifying to learn that the experiments which have been planned come very close to our interests and will be concerned with the ionosphere, and in particular its outer limits where the terrestrial atmosphere merges into that of the sun.

The long tradition of British interest and achievement in ionospheric research, and especially recent experience in launching ionization experiments in "Skylark" rockets, together with the original laboratory work on ionized gases conducted by research groups under Prof. J. Sayers at Birmingham and Drs. R. L. F. Boyd and A. P. Willmore at University College, London, no doubt influenced the choice.

Experiments planned are based on the Langmuir probe (which measures the rate of change with voltage of current due to impinging ions) and on the measurement of the complex dielectric properties (at 10 Mc/s) of the gaseous medium between parallel plates. These will give information on the identity of heavy ionized particles as well as on the density and temperature of the electron population of the fully ionized plasma at high altitude.

We know that the equipment will be well made and carefully prepared and it only remains to keep our fingers crossed for a successful launch.

* "Transistors Can be Reliable" by C. H. Zierdt, Jr. *Electronic Design*, 1st April 1957.

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Improving the Dynamic Range of

USE OF A PILOT TONE TO COMPENSATE FOR MANUAL COMPRESSION OF THE INPUT

By ***L. H. BEDFORD,*** *C.B.E., M.A., B.Sc. (Eng.), F.C.G.I., F.I.R.E., M.I.E.E., M. Brit. I.R.E.*

THE dynamic range of the domestic tape recorder is nearly but not quite good enough. A signal/noise ratio of 50 dB is frequently claimed, and more usually 40 dB is attained. This is to say that the maximum undistorted signal is 50 to 40 dB above the noise level. Even the latter figure suffices for the recording of low-contrast subject matter such as speech and some types of music. Other types of music, in particular orchestral, organ and even pianoforte, themselves extend over a dynamic range of 40 dB, and so are clearly not directly acceptable to the tape system; for this would imply that the reproduction of pianissimo passages must occur at unity signal/noise ratio.

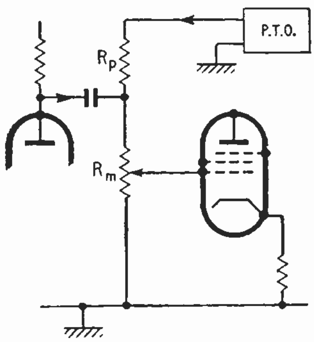


Fig. 1. Basic method of providing a pilot tone with a level proportional to the recording gain control level.

The solution commonly adopted is precisely the same as that in any other communication system of restricted signal/noise ratio, namely that the input signal is *compressed* by " monitoring "; the monitor manipulates a gain control so as to hold the fortissimo passages below the distortion level and the pianissimo passages suitably above the noise level.

This process is quite justifiable from an engineering standpoint because, once the signal/noise ratio has been thus maintained, the subject matter can be " de-compressed " by manual operation of the gain control on reproduction; this process could be called " de-monitoring." However, such an operation is little more than a theoretical possibility, since not only is the gain-control manipulation an intolerable burden but the information required for correct operation is lacking. Attempts to perform this process automatically, but still in the absence of the correct information, have appeared under the descriptive title " expander circuits "; these are now quite properly in disfavour.

So long as the monitoring process remains a manual operation, and there are good reasons why this should be the case, there is no possibility of automatic " de-monitoring " unless the monitoring gain control history can be conveyed as such to the de-monitor.

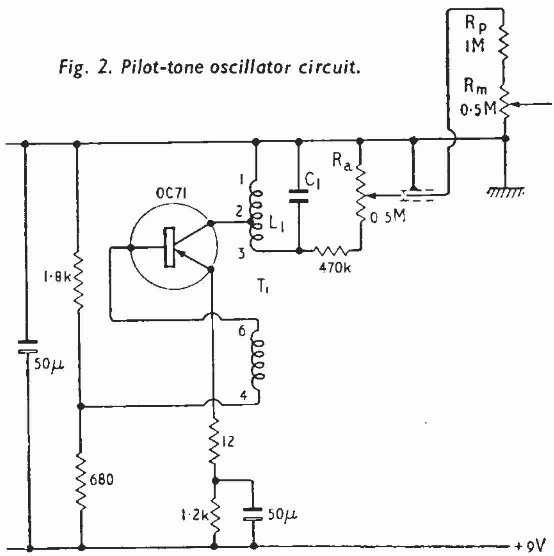
The device now to be described allows just this and so is quite distinct from an " expander." On recording, the monitoring history is written in terms of a superposed pilot tone whose amplitude is subjected to the same monitoring process as the signal. On reproduction, an a.g.c. circuit holding constant the amplitude of the reproduced pilot tone constitutes a perfect de-monitor. By this combination, the monitoring operations are precisely " unwound". The original contrast is restored and only the signal/noise advantage of the monitoring process is retained.

With this arrangement a new situation arises. The monitor, who hitherto may (or may not) have felt restricted by some artistic considerations, can now go to work to his heart's content, finally throwing aside all decent restraint, confident in the knowledge that his every effort to destroy the music will be exactly defeated.

The pilot-tone operated gain control is by no means a new idea, but it may be well to describe it basically in the present context.

In Fig. 1 is shown the part of the recorder amplifier around the monitoring gain control potentiometer R_m. The top of R_m is connected through a resistance R_p to a pilot-tone oscillator (P.T.O.). The latter provides a constant signal of a frequency outside the audio range but within the recording capability of the tape system; which in practice

Fig. 2. Pilot-tone oscillator circuit.



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Tape Recording

implies a frequency slightly *above* the required audio range.

The pilot tone thus applied is subject to exactly the same monitoring variations as the signal, it being understood that monitoring takes place exclusively by means of the gain-control potentiometer R_m. If then on reproduction the pilot tone is separated out by a frequency-selective circuit and used as input to an a.g.c. circuit controlling the audio gain, the monitoring operations are "unwound" to an accuracy defined only by the perfection of the a.g.c.

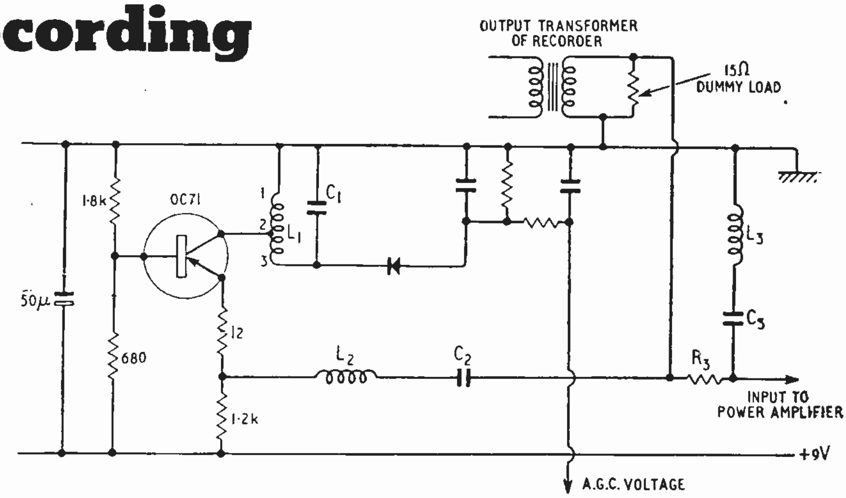

Fig. 3. Selective pilot-tone play-back amplifier for providing an a.g.c. voltage to correct the play-back level.

The following particulars relate to an experimental application of this principle to a domestic tape recorder which has worked with somewhat spectacular results. Some 15 dB stretch of the dynamic range has been obtained.

The pilot-tone frequency was selected at 13.5 kc/s, this being considered the lowest frequency that could be filtered out without detriment to the music. This implies working with a tape speed of 15in per second with a normal R/P head, but will allow 7.5in per second with a modern high-resolution head.

Only a minute power output is required from the pilot-tone oscillator, which suggests a simple form of transistor circuit. This is shown in Fig. 2. The transistor is an OC71 used in the grounded-emitter condition, but for the 12-ohms emitter-follower resistor. The circuit operates at 9 V, 6 mA total, of which the transistor current is 2 mA approx. (It will in fact oscillate and produce adequate power output down to much lower voltages.)

For play-back the same transistor and most of its circuit is used to form the selective pilot-tone amplifier. The arrangement is shown in Fig. 3. In this case, the transistor operates as a grounded-base amplifier.

Input is taken to the emitter through the 13.5 kc/s series-tuned circuit L_2C_2, which is fed from the 15-ohms output of the normal playback amplifier in the recorder. This series-tuned feed, together with the parallel-tuned collector circuit, provide adequate selectivity at 13.5 kc/s. The collector-tuned circuit now feeds a diode and can produce some 12 V of a.g.c. linearly related to the 13.5 kc/s input. In practice the a.g.c. potential will not exceed 8 V.

It remains only to suppress the transmission of 13.5 kc/s pilot tone to the final amplifier, which would otherwise be objectionably audible to those of sufficiently-low age group. Series-tuned circuit L_3C_3 and resistance R_3 perform this function, it being understood that the system will invariably work through a power amplifier and not directly through its own speaker.

Finally, Fig. 4 shows the practical arrangement of the complete de-monitor unit in which it only remains to invoke a relay for the purpose of changing over the circuit from its Record to its Play-back function. This relay is operated by the h.t. feed current to the normal bias oscillator. Thus no extra switching is involved and the only adjustment required is the pre-setting of the pilot tone amplitude control R_a.

In Fig. 4 is shown also a skeleton circuit of the basic play-back amplifier in order to clarify the connection of the de-monitor unit to it. It will be seen that the a.g.c. voltage is applied as grid bias to a single stage. The behaviour of this circuit under this somewhat peculiar condition is shown in the following table.

Bias (*V*)	*Input at* MJ (*mV*)	*Loss* (*dB*)	*Remarks*
0	2.5	0	
− 5.9	5	6	
− 6.8	10	12	
− 7.4	20	18	
− 7.8	40	24	
− 8.1	40	30	Distortion observable
− 8.4	40	36	”

The maximum undistorted tape signal at MJ in Fig. 4 being approximately 25 mV, we see that it is possible to operate over a range of 18 dB monitoring compression with an output range of 20 log (7.8/5.9) = 2.5 dB. This is to say that a monitoring range of 18 dB has been reduced by 15.5 dB.

After the adjustment of the three pilot-frequency tuned circuits there remains only one operational adjustment, namely the pilot-tone amplitude control R_a. The setting of this controls the dynamic range of the de-monitoring. The value 15.5 dB referred to above was obtained with the pilot voltage (viewed at the anode of the audio output valve) set to approximately one-third of the nominal distortion point audio voltage. This adjustment should be made with the gain control R_m set to its maximum intended value,

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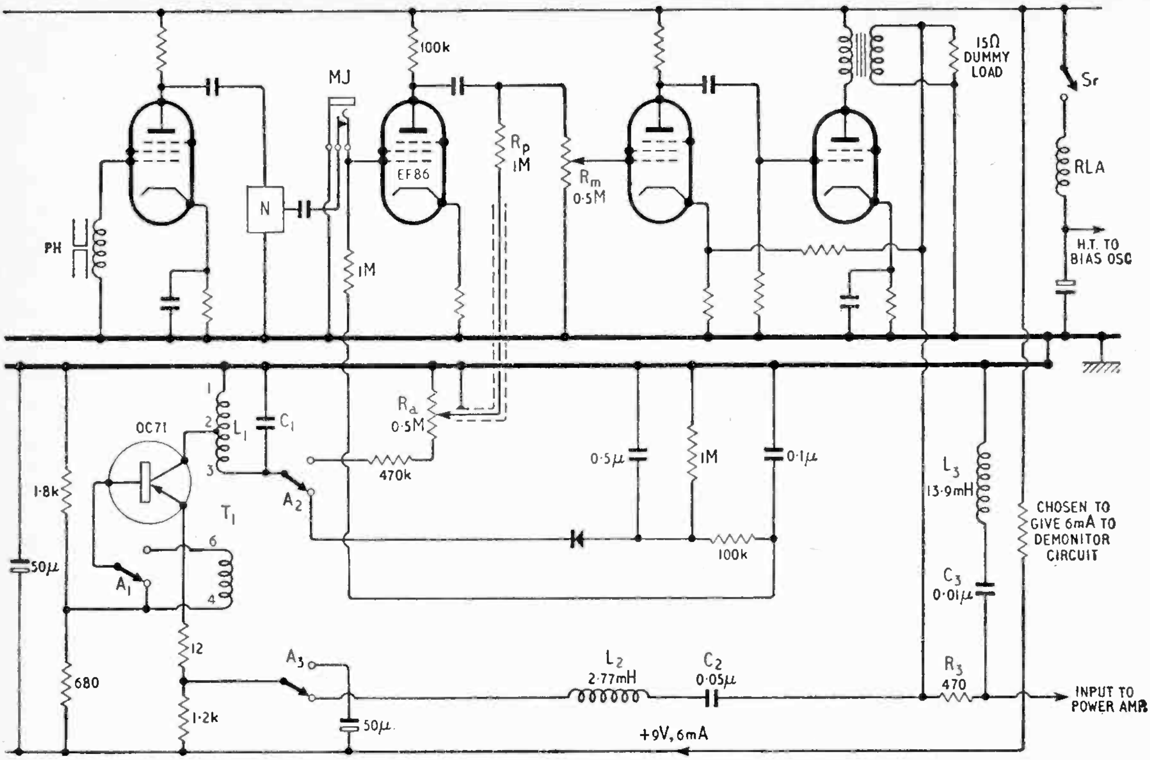

Fig. 4. Practical arrangement of pilot-tone oscillator and selective play-back amplifier and their connections to skeleton circuit of basic play-back amplifier.

KEY

PH	Play-back head
N	Frequency-correcting network
MJ	Microphone jack
RLA	Relay winding, 400Ω, 45 mA
A_1, A_2, A_3	Relay change-over contacts, shown in un-energised condition (Play-back)
S_r	Switch on "Record" button (shown in Play-back condition)
T_1	Pilot-tone oscillator transformer Winding 1, 2, 3 — 0, 50, 280 turns total 1, 3 — 40 mH nominal (L_1) 4, 6 — 4 turns (32 s.w.g. Lewmex wire on LA1 Ferroxcube core)
C_1	3470 pF nominal (to tune with L_1 for 13.5 kc/s)
L_2	2.77 mH (60 turns of 22 s.w.g. on LA7)
C_2	0.05μF nominal (to tune with L_2)
L_3	13.9 mH (165 turns of 28 s.w.g. on LA1)
C_3	0.01μF nominal (to tune with L_3)
Diode	Crystal diode, ≮ 25V p.i.v.

which will in general be its extreme maximum value.

It may be remarked that when the demonitor circuit is in operation the gain control R_m becomes inoperative as such in the play-back condition because the a.g.c. circuit acts to oppose it. It does, however, control the range over which the demonitor works and will therefore normally be set at maximum on play-back. If it is turned down by some 25 dB with a compensating (but far smaller) increase of gain in the power amplifier, the reproduction becomes un-demonitored. This is a useful test or demonstration procedure.

The circuit can be built up in compact form and will usually be small enough for installation *inside* an existing tape recorder. The likelihood of this is increased by the fact that anyone who is sufficiently quality-conscious to wish to try this arrangement is liable to have remoted the power pack in aid of hum reduction!

In conclusion, we may usefully examine the "economics" of the device. Assessing it in the form described, which by no means carries the idea to its limit, we see that we gain 15 dB of dynamic range for an increase of tape speed which may for practical reasons need to be 2 to 1. This increase of tape speed by itself would *theoretically* offer us 3 dB, so we have picked up a net 12 dB by means of the device. For this we have paid a capital investment of one transistor, three pilot-frequency tuned circuits and a relay; surely a nice bargain for the Communication Engineer! Unfortunately on the domestic front the situation is not so good. As already pointed out the existing dynamic range is *nearly* good enough. Thus the domestic user may not be interested in a further 12 dB even at so trivial a capital cost.

A 16⅔ r.p.m. record was recently released by Rank Records. This is similar to an ordinary l.p. but recorded and replayed at half speed. In addition, a bass cut and mid-frequency boost are superimposed on the standard recording characteristic, and the recording level is about 5dB lower than usual. The upper recorded frequency limit is about 5kc/s, and the total playing time for a 12in record one hour and thirty-five minutes.

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Geneva Conference

FINDINGS OF THE I.T.U. MEETINGS ON FREQUENCY ALLOCATIONS

AT Geneva on December 21st representatives of 89 countries signed the new International Telecommunication Convention and a new set of Radio Regulations which come into operation in May, 1961. These two documents were the outcome of two conferences—the Ordinary Administrative Radio Conference and the Plenipotentiary Conference—organized by the International Telecommunication Union which together lasted over four months. The main task of the Administrative Radio Conference was to apportion internationally frequencies between the various "services" and users—maritime and aeronautical mobile, maritime and aeronautical radio navigation, meteorology, amateur, land "fixed" and "mobile," broadcasting, etc. This necessitated a complete overhaul of the Atlantic City (1947) allocations and, as with most international conferences, because of the expansion of some services and the growth of the "younger" countries, it was a tug-of-war between the "haves" and the "have nots". In addition to the growing demands of expanding services provision also had to be made for the requirements of new "services" such as space communication, radio astronomy, and tropospheric and ionospheric scatter. Whereas in the Atlantic City regulations the table of frequency allocations did not go above 10,500Mc/s the new table extends to 40Gc/s (40,000Mc/s).

The demands for frequencies in some sections of the radio spectrum have been so great, and are likely to become even greater, that in order to reduce the demands on the 3-30Mc/s band and prevent interference with long-distance radio-communications "administrations are encouraged to use, whenever practicable, any other possible means of communication." It was undoubtedly this h.f. band which posed some of the biggest problems the conference had to solve. So great were they that a small panel of specially-chosen "experts" is being set up to investigate them with a view to reducing the present congestion. Also an entirely new procedure has been adopted for the registration of frequencies. The International Frequency Registration Board, which comprises eleven elected members each of a different nationality but acting as impartial advisers and custodians, has been given the task of preparing a new Master International Frequency Register. So far as broadcasting stations are concerned the broadcasting authorities have been asked to submit four operational schedules each year covering the summer, winter and the two equinoctial seasons. This information will be combined into a Tentative Schedule which will reveal incompatabilities in frequency assignments.

Whilst on the subject of broadcasting we would mention that no changes have been made in the frequency bands, but it is good to know that provision has been made just below the television Band I for the ionospheric scatter stations, some of which have been operating on frequencies in the lower channels of the band. Ionospheric scatter stations designed to operate over distances exceeding 800km must confine their transmissions to the following bands: 32.6-33, 34.6-35, 36.2-36.8 and 39-39.4Mc/s.

The use of broadcasting stations, both television and sound, "on ships or aircraft outside national territorial waters is prohibited."

New frequency tolerances for broadcasting stations are to come into force in January, 1966. In the 10-1605kc/s band it will be reduced from 20c/s to 10c/s, in the 1605-4000kc/s band from 50 to 20 parts in 10^6 and in the 4-29.7Mc/s band from 30 to 15 parts in 10^6. There have also been closer limits imposed on the television and sound broadcasting stations in the v.h.f. and u.h.f. bands.

An interesting aspect of the Regulations is the provision for communication between "space" vehicles and earth-to-space services for research purposes. The frequencies (Mc/s) allocated are 10.003-10.005, 19.990-20.010, 183.1-184.1, 1700-1710 and 2290-2300. One of the hundreds of documents circulated during the conferences dealt with telecommunications and the peaceful uses of outer-space vehicles. It covered not only the telecommunication needs of space craft both for their remote control and for transmission of information but went on to say "artificial satellites will undoubtedly be used in the near future to establish new telegraph and telephone connections . . . and . . . sound and television broadcasting services." In 1963 a special conference will be called to consider the problems of space communication.

The frequency allocation table has been called the regulation with a 1,000 footnotes for there are so many variations from and modifications and exceptions to the basic plan. Another point of interest about the plan is that it defines for the first time priorities where a number of services share a band of frequencies. Services are defined as primary, permitted or secondary. The first two have equal rights except that a primary service has a priority in the choice of frequencies. Stations in the third category must not cause harmful interference to or claim protection from either of the others.

So far as amateurs in Region I, which includes the U.K., are concerned, the only changes in their frequency allocations were a loss of 50kc/s in the 7Mc/s band and a reduction in the width of the 420-450Mc/s band to 430-440Mc/s.

A world-wide reservation of the following bands has been made "for the use and development of airborne electronic aids to air navigation":—960-1215, 1535-1660, 4200-4400, 5000-5250 and 15400-15700Mc/s. The frequency of 243Mc/s has been allocated to survival craft.

It has been impossible within the limitations of this short article to give an exhaustive survey of the Radio Regulations, which cover some 600 pages; moreover, some of the regulations or recommendations are of interest to only a comparatively small section of the radio fraternity. However, we propose to publish from time to time items of interest to particular sections of the diverse readership of *Wireless World.*

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How Long Will a Transistor Live?

ADVICE TO THE USER GAINED FROM RECENT EXPERIENCE

By R. BREWER*

IT is natural that with many commercial products we ask the question, "What is its expected life?" Transistors belong to this class of products, and even the non-technical user is beginning to ask, "How long will a transistor live?"

This article has been prepared to give guidance in a problem that appears simple, but which is really quite complex, and the basic information is given for a broad, but realistic, approach to the general question of transistor life.

The simple question, "How long will a transistor live?" has no simple answer, because it begs another question: "When is a transistor dead?" When the problem is put this way we are led to the answer of a rather different question that is probably more important to the user of transistors than the question first asked. It is also worth remembering that, as with human beings, living conditions strongly influence the length of life!

A transistor dies either when a catastrophic event, such as a short-circuit between elements, occurs, or when an electrical characteristic has deteriorated to a point that is unacceptable in the circuit *in which the transistor is being used.* The definition of death is thus closely linked to the conditions of use; only the catastrophic type of failure is unambiguous and valid for all circuits.

Comparison with Valves.—It is useful to compare the life patterns of transistors with those of thermionic valves, because these also have catastrophic and deterioration type failures. Apart from the generally much lower rate of catastrophic failures in transistors, the most striking difference between the life characteristics of the two types of device is that for many valves the deterioration process, which is gradual in the early stages, may later become so rapid as to cause system breakdown almost regardless of differences in circuit conditions. In other words, once a valve has started to "nose dive" it is more or less unacceptable in any circuit.

* Research Laboratories, General Electric Company.

By comparison, the deterioration process in many types of transistors is extremely gradual, and after an initial "settling-down" period, subsequent changes may be small. The two characteristics most likely to change during life are current gain and leakage current. Fig. 1 shows a typical record of gain in a sample of GET103 transistors which have been on life test for 20,000 hours (nearly 2½ years). These transistors are running at a junction temperature of 65°C, a figure which is fully adequate for applications such as portable personal radio receivers. It is worth noting that in apparatus of this type, where the duty may average about 5 hours a day, it would take about 11 years to build up a total operating time of 20,000 hours.

It must be remembered that transistor manufacturers are constantly striving to improve the quality of their products, including the life characteristics. Long-term life test evidence inevitably lags behind the latest production processes, and records such as that shown in Fig. 1 cannot reflect recent improvements resulting from increased production experience. Since this life test started, the introduction of better techniques has enabled the maximum junction temperature of the GET103 transistor to be raised from 65° to 85°C. Changes of this kind depend on a thorough appraisal of all the many factors involved, including extensive life test evidence, but another two years must elapse before the 20,000-hours performance at the higher junction temperature has been confirmed. At present there are no reliable, well-established techniques for accelerating transistor life effects—we have no substitute for time.

Pattern of Transistor Life.—Many of the early

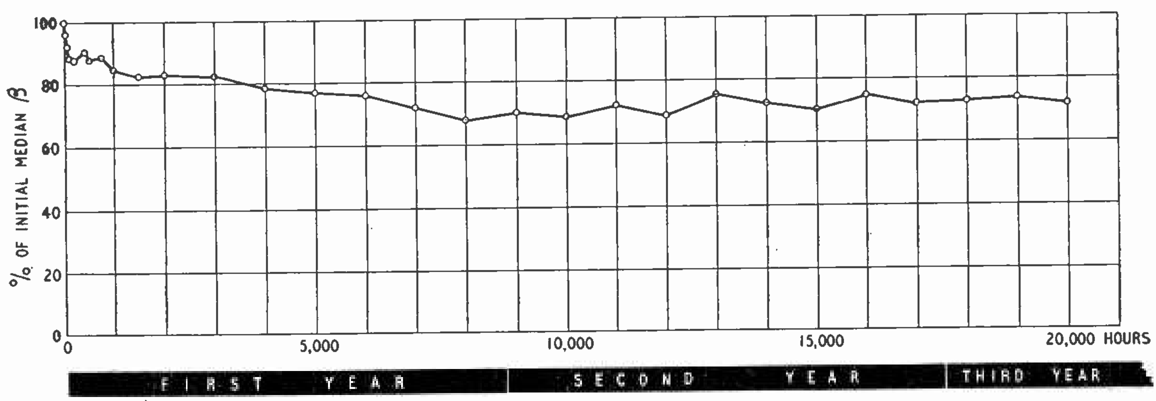

Fig 1. Change during life of median value of β for a sample of fifteen GET103 transistors manufactured in May 1957. Junction temperature during electrical life test is approximately 65°C; while β is measured at 25°C.

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junction transistors exhibited the degradation type of life failure due to imperfect manufacturing techniques, but major improvements in this respect have been made in recent years. The characteristic "nose dive" seen in many valves is generally absent in transistors, but there may be fairly large differences in the rate of change among individual specimens of similar transistors. While there is little reason to expect any tendency towards major changes in the average characteristics late in life, this fact has yet to be proved.

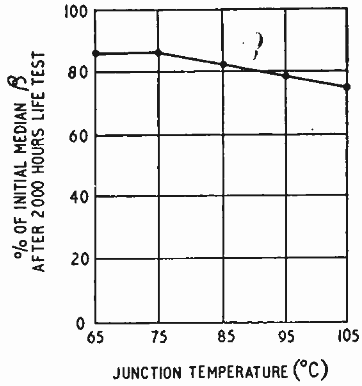
A study of the evidence from life tests such as that referred to above suggests that transistors in general may be capable of outliving the equipment in which they are incorporated. It must not be assumed, however, that all the transistors in a batch will have identical survival characteristics. Like every other mass-produced article, the transistor is subject to chance variations in manufacture that can cause an unpredictable breakdown during life, or an unusual change in gain or leakage current, and it is the incidence of troubles of this kind, rather than a general end of life having been reached, with which we are really concerned. For the operators of equipment using large numbers of transistors the question is therefore not so much "How long will a transistor live?" as "How often will chance failures occur?"

Time Between Failures.—The last question is one to which some provisional answers can be given, though they do not necessarily apply to all types of transistor, and it has yet to be shown that the failure rate is the same throughout life. Evidence from various types of transistor equipment, and from life tests involving many millions of transistor-hours, indicates that the failure rate for low-frequency germanium transistors of the GET103 type, for example, is in the region of 0.05 to 0.01% per thousand hours. With this information we can immediately work out the mean time between failures (M.T.B.F.) for an equipment, and this is something we really want to know. For example, assuming a rate of 0.05% per 1,000 hours, the M.T.B.F. in a unit using 1,000 transistors of the same type would be 2,000 hours. This order of reliability applies to germanium transistors working in ambient temperatures up to 40° to 60°C, and with junction temperatures in the region of 70° to 85°C.

Guidance to Users.—It may be held that the rapidity of technical advances in the industry, and the lack of sufficient time for long-term effects to have become manifest, make it unwise to forecast the ultimate reliability of transistors at the present time. Against this is the fact that transistors are already being used in equipment where long life is a major requirement, and it therefore seems advisable to give users some guidance on the best approach to the subject in the light of present knowledge.

The failure rate figure given above is a realistic one for several types of low-frequency germanium transistors now in production, but in considering it, a number of important reservations must be made. First, very wide differences may exist in the life characteristic of types of transistors that are superficially similar. Also it must be realized that some of the latest types of high-frequency transistors are made by advanced techniques which may produce

Fig. 2. Change in current gain of GET103 transistor after 2,000 hours electrical life test at five junction temperatures. Sample size of 20 at each temperature; β measured at 25°C.



life characteristics differing from those associated with the more well-established techniques used for low-frequency devices. Secondly, circuit characteristics and operating conditions can have far-reaching effects on the reliability achieved in practice. This cannot be stressed too strongly. Such matters are obviously absent in any general statement, and it is therefore essential to consider the details in each application. As an illustration, Fig. 2 shows how current gain can be affected by junction temperature, and it will be seen that at the higher junction temperatures greater circuit tolerance is necessary. This subject has been dealt with more fully in a paper† which is now in course of publication and should be available in the near future.

Circuit Design Factors.—The foregoing comments show how important are the details of operating conditions when considering statements about the life and reliability of transistors. Reliability information in these circumstances may easily be misconstrued, and general statements, such as have been given here, serve only as landmarks.

The designers and operators of equipment using transistors have a large part to play in determining the M.T.B.F. of the transistors used in the systems with which they are concerned, and their contribution to transistor reliability will be most effective if the following precepts are remembered:

(1) Survey the electrical and environmental conditions under which the transistors will be used, paying particular attention to the extreme values of supply voltages and temperatures likely to be encountered. The possibility of voltage transients and oscillations should also be checked.

(2) Employ tolerant circuit arrangements so that changes in transistor characteristics during life have a minimum effect on system performance.

(3) Consult the transistor manufacturer for advice if necessary.

(4) Watch for accidental misuse as a cause of transistor failure. An increasing body of information suggests that high early failure rates in transistors are due to faulty installation and maintenance procedures.

If these points are kept in mind when new equipment is being designed or installed, the chances of realizing the low failure rate of which the transistor is capable will be significantly increased.

†"A Reliability Appraisal of Semiconductor Devices," by R. Brewer and W. W. D. Wyatt, presented at the I.E.E. International Convention on Transistors and Associated Semiconductor Devices, May 1959.

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Transformerless Circuits for Broadcast Receivers

NEW CIRCUITS DISPENSE WITH A VARIETY OF CIRCUIT ELEMENTS

By R. C. V. MACARIO*, Ph.D. and N. E. BROADBERRY*, Grad.Brit.I.R.E.

CONSTRUCTION of the electronic circuit can be made simpler when transformers and other wire wound components do not form part of the circuit. This may be regarded as being due to the greater versatility of the more compact circuit elements such as the resistor, the capacitor and the transistor, which together lead to neat circuit arrangements. The modern trend of electronics towards the solid state circuit also favours the use of this type of component, to which may be added other solid state components such as the ceramic i.f. transformer[1].

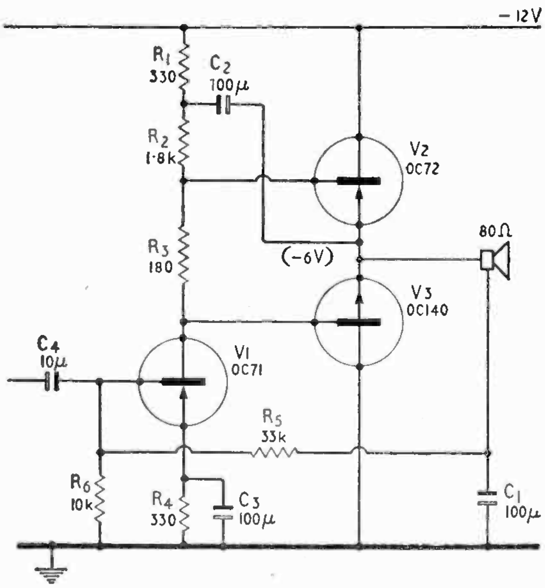

Fig. 1. Audio amplifier and 150-mW output stage for portable receiver using 12-volt two-terminal supply.

However, a review of the extensive literature on the modern transistor broadcast receiver suggests that the circuits used today are not of this type; unfortunately they make use of components other than the recommended ones. In this article alternative circuit arrangements are introduced designed to match in with the above ideas.

Portable-receiver A.F. Stage.—For the small portable receiver Class-B operation is essential unless one of the more esoteric forms of signal-controlled Class-A circuits is introduced. The complementary n-p-n/p-n-p arrangement clearly provides the simplest design without a driver transformer for a Class-B circuit. The criterion for a good design would appear to be a maximum power output with minimum distortion and minimum complexity. This suggests the use of a common-emitter stage driving a common-collector pair. A discussion of this type of transistor amplifier is to be found, for instance, in the *Handbook of Semiconductor Electronics*[2]. In a final form the circuit leads to a fairly straightforward design as shown in Fig. 1.

A description of the circuit behaviour to d.c. is as follows: the forward bias of V1 is set so that its collector potential is quiescent at −6V with the d.c. collector load $R_1+R_2+R_3$. This bias depends on the current through R_4, the emitter resistor, and the base potential determined by the potential divider R_5 and R_6. The collector of V1 is coupled directly to the bases of V2 and V3; thus the connection common to the emitters of V2 and V3 assumes a potential almost identical with that of V1 collector (emitter-follower action). To prevent a flow of d.c. through the load its " earthy " connection may be taken either to a centre tap on the battery or to earth through a d.c. blocking capacitor (C_1). When a blocking capacitor is used the p.d. across C_1 follows V1 collector potential; therefore, if the potential divider R_5, R_6 is fed from this point, a direct-coupled negative-feedback loop is closed, a loop which helps to maintain equal potentials across V2 and V3.

Turning now to the a.c. or signal conditions; the collector of V1 drives the bases of V2 and V3, which conduct on alternate half cycles, V2 on the negative and V3 on the positive half cycles. R_3 provides a small forward bias for the output pair of transistors, to eliminate crossover distortion. As R_5 is taken from the " earthy " end of the loudspeaker there is no signal feedback. If, on the other hand R_5 is taken from the " live " end of the loudspeaker there is feedback and the power gain of the stage falls by about 10dB. There is, nevertheless, some feedback due to the fact that the full output voltage of V1 is not applied between the base and emitter of the output transistor because of the presence of the load in the emitter circuit, but this has been corrected by including the bootstrap circuit C_2, R_1. The overall voltage gain of the stage is about 44dB and the input impedance is about 1kΩ.

In order to estimate the correct conditions for the driver transistor the following method may be used. Considering the half cycle when V2 conducts, the peak output current occurs when the driver just cuts off and at this instant all the base current i_{bV2} of V2 is supplied by R_2. The voltage which drives this current will be equal to 6 volts which is the supply voltage across V2, and this drive will also have to overcome the input impedance R_{in} of V2 and

* Plessey Co. Ltd.

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the reflected load $\beta_{V2}.R_L$, where β is the common-emitter current gain.

$$\therefore (R_2+R_{in}+\beta_{V2}.\ R_L).\ i_{bV2}=6\ V \quad \ldots. \quad (1)$$

i_{bV2} in turn will be equal to $1/\beta_{V2}$ times the peak load current,

$$\therefore i_{bV2}=(1/\beta_{V2}).\sqrt{(2\times\text{peak power}/R_L)} \quad .. \quad (2)$$

Considering a current gain $\beta=50$ and for 100 mW output it follows that:—

$$i_{bV2}=1\ \text{mA}$$

$$R_2+R_{in}=2\ k\Omega.$$

Since R_{in} is only about 100 ohms, R_2 should be slightly less than 2,000 ohms. Alternatively, if $\beta=100$ and for 150 mW output:—

$$i_{bV2}=0.61\ \text{mA}$$

$$R_2+R_{in}=1.8\ k\Omega.$$

It is clear that to increase the output power the β of the output stages should be increased. On the other hand, to increase the output power by reducing the speaker load leads, unfortunately, to excessive current consumption by the driver stage (because R_2 would have to be reduced) and this would reduce markedly the battery life.

The correct collector current for V1 is estimated from

$$i_{cV1}=6/(R_1+R_2+R_3/2)=2.75\ \text{mA}$$

The linearity of the output is shown in Fig. 2 and indicates the circuit operates satisfactorily up to outputs of approximately 150 milliwatts. A 12-volt battery supply has been used as this allows a much greater degree of flexibility throughout the design of the receiver circuits; this may be slightly higher than normal but it is single-ended.

Detector Stages.—The output stage just described may be driven directly from a detector stage using the conventional series-diode circuit. However, this form of detection may not always be the most efficient type because of the series resistance of the diode. The following measurements were made to compare the performance of series-diode, shunt-diode, and transistor-detector circuits. Fig. 3 shows the three circuits that were explored and in circuits (i) and (ii) the transistor is the final i.f. amplifier and the diode detects; each circuit was adjusted for maximum performance. In (i) and (ii) a ceramic wave-filter element can be connected across the

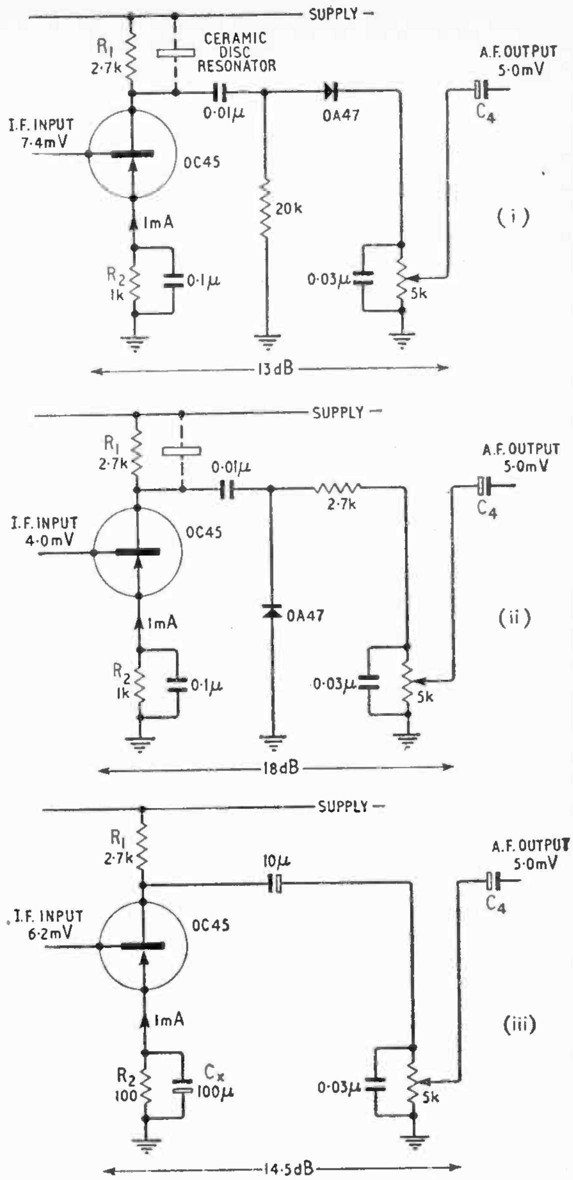

Fig. 3. Series (i)- and shunt (ii)- detector circuits and their final i.f. amplifiers compared with transistor-detector equivalent (iii). I.F. input (modulated 30% at 400c/s) shown produces 10mW a.f. output in 1-kΩ following load.

collector load of the transistor if increased i.f. selectivity is required. However, a comparison of the voltage conversion gain from i.f. to a.f. suggests firstly, that the shunt-diode is more efficient than the series connection, and secondly, the transistor detector is more attractive as a diode is not used.

In Fig. 3(iii) the transistor acts both as the a.f. amplifier and the rectifying amplifier[3]. R_1 mainly determines the direct potential on the collector as the effective load is the input impedance of the next stage. The emitter current is adjusted by varying the forward bias on the base until maximum sensitivity is obtained, noting that the current required for optimum detector efficiency is usually lower

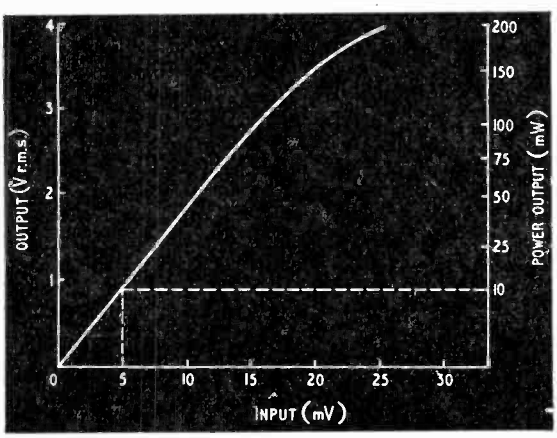

Fig. 2. Input/output characteristic of audio-frequency amplifier and power output stage shown in Fig. 1.

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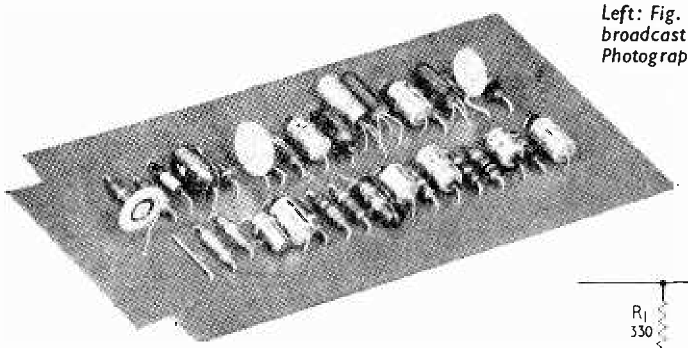
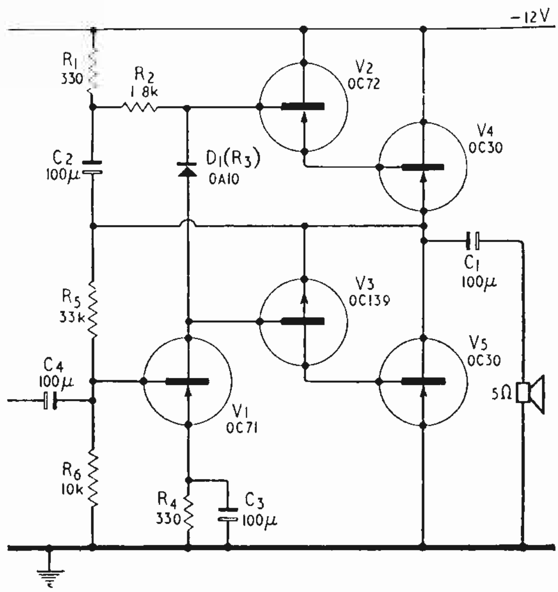


Left: Fig. 4. Photograph of i.f., detector and a.f. stages of broadcast receiver assembled on a printed-circuit board. Photograph is about half-size: i.e. board is under 6-in long.

Below: Fig. 5. Medium-power (2-W) a.f. amplifier and output stage using 150-mW amplifier of Fig. 1 as basis of driver stage.



than that required for maximum β. R_2 is included to provide d.c. and thermal stability; the value chosen is such that when a signal is present it does not unduly disturb the operating conditions. The stage also produces amplified a.g.c. and the preceding i.f. stage can be so biased that an overload-protection diode is no longer necessary[4]. The emitter bypass capacitance C_X is shown as an electrolytic in Fig. 3(iii): $0.1\mu F$ may be used at the expense of slight reduction of a.f. gain, but this gives the advantage of a.f. negative feedback.

Practical Construction.—To illustrate the simplicity of construction of the type of circuit just described, Fig. 4 shows a half-scale photograph of a printed-circuit-board assembly containing the a.f., detector and i.f. stage of a standard receiver. The a.f. and detector circuits are as described in Fig. 1 and Fig. 3(iii). The two small discs at the left-hand end of the board are piezoelectric ceramic i.f. transformers[1].

Higher Power Audio Stage.—For the better quality receiver, a higher-power a.f. stage is essential and power outputs of up to 2 watts may be desired. This would include both the car radio and f.m./a.m. home use where, on certain types of programme, strong peaks that would almost certainly be distorted by the 150-milliwatt stage occur even in low-level listening.

Fig. 5 shows the circuit and component values of the complete a.f. stage that will deliver 2 watts into a 5-ohm load. It will be observed that Fig. 5 is an extension of Fig. 1 and again represents a circuit which aims at the best output for the simplest design. The circuit may be described by extending the description of the previous audio stage. The complementary pair V2 and V3, acting as phase splitters, now drive the p-n-p output transistors V4 and V5: hence the last two stages both operate in a Class-B mode. The junction of C_2 and R_5 and the output terminal is again held at −6 volts by the feedback through R_5 controlling the current through the transistor V1. The small forward bias for both pairs of Class-B transistors is again derived in V1 load; but R_3 has been replaced by a junction diode which has a negative temperature coefficient and hence improves the temperature-stability factor of the overall circuit. R_1 and C_2 again form the bootstrap circuit enabling the full output of the driver to be applied to both halves of the following stages. The final stages V4 and V5 are also driven from low-impedance sources and this reduces the effect of current-gain fall-off at large drive currents. Consequently the proportion of distortion components in the output is reduced.

The design procedure is exactly similar to the previous amplifier. Here, however, as the driver only "sees" the loudspeaker through V2 and V4, β_{V2} of expressions (1) and (2) becomes $\beta_{V2}.\beta_{V4}$, whilst the input impedance of V2 is now much higher, at about $1k\Omega$, because of the emitter load. Thus for 2 watts into a 5-ohm loudspeaker:—

$$i_{bV2} = (1/50.30)\sqrt{(4/5)} = 0.6 \text{ mA},$$

$$\therefore \quad R_2 + R_{in} = 2.5 \text{ k}\Omega,$$

$$\therefore \quad R_2 = 1.5 \text{ k}\Omega.$$ (A higher β would increase the estimate).

A $1.8\,k\Omega$ resistor was used in the practical circuit, the correct d.c. for the driver is then again 2.75 mA. This current is set by R_5. The bleed current through R_5 should be high relative to $I_{c0} + I_c/\beta_{V1}$ to minimize temperature drift effects and the unbalancing action of the circuit due to differences between individual transistors.

The quiescent current for the complete stage is about 5 milliamps, whilst a musical programme may average about 50 mA. The battery supply is again a single-ended 12-volt source.

Further Improvements.—Although there is no detectable distortion on a.m. reception at high listening levels using the circuit shown in Fig. 5, the amplifier may be elaborated to give even better quality if it is used, say, for f.m. receivers. The frequency response appears adequate, but for wider bandwidths the higher harmonics of distortion may become noticeable. Possible extensions of the design would be the inclusion of resistors across the base-emitter junction of V4 and V5 to reduce the variation in input

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impedance of the final stages; also a resistor could be inserted in series with the emitter of V3 to balance the impedance seen by V1 on both halves of the signal cycle. The capacitance of C_1 would obviously have to be increased to make full use of the bass response, but listening to the amplifier with the loudspeaker mounted on a large baffle indicates that most of the low frequencies are reproduced.

On the other hand, if cost is important the following modifications can be made. The speaker can replace R_1, thereby dispensing with R_1 and C_1, provided the feedback in Fig. 1, introduced by connecting R_5 to the emitters of V2 and V3 and the d.c. through the loudspeaker can be tolerated and, secondly, R_4 and C_3 may be left out if a much lower value for R_6 is acceptable.

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[1] "Ceramic I.F. Filters Match Transistors," D. Elders and E. Gikow, *Electronics*, p. 59, April 25, 1958: (Vol. 31).

[2] *Handbook of Semiconductor Electronics*, Ed. L. P. Hunter. McGraw Hill, 1956.

[3] "Transistor-Amplified A.G.C.," W. Woods-Hill, *Wireless World*, February, 1958: (Vol. 64, p. 94).

[4] "Transistor A.G.C. Circuits," *Wireless World*, November 1959: (Vol. 65, p. 508).

Manufacturers' Products

NEW ELECTRONIC EQUIPMENT AND ACCESSORIES

Transistor Control Relay

IN some control systems it is necessary to use either very light or high-resistance contacts. In the first case even slight arcing can damage seriously the device and, with high-resistance contacts, it is often difficult to provide easily for satisfactory operation. The Electro Methods Control Relay Type 273B uses a maximum control-circuit power of less than 5mW, and this sensitivity is achieved by the use of a transistor which switches the current through the coil of a mechanical relay. The control circuits are completely isolated from the mains supply (200 to 250V, 50 to 60c/s) which powers the Control Relay. Indicator lamps, denoting the state of the relay, are fitted.

The load-switching capacity of the main relay is 15A at 250V a.c. (non-inductive) and the connections can be arranged so that the unit "fails safe." Manufacturers: Electro Methods, Ltd., Caxton Way, Stevenage, Hertfordshire.

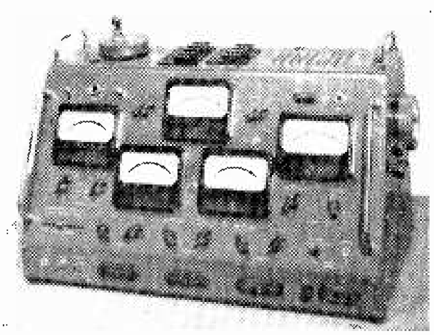
Valve Analyser and Bridge

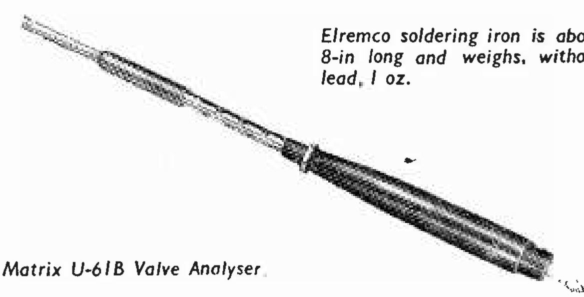
DESIGNED for laboratory investigations rather than the quick checking of valves in a servicing workshop, the main feature of the Metrix Type U-61B valve analyser is that valve-electrode potentials and currents may be indicated simultaneously and separately on five large-scale meters. Four, separate, independently-variable, stabilized power supplies feed a maximum of two screen-grid, one anode and one control-grid electrodes and heater supplies between 1.1V, 3A and 117V, 0.15A are available. Due to the provision of stabilized supplies it is possible to plot manually a valve's static characteristics with the minimum of incidental readjustment of electrode potentials. These supplies may also be used for the energizing of apparatus external to the tester: sockets for output are provided on the front panel. An unusual point is that the multitude of seldom-used sockets fitted to most valve testers is avoided by the provision of individual plug-in panels carrying one or two sockets. With the addition of the Valve Bridge Type 661 (which can be used independently) dynamic characteristics can be measured at a variety of electrode potentials.

The Valve Analyser costs £275 and the Bridge £370: both are available from Metrix Instruments, Ltd., 59 Victoria Road, Surbiton, Surrey.

Lightweight Low-Voltage Soldering Irons

THE Elremco soldering iron Type SMS is available in several ratings between 10W and 75W at 20V. Primarily designed for use with the Elremco low-voltage bus-bar installation, the high bit temperature makes possible soldering direct to equipment chassis, large solder lugs, etc., without changing to an iron of higher rating than that used for wiring. Twenty standard bits are available with tip diameters from $\frac{1}{16}$-in to $\frac{5}{16}$-in and the bit and metal stem are electrically isolated from the element and it connections, so making the iron particularly suitable for work on transistor equipment. The moulded-plastics handle has a hexagon-shaped section, which reduces to a minimum the chances of rolling when set down: the weight of the iron, without cable, is about 1oz, and the price is 11s 10d each for quantities of 100 and over. Manufacturers: Electrical Remote Control Co. Ltd., The Fairway, Bush Fair, Harlow, Essex.





Elremco soldering iron is about 8-in long and weighs, without lead, 1 oz.

Left: Matrix U-61B Valve Analyser

WORLD OF WIRELESS

E.F.F.I. Conference

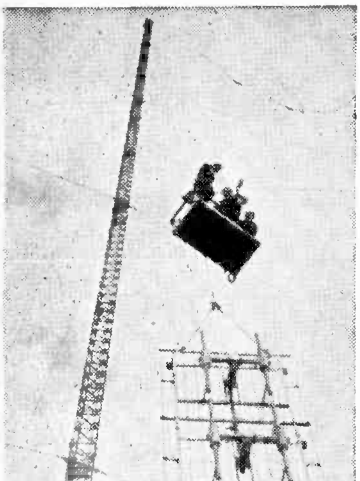
THE Electronic Forum for Industry, consisting of associations with common aims in making better known the developments and applications of electronics in industry, is to hold a three-day conference at Olympia, London, during the forthcoming Instruments, Electronics and Automation Exhibition. Details of the conference, which will be held on May 24th, 25th and 26th, will be announced later, but, broadly, the three sessions will cover practical experience of data processing, factory applications (including machine tool control) and instrumentation.

A prospectus and form of application will be available shortly from the E.F.F.I., c/o The Electronic Engineering Association, 11 Green Street, London, W.1.

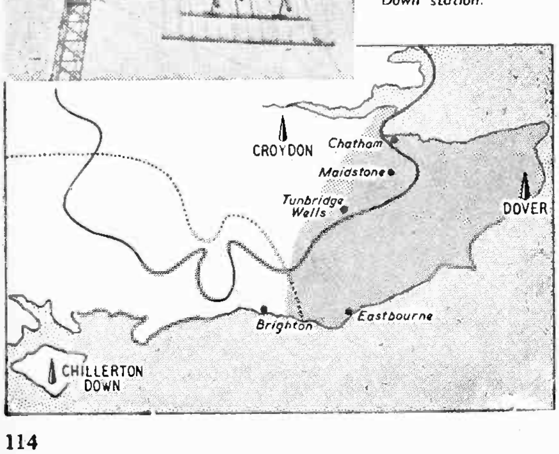
Domestic Receiver Production

DESPATCHES of both television and sound radio receivers were at record levels in 1959, according to provisional figures based on returns supplied by members to the British Radio Equipment Manufacturers' Association, which gave the net figures of deliveries by manufacturers to the home trade, including those to rental and relay companies.

The year's despatches of TV receivers totalled 2,745,000, which was 36% above 1958, the previous highest year. The total of 1,551,000 for sound receivers was 19% more than that for 1958 and 14% above 1957, the previous highest year. Despatches of radiogramophones at 187,000 were 14% lower than for 1958 and 30% below 1957.



Estimated service area of the new I.T.A. station at Church Hougham, near Dover, is shown (shaded) in relation to the 0.5mV/m contours of the London and Isle of Wight stations. Inset, riggers are shown ascending the 750-foot mast (erected by B.I. Callender's) with the channel 10 aerials (designed by E.M.I.). The aerials are screened to reduce to a minimum radiation towards France. Transmissions are vertically polarized with a vision e.r.p. of 100kW in the direction of maximum radiation. The transmitters and associated equipment were installed by Marconi's and the station is operated by Southern Television in conjunction with the Chillerton Down station.



1961 Computer Exhibition

ALTHOUGH the 1958 exhibition of electronic computers was intended to be a "once only" show, the joint organizers, the Electronic Engineering Association and the Office Appliance and Business Equipment Trades Association, have been encouraged to hold another. It will be held in the National Hall, Olympia, London, from October 4th to 12th next year. A business computer symposium will again be held concurrently with the exhibition.

Audio Fair

DEMONSTRATION rooms have been booked by nearly all the 70 or more exhibitors with stands at the forthcoming Audio Fair to be held in the Hotel Russell, London, W.1, from April 21st to 24th. We hope to publish a list of exhibitors in our next issue.

As in past years, free admission tickets will be available from the organizers (Audio Fairs, Ltd., 22 Orchard Street, London, W.1), exhibitors, audio dealers and *Wireless World*. As some of the tickets are for specific days, it would help if applicants stated their day of preference, and they are also asked to enclose a stamped addressed envelope.

P.A. Show.—Twenty exhibitors have taken space at the exhibition being arranged by the Association of Public Address Engineers at the King's Head Hotel, Harrow-on-the-Hill, Middx., on March 9th. In the morning admission is restricted to A.P.A.E. members and the Press, in the afternoon to the trade, but from 5.0 to 7.30 the public will be admitted. Free tickets are obtainable from Alex J. Walker, 394 Northolt Road, South Harrow, Middx.

The Electronic Organ Constructors' Society, proposed in a letter from A. Le Boutillier in our September, 1959, issue, has now been formed. Its objects are to "encourage and assist amateurs in the construction of organs [electronic and pipe] and to provide opportunities for the exchange of ideas and technical information." Alan Douglas is president, L. W. Roche, chairman, and A. Le Boutillier, whose address is 26 St. Catherine's Road, Chingford, London, E.4, is secretary.

B.A.R.T.G.—A change of title without altering the initials has been made by the British Amateur Radio Teletype Group since their attention has been drawn to the fact that the word "Teletype" is a registered trade mark. The word "teleprinter" has been substituted.

Transistors and transistor parts may now be imported from the Dollar Area without a Board of Trade Licence. Imports of Japanese transistors and transistor sets are still subject to control.

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"**Rocket and Satellite Instrumentation**" is the title of a one-day symposium being organized jointly by the Society of Instrument Technology and the British Interplanetary Society for September 1st in London. Subjects it is proposed to cover include a design study of a communications satellite; a digital data reduction system for use in the static testing of rocket motors; transducers for rocket motor testing; and the measurement, transmission and recording of data in the Skylark missile.

Non-Destructive Testing.—The general theme of a joint meeting between the Non-destructive Testing Group of the Institute of Physics and the Société Francaise de Métallurgie, to be held in London from May 2nd to 4th, will be the relationship between structure and physical properties of metals. Details of the programme, which will include papers on recent advances in non-destructive testing techniques, are obtainable from the Institute, 47 Belgrave Square, London, S.W.1.

Ten Million.—Last year's increase of 1,215,352 in the number of combined TV/sound licences in the U.K. brought the total at the end of the year to 10,114,419. The first million television licences was reached in 1951 —five years after the introduction of television licences— and since 1953 the average annual increase has been about 1,200,000.

Italian V.H.F.—Reference was made in January (page 12) to the rapidly increasing number of v.h.f. sound broadcasting stations in Italy. The story is going around that when the European Broadcasting Union asked the Italian broadcasting organization how many v.h.f. stations they had in service, on December 31st, they asked if they wanted the morning or evening total!

B.A.T.C. Convention.—The fifth Amateur Television Convention arranged by the British Amateur Television Club will be held on September 10th, in the Conway Hall, London, W.C.1. Details will be available later from D. S. Reid, 149 Ongar Road, Brentwood, Essex.

R.S.G.B. Officers.—The new president of the Radio Society of Great Britain is W. R. Metcalfe (G3DQ) of Whitby, Yorks. The executive vice-president is H. A. Bartlett (G5QA), who was president in 1955. The four ordinary members of the council elected at the recent annual general meeting are: C. H. L. Edwards (G8TL), R. C. Hills (G3HRH), A. O. Milne (G2MI) and G. M. C. Stone (G3FZL).

Relay Services Association.—Sir Walter Womersley, Bart., president of the Relay Services Association since 1948, has again been re-elected. J. W. Kinsman (Relay Exchanges) has become chairman of the council with B. R. King (British Relay Wireless) as deputy chairman.

B & K Laboratories, who have for the past five years organized an international instruments show in London, have decided not to hold one this year. When their show was conceived all the existing major exhibitions were national rather than international in character. This is no longer true. In making this announcement B & K Laboratories state, "We are not exhibition organizers and we hope that specialists in this field will continue the trend towards larger and better *international* exhibitions."

An international festival of sound is being held in Paris from March 18th to 23rd. Organized by the Syndicat des Industries Electroniques de Reproduction et d'Enregistrement (S.I.E.R.E.), it includes an exhibition, demonstrations of equipment, conferences and demonstrations of stereo f.m. transmissions by the French broadcasting authority, R.T.F.

A Moscow exhibition of British scientific instruments is being organized by the Scientific Instrument Manufacturers' Association for June 16th to 26th.

"**Marine Electrics.**"—Electronic and electrical equipment from the aircraft carriers *Victorious* and *Hermes* will be included in the "Marine Electrics" feature at the 9th National Electrical Engineers Exhibition at Earls Court from April 5th to 9th.

Dip. Tech. Awards.—Sir Harold Roxbee Cox, who has succeeded Lord Hives as chairman of the National Council for Technological Awards, presenting a Diploma in Technology to Ian Stanley (A.E.I. Research Laboratories), one of the first five successful candidates from the Northampton College of Advanced Technology, London. Other recipients, all of whom had completed a four-year sandwich course in applied physics which is heavily biased in electronics, were: Edward Feakes (R.A.E.), Frank Jacob (Vickers Armstrong), John Swain (A.W.R.E.) and Shirley Wallis (R.A.E.), the first woman to receive the Diploma.

Education and Training.—"The changing pattern of electrical engineering education and training" is the theme of a conference to be held at the Polytechnic, Regent Street, London, W.1, on the morning of March 8th. Particulars of the conference, of which R. E. Burnett, managing director of Marconi Instruments, is chairman, can be obtained from the Regional Advisory Council for Technological Education, Tavistock House South, Tavistock Square, London, W.C.1.

Teacher Training.—Many of the 2,000 or more teachers recruited each year for technical colleges join the staffs direct from industry. Special one-term courses aimed at improving the quality of teaching are now being provided for such teachers at four colleges. Course will start after Easter at the three Technical Training Colleges—Bolton, Huddersfield and Garnett College, London—and the College of Technology, Wolverhampton.

Vacation Courses.—Sound radio and TV servicing and telecommunication engineering are among the wide variety of subjects listed in the "Programme of Short Courses" for teachers and others in the educational service arranged by the Ministry of Education for the Easter and Summer vacations. The 30-page booklet is obtainable from the Ministry, Curzon Street, London, W.1.

A two-day conference on "The training of the industrial physicist" is being held by the Institute of Physics in Birmingham on April 21st and 22nd. Detailed programmes and registration forms are available from the Institute, 47 Belgrave Square, London, S.W.1.

Analogue Computing Techniques.—A five-day introductory course on analogue computing techniques is being conducted at the Loughborough College of Technology, Leicestershire, from April 11th. The fee for the course is 10 gns, plus 5 gns for residence.

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Personalities

The Hon. R. T. B. Wynn, C.B.E., M.A., M.I.E.E., Chief Engineer of the B.B.C. since 1952, is retiring on April 19th. Educated at Uppingham School and Trinity Hall, Cambridge, he received his engineering training with Siemens Bros. In 1922 he joined the staff at Marconi's experimental station at Writtle, Essex, where he was associated with the early broadcasts. He joined the B.B.C. in 1926 as head of the Technical Correspondence Department. Mr. Wynn, who is 62, has successively been head of the Operations and Maintenance Department and assistant chief engineer. **F. C. McLean,** C.B.E., B.Sc., M.I.E.E., Deputy Chief Engineer of the B.B.C., succeeds Mr. Wynn. The post is being redesignated Deputy Director of Engineering and the post of deputy chief engineer is being abolished. Mr. McLean, who is 56, joined Standard Telephones & Cables in 1925 after graduating at Birmingham University. He left S.T.C. to join the B.B.C.'s Planning and Installations Department in 1937. He headed various groups within the Engineering Division prior to his appointment in 1952 as Deputy Chief Engineer. He has been a member of the Radio Research Board since 1958.


F. C. McLean


K. G. Smith

K. Graham Smith, this year's vice-president of the Radio and Electronic Component Manufacturers' Federation, has been appointed deputy managing director of N.S.F. Ltd. He joined the company nearly 20 years ago as chief engineer and has been a member of the board since 1947. He has represented N.S.F. on the council of the R.E.C.M.F. for some years and was chairman in 1958/59. N.S.F., who are members of the Simms Motor and Electronics Corporation, also announce the appointment of **Percy C. D. Mace** as a director. He was for some years works manager of Welwyn Electrical Laboratories, and since March 1958 has been general manager of the N.S.F. works at Keighley, Yorks.

S. R. Wilkins, who, as announced in "News from the Industry," succeeds **J. H. Rawlings** as managing director of Avo Ltd., joined the company (then known as the Automatic Coil Winder and Electrical Equipment Company) in 1934. Six years later he was appointed chief electronic engineer and manager of the electronic instrument section in charge of design and production. He became technical director in 1956.

W. P. Rowley, M.B.E., M.Brit.I.R.E., has joined W.S. Electronics Ltd., a wholly owned subsidiary of K.G. (Holdings) Ltd., as assistant managing director. During the war he was commissioned in the Royal Corps of Signals and after a period as lecturer in radio at No. 1 Radio Mechanics School, was appointed Staff Officer (Wireless) to the Signal Officer in Chief, G.H.Q., Home Forces. He later held a similar appointment with S.H.A.E.F.


W. P. Rowley


E. A. W. Spreadbury

E. A. W. Spreadbury, M.Brit.I.R.E., who, as announced briefly last month, has succeeded **E. M. Lee,** of Belling and Lee, as chairman of the Radio Trades Examination Board, has been associated with the work of the Board since 1943 when he was appointed an examiner and a member of the examinations committee. Mr. Spreadbury represents the Brit.I.R.E. on the Board's council of management. Since 1941 he has been technical editor of *Wireless & Electrical Trader*, which he joined in 1937 after spending 14 years in the radio industry.

Air Commodore W. E. G. Mann, C.B., C.B.E., D.F.C., M.I.E.E., R.A.F. (Ret.), Director-General of Navigational Services in the Ministry of Transport and Civil Aviation since 1950, recently retired. At one time during the war he was Chief Signals Officer, R.A.F., Middle East, and since joining the Ministry in 1945 as Senior Signals Officer and U.K. Representative, Middle East, had held several administrative telecommunications posts.

R. H. Vivian, B.Sc., A.M.I.E.E., has joined Wireless Telephone Company, Ltd. as chief engineer. For many years he was development engineer in charge of transistor investigations and applications with A. C. Cossor Ltd. and since 1957 has been resident consultant with Associated Industrial Consultants Ltd.


R. H. Vivian


R. C. Parry

Roy C. Parry has joined Mullard Ltd. to take over the duties of Government Liaison Officer, covering valves, tubes, semiconductors and components. He was previously with Marconi's W/T Co., where he led a section engaged in the design of naval radar equipment. Before joining Marconi's he served for a number of years in the Royal Navy.

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Consequent upon the setting up of five new divisions under the reorganization of the A.E.I. group (see January, page 16), a number of appointments have been made. Four of the new divisions—telecommunications, radio and electronic components, cable and construction—are managed by A.E.I. (Woolwich) Ltd., previously Siemens Edison Swan. The board of directors of A.E.I. (Woolwich) includes **Lord Chandos** (chairman), **Dr. J. N. Aldington** (group managing director), **Dr. T. E. Allibone** (director of research), **L. S. Crutch** (director engineering, telecommunications). **G. W. Giffin** and **J. T. Thornhill** (directors of manufacture), **B. A. Hensler** (director, export), **J. W. Ridgeway** (commercial director), **A. Whitaker** (director of engineering, radio), **S. E. Goodall** (director of engineering, cable), **R. L. Basset** and **A. F. Street.** Except for the resignation of Sir Alexander Sim and the inclusion of S. E. Goodall (formerly chief engineer of Henley's Telegraph Works), the board is unchanged from that of Siemens Edison Swan. In the Radio & Electronic Components Division **C. C. McCallum,** A.M.I.E.E., becomes general manger. He joined Metropolitan-Vickers radio department in 1928 and two years later transferred to Edison Swan's

A. Whitaker

C. C. McCallum

radio valve department and was for ten years service department manager at the Cosmos works, Brimsdown. **A. G. Everett,** divisional manufacturing manager, has been with the organization since 1920 when he joined Metro-Vick as a college apprentice. He was appointed a director of Edison Swan Electrical Co. in 1948. **J. Donegan,** B.Sc., A.C.G.I., D.I.C., engineering manager (development), was a valve development engineer, becoming chief engineer valves and c.r. tubes on the merger of Siemens and Edison Swan. He is vice-chairman of the engineering advisory committee of the British Radio Valve Manufacturers' Association. **C. L. Hirshman,** A.C.G.I., D.I.C., now engineering manager (consultative), has been at the organization's Brimsdown applications laboratories since 1931. The divisional sales manager is **P. V. Lister.**

The following appointments are announced in the Telecommunications Division: **W. G. Patterson** (general manager); **J. M. Wilcox** (manufacturing manager); **F. G. Pheazey** (chief engineer); **T. J. Scudder** (production engineering manager); and **D. J. Green** (commercial manager). In the Cable Division the general managers are **J. S. A. Bunting** and **E. J. Vidler;** manufacturing managers, **V. L. J. Plascott** and **S. J. Wilson;** chief engineers, **W. G. Hawley** and **J. H. Savage;** sales manager, **H. D. Parsons;** and commercial manager, **F. V. Vaissiere.** In the Construction Division, **A. V. Burnett** is general manager; **W. Sim,** chief engineer; and **L. F. Capeling,** commercial manager.

B. C. Cook has joined Wolsey Electronics Ltd. as technical consultant Vision Network Systems. He has for many years been with Belchers Ltd.

T. Kilburn, D.Sc., Ph.D., M.A., M.I.E.E., reader in electronics at Manchester University, has been appointed to the newly created post of Professor of Computer Engineering in the University. Dr. Kilburn, who was at the R.R.E., Malvern, from 1942 to 1946, co-operated with Professor F. C. Williams, head of the electrical engineering laboratories, Manchester University, in building in 1948 the University's first computer, on which was based the Ferranti Mark I. He later worked on the prototype of the Mercury computer and since 1957 has been engaged on the transistorized computer to be known as Muse.

Harry Cartwright, M.B.E., M.A., A.M.I.E.E., the new Director of Industrial Power in the Atomic Energy Authority's development and engineering group at Risley, Derbyshire, was with the English Electric Co. immediately prior to joining the Atomic Energy Division of the Ministry of Supply (forerunner of the A.E.A.) in 1949 and was previously with the Decca Navigator Co. Mr. Cartwright, who is 40, took a first class honours degree in the mechanical sciences tripos at St. John's College, Cambridge, in 1940 after which he was a signals officer at R.A.F. ground radar stations He has successively been chief engineer and deputy director of the group of which he is now appointed director.

OUR AUTHORS

L. H. Bedford, C.B.E., M.A., B.Sc.(Eng.), F.C.G.I., F.I.R.E., M.I.E.E., M.Brit.I.R.E., director of engineering at the Guided Weapons Division of the English Electric Co., writes in this issue on an aspect of one of his hobbies—tape recording. Mr. Bedford, whose name is associated with the elevation attachment which he produced for the early gun-laying radar equipment, started his industrial career with the Western Electric Co. and spent some months at the Bell Telephone Laboratories in America. He joined A. C. Cossor in 1931 to initiate their development and manufacture of cathode-ray tubes. He stayed with that company until 1947 when he joined the English Electric group as chief television engineer of Marconi's W/T Co. Mr. Bedford was president of the Brit.I.R.E. from 1948 to 1950 and was appointed a member of the technical sub-committee of the Government's Television Advisory Committee in 1955.

Ralph Brewer, who was for some years in charge of the valve life-testing department of the G.E.C. Research Laboratories, is now concerned with the study of the survival characteristics of transistors and related semiconductors, and contributes an article on this subject on page 108. Mr. Brewer, who is 45, joined the Research Laboratories in 1937 and during the early part of the war worked on the development of magnetrons. He received an award for his paper on life testing of valves read at the 1958 National Symposium on Reliability and Quality Control in Electronics in the United States.

R. C. V. Macario, B.Sc., Ph.D., Grad.I.E.E., joint author of the article in this issue on transformerless broadcast receivers, graduated in 1953 at King's College, London, where in 1956 he completed post-graduate studies concerned with the propagation of very low-frequency radio waves. Subsequently he spent some time at the A.E.I. Research Laboratories on semiconductor devices, and in 1958 joined the Plessey Company, where he is working on solid-state magnetic and dielectric devices.

N. E. Broadberry, Grad.Brit.I.R.E., who with Dr. Macario contributes the article on p. 110, attended the Institute of Science and Technology, Dublin, specializing on receiver design and after spending a year with Pye (Ireland) and nearly three years as a civilian radio and radar specialist on a military aerodrome, joined Murphy Radio (Ireland) for three years. In 1953 he became a lecturer at his former college. He joined Pye (Cambridge) in 1955, and last year was appointed a senior electronic research engineer with Plessey.

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Physical Society's Exhibition

NEW TECHNIQUES IN ELECTRONICS AND MEASUREMENT

THERE are very few fields today in which electronics does not play some part: it has seemed even as if electronics were becoming a hydra-headed monster, judging by the complexity of some sections of the art. However, following last year's trend, many of the exhibits suggested by their ingenious simplicity and application of first principles that the monster is being changed into a well-mannered pet. A selection of these items is described in the following report.

The exhibition itself was even more crowded than it was last year and the organizers were unable to accommodate thirteen would-be exhibitors who had applied for space.

INDUSTRIAL ELECTRONICS

Electrical Power from Heat, without the usual intermediate mechanical stage, was the theme of a display on the stand of the United Kingdom Atomic Energy Authority.

Two working demonstrations were shown—a thermionic method using a diode, and a semiconductor thermojunction heated by steam. The diode used a bright-emitter tungsten filament and a caesium-vapour filling—this latter neutralizes the emission-inhibiting effect of the space charge which gathers round the cathode of an unsaturated diode—and produced a small but nevertheless useful current. Although the diode is primarily a d.c. generator it is possible that, by modulation of the gas discharge, a.c. may be produced. Of course, the power input to the demonstration model was far greater than its power output, but the eventual hope for this means of power generation lies in the use of hot fuel rods (at about 2,000°C) of an atomic pile as the cathodes, the physical construction being such that individual diodes are connected in series so generating high potentials. The thermojunction—really a modern version of the thermocouple—used bismuth telluride semiconducting elements. Again the power output was far smaller than the input, but this method may be economical for "mopping up" waste heat from an atomic reactor.

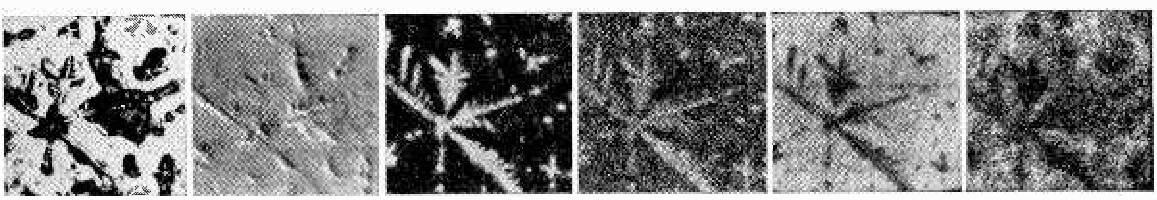
The magnetohydrodynamic method uses a jet of ionized gas to replace the moving conductors of a conventional generator and the power developed is "picked out" by electrodes placed in the gas flow. The practical application of this principle awaits the introduction of materials suitable for temperatures of about 2,000°C.

Associated with the display was a mechanical analogue (after Kaye of M.I.T.) of a diode valve. Delightfully clear in its presentation, a rotating ridged roller shot steel ball bearings up a plane with a double incline to represent work function and space charge. The balls with sufficient energy to reach the top of the plane ran down a shute (representing the external circuit) and rotated a small paddlewheel before returning to the "cathode." The paddlewheel formed part of a generator whose output deflected a galvanometer.

Radio Frequency Spectroscopy is employed for the routine analysis of free radicals (uncombined particles of the material)* in the Newport Instruments electron paramagnetic resonance spectrometer. As this instrument is designed for laboratory use it incorporates a large electromagnet and elaborate stabilization arrangements for the power supply to ensure a uniform (1 part in 10^4), constant and controllable field of between 150 and 8,000 gauss is achieved. The field is adjusted to bring the resonance being studied to 9.5Gc/s (9,500Mc/s) and elaborate precautions are taken in the waveguide assembly to ensure that accurate results are obtained—for instance, the klystron local oscillator is mounted in a constant-temperature oil bath. In operation the field is varied either at l.f. by coils on the pole pieces or at r.f. (100kc/s) by a single-turn coil round the specimen. The klystron output is thus modulated as the resonance in the sample passes through the local-oscillator frequency: but, to improve accuracy over the detection of a change of amplitude the local oscillator and "returned from sample" signals are mixed in a waveguide bridge and their relative phase is detected.

Microanalysis of Metallic Alloys by a technique originally developed in France by R. Castaing and applied by the Cambridge Instrument Company uses a 10^{-6}m.-diameter electron spot to scan a 0.5×10^{-3}m. square area of the sample. The beam is produced by an ordinary triode gun and focused by a double magnetic lens in the manner of an electron microscope. The etched

* For a fuller account of electron spin and nuclear magnetic resonances see *Wireless World*, p. 68, February, 1960.



Images obtained with Cambridge Instruments Electron-probe X-ray Microanalyser during preliminary investigation of copper(70%)—nickel-tin-iron (10% each) alloy. L to R: optical, electron and X-ray(iron, nickel, copper, tin) images.

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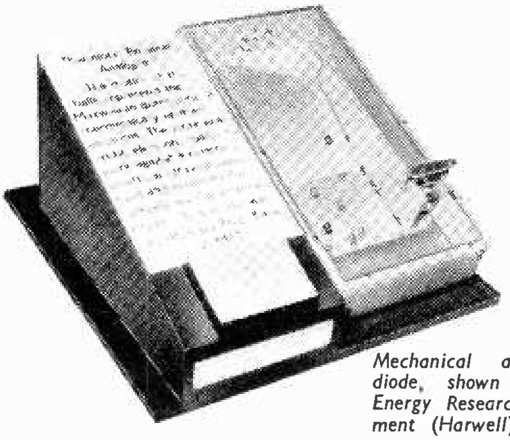
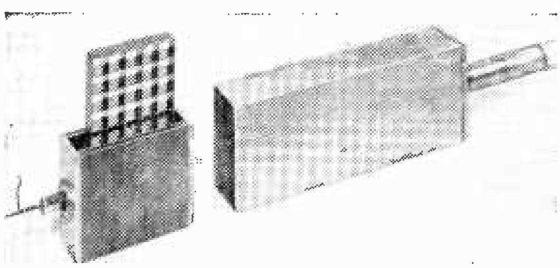
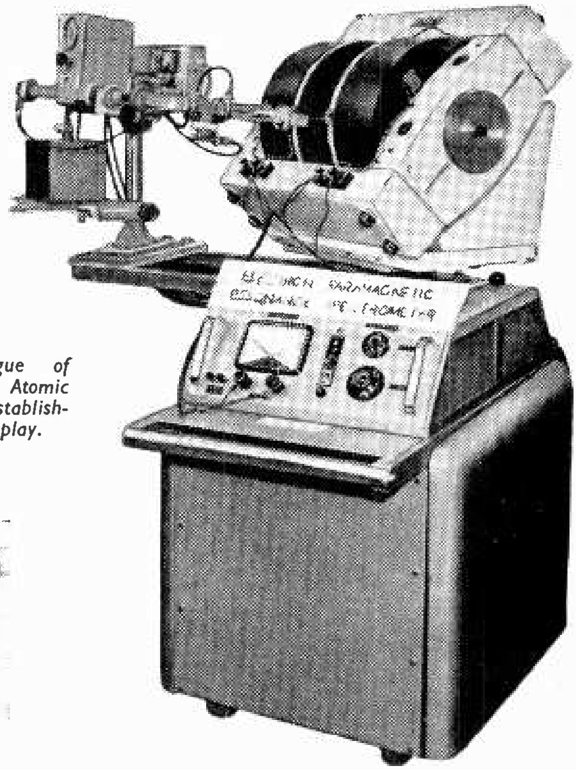


Mechanical analogue of diode, shown in Atomic Energy Research Establishment (Harwell) display.



"Exploded" view of Penning ion pump (Mullard Ltd.).



Newport Instruments electron paramagnetic resonance spectrometer, showing magnet and power supplies; also wave-guide bridge.

surface of the sample reflects some electrons and these cause the emission of light from a phosphor mounted near the sample; a photomultiplier produces from the light a signal which modulates the beam current of a cathode-ray tube, scanned in synchronism with the analyser beam. Thus an "electron picture" of the sample is built up. X-rays produced by the electrons that penetrate the surface of the sample strike an analysing crystal (gypsum or lithium fluoride) which "bends" them into a proportional-counter detector. The electrical signal from this is similarly used to produce an X-ray microgram. The wavelength of the X-rays produced by different metals varies, so that the angle through which the spectrometer crystal bends them also varies: thus by rotating the crystal the distribution of different metals in an alloy can be seen.

High-vacuum Maintenance is one of the problems associated with many electron devices and, whilst many ingenious approaches have been devised, few have the simplicity of the Penning ion pump. "Pump" is, perhaps, a misnomer, for the Penning gauge and the pump derived from it bear little resemblance to any of the commoner evacuating devices. The basic gauge is a cold-cathode discharge tube and the small current which flows under high potential is a measure of the pressure. The principle of operation of the pump is similar: a magnetic field causes electrons to take up a spiral path between the electrodes. This increases the volume swept out and hence the chance of ionization. Sputtering of the titanium electrodes occurs, so causing the titanium to act as a continuous getter. Two firms, Mullard and Edwards, were showing pumps based on the Penning-gauge principle. The Edwards pump was cylindrical in form with two cathode discs on either side of a wire-ring anode. A 500-gauss field and 3 to 5kV are applied, the current ranging from 0 to 15mA and depending naturally on the degree of ionization. The Mullard pumps use a horseshoe magnet producing some 1,000 gauss and the anode is made up as a rectangular honeycomb structure; also a small getter filament is included. Pumping speeds of 1 to 5 litres/sec and pressures down to 10^{-9} torr (mm of mercury) have been reached with Penning pumps.

Microscopic Measurements made by the use of a calibrated vertical traverse on the microscope are limited in accuracy to far below the maximum possible resolution of the microscope. However, Wayne Kerr have developed a technique using their B721 Electronic Micrometer which is a transformer-ratio bridge capable of measuring minute changes of capacitance. The microscope is fitted with a Baker interference objective (which makes exact focusing easy) and a non-contacting probe connected to the micrometer. In use the microscope is focused in turn on to the points representing the top and bottom of the "depth" to be measured, and the distance of the probe from the specimen is measured by the micrometer. Repeated measurements of the depth of the etching of photogravure printing plates gave results with a standard deviation of 5×10^{-6}in on a 2×10^{-3}in mean.

Displacement Measurement—Nearly all semiconductors increase in resistance when they are placed in a magnetic field. The use of this magnetoresistive effect, as it is called, to detect displacements down

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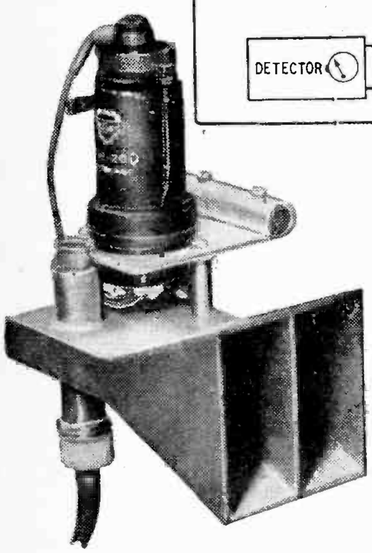

Below: Doppler sensing head of Burndept press-output counter.

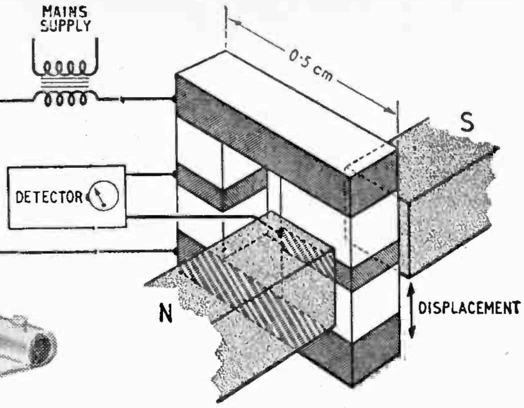

Diagram of the National Research Development Corporation magneto-resistive effect displacement meter. The soldered contacts are shown line-shaded and the direction of motion indicated by the arrows.

to about 10^{-8}cm was demonstrated by the National Research Development Corporation. The semiconductor used is indium antimonide (InSb), since in this the effect is relatively large. Four contacts are soldered on to InSb elements so that the resistances between these contacts form a Wheatstone bridge. Following normal practice, this bridge is energized from an a.c. supply across one pair of opposite contacts, and any out-of-balance signal detected between the other pair of opposite contacts. Two of the InSb resistors are arranged to be partially in a 10,000-gauss field produced by a permanent magnet, so that relative motion between the InSb and magnet in one direction moves one of these resistors further into the field and the other resistor further out of the field. The magnetoresistive effect then increases the value of the resistor which moves further into the field and decreases the value of the resistor which moves further out of the field. This unbalances the bridge and the out-of-balance signal gives a measure of the displacement of the InSb relative to the magnet.

Strain Gauges take many forms, but an unusual type was an "acoustic" gauge shown on the Acoustics Group stand. This consists of a length of ferromagnetic wire stretched between two massive supports on the body under test. Placed near the wire at its centre are two coils, one connected to the input of an amplifier and the other to the output. The connections are phased so that positive feedback takes place which results in oscillation at the resonant frequency of the wire. If the strain on the wire is altered, its frequency alters: thus the strain is given by measuring the frequency of oscillation.

Tachometer—A method of measuring rates of rotation shown by the National Research Development Corporation utilizes the magnetic field induced when a conducting cylinder rotates in a magnetic field. This induced field is at right angles to the original field, so it may be distinguished from the original field and measured by a detector, such as the fluxgate used, which measures only the component of the total field in the direction of the induced field. This method can be used to measure rotation rates as slow as 0·1 r.p.m.

A Doppler-radar Sensing Head was demonstrated with the Burndept BE250 press-output counter. The output from a small 3-cm klystron is fed into half of a waveguide horn radiator: in the other half is a mixer crystal. When a moving object passes the horn the radiation reflected from it beats with the klystron frequency at the mixer crystal, producing an a.f. pulse at the Doppler frequency. The sensitivity is such that the movement of a 2-BA washer one foot away can trigger the counter. Although this may sound an expensive method, it should overcome most, if not all, of the disadvantages of cutting beams of light or producing pulses in coils as oil and dirt should not affect it, and it will detect any object giving a reflection.

Ultrasonics are playing an increasing part in industrial measurement and test. An example of the measurement of fluid velocity in a pipe was shown on the B.S.I.R.A. stand. In this method two transducers are mounted in line along the outside of the pipe so that the beam transmitted by one is reflected from the opposite pipe wall and received by the second. As the propagation speed depends on the flow speed, the time difference between pulses travelling in each direction will represent the flow velocity. A novel feature of the arrangement is that, as both transducers operate simultaneously, the "forward" and "backward" waves travel the same path, thus eliminating any temperature effects. Slightly different frequencies centred on 5Mc/s are used so that the two sets of information may be separated and a phase-sensitive detector (operating at a low frequency) triggers a flip-flop, or bistable, circuit which generates pulses whose area is thus equivalent to flow velocity. A moving-coil meter indicates the average area under the pulses and gives a direct flow reading.

MEDICAL ELECTRONICS

Medical Manometry.—The first British "radio pill," soon to be manufactured in quantity, was shown by the Medical Research Council. It is a subminiature radio transmitter, encased in a cylinder 1.9cm long and 0.8cm in diameter, which signals pressure (or temperature) values during its passage through the gastro-intestinal tract. A 400-kc/s transistor oscillator using a Gouriet circuit is modulated in frequency by the pressure transducer. This consists of a pot-cored inductor, forming the tuning inductance of the oscillator, with its magnetic circuit including a small ferrite disc which is attached to a flexible diaphragm. Pressure variations applied to the diaphragm therefore change the inductance and vary the frequency of the oscillator. The whole assembly, including the sealed Mallory battery, is completely potted, and the oscil-

(*Continued on page* 121)

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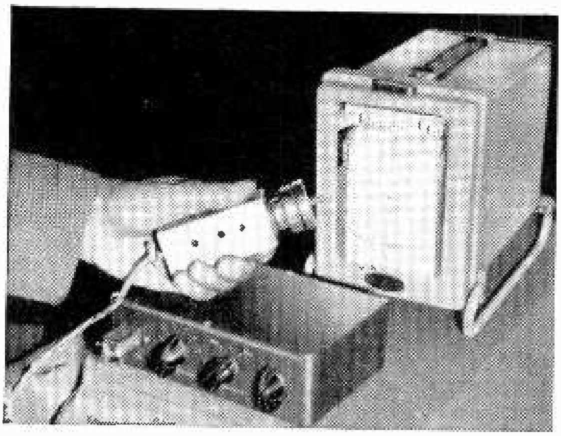
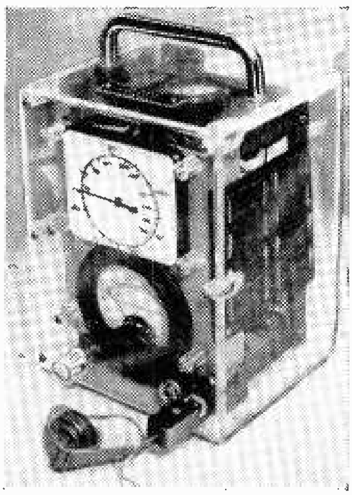


Right: Capacitance-type transistor pressure gauge (Medical Research Council).



Below: Photocell-powered medical pulse meter shown by University of Edinburgh.

lator is switched on by giving a shake to the "pill" to operate an inertia mercury switch. The maximum frequency deviation is 35kc/s. At the receiver, a superheterodyne system provides an output signal which varies between 0 and 35kc/s. The cycles of this are converted into square pulses of regular width and amplitude, which are passed to a pen recorder. The integrating effect of the pen recorder mechanism on the pulses then provides a pen deflection which is proportional to their frequency, and hence to the pressure.

Another transistorized device on the same stand was a miniature capacitance-type pressure gauge using a diaphragm of aluminized Terylene as the pressure-sensitive element. It was notable for having the frequency-modulated oscillator and discriminator all built into the body of the gauge, thereby reducing drift and avoiding trailing r.f. cables.

Reduction of drift was also the object of a recording manometer based on a servo or follower principle which was shown by Edinburgh University. Pressure is applied to one arm of a flexible U-tube containing liquid. Increasing pressure therefore causes the level of the liquid in the other arm (which has a transparent glass section) to rise. By raising this transparent arm, however, the liquid in it can be brought back to its original level—the amount of movement required being proportional to the increased pressure. The object of the follower system is to detect the initial movement of the liquid level from a reference position in the transparent arm, then to raise or lower the arm, by means of a carriage and rail system, until the level returns to the reference position. Direction of liquid movement is detected by one phototransistor in the carriage, while two others, and their associated circuitry, respond to acceleration in either direction. Appropriate signals control a motor which drives the carriage up or down in a correcting sense, and the movements of the carriage are transferred by a cord system to a pen on a recording chart which indicates the pressure.

Edinburgh University also displayed a transistorized medical pulse meter, using a carbon resistance transducer for strapping to the thumb, which was made portable and reliable by the use of light energy to provide the power via rechargeable sealed cells. A bank of eight selenium cells in series gives the charging current for the battery, which will operate the pulse meter (1-2mA drain) for 50 hours without recharging. A diode prevents discharge of the battery through the selenium cells when the instrument is left in the dark.

TEST AND MEASURING GEAR

Sine-Wave Generators. Several new transistor oscillator circuits were shown by the Royal Radar Establishment. Two of these utilized so-called class-D push-pull operation. This combines the half-cycle current flow in each transistor of class-B operation, with the nearly zero voltage drop across the transistor during the whole of current-flow period of class C. This retains the advantages of both class-B and class-C operation without their respective disadvantages of finite average voltage drop during current flow and less than half current on/off ratio. The nearly zero voltage drop across the transistor results in a high efficiency, and the half-cycle conduction period in relatively low distortion. The transistors are driven by a current switched alternately into one base or the other. One of the class-D circuits shown was a tape erase and bias oscillator. This used two OC24's to provide 3.5 W output at 35kc/s with a second harmonic distortion of less than 0.1%.

Another new transistor circuit shown by R.R.E. is the equivalent of a well-known valve circuit often used to provide very-low frequency oscillations. This circuit consists of a phase invertor followed by two similar virtual-earth Miller integrators. This provides a total phase shift of 360° at one frequency, so that when the output is fed back to the input oscillations at this frequency are produced. The output from the first integrator is limited and used to provide positive feedback at the phase-invertor input so as to stabilize the oscillation amplitude. Since the 360° phase shift and consequent oscillations are only produced at one frequency, the fact that the positive feedback consists of a limited and thus distorted sine wave does not increase the oscillation distortion.

A transistor b.f.o. was also shown by R.R.E. Here a 100kc/s oscillator is switched between a load and output at a frequency variable between 80 and 100kc/s. This produces a b.f.o. in the output which is variable in frequency up to 20kc/s. Since all spurious frequencies produced by the switching are at least as high as 80kc/s, they may be readily removed.

An unusual feature of the Solartron DO905 is that the cable supplied has no effect on the output level, since level-stabilizing feedback is taken from the end of this cable.

A grid-dip meter with plug-in coils

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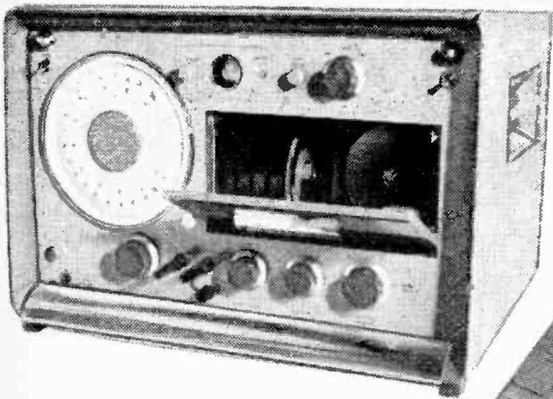
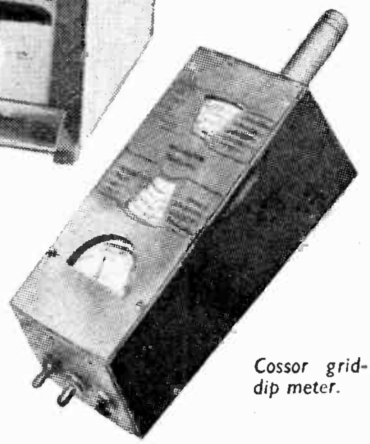


Left: Advance mechanical-optical very-low frequency waveform generator.



Cossor grid-dip meter.

covering 220kc/s to 300Mc/s in all was shown by Cossor (Model 1461). Such a device comprises a calibrated oscillator with a meter which reads grid current. It can thus be used either simply as an oscillator or, by noting the frequency at which an externally connected passive circuit produces a sharp dip in the grid current, as a resonance absorption detector. By switching the oscillator valve to act as a diode, it can also be used as an absorption meter by determining the frequency at which a peak in the meter current is produced.

The Dawe Type 1208, when fed with a sinusoidal signal in the frequency range from 5c/s to 5kc/s, produces a frequency differing from the input by an amount which can be fixed between 0.5 and 2.5c/s. This fixed difference-frequency output is for feeding a stroboscopic lamp so as to produce a slow-motion effect with objects vibrating at the original input frequency. The input is fed to two groups of phase shifters, each of which consists of a passive CR network connected between the anode and cathode of a concertina phase splitter. The first group contains four such phase shifters connected in series and tuned to produce 45° phase shift at 5, 50, 500 and 5,000 cycles respectively: the second group contains three such phase shifters in series tuned to the geometric means of these frequencies, i.e. 15.8, 158 and 1,580c/s. The phase difference between the outputs from the two groups of phase shifters is then within 5° of 90° for any input frequency between 5c/s and 5kc/s. By the use of two additional phase invertors, four outputs spaced at 90° phase intervals can then be obtained for any input frequency between 5c/s and 5kc/s. These outputs are fed to four equally-spaced tappings on a circular potentiometer whose wiper rotates at the required difference frequency. The output between the wiper of this potentiometer and any of the four tappings then has a phase difference with respect to the original frequency which increases at a constant rate of 360° per potentiometer wiper revolution period. This variable-phase output can be shown to be equivalent to a constant phase output differing from the input frequency by the rate at which the potentiometer wiper rotates.

Pulse Group Generator—To select and observe special types of nuclear particles or radiation, elaborate types of pulse groups produced by these particles or radiation may have to be dealt with by the apparatus used. Complex pulse groups may also be needed in physiological work. Specialized pulse generators are thus required for testing such nuclear and physiological equipment.

An example of such a specialized generator shown by Nagard, their Type 5101, produces groups of pulses in which the group length, and group and individual pulse repetition rates are all independently variable, subject to the proviso that, for convenience, only a whole number of pulses is produced in each group. A variable-frequency multivibrator triggers a variable-length flip-flop to provide the variable-rate and length group pulse. This group pulse is specially shaped and fed to trigger on and off a second variable-frequency multivibrator working at the individual pulse rate: the group pulse shaping being such as to only trigger on and off the individual-pulse generator at the beginning and end of a pulse.

Function Generator—The new Advance Type SG88 uses a mechanical-optical system to repeat any required waveform at any rate between 0.005 and 50 times per second. A rotating transparent disc is partially blacked out so that the remaining transparent area corresponds to the waveform to be generated expressed in polar co-ordinates. The disc is illuminated, and the light transmitted through the disc and a fixed radial slit is focused by a cylindrical lens on to a phototransistor. As the disc rotates, the fixed slit thus scans the waveform to be produced so that the output of the phototransistor reproduces this waveform. The rise time of the device is limited by the slit thickness and varies from 300msec at 0.005 waveforms/sec to 0.3msec at 50 waveforms/sec. An integral triggering device can be used to decrease these rise times to less than 3μsec for square waves at all repetition rates.

Noise Generator—A simple device for producing a broad band of noise centred on 1,500c/s for acoustic calibration purposes was shown by Dawe. This Type 1417 generator contains about 6,800, 0·06-in diameter, steel ball bearings. These fall through an aperture onto an anvil which deflects them on to a vertical mica plate where they produce the required noise output. About three-quarters of the bearings strike the mica in the useful measurement period of about 5 seconds. The noise is 3dB down at 750 and 3,000c/s and its intensity 90 ± 1dB at a distance of 8 cm from the mica.

Acoustic Measurement—A method of finding the radiation impedance on a rigid piston was shown by the Admiralty Research Laboratory. An acoustically simple source is used consisting of a longitudinally excited piezoelectric crystal cemented to a glass head. Except for the end face of the glass, this source is covered by a watertight container. The whole source is immersed in water or any other medium with a high acoustic resistance but low viscosity. All parts of the source then work into air except for the face of the glass in contact with the water. The only significant acoustic loading is thus that produced by the water on this face. The radiation reactance on this face can then be obtained from the change in the resonant frequency of the source when it is immersed in

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water, and the radiation resistance from the Q of the resonance in water.

Magnetic Measurements—The measurement of susceptibilities down to about 5×10^{-7} c.g.s. units (about that of pure water) was demonstrated by the National Research Development Corporation. An extra soft-iron pole piece containing an indium-antimonide Hall-effect magnetic-field detector is placed between the two normal soft-iron pole pieces of a permanent magnet. If the magnetic reluctances of the two gaps so formed between the extra pole piece and the two normal pole pieces are equal, no flux will be produced in the central pole piece containing the magnetic-field detector. If then a sample is introduced into one of the gaps, the reluctance of this gap is altered, the two gap reluctances become unequal, and a magnetic flux is produced in the pole piece containing the magnetic field detector. The detector output can then be shown to be proportional to the susceptibility of the sample.

A vibrating reed magnetometer for measuring the saturation magnetization of ferromagnetic materials was shown by the G.E.C. Research Laboratories. A sample of the material is attached to one end of a flat non-magnetic reed, the other end of which is rigidly clamped. The sample is placed in a non-uniform magnetic field across the width of the reed. The force on the saturated sample due to the non-uniform magnetic field is then proportional to the product of the magnetic moment of the sample and the rate of change with distance of the field strength, and this force is in the direction of the stronger field. With hemispherical pole pieces, the non-uniformity is such that this rate of change is proportional to the displacement of the sample from the central position. This adds to the force produced on displacement by the elasticity of the reed so as to alter the reed's natural resonant frequency. Attached to the reed are two barium titanate transducers; one is driven by a variable frequency oscillator so as to cause the reed to vibrate, and an increase in output from the other is used to indicate the reed's resonant frequency. The change in resonant frequency with and without the magnetic field is proportional to the saturation magnetization of the sample. The instrument is calibrated using a nickel sample for which the saturation magnetization is accurately known. The measurement can be shown to be unaffected by the size of the sample apart from a small error produced by the slight curvature of the field lines. By applying the field across the reed width, any attraction of the sample to one pole piece is counteracted by the much greater stiffness of the reed to motion in the direction of this attraction.

Microwave Measurements—An automatic complex reflection-coefficient plotter was shown by the G.E.C. Research Laboratories. Three probes spaced equally along a guide between 1/8 and 3/16 of a guide wavelength apart each feed a square-law bolometer detector. It can then be shown that if the differences between the outer probe detector outputs and between the middle and the mean of the two outer probe detector outputs are fed to the Y and X plates of an oscilloscope respectively, the c.r.t. spot is deflected to a point corresponding to the complex reflection coefficient of the impedance at the end of the guide. Because of the restriction on the spacing between the probes to between 1/8 and 3/16 of a guide wavelength, three fixed probes can only be used over a ± 20% range of guide wavelengths. There are, however, no inherent frequency-range limitations in the display unit.

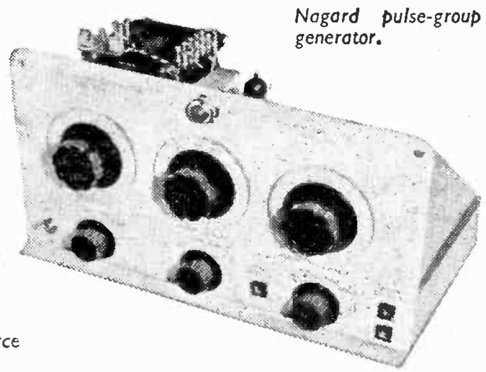
An exhibit of the A.E.I. Research Laboratories showed how large frequency differences (e.g. 1kMc/s in 35kMc/s) could be measured to a high resolution (e.g. 1Mc/s). The signal input feeds a section of waveguide which contains three phase detectors spaced at 120° intervals and which is terminated by a long length of short-circuited delay line. Any slight change in wavelength of the standing-wave pattern is added up in the long length of delay line to produce a considerable shift in the pattern, and this shift is measured by the three detectors. The three detector d.c. outputs are amplified and fed one to each of the three coils of a desyn. It can then be shown that the angular rotation of the desyn magnet pointer is proportional to the product of the frequency change and delay line length. By attaching a revolution counter to this pointer, large frequency changes can be measured.

Frequency Meters—An often-used type of circuit first transforms the input to a square wave which is then used to pass a fixed charge every cycle into a capacitor. The charge current, being proportional to the input frequency and independent of the input waveform shape, thus gives a measure of the frequency. Both the Venner Type TSA501 and the Solartron "f—C" meter used this basic type of circuit. The latter instrument can also measure capacity by means of an internally-generated input of known frequency, since the charge current is also proportional to the capacity.

Phase Meter—In the Dawe transistorized Type 630, the two signals whose phase difference is to be measured are limited, the resulting square waves differentiated, and the positive going pulses so produced used to trigger on and off a bi-stable circuit. The mean d.c. output of this circuit is indicated by a meter. This output is proportional to the "on" over "on-plus-off" current ratio of the bi-stable circuit and this is equal to the phase difference required divided by 360°.

Incidentally, Ekco, for transistor convertors, have adopted a simple method of obtaining three phases from two single-phase supplies. Known as a Scott transformer, it entails only the connection of one supply to the centre tap of the other. As long as the phase difference be-

Dawe falling-ball noise source for acoustic calibration.



Nagard pulse-group generator.

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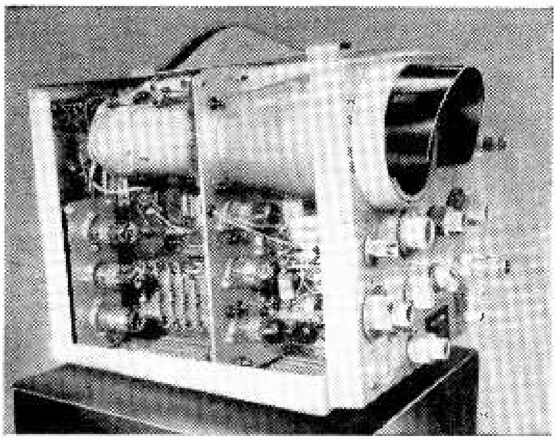
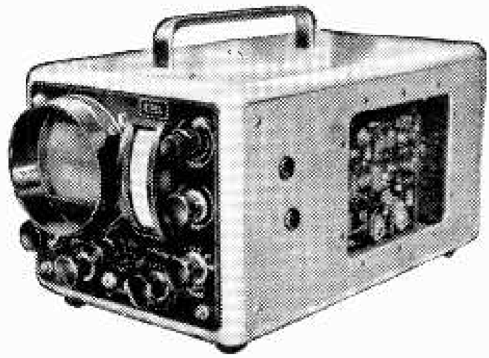




Solartron portable double-beam oscilloscope.

Electronic Tubes transistor oscilloscope designed to illustrate the use of their CR132 cathode-ray tube.

tween the single-phase supplies is held at 90° and the correct voltage ratio is achieved, a balanced, stable three-phase supply is developed between the free ends of the single-phase windings.

Logarithmic Amplifier—In the Solartron model TA965, the logarithmic characteristic is obtained simply by making use of the logarithmic forward voltage/current characteristic of a thermionic diode under low-current temperature-limited conditions. The diode is used as the anode-to-grid feedback resistance in a virtual-earth type of amplifier. Since the gain of this amplifier is proportional to this feedback resistance, this gain is also proportional to the logarithm of the input current.

Clip-on D.C. Milliameter—In a transistorized instrument shown by Solartron, their model AM1002, the magnetic field produced by the current to be measured is collected by a Mumetal clip round the wire and measured using a Hall-effect device. This device, together with as much as possible of the magnetic clip circuit, is magnetically shielded from stray fields. The effect of the earth's field near the current-carrying conductor is cancelled out by extending the magnetic circuit on the other side of the Hall-effect device away from the current carrying conductor in such a way that the earth's field there induces an equal cancelling field in the Hall-effect device. The Hall-effect device is energized at 40kc/s and the output amplified, rectified and indicated on a meter. A fraction of the rectified output is fed back to coils wound on the clip so as to produce a field opposing the detected field. This feedback linearizes the instrument against changes in the reluctance of the movable parts of the magnetic clip circuit. The feedback coils are wound on copper cylinders to provide short-circuited turns which greatly reduce the inductive reaction on the circuit being measured. The instrument is calibrated by means of a standard current.

Oscilloscopes—For illustrating the use of their CR132 c.r.t., a transistor oscilloscope was shown by Electronic Tubes. This uses 21 transistors to achieve a sensitivity of 75mV/cm from d.c. to 20Mc/s (3dB down), and an input impedance of 250kΩ. The total power consumption is 2.5W, of which the c.r.t. heater uses 1W. To achieve the relatively-high deflection voltages required, two transistors are used in series across the supply in what was termed a "beanstalk" circuit.

A new range of portable test and measuring instruments in attractive two-tone pastel colours introduced by Solartron included a double-beam oscilloscope (Model CD1014). This has a bandwidth from d.c. to 5Mc/s (3dB down) at a sensitivity of 100mV/cm. Time and voltage measurement to within at least ± 5% are possible.

A two-channel oscilloscope introduced by Nagard, their Model 311, has a sensitivity as high as 100μV/cm with a bandwidth from d.c. to 250kc/s (3dB down). An internal square-wave generator with nine alternative outputs allows voltages to be measured to within ± 2%. Time intervals can be measured to the same accuracy using the calibrated sweep speeds available.

By changing to a slightly different type of storage tube like that described in our review of the 1958 Physical Society exhibition (May 1958 issue, p. 221), Cawkell have been able to increase the maximum writing speed on their Type S01 Remscope by a factor of about 20. The trace persistance time can also now be varied between one second and two minutes, and the trace intensity varied to allow the reproduction of half tones. The new tube is also much more difficult to damage by operating the oscilloscope incorrectly.

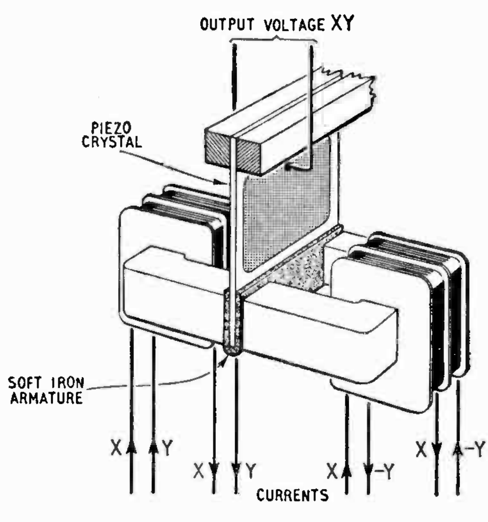
COMPUTERS

Piezoelectric Multiplier, a small and relatively simple device for analogue computing and other uses, was presented as an alternative to the Hall-effect multiplier by Imperial College on the N.R.D.C. stand. The device produces a voltage which is proportional to the product of two input currents, by using the currents to energize electromagnetic actuators which apply mechanical forces to the piezoelectric crystal. The currents, x and y, are applied to the coils of the actuator as shown in the diagram, so that the m.m.f. in one of the C-shaped cores is proportional to $x+y$ and the m.m.f. in the other core is proportional to $x-y$. The resulting forces applied to the crystal (a bender type) through the soft-iron armature are proportional to $(x+y)^2$ and $(x-y)^2$ respectively. Since these two forces are applied so as to oppose each other, the actual force on the armature and crystal is their difference, proportional to $(x+y)^2-(x-y)^2$. On the basis of the well-known relation $(x+y)^2-(x-y)^2=4xy$, this difference force produces an output voltage from the crystal proportional

(Continued on page 125)

to *xy*. A displacement of the armature of less than one micron gives an output of about 1 volt. The output for $x=y=5$mA is 250mA. Almost perfect linearity in terms of either x or y is claimed, while the response is said to be independent of input-current frequency between 15c/s and 500c/s. Extension of the frequency range up to 50kc/s is thought to be possible, giving up to 10^5 analogue multiplications per second with an accuracy of better than 0.5%.

Magnetic Thin-Film Stores for digital computers based on materials with rectangular hysteresis loops have been under development for some time (see *W.W.*, July/August issue, p. 312) because of the possibilities they offer of high switching speeds and high-density storage of binary digits. Most of the experimental stores have used arrays of separate spots of magnetic film, each capable of being switched from one direction of magnetization to the other; but the Royal Radar Establishment were showing that the basic principle could also be applied to a continuous film of material. Their store consisted of an evaporated film of nickel-iron, 1200 Ångstroms thick, surrounded by an array of one-turn driving coils. The film has a preferred direction of magnetization (obtained by applying a magnetic field during deposition) and binary digits are stored at individual positions by the driving coils causing local reversals of magnetization. These reversals take place by rotation of the direction of magnetization in the plane of the material like a compass needle. The fact that a selected area of film could be switched without affecting neighbouring areas was demonstrated by photographs in which domain walls had been made visible after local reversals of magnetization. Switching speeds are capable of dealing with pulses of 5mμsec duration, and a storage density of over 200 binary storage "cells" on a 3in × 3in film is possible. Additional coils at right angles to the drive coils are needed to provide "bias" fields so that the initial direction of magnetization is slightly displaced angularly from the preferred direction of the material. Currents applied to the drive coils can then rotate this "vector" to either of two directions, thereby making possible binary storage in each "cell" formed at the intersection of a drive conductor and a "bias" conductor. Mullard also showed work in this field, using separate spots of nickel-iron film and conductors formed by printed-circuit flexible layers.



Imperial College piezoelectric multiplier (shown on N.R.D.C. stand)

COMMUNICATIONS

Hall-effect Modulator working at 5Mc/s was a feature on the A.E.I. (Metrovick) stand. Care in the alignment of the leads to the crystal, and their arrangement, helped to reduce the carrier break-through in the double-sideband suppressed-carrier modulator but a correcting coil, carrying d.c. bias and wound on the ferrite-core, allowed a fine adjustment to compensate for errors in the positioning of the connections to the crystal, resulting in a final rejection ratio of 60dB. Associated with the modulator was a wide-band transformer to match the low impedance of the indium arsenide crystal, the whole covering 100kc/s to 20Mc/s at the −3dB points. The demonstration included a c.r.o. display of the modulated output: the bow-tie pattern typical of suppressed-carrier modulation displays was produced with the good linearity expected of a Hall device.

Fast-wave Electron-Beam Parametric Amplifiers.—Since in the wave of space-charge density modulation of an electron beam which travels faster than the beam itself, the fast-wave, the mean energy is greater than the d.c. energy of the beam, prospects are offered of absorbing the excess energy corresponding to noise density modulations in this wave. In the case of the more commonly used slow-wave, the mean energy is less than the d.c. energy of the beam, so that noise could only be eliminated by adding equal noise energy to the beam, and this in practice would be impossible.

A fast-wave amplifier in which a longitudinal magnetic field causes the electrons in the beam to spiral from the inuput to the output, and in which the spiral amplitude corresponds to the signal strength was shown by English Electric (Type N1036). This valve is similar to that described in "Technical Notebook" in our November 1958 issue (p. 555). It has the valuable property of amplifying in one direction only so that feedback from the output to the input with consequent instability is eliminated. In addition, the tube protects the following stages, since it acts as a limiter for excessively large inputs, the maximum power output being 50μW. A noise figure of 2dB at a signal frequency of 200Mc/s is quoted for this valve. Only a relatively small magnetic field of 70 gauss is required and the highest direct potential in the tube is also only 100V. Beam currents and voltages are also very low, typical figures being 30μA and 6V respectively. A 600Mc/s tube is in development.

The G.E.C. Research Laboratories demonstrated fast-wave amplification by passing a beam through two cavities into which the signal and pump frequencies were fed so as to modulate the beam, as in a klystron. A movable cavity tuned to the signal frequency was used to show the increase in the signal level along the beam.

Noise Reduction in Backward-wave Oscillators.—Due to residual gas ions, backward-wave oscillators normally exhibit peaks of noise at sideband frequencies of the order of 1Mc/s. This noise restricts their use as local oscillators to receivers with an inconveniently high intermediate frequency. However, an exhibit of the Mullard Research Laboratories showed that this sideband noise can be considerably reduced either by reducing the residual gas pressure below its normal value between 10^{-7} and 10^{-8}mm of mercury down to about 10^{-9}mm, or alternatively by draining off the gas ions by means of a trans-

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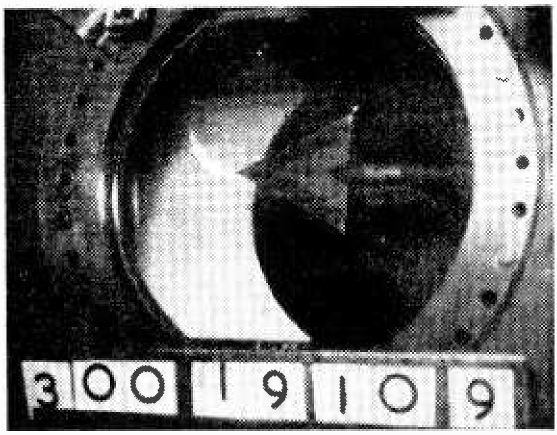

Untouched photograph of plume discharge from tip of earthed electrode in wind tunnel (R.A.E.).

Crown Copyright Photograph

verse electric field across the beam. This transverse field need only be of the order of 10V/cm.

Corona Discharge from radio aerials on aircraft at great heights is a serious problem because not only does it result in a power loss in the discharge, but also the discharge produces a serious mismatch at the aerial, further reducing radiated power and upsetting operation of the transmitter. A combined exhibit from R.A.E. and Sheffield University showed some of the approaches to the investigation of the problem. A $\lambda/4$ radiator on a ground plane was enclosed in an evacuated bell jar and an r.f. output applied. At first the discharge started, as would be expected, round the high-potential point at the tip of the radiator; but, above a certain power level, the discharge produced such a mismatch that it moved to the lower part of the aerial, so wasting more than half the transmitter power. One detection method used is to modulate the r.f. with square waves: mounted in the tip of the radiator is a small capacitance "microphone" whose resonant frequency corresponds to the modulating frequency. At the onset of corona the potential gradient changes sharply, altering the force on the diaphragm; this results in a change of output.

A display of photographs (taken at R.A.E.) of earthed electrodes in a wind tunnel revealed an interesting phenomenon. At high speeds (Mach 1.9), low pressures ($\frac{1}{10}$ atmospheric) and in the presence of water vapour, a plume of corona discharge takes place against the air stream from a sharp point on the leading edge of an earthed electrode. Although still under investigation it is thought that this is due to the gathering up of charges from the air.

COMPONENTS

Microwave Components.—It was surprising to find three new components produced by novel methods rather than merely by the usual adaptation of existing methods to new frequency bands. These new components were shown by Mullard for the $2\frac{1}{2}$ mm band.

The first of these components, a variable attenuator, is restricted to use at such high frequencies. It consists of an intrinsic region of semiconductor material placed across the guide between two heavily doped p- and n-regions outside the guide. By applying a forward voltage between the p- and n-regions, electrons and holes are injected into the intrinsic region where they absorb a fraction of any incident microwave power. For correct operation of this device, the intrinsic region cannot be made much wider than 10^{-2}cm, so that the new waveguide must be tapered even at $2\frac{1}{2}$ mm wavelengths.

Another of the new components shown by Mullard was a variable directional coupler in circular waveguide. A long strip, one end of which is fixed, is placed centrally in the guide. If the other end of the strip is rotated, incident radiation which is plane polarized at right angles to the initial plane of the strip has its plane of polarization gradually rotated as it passes by the strip. Depending on the angular rotation of strip end, a variable fraction of this incident radiation can then be coupled out via a probe parallel to the initial plane of the strip. Any reflected radiation, since it consists of the reflected portion of the incident radiation not coupled out by the probe, has its plane of polarization at right angles to the coupling probe and is thus not coupled to this probe. Attached to the movable end of the absorbing strip in the same plane as this end is a flat tapered absorbing vane. This absorbs the same fraction of the reflected radiation as is coupled out from the incident radiation. This vane is at right angles to the rotated plane of polarization of the incident radiation so that it does not absorb any of the incident radiation.

The third new component shown by Mullard was a variable impedance, also in circular waveguide. This consists of a flat tapered absorbing vane attached to a movable metal plunger filling the guide. The component of the incident radiation whose plane of polarization is parallel to the vane is totally absorbed by the vane, whereas the component at right angles to this vane is totally reflected by the plunger. Thus, by rotating the vane and moving the plunger along the guide, any required complex reflection coefficient can be obtained. A second fixed flat tapered absorbing vane perpendicular to the plane of the incident radiation absorbs any interfering reflected power polarized at right angles to the incident radiation.

A simple type of waveguide to coaxial directional coupler was shown by Decca. This consists of a piece of strip line inclined to the guide length near one narrow guide wall, the signal being coupled out from the strip at its end furthest from the incident radiation. The strip occupies a space of one quarter of a wavelength along the guide: its width and distance from the guide wall effect the match and coupling. This type of coupler can be made with a performance which compares favourably with that of a normal two-slot waveguide coupler.

A self-calibrating coaxial line wavemeter consisting of a movable short circuit which was shown by Flann illustrates how it is possible to obtain very wide bandwidths using coaxial line: in this case the bandwidth is from 800 to 9,000Mc/s. The distance moved by the short circuit between two adjacent resonance positions is half a line wavelength.

A slot-array aerial for X-band was shown by Elliott. This consisted of eight rows of eight slots in the single metal ground plate of a strip transmission line, the whole aerial being about seven inches square. The strip transmission line is divided up rather like a family tree to provide radiators opposite the slots. This type of aerial possesses a number of advan-

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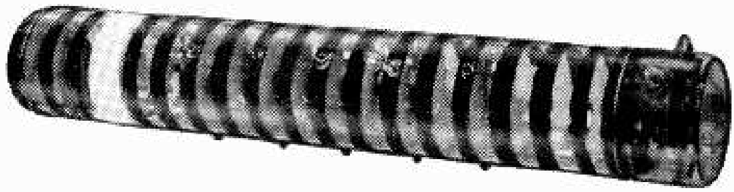
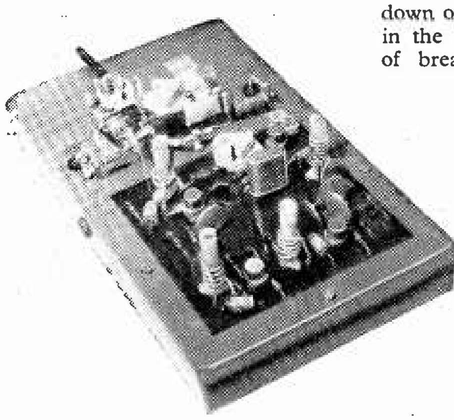


20th Century image-intensifier tube. Note ring accelerator electrodes on inside of glass envelope.

tages over the normal paraboloid, for it is smaller and lighter, and the feed does not obstruct the aerial radiation. Such slot aerials can be easily reproduced since the strip line and slotted ground plate can be printed on dielectric slabs of the correct thickness to provide the required line-to-plate spacing.

V.H.F. Transistors operating at over 100Mc/s are now beyond the development stage and are available as commercial products. As an example, Texas Instruments demonstrated a diffused-base germanium transistor of "mesa" construction operating at 200Mc/s in a 50mW power output stage of a transmitter. Another "mesa" transistor was shown operating in a decade counter of 10Mc/s p.r.f., while other similar types on view, both germanium and silicon, were intended for amplification in the 100-150Mc/s region. Mullard have a v.h.f. transistor made by the alloy diffusion process with a cut-off frequency of 100Mc/s, but they also showed an experimental type of similar construction which would amplify at this frequency. It was demonstrated in a series of 100Mc/s amplifiers, each using two transistors in push-pull giving an output of 0.5W. A silicon "mesa" transistor with a cut-off frequency of 80Mc/s (in the common base connection) represents the first essay of Ferranti's in the transistor field. It is an n-p-n type and the method of construction is shown in the diagram. A slice of the n-type silicon which subsequently forms the collector has a layer of p-type material diffused into it (providing the base), and then, by means of masking techniques, a small n-type layer (the emitter) is diffused into a part of the p-type base. The "mesa" or raised structure (named after a flat-topped steep-sided mountain) has the object of reducing collector capacitance, and is formed by etching away the surrounding silicon. Metallizing is applied to the base and emitter for contacts, while the collector connection is made through a large metal support on which the collector is mounted.

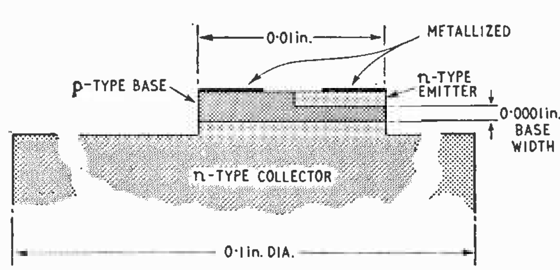
Transistor transmitter producing 50mW at 200Mc/s. Texas Instruments "mesa" transistor is used in output stage.



Current Regulating Semiconductor diode demonstrated by G.E.C. Research Laboratories is a counterpart of the well-known Zener diode voltage regulator. The principle of control is the constriction of the current carrier path through the semiconductor by two space-charge regions, rather as in the Tecnetron and other field-effect devices. A somewhat complex structure is used, in which the widening space-charge regions are produced by the voltage drop sustaining the current flow through the device. The two regions actually meet at a certain applied voltage, the "pinch-off" voltage. Thereafter the current is limited to a constant value with increasing voltage until a breakdown of the reverse-biased junctions in the device allow a sudden surge of breakdown current. A typical value for the "pinch-off" voltage is 5V, and the current after this is limited to 5mA until the breakdown occurs at 100V. A voltage regulating circuit giving 6 volts output was demonstrated in which the new device formed a series element while a Zener diode provided a shunt element. Variations of 50% in supply voltage produced output variations of only ±0.005%.

Image Intensifiers normally work by the acceleration of photo-electrons from a photo-emissive layer and by the concentration of the image into a smaller area. A new intensifier tube shown by 20th Century Electronics accelerates the electrons from the photocathode in the normal way, but provides additional gain by using five electron multiplier stages of the transmission type. In these the electrons pass through a thin layer of alkali halide on an alumina support, and after multiplication are accelerated by ring electrodes (metallized on the inside of the glass envelope) to the next stage. There is a total electron gain of 2,000 in the multiplication system, while the overall light gain from photocathode to fluorescent screen (15kV potential) is of the order of 50,000. The image remains the same size throughout, and the electron rays are kept parallel by enclosing the tube in a magnetic focusing solenoid.

Last year Siemens Edison Swan showed an image intensifier for electron microscope work which used a photoconductive pick-up tube to give television-type pictures (March, 1959, issue, p. 133). This year A.E.I. (as they now are) were demonstrating a modified version for light amplification. Electrons from the photocathode are imaged by an electrostatic lens system on to the front of the selenium photoconductive layer of the pick-up tube. The resultant charge pattern at the rear of the layer is then scanned in television fashion by a low-velocity electron beam. Sensitivity is such that about 5 incident photons on the photocathode



Cross-section of Ferranti h.f. transistor, showing "mesa," or plateau, form of construction.

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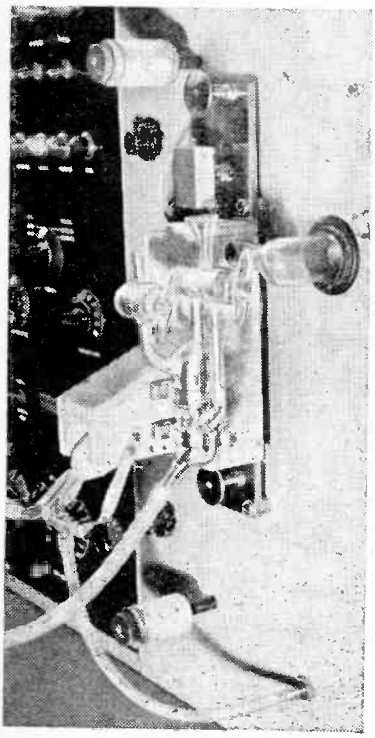
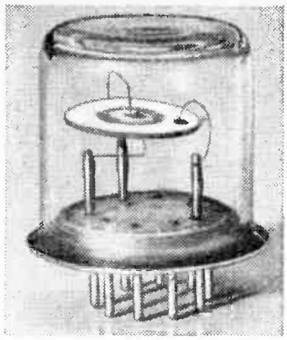
will give a visible spot on the display monitor.

Storage Tubes, which hold information as patterns of electrostatic charges, were shown in both the display and non-display types by various firms. A new non-display tube by Mullard uses a single electron gun for both "writing" and "reading" on to the magnesium fluoride storage surface and is notable for its small dimensions of about 1½in diameter and 7in long. It has a resolution of 600 lines and operates with an anode voltage of about 300V. The Vidicon type of television pick-up tube is often criticized because of the storage properties of its photo-conductive light-sensitive layer, but E.M.I. were showing a version in which this effect had been deliberately enhanced for the purpose of holding images. Storage time was in the region of 1-3 minutes, depending on image brightness.

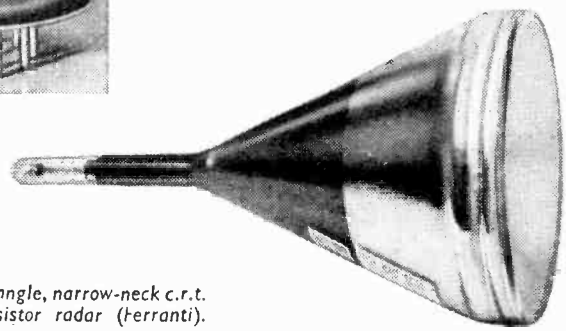
7-in Radar C.R. Tube developed primarily for transistor equipments was shown on the Ferranti stand. It has a narrow deflection angle of about 30° and a narrow diameter



Machine by G. V. Planer, Ltd., for the application of resistive oxide films to glass fibre. Whole machine is complete in one cabinet, including instrumentation and control apparatus.



Above: Plessey experimental ceramic i.f. filter element showing ring and dot connections.



Narrow-angle, narrow-neck c.r.t. for transistor radar (Ferranti).

neck (23mm), both of which facilitate scanning by low-power transistor circuits. This firm was also showing a new 6-inch c.r.t. of high sensitivity and brightness specially designed for displaying characters for xerographic printing (as used for computer output data). The well-known 1CP1 c.r.t. with the 1-inch screen was shown by Electronic Tubes in a new version which requires an anode voltage of only 350V, thereby allowing it to be operated from normal h.t. supplies.

Digital Display Tube working on a new principle was shown in experimental form by G.E.C. Research Laboratories. It is basically a small c.r. tube and the numerals are formed as the shadows of shaped wire electrodes in the path of an "unfocused" electron beam which floods the whole area of the 1½-inch fluorescent screen. Ten such electrodes, shaped respectively 0-9, are provided and each one is selected for display by applying to it a negative voltage of about 60V. This repels the electrons in the beam close to the wire and so forms the shadow of the selected numeral on the screen. The shadows are very clearly defined and the only limitation appears to be in the precision and artistry with which the wire numerals can be shaped. An anode voltage of 600V is required.

Ceramic I.F. Transformers were shown by Plessey in the form of small circular discs of lead titanate zirconate. This material exhibits piezoelectric properties and, when a circular disc is excited in the radial mode the performance resembles that required of an i.f. transformer for transistor applications. The disc (about the size of a sixpence) is metallized to provide contacts—one side completely and the other with a ring and dot—and the input, at an impedance of about 5kΩ, is applied between the dot and backing. The element works on the first overtone of 160kc/s (its fundamental resonance) which is 455kc/s and the output, at an impedance of about 1kΩ, appears between the ring and backing. The characteristics of the radial-mode resonances are such that, by pairing a fundamental-frequency resonator with one operating on its first overtone, the overtones do not coincide. Consequently out-of-band responses are not troublesome; also the selectivity curve is improved.

Oxide-film Resistance Elements are used in new components by G. V. Planer Ltd. The component is a tilt-sensing device giving a continuous response. It consists of two shaped stannic-oxide films coated onto the inside of a sealed glass tube in which a drop of mercury runs, joining the two "stripes". To avoid contamination of the mercury by metallic contacts the oxide films are brought out through the glass of the seal to contacts outside.

The continuous coating of oxides on to 10^{-3}-in diameter glass fibre, which can subsequently be wound on a bobbin to produce a resistor, is performed by a machine developed by Planer. This comprises precision winding gear for passing the fibre through the coating furnace and an automatic speed control system to ensure the deposition of correct film thickness. After leaving the lower bobbin the fibre is first sprayed with the mixture of salts. It then passes through a furnace to fire and oxidize the film, and on leaving for the take-up spool it passes through two mercury cups, the resistance between which governs the drive speed. Values as high as 2MΩ per linear inch of fibre are achieved.

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Signal-Flow Diagrams

2.—Application to the Schmitt Trigger Circuit Using Valves

By *THOMAS RODDAM*

LAST month I discussed the general principles of signal-flow diagrams, the maps which frequently show useful short-cuts to the solution of complicated circuits. The rules for drawing maps and for simplifying them were described and a not particularly illuminating example was used to illustrate the application of the method. It was not particularly illuminating because it was too simple: you don't draw a map when you want to say " Turn left at the end of the road and it's there on your left." This month we can consider something more ambitious which really gives the method a chance. I had thought of tackling the transistor Schmitt trigger, but I have decided to take the valve version which is used as an example by J. G. Truxal in " Automatic Feedback Control System Synthesis " (McGraw-Hill, 1955). My reason is that he goes on to discuss a whole lot of other developments, such as impedance determination and return difference evaluation, and although I do not propose to discuss these topics, this article will break the ground for any of you who want to go further by consulting this book.

The circuit is shown in Fig. 1. It is a two-stage d.c. amplifier with positive feedback produced by the common-cathode resistor. To avoid using primes in the analysis we shall assume that

$$1/R_1' + 1/R = 1/R_1$$

so that R_1 is the effective anode load of the first stage. In a practical case R is usually so much bigger than R_1 that within the usual tolerances we can take the anode resistor as the total load.

We are treating this circuit in its a.c. application as a limiter, not in its on-off large-signal application. The usual problem then is to find the conditions for just snapping over. Signal-flow diagrams are concerned with linear differential equations, so we must assume that the circuit is somehow poised at mid-travel, either because it has not enough feedback to make it unstable, or because we have caught it in mid-travel. All our terms are small signals, not the fixed biases and standing currents.

The starting point for the map is e_{in} and I have begun Fig. 2 by putting in the first move, e_{in}. The first equation which springs to mind is the obvious one:

$$e_{in} = e_{g1} + e_k$$

Like this the equation would have two branches, from two new nodes, leading to the input node e_{in}. This is not considered good practice, so we rewrite the equation as

$$e_{g1} = e_{in} - e_k \quad \ldots \quad \ldots \quad (1)$$

mark in the nodes e_{g1} and e_k and draw the two unit arrows shown in Fig. 2(a). At this point Truxal decides to put e_k down below the main horizontal line. One application of the circuit is as a phase-splitter, the long-tailed pair, with the anode-grid coupling as an extra something—positive feed-forward one might call it—to push up the gain. This interpretation makes us think of the second stage as fundamentally grounded-grid, with e_k as the drive, and so I shall keep e_k on the line.

The anode current of the first valve is given in the usual way by

$$i_1 = (\mu_1 e_{g1} - e_k)/(\rho + R_1)$$

$$= \left(\frac{\mu_1}{\rho + R_1}\right)e_{g1} - \left(\frac{1}{\rho + R_1}\right)e_k \quad \ldots \quad (2)$$

This adds a new node i_1 and two new branches leading to it from e_{g1} and e_k. These are shown in Fig. 2(b), where the new branches are the heavy lines: in each following figure the latest additions will be identified in this way.

The drive to the second valve, in my view, comes from e_k, which is the drop across the cathode resistor due to both anode currents. Thus

$$e_k = i_1 R_k + i_2 R_k \quad \ldots \quad \ldots \quad (3)$$

We need to mark in the new node i_2 and then we can add the local map representing this equation to give us Fig. 2(c).

Before we can write an equation for i_2 we need to know something about the feed-forward path. Clearly

$$e_{a1} = -R_1 i_1 \quad \ldots \quad \ldots \quad (4)$$

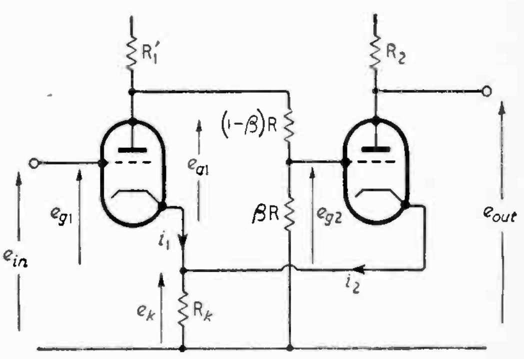
and this equation is shown by the new heavy branch in Fig. 2(d).

We now need to find out what happens in the second valve. The grid to cathode signal is quite clearly given by

$$e_{g2} = \beta e_{a1} - e_k \quad \ldots \quad \ldots \quad (5)$$

and we can establish the new point e_{g2} in Fig. 2(e) by this equation.

Fig. 1. Schmitt Trigger Circuit.



ordinary valve equation for the second valve

$$i_2 = (\mu_2 e_{g2} - e_k)/(\rho + R_2)$$
$$= \left(\frac{\mu_2}{\rho + R_2}\right) e_{g2} - \left(\frac{1}{\rho + R_2}\right) \cdot e_k \quad .. \quad (6)$$

This equation makes its appearance in the next figure, Fig. 2(f).

Now all we need is to know e_{out}, which is given by

$$e_{out} = -i_2 R_2 \quad .. \quad .. \quad (7)$$

and leads us to Fig. 2(g).

Quite obviously the signal-flow diagram of Fig. 2(g) is a complicated affair, but the original circuit, as anyone who has ever carried out the solution by algebra knows, is by no means as simple as one might expect from five resistors and two valves. In the form of Fig. 2(g) the diagram is not of much use to anyone, so we must settle down to the task of simplifying it.

We take a new sheet of paper and begin Fig. 3(a). A first step is to notice that we do not really care about the point e_{a1} and we can go straight from i_1 to e_{g2} by a branch $- R_1\beta$. Sheer laziness makes me leave out the diagram with this reduction in it, because I can also see that the signal which flows from e_k through e_{g2} to i_2 can be written as a contribution directly from e_k to i_2 of size $- 1 \times \mu_2/(\rho + R_2)$ and then I can get e_{g2} out of the picture as well. These steps are all combined to give Fig. 3(b).

The two parallel branches in the same direction from e_k to i_2 can be added together, but before we do this in Fig. 3(c) let us notice also that we have another easily seen step in the reduction. There is a flow of signal from e_k to i_1 by way of e_{g1} which we can replace by a direct path. This direct path, which will have transmittance $- 1 \times \mu_1/(\rho + R_1)$ is in parallel with the existing direct path $-1/(\rho + R_1)$ and these two can be combined together. The result of these various operations is shown in Fig. 3(c).

To make the figure look a little neater it is re-arranged in Fig. 3(d) and the point e_{g1} is dropped altogether.

The next stages in the reduction require a certain amount of care to avoid throwing the baby out with

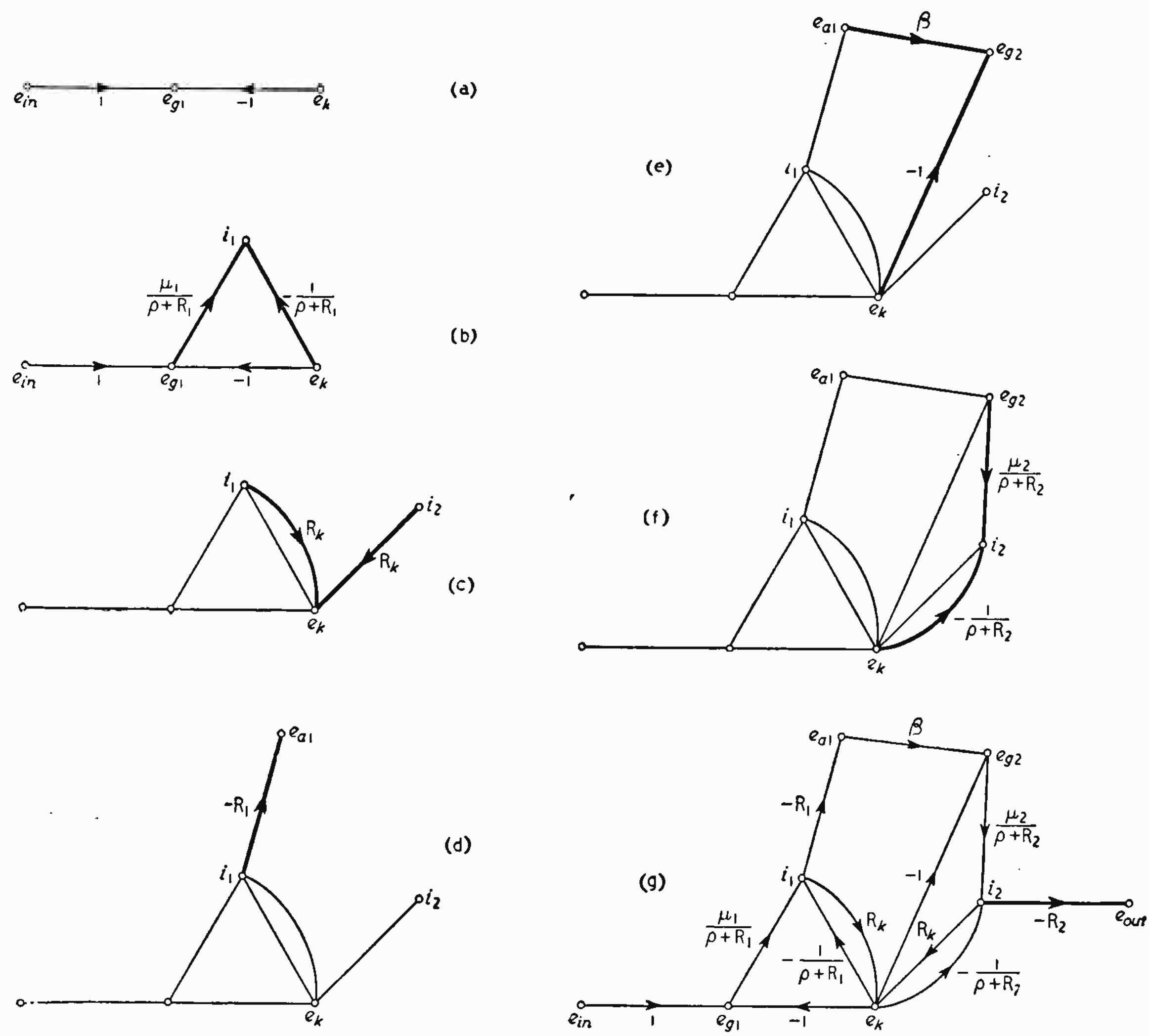


Fig. 2. Signal-flow diagram for the circuit of Fig. 1 obtained step by step. Heavy lines indicate the additions corresponding to successive equations.

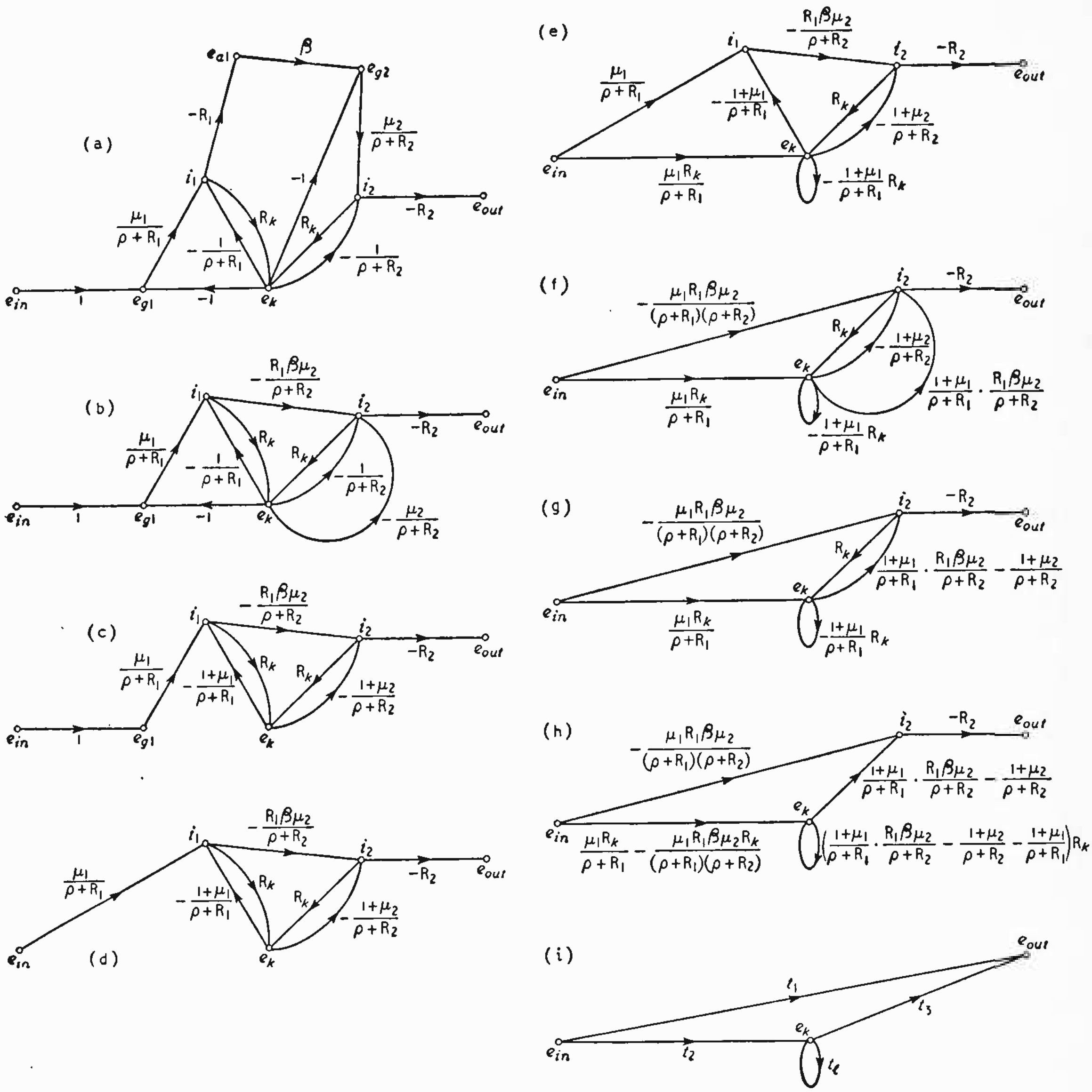


Fig. 3. Stages in the reduction of the signal-flow diagram for the circuit of Fig. 1.

the bath-water. Let us focus our attention on the flow of signal from e_{in} to e_k. There is a contribution through i_1 which is clearly of total transmittance $[\mu_1/(\rho + R_1)] \times R_k$. We can therefore construct a direct branch from e_{in} to e_k and cross out the i_1 to e_k branch of transmittance R_k. When we do this, however, we are breaking the loop e_k to i_1 to e_k, of transmittance $[-(1 + \mu_1)/(\rho + R_1)] \times R_k$, and we must put in the corresponding self-loop. But the signal from e_k to i_1 also contributes to the path i_1 to i_2, and it is not legitimate to drop the e_k to i_1 branch. The reduction therefore gives us Fig. 3(e).

Now we consider the contribution made by e_k to i_2 by the route e_k to i_1 to i_2. The transmittance is $[(1 + \mu_1)/(\rho + R_1)] \times [R_1\beta\mu_2/(\rho + R_2)]$, with two minus signs disappearing together. We can make this a direct contribution, when we no longer need the point i_1. This leads us to Fig. 3(f) and, immediately, to Fig. 3(g).

Again we consider the flow of signal from e_{in} to e_k and we see there is a path via i_2 with a transmittance

$$\frac{-\mu_1 R_1 \beta \mu_2}{(\rho + R_1)(\rho + R_2)} \times R_k$$

and that this will introduce another self-loop at e_k of transmittance

$$\left(\frac{1 + \mu_1}{\rho + R_1} \cdot \frac{R_1\beta\ \mu_2}{\rho + R_2} - \frac{1 + \mu_2}{\rho + R_2}\right) \times R_k$$

Fig. 3(h) shows the effect of this change on the diagram.

In the final diagram, Fig. 3(i), the point i_2 has been eliminated in the obvious way, to leave us with what is called an essential diagram of order one. Once you get the trick of it the steps described above can be carried out very quickly. In the same way you can go on to reduce the essential diagram to a single

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branch joining input to output and having a transmittance

$$t_1 + t_2 t_3/(1-t_1)$$

Each of these t's is an expression as long as your arm, which is why I have not written them out in full. For specific problems you may not want to do this anyway. As an example, the determination of the conditions in which the circuit will just turn over, implying infinite gain, are seen to be that the term t_1 should be unity. We know, in any practical case, the values of μ_1, μ_2, ρ, R_1, R_2. We may wish to make β unity and find R_k, or to fix R_k and find β. But the expression for t_1 is greatly simplified by putting in numbers. In fact, as you will see if you consult Truxal (loc. cit.) you can carry numbers all the way through to considerable advantage.

The only way in which you can get the full benefit of this method of handling circuits is by practice. Once you get the swing of it you will find that it really does help enormously to be able to concentrate on one limited aspect of your circuit equations and to ease that bit a step or two towards the final solution. This discussion is only an introduction to the method, which can be extended to the determination of input and output impedances, to the effects of reactances, and to the whole field of linear circuit problems. For complex problems it seems to be an extremely useful method for those who want to keep their eye on what is happening as they solve their equations.

BOOKS RECEIVED

Stereo Handbook, by G. A. Briggs. Wide survey of fact and opinion on the methods and results of stereophonic sound reproduction. Takes the form of an inquiry in which awkward questions were posed to a number of experts and from which some sound sense has been distilled by the author. Topics considered include pickups, record wear, loudspeakers, room acoustics and broadcasting. Pp. 146; Figs. 88. Price 10s 6d. Wharfedale Wireless Works, Ltd., Idle, Bradford.

Stereo Record Guide, by Edward Greenfield, Ivan March and Denis Stevens. Collection of critical assessments of existing stereo gramophone records, as regards both musical content and recording quality. Arranged under composers' names and with entries up to the end of 1959. (Supplements are to be issued.) Pp. 320. Price 21s. The Long Playing Record Library, Ltd., Squires Gate Station Approach, Blackpool, Lancs.

Stereo and Hi-Fi as a Pastime, by Douglas Gardner. Layman's introduction to the technicalities of disc, tape and broadcast sound reproduction. Pp. 147; Figs. 15, and illustrations of typical commercial installations. Price 15s. Souvenir Press, Ltd., 94, Charlotte Street, London, W.1.

Mullard Circuits for Audio Amplifiers. Designs for power amplifiers and pre-amplifiers for mono and stereo sound reproduction from microphone, tape, gramophone disc and radio signals. Includes dimensions of suggested chassis and general notes on construction and assembly. Pp. 136; Figs. 160. Price 8s 6d. Mullard, Ltd., Mullard House, Torrington Place, London, W.C.1.

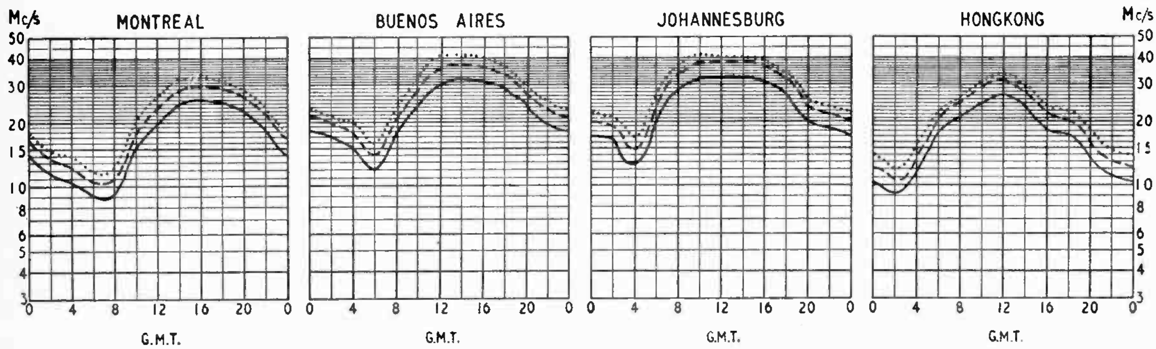
The Practical Hi-Fi Handbook, by Gordon J. King, Assoc. Brit.I.R.E. Introduction to high-quality sound reproducing equipment written with the needs of the service technician in mind. Pp. 224; Figs. 158. Price 25s. Odhams Press, Ltd., Long Acre, London, W.C.2.

The Conversion of Ionospheric Virtual Height/Frequency Curves to Electron Density/Height Profiles, by J. O. Thomas, M.A., Ph.D. (Cavendish Laboratory, Cambridge) and M. D. Vickers, B.Sc. (D.S.I.R., Radio Research Station, Slough). D.S.I.R. Special Report No. 28 on a digital computer programme and the basis of its formulation, with appendices including an extensive bibliography. Pp. 48; Figs. 10. Price 3s 6d. H.M. Stationery Office, Kingsway, London, W.C.2.

From Microphone to Ear, by G. Slot. Second edition of a Philips Technical Library review of modern sound recording and reproducing techniques, now including a long chapter on stereophony. Pp. 268; Figs. 110. Price 21s. Cleaver-Hume Press, Ltd., 31, Wright's Lane, London, W.8.

SHORT-WAVE CONDITIONS

Prediction for March



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 March.

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

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

— — — PREDICTED MEDIAN STANDARD MAXIMUM USABLE FREQUENCY

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

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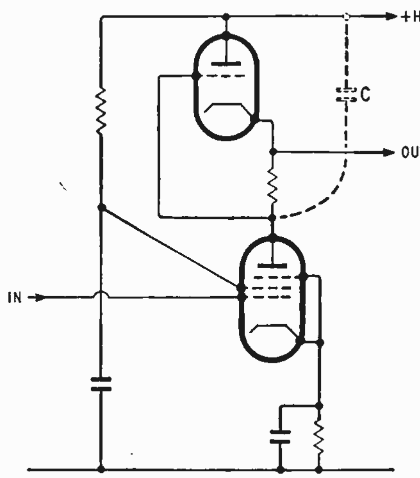
LETTERS TO THE EDITOR

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

"Economical High Gain A.F. Amplification"

MUCH as I admire the ingenuity of your contributor Arthur R. Bailey in devising the circuit described in the article in the January issue, I must point out that he has omitted mention of the most important features of this circuit. In respect of gain, hum and noise level, and low output impedance, two R-C coupled pentodes with voltage negative feedback can compare favourably with this circuit. In my opinion the principal advantages of the circuit described are that it lends itself readily to direct coupling, and that this circuit has effectively only one stray capacitance.

At the low anode current mentioned by the author (0·1mA) the cathode bias resistor for the triode can be of the same order as the anode load of the pentode,



(G.J. TILY)

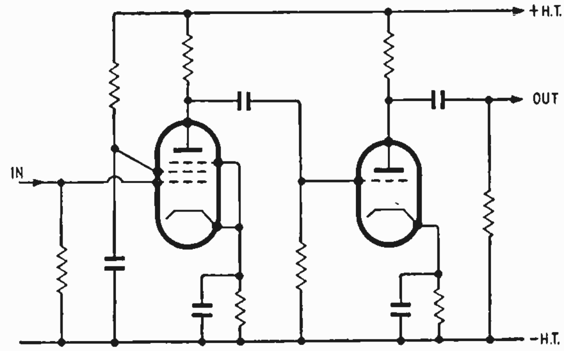
and one resistor can be used for both functions as in the accompanying diagram. A possible use for this arrangement is deflection amplification for a cathode ray tube.

The single stray capacitance can be an important factor if this circuit is used as the amplifying stage in a feedback amplifier, as it restricts the phase shift to 90°, which ensures stability in such circuits.

Hounslow, Middlesex. G. J. TILY.

FEW readers will fail to sympathise with Mr. Bailey's aim "to obtain the maximum amplification from the minimum number of components" (January issue, p. 25). But it is to be doubted whether his circuit represents a marked advance in this direction. Seven resistors and four capacitors are employed in the basic circuit (Fig. 2 of the article) and the gain of a practical version is given as 3500. If we take as a figure of merit the gain divided by the number of components, we get 3500/11 = 318. The completely conventional circuit shown here in diagram (A) uses 13 components, and taking Mr. Bailey's own figures for the gain of the pentode without any fancy business (200) and the gain of the triode (40), it provides, by cascading a gain of 8000. So its figure of merit is 8000/13 = 615, which is nearly twice as good as that of the unconventional circuit. If valves, valveholders and decoupling components are counted, the conventional circuit shows up rather better.

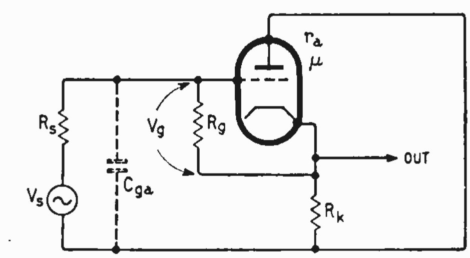
Moreover, some of Mr. Bailey's statements do not



(G.W. SHORT (A))

bear examination. He rightly gives the effective first-stage output resistance for a response 3dB down at 10kc/s, with 5pF strays, as $10/\pi$ MΩ, and this value is indeed attained with an 8-MΩ anode load in parallel with a 5-MΩ anode impedance. But taking the capacitance as 10pF (which is a reasonable figure allowing for wiring strays), the required effective output resistance becomes $10/2\pi$ MΩ, or 1.59 MΩ. To obtain the required value of 1.59 MΩ, the anode load resistance must be reduced to 2.3 MΩ in contrast with Mr. Bailey's value of 4MΩ. The gain is then reduced to about three-quarters of the original amount.

Mr. Bailey refers to the output stage as a cathode-follower, but this is not correct. Disregarding supply voltages and biasing arrangements, the circuit reduces to diagram (B), where V_s, R_s represent the signal source, R_g is the physical grid-cathode resistance, and R_k is the load resistance. If the effect of C_{ga} is ignored, and if



(G.W. SHORT (B))

R_g approaches infinity, then R_s can be removed without materially affecting the output impedance, which is then R_k in parallel with r_a. In other words, it is the same as that of a normal triode amplifier stage with an anode load equal to R_k. The circuit is then a "bootstrap" amplifier. To make it into a cathode-follower R_s must be small, but this is not so in Mr. Bailey's circuit, where it is 5MΩ, the anode resistance of the preceding pentode stage. The output impedance is actually $r_a (R_s + R_g)/[r_a + R_s + R_g (1 + \mu)]$, in parallel with R_k, which comes to roughly $\frac{r_a}{2}$ in the practical circuit.

In so far as the circuit behaves as a bootstrap amplifier, the effective size of C_{ga} is increased as a result of Miller effect. The voltage acting upon C_{ga} is $V_g + V_{out}$, which is $V_g(1 + A)$ as in a normal triode stage.

Finally, it is perhaps worth remembering that, with a.f. amplifiers as with h.f. amplifiers, the product of

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gain and bandwidth obtainable with a given valve is a constant. If a gain of 3500 and a bandwidth of 10kc/s are to be attained, then the gain-bandwidth product must be 35Mc/s. While good h.f. pentodes may be expected to have gain-bandwidth products running into hundreds of Mc/s, it must be remembered that in h.f. amplifiers the full rated mutual conductance can be achieved, whereas in an audio stage, operating with low current into a resistance load, the actual g_m is only a small fraction of the normal value, and the gain-bandwidth product is correspondingly reduced.

Croydon. G. W. SHORT.

A. R. BAILEY'S article on high-gain a.f. amplification reminded me of some experiments I carried out on the Jeffery circuit. The final modification to the Jeffery circuit (*Wireless World*, Aug., 1947, p. 274) used direct coupling (inspired by D. T. N. Williamson's phase splitter) of the pentode anode to the triode grid, so saving three resistors and three capacitors. The pentode was biased back so that it drew only a small anode current, and this current, flowing through the triode grid leak (50 to 100kΩ), provided the correct grid bias for the triode. However, this was in the days of Government-surplus EF36 and 6J5 valves, and the circuit was never applied successfully because it suffered from a high hum level and excessive h.f. losses. To reduce the hum to a tolerable level much negative feedback was necessary; but the application of this was precluded by the combined phase-shifts of the phase splitter and the particular amplifier used. Also the heater-cathode insulation of the triode was too highly stressed (at under half h.t.) unless a separate supply was used; this offsets the saving of a valve. As most of these disadvantages can be overcome with modern valves and techniques this circuit might bear re-examination.

But what happens if we apply these ideas to Bailey's circuit? A saving of two resistors and one capacitor is made, and the result looks very much like a straightforward bootstrap. Another point to be considered is heater-to-cathode potential limits for the triode: just under h.t. potential is applied. The writer's (sad) experiences indicate that it is unwise to exceed 100V or so for long-term reliability. In fact, the only superiority of Bailey's circuit may lie in the tape pre-amplifier, where the very high impedances make it easy to obtain a low l.f. boost roll-off point.

Surbiton, Surrey. E. MANSFIELD.

"Subjective Colour Tests"

IN your article on this subject in the January issue it was reported that a Land-colour rendering of the scene was obtained when the two photographs were viewed by displaying one to each eye with the appropriate filter in the light path to one eye. I find it difficult to understand this statement as I have found a very different effect. If the two photographs are viewed in a stereoscope with a red filter over the appropriate eyepiece, there is almost a complete absence of the colours seen during projection in the normal manner. When the two transparencies are projected through Polaroid filters and viewed through Polaroids, so arranged that each eye sees one of the images, there is a very marked decrease in coloration, although more colour may be seen than when using a stereoscope. This may be due to imperfections of the projection system and screen which results in incomplete channel separation, for it can be shown that even a small difference in the wavelength-intensity distributions of the two lights used for projecting the transparencies can give rise to Land colours. Thus, when using a 300 watt and a 1000 watt projector, without any filters, Land colours may be observed owing to differences in the colour temperatures of the two light sources.

When photographs of a test chart containing 24 areas of different colours against a neutral background are viewed in a stereoscope with a red filter over the appropriate eyepiece, most subjects report absence of colour other than reds, whites and pinks. Some subjects, however (including myself), observe that one of the test areas has a bluish-red or purple appearance. This area is seen as green in the original display and is reported as blue-green when viewed in the conventional Land manner. With continued viewing in the stereoscope, retinal rivalry is observed. In this case there is a slow oscillation between seeing mainly what is fed to the left eye or mainly what is fed to the right eye.

Thus it appears likely, to me, that the Land colours are due mainly to processes in the retina and not in the brain as suggested in your article. The effects due to retinal rivalry are, on the other hand, due to activity in the brain, as they can be controlled by attending to one eye or the other. This effect is similar to that encountered when using a microscope when it is possible to keep both eyes open without interference from the eye which is not looking through the microscope.

Whilst not wishing to over-emphasize the importance of Land's work in relation to colour television, it should be pointed out that all colours are, in a sense, subjective. The objective stimulus is light of a certain wavelength-intensity distribution. It may be seen differently in terms of colour by different observers and the colours may appear different to the two eyes of the same observer if he is colour defective in one eye. In colour television it is unlikely that the amount of light leaving the screen will ever approximate to the amount of light being reflected from the objects which are being recorded by the television camera. In order to make the picture appear like the display, changes are necessary in the tricolour specifications of individual areas to allow for the increases in saturation, and possibly changes in colour, due to the decreased level of illumination of the screen. The Land process tends to desaturate colours (whilst the trichromatic system tends to oversaturate them), and to some extent this is a desirable characteristic. As the display which is televised has other attributes than that of colour which are at present relatively imperfectly reproduced, it may well be that, with a fixed available bandwidth, a two-channel system would give a satisfactory compromise between definition, clarity of movement, and colour.

C. E. M. HANSEL,
Department of Psychology,
Manchester, 13. University of Manchester.

Early Public Address

IT may interest Mr. Haydon G. Warren (Dec. 1959 issue) to know that in 1919 or 1920 when I was with the Western Electric Company at North Woolwich we received from America a p.a. equipment of no mean performance. Associated with the rather enormous amplifier was a stretched diaphragm carbon microphone. A battery of balanced-armature loudspeakers with corrugated Bakelized linen diaphragms provided a considerable volume of good quality speech. I toted this lot about the country and had a lot of fun with it, for it was new and exciting. I even took it to sea for trials of gun control but, alas, the first round blasted the diaphragms beyond repair. On the mess-decks the matelots had other means of damping the output!

On another occasion I remember we stopped the traffic in Birmingham while doing tests prior to a visit by the then Prince of Wales, later Edward VIII.

Those were the days!

Walmer, Kent. S. G. KNIGHT.

Editors and Editing

I TAKE it that Mr. Waldron, whose letters you published in the January and February issues, will not be contributing to the Indian radio journal whose editor frankly warns intending authors of his right "to suppress, revise, alter or mend each or any para of the article"!

London, S.E.22. J. P. HAWKER.

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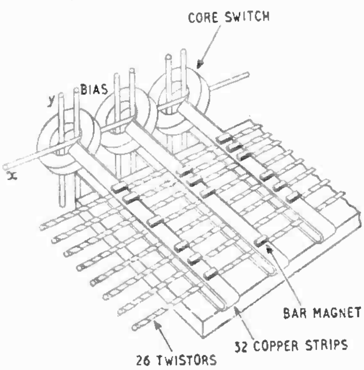
Technical Notebook

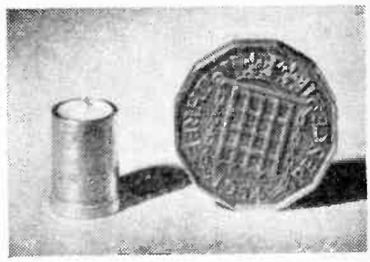
Television Aerial Design is a field in which many specialized problems have to be solved—for instance, the making of an aerial which responds efficiently to one channel in Band I and one in Band III. One of the earliest methods of doing this was by the addition to the Band-I dipole of $\lambda/4$ (at the Band-III frequency) rods, or "twigs" as they became known, in such a way that, when excited by the Band-III signal, they acted as "metallic insulators" or short-circuited $\lambda/4$ stubs. These reflect a high impedance at the ends of part of the dipole, so forming a $\lambda/2$ or $3\lambda/2$ Band-III radiator. J. D. Burke has discovered that the function of the "twigs" may be carried out by ferrite beads or sleeves round the dipole elements (Prov. Pat. Spec. 17109/59) in much the same way that small ferrite beads are used for decoupling in place of wound r.f. chokes in valve heater circuits, etc. The sleeves may be placed either $\lambda/4$ or $3\lambda/4$ from the feeder connections to the dipole and they appear to act in much the same manner as the "twigs" in that Band-I performance is not materially altered. Burke points out that a similar technique may be useful for "tuning" the metal legs of a television receiver, so that they can act as a resonant aerial.

Magnetic "Punched Cards", or permanent information stores, from which programme data can be electrically fed into computers much faster than from conventional punched cards, have been developed by Bell Telephone Laboratories in the U.S.A. and prepared for mass-production by the associated Western Electric Company. Whereas a punched card stores information by the positions of the punched holes, the new medium stores it by the positions of tiny "bar magnets" etched from a continuous magnetic film on a plastic card. The new units are not read by being fed through a machine but are kept stationary in close proximity to wire-grid sensing planes, and a complete store consists of a whole stack of alternate magnet-cards and sensing grids. In each sensing grid the wires running in one direction are "Twistors" (see January, 1958, issue, p. 32), while those in the other direction are ordinary conductors. The Twistors have a spiral wrapping of magnetic tape round a copper wire, providing a helical magnetic path, and are embedded in a strip of Mylar film. The other co-ordinate of the grid is made up of strips of copper foil 0.060in wide, also embedded in a Mylar film. This film is folded over the Twistor strip so that one complete loop is formed, each loop of copper strip providing a single-turn coil at right-angles to the Twistors. For access to the store, each copper-strip coil, or "word coil", is connected to a biased square-loop ferrite-core switch. This provides a means of selecting a particular "word coil" out of a matrix of such coils. Reading out from the store is accomplished by pulsing the copper-strip "word coils" by means of the ferrite cores, and the action of the "bar magnets" is to magnetically inhibit the effect of this pulsing on the Twistors. If there is no magnet at a given intersection of "word coil" and Twistor, a pulse is generated in the Twistor and is read out. If a magnet is present, its field prevents the production of the Twistor pulse, and no signal is read out. The pulse from the Twistor is about 6mV and 1μsec in duration. Speed of reading has not been stated precisely but is presumably of the order of 10^{6} binary digits per second. The magnet cards can be changed easily when a new programme is required.



Irasers, Lasers and Rasers are similar to masers except that they operate at infra-red, light and radio frequencies respectively, rather than at microwave frequencies as does the maser. Since the first letter of the word maser stands for its operating frequency, this letter has been changed in the names of these three varieties of maser to correspond to their different operating frequencies. According to *Electronic News* for June 22, 1959 (p. 5) the operation of irasers will depend on transitions between electron spin quantum energy levels in the same way as masers. Rasers, on the other hand, because of their lower operating frequency, must use smaller energy differences than those which can be obtained between electron spin levels. These required smaller energy differences can be obtained between nuclear spin quantum levels. It is proposed to induce transitions between suitable nuclear spin quantum levels by means of electron spin transitions.

Variable Capacitance Diodes are used in parametric amplifiers for operation in the u.h.f. and s.h.f. region because they have the necessary speed of response for variable-reactance elements at these frequencies. A diode with the required properties has now been put on the market in Britain by G.E.C.



Suitable for use in radar and communications systems, it will operate at frequencies up to about 4 Gc/s. It is mounted in a coaxial structure for direct insertion into coaxial and waveguide circuits, and has the very low series inductance of 0.5mμH. Because of its very low forward impedance and very high reverse impedance, the device can be used as a microwave switch. Another application is as a frequency multiplier—an important aid to the design of microwave receivers based entirely on solid state devices.

Figure of Merit for audio output valves suggested by R. M. Mitchell in *Audio* for November, 1959 (p. 40), is power output × damping factor × efficiency × maximum possible grid circuit resistance ÷ (input voltage × harmonic distortion × price), the harmonic distortion and input voltage being taken at the stated power output. A high maximum possible grid resistor and low input voltage are desirable so as to make the valve easier to drive. The effect of feedback and qualifications to this figure of merit (such as weighting individual items) required for particular types of circuit are discussed in the article.

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Elements of Electronic Circuits

11.—TRIGGERED TWO-STATE CIRCUITS

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

A COMMONLY used two-state circuit which requires only one valve is the transitron, shown in Fig. 1. It consists of a pentode with suppressor and screen grids linked by a capacitor, and it behaves as a single-stage amplifier with feedback from screen to suppressor. It possesses only one stable state followed by one unstable one; does not freely run (as in the case of the multivibrator); and requires a trigger or initiating signal to maintain the action. The action will be described with reference to Fig. 2 and will be divided into three main intervals.

Interval 1:

(a) Initially the circuit is in a stable state with I_a and I_{g2} flowing. $V_{g3} = 0$ and C is charged.

(b) A positive-going sync voltage applied to V_{g1} causes I_a and I_{g2} to rise. V_{g2} and V_a therefore fall. As g_3 is connected to g_2 by C the instantaneous potential change is conveyed directly to g_3, which consequently follows and V_{g3} goes negative. I_a is therefore reduced and I_{g2} increases. A further reduction in V_{g2} results in a corresponding fall in V_{g3}. This action is cumulative and ends when I_a is cut off and all the space current flows to the screen.

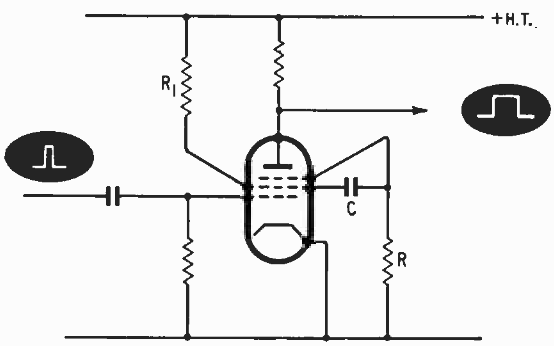

Fig. 1

(c) After the initial drop, V_a very quickly rises to h.t. potential.

(d) The first stage terminates when V_{g1} drops to zero. I_{g2} drops and V_{g2} and V_{g3} rise, but I_a remains cut-off. This is because g_3 was driven sufficiently negative during the first stage and is still well beyond suppressor cut-off voltage.

Interval 2:

(e) During the next interval C discharges through V and R with time constant CR ($R \gg R_1$), and the voltage on g_3 rises towards suppressor cut-off.

(f) I_a begins to flow, V_a drops and I_{g2} is reduced. V_{g2} increases, a further rise in V_{g3} is caused; I_a increases, causing a further drop in V_a. This action

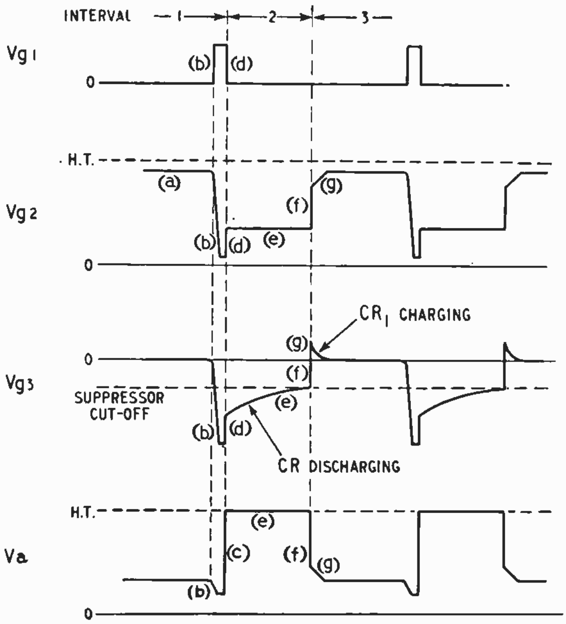

Fig. 2

is cumulative and the circuit returns to its stable condition.

Interval 3:

(g) V_{g3} follows the rise in V_{g2} and, due to its positive excursion, I_{g3} flows, causing C to charge rapidly through R_1. This flow of current through R_1 produces an irregularity in the anode and screen grid waveforms at the trailing edge of the output pulse.

The duration of the output pulse from the anode depends on the time constant CR, and since the anode voltage is only indirectly affected by the charging and discharging of C, the waveform is square. Instead of applying a positive-going sync pulse to g_1 it is possible to trigger the circuit by a negative-going pulse either at g_2 or g_3. The action is similar, although the sync pulse must be of larger amplitude.

It may also be noted that, under certain conditions, provided that the sync pulse is of sufficient amplitude and duration, the cumulative actions described above can be initiated by a negative-going sync pulse applied to the control grid.

The control of I_a by V_{g3} requires the creation of a space charge ("virtual cathode") between g_2 and g_3. Under these conditions the pentode may be regarded as a pair of triodes with cathode, g_1 and g_2 as one valve; and with "virtual cathode", g_3 and anode as the other.

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The Reflectometer

By "CATHODE RAY"

Principles of a Measuring Device Used on Lines and Waveguides

A READER, sharing my dislike for hazy or uncertain ideas, has cited the reflectometer as an example. He has seen a number of treatises on it, all of which failed to convey to him how it works. On the assumption—which I, knowing him, regard as most reasonable—that if he is puzzled others will be, he has urged me to do something about it.

Students of *Q.S.T.* and the A.R.R.L. Handbook (for 1957 thru 1959, as they say over there) will know the reflectometer better as the Monimatch. It has also been called the Directional Coupler. Whatever the name, its purpose is to enable r.f. power travelling along a line or waveguide to be sorted out according to direction of flow, so that the direct and reflected power can be measured separately. This obviously enables the standing-wave ratio* to be calculated. In turn this indicates the ratio of mismatch at the far end of the line, which is what one wants to know when setting up a transmitter for maximum efficiency or when measuring v.h.f. impedances.

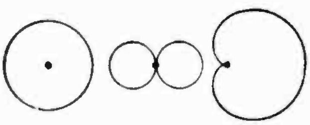

Fig. 1. Polar diagrams showing the directivity of (a) an ordinary vertical aerial, (b) a loop aerial, and (c) the well-known direction-finding aerial in which (a) is added to (b)—one loop of (b) being negative.

The more familiar method of measuring s.w.r. is to have a slot cut along more than half a wavelength of the line, through which a suitable voltmeter probe can be slid. The maximum and minimum readings give the ratio directly. The sliding process is not always very convenient; and if the source of power is a magnetron, which is apt to generate undesired frequencies when badly adjusted, it can happen that the best s.w.r. is indicated when the power is divided up amongst the greatest number of such frequencies—quite the reverse of the general intention. The reflectometer, on the other hand, can be fixed at any convenient point in the line, and indicates the reflected power directly—either in total, or frequency by frequency, according to the type of detector. It is also very easy and cheap to make. Between them, published designs of reflectometer cover frequencies at least from 2 to 3,300 Mc/s, but the most usual applications seem to be in the v.h.f. band.

At first thought it may appear rather a difficult thing to tell how much of the r.f. power is going each way when it is going both ways at once. Come to that, it's not altogether obvious how to tell which way it is going even when it is all going one way. The ordinary loop aerial can show the line of travel but not the direction along it. Readers familiar with radio direction finding, however, will remember the old dodge of combining a loop aerial with an ordinary vertical aerial giving the same amount of output. With the combination aerial facing one way, these two outputs are out of phase and cancel one another; facing the opposite way, they add up to give a maximum. Plotted on a polar diagram, the combined output yields a cardioid or heart-shaped diagram, compared with the ambiguous figure-eight of the loop alone and the omnidirectional result with the vertical aerial alone—Fig. 1.

Essentially the same principle is used in the reflectometer. Whether the line has a central conductor (coaxial) or not (waveguide), the space inside is being swept by the electric and magnetic fields which together make up the electromagnetic wave-train conveying the power along it. Now we know (if we don't, we shall in a moment) that the directions of these two component fields and the direction in which the waves are travelling are all three at right angles to one another. This is a thing that fairly shouts to be illustrated by an animated diagram in colour, but with a little imagination Fig. 2 should convey the essential facts. The invisible fields are here represented in the usual way by "lines of force," which are fair enough so long as they don't give anyone the idea that the lines really exist or that the fields act only along the lines and not in the spaces between. The electric field is represented by continuous lines and the magnetic field by broken ones. And, of course, the directions marked are those established arbitrarily by convention. The direction of wave motion is at right angles to both sets of lines, (a) towards or (b) away from you.

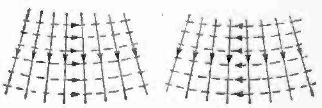

Fig. 2. The continuous lines represent the electric field, and the broken lines the magnetic field, together making an electromagnetic wave travelling at right angles to them, (a) towards you, and (b) away from you.

The novice might ask why it should be the magnetic field that has been reversed in (b). The answer is that it would be equally correct to show reversed electric field. At any given place along the line, these two alternatives alternate at the frequency of the waves. And at any given instant of time, the same two alternatives alternate at half-wavelength distances along the line. If the directions of *both* fields in either (a) or (b) were reversed it would not affect the direction of wave motion.

Another fundamental point is that in so far as power is being conveyed either way the two fields are in phase with one another.

What the problem boils down to, then, is to find which way across the cable or waveguide the magnetic field is directed, relative to the direction of electric field. If one places oneself so that the electric field

* Incidentally, why is the term "v.s.w.r." (voltage standing-wave ratio) so often used where there is no point in emphasizing voltage particularly? The current ratio is the same, so why not just "s.w.r."?

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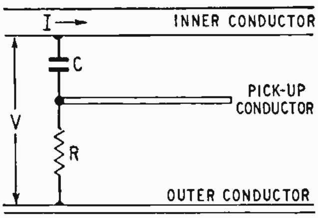

Fig. 3. The basic principle of a reflectometer is the coupling of a pick-up conductor to both electric and magnetic fields in such a way that the two effects cancel out for either direct or reflected wave as desired.

at any instant is downward, then if the magnetic field at the same instant is from left to right the waves are coming towards one; if from right to left, they are going away.

A reflectometer must be made so that it responds to both fields equally. Then if these responses add up to give a double measure from a wave going wholly one way, they will cancel out and give no response at all to a wave going wholly the opposite way.

The essential feature of all reflectometers, then, is a device for responding simultaneously to electric and magnetic fields. It has appeared in two main forms. In one (which includes the Monimatch) there is a short length of rod or wire fixed parallel to the inner conductor of the coaxial line, so that it is magnetically coupled to the said inner conductor and a.c. flowing therein generates an e.m.f. in it. Being located in the electric field between inner and outer conductors, it also has an e.m.f. between it and the outer conductor. This pick-up rod is dimensioned and connected so that the two e.m.fs equally operate on a suitable indicator, either in phase or 180° out of phase.

Constructional details vary, but they have to take account of the fact that the e.m.f. induced by magnetic coupling is proportional to the mutual inductance and the *rate of change* of current flowing in the "primary." So its peak is displaced 90° from the current peak. And because the voltage between the two line conductors is *in* phase with the current through them, the pick-up circuit must be arranged to give a 90° phase shift between the line voltage and the resulting voltage fed to the indicator. The usual way of doing this is shown in Fig. 3. The pick-up conductor is connected to the inner conductor through a small capacitance C—its self-capacitance is usually enough—and to the outer conductor through a resistance R which is very low in comparison with the reactance of C. The phase of the current driven by V through C and R in series is therefore determined almost entirely by the reactance, so it leads V by nearly 90°. So it is nearly in phase, or 180° out, with the e.m.f. induced in the pick-up conductor by I. Provided that the length and spacing of the pick-up are right, these two voltages are equal, so the voltage between the pick-up and outer conductor is a measure of the power travelling along the line in one direction only. Power in the other direction makes the voltages cancel out, to give no reading.

It will be obvious that Fig. 3 is rather too theoretical. For one thing, if C is self-capacitance it will be distributed all along the pick-up. And what about the indicator?

Fig. 4 shows a practical design for 4–15 Mc/s, described by O. Norgorden in U.S. Naval Research Laboratory Report No. 3538 of 1949. The coaxial line has half of the outer conductor cut away

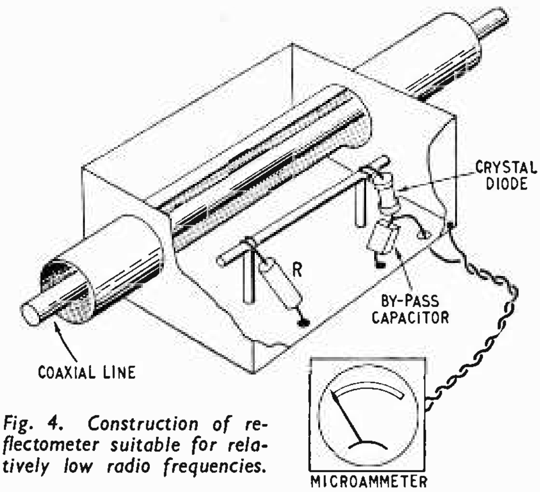

Fig. 4. Construction of reflectometer suitable for relatively low radio frequencies.

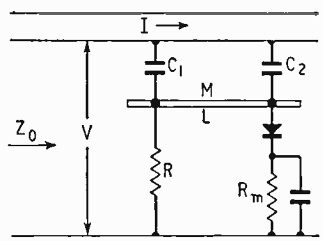

Fig. 5. Approximate equivalent circuit diagram of the Fig. 4 type of reflectometer.

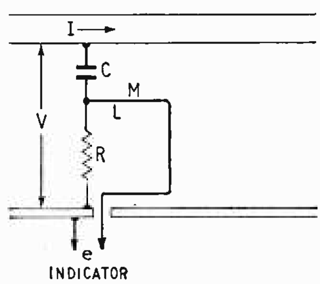

Fig. 6. Circuit diagram of loop type of reflectometer.

for a distance which is a small fraction of the wavelength. The screening is maintained by a surrounding metal box, inside which is installed the pick-up unit shown, differing from Fig. 3 only in C being distributed over the whole length of the conductor, and the addition of a crystal diode and microammeter as an indicator. R is of the order of 100Ω, and the resistance R_m of the meter is chosen to give it a suitable range in relation to the r.f. power used. For purposes of analysis the distributed capacitance between pick-up and inner conductor is assumed to be concentrated at the points where the connections are made, as in Fig. 5. This assumption seems to be justified in practice. So as not to interrupt ourselves with a lot of algebra at this point, the working has been exiled to an appendix. The upshot of it all is that the condition for no meter reading, when all the power is flowing in the direction causing the inductive and capacitive responses to oppose one another, is

$$M \simeq RCZ_0$$

where M is the mutual inductance between the

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For instance, over a 2 : 1 frequency band the lowest frequency gives a response 6 dB less than the highest. And there is loss in the pick-up. Allowing, say, a total of 75 dB, the reflected-wave voltage picked up from 10 watts with a s.w.r. of 1.05 in a 70-Ω line comes out at 4.7mV. This is really too small for a crystal and microammeter.

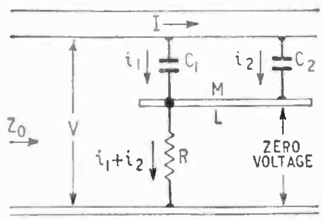
A sensitive measuring gear using a radio receiver is shown by W. H. Elkin in *Marconi Instrumentation*, Dec. 1956. Fig. 8 is fairly self-explanatory. It can be worked with an oscillator uncalibrated for output level, but does call for a calibrated piston attenuator with which to measure the ratio of direct to reflected power giving equal receiver output. Alternatively if an output-calibrated signal generator is available the input can be varied by its attenuator to get equal receiver response with the reflectometer loop in its two set positions.

Anyone whose thirst for information on reflectometers, especially their practical details, has not yet been slaked should refer to this and other literature I have mentioned, and perhaps also an earlier paper by H. R. Allan and C. D. Curling, in *Proc. I.E.E.*, Jan. 1949, which deals particularly with 10cm. waveguide technique.

APPENDIX

If the reflectometer is properly made it will give zero reading with power flowing along the line in one direction. In that case the voltage across the detector in Fig. 5 is zero and that arm of the circuit can be omitted, as in Fig. 9. The voltages across C_1 and R must add up to V;

Fig. 9.



the voltage across C_2 must be the same; and the voltage across the rod and that across R must add up to zero:

$$\frac{i_1}{j\omega C_1} + (i_1 + i_2)R = V \quad .. \quad .. \quad (1)$$

$$\frac{i_2}{j\omega C_2} = V \quad .. \quad .. \quad .. \quad .. \quad (2)$$

$$(i_1 + i_2)R + i_2 j\omega L - Ij\omega M = 0 .. \quad (3)$$

$$V = IZ_0 \quad .. \quad .. \quad .. \quad .. \quad (4)$$

The value of i_2 found from (2) is substituted in (1), from which i_1 is found, and both are substituted in (3), where I is replaced by V/Z_0 from (4). After a bit of manipulation this yields

$$\frac{M}{Z_0} = R(C_1 + C_2 - C_1\omega^2 LC) + j\omega\left(C_2 L - C_1 R\frac{M}{Z_0}\right) \quad .. \quad (5)$$

To make this possible, the "j" term must be zero; i.e.,

$$C_2 L = C_1 R\frac{M}{Z_0}$$

$$\text{or } \frac{M}{Z_0} = \frac{C_2 L}{C_1 R}$$

The factor $\omega^2 LC_2$ in (5) is the ratio of the reactance of L to the reactance of C_2, and in practice this is much less than 1. (In other words, the pick-up is much too small to resonate at the working frequency). So $C_1\omega^2 LC_2$ can be neglected in comparison with $C_1 + C_2$. With these amendments, (5) boils down to

$$\frac{M}{Z_0} = \frac{C_2 L}{C_1 R} \simeq R(C_1 + C_2) \quad .. \quad (6)$$

This states how the circuit must be proportioned if the reflectometer is to ignore waves travelling in one of the two directions through it. When the position of the detector, or the loop itself, is reversed, M in (3) is reversed in sign and a reading is given. The current in the detector circuit is then proportional to the current in the line (1) and therefore to the square root of the r.f. power. (There is, of course, mutual inductance between the pick-up and outer conductor, so M is really the coupling to the inner conductor minus that to the outer.)

The type of instrument shown in Fig. 4 is reasonably well covered by (6) if $C_1 = C_2$ and $C_1 + C_2 = C$, simplifying it to

$$\frac{M}{Z_0} = \frac{L}{R} \simeq RC$$

In the loop type with capacitance concentrated mainly at one end (Fig. 6), on the other hand, $C_2 = 0$ and $C_1 = C$; adapting (5) accordingly gives

$$\frac{M}{Z_0} = \frac{RC}{1 + j\omega CR}$$

and since R is made much smaller than the reactance of C, $j\omega CR \ll 1$ and

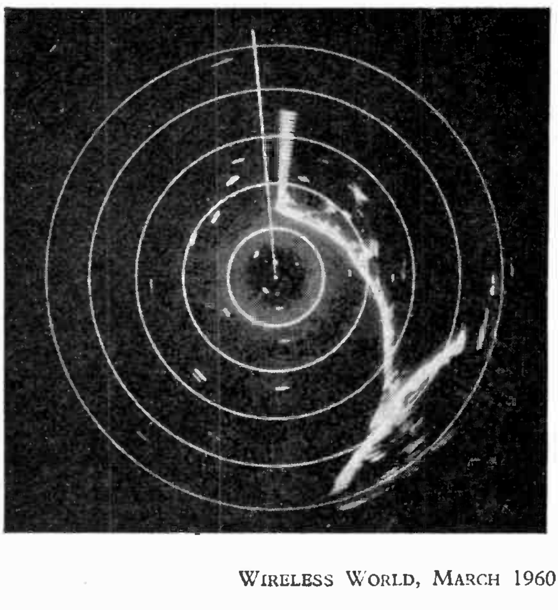
$$\frac{M}{Z_0} \simeq RC$$

which is the same as with Fig. 5 except that there is no stipulation about L. Note that within the limits of the approximations the balance condition is independent of frequency, so the setting up is effective over a wide frequency band.

Secondary Radar For Marine Use

THE correlation of radar paints and a navigation chart is eased by the use of secondary radar, as transponder-carrying "targets" will give a strong identified response. RACON is one such transponder beacon for marine use: it produces, when triggered by a ship's radar transmission, a chain of impulses corresponding to 15 to 20 dots extending over the equivalent of four miles of the p.p.i. screen on the bearing, and starting at the range, of the beacon-equipped object. The transponder sweeps the allocated band of frequencies once in 75 sec during 5-min operating periods between 5-min intervals. RACON is made by Kelvin & Hughes (Marine) Ltd. to a Trinity House specification and is, at the moment, undergoing trials.

Response (to right of radial marker) from RACON transponder at about two-miles range.



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inner and pick-up conductors, $C=C_1+C_2$, and Z_0 is the characteristic impedance (=V/I) of the line.

A procedure for achieving this condition is to terminate the line with an accurately matched load and feed it with power. The spacing between conductors (which determines M and C), or R, is then varied to give zero reading.

The instrument having been set up correctly, any reading indicates reflected power. To indicate direct power for comparison, the mutual inductance must be reversed in sign. This could obviously, but inconveniently, be done by reversing the whole reflectometer in the line. The same effect is produced by interchanging R and the indicator. In the Monimatch it is done by having two reflectometer units and switching the microammeter from one to the other. Details of a construction in which the pick-up wires are mounted end-to-end, with a common resistor R in the middle, are given by L. G. McCoy in *Q.S.T.*, Oct. 1956, and in the 1957 A.R.R.L. Handbook, p.516. A more compact version, with separate wires lying head-to-tail on opposite sides of the inner conductor, is described in *Q.S.T.*, Feb. 1957, and in the 1958 Handbook, p.530. A still more compact version, in which the first arrangement is adapted to a length of flexible coaxial cable wound into a hank, and balance is obtained by varying R, is shown in the 1959 Handbook, p.530.

The other main variety is the rotatable loop type, which is tending to supersede the foregoing, presumably because it is more suitable for higher frequencies and is applicable to waveguides. It is also easier to adjust. But the differences are more mechanical than electrical. Fig. 6 shows that electrically it is essentially the same as Fig. 5, except that the loop may be shaped to put extra capacitance at one end. The algebra used for Fig. 5 can easily be adapted for Fig. 6 by putting $C_2=0$ and $C_1=C$, and the result is the same, apart from quantities small enough to neglect. Mechanically, the loop is arranged so that it can be rotated from outside through 180°. So its kinship with the d.f. aerial is more obvious.

This continuous rotability makes it easier to tell whether the capacitive and inductive couplings are equal. If C is too small or too large in relation to M, either there will be two zero readings each side of the position where the loop lies along the line, as in Fig. 7(a), or no zero at all, (b). These diagrams, incidentally, are just cartesian versions of what come out as cardioids in the polar form (Fig. 1).

Besides being proportioned for equal capacitive and inductive e.m.fs, a reflectometer pick-up device must extend along the line for only a small fraction of a wavelength—which means a very small loop in centimetre waveguides—and not be large enough to cause appreciable reflection or absorption of the transmitted power itself. At the same time it must be sensitive enough to indicate small amounts of reflected power.

Suppose, for example, that standing-wave ratios at least down to 1.05 are to be measurable. That is to say,

$$\rho = 1.05 = \frac{V+v}{V-v}$$

where ρ is the s.w.r. and V and v the voltages of the direct and reflected waves. From this we get

$$\frac{v}{V} = \frac{\rho-1}{\rho+1} = 0.0244$$

The ratio of reflected to direct power is equal to the square of this, 0.0006. The power taken by the reflectometer ought not to be more than a like fraction of this power, or 0.00000036; in other words, a loss of at least 65 dB between the lowest power to be monitored and that available for the indicator. If the reflectometer is to be used over a band of frequency there is a further loss, because the voltages picked up are proportional to the rate of change, and hence the frequency, of the wave voltage and current.

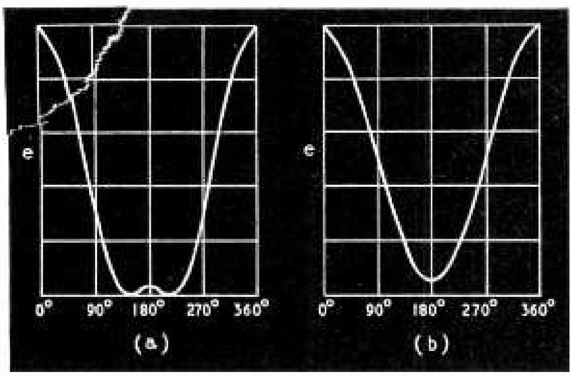

Fig. 7. Variation of response as the loop in Fig. 6 is rotated through one whole turn, with the magnetic coupling (a) too tight, (b) too loose, compared with the electric.

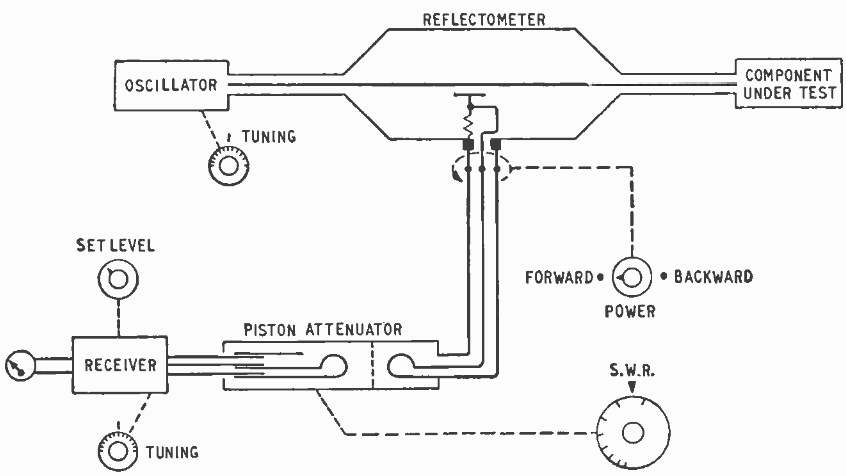

Fig. 8. Diagram of apparatus using a reflectometer for measuring standing-wave ratio and hence the impedance of line terminations.

THE SMITH CHART

By R. A. HICKSON*

3.—Matching Transmission Lines to Aerials and Uses of Stubs

(Concluded from page 85 in the February issue)

CONTINUING with our study of the applications of the Smith Chart we will now consider one of the most common requirements, namely matching transmission lines to aerials and how mismatch can be corrected by means of stubs.

Matching a Resistive and a Reactive Impedance.—Normally this means matching a load such as an aerial, to a transmission line, and the problem will be discussed in these terms. Various matching elements may be used, such as:—

(*1*) Matching stub connected in parallel with the load.
(*2*) Matching stub which can be located at any point on the line.
(*3*) Matching stubs which are located at fixed points on the line.
(*4*) L-networks.
(*5*) Series elements, such as quarter-wavelength transformers, in conjunction with phasing sections. A phasing section is a length of line between the load and the transformer, used to convert the load impedance to a resistive value. A more practical embodiment of this idea is the slug tuner, which is a quarter-wavelength long metal or dielectric sleeve, sliding on the inner conductor of a coaxial line. The double-slug tuner has two independent sleeves and will match a wide range of impedances. A full description can be found elsewhere[7].

In order to avoid losses in the stubs, they are normally terminated in a short circuit and their length is adjusted to obtain the required reactance. Capacitive terminations are used on occasion, for example, when the transmission line is also used to supply low-frequency de-icing current to an aerial.

A useful discussion of various matching methods in relation to their performance over a wide band of frequencies is contained in reference 8.

Stub in Parallel With the Load.—This is best treated on an admittance basis, since two admittances add when connected in parallel. Consider the admittance curve of a simple dipole, resonant at 56Mc/s, Fig. 18. If the tolerable v.s.w.r. is 2, then the bandwidth of the dipole is 5Mc/s. The effect of adding susceptance is to shift each point on the curve along the line of constant conductance. Thus point A, at the intersection with the $G = 0.5$ circle can be moved at $0.5 + j0$ by the addition of $+j0.48$. Similarly point B can be moved to $0.5 + j0$ by the addition of $-j0.88$. Intermediate points will require correspondingly smaller susceptances to bring them within the "v.s.w.r. = 2" circle.

The susceptance of a short-circuited quarter-wavelength stub, resonant at a frequency between 52Mc/s and 60Mc/s, will provide the required compensation. In general, the susceptance variation of a simple dipole is such that it can be compensated by a stub of this sort. As is well known, the two elements of a simple dipole may be bent over to form a Vee, imparting some directional properties to the aerial. If the elements are bent further than usual, so that they tend to become parallel, the similarity of the aerial to the quarter-wavelength open-circuited section of transmission line can be readily seen. Its susceptance variations are accordingly such as to be compensated by a quarter wavelength short-circuited section.

The resonant frequency of the stub is found by an approximate method which depends on the fact that the variation of susceptance with frequency is very nearly linear in the region of the resonant frequency. For a frequency change of 60 − 52 = 8Mc/s the normalized susceptance changes by 0.88 + 0.48 = 1.36. The change in frequency for a change in susceptance of 0.48 is therefore

$$8 \times 0.48/1.36 = 2.825\text{Mc/s}.$$

The resonant frequency of the stub is, 60 − 2.825 = 57.175Mc/s and the electrical length of this stub at 60Mc/s is $0.25 \times 60/57.175 = 0.2625$ wavelength.

The susceptance of a stub of the same characteristic impedance as the transmission line at 60Mc/s is given by moving 0.2625 wavelength towards the load from the point of infinite susceptance. This brings us to $+j0.082$. We need $+j0.48$, therefore the impedance of the stub must be $(0.082/0.48)Z_0$ or $0.171Z_0$. As the chart is normalized to 75 ohms, the stub impedance required is 12.8 ohms. (In Fig. 18 the movement is in the direction "Towards Generator" because the short-circuited end of the stub is electrically further from the generator than the actual load which is to be matched.)

Calculations for the other frequencies may now be carried out on this basis. The procedure is:—

(*1*) Calculate the stub length in wavelengths at the required frequency.
(*2*) Determine from the Smith chart the susceptance of the stub if its characteristic impedance is equal to Z_0.
(*3*) Multiply this susceptance by 75/12.8 to obtain the susceptance of the 12.8-ohm stub.
(*4*) Add this susceptance to the aerial by moving the point the required distance along the circle of constant conductance.

The result is as shown in Fig. 18. The bandwidth for a v.s.w.r. of 2 is now 8Mc/s, an increase of 60%. A greater improvement could be obtained by selecting a 50-ohm feeder. This would shift the whole curve downwards, so that a greater proportion of it could be folded into the "v.s.w.r. = 2" circle by adding reactance. This is of course not practical for the television receiving installation but has applications elsewhere.

The only admittances which can be matched by

* Belling and Lee Ltd.

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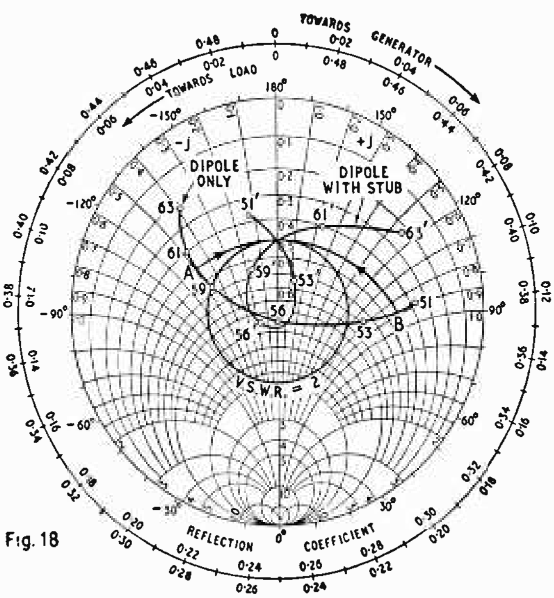

Fig. 18

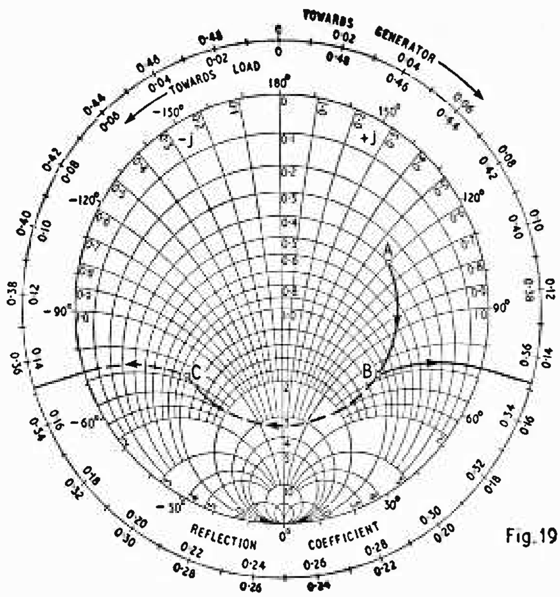

Fig. 19

Fig. 18. Use of a stub in parallel with an aerial to increase the useful frequency range.

Fig. 19. Use of a sliding stub to match the load at a single frequency.

this technique are those lying within the crescent defined by the circles of constant conductance which are tangent to the circle of constant v.s.w.r. within which the admittance is required to fall. Such admittances can always be matched at one frequency, but matching over a band may not always be possible. (See Ref. 8.)

Stub at any Point on the Line.—This technique makes use of the fact that the impedance of a mismatched line varies along its length. It can be applied to any load and is in principle carried out in two steps:—

(*1*) Move along the line away from the load to reach a point at which the conductance is unity.

(*2*) Add a stub to cancel the susceptance present at this point.

On the Smith chart we plot the normalized load admittance and draw the arc of a circle centred on the centre of the chart, moving clockwise through the load to intercept the circle of unity conductance. There will be two interceptions and normally the one nearer the load is chosen. However, the other may lead to a shorter stub, which may be preferable in some applications. The required stub susceptance will be equal and opposite to that of the line at the point of intersection with the circle of unity conductance.

As an example we may consider a load of $0.4 + j0.6$, point A, Fig. 19. Moving 0.062 wavelength along the line brings the admittance to $1 + j1.33$. The length of a short-circuited stub having a susceptance of $-j1.33$ is found by moving along the circle of constant susceptance $-j1.33$ to the edge of the chart and thence along the edge, i.e. the circle of pure susceptance, to the short circuit, which is the point of infinite susceptance. The stub length is 0.102 wavelength.

The same load may also be matched by moving 0.234 wavelength along the line to bring the admittance to $1 - j1.33$. The stub length required now is 0.398 wavelength.

The technique is suitable for single-frequency operation with a constant load, or for experimental work with open-wire lines. For most other purposes, the disadvantage of providing a sliding contact on the transmission line is found to be excessive. The variation in matching with frequency is therefore of little interest.

Matching Stubs at Fixed Positions on the Line.—This system allows a greater range of load impedances to be matched than does the single stub in parallel with the load, and it does not require the provision of sliding or movable contacts on the line. Two stubs will allow most loads to be matched, and the two-stub system will be described in detail. Three stubs will allow all loads to be matched; they are commonly spaced $\frac{1}{8}$-wavelength apart and their operation is the same in principle as that to be described for the two-stub system.

One stub is connected in parallel with the load, the other at a distance of $\frac{1}{8}$ or $\frac{3}{8}$ wavelength along the line. So far as the remainder of the line is concerned the effective load is formed by the two stubs, the section of line between them, and the load, all taken together. The stub, nearest the generator, therefore, can only be used to cancel susceptance. The stub at the load is adjusted so that the resultant admittance produced by this stub in combination with the load, when transformed by the intermediate section of line, falls on the circle of unity conductance. The addition of susceptance by the second stub will then result in a pure conductance of the required value. The admittance of the actual load in parallel with the load-end stub must lie on a point which can be reached by travelling $\frac{1}{8}$ (or $\frac{3}{8}$) of a wavelength towards the load from the circle of unity conductance. In other words, it must lie on a circle of the same diameter as the circle of unity conductance, rotated bodily through $\frac{1}{8}$ (or $\frac{3}{8}$) of a wavelength about the centre of the chart. These circles are shown in Fig. 20(a).

The load admittance, therefore, must have a conductance component which will allow the point

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representing it on the chart to be moved on to the transformed unity-conductance circle by the addition of the susceptance of the load-end stub. An examination of the chart shows that this condition can be met for all loads except those within the circle of "conductance = 2," which is shaded. Such loads may be inverted by a quarter-wave section line, i.e. the load-end stub may be placed a quarter-wavelength from the load. In fact, the circle representing the loads which cannot be matched may be placed at any position round the edge of the chart by choosing the appropriate length of line between the load and the load-end stub.

The choice of spacing between the two stubs arises from the facts that (*a*) any closer spacing than $\frac{1}{8}$ wavelength would lead to field distortion and would effectively place the two stubs in parallel: (*b*) the use of spacings between $\frac{1}{8}$ and $\frac{3}{8}$ wavelength would increase the area on the chart representing loads which could not be matched. At $\frac{1}{4}$-wavelength spacing, loads within the circle of unity conductance could not be matched. A spacing of $\frac{3}{8}$ wavelength may be used where $\frac{1}{8}$ wavelength is mechanically inconvenient. Wider spacings than $\frac{3}{8}$ wavelength would offer no electrical advantage; a spacing of $\frac{1}{2}$ wavelength, for example, would be equivalent to placing the two stubs in parallel.

As an example, we will match the load $0.6 + j0.6$, point A on Fig. 20(b), using one stub in parallel with the load and the other stub $\frac{3}{8}$ wavelength along the line. The first stage is to select the susceptance of the load-end stub so that the resultant load lies on the rotated circle. There are two choices, points B and C, where the "conductance = 0.6" circle intersects the rotated circle. When transformed through the $\frac{3}{8}$-wavelength section of line, the admittances become points D and E. From either of these points, the addition of susceptance by the generator-end stub will result in a completely matched system.

L-Network Design.—Matching with an L-network, using the Smith chart, follows similar lines to matching with a stub of adjustable position. In this case, however, the impedance-transforming property of a length of line is not used, a reactive element being placed in series with the line instead, and accordingly the chart must represent impedance as well as admittance.

There are two general types of L-network, as shown in Fig. 21. Considering first the type A network, the resultant admittance of $X_2 + Z_L$ must lie on the circle of unity conductance, so that susceptance only need be added to complete the matching process, exactly as in the case of single-stub matching. In other words the resultant impedance of $X_2 + Z_L$ must lie on the circle surrounding area B. To be matched by a type-A network, therefore, the load impedance must be such that, by adding or subtracting reactance, we can reach the circle surrounding area B. The shaded area A on Fig. 21 defines the loads which cannot be matched by a type-A network. Similar reasoning shows that the loads which cannot be matched by a type-B network are those defined by the shaded area B on Fig. 21.

As an example of the design of an L-network, we will match an impedance of $20 + j50$ ohms to a 50-ohm line with a loss-free type-A network. The procedure can be followed on Fig. 22. The normalized impedance is $0.4 + j1.0$ (point A). The series element will be a capacitor of reactance equal to $1.49Z_0$ at the operating frequency. This produces a resultant impedance as shown at point B, corresponding to the admittance (relative to 20 millimhos) shown at point C. The addition of inductance of susceptance equal to $1.25Y_0$ at the operating frequency results in complete matching.

If losses in the inductor or capacitor are not negligible an allowance must be made for them. Considering the inductor first, let $G = -B/Q$ so that a susceptance of -1.0 will involve a conductive component of $+1/Q$. The resultant admittance of load and capacitor combined must now lie on the line

Fig. 20 (a). Limits within which the double-stub matching method can be applied.

Fig. 20 (b). Matching with two stubs spaced at 3λ/8.

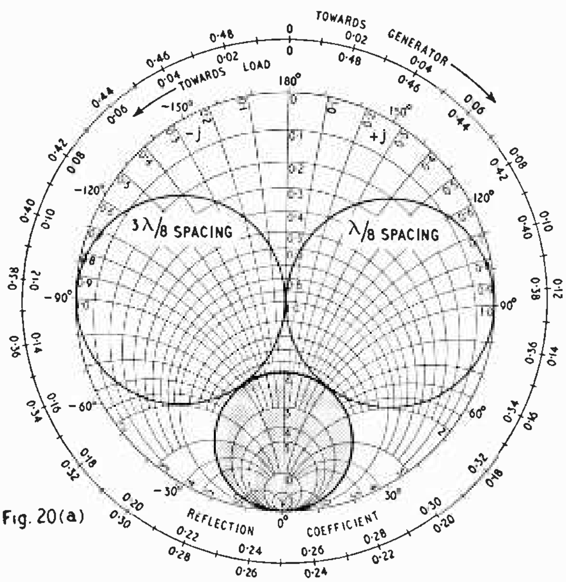

Fig. 20(a)

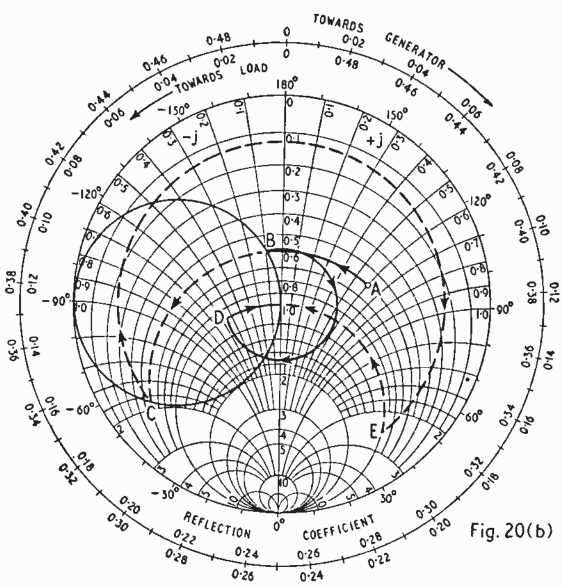

Fig. 20(b)

1 − B/Q + jB, where B is the required susceptance. For example, if Q = 10, this line will pass through the points 1 + j0, 0.9 + j1, 0.8 + j2......0 + j10; it is, in fact, a circle, the centre of which can be found by laying off arcs from three or more points such as those calculated above. The corresponding circle for the resultant impedance of load and capacitor combined is now readily drawn. Any losses in the capacitor may be taken into account without a geometrical construction by remembering that for every unit of reactance (movement along a line of constant resistance) we must add 1/Q units of resistance. As 1/Q, which is virtually equal to the power factors, is about 0.0005 for a ruby-mica dielectric and about 0.0001 for air dielectric, correction is not often needed for capacitor losses.

The same load (point A) can be matched with an all-capacitor network. The series capacitor should now have a capacitance equal to $0.51Z_o$ at the operating frequency. This produces the resultant impedance shown at point B′, corresponding to the admittance shown at point C′. The addition of a

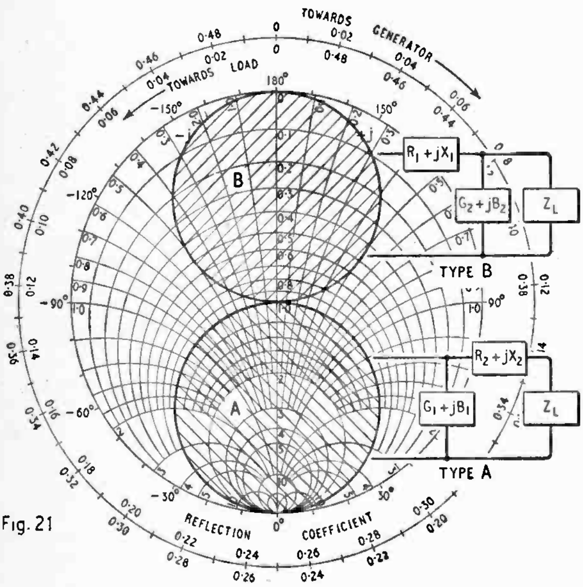

Fig. 21

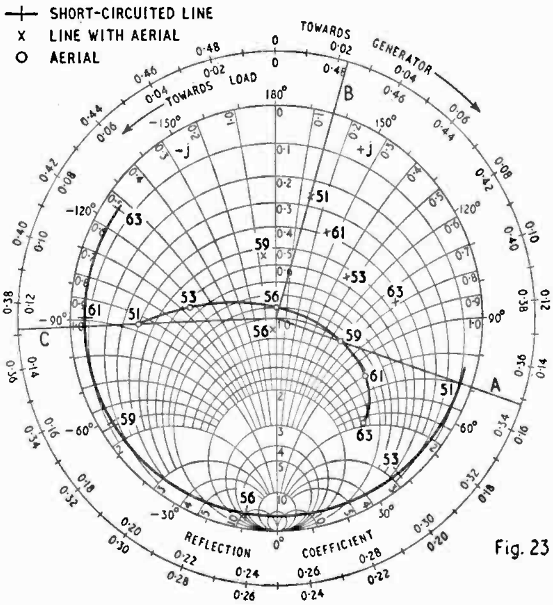

Fig. 23

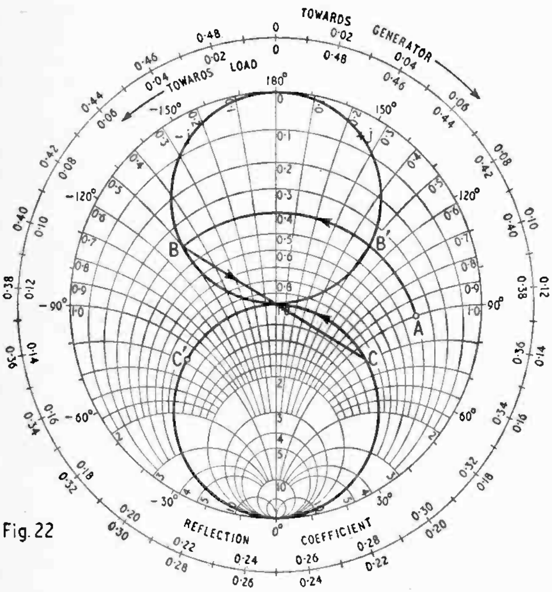

Fig. 22

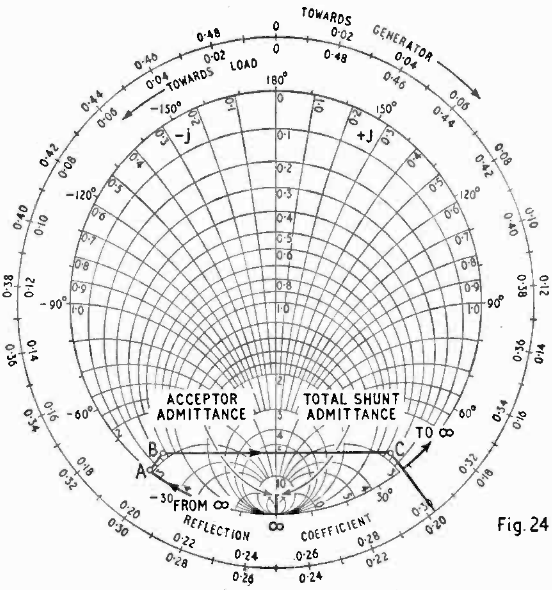

Fig. 24

Fig. 21. The two basic types of L-network, showing the load impedances (shaded) for which each is not applicable.

Fig. 22. Matching with a loss-free type A L-network.

Fig. 23. Allowing for the effect of the line on the apparent impedance of a dipole at various frequencies.

Fig. 24. Single-frequency acceptor-circuit wavetrap, with compensation.

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shunt capacitor of susceptance equal to $1.25Y_o$ at the operating frequency results in complete matching (Fig. 22).

Effect of Line Length in Measurements.—The effect of line length on the apparent impedance of an aerial has been discussed by Strafford[9] whose example, a Channel-3 dipole, will be used here. The principle applies to any type of load.

The first step is to measure the input impedance of the line with a short circuit in place of the unknown load, at the frequency of interest. The result might be, for example, $0.1 - j1.4$. As we started with a short circuit, $0 + j0$, the effect of the line has been to move the point on the chart 0.151 wavelength clockwise and 0.32dB radially inwards. Therefore, when the short circuit is replaced by the unknown load, the apparent impedance must be moved 0.151 wavelength counter-clockwise and 0.32dB radially outwards, to obtain the true load impedance. This procedure must be repeated at each frequency. It must be borne in mind that, while 0.151 wavelength always corresponds to the same angle (109°) on the chart, the radial distance represented by 0.32dB depends on the point at which the " Effect of Line Attenuation " scale is entered and must be evaluated afresh with this scale for each new point.

Point A in Fig. 23 represents the input impedance of the short-circuited line. Point B represents the input impedance of the line with an aerial connected in place of the short circuit. Point C is the actual impedance of the aerial, obtained as described above. The construction is shown for one frequency only, 51Mc/s. At this frequency the effective length of the line is 0.151 wavelength. The point B, representing the input impedance of the line with the aerial at 51Mc/s must therefore be moved 0.151 wavelength counter-clockwise, from 0.477 to 0.128 on the " Wavelengths towards Load " scale. At the same time the loss of 0.32dB in the line is allowed for by moving the point the correct radial distance outwards, as described above.

Compensated Coaxial-Stub Acceptor Circuit.—In cases where two frequencies are present on a transmission line, one of which is undesired, this frequency can be considerably attenuated by a coaxial stub which is one half-wavelength long at the undesired frequency and is short circuited at the free end. This stub will " repeat the load " and will short circuit the line at its resonant frequency. It will also present a susceptance across the line at the signal frequency, and this susceptance may be cancelled by a second stub of suitable length.

Certain special cases must be distinguished. If the desired frequency is an integral multiple of the undesired frequency, the stub will short circuit both signals impartially. If, on the other hand, the undesired frequency is exactly twice the desired frequency, the acceptor stub will be a quarter-wavelength stub at the desired frequency and no compensation will be needed.

Suppose that the two frequencies are F_D and F_u. The electrical length of F_D of a stub which is one half-wavelength at F_u will be $0.5F_D/F_u$ wavelengths. The problem is best handled on an admittance basis so we start at the infinity point on the chart and move clockwise round the edge of the chart for the distance $0.5\ F_D/F_u$ wavelengths. The point so reached is the susceptance placed across the line at the desired frequency. To reduce this susceptance to zero, we must add an equal and opposite susceptance. We therefore locate the required point on the chart and move counter-clockwise round the edge of the chart to the infinity point. The distance travelled in wavelengths is the length of the required compensating stub. The compensating stub, of course, presents a certain susceptance at the undesired frequency, but this is of no importance, as it is in parallel with a much greater susceptance. The effect of losses in the stubs may be taken into account by using the " Effect of Line Attenuation " scale.

As an example (Fig. 24) we will consider interference at 38Mc/s to a signal at 42Mc/s. The electrical length of the acceptor stub at the signal frequency will be $38/2 \times 42 = 0.5527$ wavelength. Moving this distance from the infinity point in a clockwise direction round the edge of the chart we reach point A, $0 - j2.9$. Assuming that the stub has an attenuation of 0.4dB, we move radially inwards by the distance indicated on the " Effect of Line Attenuation " scale to point B, $0.5 - j2.85$. The compensating stub must have a susceptance of $+j2.85$ to cancel this, and will have very nearly the same attenuation. Its admittance is therefore located at point C, which is the mirror image of point B in the pure conductance scale, and its length is found by moving 0.4dB radially outwards to the edge of the chart and thence counter-clockwise to the short-circuit (infinity susceptance) point. The length is 0.447 wavelength.

The admittance of the acceptor stub at the undesired frequency is not infinite, but is reduced by the attenuation of the cable used to make the stub. The actual admittance is found by moving radially inwards by the distance indicated on the " Effect of Line Attenuation " scale. Therefore, to the admittance thus found, $20 + j0$, must be added the admittance $0.5 + j2.85$, corresponding to point C, making the total shunt admittance due to the pair of stubs $20.5 + j2.85$ at the undesired frequency. It will be seen that the effect of the compensating stub at this frequency is negligible. The ratio of the admittance of the cable following the acceptor circuit to the combined admittance of the stubs is 1 to 20.7. The interfering signal power is therefore divided between the two paths in the ratio 428 to 1, corresponding to an attenuation of 26.3dB.

SYMBOLS

e = Effective relative permittivity (dielectric constant) of the dielectric.
F = Frequency Mc/s.
L = Physical length of line in metres.
l = Length of line in wavelengths
= $FL\sqrt{e}/300 = FL/300v$.
v. = Velocity factor of line = $1/\sqrt{e}$.
Y = Load admittance.
Y_o = Line admittance.
y = Normalized load admittance, = Y/Y_o.
Z = Load impedance.
Z_o = Line impedance.
z = Normalized load impedance, = Z/Z_o.

REFERENCES

[7] " Transmission and Propagation." Volume 5 of the Services Textbook of Radio, H.M.S.O., 1958, pp. 117-119.

[8] C. H. Westcott and F. K. Goward. " The Design of Wide-Band Aerial Elements for 500-600 Mc/s Ground Radar." I.E.E. Paper No. 732, Radio Section, *Proc.*

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I.E.E. Volume 96, Part III, No. 39, January 1949, pp. **41-51.**

[9] F. R. W. Strafford. "Measuring TV Aerial Performance; Part 3, Impedance Measurements," *Wireless World*, Volume 64, No. 6, pp. 295, 296, June 1958.

ADDENDUM

Since publication of the first two parts of the article it has been pointed out that certain statements and equations need clarification.

On page 7 second column of the January issue the statement that the v.s.w.r. is simply related to the load does not apply where the load comprises both reactance and resistance; S should then equal r not z.

As derived $$S = \frac{1 + |K|}{1 - |K|}$$

Now $K = \dfrac{z-1}{z+1}$ and if $z = r + jx$

$$K = \frac{r - 1 + jx}{r + 1 + jx}$$

Since the modulus of a complex number is equal to the square root of the sum of the squares of the real and imaginary parts:—

$$|K| = \left[\frac{(r-1)^2 + x^2}{(r+1)^2 + x^2}\right]^{\frac{1}{2}}$$

If the load impedance is resistive ($x = 0$) this simplifies to:—

$$|K| = \frac{r-1}{r+1}$$

So that:— $$S = \frac{1 + \dfrac{r-1}{r+1}}{1 - \dfrac{r-1}{r+1}} = \frac{r + 1 + r - 1}{r + 1 - r + 1} = r$$

The statement at the end of this section that the decibel may be used only when . . . " voltages are developed across identical impedances " should read . . . " across impedances having the same resistive component."

In Appendix 1, page 8, January issue, the fourth line from the bottom of the second column should read:—

$$u^2 - \frac{2ru}{1+r} + \frac{r}{1+r} = \frac{1}{1+r} - v^2$$

while the penultimate line should read:—

$$u^2 - \frac{2ru}{1+r} + \frac{r^2}{(1+r)^2} = \frac{1}{(1+r)^2} - v^2$$

In the February issue page 83, second column, line 12 the equation "attenuation (dB) = $k\sqrt{\text{frequency}}$" is given without specifying that k is a constant. It could be re-written "attenuation dBα frequency."

On page 84, first column, line 10, the derivation of the equation for velocity factor is as follows:— The electrical length (l) of the line is given by:—

$$l = \frac{L}{\lambda} \text{.......(wavelengths)}$$

where:— L is the physical length in metres,

λ is the wavelength in metres, given by $\lambda = 300v/F$ metres,

300 is the (approximate) velocity of electromagnetic waves in free space in megametres/second,

v is the velocity factor of the line,

F is the frequency in Mc/s.

$$\therefore l = \frac{FL}{300v} \text{....(wavelengths) and } v = \frac{FL}{300l}$$

Let the electrical length be l_1 at F_1 and l_2 at F_2. Then:—

$$v = \frac{F_1 L}{300 l_1} = \frac{F_2 L}{300 l_2} = \frac{(F_1 - F_2)L}{300(l_1 - l_2)} = \frac{\delta F L}{300 \delta l}$$

In Fig. 15 on page 84 the direction of movement from the short-circuit should be towards the generator as stated in the text (page 85 column 1), indicating a load impedance of $1 + j0.6$.

"ELECTRONIC COMPUTERS"

SINCE the first edition of this *Wireless World* book came out just over three years ago it has been reprinted once and also translated into Russian and republished by the Soviet authorities. Technical developments in the computer field have been so rapid, meanwhile, that a second edition of the book has become necessary, and this is now available from our publishers. The opportunity has been taken to improve the exposition of basic principles which is the main purpose of the book, and it has, in fact, been largely rewritten. Three new chapters, on analogue computer circuits, programming of digital computers and the future development of "intelligent" machines, have been added, together with new illustrations throughout the book, which now contains 263 pages, including 32 plates. As before, the new edition covers the principles and applications of both analogue and digital machines, and is suitable as an introduction to the subject for students, technicians or laymen with some knowledge of radio and electronic techniques. "Electronic Computers," by T. E. Ivall, 2nd edition, can be obtained from any bookseller, price 25s, or direct from the publishers, Iliffe & Sons Ltd., at 26s by post.

CLUB NEWS

Birmingham.—A 160-m mobile rally has been organized by the South Birmingham Radio Society for 10.30 a.m. on March 6th, at Lickey Beacon, Rednal. At the club meeting at 9.30 on March 17th at Friends Meeting House, 220 Moseley Road, Birmingham, 12, G. E. Simonite (G3JAO) will speak about the electronic equipment at Birmingham University.

The March meetings of the Slade Radio Society include a Mullard film show in the Bennett Hall, Y.M.C.A., Snow Hill at 7.45 on the 4th. At the meetings on the 11th and 25th, which will be held at 7.45 at Church House, High Street, Erdington, the subjects of v.h.f./f.m. reception and electronic digital computers will be dealt with respectively.

At the meeting of the Midland Amateur Radio Society on March 3rd D. Edwards (G3DO) will talk on DX working, and at the meeting on the 15th, R. Rew (G3HAZ) will deal with v.h.f. reception. The society meets at 7.0 at the Midland Institute, Paradise Street.

Bradford.—J. C. Belcher (G3FCS) will discuss interference in relation to sound and vision reception at the March 8th meeting of the Bradford Amateur Radio Society. The club meets on alternate Tuesdays at 7.30 at Cambridge House, 66 Little Horton Lane.

Cleckheaton.—Dr. N. H. Chamberlain, of Leeds University, will speak on electronics in industrial research at the meeting of the Spen Valley Amateur Radio Society at 7.30 on March 30th at the George Hotel.

Leeds.—The month's meetings of the Leeds Amateur Radio Society include lecture-demonstrations of photoelectric devices by E. Sollitt, the president (2nd), of hi-fi equipment by Fane Acoustics (16th), and a home-built table-top transmitter by W. Ripley (23rd). Meetings are held at 7.45 at Swarthmore Education Centre, 4, Woodhouse Square.

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News from the Industry

J. Langham Thompson Group, which includes Datum Metal Products Ltd. and Automation Systems & Controls Ltd., was recently acquired from the Camp Bird Group by Ether Ltd. of Erdington, Birmingham. The title of the company holding the entire share capital of Ether Ltd., its wholly owned subsidiary Electro Methods Ltd., and the J. Langham Thompson Group is now Ether Langham Thompson Ltd. The chairman and managing director is F. B. Duncan. Other members of the board are C. E. Blunt and F. Coulling (directors of Ether Ltd.), and J. Langham Thompson and Rear Admiral Sir Philip Clarke (directors of the J.L.T. Group).

The Decca Record Company, the parent company of the Decca group, records a trading profit of £3,305,313—an increase of £352,774 over the previous year. The net profit of £1,031,205 was £100,221 up on last year. Exports during the year reached the record total of £5,860,000 including £1,380,000 to the U.S.A. and Canada. The chairman, E. R. Lewis, stated that during the ten years to last March, the company had produced 41M long-playing records, 150M 78 r.p.m. records and 33M 45 r.p.m. records.

I.C.T.—The trading profit of International Computers and Tabulators Group up to September 30th, which includes a year's operation of B.T.M., but only nine months of Powers-Samas, was £2,328,000. The joint figure for the previous year's operation of the two former groups was £2,020,000. Taxation absorbs £1,025,000 of last year's profit.

S.T.C. are developing tunnel diodes and in order that circuit designers may familiarize themselves with the new properties and obtain early experience with the circuit performances achievable, the company is offering sample devices. Details of the samples and of the proposed range of diodes for use at v.h.f. are obtainable from Standard Telephones and Cables, Ltd., Transistor Division, Footscray, Kent.

B.T.H. Sound Equipment Ltd.—Under the general reorganization scheme of the A.E.I. Group the name of this company has been changed to A.E.I. Sound Equipment, Ltd. The company's office is still at Crown House, Aldwych, London, W.C.2.

Radio Resistor Co., wholesale distributors of Morganite products, are assuming exclusive wholesale distribution of Electrosil resistors, made by James A. Jobling & Co., of Sunderland. The company's new address is 9-13 Palmerston Road, Wealdstone, Middx. (Tel.: Harrow 6347.)

KOVO of Czechoslovakia.—Nash and Thompson were recently appointed agents in the U.K. and certain other countries for KOVO, the organization for marketing Czechoslovakian instruments. In their announcement (page 490 of our November issue), Nash and Thompson stated in error that they were agents for the Commonwealth, whereas in Australia, Jacoby, Mitchell & Co., of Sydney, have, in fact, been the exclusive agents for some years.

Multisignals Ltd., the recently formed television relay company, announces that Ultra have joined the enterprise, with which Ekco and Thorn are already associated. A. V. Edwards, managing director of Ultra, has been appointed to the board of Multisignals.

Hacker Radio, Ltd., formerly a sales company, is being developed by R. H. Hacker and A. G. Hacker, until recently joint managing directors of Dynatron Radio, Ltd., to manufacture high-quality radio and electronic equipment. A new factory is being built at Norreys Drive, Cox Green, Maidenhead.

Non-destructive Test Equipment.—An agreement has been concluded between Kelvin & Hughes Ltd., and the Curtiss-Wright Corp., of America, for the exclusive right to manufacture and sell the non-destructive testing equipment of the other partner. This includes instruments for the inspection and measurement of materials, and industrial ultrasonic equipment. Kelvin Hughes will represent both interests in the U.K., the Commonwealth (except Canada) and Europe, and Curtiss-Wright in North America.

Avo and Taylor.—Changes in the boards of Avo and Taylor Electrical Instruments, both members of the Metal Industries Group, have been announced. Because of indisposition J. H. Rawlings has relinquished the position of managing director of Avo Ltd., but he is remaining on the board as deputy chairman, and also on the board of Brookhirst Igranic Ltd. Succeeding him as managing director of Avo is S. R. Wilkins who also joins the board of Taylor Electrical Instruments. E. Strauss has been appointed director and general manager of Taylor's and also joins the board of Avo.

EXPORT NEWS

U.S.-Bahamas forward-scatter link, providing 72 trunk telephone circuits, which came into operation in January, employs at the Nassau terminal equipment manufactured by Standard Telephones & Cables. At Nassau two 10-kW transmitters, operating in the 2,000-Mc/s band, feed into two 30-ft diameter paraboloids. Two dual-diversity receivers provide quadruple diversity reception. S.T.C. also supplied line-of-sight microwave equipment linking the forward-scatter station to the telecommunications centre in Nassau City.

Sweden.—The first of three Decca D.A.S.R.1 air surveillance radar installations for use at major Swedish airports has been installed at Arlanda, Stockholm's new airport. The D.A.S.R.1 employs duplicate 800-kW transmitters feeding into separate aerial reflectors which are mounted back-to-back on top of a 90-foot cylindrical tower. The beams are staggered in elevation. The transmitters operate on about 3,000 Mc/s in the S-band.

Colour television equipment, including the latest E.M.I. camera (using three vidicon tubes) and control equipment and a Rank-Cintel large-screen colour projector, has been exported to China. The equipment forms a complete closed-circuit installation.

Computers.—International Computers and Tabulators Ltd. have received orders from three commercial concerns in France for their medium-sized general-purpose computer, the I.C.T. Type 1202. The capital value of the machines and ancillary equipment is of the order of £60,000 in each case. Last October SAMAS, previously the French subsidiary of Powers-Samas Accounting Machines, became I.C.T.—France.

V.H.F. equipment manufactured by Pye Telecommunications, is to be installed by the Suez Canal Authority for communication with its vessels in the Canal.

Cyprus.—Equipment for the sound reinforcing and language interpretation systems in the new House of Representatives in Cyprus is being installed by Tannoy.

India.—Sundeep Electronics Corporation, of New Delhi, wish to get in touch with British manufacturers of components and equipment with a view to representing them in India and possibly undertaking the manufacture of certain items under licence. Their technical representative is visiting this country and can be contacted at 8, Crescent Road, London, N.8. The firm's headquarters are at Gurdwara Road Crossing, Karol Bagh, New Delhi, 5.

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East Pakistan's port of Chittagong is to be equipped by Marconi's with v.h.f. radio-telephone transmitters and receivers at two base stations. Also mobile installations are being supplied for harbour tugs and a pilot launch. The order was placed by the Port Commissioners with International Industries Ltd., of Karachi, Marconi's agents.

A linear accelerator designed for X-ray treatment of deep-seated tumours, has been ordered from Mullard by the Soviet Union for installation in Moscow.

Western Germany.—A. B. Metal Products Ltd., manufacturers of Clarostat controls and resistors, whose new address is Walkden House, Melton Street, Euston Square, London, N.W.1, have appointed Heinz Michalski, Myliusstrasse 54, Leverkusen 3/Rhld, to represent them in Western Germany.

Anglo-Canadian Agreement.—Television broadcasting equipment manufactured by E.M.I. will be distributed and serviced in Canada by the Canadian General Electric Co.

MARCH MEETINGS

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

LONDON

1st. I.E.E.—" Digital computer developments at Manchester University " by Dr. T. Kilburn (with supporting papers) at 5.30 at Savoy Place, W.C.2.

1st. Association of Supervising Electrical Engineers.—" Silicone rectifiers " by D. R. Coleman (S.T.C.) at 7.30 at Windsor Castle Hotel, 134 King Street, Hammersmith, W.6.

3rd. Brit.I.R.E.—" Time sharing in on-line computer applications " by A. St. Johnston at 6.30 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

4th. I.E.E.—Medical Electronics Group discussion on " Direct writing oscillographs " opened by A. J. Smale and S. N. Pocock at 6.0 at Savoy Place, W.C.2.

7th. I.E.E.—" An introduction to the theory of masers with particular reference to the travelling-wave maser " by Dr. P. N. Butcher at 5.30 at Savoy Place, W.C.2.

7th. Society of Instrument Technology.—" Data reduction for guided weapon trials at Aberporth " by A. S. Younger, G. C. Morgan and E. S. Mallett at 7.0 at Manson House, 26 Portland Place, W.1.

9th. Association of Supervising Electrical Engineers.—" Cathode-ray tubes " by C. H. Gardner (Mullard) at 7.45 at Eltham Green School, Queenscroft Road, Eltham, S.E.9.

10th. Physical Society.—" Electronic music " by Dr. J. Bowsher at 5.30 at Imperial College, Prince Consort Road, S.W.7.

11th. Television Society.—" Television receiver production " by S. T. Palmer (G.E.C.) at 7.0 at the Cinematograph Exhibitors' Association, 164 Shaftesbury Avenue, W.C.2.

14th. I.E.E.—Discussion on " Should engineers be encouraged to take up administrative positions early in their careers? " opened by K. E. Greene at 6.0 at Savoy Place, W.C.2.

14th. Brit.I.R.E.—Discussion on " Short-range navigational aids " at 6.30 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

15th. British Computer Society.—" Axis transformation using analogue equipment " by N. Doveton (E.M.I.) at 2.30 at the Northampton College of Advanced Technology, St. John Street, E.C.1.

15th. I.E.E.—" Fast-response transistor chopper-type amplifier with low carrier frequency " by I. C. Hutcheon and D. Summers at 5.30 at Savoy Place, W.C.2.

18th. B.S.R.A.—" Problems of reviewing tuners " by R. S. Roberts at 7.15 at the Royal Society of Arts, John Adam Street, W.C.2.

23rd. I.E.E.—" The challenge of the propagation medium to the radio engineer " by G. Millington at 5.30 at Savoy Place, W.C.2.

24th. Brit.I.R.E.—" The continuous recording of heart activity " by Dr. I. Boyd and W. R. Eadie at 6.30 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

24th. Television Society.—" Operating a commercial television station in the U.S.A." by J. H. Battison (Associated Rediffusion) at 7.0 at 164 Shaftesbury Avenue, W.C.2.

25th. R.S.G.B.—" High-fidelity sound reproduction for the amateur " by H. A. M. Clark at 6.30 at the I.E.E., Savoy Place, W.C.2.

28th. Radar & Electronics Association.—" Computers: some design problems " by Peter D. Hall (Ferranti) at 7.30 at the Royal Society of Arts, John Adam Street, W.C.2.

29th. Society of Instrument Technology.—" Application of transistors in instrumentation " by G. G. Bloodworth at 7.0 at 26 Portland Place, W.1.

30th. Brit.I.R.E.—" Silicon photovoltaic cells for instrumentation and control applications " by Dr. V. Magee and Dr. A. A. Shepherd at 6.30 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

31st. I.E.E.—The Fifty-first Kelvin Lecture on " Cosmic radiation " by Professor C. F. Powel at 5.30 at Savoy Place, W.C.2.

ARBORFIELD

21st. I.E.E. Graduate and Student Section.—" Inertial navigation systems " by Wing Commander E. W. Anderson at 7.0 in the R.E.M.E. Assembly Hall.

BARNSLEY

16th. I.E.E.—" The reliability and life of impregnated-paper capacitors " by J. P. Pitts at 7.0 at the Arcadian Restaurant.

BELFAST

8th. I.E.E.—" The recognition of moving vehicles by electronic means " by T. S. Pick and A. Readman at 6.30 at the David Keir Building, Queen's University, Stranmillis Road.

BIRMINGHAM

8th. Brit.I.R.E.—" Transistor power amplifiers " by F. Butler at 7.15 at the Matthew Boulton Technical College.

11th. Society of Instrument Technology.—" Reading with electronics " by I. Merry at 7.0 in the Lecture Theatre of the Byng Kendrick Suite at The Gosta Green College of Technology, Aston Street.

28th. I.E.E.—" Television on tape " by W. Silvie at 6.0 at the James Watt Memorial Institute.

BRISTOL

30th. Brit.I.R.E.—" Training for operating and maintaining television studio broadcasting equipment " by Dr. K. R. Sturley and A. E. Robertson at 7.0 at the School of Management Studies, Unity Street.

BRADFORD

10th. Association of Supervising Electrical Engineers.—" H.F. heating " by M. R. Padget (Radyne) at 7.30 at The Midland Hotel.

CARDIFF

16th. Brit.I.R.E.—" Recent developments in printed and potted circuits " by H. G. Manfield at 6.30 at the Welsh College of Advanced Technology.

CATTERICK

29th. I.E.E.—" Progress on problems in ionospheric propagation during the International Geophysical Year " by W. R. Piggott at 6.15 at Headquarters Mess, School of Signals, Catterick Camp.

CHELTENHAM

4th. Brit.I.R.E.—" The use of radio aids in the control of modern transport aircraft " by K. Fearnside at 7.0 at the North Gloucestershire Technical College.

COLCHESTER

11th. Institution of Production Engineers.—" Numerical control of machine tools from the production engineer's point of view " by O. S. Puckle at 7.30 at Britannia Works Canteen, Davey Paxman & Co., Ltd.

DUBLIN

10th. I.E.E.—" Aviation communications and navigational systems " by G. E. Enright and G. Jones at 6.0 at the Physical Laboratory, Trinity College.

EDINBURGH

25th. Brit.I.R.E.—" Radio guidance in the automatic landing of aircraft " by J. Shayler at 7.0 at the Department of Natural Philosophy, the University, Drummond Street.

FAWLEY

4th. Society of Instrument Technology.—" Transistors as applied to control equipment " by R. J. Miles at 5.30 at the Administration Building, Esso Refinery.

GLASGOW

24th. Brit.I.R.E.—" Radio guidance in the automatic landing of aircraft " by J. Shayler at 7.0 at the Institution of

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Engineers and Shipbuilders, 39 Elmbank Crescent.

HANLEY
8th. I.E.E.—Faraday Lecture on "Electrical machines" by Professor M. G. Say at 7.30 at the Town Hall.

HULL
31st. I.E.E.—"Recent developments in colour television" by I. J. P. James at 6.30 at the Y.E.B. Offices, Ferensway.

LEEDS
1st. I.E.E.—"The transmission of news film over the transatlantic cable" by C. B. B. Wood and I. J. Shelley at 6.30 at the Leeds and County Conservative Club, South Parade.
7th. Association of Supervising Electrical Engineers.—"Two-channel stereo sound systems" by D. Humphries and F. H. Brittain (G.E.C.) at 7.30 at the Great Northern Hotel.

LIVERPOOL
10th. I.E.E.—Faraday Lecture on "Electrical machines" by Professor M. G. Say at 6.45 at the Philharmonic Hall.

MALVERN
7th. I.E.E.—"Masers" by Dr. M. H. Oliver at 7.30 at the Winter Gardens.
29th. Brit.I.R.E.—"Microwave propagation" by M. W. Gough at 7.0 at the Winter Gardens.

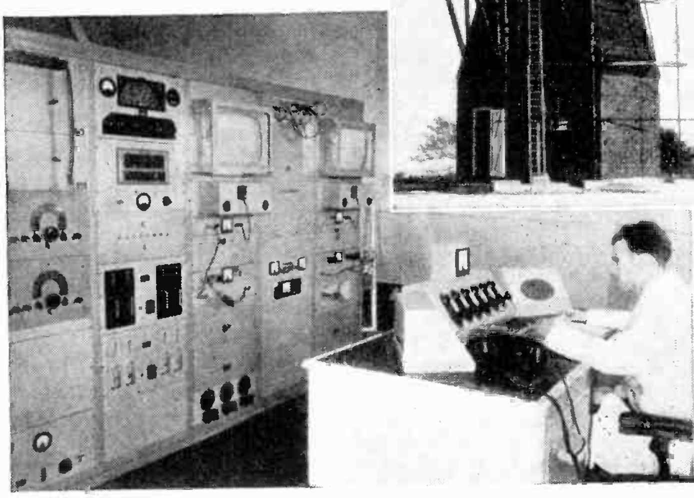
MANCHESTER
3rd. Brit.I.R.E.—"Electronics in oceanography" by M. J. Tucker at 6.30 at Reynolds Hall. College of Technology, Sackville Street.
16th. I.E.E.—"Data processing" by J. C. Gladman at 6.15 at the Engineers' Club, Albert Square.
21st. Institute of Physics.—"Astronomical and atomic time" by Dr. L. Essen (N.P.L., Teddington) at 7.0 at the University.

NEWCASTLE-ON-TYNE
9th. Brit.I.R.E.—"Silicon photovoltaic cells in instrumentation and control" by Dr. A. A. Shepherd at 6.0 at the Institution of Mining and Mechanical Engineers, Neville Hall, Westgate Road.
14th. I.E.E.—Discussion on "Component reliability" at 6.15 at the Rutherford College of Technology.

SHEFFIELD
21st. Institution of Production Engineers.—"Electronic control mechanism" by O. S. Puckle at 6.45 at the Devonshire Room, Grand Hotel.

WORKINGTON
8th. I.E.E.—"The reliability and life of impregnated-paper capacitors" by J. P. Pitts at 7.0 at Workington College of Further Education.

REDIFFUSION.—A variety of aerial arrays sprout from Ripple Mill, near Deal, Kent, for it is now used by Rediffusion as a receiving centre for its sound and vision distribution system in the area. Two Band I aerials and a Band II aerial surmount a corner reflector array for Band III. Until the opening of the Dover station I.T.A. transmissions were received from London by means of a microwave link (the paraboloid can be seen on the out-rigging) from another reception site at Thanet, 20 miles away. The control room is housed in the mill.



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RANDOM RADIATIONS

By "DIALLIST"

The Colour Mix-up

QUITE a bit more evidence has come my way about different kinds of apparatus imported from West Germany, whose triple flex leads don't conform to our standards. One kind reader reports electric clocks with the red wire connected to the metal cases. From others and from dealers whom I've visited have come tales of spin-driers, food-mixers and other domestic gear with red earth wires. I therefore make no apology for mentioning the matter again. The risk is great, for if any of this apparatus were connected according to British conventions to a 3-pin plug, a severe shock would inevitably be received by anyone who touched the casing. And that's just what people *would* do when the thing didn't function—as, of course, it wouldn't with its "works" connected across neutral and earth. It's almost instinctive when nothing happens after switching on to get hold of whatever it may be to see what's amiss. I do beg anyone who contemplates buying apparatus of foreign origin to make sure that it's not potentially lethal by getting the dealer to test for continuity between the green wire and the casing. If possible, he should insist on seeing it tried out in the shop.

A Spectacle Question

AN optician, I read, has suggested that special glasses are advisable for watching TV. If he's correctly reported, he holds that the normal viewing distance is about six feet and that that doesn't fit in with either reading or distance glasses. The former normally focuses at about 14 inches; the latter's name is self-explanatory. I suppose that the screen most widely used today is the 17-inch and the minimum viewing distance for that is a good bit over six feet. I've worn glasses for some years now and my experience is that so long as you don't sit too close to the screen, distant lenses give you as good a picture as you could wish for from a 405-line system. Have your eyes too close to the screen and you get undue lininess. Anyone who wants to watch a 17-inch screen with glasses focusing sharply at six feet needs to have not his eyes, but his head examined!

Piped TV

THE G.E.C., I see, is to take a financial and technical interest in General Piped Television, which intends to provide services in places where poor reception is obtained in the ordinary way. One of the strong points of this and similar schemes is that any make of receiver can be used. "The new service," it was said, "finishes at the plug-in point." I've always been in favour of piped TV for several good reasons. First, it does away with the necessity for aerial arrays, which can't be claimed by anyone to add to the good looks of houses. Then, it means that good reception is assured. It's a great thing to be sure at all times of a good picture, free entirely from the effects of interference. And I do like the idea that you can choose any kind of receiver you care for, for that means a free hand not only for set owners, but also for manufacturers and dealers. Piped TV has expanded rapidly since it first came along, though there has been some opposition to systems requiring special receivers. I forecast that "any-set" piped services will spread over much of this country in the next few years.

We Did It First

THE Germans are a little late with their claim that the *Medizinische Tonbandzeitung* (*Tape - recorded Medical Journal*) conducted by the Kongressgesellschaft für Arztliche Fortbildung, or congressional society for medical advanced studies, is the first of its kind in this field. Our British College of General Practitioners has been running a tape-recorded service for its members for some time now. The college organizes lectures and discussions to keep G.P.s up to date with the latest developments. These are normally held in London, and any country doctors who are unable to attend them can obtain the tape-recordings on loan. It would be no bad thing if some other institutions adopted a similar system, for many of their members can't always manage to get to meetings that they'd like to attend and might appreciate such a service.

Gale Casualties

ON the East Coast this winter we've had even more than our normal ration of gales and casualties among television and v.h.f. aerial arrays, especially those of the less-robust makes, have been many. From the window of the room where I'm writing I can see three which have suffered. One looks like a com-

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plete write-off, another has lost one half of its director and the opposite half of its reflector; the third is pretty bady buckled. That sort of thing is, I suppose, only to be expected, for some of the gusts have been terrific—strong enough to make it difficult to keep on your feet when you are out and about. What I'd like to have is a ferrite aerial mounted in the attic. One knows how effective built-in ferrite aerials can be; but the trouble with them, if you use your set in a ground-floor or first-floor room is that they pick up a good deal of interference which you don't want as well as the signals which you do want. So far as I know, no maker has produced a compact ferrite aerial working at high enough frequencies, though I don't see why in time it couldn't be done. I'm sure there would be a good demand for them in exposed, windy places if they were available.

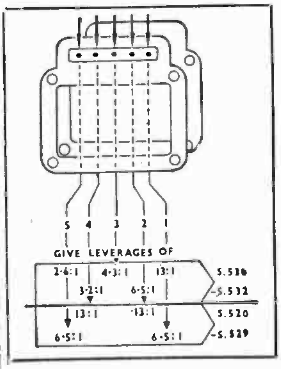
Well Equipped

WHEN the fitting out of the recently launched Orient Line's s.s. *Oriana* is completed a bit later in the year she will be the most fully equipped passenger ship in the world from the television point of view. Her Marconi installation will enable her to receive programmes on Band I and III from transmitters in almost any part of the world when she's within their range, for it can handle 405-, 525- and 625-line signals. I write "almost any part of the world" because it won't handle the French 819-line pictures—still, one can't expect everything! Dual standard receivers for 525 and 625 lines will be installed in public rooms and first-class cabins. Incoming 405-line signals will be converted to 625 lines in the ship's central TV control room. Where alternative programmes are available passengers will be able to switch from one station to another. There'll be 60-odd sets to begin with, but the number can later be increased to nearly 400 without any basic alteration. And there will also be TV available for those who want it when the ship is beyond the range of transmitters ashore, for she will have a comprehensive closed-circuit installation. This will enable films chosen from the ship's extensive library of reels to be used and it will also make live TV broadcasts possible—simple studio sequences, interviews and so on. Dare I say that I hope there'll also be TV-free rooms, to which those who want a holiday from the daily ration of television at home can retire?

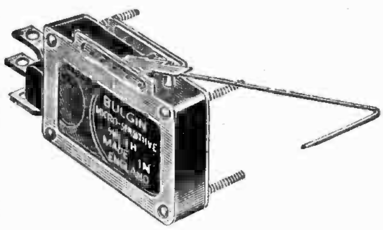
"THE CHOICE OF CRITICS"

BULGIN

"M" TYPE MICRO SWITCHES



To increase the utility of the large range of "M" Micro Switches (*full technical details page* 97 *of Bulgin Catalogue*) we offer six different Operator Attachments. Each operator is complete with a pair of side brackets, and four 8-B.A. bolts and nuts, for the sandwiching assembly and fixing. Each operator-lever can be pivoted in its brackets, in up to 5 different ways; providing over 750 **possible combinations**! Side brackets are of brass and barrelled-nickel-plated; Operators-levers are nickel-silver blades. The rollers and wire extensions are as tabled. Patented by **BULGIN** in the U.K. and **U.S.A.** All the devices on this page are essential when operating movement is by wiping or smearing motion—as with Cams or Slides, and not by direct button movement. **NOTE:** Wipe, or slide-deflexion to be *away* from Lever-anchorage or pivoting.



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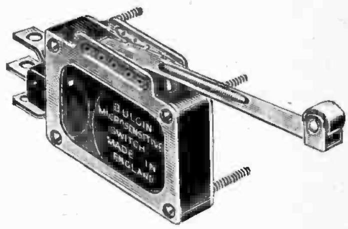
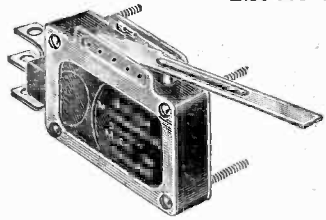


List No. XXX/L/R-G to L/R-P

For

Tape Recorders
Film Projectors
Sorting Machines
Weighing Machines
Dictating Machines

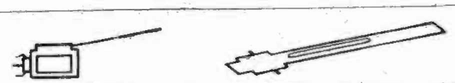
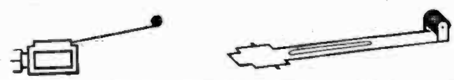


List No. XXX/L

For

Electric Clocks
Vending Machines
Document Copiers
Product Counting
Printing Machinery

COMPETITIVE PRICES ON APPLICATION

Add suffix to List No. of Switches	TO OBTAIN EXTERNAL OPERATOR :—
Stainless Steel Wire –/W	
Nickel-silver blade –/L	
–/L/R.G.* –/L/R.B.* –/L/R.SS.* –/L/R.P.*	

*Having **GRAPHITE, NICKEL-PLATED, BRASS, STAINLESS STEEL and TUFNOL (PLASTIC) ROLLERS**, respectively. **Note:** Operators may also be reversed to project towards terminal tags.

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UNBIASED

By FREE GRID

Pædiatric Peepboxes

IN the Building Exhibition which was held at Olympia last December, one of the exhibiting firms provided what was called "a glimpse into the future"—in which various domestic applications of television and telearchics were shown. I must confess, however, that I did not see a great deal beyond an elaboration of things that have already been done in simpler form.

Thus the famous and now ubiquitous Baby Alarm, which first appeared in the Readers' Problems section of this journal well over thirty years ago, has now been elaborated into a closed-circuit television outfit; but I award full marks for it.

TV in the bathroom is, of course, something I installed long ago and described in these columns. I seldom use it as I always feel uncomfortable when a female television announcer gazes at me from the screen as I lie full length in the bath. Perhaps a psychiatrist could explain this.

The photograph with which I illustrate this note is of the actual bathroom television installation shown at Olympia. To forestall enquiries I would hasten to add that the YL demonstrating the apparatus is unknown to me. The photograph came from the exhibitors, Laconite, Ltd., manufacturers of the wall surfaces, with whom you should communicate if you want further information about her or the unit.

This electronic baby-watching craze seems to have spread to the world of bowling alleys, for in the one opened recently in North London a closed-circuit pædiatric peepbox has been installed by Pye, Ltd., to enable parents to keep an eye on their children parked in an adjoining room. The 625-line camera is remotely controlled so that general views of the nursery or close-ups of individual children can be seen in the bowling alley where there are two 21-in monitors.

Not Dead Yet

A FEW weeks ago, a B.B.C. speaker warned listeners of the danger of going to sleep with an electric blanket switched on, especially after taking sleeping tablets. I have done both these things without coming to any harm for over thirty years, but, be that as it may, my reason for mentioning the matter is because of the interference caused by the older type of blanket.

In publicizing this warning the B.B.C. really fouls its own nest since, by inference, it is obviously intended that the blankets should be switched on early in the evening; in other words during the peak listening hours when the clicking on and off of the unsuppressed thermostats of the older type of blanket will provide an irritating background to the programmes.

Of course, this clicking interference is not nearly as bad as it was 24 years ago when I made my first protest about it in these columns. It was so bad during the war years that I always thought that, despite the blackout, Hitler's bombers would know when they were over a large city because of the ambient cloud of clicks which "blanketed" each large centre of population. Doubtless the bombers' radio operators were briefed to keep a special look out for these betraying signals. As so many of our pre-war blankets were of German origin, it is probable that the far-seeing Führer gave instructions for special interference-producing thermostats to be fitted to all those intended for export.

Be that as it may, it is clear that the B.B.C. speaker regards the heat-regulatory thermostats of modern electric blankets as so unreliable that they will not cut out at the pre-set temperature, with the result that the sleeping user will roast in his bed. During 30 years I have tried out many types and will admit that on one occasion I did find that a thermostat let me down. But despite my sleeping tablet, the undue warmth soon roused me.

Nowadays, of course, blankets are far more reliable. The one I use at present is not fitted with a thermostat, it being of a type supplied for every bed in a well-known hospital for the very purpose of being left switched on continuously.

The B.B.C. speaker may, of course, have envisaged a lethal shock being received by a sleepy wife upsetting the early-morning cup of tea brought up to her by a dutiful husband, which could effectively reduce the contact resistance between her torso and any faulty insulation in the blanket. What a suggestion for a henpecked husband toying with the idea of lawproof uxoricide! However, the heater element of a modern blanket is waterproof as well as fireproof; one firm even invites you to test their product by dropping it in the bath. But nervous people *do* exist, and I think the B.B.C. might have pointed out that it is possible to buy a 24-volt blanket for use with a transformer on a couple of car batteries.

Closed-circuit TV from the front and back doors (with intercom. facilities) and a B.B.C./I.T.A. receiver are incorporated in this bathroom outfit.

Babelissimo

JUST forty years ago I recollect standing on the summit of what was then America's tallest structure, namely the 792-foot-high Woolworth building. One of the officials of the building pointed out to me with pride how puny the 612-foot Singer building and other neighbouring skyscrapers looked beside the structure which its owner had fancifully called "The Cathedral of Commerce."

I tried to deflate his ego by pointing out that America was still nearly 200 feet behind Europe with its 984-foot Eiffel Tower which, apart from its other functions, was then the tallest radio mast in the world. I was, however, reckoning without the resiliency of Americans as he was in no way abashed, but promptly prophecied that the U.S.A. would soon have a radio mast far higher than any in Europe.

It was a wild boast that came true not so many years afterwards when a radio mast was erected on the Empire State Building making the overall height 1,250-feet above the sidewalk.

When the height of the mast at the recently opened I.T.A. station at Mendlesham, Suffolk, was announced (1,000ft) it was thought to be the tallest in Europe. However, Sweden justifiably lays claim to this "honour," for the mast carrying the television and v.h.f. sound aerials for the new Hörby station is 320 metres (c.1,050 ft.).

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