Wireless World

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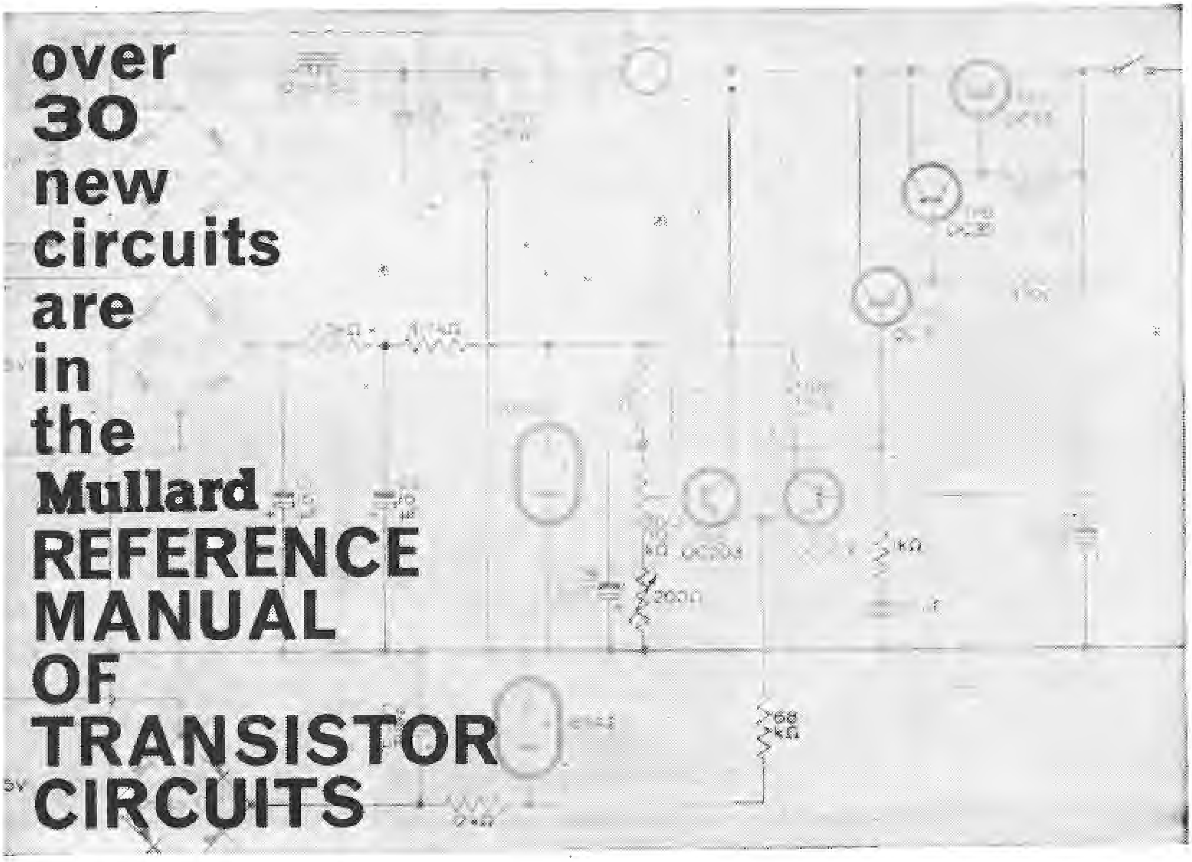

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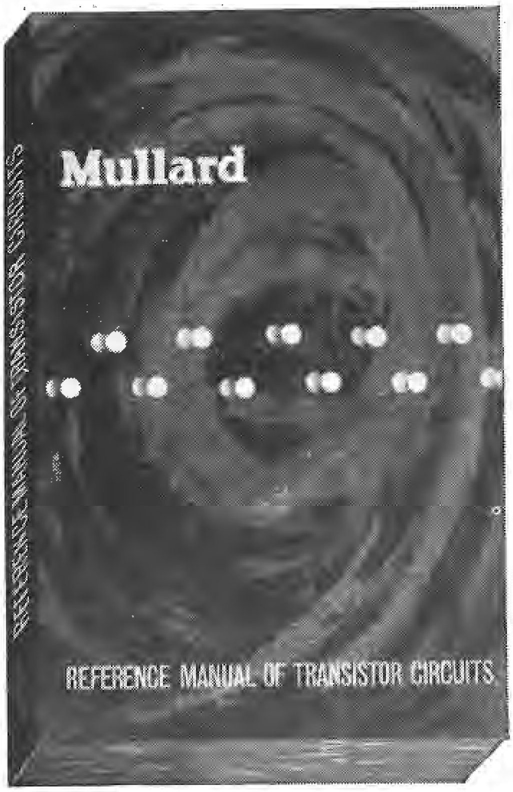

This manual of transistor circuitry has been prepared by Mullard engineers, as an up-to-date and readable volume which will be of use and interest to technicians, service engineers, junior designers and electronics students.

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Wireless World

VOL 68 NO. 4 APRIL 1962

A Television University?

DISCUSSION of the potentialities of television for education, and the reflex benefits of educational programmes in sustaining or reviving interest in the possession of a television receiver has been widespread in recent months, and has figured in many of the proposals which have been submitted to the Pilkington committee. Although the "programme" side of broadcasting is not our primary business, technical problems are often inextricably involved, and we all have an interest in education, whether it be narrowly technical or widely liberal. This was our justification for commenting on the role of education in television (and vice versa) in our August 1961 issue. Our reason for returning to the subject is to support Dr. R. C. G. Williams' proposal for the establishment of a television university.

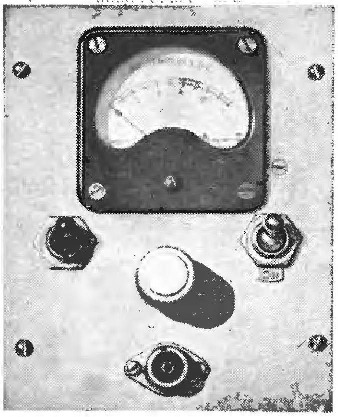
Dr. Williams who is Chief Engineer of Philips Electrical Ltd. and a past chairman of the Electronics and Communications Section of the I.E.E. is not a professional educationist, but is vitally interested, as are most of us, in the future supply of trained scientists, engineers and technicians in this country. He points out that the building and staffing of the ten or more new universities which will be needed to put us on a comparable footing with other industrial nations will take time and may still prove to be inadequate in securing the penetration of higher education throughout the population in sufficient depth; particularly in reaching those "late starters" who for one reason or another have not been able to adhere to the normal timetable.

Specifically, Dr. Williams proposes that one of the new universities should be entrusted with the task of developing the methods of television education. In addition to being a residential academic centre for about 3,000 students it would "build into the foundation the concept of extramural education by television, perhaps with a faculty specifically exploring the best way in which this could be done." Dr. Williams suggests, for example, that tutorial classes with a "live" audience in the lecture theatre, asking the questions that they themselves would like to ask, might be broadcast. The necessary finance for such an enterprise could come from Government sources and might be supplemented by advertising revenue from employers who could contribute programmes showing the opportunities open to qualified applicants in their industries.

We are entirely in agreement with Dr. Williams in thinking that the potentialities of television as a medium for education are vast and have as yet been only tentatively exploited. Too much valuable programme time has in the past been squandered on what might be termed the fantasies of the "wonders of science." That is not to deny the value of the romantic approach in stimulating first interest, but it should be quickly followed by a glimpse of some of the difficulties and of the active participation (hard work) inherent in studying for qualification and practising as a professional. But if some educational films have failed we have, on the other hand, seen excellent examples of the value of the mobility of the television camera which has taken us into many specialized research laboratories which could otherwise be visited by only a small proportion of the total number of students at present distributed among the universities of the country. The camera has also brought us all face to face with some of the finest scientific expositors, whose personality could otherwise have influenced only a few students in particular colleges or institutions.

It is for these reasons that we would not like to see the "University of the Air" tied to one establishment. Every university should give thought to the contributions which it might make to television education and an independent body or bodies should be given the task of assessing all available resources and co-ordinating the best into a "master course." Such a course or courses would be of a quality which would find universal acceptance as a foundation for discussion between teacher and pupil, just as at present much university teaching is based on the reading of standard textbooks, the setting of test questions and the guidance which the students' answers give to the teacher in finding out the difficulties of understanding.

Is there a danger that mass instruction of the kind proposed for television, however good, may produce a stereotyped outlook and a lack of originality in future graduates? That need not be so if the number of channels available will allow alternative courses and if these courses are regarded as a foundation and not as a substitute for the continuous processes of learning by discussion either with professors or demonstrators in a university or later with colleagues in a learned society.



Transistor voltmeter showing range switch on left, on-off switch on right, and zero-set control in centre. R.f. input is to coaxial socket.

Simple Transistor Voltmeter

By H. B. DENT

R.F. TEST METER COVERING 0.1V TO 8V R.M.S.

REQUIRING a simple r.f. voltmeter for plotting response curves of some experimental i.f. transformers for a transistor receiver, the opportunity was taken to investigate the potentialities of a transistor voltmeter for the purpose. That an instrument of this kind could be made conveniently small and entirely self-contained enhanced the attractiveness of the test meter for general use in the future.

The circuit employed is shown in Fig. 1, from which it will be seen that it follows well-tried practice in valve voltmeters of a similar kind in that it consists of an r.f. rectifier, d.c. amplifier and a backing-off circuit to balance out the "no signal" or standing collector current. The function of the last-mentioned network is to ensure that the meter reads only the changes in collector current with input signal so that the full length of the meter scale is available.

So far only two voltage ranges have been employed, resistor R_1 of 33kΩ providing a full-scale meter deflection for an input of 0.8V r.m.s., while R_2 of 470kΩ extends the range to 8V r.m.s. These resistance values arise from the type of meter used and the characteristics of the diode D1 and the transistor. The smallest initial deflection that can reliably be read on the meter, with the smallest input voltage required to be measured, is also a contributory factor.

A 0-1mA meter was the only low-range indicator available at the time the instrument was conceived and although it is only a small 2¼-in square type it has the advantage of being fitted with a finely-graduated scale of 50 divisions and a pointer which enables changes of 0.01mA to be easily determined. Whilst a larger meter with a longer scale and knife-edged pointer would no doubt be more suitable, the expense of acquiring a new meter was considered unjustified in the present case, as only occasional use is made of test gear of this kind in a home laboratory.

Although a pointer deflection of half a division is readily detectable on the meter it is known from past experience with the circuit of Fig. 1 in valve-voltmeters that the sensitivity is inclined to be poor with very small input voltages. Therefore it was decided to make a meter deflection from zero of one scale division, or 0.02mA, represent an r.f. input of 0.1V r.m.s. Experiment showed that the resistor R_1 would have to be about 33kΩ to satisfy this requirement. The full-scale meter deflection thus proved to be 0.8V r.m.s. approximately.

Since decades are nice convenient ratios it followed that Range 2 should have a f.s.d. reading of 8V r.m.s. for which a 470kΩ resistor was needed.

An overall voltage range of 80 to 1 may not seem very large, but it represents 38dB in voltage; and so far has been found to satisfy most of the writer's requirements for this voltmeter. However, an additional range or ranges can easily be added, but the voltage-handling capability of the rectifier diode D1 must be borne in mind.

Readers of this journal may recall the "Transistorized Absorption Wavemeter" described by G. W. Short in the April, 1959 issue, in which instrument an OC71 transistor was employed as an amplifier, and where it was explained that improved sensitivity can be obtained with very small inputs by moving the working point of the transistor from the foot of the base-collector (transfer) characteristic to a point well up the curve, where the slope is steeper and far more linear. The sign of the input voltage to the transistor is reversed and increase in input depresses the collector current so that the meter registers in a "backward" direction.

Whilst giving higher sensitivity to small inputs this mode of operation would be of doubtful advantage for plotting tuned-circuit response curves. The part of the curve providing the essential information is usually not where voltages are low but where they

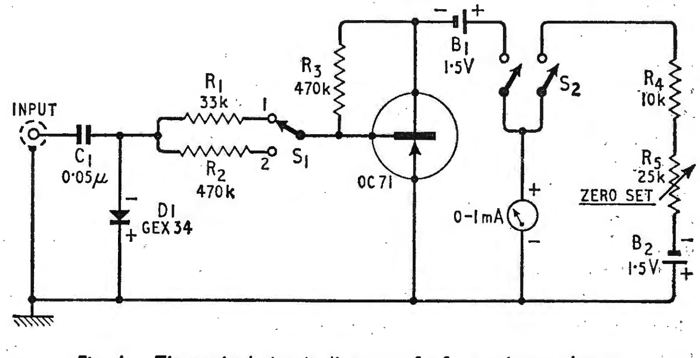


Fig. 1. Theoretical circuit diagram of r.f. transistor voltmeter.

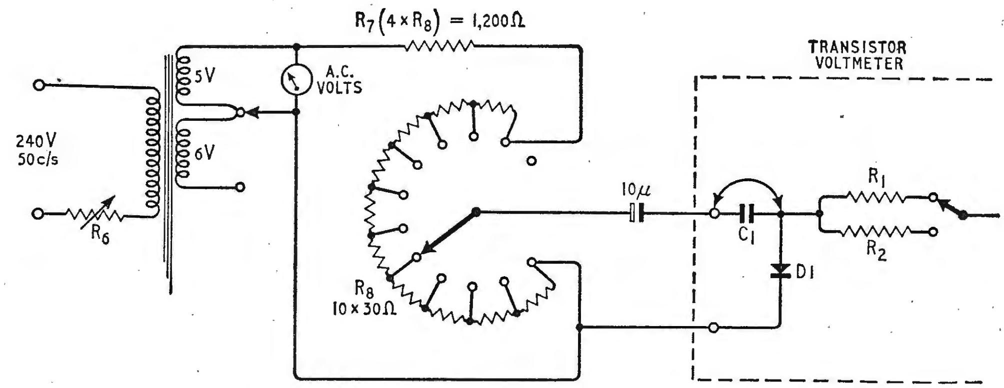


Fig. 2. Circuit arrangement of set-up used for calibrating transistor voltmeter.

are high. It is around the resonant frequency that this condition obtains and it is here that the voltmeter should be most sensitive to small changes in voltage.

When the meter is switched on, the idling time, that is to say the time during which no readings are taken and no input is applied, is usually far longer that the actual working periods, so it is more economical in battery power to have the lowest possible idling current. In the circuit described the idling current is approximately only 80μA. As the average power dissipated in the transistor is therefore small the zero stability should be quite good, and the customary precautions to combat thermal run-away are not applied.

The construction of the instrument hardly needs comment as any convenient form and layout are permissible. In view of the very small current drain imposed on the battery there seemed no point in needlessly increasing it some hundredfold by fitting an "ON" indicator lamp.

Calibration: As calibrating the voltmeter was effected without the aid of a similar instrument for direct comparison the method employed might be of some interest. Facilities were available for measuring 50c/s voltages from a few volts upwards so it was decided to use a 50c/s supply for the purpose. However, this introduced some initial difficulties as the voltmeter is intended for r.f. measurements only and in its present form is not suitable for audio or mains frequency measurements.

Owing to the rather low input impedance of the voltmeter, especially on Range 1, the reactance of the blocking capacitor C_1 (Fig. 1) cannot be ignored at frequencies where it amounts to more than about one hundredth of R_1, to take an arbitrary figure. Alternatively, C_1 can have a sufficiently large capacitance to render its reactance negligible at any frequency above say 30c/s.

To comply with this requirement at 50c/s, for example, C_1 needs to be at least 10μF, which is an impracticable value for general use in the instrument owing to the high time constant involved. A capacitor of this value may, however, be employed for calibrating the voltmeter as sufficient time can always be allowed between readings for conditions to stabilize. No difficulty arises with increments of input voltage, but on falling voltages adequate delay time is necessary before a reading is taken. As calibration was carried out with increasing voltages this trouble did not manifest itself.

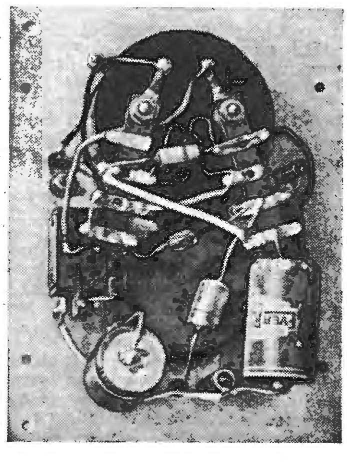
If now calibration is effected with a 10μF capacitor at 50c/s, and for practical applications it is replaced by one of a value which does not introduce undesirable effects, the voltmeter should behave in a rational manner. It only remains to find a capacitance which fulfils these requirements and this was found to be about 0.05μF.

As an example of the effect of the input capacitor at 50c/s, one of 10μF gave a meter deflection on Range 1 of 0.98mA for an input of 0.8V r.m.s. but when replaced by one of 0.05μF the meter reading fell to only 0.17mA for the same input voltage. On Range 2, with 8V r.m.s. input, the meter read 0.92mA but dropped to only 0.66mA with the smaller capacitor.

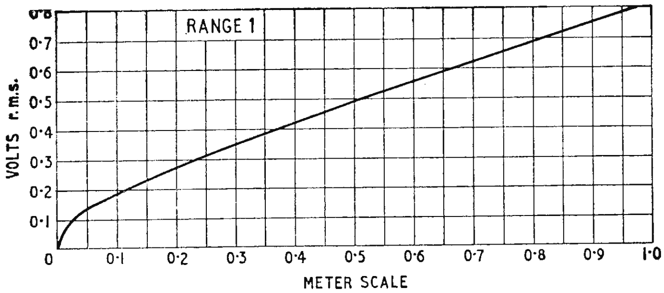
It is obvious there will be some frequency at which the 0.05μF capacitor might be expected to give comparable readings on the meter as one of 10μF at 50c/s and this frequency is arbitrarily put at 100kc/s on Range 1, at which frequency the reactance of 0.05μF simulates that of 10μF at 50c/s.

At frequencies above 100kc/s the voltmeter readings will be a little higher for a given input voltage than the calibration figure, but the errors are felt to be too small to be worth worrying about.

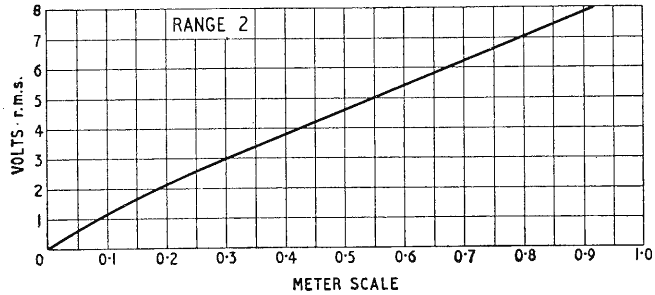
The calibration set-up is shown in Fig. 2. A standard mains transformer having 5V and 6V windings was employed, and a wire-wound variable



All components of transistor voltmeter are mounted on underside of cover plate.



Calibration curves of Ranges 1 and 2 of transistor voltmeter.



resistance connected in series with its primary and the mains to enable the output voltages to be adjusted to an exact value as measured on the 50c/s voltmeter. Unless a high precision voltmeter is available, it is unlikely that alternating voltage readings of the order of 1V will be reliable, but those of the order of 5V and higher can usually be fairly reliable. Therefore, 5V was used for calibrating Range 1, this voltage being applied to an accurately calibrated resistor or R_8 (Fig 2) with an equally accurate resistor of four times the value of R_8 in series. This is shown as R_7. Each tapping on R_8 provides an output of 0.1V r.m.s. which should be reasonably accurate. If R_7 and R_8 are carefully made the incremental outputs from R_8 should all be exactly equal so that even if the acutal voltages are not exactly 0.1V (which would perhaps be too much to expect) at least the relative measurements on the transistor voltmeter will be as reliable as can be expected under the circumstances.

For calibrating Range 2 of the voltmeter the 5V and 6V windings are joined in series and correctly phased to give added voltage. The full output voltage is applied to the decade only, R_7 in Fig. 2 being omitted and the 50c/s voltmeter connected across the two series-connected windings. The decade windings must be sufficiently robust to carry the higher current, where the 10V (or 11V if preferred), are applied direct to R_8. The total resistance of the decade R_8 should be high enough to keep the current within reasonable bounds.

The writer used a home-made decade of 300Ω total, each section having a resistance of 30Ω. It was constructed and measured in the manner described by the writer in the April, 1960, issue of *Wireless World* ("Simple Wheatstone Bridge").

Accuracy: It is difficult to assess the real accuracy of this method of calibration as so many factors are involved. The principal ones, however, are the accuracy of the a.c. 50c/s voltmeter and of the resistances R_7 and R_8 in Fig. 2. Reading errors of both meters contribute their quota. However, for taking i.f. transformer response curves the voltages that really count are relative ones only. If R_8 (Fig. 2) is an accurate decade resistance this requirement can be satisfied as the small changes in frequency usually entailed are too insignificant to be affected by the presence of C_1 (Fig. 1).

It should, perhaps, have been mentioned earlier that the meter (Fig. 1) has to be zero-corrected by R_5 when changing ranges. This defect, if such it can be called, is not easy to overcome and in any case will entail the addition of several more components, also possibly an extra diode and transistor, so that the added complication and expense is considered unjustified.

Commercial Literature

H.f. radio-telephone ("Mercury" by Pye) for 12 or 24V supplies gives 20W r.f. output on eight crystal-controlled frequencies in the 1.6-3.8Mc/s and 3.8-10Mc/s bands. The all-transistor receiver covers the m.w. broadcast band in addition to the transmitter bands and the transmitter is powered by a transistor convertor. Leaflet from Pye Telecommunications Ltd., Newmarket Road, Cambridge.

Headphones and headsets meeting climatic and durability requirements of the Ministry of Aviation and the Federal Aviation Agency are made by Amplivox. Sound insulating shells and liquid-filled ear seals protect the ear against high external noise levels and a built-in transistor pre-amplifier is available for three types of microphone mounted on the headset-boom. Leaflet from Amplivox Ltd., Beresford Avenue, Wembley, Middlesex.

Polytetrafluoroethylene (Fluon or Teflon) combined with glass-fibre reinforcement can be used for bearing surfaces and thrust discs. Cold flow is reduced but no significant increase in friction is caused by reinforcement. Leaflet from Crane Packing Ltd., Slough, Bucks.

Communications receiver Eddystone Type 840C includes international distress frequencies in its m.w. and 1.12-2.58 Mc/s ranges. Other ranges are 2.5-6.1Mc/s and 5.2-30Mc/s (in two bands). A.f power stage and loudspeaker are incorporated. Leaflet from Stratton and Co. Ltd., Alvechurch Road, Westheath, Birmingham, 31.

Experimental chassis construction using Lektrokit is described in a new handbook from A.P.T. Electronic Industries Limited, Chertsey Road, Byfleet, Surrey. A leaflet is included on the introduction of rack units, and resistor and capacitor decade boxes.

Relay EB, on octal base and weighing only 3.5ozs, can be operated up to 3,600 times per hour. Coil voltages are 24 to 220 a.c.: d.c. types are also available. Operate and release times are 8-10 msec. Details from Dewhurst and Partner Ltd., Hounslow, England.

Lead zirconate-titanate piezo-electric crystals for use in ultrasonic transducers are described in a booklet by the Brush Crystal Co. Ltd., Hythe, Southampton.

I.E.E./Brit.I.R.E. Collaboration

THE Councils of the Institution of Electrical Engineers and the British Institution of Radio Engineers have set up a Joint Committee "to suggest and to examine means by which, through collaboration between the two Institutions, the progress of electronic and radio engineering can be fostered, and to make recommendations for submission to the Councils of the two Institutions." The following representatives of the two Institutions constitute the Committee:

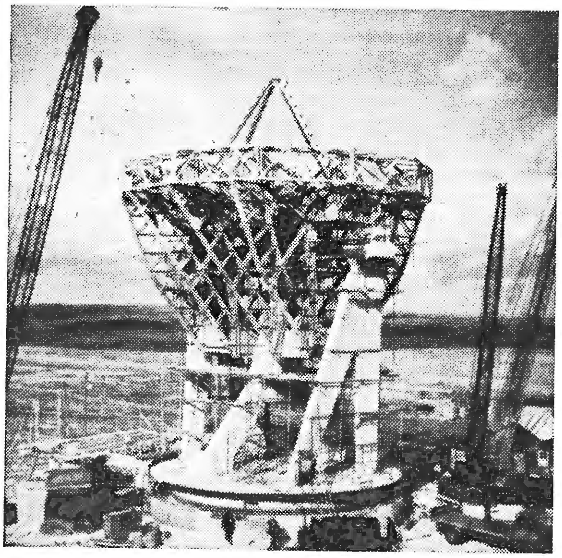
Brit.I.R.E.
L. H. Bedford, C.B.E., M.A., B.Sc., F.C.G.I.
I. Maddock, O.B E., B.Sc.(Hons.).
W. E. Miller, M.A. (deputy chairman).
Colonel G. W. Raby, C.B.E.

I.E.E.
Sir Harold Bishop, C.B.E., B.Sc.(Eng.), F.C.G.I.
R. J. Halsey, C.M.G., B.Sc.(Eng.), F.C.G.I.
Sir Hamish D. McLaren, K.B.E., C.B., LL.D. (chairman).
T. B. D. Terroni, B.Sc.

Space Communications

REPRESENTATIVES from 11 Commonwealth countries* are meeting in London from March 28th to April 13th to discuss the potentialities of satellites for Commonwealth telecommunications and also the problems associated with their use. The conference, which will be presided over by Sir Ronald German, director-general of the Post Office, will prepare a report for consideration by Commonwealth governments. The leader of the U.K. delegation of 40 members will be Sir Robert Harvey, deputy director general of the G.P.O., and the conference secretary, W. Stubbs, who is secretary general of the Commonwealth Telecommunications Board.

At the end of February, a two-day international meeting was held at Falmouth, Cornwall, to discuss the satellite projects Relay and Telstar. The ground stations to be employed for these transatlantic experiments later this year are Goonhilly Downs, Cornwall, Pleumeur-Bodou, North-west France, and Andover, Maine. The Post Office station at Goonhilly is being equipped with a steerable parabolic dish aerial and the other two stations with horn aerials of the type developed by the Bell Telephone Laboratories. Other stations are at Fucino, Italy, Nutley, U.S.A., and Rio de Janeiro, Brazil.



Framework for the support of the steerable paraboloid at the Goonhilly Downs satellite communications station which is being set up by the Post Office. The parabolic reflector will be 85-ft in diameter and 21-ft deep.

* Australia, Canada, Ceylon, Ghana, India, New Zealand, Nigeria, Pakistan, the Federation of Rhodesia and Nyasaland, Sierra Leone and the U.K.

Motorists' Radio Service?

A LOCAL broadcasting service giving on-the-spot road and traffic information for motorists was outlined by the Automobile Association in a memorandum to the Pilkington Committee on Broadcasting. It is pointed out that because of the localized nature of the information to be given, national or even regional broadcasting stations would be unsuitable, and it is therefore suggested that either local broadcasting stations (if established) or mobile stations should be used. The latter is envisaged as the most practicable as a station could then be brought into service for a few days in the vicinity of, for instance, the Farnborough air show, or an agricultural show. As "car radios in the v.h.f. band are not generally on the market in this country," it is suggested that very low-power medium-wave transmitters with a range of 10 to 12 miles should be used. The A.A.'s proposal includes the suggestion that music should be broadcast between transmissions of official announcements which would be made at specified intervals.

The British Institution of Radio Engineers has accepted an invitation to become a member society of the British Conference on Automation and Computation. Andrew St. Johnston and William Renwick have been appointed as the two representatives of the Institution on the B.C.A.C. Council.

Anglo-Soviet Trade.—Included in the £2.75M worth of Soviet capital goods to be imported into the U.K. during 1962 are radio and electronic components to the value of £75,000, of which not more than £15,000 is permitted for transistors. The quotas from both countries include scientific and industrial instruments, the value of the U.K. exports being £750,000.

Mullard Research Laboratories is to hold Open Days on July 4th, 5th and 6th, when each of its five divisions will show aspects of the extensive research programmes in physics, electronics and allied fields now being undertaken by Mullard.

Receiving Licences.—The number of combined television and sound radio licences in the U.K. increased by 35,941 in January, bringing the total to 11,693,445. The total of sound-only licences (3,595,098) includes 496,287 for sets fitted in cars.

"The Electroneers."—This new Mullard 20-minute colour film highlights the research, organization and knowledge behind the design and manufacture of special valves and tubes. Basically the film tells the life story—from prototype to production—of one special type of microwave valve called a travelling wave tube developed for multi-channel radio communications networks. At the same time it is also the story of the other three hundred and more equally specialized Mullard tubes and valves for applications ranging from radar and machine tool control to the measurement of minute electric currents. It will be available on 16mm stock for distribution to engineers in industry and government departments, educational establishments, radio and electronics societies and film societies.

"European Technical Digests."—This monthly publication contains independently written reports of selected articles published in about a thousand scientific and technical journals in 25 different countries. Main object is to give small- and medium-size industrial firms, which do not normally have access to foreign literature, easily digested information on recent developments in science and industry. *European Technical Digests* is published by the Organization for Economic Co-operation and Development, and is sponsored in the U.K. by the Department of Scientific and Industrial Research, 14-18 Cornwall Terrace, London, N.W.1. Annual subscription rate in the U.K. is £3 10s.

B.S.I. Changes.—The division of standard projects undertaken by the British Standards Institution has hitherto been handled internally within five sections. This number has now been increased to seven and some changes of the technical directorate have resulted. Among former senior technical officers now promoted to divisional chief technical officers are P. Bingley (electrical, telecommunications, acoustics, etc.), and J. Brown (data processing, instrumentation, etc.).

Cardiological Technicians.—The annual exhibition of cardiological apparatus, which is organized by the Society of Cardiological Technicians of Great Britain, will be held on October 26th and 27th at the Londoner Hotel, Welbeck Street, London, W.1. Further information is obtainable from Miss Margaret Hale, Cardiac Research Dept., Guy's Hospital, London, S.E.1.

The Society of Non-Destructive Examination is arranging to hold a conference in Cambridge, from July 20th-21st, on the theme: "The examination of thick sections." Further information may be obtained from the honorary secretary of the Society, H. L. Carson, Central Electricity Research Laboratories, Cleeve Road, Leatherhead, Surrey.

S.M.P.T.E. Convention.—The Society of Motion Picture and Television Engineers are to hold their 91st convention in Los Angeles from April 30th to May 4th, when the accent will be on advances in colour techniques and equipment. Papers on colour research work from several countries will be read, and E.M.I.'s U.S. Division are to show newly developed colour equipment.

A radio and television course covering theory and some practical work, and mainly intended for amateurs, is to commence on May 7th at the Wesley Evening Institute, Wesley Road, Stonebridge, London, N.W.10, from whence full details may be obtained.

Conference Date Change.—The Institute of Physics and the Physical Society advises that the date of the Low Energy Nuclear Physics Conference, at Harwell, has been changed from that listed on page 147 of the March issue, and is now September 12th-14th, 1962.

Union List of Periodicals on Electronics and Related Subjects, compiled by R. England, B.Sc., M.I.Inf.Sc., of the Plessey Company, contains entries of organizations and firms having libraries of journals covering television, radiocommunications, telegraphy, physics, patents, instruments, computing and automation, etc. Primarily intended for members of the Electronics Group of the Association of Special Libraries and Information Bureaux, copies of the list (15s each) are, however, available to non-members on application to Miss B. Newman, Secretary, ASLIB Electronics Group, Ericsson Telephones Ltd., Beeston, Nottingham.

Experiments in Soldering.—The International Tin Research Council's report for 1961 on the work of the Tin Research Institute covers a wide variety of activities designed to promote the use of tin. On the subject of soldering it states that commercial trials have been made using polyethylene glycol as a solvent for hydrazine halide type fluxes. Hitherto the use of this type of flux has been attended by some risk of dermatitis. It seems likely, states the report, that the use of polyethylene glycol can virtually eliminate this hazard without seriously reducing the effectiveness of this most useful fluxing compound. Copies of the report are available free of charge to libraries, and scientific and industrial organizations from the Tin Research Institute, Fraser Road, Perivale, Greenford, Middx.

All types of d.c./a.c. converter are classified and their principles of operation, characteristics, advantages and short-comings are described in a new survey by E. Komolibus entitled "D.C./A.C. Converters for D.C. Amplifiers." Published by the British Scientific Instrument Research Association, South Hill, Chislehurst, Kent, the survey runs to 147 pages including 105 figures and 144 references. Tables of data provide operating frequency, supply voltage, maximum input or contact rating, noise level, mounting, etc., of all d.c./a.c. converters commercially available in the U.K. Price is 3gn in U.K., post free.

"Sound and Vision" stand at the current Ideal Home Exhibition (Olympia, London, March 6th-31st) features a selection of television and sound radio receivers, tape recorders and stereophonic record reproducers in various room settings. Eye-catching are a £500 radiogram by Zenith and three transistor portable models by Roberts' Radio which are respectively encased in 18 carat solid gold, mink, and synthetic diamonds.

I.F.A.C.—J. F. Coales, O.B.E., M.A., M.I.E.E., Reader in Engineering at Cambridge University, has been elected a vice-president of the International Federation of Automatic Control. The Federation, of which there are 26 national member organizations, is at present preparing its 2nd International Congress of I.F.A.C. for Automatic Control to be held in September, 1963, in Basle, Switzerland.

West Germany may adopt the American stereophonic radio broadcasting system using the F.C.C. standards. This is the view expressed by Professor Dr. Werner Nestel of Telefunken, one of the leading German research and development scientists in the field, in a paper given in Berlin recently. So far the Bonn Government has not indicated that it is actively preparing for the introduction of a stereo broadcasting service.

"Elettra III," Marconi Marine's new research and demonstration vessel, was launched at Berwick-on-Tweed on March 8th. To be fitted with a full range of the company's latest electronic aids to communication and navigation, the "Elettra III" is 82ft in length, with a beam of 20ft, and will replace the present "Elettra II."

Personalities

J. R. Brinkley has been elected chairman of the Electronic Engineering Association. Mr. Brinkley, who was born in Glasgow, began his career there in the Post Office engineering department. He was subsequently appointed to the engineering chief's office and then to the G.P.O. Radio Research Department at Dollis Hill, London. He was seconded to the Home Office early in the war to assist in the development of v.h.f. radio services for the police, fire and civil defence. During this period and until 1948, he was responsible for much of the development of police radio in Britain and in particular for the introduction of the multi-carrier mobile radio system. He joined Pye Ltd. in 1948 and was appointed technical director of Pye Telecommunications in 1949. Since 1956, Mr. Brinkley has been managing director of Pye Telecommunications Ltd. and is also an executive director of Pye Ltd., and a director of the Telephone Manufacturing Co. Ltd.

The B.B.C. announces the appointment of **J. Redmond,** M.I.E.E., as superintendent engineer, television (regions and outside broadcasts), in succession to **T. H. Bridgewater,** M.I.E.E., who, as reported in the March issue, became chief engineer, television. Mr. Redmond joined the B.B.C. in 1937 as a maintenance engineer at Edinburgh and transferred to the television service at Alexandra Palace in 1938; eventually becoming superintendent engineer, television (recording) in 1960. In this latter post he was responsible for the introduction and rapid extension in the use of video-tape recording equipment.

Dr. H. R. Baumgartner, formerly chief engineer, has been appointed manager of the Transistor Division of Standard Telephones & Cables. Dr. Baumgartner came to Great Britain in 1955 and joined S.T.C. two years later as head of the Transistor Design Section. He graduated from the Swiss Federal Institute of Technology in Zurich with a degree in electronics and physics. **B. D. Mills,** B.Sc., B.E., A.M.I.E.E., has been appointed to succeed Dr. Baumgartner as chief engineer of the S.T.C. Transistor Division. Mr. Mills joined the company in 1951 as a development engineer specializing in high-reliability receiving valves. He is a graduate of the University of Queensland. Other S.T.C. Transistor Division appointments are those of **J. G. Litterick,** A.M.I.E.E., as marketing manager, and **H. T. Lofthouse** B.Sc.(Eng.), A.M.I.E.E., as sales manager.

J. A. Lawrence, T.D., M.I.E.E., who was recently appointed staff engineer of the new Telephone Electronic Exchange Systems Development Branch of the Post Office, has been with the G.P.O. since 1927 when he entered the Engineering Department as a youth-in-training. After war service and a period on the development of subscriber trunk dialling, he took charge in 1950 of a group set up to study the application of electronic techniques to telephone systems. Since 1956 he has played a major part in the joint electronic research projects in which manufacturers and the G.P.O. are pooling ideas on electronic telephone exchanges.

New Director of Technical Policy at the Air Ministry is **Air Commodore Antony G. Powell,** A.M.I.E.E. A former Cranwell cadet, Air Commodore Powell has held a number of senior signals appointments, and was chief of the electronics branch of the signals division of SHAPE for two years from June, 1955. In 1958 he went to H.Q., Signals Command, as senior air staff officer. He completed the 1961 Imperial Defence College course prior to his new appointment.

G. F. Gainsborough, B.Sc., Ph.D., A.M.I.E.E., is to succeed **W. K. Brasher,** C.B.E., M.A., M.I.E.E., later this year as secretary of the Institution of Electrical Engineers. Dr. Gainsborough, a barrister-at-law who is 46, is now an assistant secretary in the Establishment and Organization Division of the Ministry of Aviation. Educated at Christ's Hospital, and King's College, London, where he served for a time in the Physics Department, he joined the Radio Division of the National Physical Laboratory and was attached, in 1944, to the British Commonwealth Scientific Office in Washington as a senior scientific officer. Shortly after returning to this country he was transferred to the Ministry of Supply, now the Ministry of Aviation.

G. F. Gainsborough

D. S. Ridler

D. S. Ridler, A.M.I.E.E., has been appointed technical director of Standard Telephones & Cables. Educated in London, Mr. Ridler first joined S.T.C. in 1939. In 1946 he took charge of a department within Standard Telecommunication Laboratories and was responsible for many developments in electronic telephone and telegraph switching and data processing. He rejoined S.T.C. in 1958 as chief engineer (development and engineering), and now has 51 British patents covering a wide range of inventions.

D. Hadfield, Ph.D., M.Sc.(Eng.), M.I.E.E., F.I.M., has been appointed director of research at Swift Levick & Sons Ltd. Dr. Hadfield has held the position of research manager with the company for the past 12 years and prior to that was 13 years with the B.S.A. Group Research Centre and for eight years in charge of the Magnetic Research Laboratory based at Jessop-Saville Ltd., Sheffield. For the past four years he has been chairman of the Permanent Magnet Association Technical Committee, and is also editor of a comprehensive book produced as a symposium of authors and entitled "Permanent Magnets and Magnetism," to be published shortly by Iliffe Books Ltd.

V. J. Francis, B.Sc., F.Inst.P., M.I.E.E., has been appointed executive director of G.E.C. (Research) Ltd. He succeeds **O. W. Humphreys** as director of the Central Research Laboratories and administrative head of the Hirst Research Centre. Aged 53, Mr. Francis studied at Imperial College, South Kensington, and graduated first in mathematics and later in physics, both with first-class honours. He joined the research laboratories of the G.E.C. in 1931 and was promoted to the leading scientific staff in 1937.

E

Geoffrey N. Bowling, B.Sc. (Eng.), A.M.I.E.E., has joined the Marconi International Marine Communication Company as deputy technical manager, a position which has remained vacant since the death, in 1960, of Commander C. M. Jacob. A graduate of Southampton University, where he also obtained a diploma in electronics, he has been several years in Australia, after completing his national service in the Royal Navy. He was for a time with Amalgamated Wireless (Australasia) and later at the Royal Australian Naval Torpedo Establishment, Sydney. Since returning to the U.K. in 1957, Mr. Bowling has been with Southern Instruments of Camberley.

G. N. Bowling

N. D. Hill

Norman D. Hill, who for some years has been associated with all aspects of E.M.I. computer work, has been appointed head of the computer division of E.M.I. Electronics Ltd., with full responsibility for all sales, engineering, programming and administration. Mr. Hill, who joined E.M.I. in 1956, has lectured on the subject of computers all over the world.

M. M. Macqueen, chairman of G.E.C. (Radio & Television) Ltd. is retiring at the end of March, 1962. He has been associated with the radio and television industry from the outset, joining G.E.C. in 1923 as assistant to the manager of the radio department. Mr. Macqueen is well-known for his work for the various industry associations. He has been a member of the council and principal committees of the R.M.A., and later B.R.E.M.A. He was chairman of the R.M.A. in 1937 and chairman of B.R.E.M.A. in 1949, 1950 and again in 1954, serving until May 1957. He was also B.R.E.M.A. representative on the Radio Industry Council for seven years and took a leading part in the formation of the Radio Communication and Electronic Engineering Association, now known as the Electronic Engineering Association, of which he was vice-chairman in 1946.

A. M. Humby, M.I.E.E., a well-known figure in the field of radio propagation and a contributor to *W.W.* on aspects of this subject, retired at the age of 66 at the end of February. Educated at Christ's Hospital, Mr. Humby served as a battalion signals officer in the first world war and later joined the engineering staff of Marconi's. In 1929 he joined Cable & Wireless as manager and engineer-in-charge of the Bridgwater W/T station and was subsequently for four years from 1934 engaged on research and development work at Electra House. He was seconded to the Admiralty in 1941 and later joined the Royal Navy Scientific Service. In 1951 he was seconded to the British Joint Communications Electronics Board and was later appointed to the Joint Communications—Electronics Staff of the Ministry of Defence. There his duties included that of chairmanship of the N.A.T.O. Study Group on Ionospheric Scatter and membership for the U.K. of the Study Group on Tropospheric Scatter. Mr. Humby is to continue to participate in certain N.A.T.O. study groups.

H. W. Baker, O.B.E., M.I.E.E., has been appointed senior superintendent engineer, television, of the B.B.C. This is a new post in which Mr. Baker will co-ordinate the work of the three superintendent engineers responsible for studios, outside broadcasts, and recording, in the television service. He will also be deputy to the chief engineer, television. Mr. Baker joined the B.B.C. in 1926, and after service at several of the Corporation's transmitting stations he transferred to the television service when it was started in 1936. He became assistant engineer-in-charge at Alexandra Palace in 1937, and, later, engineer-in-charge when it was re-opened in 1945. He was appointed assistant superintendent engineer, television, in 1950 and superintendent, television studios, in 1952.

OUR AUTHORS

G. M. Gould, M.Sc., Ph.D., who with **W. R. Carter,** B.Sc., writes in this issue on v.l.f. propagation, has recently emigrated to New Zealand where he has taken up the appointment of senior lecturer in physics at Victoria University of Wellington. For the past ten years he has been in the Royal Naval Scientific Service, in which he was a principal scientific officer, and has been working at the Admiralty Surface Weapons Establishment, Portsmouth. Dr. Gould's work was originally concerned with perturbation theory and its applications to microwave electronics, but for the past five years he has been dealing mainly with the applications of v.l.f. to communications and navigational aids. Mr. Carter, who is also at A.S.W.E., was from 1950 to 1960 conducting research first on h.f. propagation and its applications to Naval communications and subsequently on navigational aids particularly in connection with the Decca Navigator. For the past two years his main interest has been in the v.l.f. band.

J. McA. Steele, B.Sc. (Eng.), author of the article in this issue on standard frequency transmissions, graduated from Glasgow University in 1945. After a year with the Ministry of Supply he joined the staff of the National Physical Laboratory where he has been engaged almost continuously in the field of precise frequency measurement and standardization, including studies of the effect of ionospheric propagation on the received frequency stability of both low and high radio frequency signals. He is the present NPL representative on the British National Committee for Scientific Radio.

OBITUARY

F. Stanley Mockford, one of the pioneers of the use of radio in aircraft, died on March 1st after a short illness. Until his retirement (reported in the last issue) Mr. Mockford was commercial manager of Marconi's Wireless Telegraph Company, a post he had held for fourteen years. Born in 1897—the same year as the company was founded—Mr. Mockford began his long and varied career in wireless in the Royal Flying Corps in 1915 and the Royal Air Force and afterwards, as an Air Ministry official, helped in the early development of wireless services for civil aviation. He was the first examiner of candidates for the air operator's licence, devised the first international phonetic alphabet and at this period introduced the "Mayday" distress call. In 1930 he joined Marconi's, and three years later became assistant sales manager and, in the August of 1935, manager of the company's Aircraft Department. The same year he was appointed assistant general manager and later deputy general manager. Since its foundation, he was continuously a council member of the Electronic Engineering Association and three times chairman; he was also a founder member of the Radio Industry Council.

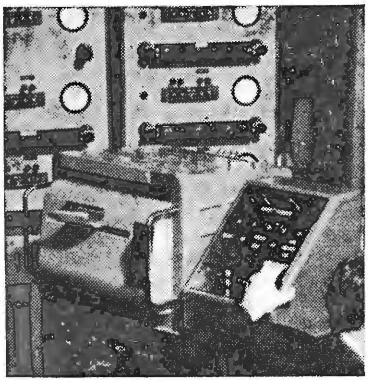
C. R. Robertson, chairman of the McMurdo Instrument Company, died on February 28th after a short and sudden illness.

"BELLING-LEE" NOTES

No. 39 of a Series:

Recording Transients, Part 2.

Having decided the method of recording to be used, next came the matter of synchronising the experiment and the recording run. There is more to this than just throwing a switch, for any event takes a finite time to happen, and in starting a mechanical recorder and bringing it up to steady speed, this is appreciable. It also takes time, and this may be longer or shorter, to start the experiment or test run, and therefore a switching initiation programme is necessary, which must be performed automatically once it has been inaugurated. The neat solution to this problem was to employ a cold cathode counter to trip a series of high speed relays, thus giving us a sequence switch. For the purposes immediately envisaged, 100 milli-second intervals have been chosen, the sequence terminating at the tenth position, but any appropriate periods can be set up. The sequence is started by a master switch, and Station 10 is used for tape drive "off."



Now let us consider the application of the recorder to a fuse rupturing test. The fuse-link is, say, one of the fast action type, and under the conditions envisaged should clear the circuit in a few milli-seconds. The rupturing current is switched on by a contactor, which must be positive in action, and free from contact bounce since this would invalidate the experiment. This, of course, is a desirable feature in any contactor, but we were looking for a standard surpassing all normal electrical requirements, and were obliged to modify considerably the best commercial product that could be found. The modified contactor and its control circuit takes, say, 50 milli-seconds to operate, and is therefore connected to Station 9 of the sequence switch; this means that the fuse-link will blow approximately in the middle of period 9. The recorder tape drive takes, say, 100-150 milli-seconds to run up to full speed, and so this is switched from Station 7, and held on until the end of the sequence; the equipment is therefore available for recording for the whole of period 9.

Thus, approximately 3/4 of a second after the master switch is operated, the tape drive begins to pick up speed. 200 milli-seconds later, when the paper speed is constant, the fuse gear contactor is energised and the current is switched on through the fuse-link. When this blows, the current in circuit ceases to flow, and the recording is complete; the recorder tape drive is switched off when the sequence switch reaches Station 10. The current recording will have been made by one of the twelve galvanometers, driven by the voltage developed across a suitable low resistance connected in series with the fuse.

This illustrates the essential parameters of a fuse rupturing test, and the simplest application of the recording gear. In practice, other galvanometers would probably be utilised simultaneously to record reference levels, circuit voltage, a time scale (derived from a master oscillator), and so on.

An essentially similar application, which is currently being investigated, suggests itself in connection with mechanical shock test experiments. This is a subject of increasing importance in the development of ballistic vehicles, and the placing of artificial satellites in orbit for communications and other purposes, owing to the high accelerating forces that are involved. The basic principle of shock testing consists in securing to a carriage the component or equipment to be tested; this is accelerated under known conditions, and then arrested in a very short distance by a linear retarding force applied suddenly by impact. To derive the full value from such an experiment, the applied shock force and the energy distribution must be known, and by attaching accelerometers to the carriage these factors can be monitored and recorded in very much the same manner as described in the fuse experiment.

Advertisement of
BELLING & LEE LTD.
Great Cambridge Rd., Enfield, Middx.

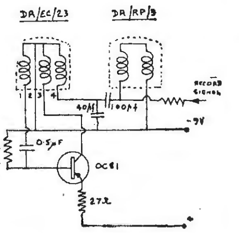
we can now report new and interesting information in the field of tape recording. An intensive research and development programme over the last eighteen months has been devoted to the improvement of record, playback and erase heads.

The tendency towards transistor portable tape recorders has received our special attention as the necessity for improvements in heads for this application has been an obvious requirement.

COMBINED ERASE HEAD AND OSCILLATOR COIL

" A most amazing component!" is the reaction of most people who test these, for in a space of only $\frac{3}{8}$in. diameter by $\frac{5}{8}$in. long, is contained a complete oscillator coil and erase head.

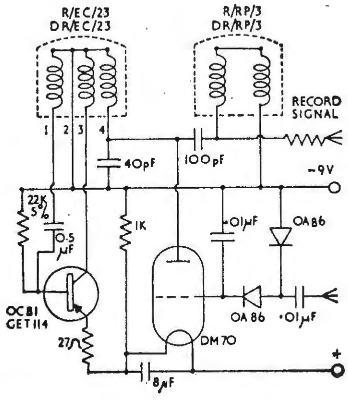
A simple oscillator circuit operates with a single OC81, or similar type of transistor, and requires only 20 mA at 9 V from the battery.



As well as acting as an erase head, this component also provides the required bias supply to the recording head and (if required) HT for a recording level indicator of the DM70, or similar type. Although DC flows within the oscillator coil inside the head there is no DC flux whatsoever produced in the erase section.

Where an indicator of the DM70 type is used the heater may be seriesed with the circuit, as shown below. This offers a further economy of power, and in this case a total of 25mA at 9V, therefore, supplies indicator heater, indicator HT, 30 Kc bias supply and erase power.

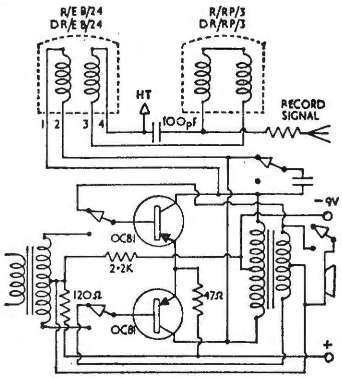
A further trend of transistor tape recorders may be to combine a radio tuner input—the erase head/oscillator coil would enable such a recorder to record with a transformerless loudspeaker output stage in operation.



ERASE HEAD/TRANSFORMER

The obvious use of the output push-pull stage switched as an oscillator when recording can offer a substantial saving in components as the existing output transformer can be used as an oscillator coil. However, it becomes desirable to generate a higher voltage than would normally be available from such a circuit for the bias supply and a further requirement may be for high voltage as HT for a recording voltage level indicator.

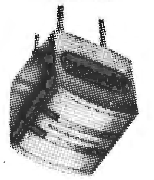
Special erase heads are now available that are double wound having a low impedance winding for coupling to the oscillator and a high impedance output winding for providing the required bias supply to the recording head, and (if required) HT for an indicator of the DM70 or similar type.



CLOSE TOLERANCE ON RECORD AND REPLAY HEADS

As the tape recording art has developed, so manufacturers have quite rightly asked for closer tolerances and higher performances in heads.

X SERIES



How can you produce an extremely high quality range of record and playback heads offering the maximum in performance, having far closer tolerances in all mechanical and electrical characteristics than hitherto envisaged and at the same time offer these at a reasonable price? That was the development and production problem we set ourselves eighteen months ago.

Some 75 heads from manufacturers throughout the world were examined and tested. Performance features were co-related to design factors applicable and so a design took shape based upon the rejection of all known bad features and the incorporation of good. Our design and production experience of over $3\frac{1}{2}$ million heads over fourteen years, including heads for practically every special purpose, enabled us to maintain a realistic approach to the problem. We purchased superb new machinery and produced many special purpose machines ourselves, numerous items of special electronic test gear were developed to provide as comprehensive a system of quality control as could be envisaged, and last but not least, we engaged many highly skilled personnel.

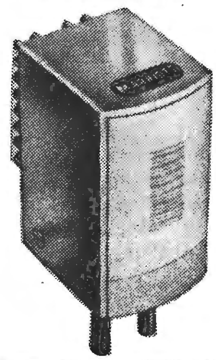
We have now completed our task and the results fully measure up to our expectations. Tolerances in output from standard test tapes are now reduced to $\pm$ 1 dB, whilst tolerance on inductance is $\pm 8\%$, to give but two typical examples. Performances are, in fact, superior to the vast majority of heads and equal to the best of any we have ever tested.

A complete range of record, playback and erase heads (' X ' series) is available with these qualities for providing all the requirements of heads for $\frac{1}{4}$in. tape. Full track, $\frac{1}{2}$ track, 4 track stereo and 2 track stereo are all available and most of these in various impedances. A special feature of the erase heads is their extremely low power requirement, and that they can be operated at 100 Kc without appreciable heating.

A complete range of record and playback multitrack heads is available (' U ' series) offering the close tolerances described—*we do not think any other manufacturers have offered heads of this type with such close tolerances.*

Heads for 4 tracks on $\frac{1}{4}$in., 8 on $\frac{1}{2}$in. and 16 on 1in. tape are available, as well as full track, or individual track erase heads. Standard heads can be supplied at 5mH or 110mH. The latter offering considerably higher voltage output than hitherto obtainable.

MULTITRACK



8 TRACK $\frac{1}{2}$in. TYPE U/8

Details of all the above types of heads are available from:

P. A. MARRIOTT & CO. LTD.
284a WATER ROAD, WEMBLEY, MIDDX.
Tel. No. WEMbley 7493
ALPerton 2020
ALPerton 2029

News from Industry

Thorn-Murphy Discussions.—Thorn Electrical Industries announce that preliminary discussions have been taking place with the board of Murphy Radio with a view to finding a basis for an offer for the issued ordinary share capital of Murphy Radio Ltd. by Thorn Electrical Industries Ltd. Negotiations are still at an early stage and a further statement will be made as soon as possible. Murphy have a substantial electronics section and a holding of about 10 per cent in British Relay Wireless & Television.

English Electric Co. Ltd.—Group profit for the year 1961, after all charges other than taxation, is £4.6M as against £6.6M for the previous year. Taxation absorbs £1.7M (£2.8M) and the group profit for the year 1961 attributable to members of the English Electric Company is £2.2M (£3.1M).

Marconi's Wireless Telegraph Co.—Group profit for the year ended December 30th, 1961, after all charges other than taxation, is £537,745. This compares with £371,732 for the year 1960. After taxation of £127,887 (£66,840) and transfer to reserves of £115,000 (£47,000) the group profit is £194,858 (£57,892).

Texas Instruments Incorporated reported recently to shareholders that 1961 total sales were $233M—much the same as for the previous year. Net income was $9M as against $15M for 1960. On T.I. activities in this country the report states: "Because of the United Kingdom's austerity measures, the semiconductor plant at Bedford, England, failed to reach anticipated volume but operated profitably nevertheless."

A new computer equipment division has been formed by Decca Radar Ltd. It will be managed from the company's London head office by Eric Tyler, A.M. Brit. I.R.E., who was until recently general manager of Decca Radar Inc., New York. The new computer equipment division will be responsible for the sales, services and commercial exploitation of all Decca computer peripheral equipment.

Research activities of the General Electric Company are now under the management of a new subsidiary company, G.E.C. (Research) Ltd., at the Hurst Research Centre, East Lane, Wembley, Middx. Chairman of the new company is O. W. Humphreys with V. J. Francis as executive director. Other members of the board are Dr. H. K. Cameron, R. J. Clayton and K. Veseley.

E.M.I. Electronics Divisions Reorganized.—In order to co-ordinate and strengthen the activities of E.M.I. Electronics Ltd. in the sound and television fields, a Broadcast and Recording Equipment Division under the management of Kenneth Owens, B.Sc.(Eng.), A.C.G.I., A.M.I.E.E., has been formed by the amalgamation of the existing Broadcast Equipment Division and the Recording and Relay Equipment Division.

Solartron (Farnborough) Ltd. is the title of a newly registered company which is to take over the executive functions of all Solartron subsidiary companies located at Farnborough, Hants. J. E. Crosse is chairman and managing director of the new company, which has a nominal capital of £1,000 in £1 shares.

Grundig's New Oxford Street showrooms have been closed following transfer of the company's publicity department to join the sales department, general administrative offices and factory at 40 Newlands Park, Sydenham, London, S.E.26 (Tel.: Sydenham 2211).

Roberts' Radio advise a change of address to Molesey Avenue, West Molesey, Surrey (Tel.: Molesey 7474).

Louis Newmark has entered into an agreement with Ebauches S.A. of Neuchatel, Switzerland, whereby the two companies will collaborate in the exploitation of the electronic instrument field in the European Market. The aim is to co-ordinate market research, development, production, sales, distribution and servicing facilities of both companies. Louis Newmark are large importers of Swiss watches, but have over the past ten years expanded into the field of aircraft navigational instruments and industrial electronics. Ebauches S.A. supply watch components to the Swiss watch industry and have recently diversified into the electronic field.

Commercial activities of Semiconductors Ltd. and Simet (the silicon rectifier division of the Plessey Company) have been integrated, thus combining all sales forces concerned in marketing semiconductor devices. In each sales area a single organization can now offer the services of a transistor specialist and a rectifier specialist. Control of the sales force will be centralized in Semiconductors Ltd. at Swindon, where the applications laboratories are sited, and which will in future be responsible for handling all sales enquiries.

Alma Components, the Diss, Norfolk, manufacturers of precision wirewound resistors, have purchased the whole of the issued share capital of Alston Capacitors Ltd., of Halesworth, Suffolk. A new board of Alston has been formed with J. R. Price, technical director, R. F. Mann, production director and D. C. F. Bartlett, sales director. Alston's offices are being transferred to Diss and the London sales office at 551 Holloway Road, London, N.19, will be shared with Alma.

Wales Television Ltd. (Teledu Cymru), the programme contractor to the I.T.A. who will soon be bringing independent television to North and West Wales, has appointed E.M.I. Electronics Ltd., as the major supplier of television studio equipment for the Wales Television Centre now being built at Cardiff. The order is valued at approximately £40,000. The studios are scheduled to go on the air during September next.

Wholesale Supplies (Swinton) Ltd., 16-18 Worsley Road, Swinton, Manchester (Tel.: Swinton 3232), are now distributing the Pygmy and Clarville ranges of transistor portable radio receivers, which are of French manufacture.

OVERSEAS TRADE

Ten bulk carrier vessels, which the Livanos Group of Companies have recently ordered from Split and Pula shipyards in Yugoslavia, are to be fitted with Kelvin Hughes navigational equipment comprising radar, echo sounders and reflector compasses.

£60,000-worth of Racal communication equipment left London recently bound for Salisbury, S. Rhodesia. The equipment is for use by the British South African Police and comprises 90 radio-telephones, 20 receivers and 20 transmitters together with associated control gear, head sets and microphones.

At the Chicago World Fair orders in excess of $500,000 were secured by Elizabethan Tape Recorders Ltd.

In Mauritius Marconi's have obtained contracts worth over £¾M for the installation of the major portion of the radio equipment for the Admiralty station on the island. The Mauritius project consists of a transmitting installation at Bigara, a receiving installation at Tombeau Bay and a communications centre at Vacoas.

Standard Frequency Transmissions

CHARACTERISTICS OF STANDARD FREQUENCIES AND TIME SIGNALS

By J. McA. STEELE,* B.Sc.(Eng.)

THE Administrative Radio Conference at Atlantic City (1947) allocated to the standard frequency service the following frequencies and frequency limits: 2.5 Mc/s ± 5 kc/s (2.5 Mc/s ± 2 kc/s in Western Europe, USSR and Africa); 5 Mc/s ± 5 kc/s; 10 Mc/s ± 5 kc/s; 15 Mc/s ± 10 kc/s; 20 Mc/s ± 10 kc/s and 25 Mc/s ± 10 kc/s. The most recent Conference, Geneva (1959), at the request of the International Radio Consultative Committee (C.C.I.R.) added a band 100 c/s wide centred on a frequency of 20 kc/s. With the exception of The People's Republic of China all the countries operating standard frequency transmissions are represented on the C.C.I.R. which is charged with considering the questions that arise in establishing and operating a world-wide system of time and frequency reference. For this purpose it issues general recommendations on the form, accuracy and content of standard frequency services which provide an internationally accepted basis for the design and operation of such services by member administrations. In addition the C.C.I.R. formulates questions for study and experiment affecting various aspects of standard frequency transmissions such as the reduction of mutual interference and the possibilities of distributing standard frequencies and time signals in bands above and below the h.f. band† mainly used at present.

The documents at each Plenary Assembly of the C.C.I.R. contain a report giving the main characteristics of standard frequency transmissions in operation throughout the world. Tables 1 and 2 are based on similar tables appearing in the last (1959) C.C.I.R. report, although extensive revision has been necessary to accommodate recent changes in both the number and characteristics of stations, especially those in the v.l.f. band.

Characteristics of stations

The characteristics of 18 stations known to be operating at present (March 1962) on the seven allocated frequencies and embracing a total of between 37 and 39 transmissions on each week-day are given in Table 1. The data include details of location, power, antenna, periods of operation and the duration of time signal and tone modulation. While this information is complete in itself there are areas, such as Western Europe, where some degree of interference between one or more standard frequency transmissions may be expected at all times. In these circumstances it is more important to know the sequence of events in transmission and modulation rather than the total period of operation in hours per day or minutes per hour. For this reason Figs. 1 and 2 have been prepared giving in partly schematic form the times of operation (UT)§ on each frequency and the pattern of modulation in each hour, where this is appropriate. (The station at Uccle, and stations WWVL and ZLFS do not modulate their carriers while RWM follows a 2-hourly schedule and is dealt with at greater length below.) Using both of these tables the possibilities of interference at any time may readily be appreciated and listening times adjusted to obtain the most favourable conditions for reception of carrier or modulation frequencies. The details of the station announcement and the form of the second and minute signals—and particularly the latter—may be helpful at times in identifying the source of a received signal.

It has not been possible within the framework of Table 2 and the associated figures to include all the relevant information on some of the stations and supplementary details of the schedules are given below.

RWM, Moscow.—Time signals are radiated every two hours according to the following programme:

Minutes past odd hour	*Transmission*
45–46	Call sign
46–50	Seconds, preliminary signal
50–55	No modulation
55–60	Seconds
60–61	Call sign
61–66	Rhythmic seconds, 61/minute

The signals at 06, 08, 10 and 12 hours are transmitted by modulated carrier (A3 signal). At all other times telegraphy (A1) signals are emitted. The frequency in use at each second hour is given in Fig. 1, which also shows the total period of standard frequency operation. Between telegraphy time signals an unmodulated carrier (A0 signal) is radiated except for the following periods when it is modulated with 1000 c/s:—

5 Mc/s: 0500–0745 (break for time signals at 0545–0607)

15 Mc/s: 0830–1145 (break for time signals at 0945–1007)

RWM does not operate between 0607 and 1345 UT on the first and third Wednesday of each month.

WWV, Washington.—In addition to the other timing signals and time announcements WWV now transmits a special timing code 10 times per hour.

* National Physical Laboratory.

† V.L.F. 3– 30 kc/s; L.F. 30– 300 kc/s; M.F. 300–3000 kc/s; H.F. 3–30 Mc/s; V.H.F. 30–300 Mc/s

§ Universal Time is used throughout this article.

TABLE I
Characteristics of standard frequency and time signal transmissions in the allocated bands at March 1962

Station call sign and approximate location		ATA New Delhi, India	BPV Peking, China	FFH Paris, France	HBN* Neuchatel, Switzerland	IAM Rome, Italy	IBF Turin, Italy	JJY* Tokyo, Japan	LOL Buenos Aires, Argentina	MSF* Rugby, U.K.	OMA Prague, Czechoslovakia	RWM Moscow, U.S.S.R.	Uccle, Belgium	WWV* Washington, U.S.A.	WWVH* Hawaii, U.S.A.	WWVL* Boulder, U.S.A.	ZLFS Lower Hutt, N. Zealand	ZUO* Olifantsfontein, S. Africa	ZUO* Johannesburg, S. Africa
Latitude Longitude		28° 34′N 77° 19′E	— —	48° 59′N 2° 39′E	46° 58′N 6° 57′E	41° 52′N 12° 27′E	45°03′N 7° 40′E	35° 42′N 139° 31′E	34° 37′S 58° 21′W	52° 22′N 1° 11′W	50° 07′N 14° 35′E	55° 45′N 37° 33′E	50° 48′N 4° 21′E	39° 00′N 76° 51′W	20° 46′N 156° 28′W	40° 02′N 105° 27′W	41° 14′S 174° 55′E	25° 58′S 28° 14′E	26° 11′S 28° 04′E
Carrier power to antenna (kW)		2	—	0.3	0.5	1	0.3	2	2	0.5	1	20	0.02	0.1-9	2	8†	0.3	4	0.25
Type(s) of antenna		Horiz. dipole	—	Inverted L	Horiz. dipole	Horiz. λ/2 dipole	Horiz. dipole	Vertical λ/2 dipoles: λ/4 dipole (2.5 Mc/s)	—	Horiz. quadrant dipoles: vertical monopole (2.5 Mc/s)	T	—	Vertical	Vertical λ/2 dipoles: vertical λ/4 (2.5 Mc/s)	Vertical λ/2 dipoles: vertical λ/4 (5 Mc/s)	T	—	Quadrupole	Horiz. dipole
Number of simultaneous transmissions		1	3	1	1	1	1	3-4	6	3	1	1	1	6	3	1	1	1	1
Period of operation	Days per week	5	7	2	7	6	6	7	6	7	7	7	7	7	7	7†	1	7	7
	Hours per day	5	24	8½	24	1	1	24 16 (2.5 Mc/s)	5	24	24	19	22	24	23½	24†	3	24	24
Standard frequencies used	Carrier (Mc/s)	10	5, 10, 15	2.5	5	5	5	2.5, 5, 10, 15	2.5, 5, 10, 15, 20, 25	2.5, 5, 10	2.5	5, 10, 15	2.5	2.5, 5, 10, 15, 20, 25	5, 10, 15	0.02	2.5	5	10
	Modulation (c/s)	1,1000	1,1000	1,440, 1000	1,500	1,440, 600, 1000	1,440, 1000	1,1000	1,440, 1000	1	1,1000	1,1000	nil	1,440, 600	1,440, 600	nil	nil	1	1
Duration of audio modulation (minutes)		4 in each 15	5 in each 15	10 in each 20	5 in each 60	8 in each 15	5 in each 10	4 in each 5 nil (15 Mc/s)	4 in each 5	nil	4 in each 15	5¼ hours/day	nil	2 in each 5	3 in each 5	nil	nil	nil	nil
Duration of time signal transmission (minutes)		cont.	3 in each 15	10 in each 20	5 in each 10	5 in each 15	5 in each 10	cont.	4 in each 60	10 in each 15	15 in each 30	10 in each 120	nil	cont.	cont.	nil	nil	cont.	cont.
Accuracy of frequency and time intervals (parts in 10^9)		±20	—	±20	±0.5*	±20	±10	±5*	±20	±0.5*	±1	±10	±10	±0.1*	±0.1*	±0.05*	±5)	±5 relative WWV*	
Method of time signal adjustment		Steering	—	Steps of 50 ms	Steps of 50 ms	Steps of 50 ms	Steps of 50 ms	Steps of 50 ms	Steps of 50 ms	Steps of 50 ms	Steering	Multiples of 10 ms	nil	Steps of 50 ms		nil	nil	Steering by WWV	

* These stations have indicated their participation in the international co-ordination of time and frequency. The time signals remain within 50 ms of UT2 and the frequency is maintained as constant as possible by reference to atomic or molecular standards and at the offset from nominal announced for each year by the Bureau International de l'Heure. For 1962 the offset is −130 parts in 10^{10}.
† See text for qualification of these figures.

TABLE 2
Characteristics of standard frequency and time signal transmissions in additional bands at March 1962

Station call sign and approximate location		CHU* Ottawa, Canada	DCF77 Mainflingen, W.Germany	Droitwich, U.K.	GBR* Rugby, U.K.	MSF* Rugby, U.K.	NAA* Cutler, Maine, U.S.A.	NBA* Balboa, Panama C.Z., U.S.A.	NPG/NLK* Jim Creek, Washington, U.S.A.	NPM* Lualualei, Hawaii, U.S.A.	NSS* Annapolis, Maryland, U.S.A.	OMA Podebrady, Czechoslovakia	RES Moscow, U.S.S.R.	RW166 Angarsk, U.S.S.R.	SAZ Enköping, Sweden	WWVB* Boulder, U.S.A.
Latitude Longitude		45° 18′N 75° 45′W	50° 01′N 9° 00′E	52° 16′N 2° 09′W	52° 22′N 1° 11′W	52° 22′N 1° 11′W	44° 40′N 47° 14′W	9° 04′N 79° 39′W	48° 05′N 121° 35′W	21° 24′N 158° 10′W	38° 59′N 76° 30′W	50° 08′N 15° 08′E	55° 45′N 37° 33′E	—	59° 35′N 17° 08′E	39° 59′N 105° 16′W
Carrier power to antenna (kW)		0.3, 3, 5	12	150	300	10	2000	—	1200	1000	—	5	—	—	0.05	2
Type of antenna		folded dipoles & rhombic	Omni-directional	T	—	—	—	—	—	—	—	T	—	—	Yagi (12dB)	Omni-directional
Number of simultaneous transmissions		3	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Period of operation	Days per week	7	6	7	7	7	—	7	—	—	—	7	7	6	7	7
	Hours per day	24	6	18–20	22	1	—	24	—	—	—	24	24	20½	24	23
Standard frequencies used	Carrier (kc/s)	3330, 7335, 14670	77.5	200	16	60	14.7	18	18.6	19.8	22.3	50	100	200	100000	60
	Modulation (c/s)	1	1,200, 440	nil	1	1	—	1	1	1	1	1	1	nil	nil	nil
Duration of time signal transmission (minutes)		Cont.	7 in 180	nil	4 x 5 per day	10 in each 15	—	Cont.	4 x 5 per day	4 x 5 per day	8 x 5 per day	23 hours per day	10 in each 120	nil	nil	nil
Duration of audio modulation (minutes)		nil	17 in 180	Cont. A3 broadcast	nil	nil	nil	nil	nil	nil	nil	nil	nil	Cont. A3 broadcast	nil	nil
Accuracy of frequency and time intervals (parts in 10^9)		±5*	−10† (frequency) +10 (time)	±50	±0.5*		±0.1* NBA controlling station for other transmitters					±1	±10	±10	±10	±0.05*
Method of time signal adjustment		Steps of 50 ms	Steps of 50 ms	nil	Steps of 50ms		By steps of 50 ms for all stations					Steering	Multiples of 10 ms	nil	nil	nil

* These stations have indicated their participation in the international co-ordination of time and frequency. The time signals remain within 50 ms of UT2 and the frequency is maintained as constant as possible by reference to atomic or molecular standards and at the offset from nominal announced for each year by the Bureau International de l'Heure. For 1962 the offset is −130 parts in 10^{10}.
† See text for qualification of these figures.

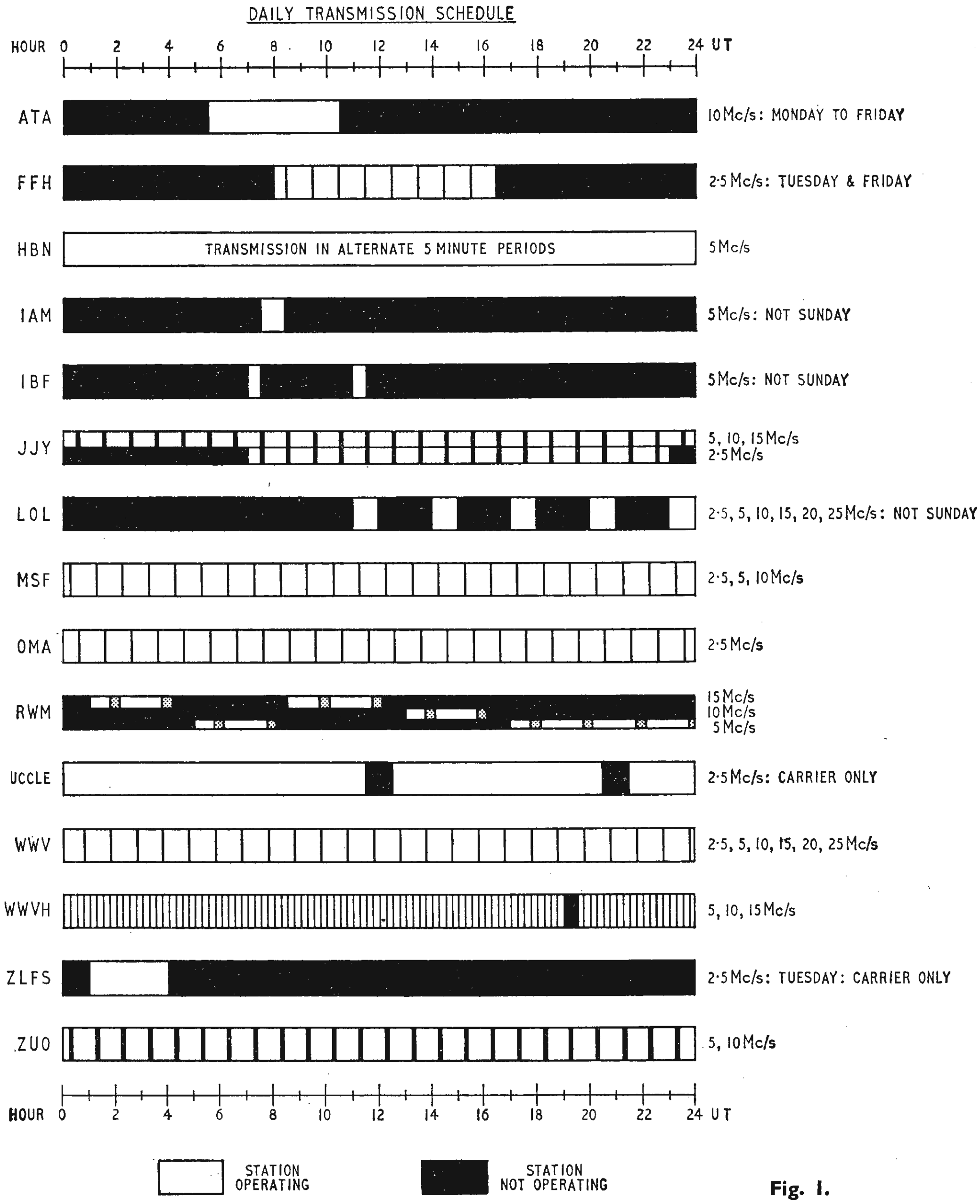
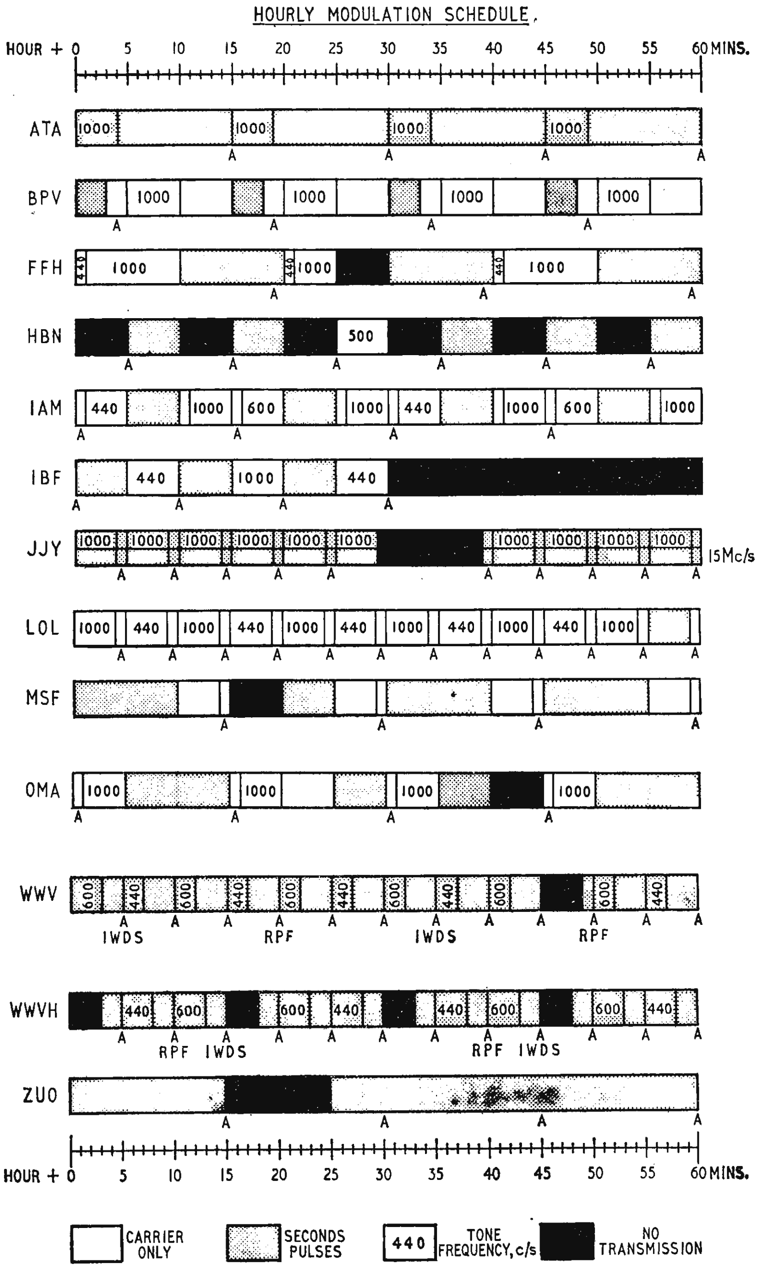


Fig. 1.

Consisting of 36 bit, 100 pulse/sec binary coded decimal carried on 1000 c/s modulation, it gives the second, minute, hour and day of year. A complete time frame lasts one second and the code is broadcast for one minute in each 5-minute period, except the first after the hour. The code contains 100 c/s, 10 c/s and 1 c/s markers which are locked to the frequency and time signals.

WWVL, Boulder.—This was the first station to be established using the 20 kc/s standard frequency and the carrier is stabilized by means of a phase-lock system to an atomic frequency standard at the Boulder Laboratories of the National Bureau of Standards. A temporary antenna of low efficiency is in use at present, the radiated power being about 14 watts for an input of 8 kW. Transmission is continuous except for two weeks in each month during the dark phase of the moon when the antenna is required for other purposes at night.

The characteristics of 15 stations operating regular standard frequency and time services on other than the internationally allocated frequencies are given in Table 2. With the exception of CHU, Ottawa transmitting continuous time signals in the h.f. band and SAZ which provides a controlled v.h.f. reference for use in Sweden, all the stations have frequencies lying in the l.f. and v.l.f. bands. Long-distance propagation at these low frequencies is for the most part exceedingly stable when homogeneous con-



FORM OF SECOND AND MINUTE SIGNALS MORSE AND VOICE ANNOUNCEMENTS (A)

Pulse of 5 cycles of 1000 c/s tone, lengthened to 100 ms at minute. Call sign and time (UT) in Morse.

Pulse of 100 cycles of 1000 c/s tone; no identification of minute. Call sign in Morse repeated during two minutes.

Pulse of 5 cycles of 1000 c/s tone: minute pulse lengthened to 100 ms followed by 440 c/s tone for 200 ms. Call sign in Morse.

1 ms carrier break repeated 5 times every second and 250 times at minute, exact time being *start* of first break. Call sign in Morse.

Pulse of 5 cycles of 1000 c/s tone, repeated 4 times at minute. Call sign in Morse and voice identification.

Pulse of 5 cycles of 1000 c/s tone repeated 7 times at minute. Call sign and time (UT) in Morse: voice identification at half-hour.

20 ms carrier break lengthened to 200 ms at minute, exact time being *end* of break. Call sign and time (JST) in Morse and voice. Radio propagation warnings in letter code: N (Normal), U (unstable) or W (disturbed).

Pulse of 5 cycles of 1000 c/s tone, 59th pulse omitted. Call sign in Morse: identification and time (UT—3h) in voice.

Pulse of 5 cycles of 1000 c/s tone, 100 ms pulse at minute. Call sign in Morse and voice announcement.

Pulse of 5 cycles of 1000 c/s tone, 100 ms pulse at minute and 500 ms pulse every 5th minute Last 5 pulses in each quarter hour 100 ms long. From minute 55-60 in every 3rd hour 100 ms pulses lengthened to 500 ms at minutes. Call sign in Morse.

Pulse of 5 cycles of 1000 c/s tone, 59th pulse omitted and 60th repeated 100 ms later. Radio propagation forecasts (RPF) and geophysical alert warnings (IWDS). Time code (second, minute, hour, day of year) 10 times per hour. Call sign and time (UT) in Morse; time (EST) in voice.

Pulse of 6 cycles of 1200 c/s tone, 59th pulse omitted. RPF and IWDS code announcements. Call sign and time (UT) in Morse.

Pulse of 5 cycles of 1000 c/s tone, lengthened to about 0.5s at minute.

Fig. 2

ditions exist along the transmission path and daily frequency comparisons of high precision (1 part in 10^{10}–1 part in 10^{11}) can be made using some of the l.f./v.l.f. transmissions received at distances of between 6000 and 8000 km.

Three of the stations, NBA, OMA and WWVB maintain continuous transmissions of standard frequencies and/or time intervals but the majority of the transmitters while having stable drive or carrier frequencies, continue to operate general broadcast or Naval communication services. Stations DCF77 and MSF (60 kc/s) are available for 6 hours and 1 hour respectively per day for standard frequency use. They resemble each other in that they both transmit modulated (A3) time signals for certain periods as opposed to the general use of keyed (A1) signals by the other stations listed in the table. More complete information in respect of most of the transmissions is given below.

DCF77.—Radiates standard frequencies and time signals under the control of the Physikalisch-Technische Bundesanstalt (PTB). The programme extends essentially from 0700-1200 and from 1900-2000 each week-day with breaks of 10 minutes at 0800, 1100, 1900 and 1930 for the transmission of (telegraphy) time signals of the Deutsche Hydrographische Institut, Hamburg. The carrier is modulated with PTB seconds pulses at 1911-1929 and 1941-1959 with 440 c/s tone at 0710-0727 and

200 c/s tone at 1010-1027. For the remainder of the time the carrier is unmodulated except for 2-minute interval signals and two breaks of seven minutes at 0728 and 1028 for transmission of PTB telegraphy seconds pulses.

The frequency of the controlling oscillator is increasing slowly at the rate of about 2 parts in 10^9 in 3 months and at present is about 10 parts in 10^9 below nominal referred to the caesium resonance frequency.

Droitwich.—Operated by the British Broadcasting Corporation the carrier frequency is maintained constant to close limits. During 1961 the overall deviation from nominal did not exceed ± 3 parts in 10^8, the day-to-day stability being about 1-2 parts in 10^9. The frequency is measured at 1030 each day at the National Physical Laboratory and results together with those of MSF (60 kc/s) are published monthly in *Electronic Technology*.

GBR and MSF (**60 kc/s**).—These transmissions are synchronous both in frequency and time with the MSF signals on 2.5, 5 and 10 Mc/s. The maintenance period for GBR is approximately 1300-1430 each day: time signals are radiated for 5 minutes preceding 03, 09, 15 and 21 hours.

NAA, NBA, NPG/NLK, NPM, NSS.—These five U.S. Navy v.l.f. transmitters are now stabilized in frequency with high precision (parts in 10^{10}). NBA acts as the master station and transmits time signals continuously except for the maintenance period from 1300-2100 each Wednesday. Brief time signal transmissions are made by some of the other stations according to the following schedule:

NPG/NLK, NPM	For 5 minutes preceding 06, 12, 18 and 24 hours.
NSS	For 5 minutes preceding 02, 06, 08, 12, 14, 18, 20 and 24 hours.

OMA.—This transmission on 50 kc/s is synchronous in frequency and time with OMA 2.5 Mc/s. The carrier is radiated unmodulated, except for the call sign at the beginning of each quarter-hour, for the period 1000-1100 each day.

RES.—This station operates continuously on 100 kc/s with breaks for the transmission of telegraphy time signals at every even hour. The time signal pattern is the same as that of RWM but there are additional interruptions at 0007-0100, 1207-1300 and 1607-1700. RES does not operate for the period 0607-1345 on the first and third Wednesday of each month.

RW166.—Like Droitwich this station radiates a broadcast programme; it operates on 200 kc/s for the period 2225-1900 (0125-2200, Moscow time). Maintenance is carried out on each Monday.

WWVB.—Transmits unmodulated carrier (60 kc/s) continuously each day except for the period 1430-1530, when it is interrupted to avoid interference with the reception of MSF on 60 kc/s.

Accuracy of frequencies and time intervals

The widespread use of atomic frequency standards in recent years has resulted in a notable increase in the accuracy and stability of standard frequency broadcasts. The frequencies of a number of stations in Tables 1 and 2 are now maintained constant by reference to a caesium frequency standard either directly or by aligning their frequencies with those of other transmissions which are so controlled. The frequencies of HBN, GBR/MSF, NBA and WWV do not deviate from their assigned values by more than a few parts in 10^{10} and where particularly close control by the atomic standard is possible, as with WWVB and WWVL, the tolerance has been reduced to ± 5 parts in 10^{11}. It should be noted, however, that these deviations are with respect to an offset value and not to the nominal frequency as defined by the caesium standard. The offset remains constant for any one year at the value announced by the Bureau International de l'Heure but will vary, in general, from year to year. It is applied in order to accommodate the difference between the internationally agreed second (of Ephemeris Time), as realized by atomic clocks, and the second of Universal Time which is based on the rotation of the earth and used for most civil and navigational purposes. The relative difference, at present, between the units of atomic time (A1 time scale) and Universal Time (UT2 time scale) is 130 parts in 10^{10}. Thus, if the standard frequency transmissions were to operate on nominal frequency the time signals, which are locked to the frequency, would gradually diverge from UT2, the difference amounting to about 0.5 second at the end of a year. For many purposes such a large difference would be inconvenient and the frequencies of the stations participating in the co-ordination scheme referred to below are therefore offset by the necessary amount so that the time signals keep approximately UT2 time with, perhaps, the necessity of only one or two step adjustments in the course of a year to maintain the signals within the agreed limits of ± 50 ms.

International co-ordination

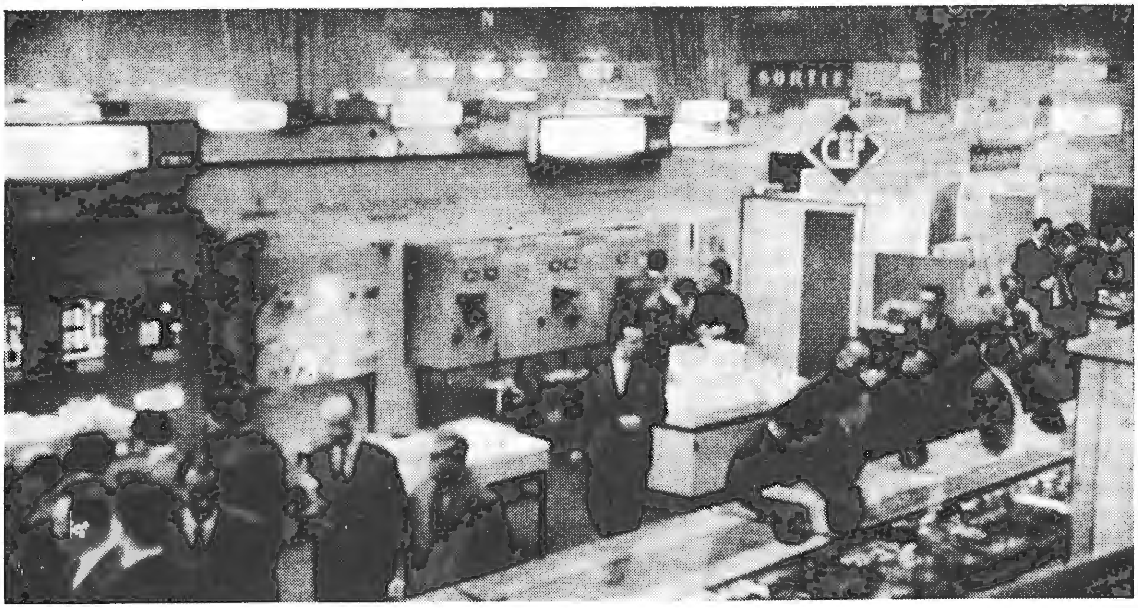
The following stations are now participating in an international scheme for the co-ordination of time and frequency:

CHU, GBR/MSF, HBN, JJY, NBA (and associated stations), WWV, WWVB, WWVH, WWVL and ZUO.

It is understood that station LOL will also join the co-ordinated system in the near future. All these stations attempt to maintain their frequencies as closely as possible at the offset value for each year and the emission time of their time signals at the same instant to within 1 millisecond. Very large areas of the world are now covered, therefore, by a uniform system of time and frequency and if due allowance is made for propagation any of the stations listed may be used interchangeably as a time or frequency reference.

Acknowledgements

Thanks are due to the administrations and laboratories which have contributed information on the characteristics and operation of standard frequency transmissions. This survey has been prepared as a contribution by the National Physical Laboratory to C.C.I.R. studies and is published by permission of the Director of the Laboratory.



Salon International des Composants Electronique

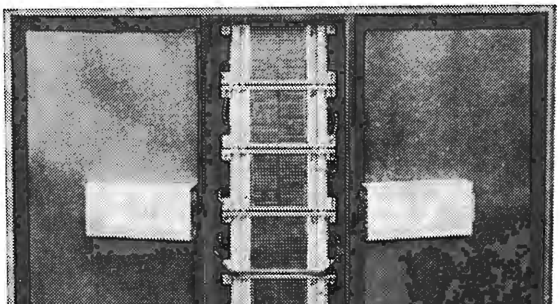
SOME NOTABLE EXHIBITS AT THE PARIS SHOW, 16th—20th FEBRUARY, 1962

SINCE the French Components Show became international, five years ago, it has grown steadily in size and importance. This year the exhibition area has been further increased, the new section at the far end of the hall being occupied by electronic tubes and semiconductors. More than 600 firms (206 foreign) took part, some of them with more than one stand, for there are specialist sections in which similar products are grouped, e.g., tubes and semiconductors (40 exhibitors), electro-acoustic equipment (90), meters and counters (95), fixed condensers (70), relays (60), miscellaneous (350). To the buyer looking for specific products and with less than a week to spend this is a great help, but to the general visitor entering for the first time it is, in the words of the organizers, *une grande confrontation.*

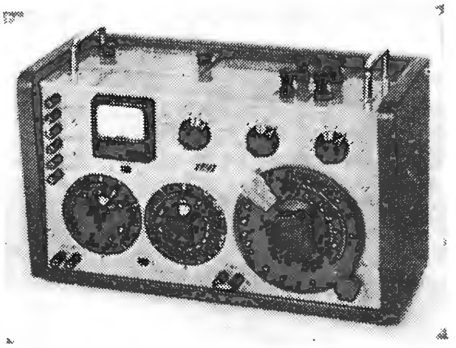
Pièces détachées, the true components, were as numerous as ever and there is obviously still room for competition between a number of small manufacturers of transformers, coaxial plugs and sockets, resistors, capacitors, ceramic insulators, etc., as well as between the larger producers. We were also interested to find firms specializing in the production of "components of components," e.g., the French firm Pacific and the Austrian firm Electrovac who concentrate on vacuum seal bases for transistors and valves.

If there is some sub-division there is even more sub-assembly of components into convenient units for the larger equipment manufacturer, e.g., the tuner units made by the German firm of Hopt, who this year were showing two transistor v.h.f./f.m. tuner units (osc. and mixer). Type FMT4 uses a printed circuit panel fitting the base of a standard miniature two-gang variable capacitor and adding only 15.5 mm to the depth, while Type FMT 100 has the components mounted inside the capacitor frame which measures only $30 \times 31 \times 43$ mm.

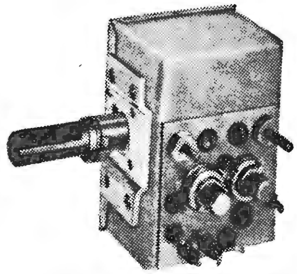
Among microwave valves and components new



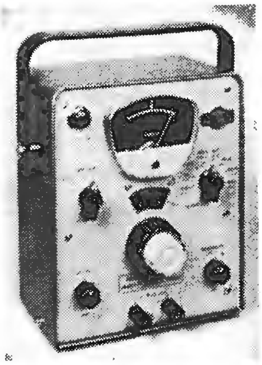
Rear view of Orthophase loudspeaker with built-in 120-W (peak) transistor amplifier.



LEA universal Bridge, Type I.P.T.I.



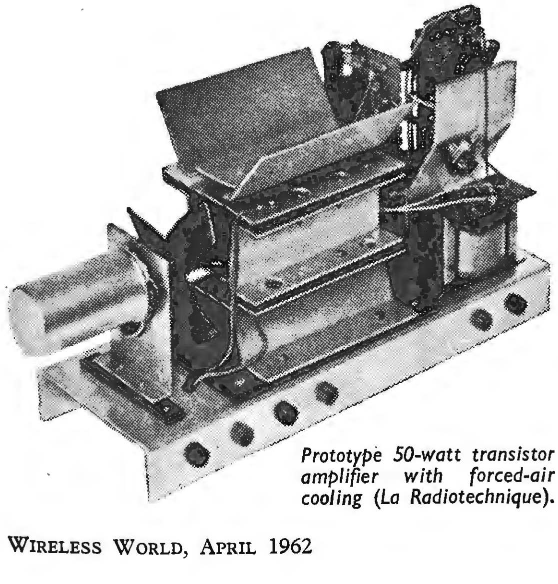
Hopt transistor FM-Micro-Tuner, FMT-100. The offset tuning capacitor is driven through a 1:3 reduction gear and the dimensions of the unit are 3 x 3·1 x 4·3 cm.



Above: Metrix resistance-capacitance bridge, Type 621.

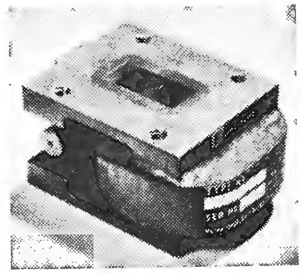
developments by British firms were prominent. Ferranti were showing a miniature X-band isolator only $1\frac{1}{4}$ in long and weighing $\frac{1}{2}$ lb. With a peak rating of 5 kW and isolation >20 dB and voltage standing-wave ratio of <1.2 dB average over a bandwith ± 450 Mc/s, this component is remarkable for the extent to which the minimum v.s.w.r. of 1.07 and maximum isolation of 32 dB is sustained over a useful bandwidth (± 100 Mc/s) near the centre frequency. There is also a new range of Ferranti Y-junction circulators with peak power handling capacity of 10 kW for communication frequency allocations in the C band. Among klystrons shown by E.M.I. was noted the type CV2116 which is used in the Tellurometer system of microwave distance measurement and the Etablissements Tranchant, agents of the English Electric Valve Company included a number of high-power klystrons and magnetrons in their display. Prominent on the M.O. Valve Company's stand was a 35 kV, 10,000A peak (15A mean) thyratron switching valve of advanced design using a deuterium-filled water-cooled metal envelope in which the grid forms part of the envelope. A long life is claimed due to the reduction in the effects of sputtered material from the anode.

Transistor developments seemed mostly in the direction of higher power outputs in audio amplifiers. Le Las, manufacturers of p.a. and intercomm. equipment, showed a wide range of compact transistor



Prototype 50-watt transistor amplifier with forced-air cooling (La Radiotechnique).

Right: Ferranti X-band miniature isolator.



pre-amplifiers and power amplifiers in ratings up to 15 watts. La Radiotechnique showed a prototype 50-watt amplifier with OC 28 transistors in Class B push pull. It had been built to demonstrate that forced-air cooling can be used economically to reduce the overall dimensions of an amplifier of this power, compared with the use of normal convection heat-sink finning. Using a 6V, 0.1A motor the overall dimensions of the unit are 35×19×11 cm.

The latest version (OR 6T 10) of the Orthophase loudspeaker, which was first shown in Paris last year (see *W.W.* April 1961, p. 194), is equipped with built-in driver and amplifier units using transistors and designed to feed the 2 ohm driving elements direct. Four ASZ18 transistors in the output stages are rated at 120 watts peak. Heat dissipation is effected through the large rectangular aluminium wing baffles of the loudspeaker. Each of the six cells in the drive assembly consists of a rectangular foamed plastic diaphragm carrying a zig-zag strip conductor running between the poles of a parallel ceramic bar magnets.

Measuring instruments are an important feature of this show and some interesting new models were shown. Marconi Instruments showed a completely transistorized version (TF 1417) of their counter/frequency meter for frequencies up to 10 Mc/s, and the Dutch firm of van der Heem demonstrated a counter giving a direct read-out at frequencies up to 20 Mc/s.

A new universal bridge (I.P.T.1) by Laboratoire Electro-Acoustique (LEA) and a portable RC bridge by Metrix (Type 621) illustrate the trend towards compactness and portability. Both use transistors and internal battery supplies.

An important section of the French components industry is concerned with relays of all types, from cut-outs designed to clamp on to power-station bus-bars down to micro-relays for guided missiles. A highly sensitive "galvanometer relay" incorporated in a meter movement was shown by Metrix. Contact is made between the pointer and an adjustable index on the scale. When this circuit is closed the relay current passes through a supplementary winding on the moving coil former, and this increases the contact pressure. Several variations are possible, e.g., continuous indication so that the pointer can pass or repass the index, or double contacts for operation on adjustable minimum and maximum settings.

We have been able to mention only a few of the highlights, and if this year it has been difficult to trace any startling innovations or trends, it is nevertheless with satisfaction that we can report growing volume and variety of products and the firm establishment of this exhibition as one of the most important international events of the year.

BOOKS RECEIVED

Linear Circuits by Ronald E. Scott. An introduction to electrical engineering by way of network theory. In two volumes, the work deals first with the time domain—step and transient responses, differential equations and convolution theory, and proceeds in the second volume to a discussion of the frequency domain. Fourier analysis, Laplace transforms and power density spectra are treated, and signal-flow graphs, *s*-plane plots and relaxation methods are all covered. Pp. 928; Figs. 981. Addison-Wesley Publishing Company Inc., 10-15 Chitty Street, London, N.W.10. Price (each volume) 38s.

Electronics: A Bibliographical Guide, by C. K. Moore and K. J. Spencer. A guide to published literature on subjects covering the whole field of electronics. Contributions from all countries, East and West, are noted, and three items of information are given on each entry. The title of the article, together with journal name and date, is followed by the number of references given in the article. A short synopsis is included for each entry. Pp. 411. Macdonald and Co. (Publishers) Ltd., 16, Maddox Street, London, W.1. Price 65s.

World Radio TV Handbook.—The 1962 edition (16th) of this well-known Danish publication, which is available in English or German, has been completely revised. In addition to general articles on how to obtain the best reception, it gives particulars of the world's broadcasting stations, including interval signals and programme times. Pp. 228. Edited and published by O. Lund-Johansen, it is available in the U.K. from Surridge, Dawson & Co., 136-142, New Kent Road, London, S.E.1. Price 18s 9d.

Handbook of Meteorological Instruments, Part II. A review of instruments and methods of measurement of upper-air phenomena. A major part of the book is devoted to the application of radio and radar techniques, and meteorological instruments for use in aircraft are described. Design, operation and maintenance information is given on instruments used at Meteorological Office stations. Pp. 209; Figs. 98. H.M. Stationery Office, Cornwall House, Stamford Street, S.E.1. Price 25s.

B.B.C. Engineering Division Monographs

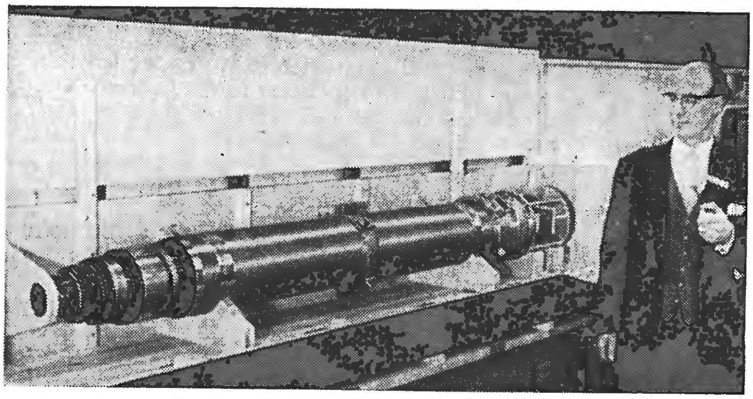
No. 26. *Transistor Amplifiers for Sound Broadcasting*, by S. D. Berry. A description of the design and construction of high-performance amplifiers for use in sound broadcasting. Design principles are discussed, and examples, with performance figures, of several types are given. The design of feedback pairs and of "super-alpha" pairs is described. Pp. 19; Figs. 9.

No. 28. *Programme Switching, Control and Monitoring in Sound Broadcasting*, by R. D. Petrie and J. C. Taylor. A discussion of technical and economic factors involved in the use of programme switching elements. Uniselector switches are described and the design of B.B.C. switching systems is presented. Pp. 32; Figs. 25.

No. 27. *The Equipment of the B.B.C. Television Film Studios at Ealing*, by N. F. Chapman. A description of the work and equipment of the studios. Pp. 31; Figs. 28.

No. 32. *A New Survey of the B.B.C. Experimental Colour Transmissions*, by I. R. Atkins, A. R. Stanley, and S. N. Watson. A description of the experience gained by the B.B.C. in its colour transmissions since October 1957. Programme production problems are discussed, and experimental work which was undertaken to prove the existing distribution system is described. Pp. 31; Figs. 6.

All from B.B.C. Publications, 35, Marylebone High Street, London, W.1. Price 5s each.



***Large Travelling Wave Tube** shown in the photograph is being developed by the G.E.C. Hirst Research Centre for the lower part of the u.h.f. band ($\approx$400Mc/s). It is intended to produce peak pulsed outputs of a few hundred kW with a gain of 20dB. It uses a ring and bar slow-wave structure and a hollow cylindrical high-perveance electron beam.*

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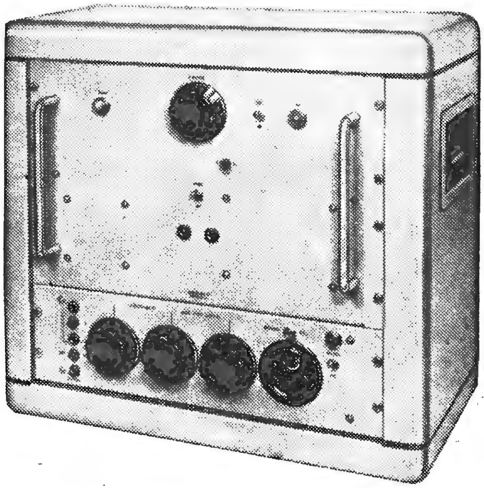

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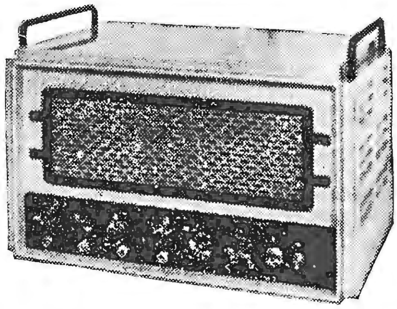

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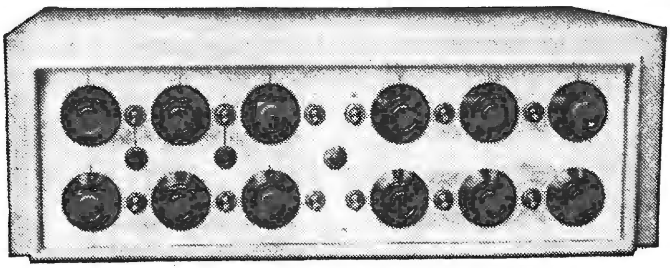

The 12-way electronic mixer has facilities for mixing 12 balanced line microphones. Each of the 12 lines has its own potted mumetal shielded microphone transformer and input valve, each control is hermetically sealed. Muting switches are normally fitted on each channel and the unit is fed from its own mumetal shielded mains transformer and metal rectifier.

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LETTERS TO THE EDITOR

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

Transistor Circuit Conventions

IN his article "Collectors Upwards or Positive Upwards" (January issue), Mr. Baxandall has stated his views admirably. In so doing, however, he has dealt with the general problem of transistor circuit diagrams in a superficial way, failing to appreciate the more fundamental issues in dispute. His article misrepresents the views of school (a), emphasizes what are to school (a) secondary features of the circuit diagram and does not indicate the full effects of the views of school (b) if carried to logical extremes.

To understand the real issues in dispute, we must re-define the two schools of thought in more general terms as follows:

School (*a*) Those who conceive the circuit diagram as presenting what is fundamentally a problem in visual communication, to the solution of which the principles of language and sematography are more applicable than the principles of electrical engineering. People in this school aver that a large circuit diagram is easier to read and understand as a whole if the individual "stages" or function generators, of which it is composed, are drawn to recognizable patterns suggestive of function.

School (*b*) Those who conceive the circuit diagram as being fundamentally a mathematical concept based upon the Cartesian frame of reference. People in this school aver that a circuit diagram can be understood in detail more easily if the page is regarded as a Cartesian frame, the vertical axis representing potential difference and the horizontal axis representing "events."

Viewed in these terms, the question "Collectors upwards—positive upwards?" is recognized as only one aspect of the dispute and unrepresentative of the views of school (a). For example, no one belonging to that school would consider destroying the pattern of symmetry which has become established for push-pull amplifier circuits merely to establish the rule "anodes upwards." It may be argued that neither would anyone in school (b), and this reveals a major inconsistency in their case. Nor would a true protagonist of school (a) accept as correct Mr. Baxandall's interpretation of how they would draw the circuit diagrams which illustrate his article.

Argued on the basis of two- or three-valve or transistor stages, there is not much to choose between either school, and on the whole school (b) tends to score over school (a). It is only when we come to consider the problem on a larger scale that we begin to understand the underlying reasons which motivate school (a). Baxandall is correct in his view that the main opposition to his views will come from "users," since it is the user who has the large-scale problem and not the circuit designer.

As Baxandall suggests, school (a) are mostly "users"; that is to say they comprise in the main that vast body of technicians who are responsible for maintaining and servicing equipment long after the designer and manufacturer have ceased to be concerned with it. Their views on circuit diagrams are conditioned by the job they have to do, and it is necessary to understand what this job is before one can appreciate their views and their reasons for holding them.

A technician may be responsible for maintaining over a period of time (often several years) a large number of relatively small but different equipments or a single very large and complex equipment. In both cases the main tool of his trade is the circuit diagram, but sheer volume of paper prevents him from ever having more than a nodding acquaintance with any given one; therefore every time he looks at a circuit diagram he is seeing it for virtually the first time.

To understand why this is so one has to appreciate that over the past ten years or so the complexity of electronic equipment has increased several fold, and a single large electronic equipment might nowadays require upwards of 150 circuit diagrams, each of which might represent anything from 20 to 50 valve or transistor stages.

A technician is usually required to use a circuit diagram under conditions of stress; that is to say when the equipment has developed some fault and there is pressure and urgency in the need to rectify the fault and get essential services restored as quickly as possible. Under such conditions, his first task is to decide which circuit diagram is relevant to the problem, and his second to decide what the selected circuit diagram is all about. This he must be able to do quickly, and it is essential, therefore, that he be able to grasp the essential significance and structure of a large and relatively unfamiliar circuit diagram in a matter of seconds.

This he cannot do using Baxandall's method, for he hasn't the time to study the diagram in detail in terms of current flow, component by component, from left to right and from top to bottom. Moreover, under the conditions of stress prevailing, the mental climate is not usually conducive to such a study. For these reasons the average experienced technician soon develops a kind of shorthand reading method which enables him quickly to get a grasp of the circuit and to estimate the probabilities of the source of trouble being in one area of the diagram more than another. Only when he is certain that the fault is in a particular area does he get down to a detailed study of the selected area, and even here he will tend to use a short-cut method which saves a great deal of his time provided that the diagram has been drawn so as to help him to apply it.

It is significant that although no formal training is given in this short-cut reading technique, investigation reveals that most successful technicians acquire it and use it almost exclusively in their work. If we ask ourselves why this should be so, we come to realize that the reading of a large circuit diagram is primarily a problem in visual communication which at first instance has only an implied connection with electrical engineering as such.

The basis of this short-cut is physiological rather than technological, and its roots spring from the principles of sematography rather than from the principles of electrical engineering. Fundamentally, two concepts are involved, these being (a) the function generator; (b) the visual recognition pattern.

These concepts are not peculiar to the technician, for we all use them to a greater or lesser extent—even Baxandall writes of emitter followers and sawtooth generators. But the technician has developed their use to a fine art for they offer him the only reasonable basis for speed and efficiency in his work.

Strictly speaking, it is not possible to consider the operation of any given part of an electronic circuit in isolation from the rest, for each component influences the behaviour of its neighbours and, in theory at least, an event occurring in one part of the circuit is but one facet of a single overall event occurring simultaneously throughout the whole.

However, such a concept presents a very difficult mental exercise when applied on a large scale, and it has become the practice to introduce an intermediate concept whereby the circuit as a whole is divided into parts, the behaviour of each being considered separately from the rest over an arbitrary time interval—usually one cycle of the input waveform.

The boundaries of the parts are determined arbitrarily, usually at points where there is a clear and easily recognizable functional discontinuity; for example, at points where a measured waveform or function indicates some kind of logical and evolutionary change from a previously measured waveform. The parts of the circuit which have given rise to the new function are thought of as constituting collectively a function generator. Thus, in these terms, an electronic circuit becomes basically a series of function generators in cascade, and the operation of the circuit is conceived as a series of events occurring in sequence rather than simultaneously.

In any given case, just which components as a group form a particular function generator is determined largely by convenience as regards either the mental effort required to envisage a number of events occurring simultaneously, or the need to develop a logical step-by-step sequence to explain the action of the circuit as a whole. Thus a simple series C-R circuit might be considered to be a separate function generator in one application; but in another, where it performs exactly the same operation it might be considered to be only part of a larger group of components collectively forming a different kind of function generator.

In spite of this arbitrariness, certain kinds of component groupings have, over the years, become recognized by common consent as constituting basic or generic types of function generator. Thus, when we speak of a π-attenuator, an anode-tuned amplifier, a Kipp relay, or a Foster-Seeley discriminator, we know broadly what is meant and for each we are usually able to draw from memory a circuit diagram showing the essential function components.

Only a limited number of generic types of function generators have been evolved over the years, and although there are many variants of each, none of these differs fundamentally from its generic type. Thus, in these terms, Baxandall's ingenious sawtooth generator (Fig. 10 in his paper) is nothing more than a blocking oscillator (generic type) in which the C-R time constant occupies an unusual position requiring special biasing arrangements for the active device (see accompanying Fig. 1). Again, in Baxandall's Figs. 6 and 8, the considerations which he explains at some length are only trivial refinements to existing generic types of function generators, and would interest most technicians only in passing.

It is implicit in the function generator concept that

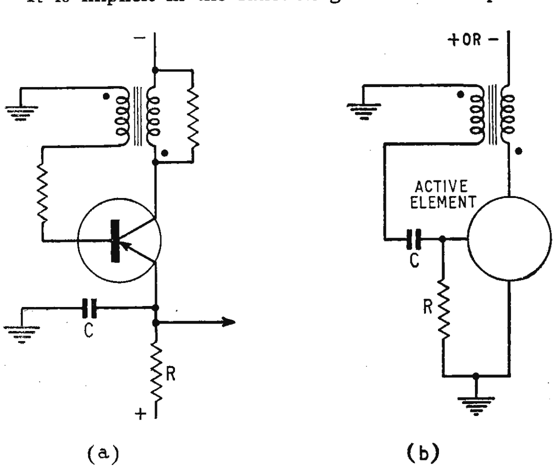


Fig. 1. Sawtooth generator (a) to circuit of Mr. Baxandall's Fig. 10, and (b) generic form of the same circuit.

there should be as few generic types as possible and that no new type should be accepted unless it embodies some fundamentally new principle of operation or generates some fundamentally new type of function. The mere substitution of one type of component for another which has similar characteristics and performs basically the same function does not warrant the acceptance of the modified circuit as a new generic type. This applies equally to active devices since these are in themselves but one type of component among many.

Thus the valve circuit of Fig. 2(a) is recognized as being of the same generic type as the transistor circuit in Fig. 2(b) and the hypothetical relay circuit in Fig. 2(c). The important thing is to recognize the basic identity of all three, and to relate them to each other as regards function and principles of operation. The fact that power supply polarities and waveforms might be inverted in one case relative to the others does not cause any embarrassment because, knowing the basic principles of operation of one, it is a simple matter to determine in what way the others differ from it.

Further training and experience encourage the technician to seek the generic in any unusual circuit he might meet, and thus relate the circuit to his existing experience in terms of similarities and differences. This is what most of us have been doing in one way or another for a long time, since few of us have the inclination, and even fewer of us have the time to get down to first principles on every occasion when an alleged new circuit makes its appearance.

Of course, one cannot expect the circuit designer to go along with this line of reasoning, because it strikes at his professional pride. Every designer has the ambition to produce something new and original but rarely succeeds in doing more than refining or modifying the old. Therefore, we must not take seriously any claims for the circuit designer to be regarded as an oracle. He has, in fact, a vested interest in confusing the rest of us to highlight his own originality and ingenuity, however trivial these might be in any given case.

It is part of the normal training of every technician to study the principles of most generic types of function generator. This study usually proceeds along the lines recommended by Baxandall but in largely non-mathematical form. For this purpose, circuits have usually been assumed to contain thermionic valves since these introduce fewer teaching complications than transistors, and represent more nearly the ideal form of active device. Further instruction is given on circuits containing transistors, where appropriate.

For any given type, the process usually begins with a circuit diagram drawn on a blackboard and copied by the student into his notebook. This circuit diagram is repeated subsequently in laboratory experimental equipment and in textbooks; the student, therefore, ultimately comes to recognize it on sight provided it is always drawn in the same way so as to make the same pattern on the page.

Thus, the technician in his early training comes to associate each generic type of function generator with a certain pattern of lines and symbols and he carries these patterns in his mind long after he ends his formal training and starts his working life.

Investigation reveals that when the average trained and experienced technician looks at a large and relatively unfamiliar circuit diagram, his first action is to seek out these significant patterns so as to identify the various types of function generator of which the circuit as a whole is composed. Thus, provided the individual function generators are drawn to patterns which he can recognize he usually has little difficulty in getting quickly to grips with the circuit as a whole. Even where a function generator is an extreme variant of a generic type, he rarely has difficulty in understanding its principles of operation because the pattern helps him relate the unfamiliar to his existing knowledge and experience.

Slight distortions of the patterns do not affect his ability to understand the diagram, but where they are

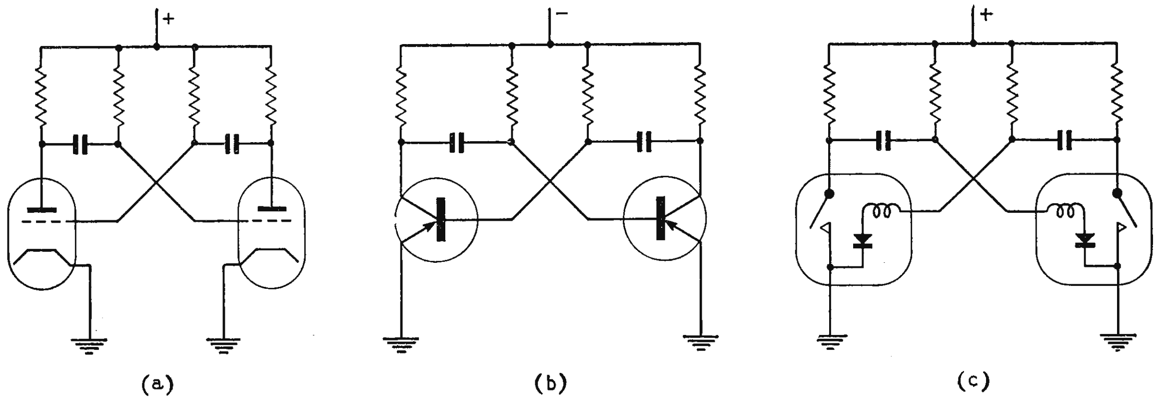


Fig. 2. (a) Thermionic valves, (b) p-n-p transistors. (c) Relays and diodes.

very seriously distorted, or are drawn to resemble a pattern he has come to associate with another kind of function generator, then doubt, confusion and delay occur. This will often result in a situation where he has to work out in detail the operation of the circuit and will usually end with his re-drawing the offending part of the diagram to conform with a pattern he feels more at home with. This, in the past, has frequently occurred because circuit diagrams have been produced without sufficient thought for the "user."

Where he can recognize nothing on a large diagram, then he is forced to study the whole of it in detail on the lines recommended by Baxandall. This takes a very long time and a lot of experience for a large diagram, and he may even have to call for help from a superior.

Whilst these situations might represent a useful technological exercise that might be considered as good for the soul of the technician, they usually occur at a time when the equipment is out of action and must be got back into operation without delay. It is therefore desirable that they should be avoided as far as possible by designing the circuit diagram in such a way as to aid his powers of recognition.

This recognition factor has other uses, for in each generic type of function generator, the technician comes to expect certain functional component symbols (e.g., load resistors, bias and decoupling combinations, coupling components, etc.) to occupy particular relative positions in the pattern, and because of this he is able to make quick decisions about the possible or probable causes of a fault or malfunction.

Thus, although the recognition pattern might not conform strictly to rules framed in engineering terms, it nevertheless has a very valuable and convenient economic function and it has a sound basis in sematology. In terms of sematics, the individual component symbols are pictograms and form a basic and very flexible alphabet for building larger symbols (recognition patterns); these latter convey more meaning than do the sum total of the symbols when not arranged in any purposive pattern.

Thus, in simple terms, the component symbols are "letters" which by their relative positions form "words"; these in turn providing a coherent story about the diagram as a whole. To distort a pattern is to make the reader indulge in anagrams and this the technician cannot afford to do; it is, however, just what school (b) propose.

Now school (b) may well say that this is not electrical engineering, and with this view we must all agree; but let us look at the problem in another light. A circuit diagram is a means of communication and its structure and arrangement should therefore be designed to facilitate this. In principle, communication by means of arbitrary symbols printed on paper is language, and it is not unreasonable therefore to expect the rules for constructing circuit diagrams to evolve along the same lines as those of most other rudimentary languages.

Strength is lent to this argument because, unknowingly, we have all been subscribing to it for years. Some examples are as follows:—

(a) In stating the primary guiding principles to be observed in drawing circuit diagrams, BS 530 enjoins us:—
   (i) to ensure that the main flow of events is from left to right and from top to bottom of the page—thus conforming to the same pattern of scanning which we use to read a page of typescript.
   (ii) to draw circuit diagrams to conventional patterns as far as possible. (Some rudimentary examples are given.)

(b) Push-pull amplifier circuits and f.m. discriminator circuits are always drawn to show a pattern of symmetry which is suggestive of function. (Note: the anodes upwards convention is waived.)

(c) Relaxation oscillator diagrams are given a characteristic criss-cross pattern which makes them easy to recognize but which is not necessary on purely technological grounds nor is it directly suggestive of function.

(d) In voltage regulator diagrams, the current control valve (or transistor) is usually shown in a cross-page position which is suggestive of function.

As a simple exercise, consider the patterns shown in Fig 3. These are simple line patterns in which the components are omitted except for the envelopes of the active device which provides a focal point but is not really necessary to the experienced eye. Try to see if you can put a name to any of these—and note that no power supply potentials are shown. In most cases it is possible even to draw a waveform diagram to illustrate function, although, naturally, it will not be possible to assign polarities to these owing to a lack of information.

That we should all have been making use of recognition patterns is not surprising, because it is a natural physiological reaction to seek pattern and structure, order in chaos, whenever we are faced with a complex visual problem. This reaction will always recur, whether intended or not, because we and many other animals are designed in this way. If Mr. Baxandall has his way, all he will achieve will be the creation of new patterns which will themselves cause just the same complications in the future. Moreover, the new patterns will not become established in much under a generation, and in the meantime a great deal of confusion will result. It is therefore better to accept and develop those which are now generally accepted and to growl in our beards about our ancestors' failure to guess correctly the true direction of movement of charge in a conductor.

Most members of school (a) would disagree with Mr. Baxandall in his contention that confusion must arise in non-linear circuits unless the positive-upwards convention is used. Practical working experience, admittedly at this stage limited, of complex transistorized equipments in the services leads us to believe that technicians hold the opposite view.

Here again, this seems to be because technicians do not think of waveforms as graphs in the normal course of events, but treat them as ideographs. For this reason, a rising waveform on a valve grid or transistor base is viewed as a movement away from the reverse bias condition and is associated with a falling waveform at the anode or collector. This concept is true both for valves and transistors and is a universal rule which is simple to understand and apply. Where there is a doubt as to the actual polarity of the waveform, this is easy enough to indicate and Fig. 4 is a suggested method of doing it.

This is the way in which most technicians seem to prefer to think of waveforms when interpreting circuit operation, and there is no reason why they shouldn't, for the axes convention is by no means inviolable either in principle or in practice—one has only to look at any manufacturer's transistor characteristics to see that this is so.

In fact, to put it bluntly, most technicians would regard the preoccupation of school (b) with power supply polarities and h.t. rails as old-fashioned, and evocative of amber rods, fur rubbers, pith balls, and the general scientific atmosphere of the eighteenth century. After all, we are all aware that our conventions relating to polarity and current flow have been known to be wrong for nearly a century but we continue to use them from force of habit. They have no magical significance, and most of us have got into the habit of thinking of current flow and electron flow simultaneously without getting unduly confused.

As has been stated above, the recognition pattern is not a new concept but it is doubtful if it has been propounded previously in terms of communication, sematics, and language evolution. Nevertheless, in principle this is what it is, and its formal statement given above clarifies the real issues between school (a) and school (b).

By analogy, these issues can be likened to those which might arise between those who study words and those who use them. Most of us can recognize the misspelling of a word by visually relating the letter pattern we see with that which we expect to see, and we often use this same visual perception to relate adjectival or adverbial forms of a word. In neither case do we need to know or study the etymological roots of a word unless, like horticulturalists, we are trying to design a new one.

Thus there is much to be said for the school (b) concept, of viewing the circuit diagram as a voltage-event graph, where design work is concerned. The designer tends to do his job in these terms, and needs to be able to fix various points as voltage data for the purpose of calculation. However, for most applications, it does not provide a sufficiently quick and efficient method of communication, and the school (a) method is probably most suitable for this purpose.

Now, in considering which school has the prior claim, let us look at the factors involved.

(a) A circuit designer cannot be said to *use* circuit diagrams frequently on a large scale and over a wide field. His interest over a period of a week or a month is usually confined to a small field of circuitry and is transient in the sense that when he has completed the design he will probably not require subsequently to use it or even to refer to it.

(b) The technician uses continually a multitude of circuit diagrams, often under conditions of stress, unlike the designer, he regards them as principal tools of his trade.

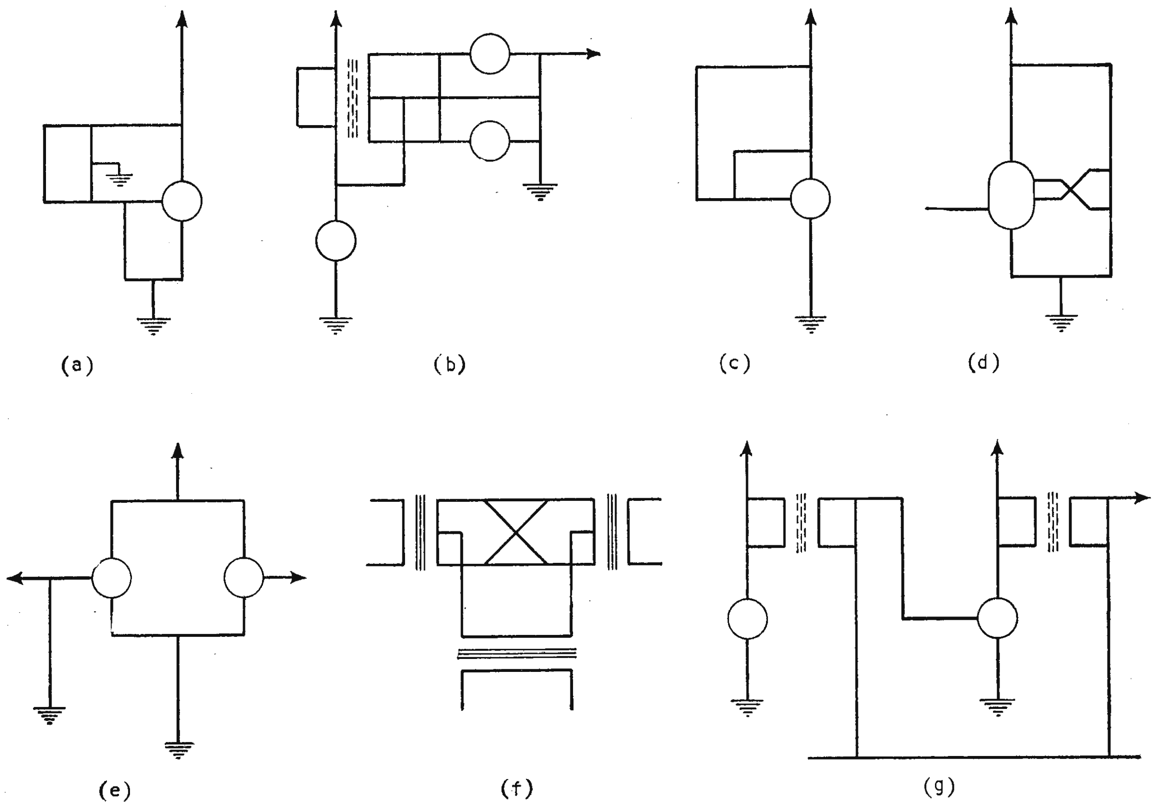


Fig. 3. An exercise in pattern recognition.

(a) Colpitts oscillator. (b) Foster-Seeley discriminator (c) Miller feedback circuit. (d) Transitron. (e) Long-tailed pair. (f) Bridge demodulator. (g) Tuned-anode/tuned-grid amplifier.

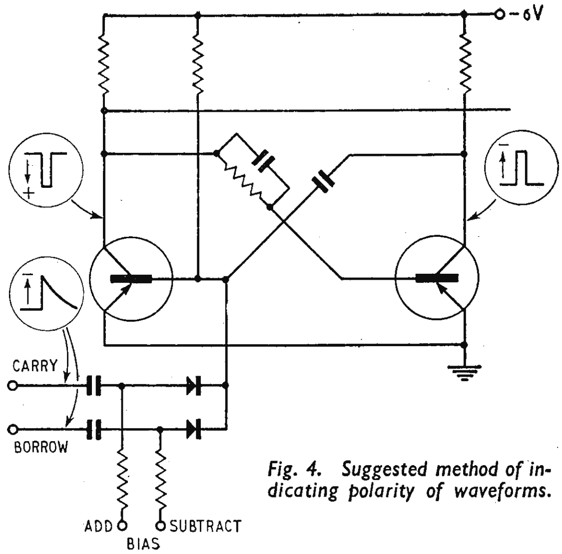


Fig. 4. Suggested method of indicating polarity of waveforms.

(c) The technician is required to understand and interpret the work of many designers, and cannot afford to be misled by their individual fads and fancies.

(d) The technician is required always to work with one eye on the clock. The time wasted by technicians might collectively cost the employer more than the yearly salaries of several designers put together. With service equipment the result may be even more serious than a purely economic loss.

(e) Circuit designers are a small minority of the workers in the broad field of electronics and are outnumbered by technicians to the tune of several orders of magnitude.

(f) Circuit designers have an interest in circuit diagrams, peculiar to their task, which can conflict with the requirements of the "users."

From the above, it is clear that the interests of the circuit designer should be subordinated to those of other workers. That is not to say that circuit designers should not continue to draw their circuit diagrams in any way they choose, but they must not be allowed to impose their views on the rest of us.

Conclusions

1. Mr. Baxandall has failed to appreciate that the views of school (a) are based upon sound sematological principles which make just as much sense scientifically as do his own proposals. Moreover, school (a) are able to offer convincing economic arguments to back up the stand they have taken.

2. By restricting his illustrations to two or three function generators, he has failed to present the problem in its true light and has, therefore, failed to realize that, on a large scale, the circuit diagram presents a fundamental problem in communication.

3. The preoccupation of school (b) with polarities is out of place and old fashioned. These are of only secondary importance and even if omitted they can be inferred from other information on the circuit diagram. Compared with the communication problems as a whole, they have little significance.

4. School (b) will probably lose their case in the long run, whatever might be decided at this stage. This will not occur for any technological reasons, but because human beings generally prefer to relate new experiences to old ones, and are always likely to use their visual sense rather than engineering principles when confronted with what is, in the first instance, a visual problem.

5. It is possibly a weakness in our training methods that we do not give technicians formal instructions on the use of visual recognition patterns. Considering their economic implications, and the need for technicians to be able to work speedily and efficiently, there is a sound case for studying the technique so as to place it on a firm scientific footing, and for standardizing the patterns of all generic types of function generators. In this way we might be able to develop the circuit diagram into a really efficient means of communication based on sound scientific principles instead of upon a somewhat shaky foundation of outmoded conventions and individual opinions.

Malvern. R. KNOWLES
S. BRAITHWAITE
Radar Branch, Electrical Wing,
Technical Group, R.E.M.E.

MY chief concern is helping people understand transistors and my approach is therefore coloured as much by the phenomenon of understanding as by the device itself: to this end I find myself in sympathy with Mr. Baxandall. The promotion of understanding is a subtle business, however, and one of its more important principles is that the "real" experience of the learner must be used whenever possible.

This is one of the difficulties of electronics as opposed to, say, mechanics. Very few people get far through life without experiencing some elementary mechanics for themselves. In talking to North American young men, for example, I find that by resorting to simile involving the automobile, understanding is decidedly quickened. Real experience in electronics is left to hobbyists almost exclusively; the onslaught of the *results* of radio and television circuitry does little to reveal their workings. Thus when my aforementioned N.A.Y.M. are confronted with the crystal triode (transistor) their real experience that is relevant is a fairly good grasp of the workings and characteristics of the p-n junction diode.

To show that they are not on unfamiliar ground the forward characteristic of the "emitter diode" and the reverse characteristic of the "collector diode" are found by measurement to resemble those diodes with which they are already familiar. Hence my fondness for transistor symbols which look like diodes.

The *ill* effects of real experience are not to be overlooked. The trouble I have convincing my young men that a diode which is operated in its "breakdown" or "avalanche" mode has not really "broken down" or become the victim of a catastrophe has to be seen. (I'm promoting "thresholds" this year.)

I hope I have succeeded in making it clear that whatever symbols or conventions one puts forward their basis ought to be clarity of understanding. Whether the symbols are the lines, circles and triangles that represent devices and circuits or those which are gathered into groups, the groups into sentences, the sentences into paragraphs, their efficacy cannot be divorced from the reader's real experience.

"Positive up, negative down" I put in the class of real experience for everyone (especially here in Ottawa where every verandah carries a thermometer which registers temperatures above and, at present, below zero F) and I would like to add my voice to that of Mr. Baxandall in its favour. May we hope that it will lead to presentation of collector characteristics in the correct quadrants?

As a final illustration of the effect of experience upon understanding I not long ago checked a laboratory report in which the anode characteristics of a 6CB6 were described as having a "transistor-like form."

Ottawa, Canada. J. BATESON.

The author replies:

Lt. Col. Knowles and Mr. Braithwaite have, I feel, seriously misrepresented the attitudes of my colleagues and myself. In actual fact, we are in wholehearted agreement about the importance of drawing circuit diagrams so that the significant functional sub-circuits (such as amplifier stages, emitter followers, trigger circuits, long-tailed-pairs, etc.) can be rapidly picked out by anyone having the necessary background of circuit experience. Indeed, I have devoted a good deal of time, over the years, to trying to persuade people to pay more attention to this important aspect of circuit diagram drawing.

In my view, if one adopts the "positive upwards" convention, there is no need to forgo the undoubted advantages of being able to assimilate rapidly the broad scheme of a complex circuit by a process of pattern recognition. Admittedly, in circuits employing p-n-p transistors, some familiar configurations will appear in an orientation which will, at first, be regarded as "upside down" by those thinking in terms of valve circuits. Here, however, I would make the following observations:—

(a) A familiar pattern is really quite easy to recognize "upside-down."
(b) It is surprising how rapidly one ceases to regard the new presentation as being "upside down."
(c) The number of standard configurations common to valve and transistor circuits is actually quite small—it is difficult to think of more than about a dozen really significant ones.
(d) There are plenty of transistor circuits which cannot be regarded as mere modifications of well-known valve circuits. They exploit such things as the bi-directional switching properties of transistors, avalanche operations, the hole-storage delay time, and complementary circuitry. Thus the valve man will find new patterns and circuit concepts to assimilate no matter what circuit diagram convention is used.
(e) In answer to Mr. Cain's comment that "we must not cloud this issue by looking at a small minority of the awkward cases," I would point out that some of the circuits which he now regards as awkward may well, in due course, become commonplace.
(f) We have found no difficulty at all in getting new Scientific Assistants to look at things our way, even though they may come to us having some familiarity with valve circuits.

Of course, I do admit that if easy pattern recognition were the *only* consideration, then there is everything to be said for the "collectors upwards" convention, since it avoids the necessity for recognizing some patterns either way up.

But I am sure that even Lt. Col. Knowles and Mr. Braithwaite would agree that it is also *very* important to draw circuits so that they will facilitate, when the occasion arises, sound reasoning about their functioning.

I maintain that the "positive upwards" convention is the only one which is free from serious snags in this respect, and that in adopting it one is paying merely a reasonable price for, in the long run, a very large gain in ease and clarity of thought.

I am glad to see that "Cathode Ray" and Mr. Bateson, who are both closely concerned with the elementary educational aspects of the subject, have also come to support unreservedly the "positive upwards" convention.

It seems to me, from several letters written by supporters of the "collectors upwards" school, that their writers have not yet become fully conscious of the confusion which is inherent in the use of their convention, particularly in circuits using p-n-p and n-p-n transistors in combination. None of the suggested remedies, such as that proposed by Mr. Bedford, is completely satisfactory.

It is evident from Fig 4 of the letter from Lt. Col. Knowles and Mr. Braithwaite that they do like the waveforms to tie up with the voltage movements visualized in relation to the circuit diagram, for their waveforms are intentionally drawn this way. Nevertheless, because they have put the negative supply line at the top, they have had to add the comment "*where there is a doubt* as to the actual polarity of the waveform, this is easy enough to indicate and Fig. 4 is a suggested way of doing it." On applying any normal modern oscilloscope to their circuit, however, the waveforms actually seen would be upside down versions of those shown on the diagram.

Now, surely it is desirable for the waveforms indicated in circles on a circuit diagram to represent what the technician ought actually to see when he connects an oscilloscope—indeed, in conversation with Lt. Col. Knowles and Mr. Braithwaite, it was evident that they too regard this as desirable in a circuit diagram of a practical equipment, if not in a diagram on a blackboard in an elementary lecture.

I would ask all those who are at present tending towards the views of the "collectors upwards" school to ask themselves the following question:— "Are you really happy about recommending a system in which waveforms drawn in circles against points on a circuit diagram cannot, at one and the same time, represent (a) what a technician will see on an oscilloscope and (b) the waveform he will visualize to himself if he thinks in terms of voltage movements in relation to the supply lines or supply terminations?".

Dr. Sturley and Mr. Amos, and Mr. Cain, have argued that there is no difficulty in tracing the passage of a signal through the various stages of an equipment, provided one remembers certain simple rules, e.g. that there is a phase inversion in a common emitter stage but not in an emitter follower. Whilst it is often quite satisfactory to regard amplifiers this way (and, indeed, we all frequently do so), and whilst some non-linear circuits can be regarded largely as overloaded amplifiers, nevertheless it is quite unrealistic to imagine that the non-linear circuit field as a whole can be satisfactorily expounded on this basis. I doubt whether anyone working closely in this field would regard it as reasonable to attempt to do so.

The suggestion that the preoccupation of the "positive upwards" school with polarities is out of place and old fashioned seems quite unreasonable to my colleagues and myself; the behaviour of a circuit such as a multivibrator, for example, is closely bound up with the d.c. supply polarities and magnitudes—this is a fact and is quite unavoidable.

Admittedly, one may argue in terms of movements "towards rail" and "towards ground," without actually mentioning polarities as such, but this is satisfactory only when one is thinking in "theoretical isolation" so to speak. As soon as one puts an oscilloscope on a practical piece of equipment, one becomes concerned with *actual* polarities.

Moreover, I would think that the moment when a practical waveform is being observed is a particularly inopportune moment for confusion over signs to arise—much better to get all this cleared up in the elementary training stage by adopting the "positive upwards" convention right from the beginning.

I agree that there are a few circumstances, such as some push-pull circuits and stabilized power pack circuits, where other considerations make it desirable to depart from the conventions of either school (a) or school (b).

Malvern. P. J. BAXANDALL.

Line Standards for British Television

I HAVE followed the arguments of those (apparently the majority) who feel that it is imperative to change our standards to the 625 line system, because of the advantages of increased exports, more international programmes, better pictures with larger tubes, etc., but I am often left with some doubts about the validity of these so-called advantages, because of the unwillingness of such advocates to go any further than broad generalizations. One hears very little of the facts to support the arguments (if indeed any substantial ones exist).

Standardization (with Europe) is no doubt a very desirable objective, but it must be questioned whether the state of the television art is sufficiently stable (for the next 25 years) to warrant our making such a drastic change for such marginal advantages.

Our present 405 system needs no defence; it has been in use for nearly 25 years now, and has been shown to satisfy the requirements of an excellent television distribution system very well indeed. It provides a good compromise between picture quality, cost and complexity of receivers, range of transmission, and simplicity of operation.

The best that can be said for the 625 system is that it is similar, but possesses marginal improvements. Horizontal definition is about the same, while the line structure is, of course, reduced in visibility.

There is, however, no large body of lay opinion which finds 23in/405 pictures unsatisfactory as a result of line visibility.

It can be said, I think, with fair certainty, that the vast majority of viewers will not be aware of any substantial improvement in picture quality if the changeover is made. Therefore, we must ask ourselves with the utmost seriousness whether such a change is really worth while. The arguments for a change seem to be mainly that we would bring ourselves into line with Continental practice and that as tubes grow larger the significance of the line structure increases, and some improvement over our present 405 system is necessary. Against this it has been argued that the value of standardization, so far as programme exchange is concerned, is negligible, since the vast majority of television programmes could not be shared, even with common standards, because of language difficulties. This problem obviously would not be altered, whatever the number of lines are.

In any event, the technique of recording programmes on film is quite suitable for programmes having an export potential. Video tape recording (requiring common standards) carries advantages from the programme contractor's point of view. These must, of course, be taken into account, but are by no means an overriding consideration.

Secondly, there is the question of exports and imports. Have we any real reason to believe that the industry will do better on exports of television than it has done in the past years on radio, where the system parameters have always been compatible but the volume of exports industry-wise has been relatively insignificant, simply due to the unwillingness of British manufacturers to meet export requirements in terms of performance, cost and styling? Indeed, it is very probable that should our standards fall into line with Europe, we would find the increase in imported television receivers would counterbalance any increases in exports, and thus leave us with no advantage. We certainly have no factual evidence to support a belief that a large upsurge in exports would result. In the main the pattern of Continental receivers is one of complex facilities (as with their radio receivers) which in Great Britain have not proved to be required—and since their provision would undoubtedly increase the cost of receivers significantly, it is unlikely that similar specifications would be adopted for the British market. Unless export receivers were in the main identical to the home market models, the advantages of common line standards, so far as production is concerned, would not be as great as some people would have us believe. Television sets are relatively easy to manufacture, and if it transpired, as well it might, that the facilities, performance, and appearance of export television receivers are noticeably different to those required by the home market, separate production lines would have to be laid on for them in any event.

If a change to 625 lines were made, the viewing public of this country would obtain no great improvement in picture quality, nor would the economics of the industry be substantially affected, nor would the variety of television programmes available to us be greatly increased.

The T.A.C. were asked to consider the technical requirements for television broadcasting in this country in the next 25 years. It was stated in their report that 405 would not be adequate, and the recommendation made for a change to 625 lines . . . this recommendation did not specifically state that 625 was adequate (in the sense of being worth the change) for the next 25 years, and I feel that it was a shortcoming of that report not to have discussed the possible life of any such change in the light of the rate of technological advances.

In my view, it would be a rash engineer who made the firm statement that within the next ten years even, significant advances will not emerge that will make it possible to make a change that produces, for example, a 2:1 improvement in definition, plus colour. Indeed, indications in the industry are that the intensive work that has been carried on in the last 15 years with this objective in view may well produce a break-through, in the near future. If that report were intended to convey the meaning that it was worthwhile to make such a change to 625, with an undisputed life of, say, the next 10 to 15 years, that is one thing; but to imply that it is worthwhile to do this for the purpose of living with it for the next 25 years is quite another.

I think there is a great danger of the following circumstances arising: that there will be a major break-through within the next 10 years, and that the Continent, having lived with their system for what will be by then nearly 20 years, will be favourably disposed to making a change to the new improved system. In Britain, however, we will by then only just have settled down (we presume) to overcome the semi-chaos that will arise in the next few years during the changeover period, and then having just got that over, we will be faced with the strong possibility of having to do it all over again. I think this to be an untenable situation and far too great a danger for us to risk at the present time, bearing in mind, of course, as stated above, that the accrued advantages from the change at the present time would be very small.

We have the situation in this country where arguments are being made in favour of a third programme. It has been shown that if the standards used remain on 405 lines, this third programme could be transmitted in Band 3 if the remaining channels were allocated for this purpose. Obviously the *efficiency* of implementing such a proposal is very great indeed, but if the third programme is required with a 625 line system (and it may well be necessary to put forward a third programme merely for the purpose of giving the public an incentive to buy sets with 625 lines) it is almost certain that we will have to utilize at least Band 4, if not Band 5. Here indeed is a vast field of problems that the industry will be saddling itself with (unnecessarily in my view), which may well have the effect of doing more damage to 625 lines than the advantages claimed for it, simply because unsatisfactory reception, due to the reduced performance of receivers and increased propagation problems on u.h.f. will be very much more noticeable to the viewers as a degradation than the finer line structure of 625 lines will be observable as an improvement.

Finally, I would conclude by suggesting the following propositions to cover us for the next ten years:

1. Remain on 405 lines.
2. Transmit on colour immediately (this not being bedevilled by non-compatibility problems).
3. Introduce a third programme (if this is required) on Band 3.
4. Pursue intensive development, preferably on an industry basis, with a view to introducing a greatly improved television service in 10 to 15 years' time, when we may be able to put ourselves in the position of once again leading the world as we were able to do in 1936.

Loughton, Essex. P. SCADENG.

Colour Television

P. P. ECKERSLEY'S description ("Open Letter to The Pilkington Committee," *Wireless World*, December 1961) of colour television as "an oleographic horror" might very well apply to present British systems, but it certainly does not apply to the N.T.S.C. system as used in the United States today.

While there are, admittedly, some poor colour programmes, they are very much in the minority, and the average programme viewed on modern receivers (particularly those using the improved-phosphor c.r.t.) is breathtakingly beautiful.

The glories of "Wagon Train," "Bonanza," "Perry Como," Walt Disney, the N.B.C. Opera Company, etc., etc., have to be seen to be believed. No noticeable deterioration can be seen in programmes transmitted 3,000 miles from Hollywood, over a combination of microwave links and coaxial cable.

The question "Would you pay three times as much to see a film in colour as you would in black and white?" is irrelevant, because the premium paid for the colour film is irretrievably lost whereas the premium paid in purchasing a colour television set is repaid a thousandfold in the weeks, months and years of highly enjoyable colour television viewing.

In the U.S.A. colour sales are up by over 200% from last year and 300,000 sets will be sold. Colour programming is up also, with an average of 4½ hours per day; this will be doubled in the autumn with virtually every major N.B.C. evening programme being in colour.

I hope negative thinking, such as P. P. Eckersley's, will not delay colour inception in the United Kingdom.

New York. B. W. SHEFFIELD.

The author replies:

There is no disputing about taste so I can do little more than say how pleasant it is to learn of Mr. Sheffield's rapture in face of American colour television. I must add, having seen demonstrations of American colour television, which are in no way inferior to British, the effect produced upon me differed in considerable degree from that expressed in such glowing terms by Mr. Sheffield. Mr. Sheffield is obviously the better, or is it the more easily pleased?

P. P. ECKERSLEY.

Safety of Life at Sea

IN our letter appearing in your February issue (p. 69) under the above heading, we stated that the range of m.f. survival equipment when operated from a dinghy would be "reduced to perhaps only a few miles."

We have since been authoritatively advised that a range of more than one hundred miles can be obtained. This figure, we have been assured, has been established as a result of extensive practical tests conducted by design personnel working from a naval type life raft under simulated survival conditions.

Our figure for range was based on information obtained from an external advisory body. In view of this refutative evidence which we accept without question, we should be obliged if you would publish this letter in the correspondence page of the next issue of your journal with our apologies for the error in this regard.

Erith, Kent. W. R. TIBBENHAM,
Burndept Limited.

"High-quality Tape Pre-Amplifier"

IN Mr. P. F. Ridler's article in the February issue (p. 52) an economy in power consumption and components is possible by replacing the network R_1, R_2, R_3 by the equivalent delta network of three resistors, and then omitting the redundant resistor across the power supply.

The remaining two resistors have a theoretical value of 208kΩ each, but the nearest preferred value of 220kΩ would suffice.

London, N.14. D. SHARP.

THE base bias circuit of Q1 in Mr. P. F. Ridler's tape pre-amplifier (Fig. 1) is equivalent to that of the accompanying Fig. 2 (e.g. by star-delta transformation) whence it is seen that only two resistors are needed, R_c being redundant.

The aim of this method of biasing is to maintain the

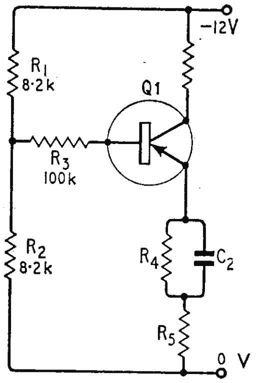


Fig.1

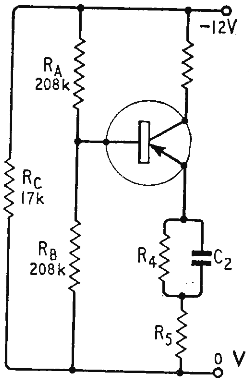


Fig. 2

base potential, and hence the emitter current, constant. The junction of R_1 and R_2 will indeed be held to -6 volts, but small changes in the current through R_3 (due to the effect of temperature changes on I_{co}) will considerably affect the base voltage, and hence the operating conditions.

In practice the circuit is likely to be mounted close to a tape deck in an enclosed space, and many tape decks become very warm after being run for a few hours. There is thus a risk of Q1 becoming bottomed, and I feel that the temperature stability of the circuit may not be as good as Mr. Ridler intended.

The input impedance at the base of the transistor itself can be increased as much as desired by suitable feedback, but this is always shunted by R_A and R_B. R_B may be taken to R_4, R_5 junction (thus reducing its shunting effect so long as $1/\omega C_2 << R_4$) but R_A remains. The problem of obtaining a high input impedance then reduces to the problem of increasing R_A as much as possible.

This may be achieved by increasing the negative supply voltage to which R_A is returned, or by reducing the collector current (and hence the base current). The high I_{co} of germanium transistors sets a limit to the latter solution, and it is preferable for this application to use a silicon transistor, with its much lower I_{co}.

If a very high input impedance is required, two silicon transistors in a "super-alpha pair" seems to offer the best solution.

Coventry. A. C. DAVIES

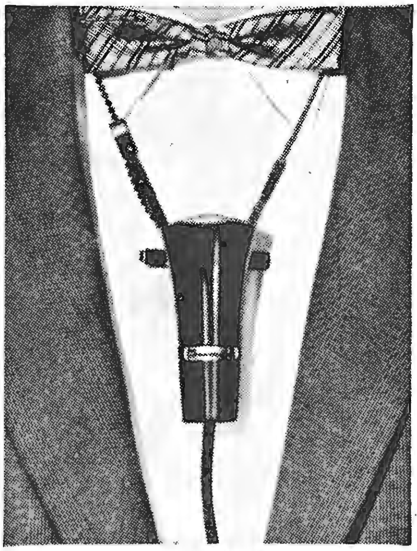
The author replies:

Both Mr. Sharp and Mr. Davies are correct in their delta-star transformation calculations, and I consider this rather ironic, as I have been stressing to my students for a number of years that this transformation may lead to simplification in many circuits. However, although both Mr. Davies and Mr. Sharp and I may have access to considerable resources in the way of high-stability resistors, the average experimenter has not, so that the delta, although simpler, is not necessarily more economical. In Mr. Davies' Fig. 2, R_C is eliminated, but both R_A and R_B must be low-noise (high-stability) types at about 2s. each, whereas in his Fig. 1 only R_3 must be a low-noise type, and R_1 and R_2 can be composition types at 4d. each. As 4s. is more than 2s. 8d. and there are no electrical advantages the choice is clear.

With regard to Mr. Davies' scepticism about thermal stability no attempt was made to select a transistor or to try a range of transistors, but a random sample GET 106 did not bottom until 45°C., which should be adequate. The substitution of an OC 44 would probably give a higher thermal stability with possibly slight degradation of the signal-to-noise ratio.

Mr. Davies' suggestion with regard to the increase in input resistance is basically the same as the scheme used by Baxandall in a recent *Journal of the British Sound Recording Association* (Vol. 6, No. 11, Nov. 1961).

PHILIP F. RIDLER.



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TRANSFER FUNCTIONS

By "CATHODE RAY"

WHEN I first mentioned to the Editor that I was thinking of saying something about transfer functions, his reaction was as if I had been offering to write a do-it-yourself manual on how to get into orbit. This worried me rather, because up to that moment nothing had looked simpler than explaining what a transfer function was. One could start by defining it as the ratio of output to input of any system that has an output and input. One would then add a bit of padding to make this clear to the dimmest intellects, and there one would be, ready to knock off for the week. Even the impressively named and highly expensive Transfer Function Analysers are basically simple. But now, was there a snag?

Well, there are a lot of very difficult books mainly on transfer functions, at about £5 each, and perhaps the Editor thought I was going to paraphrase them into half an hour's pleasant reading. To put it in terse if not very sensitive or sincere contemporary speech, he'll be lucky.

The fact that transfer functions usually do reside in such highly mathematical and complicated contexts may however, as he suggested, well make readers fight shy of them. My object, then, is to show that they are something you probably know quite well already but didn't recognize under such a pompous name.

I had better start by clearing away a possible cause of confusion. Transfer functions are not the same as transfer characteristics, though both are relationships between input and output. A transfer characteristic is a graph of instantaneous output voltage, current or whatever, plotted against the input ditto. Fig. 1 is an example. A quick way of obtaining this kind of graph is to connect a suitable

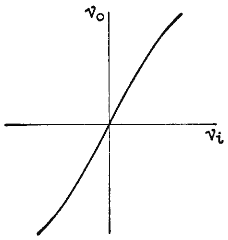


Fig. 1. This is an example of a transfer characteristic, which is a graph of instantaneous output (voltage, etc.) against instantaneous input (voltage, etc.). It is useful for showing up non-linearity. A transfer function is the "complex" ratio of r.m.s. or peak output to input at any frequency.

oscillator to the input, in parallel with the X plates of a cathode-ray tube, and connect the Y plates of the same tube to the output. A perfect amplifier (or whatever it is being examined) gives a straight diagonal line. Curvature shows non-linearity, and looping shows phase shift.

Note I said *instantaneous* voltage, etc. There is another type of output/input graph in which r.m.s., peak or average values are plotted. This sort does show up distortion, but is less useful for analysing it.

Now that we know what transfer functions aren't, we can go on to see what they are. I have already given one definition. In the world of amplifiers, the transfer function is often called simply the gain. To be more precise it would have to be called complex gain, and I would hasten to add for the benefit of beginners that "complex" here doesn't mean what it does in ordinary language. I dealt with that at length in the February 1953 issue (and in "Second Thoughts on Radio Theory"). It just means taking account of phase as well as magnitude. But of course there is an output/input ratio in many systems which don't yield a gain in the literal sense. Such things as filters, attenuators and transformers. And the same idea can be—and nowadays commonly is, hence the proliferation of difficult books—applied to mechanical systems, especially those with feedback, such as servomechanisms. It is even being applied to chemical engineering.

Forms of Expression

There is no difficulty at all, then, in understanding what a transfer function is. But of course if you have a complicated system, its transfer function is likely to be complicated too. And all sorts of very sophisticated mathematical techniques have been devised—some of them comparatively recently—for dealing with such. Another thing that leads to difficulty is non-linearity of the system. And still another is non-sinusoidal waveform of the signal applied to the system. Just now we are going to stick to simple sine-wave signals and linear systems. Even a so-called ultra-linear amplifier is not perfectly linear, but it should be at least a good approximation to the ideal linear system.

First let us review the various forms in which transfer functions can be expressed. You may know them already, but one can hardly go over it too often.

Suppose you put a signal of, say, 0.1V r.m.s. into an amplifier and get 23V out. Then the ratio of V_o to V_i is $23/0.1 = 230$. That is what would usually be called the voltage gain. It is also the *magnitude* of the amplifier's transfer function. The other part of the same function is the *phase difference* between V_i and V_0. (Mathematicians tend to call these two parts the *modulus* and *argument*.) If V_o lags 32° behind V_i, then the phase difference —often denoted by ϕ—is $-32°$. In more strictly mathematical terms it is -0.56 radians. (A whole cycle is 360° or 2π radians.) One way of writing this particular transfer function is therefore $230\underline{/-0.56}$.

A direct graphical representation would be as two sine waves, one (representing the output) 230 times the amplitude of the other (representing the input) and 32° behind it in phase. But sine waves are difficult to draw, and don't show the important quantities clearly, so a preferred form is a straight line 230 units long, drawn at an angle of 32° clock-

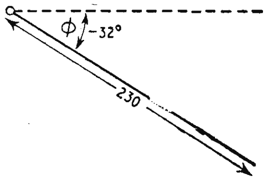


Fig. 2. Here is the vector (more correctly phasor) form of a transfer function for one particular frequency.

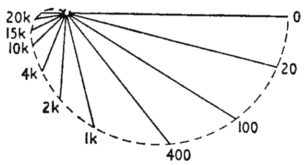


Fig. 3. If the phasors of a system are plotted for a representative selection of frequencies, their tips trace out a Nyquist type of diagram, as in this example.

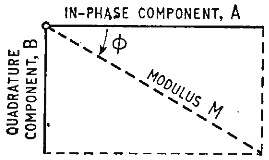


Fig. 4. Relationship between Cartesian or rectangular transfer-function co-ordinates, A and B, and the corresponding polar co-ordinates, M and φ.

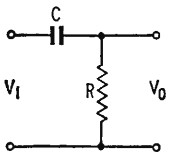


Fig. 5. Simple example of a system for which a transfer function exists.

wise with reference to the conventional zero ("3 o'clock")—Fig. 2. This sort of line is commonly called a vector, but since that name is not entirely appropriate the tendency nowadays is to call it a phasor. Sometimes an arrow head is stuck on the end farthest from the point around which the line is slanted to indicate ϕ, but because the natural interpretation of an arrow head is motion in the direction in which it points, which would be quite wrong here, I prefer a little circle at the other end to mark the centre.

Mathematically, a transfer function is what is called an operator. The thing it operates on is the input signal. The effect of the operation, in the example in Fig. 2, is to multiply the magnitude (voltage, in this case) by 230 and delay its phase by 32°. If this amplifier were followed by another, without any interaction except that the output of the first provided the input of the second, it is pretty obvious (I hope) that the transfer function of the combined amplifiers would be obtained from their separate functions by *multiplying* their magnitudes and *adding* their phase angles. So if the second function was, say, $170/\underline{59^\circ}$, the combined function would be $230 \times 170/\underline{-32^\circ + 59^\circ} = 39{,}100\ /\underline{+27^\circ}$ Alternatively the magnitude can be expressed in decibels, which, being the logarithms of the gains, are combined by adding, like the phase angles. This is one of the reasons for preferring dB.

The most important thing about a transfer function is that it varies with frequency. Often one wishes it didn't, because for many purposes the ideal amplifier is one that treats all frequencies alike. But while it is possible to approach this ideal very closely over quite a useful band of frequencies, there are always limits due to the inevitable stray capacitances and inductances, to say nothing of the more involved effects in transistors. There are instruments—the so-called transfer function analysers—for measuring the complex gain at different frequencies. The question then arises, how to show the results, since both magnitude and phase vary with frequency. The length and angle of a phasor, as in Fig. 2, show these two quantities at a single frequency, so one method is to draw other phasors for other frequencies. Fig. 3 is an example. The figures denote the frequencies, and the dotted line tracing out the end of the phasor as it varies with frequency is particularly valuable in negative feedback problems, where as a Nyquist diagram it shows at a glance whether there is any possibility of the system oscillating.

But when one is interested in how successful or otherwise the system is in working uniformly over a certain range of frequency, it is usually more helpful to plot magnitude and phase separately against frequency. Often the phase graph is omitted. We then have that even better known type of diagram—the amplitude/frequency characteristic.

Conversion

The Nyquist diagram is a particular kind of polar diagram (Fig. 3), the two parts of the transfer function being specified in polar co-ordinates; angle and radial length. Most graphs are plotted in Cartesian or rectangular co-ordinates, and the two parts of transfer functions can be alternatively specified in them. They are known as the in-phase and quadrature components. The corresponding written form of the transfer function is $A + jB$, in which j is an instruction to reckon the quantity to which it is attached as a vertical distance (positive upwards) instead of horizontally to the right. The two types of co-ordinates are related as shown in Fig. 4, thus:

$$M = A + jB = \sqrt{A^2 + B^2}$$
$$\tan\phi = \frac{B}{A}$$
$$\text{also } A = M\cos\phi$$
$$B = M\sin\phi$$

A reason why it is necessary to be able to convert from one form to the other is that some methods of measuring transfer functions give the results in one form and some in the other, and the particular method available—or most convenient—may not be the one that fits best into one's calculations.

Obviously (looking at Fig. 4) the A and B values

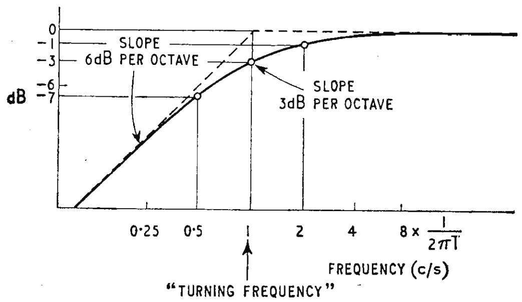


Fig. 6. Method of quickly drawing a frequency characteristic curve for the Fig. 5 system. This graph has been " normalized " by writing the scale in terms of 1/2πT, so that the " turning frequency " is at 1.

can be used for plotting phasors and therefore a Nyquist diagram. Alternatively the polar quantities can be plotted separately against frequency as Cartesian co-ordinates, giving gain/frequency and phase/frequency characteristic curves.

In case the frequent reference to amplifiers has given anyone the impression that transfer functions refer mainly to them, let us take as an example of a " system " the simple one shown in Fig. 5. This, of course, often occurs as part of an amplifier. One of its roles is as a device for coupling one valve stage to the next without imposing the d.c. component of the anode voltage on the grid. In this role the variation of transfer function with frequency, though necessary for separating signal frequency from zero frequency, is undesirable within the working frequency range, and the aim is to avoid it as much as practicable. But the same device with different values of C and R is used deliberately in tone-control arrangements as a bass-cut device.

If the input signal is reckoned as the voltage V_i across the input terminals, and the output is the voltage V_o across the output terminals, which are not called upon to supply any appreciable current to a load (i.e., they are practically an open-circuit), then the system can be regarded as a potential divider, in which the transfer function is the ratio of R to the whole impedance of C and R in series:

$$\frac{V_o}{V_i} = \frac{R}{R + 1/j\omega C}$$

Because the transfer function is a function of $j\omega$ ($= j2\pi f$) it is often written as F ($j\omega$). So

$$F(j\omega) = \frac{R}{R + 1/j\omega C} = \frac{j\omega CR}{1 + j\omega CR}$$

The thing to notice here is that the values of C and R don't matter individually; it is their product CR that counts. This CR is well known as the " time constant " of the system, reckoned in microseconds if R is in ohms and C in microfarads. (CR in the formula must then be multiplied by 10^{-6} to bring it to seconds.) The value of the transfer function at any given frequency depends on it alone. So the tendency nowadays is to work in time constants, and accordingly we will substitute T for CR.

In looking at the above transfer function again to see how it varies with frequency, we note first that when the frequency is zero ($\omega = 0$), F ($j\omega$) is zero. That, of course, is as it should be for blocking d.c. At the other end of the scale, when ω approaches infinity, F ($j\omega$) approaches 1; so at very high frequencies the system passes practically the full signal voltage. But the most significant frequency is the one that can be regarded as a sort of change-over point between these two extremes. It is conveniently defined by

$$\omega = \frac{1}{T} \text{ or } f = \frac{1}{2\pi T}$$

because that makes $\omega T = 1$, and $1 + j1 = \sqrt{2}$, and $1/\sqrt{2}$ is 0.707, which in terms of voltages or currents is almost exactly 3 dB down on 1. In terms of power, it is exactly a half. The effective frequency bandwidth of an amplifier is usually reckoned between the upper and lower half-power points.

At frequencies above zero but so much below $1/2\pi T$ that there is little difference between $1 + j\omega T$ and 1, the magnitude of F ($j\omega$) is very nearly proportional to the frequency. If the frequency is halved the voltage amplitude is halved. The way this is usually put is that the amplitude/frequency characteristic slopes 6 dB per octave. To be a uniform slope, both amplitude and frequency scales must be logarithmic, which is usually achieved by using special graph paper obtainable for plotting dB against logarithmic frequency.

Simple Rules

Putting all the foregoing information together provides us with simple rules for making a quick sketch of the amplitude/frequency characteristic of any circuit comprising one resistance and one reactance. Fig. 6 shows them applied to the Fig. 5 circuit. Locate the point on the frequency scale where $f = 1/2\pi T$ ($= 1/2\pi CR$); the " turning frequency " or " corner frequency ". If C and R are in microfarads and megohms, T is in seconds and f in c/s, but usually it is more convenient to divide 10^6 by 2π times the number of microseconds. Draw a horizontal line at the 0 dB level from this point rightwards, and a line sloping to the left downwards at 6 dB per octave, as shown dotted. Mark the $-$ 3 dB point at the turning frequency and draw a smooth curve through it to approach the two straight lines. Incidentally, the slope at this $-$ 3 dB point should be 3 dB per octave. As a further guide to drawing the curve, it is helpful to note (as can

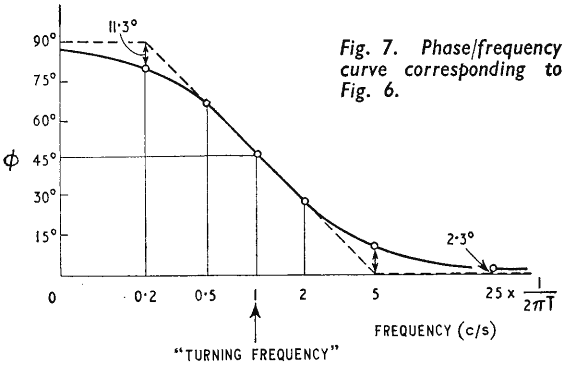


Fig. 7. Phase/frequency curve corresponding to Fig. 6.

easily be shown by calculation) that at half and double the turning frequency the curve is very nearly 1 dB below the straight lines, as shown .

This type of diagram owes its convenient straight-line-approximation feature, with the facility for filling in the curve accurately enough for practical purposes without any actual plotting, to the fact that both scales are logarithmic. As we shall see, it has other advantages.

What now about phase angle? As we have seen, the formula is

$$\tan \phi = \frac{B}{A}$$

where B is the quadrature component and A the in-phase component. The catch is that B can be either negative (as in Fig. 4) or positive, and this decides the sign of ϕ. It can be found mathematically by multiplying the transfer function (in this case $\frac{j\omega T}{1+j\omega T)}$ above and below the line by $1-j\omega T$ to eliminate j from the denominator, and then noting the sign of the j term in the numerator. In this case it is positive. But the easier way is to

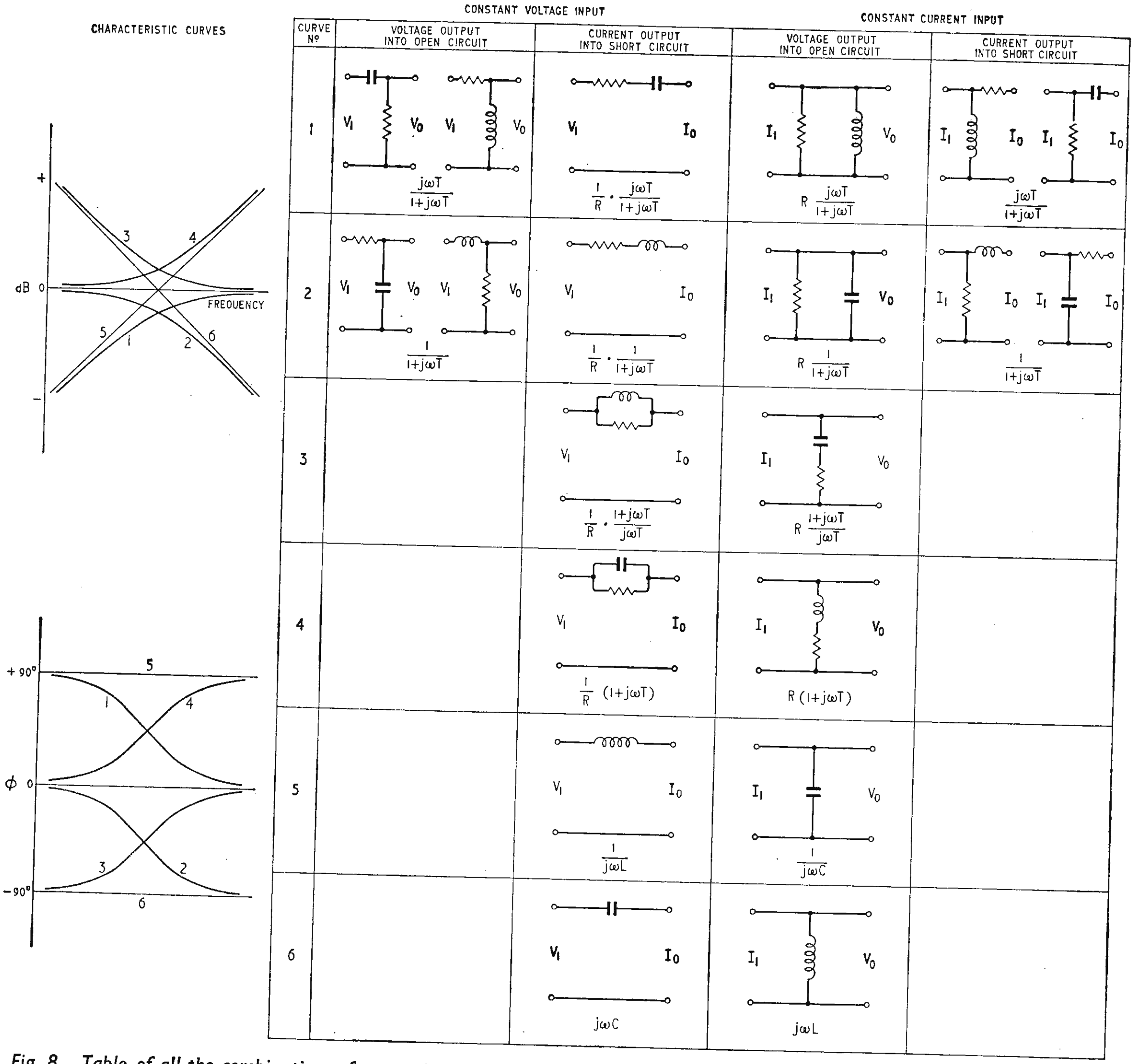


Fig. 8. Table of all the combinations of one resistance and one reactance, and of one reactance only, and their frequency characteristics (magnitude and phase) and transfer functions.

remember that the current through a capacitive circuit (such as Fig. 5) *leads* the applied voltage, and as the output voltage—being taken across a resistance—is in phase with the current, the output voltage must lead the input voltage; so its phase angle is, according to convention, positive.

It is convenient to plot the phase angle against the same logarithmic frequency scale as for the "gain," not only for making the same scale do for both, but also because the curve turns out symmetrical that way; one half of it is exactly the same as the other turned upside down and left to right—Fig. 7. Note that the angle scale is linear; this is not only to preserve the said symmetry but also because (as we have seen) the overall phase angle of a combination of transfer functions is the simple algebraical sum of the separate angles.

As Fig. 7 shows, a rough approximation to the curve is obtainable by drawing a straight line from one-fifth to five times the turning frequency (where the angle is always 45°). The true curve almost exactly coincides with this line from half to double the turning frequency. It can be sketched in by plotting points at five times (11.3°) and one-fifth (90° − 11.3°) as shown. Farther away still, the departure of the curve from 0° and 90° tails off in the same ratio as the frequency varies.

If C in Fig. 5 is replaced by R, and R by L, and F (jω) is calculated, precisely the same result will be found, if it is remembered that the time constant of an LR circuit is L/R. So Figs. 6 and 7 hold good for this system too.

If in either of these two systems the resistor and reactor are interchanged, the appropriate graph is the mirror image of Fig. 6, falling from 0dB at zero frequency to −3dB at $1/2\pi T$ and thereafter tending towards a downward slope of −6dB per octave. The actual formula is

$$F(j\omega) = \frac{1}{1 + j\omega T}$$

In all these four systems we assumed that the input voltage was constant and the load impedance was infinite. If we pass a constant *current* through R and C or L in parallel, the voltage across these varies in a similar manner; Fig. 6 for R and L, and its image for R and C. By passing constant current through R and C or L in series, we get the same output voltage curves upside down. Because we are converting a current signal into a voltage signal the "dimensions" of the transfer functions we have been using for voltage-to-voltage (a pure number) would be wrong; on working it out we find they must be multiplied by the constant factor R. So 0 dB corresponds to the output voltage obtained by passing the constant input signal current through R.

If you remember my enthusiasm for the principle of duality ("two formulæ for the price of one") you will expect me to include the duals of the foregoing arrangements, obtained by exchanging current and voltage, inductance and capacitance, resistance and conductance, and series and parallel. The duals of constant current input and open-circuit voltage output are therefore constant voltage input and short-circuit current output, and the transfer functions of the systems (as modified by the dual exchanges) are the same as before, except that of course the factor R for resistance becomes 1/R for conductance. The original series fits the conditions of feeding into a negatively biased valve—practically an open circuit—and the new one approximates the situation when driving a transistor, if the resistances and reactances of the "system" are relatively high.

By now we have accumulated quite a variety of systems covered by only four stock shapes of frequency characteristics—or, rather, one stock shape, which can be made up as a template, turned this way or that. A single curve likewise serves for all the phase graphs. Fig. 8 displays all the possible combinations of one resistance and one reactance, with the addition (for the sake of completeness) of the still simpler systems made up of one reactance only. These give continuous 6 dB-per-octave slopes and constant 90° phase shifts.

The systems shown, although so simple, are of real practical value, as any tone-control designer knows. They are also real practical nuisances, as any feedback-amplifier designer knows.

Next time we shall see how more elaborate transfer functions can be analysed into combinations of these simple ones.

MANUFACTURERS' PRODUCTS

NEW ELECTRONIC EQUIPMENT AND ACCESSORIES

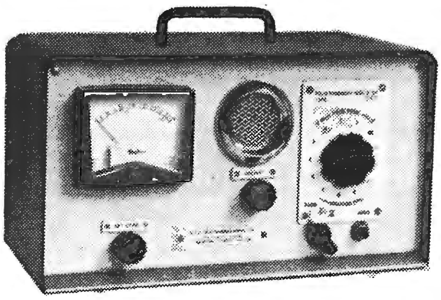
Suction Handling Aid

AN AID to the handling of small pieces of, say, semiconductor material has been produced by the Solo-Seeda Limited. In both of the models air is drawn in through a nozzle which is designed to receive and hold the object to be lifted; thus special types are available for individual purposes. The makers claim that lifting, moving and dropping again at the rate of 100 objects per minute is relatively simple. Releasing the held object with the model fitted with a pump is accomplished by uncovering a small suction-release hole in the nozzle holder. Retail prices are: hand model with squeeze bottle 5s; model with water-operated pump 15s; both including a standard nozzle.

Solo-Seeda Limited, Spencer Road, Berkswell, Coventry, Warwickshire.

Field Strength Indicator

CARRIER level measurement in Bands I, II and III can be undertaken with the "Telecomm" Indicator Type FS4/T. This instrument, which uses transistors throughout, employs a 13-position turret tuner covering all f.m. and television channels, and indicates field strength directly on a moving-coil meter calibrated from 10μV to 30mV. The Indicator can be supplied to cover other channels in the range 30 to 220Mc/s. The makers of the FS4/T are R.E.E. Telecommunications Ltd., 15a Market Square, Crewkerne, Somerset.



R.E.E. "Telecomm" field strength indicator.

V.H.F. Frequency Meter

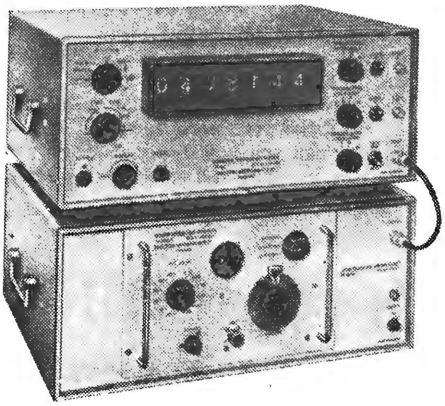
ONE result of the Wayne Kerr-Gertsch agreement is the appearance on the British market of the v.h.f. frequency meter FM-7, which will measure and generate frequencies to an accuracy of 0.0002%. Both amplitude and frequency modulation are available—30% a.m. and

Wayne Kerr-Gertsch FM-7 frequency meter, with a frequency converter in the lower half.

from 1kc/s to 15kc/s f.m., depending on the carrier frequency. Used in conjunction with multipliers or dividers, space for which is provided in the lower part of the case, the measurement of frequencies in the range 50kc/s to 30Gc/s is possible. Fuller details are available from Wayne Kerr at 44 Coombe Road, New Malden, Surrey.

Digital Frequency Meter

INTEGRATED counter/digital frequency meter TF-1417 is announced by Marconi Instruments Ltd., Longacres, St. Albans. With a top counting speed of 10Mc/s, the resolution in time-interval measurement configuration is 0.1μsec down to a minimum time of 0.2μsec. The use of semiconductors throughout renders the instrument extremely robust, and r.f. signal switching

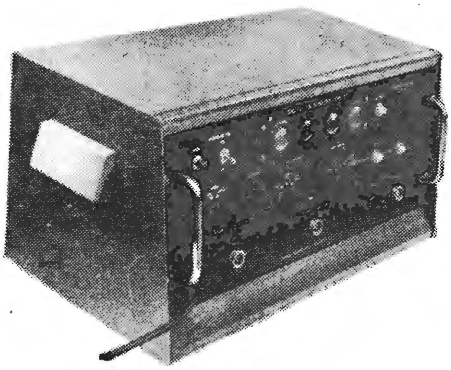


Marconi Instruments TF1417 Counter. Lower unit contains one of two converters, which extend frequency coverage to 220Mc/s.

is accomplished by diode gates, which means that the wafer switches need only operate at zero frequency. Aperiodic time-base dividers are employed.

Digital Tachometer

DESIGNED principally for use by mechanical engineers, the Farnell D.T.1 Tachometer is not intended to be a general purpose counter and has, therefore, only the facilities which are relevant to its intended sphere of operations. This being so, it is possible to dispense with the gate times based on multiples of 1 millisecond and to use a system based on 6, thereby providing direct reading of rotational speeds in r.p.m. External control

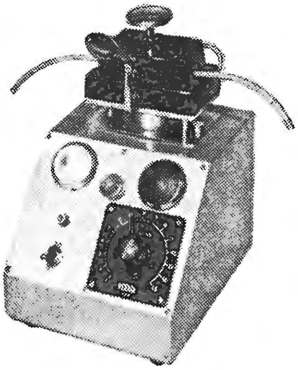


Farnell digital tachometer.

of gate open and shut times is provided, and an output is provided for the operation of a pen recorder. A leaflet is available from Farnell Instruments Ltd., Light Industrial Estate, Wetherby, Yorks.

Cable-jointing Machine

PERMANENTLY insulated, watertight joints can be made in p.v.c. and polyethylene cables by means of the Egerton "New Way" machine. The joint is made by

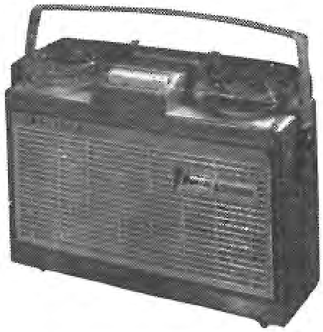


Egerton "New Way" cable-jointing machine.

laying the electrically made joint between two heated platens and injecting the appropriate plastic material. Special moulds are available for the forming of Y- and T-joints, and the machine can be adapted to reinforce plug and socket outlets. Two sizes of machine are made, to cope with joint diameters of $\frac{7}{16}$in and $\frac{15}{16}$in, or $\frac{3}{8}$in and $\frac{7}{8}$in bulbous joints. A complete description can be obtained from Vinatex Ltd., Devonshire Road, Carshalton, Surrey.

Transistor Tape Recorder

WITH the new Philips EL3585 recorder at $1\frac{7}{8}$ in/sec, the single speed provided, the frequency response is within $\pm$3dB from 120 to 5,500c/s, the wow and flutter less than 0.5% r.m.s. and the signal-to-noise ratio better than 40dB. Some of the components in this recorder have different functions on record and replay: two of the transistors and an edge-reading meter respectively pro-



Philips EL3585 transistor tape recorder.

vide push-pull erase/bias and level indication on record, and 250mW push-pull output and battery voltage indication on replay. The battery life is of the order of 20 hours and six U2s are used. Up to 4-in diameter reels can be used. This recorder weighs 8lb, measures $11\frac{1}{8}$ by $7\frac{3}{4}$in by $3\frac{7}{8}$in and costs 24 guineas. It is available from Philips Electrical Ltd., of Century House, Shaftesbury Avenue, London, W.C.2.

FUNDAMENTALS OF FEEDBACK DESIGN

4.—COMBINATIONS OF FIRST ORDER NETWORKS

By G. EDWIN

IT may appear that we are a long time getting down to the 'osses and turning to the discussion of some sort of amplifier. Any useful amplifier, however, must include some sort of decoupling circuits and any useful amplifier will probably need some sort of response-shaping circuits. We might just as well get this elementary network material cleared up and out of the way before we run into the need for it. After all there is really very little to the design of a feedback amplifier except the design of the coupling and decoupling circuits.

To begin with let us consider the circuit shown in Fig. 14. This is typically the anode load of a pentode in which the valve impedance is considered to be so high that it can be neglected, R_1 is what we usually consider to be the load while R_2 and C are the decoupling components. We can write down at once

$$\frac{V}{I_0} = R_1 + 1/(1/R_2 + j\omega C)$$
$$= R_1 + R_2/(1 + j\omega CR_2)$$

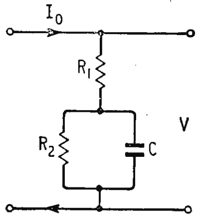


Fig. 14 Typical pentode anode load (neglecting the valve impedance).

For reasons which will become apparent we manipulate this to get

$$\frac{V}{I_0} = (R_1 + R_2)\left[\frac{1 + j\omega CR_1R_2/(R_1 + R_2)}{1 + j\omega CR_2}\right]$$

It might appear that the original form was more convenient but we will now split this result up a little and show how it can be used very easily. When $\omega \to 0$ the ratio is just $R_1 + R_2$. When $\omega \to \infty$ the ratio is just R_1. Conveniently we use $\omega \to 0$ as our reference and turn our attention to the term inside the square brackets. Let us write $\omega_1 CR_1R_2/(R_1 + R_2) = 1$ and $\omega_2 CR_2 = 1$ as definitions of ω_1 and ω_2 and $\Omega_1 = \omega/\omega_1$, $\Omega_2 = \omega/\omega_2$ as definitions of Ω_1, Ω_2. The frequency-dependent term in the square brackets is then

$$\left[\frac{1 + j\Omega_1}{1 + j\Omega_2}\right]$$

The amplitude characteristics of this is thus

$$20 \log(1 + \Omega_1^2)^{\frac{1}{2}} - 20 \log(1 + \Omega_2^2)^{\frac{1}{2}}$$

with the phase characteristic simply

$$\theta_1 - \theta_2$$

where $\theta_1 = \arctan \Omega_1$ and $\theta_2 = \arctan \Omega_2$.

It really is just not worthwhile considering whether there should be a minus sign in front of the whole lot because the behaviour of the circuit can be easily assessed in physical terms. Commonsense tells us that $R_1R_2/(R_1 + R_2)$ must be less than R_2 because it is the resultant of R_1 and R_2 in parallel. This means that ω_1 must be bigger than ω_2. The gain of this pentode will depend at high frequencies on R_1, but at the first characteristic frequency ω_1 the gain will increase with decreasing frequency towards a value depending on $R_1 + R_2$. This increase of gain will flatten out in the region of ω_2. As an example let us take $R_1 = 1{,}430\Omega$, $R_2 = 10{,}000\Omega$ and $C = 1\mu F$. Then $R_1R_2/(R_1 + R_2) = 1{,}250\Omega$ and $\omega_1 = 800$ and $\omega_2 = 100$. The ratio of the gain at high frequencies to the gain at low frequencies is $R_1/(R_1 + R_2)$ or 1,430/11,430, so that the difference in decibels is just about 18dB.

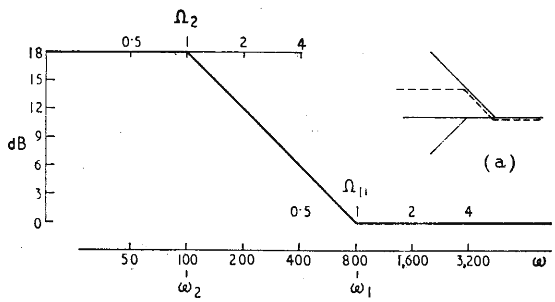


Fig. 15 Straight-line approximation to the amplitude response of the circuit of Fig. 14, with inset (a) its derivation as the sum of two simpler amplitude responses.

In the region where the capacitance is either a short-circuit or an open-circuit the phase shift will be zero: between these regions the phase shift will be dominated by phase shift due to $(1 + j\Omega_1)$ or $(1 + j\Omega_2)$ or by both. Using the straight-line approximation the amplitude response is very easily seen to take the form shown in Fig. 15 which is the sum (the Ω_2 term minus sign is looked after in the plotting) of two simple responses of the form we have already considered. In Fig. 16 the phase response is

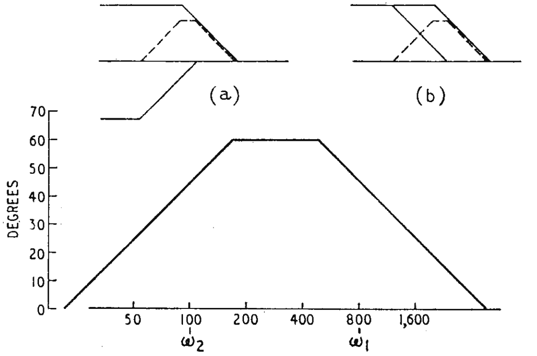


Fig. 16 Straight-line approximation to the phase response of the circuit of Fig. 14 with insets (a) and (b) its derivation as the sum and difference of two simpler phase responses.

derived as the sum or difference, depending on how they are plotted, of two straight-line approximations. The final answer is the same whichever end you start from and the angle is plotted upwards purely as a matter of convenience. The object of this is to make you think what each term does to the overall phase characteristic.

Before we discuss this sort of response in any more detail let us consider the coupling circuit shown in Fig. 17. To keep the analysis simple we shall assume a zero impedance generator so that we can write down

$$\frac{V_0}{V_1} = \frac{(1/R_2 + j\omega C)^{-1} + R_1}{R_1}$$

$$= \frac{R_1 + R_2}{R_1}\left[\frac{1 + j\omega C R_1 R_2/(R_1 + R_2)}{1 + j\omega C R_2}\right]$$

This will be seen to be the same kind of frequency dependence as we had for Fig. 14. Rather than examine the minus signs we can use purely physical reasoning to say that an amplifier containing this circuit as a coupling element will show a fall of gain when ωCR_p, where R_p is the resultant of R_1 and R_2 in parallel, is reduced to unity. The gain will in fact be 3dB down at this point and will fall 6dB/octave until ωCR_2 approaches unity, when the effect of C will no longer be appreciable. That 3dB is, of course, neglected in the straight-line approximation. The shapes of the amplitude and phase characteristics for the circuit of Fig. 17 will be exactly the same as those for the circuit of Fig. 14, apart from the signs. Fig. 14 is a bass boost circuit while Fig. 17 is a bass cut circuit. For both circuits, however, the critical

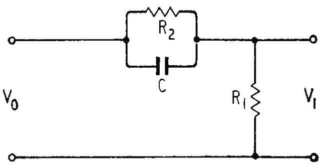


Fig. 17. Coupling circuit.

frequencies are determined by an expression of the form $\omega_c CR = 1$ where R is for one critical frequency the resistance immediately associated with the capacitor and for the other the parallel combination of the resistors.

The corresponding forms for two resistances and one inductance can easily be derived directly or they can be obtained by noting that whenever ω/ω_c appears for one type of reactance we can convert to the other by writing ω_c/ω. It is therefore not worth the trouble of pursuing this in detail.

The example in Figs. 15 and 16 was carefully chosen so that the straight-line approximation could be used. To justify this the same conditions have been used for an exact plot in Fig. 18 which was prepared with the aid of a template. The maximum error in the amplitude characteristic is at the characteristic frequencies, where it is 3dB. This is very easily corrected by a freehand addition if there is any reason to expect that stability problems will arise near a characteristic frequency. The maximum error in the phase for this particular example amounts to about twelve degrees. As this is at some of the rather special corner frequencies associated with the linear approximation, it will usually be desirable to work out the phase fully in the interesting regions after these have been identified by a linear approximation plot.

For smaller steps it is usually sufficient to sketch out the amplitude characteristics on the basis of the 3dB points and the inherent symmetry of the characteristic. The linear approximation is poor because although the line segments fit together their joins relate to the regions in which the approximation is particularly bad.

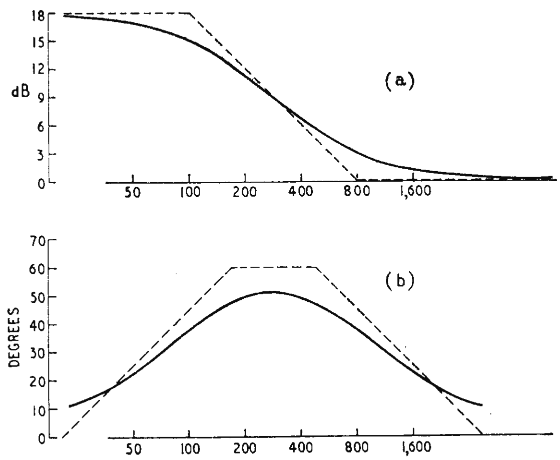


Fig. 18. Exact amplitude (a) and phase response (b) curves of circuit of Fig 14 (full lines) with approximations of Figs. 15 and 16 shown dotted.

Looking at the phase characteristic in Fig. 18 we see that the phase has a maximum value mid-way, on a logarithmic scale, between ω_1 and ω_2. It is quite useful to know what this maximum value will be for any spacing of the characteristic frequencies. It is also useful to know what step size corresponds to this spacing. Examination of the substitution shows without further discussion that the step is just 20log (ω_1/ω_2). The phase angle can be found by noting in Fig. 16 that the peak phase differs from 90° by just twice the amount that the simple characteristic phase falls below 90°. This means that as the simple characteristic phase is $\theta = \arctan(\omega_1/\omega_2)^{\frac{1}{2}}$, the peak phase is 2θ-90°. This result, together with the step height, is plotted in Fig. 19. This information is of special value when networks are needed to modify the amplifier response characteristics in order to get stability.

A practical coupling network takes the form shown in Fig. 20. As before we write down

$$\frac{V_0}{V_1} = \frac{R_0 + R_1 + 1/j\omega C_1 + R_2/(1 + j\omega C_2 R_2)}{R_1}$$

and proceed to manipulate until we reach a rather tedious form. It appears to be more satisfactory to adopt some rather simple physical reasoning. We can assume to begin with that C_2 is a good deal smaller than C_1. At high frequencies the results of the manipulation with the circuit of Fig. 17, can then be applied except that instead of R_1 we must now write $R_1 + R_0$ and we must remember the effect of R_0 in calculating the limiting gain as $\omega_1 \to \infty$. At lower frequencies when C_1 comes into action the network will approach asymptotically the simple combination of C_1 with R_0, R_1 and R_2 all in series.

The straight-line approximation to the amplitude response must then be of the form shown in Fig. 21 and we can say immediately that $\omega_1 C_2 R_2 = 1$, which fixes ω_1 and $\omega_3 C_1(R_1 + R_2 + R_0) = 1$ which fixes ω_3. The step height in the first approximation will be 20 log $(R_1 + R_0 + R_2)/(R_1 + R_0)$ and we can

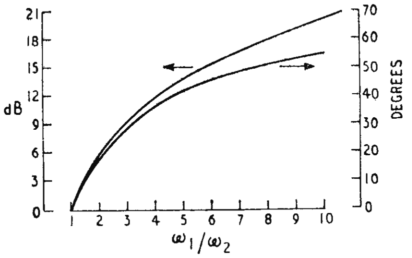


Fig. 19 Step height and peak phase angle for circuit of Fig. 14 and graphs of Fig. 18 plotted against ω_1/ω_2.

immediately get ω_2 from this, without bothering to write it down explicitly. The phase characteristic is made up of three operations with the simple arc tan Ω characteristic and will be shown in detail when we come to discuss specific examples.

The other important shaping network is the one shown in Fig. 22, which is used to steer the characteristics at high frequencies. If we neglect C_1 for the moment it is very easy to see that when ωC_2 is large enough to be neglected we have $I_0/V = 1/R_1$ and when $\omega \to \infty$ we have $I_0/V = 1/R_1 + 1/R_2$. This circuit produces a step-reduced gain at high frequencies and it is merely a matter of algebra to show that the characteristics frequencies are given by $\omega_1 C_2 R_2 = 1$ and $\omega_2 C_2(R_1 + R_2) = 1$. The use of the simple response characteristics then follows exactly the procedure already outlined in connection with Fig. 17.

When C_1 is added it is easiest to adopt the slightly fudging technique we have already used for Fig. 20. To get any real good from this circuit we must have C_2 a good deal bigger than C_1. Thus we forget about C_1 until we approach a third characteristic frequency at which C_2 is virtually a short-circuit and we can then plot our final 6dB/octave fall away based on a characteristic frequency given by $\omega_3 C_1 R_1 R_2/(R_1 + R_2) = 1$.

Undoubtedly there are more precise ways of treating these networks: equally there is the possibility of using more complicated networks. If the reader is capable of attacking this sort of problem now he is presumably experienced in the design of feedback systems and this survey was never meant for him.

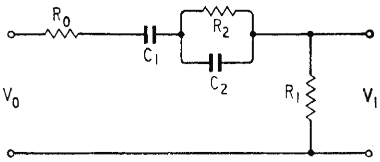


Fig. 20 Practical coupling network.

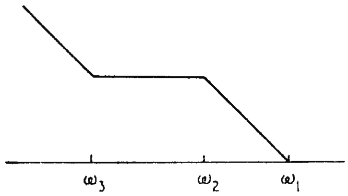


Fig. 21 Straight-line approximation to amplitude response of circuit of Fig. 20.

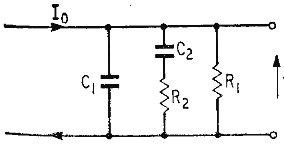


Fig. 22 Shaping network for steering characteristic at high frequencies.

The application of the step network analysis to the cathode decoupling capacitor, and for that matter to the emitter decoupling capacitor, though here there are other problems which appear, is quite straightforward. If we consider a pentode with an impedance Z_k connected in the cathode lead the signal current i will be produced by the grid-cathode voltage e_g. But $e_g = e_o - iZ_k$ and $i = g_m e_g$, where g_m is, of course, the mutual conductance and e_o is the input signal. Thus $i/g_m + iZ_k = e_o$ and the gain is just the reciprocal of $1/g_m + Z_k$. Now if we make $Z_k = (1/R + j\omega C)^{-1} = R/(1 + j\omega CR)$, a resistance and capacitance in parallel, and write $r_m = 1/g_m$, we have for the " square bracket " term in the response $[1 + j\omega CRr_m/(R + r_m)(1 + j\omega CR)]$. The two critical frequencies are given by $\omega_1 CR_p = 1$ and $\omega_2 CR = 1$, where R_p is the parallel combination of R and $1/g_m$. The response is just a step response, the result of the local negative feedback at frequencies too low for the capacitance to provide proper decoupling. More complex networks can be used but any user should already be capable of assessing their performance for himself.

It will not have escaped the reader's notice that the form $[1 + j\Omega]$ which is the backbone of all this discussion is exactly that which we encounter in discussions of the alpha cut-off of a transistor. Although this is an approximation to a more complex expression it is quite good enough for all but the most sophisticated designs. In combinations this form occurs in a very wide range of phenomena and once identified the straight-line approximation or the more accurate element template can be used in all such cases.

Elements of Electronic Circuits

READERS who found the series of articles published between 1959 and 1961 of interest or use will be pleased to know that the series has now been published, with additional material, in book form. For those who did not see the original articles by J. M. Peters, the aim of the book is to explain, in as simple and non-mathematical a way as possible, the functioning of the individual circuits that are combined to make, for instance, a computer or radar set. Using clear circuit diagrams and waveforms juxtaposed with the text to which they are related, the book is divided into nine chapters starting with an exposition of the general principles of pulse techniques. Following chapters then deal with two-state circuits, timebases, electronic markers, logarithmic amplifiers, gates and coincidence circuits, delay lines and their functioning and use, pulse modulation and mathematical operations on waveforms. Included are a full index and a three-page bibliography intended not as a list of references for the subjects dealt with but for further reading once the exposition given in Peters's book has been absorbed. No longer is it necessary for one, after understanding the functioning of the overall system, to be driven to searching in a dozen books for the details of the individual parts: reference to " Elements of Electronic Circuits " will answer at least the first-ditch queries.

The book has 131 diagrams distributed among its 98 pages, its full title is " Elements of Electronic Circuits " by J. M. Peters, B.Sc.(Eng.), A.M.I.E.E., A.M.Brit.I.R.E., and it has been published for *Wireless World* by Iliffe Books Ltd., costing 21s., or 22s. by post.

VERY LOW FREQUENCY ELECTROMAGNETIC WAVES

THEIR USES AS TIME STANDARDS AND FOR COMMUNICATION AND NAVIGATION

By R. N. GOULD,* M.Sc., Ph.D. and W. R. CARTER,* B.Sc.

AN IMPORTANT characteristic of very low frequencies (v.l.f.) of a few tens of kc/s is their ability to support stable long-range propagation without frequent changes in operating frequency. The fundamental reason is that the small ionospheric perturbations which occur and effect the higher frequencies with their short wavelengths are scarcely able to modify the v.l.f. field pattern with its large wavelength of the order of kilometres. Transmission to very long ranges can be achieved by the sky-wave mode alone, which may be thought of as due to multiple reflections between the earth's surface and the lower regions of the ionosphere at heights between 60 km and 90 km. At these frequencies, however, the ground-wave component provides workable signal strengths to relatively large distances; interaction of the ground-wave and sky-wave components produces an interference pattern which is dependent on ionospheric height. Changes in ionospheric height shift the associated interference patterns, producing some local instability which is most evident up to ranges of about 2,500 km. The depth of the interference minima is greatest at short range, where the components of the two modes are of comparable magnitude, but decreases with increasing range as the ground wave suffers progressive attenuation. This effect is illustrated in Fig. 1.

Most of the early investigations consisted of the measurement of field strength and its variation with range and time. Major contributions were made by Austin[1]; Round, Eckersley, Tremellen and Lunnon[2]; Espenchied, Anderson and Bailey[3]. Austin's measurements were made at frequencies in the range 13-60 kc/s over a transatlantic path between the years 1911 and 1930. From the results obtained the well-known Austin-Cohen empirical formula was derived. With later modification[4] this formula has been generally accepted for the calculation of daylight field strengths over distances up to about 8,000 km. The modified formula which has proved to be particularly applicable at frequencies around 25 kc/s is

$$E = \frac{377hI\sqrt{\theta/\sin\theta}}{\lambda r}.e^{-8\cdot833.10^{-5}r/\lambda^{0.6}} \qquad (1)$$

where

E = field strength in volts/metre,
h = effective height of the transmitting aerial in metres,
λ = wavelength in metres,
r = range in metres,
θ = angle subtended at the centre of the earth by transmission path in radians,

and

I = aerial current in amperes.

Similar measurements were made by Espenchied and his co-workers[5] during the period 1923-1925 over a transatlantic path using frequencies in the range 17-57 kc/s. From the values of average daylight field strength the following transmission equation was derived:—

$$E = \frac{377hI}{\lambda r}.e^{-0\cdot02812r/\lambda^{1.25}} \qquad (2)$$

Typical field strength variations are given for various frequencies in Fig. 2.

In the next section brief descriptions of the more important theories of v.l.f. propagation are given.

The Ground Wave.—In addition to satisfying an equation of wave motion throughout the space of interest, the solution to any problem of electromagnetic propagation must satisfy particular conditions at the boundaries between different media. In the case of pseudo-plane-wave propagation above the earth's surface the boundary conditions at the air/ground or air/sea interface cannot be fulfilled on the assumption of a transverse electric and magnetic wave. However, a solution can be found which possesses in addition a component of the electric field in the direction of propagation, the amplitude of the wave being greatest at the plane boundary and falling off with increasing height. The wave thus follows the boundary and the mode exists quite independently of the existence of the ionosphere.

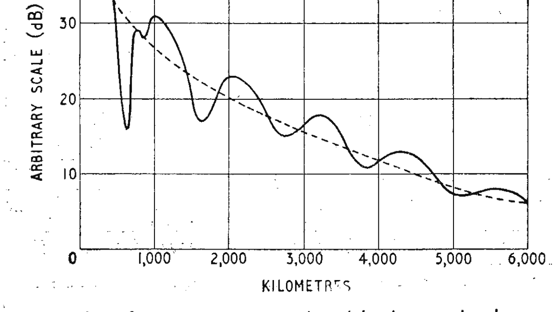


Fig. 1. Interference pattern produced by interaction between ground-wave and sky-wave components at 18kc/s (The dotted curve represents the average field strength variation.)

* Royal Naval Scientific Service.

This approach was first explored by Uller and given later in detail by Zenneck[6]. In the case of interest, where a transmitting aerial is radiating close to the ground, this type of wave will be excited, the field being confined to a region near the ground. The full solution for a spherical earth was given by Sommerfeld, the work being partly invalidated, however, by a famous mistake in sign[7]. Another notable contribution was due to Weyl.[8]

The mathematical treatment shows that (i) the amplitude of the waves decrease with distance from the interface, (ii) the waves also suffer a spatial damping in the direction of propagation and (iii) the wave is forward tilted in the direction of propagation by an amount depending on the electrical properties of the media.

The ground wave is not important for the extremely long range operation to which v.l.f. is best suited and consideration will now be given to the sky-wave mode which is responsible for the low attenuation characteristics at long range.

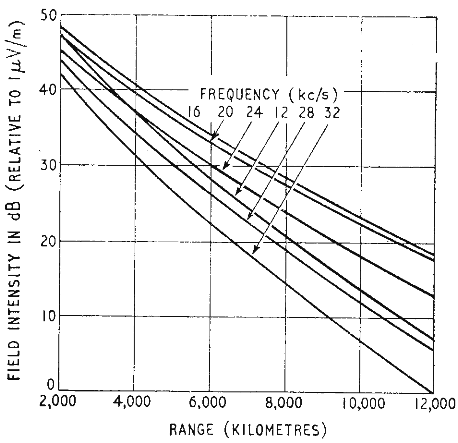


Fig. 2. Average daylight field strength variation with range at frequencies in the band 12—32kc/s for a radiated power of 1kW.

The Sky Wave.—Much detailed early work was based on the consideration of the interaction of various possible propagation paths determined by the geometry of the earth-ionosphere space. To a large extent this work has been superseded by a more sophisticated approach, known as the waveguide mode theory of v.l.f. propagation. This theory takes into account the detailed field configurations permitted by the boundary conditions imposed on the radiation by the earth's surface and the ionosphere.

At v.l.f. the wavelength is of the same order as the conducting layer height and this type of propagation is analogous to that occurring in a lossy waveguide. To a first order a parallel may be made between v.l.f. propagation and propagation in a parallel plate waveguide. Budden[9] has developed such a concept in which he regards the earth as a perfect conductor and hence considers only one plate of the equivalent waveguide to be lossy. Several other approaches have also been made from slightly different viewpoints[10]. J. R. Wait in a series of publications[11] has given an exhaustive and gifted exposition of this approach.

The complicated solutions are amenable to treatment by computers and the predictions of the theory provide a complete description of the propagation mechanism, including the interference effects of ground- and sky-wave components.

It is not immediately clear how the familiar physical picture of rays suffering successive reflections from the earth and ionosphere can be reconciled with the conventional field patterns associated with waveguides. A most illuminating demonstration was given by Brillouin[12] in a slightly different context. It was shown that a guided wave, propagated between two parallel conducting sheets, is equivalent to the interference pattern of two plane polarized waves, each travelling with the free space velocity and being reflected back and forth in zig-zag fashion. The physical correspondence between mode propagation and ray-tracing is thus illustrated. For the case of an actual aerial radiating close to the earth's surface a more complicated picture is required, since the initial conditions must be built up from a superposition of many mode fields.

The waveguide mode theory lends itself to the explanation of an absorption band at ultra low frequencies. Thus at the critical or cut-off frequency the two plane polarized waves referred to above are reflected back and forth at an angle of 90° to the axis of the guide and hence do not propagate. It might be expected that the absorption band at ultra low frequencies would be explicable in terms of evanescent waveguide modes with frequencies below the cut-off values. Approximating the waveguide formed by earth and ionosphere in terms of a parallel plate waveguide, an estimate of the position of the absorption band can be made. Thus the zero-order mode possesses no critical frequency and is responsible for carrying energy to great distances below the cut-off frequencies of the initial modes. The cut-off frequency at the first order mode is given by the velocity of light divided by twice the ionospheric height, and the second order mode critical frequency by the velocity of light divided by the ionospheric height. If the ionospheric height is taken to be 70 km, these frequencies are 2.1 kc/s and 4.2 kc/s respectively. Assuming these low order modes to be important ones, an absorption band might be expected in the vicinity of 2 kc/s to 4 kc/s. This is in fact observed experimentally.[13]

The Whistler Mode.—An anomalous means of propagation at these frequencies has become known as the whistler mode. For a given transmitting point, whether the source be man-made or natural, the observed effect is localized within an area around the magnetic conjugate point of the position of origin.

The term whistler arose because the phenomenon was first observed as a low audio tone (about 8 kc/s) which dropped sharply to lower frequencies in periods of the order of seconds. A proposed mechanism for whistler propagation is as follows. Radiation is generated in the first place by lightning discharges. Although most of this energy is transmitted in the usual way, some of it becomes trapped in a tenuous extension of the ionosphere reaching out for several earth radii. The trapped energy is propagated out from the earth along a line of magnetic force and returns to the earth again at the conjugate point. This process may be repeated, giving multi-path

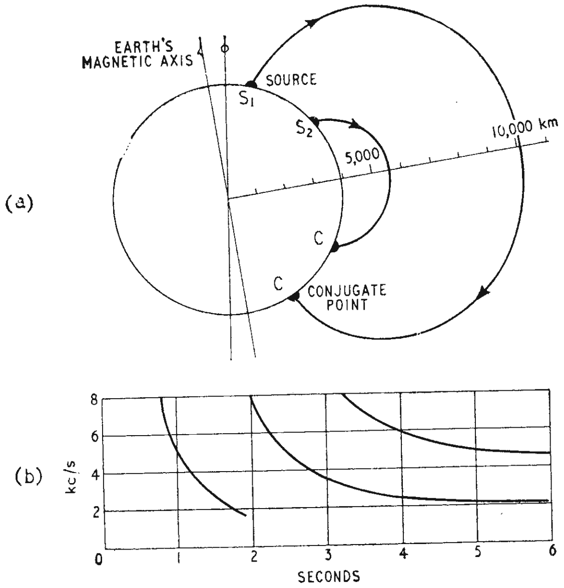


Fig. 3. (a) Whistler mode paths following directions of earth's magnetic field. (b) Typical form of received whistler modes at conjugate point.

propagation between the source and the conjugate point. The magnetic lines of force in space are a preferred path because the conductivity along a line of force is very much larger than in directions perpendicular thereto. Different velocities of propagation are experienced according to the frequency transmitted; in particular the higher frequencies in the audio band travel with greater velocity than lower frequencies. In consequence there is a progressive time delay with decreasing frequency. In this way the Fourier components of the impulsive source arrive at the conjugate point at different times, giving rise to an audible note of rapidly decreasing pitch. The phenomenon of whistler mode propagation is illustrated diagrammatically in Fig. 3, and a useful reference is a recent article in the *New Scientist*.[14]

Use of V.L.F. at Long Range

Two very significant properties of v.l.f. propagation emerge from the above considerations. These are (i) the rate of attenuation decreases with increasing range, approaching extremely low values, and (ii) the phase stability of the received signal is of a very high order.

The most economical use of v.l.f. is thus at great range; this is quite apart from the advantages due to stability of propagation which renders choice of frequency, as required in the h.f. band, quite unnecessary. Hand-speed morse communication to shipping at long range is thus one of the major uses to which v.l.f. is applicable. Additionally a single high-power transmitter can be used for the provision of a time standard over a wide area.

The high phase stability of the propagation suggests the use of a stabilized v.l.f. transmitter as a standard frequency source for widely spaced laboratories. To some extent the need to supply a large number of such laboratories with their own frequency standards would thus be avoided. A further possible use would be as a navigational aid to shipping along the lines of the present Decca Navigator system which works in the medium frequency band. The range limitation applicable to the Decca system would be removed at v.l.f. at the expense of extremely costly transmitting stations. Since v.l.f. radio waves are able to penetrate sea water, a possible application would be to future submerged nuclear mercantile fleets, which could then navigate without breaking surface. The point of this is that such proposed ships lose their independence of weather conditions and streamline advantages on breaking surface. However, quite apart from cost there are other technical difficulties which render this hardly a prospect of the immediately foreseeable future.

Technical Difficulties

Transmitting Aerial.—One of the major difficulties encountered in exploiting the above favourable propagation characteristics of v.l.f. is the expense and size of reasonably efficient transmitting aerials. Typical of these is the long wave aerial installation at Rugby, which is shown diagrammatically in Fig. 4.

The radiation resistance of electric antennas short compared with a wavelength is extremely small. For example, at a frequency of 10 kc/s the radiation resistance of a vertical electric aerial 500ft high is only of the order of a few hundredths of an ohm. Huge aerial currents would therefore be required in order to radiate appreciable energy. Unfortunately such aerials are necessarily of high impedance, which makes it extremely difficult to induce sufficient current to flow. Such high driving voltages are required that severe technical problems arise in the design of transformers together with difficulties encountered in insulating the high-potential aerial system from earth under all weather conditions.

Conventional solutions consist in erecting masts as high as is practicable to support a large aerial array consisting of a conducting system of wires at great height. These wires increase the aerial capacity to earth and reduce the aerial input impedance. Such measures are extremely costly to effect.

Atmospheric Noise.—Lightning discharges in thunderstorms can be considered as huge natural transmitters radiating energy over a wide frequency spectrum. Unfortunately for our purposes there is a predominance of low-frequency components resulting in high noise levels in the v.l.f. band. Moreover in view of the low attenuation characteristics of v.l.f. waves noise power from natural sources over a wide area will make significant contributions. Each source will make a contribution at a particular receiving terminal depending on the spectrum of the original discharge as modified by the propagation characteristics over the band for the range in question. The sum total of all such received spectra constitutes the observed noise spectrum at the position of interest. The type of spectrum typical of the v.l.f. band is shown in Fig. 5, where the modifying effect of the absorption band at 2-4 kc/s can be seen in the lowering of atmospheric noise levels near these frequencies.

Bandwidth.—The quantity of information which can be impressed upon a carrier is related to the bandwidth available. For example it is a relatively simple matter to impress voice modulation on an h.f. carrier since the bandwidth required is a small fraction of its frequency. At v.l.f., however, the imposition of voice modulation, occupying a bandwidth of a few kc/s, would entail severe degradation of the quality factors of the transmitting circuits in order to pass the information; for example, transmitting aerial bandwidths are normally of the order of only 100 c/s at these frequencies. Moreover even if successful radiation could be achieved, the desired advantage of long range reception would be lost owing to the different propagation characteristics within the band which would result in distortion of the signal. At h.f. the propagation characteristics are essentially similar over the bandwidths involved.

Quite apart from these difficulties, attempts to provide multiple services to any given area require very careful frequency allocation within a severely limited available band if mutual interference is to be avoided. The number of transmissions serving a given area is thus strictly limited at v.l.f.

Phase Instability.—In spite of the great stability of v.l.f. compared with higher frequencies, minor phase perturbations due to propagation irregularities are present in sufficient degree to cause errors in v.l.f. navigational aids and frequency standard applications. These can be caused by changes in ionospheric height and large scale ionospheric discontinuities.

Further, with a mobile receiving terminal, changes in phase of the received signal can occur due to changing types of terrain over the moving transmission path.

The whistler mode of propagation discussed above can cause additional phase instability in the received signal due to an alternative transmission path over limited areas in the neighbourhood of the point conjugate to the transmitter. However, the component due to the whistler mode is unstable and its effects can be averaged out in cases where a low data rate is acceptable.

Techniques

Transmitting Aerial.—As discussed above the major difficulty arises from the fact that practicable aerials are short compared with a wavelength.

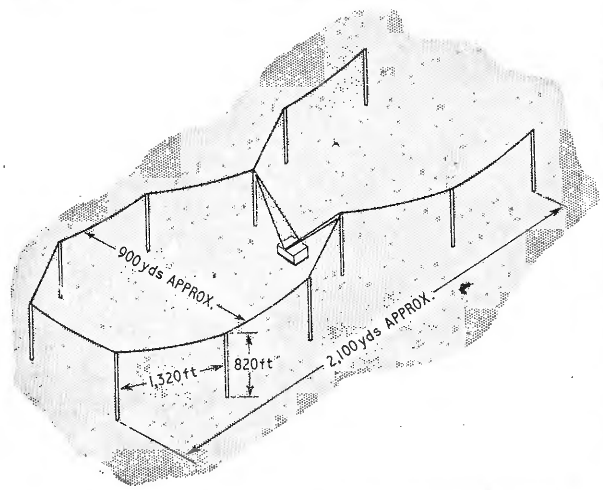


Fig. 4. Isometric representation of long wave aerial system at Rugby.

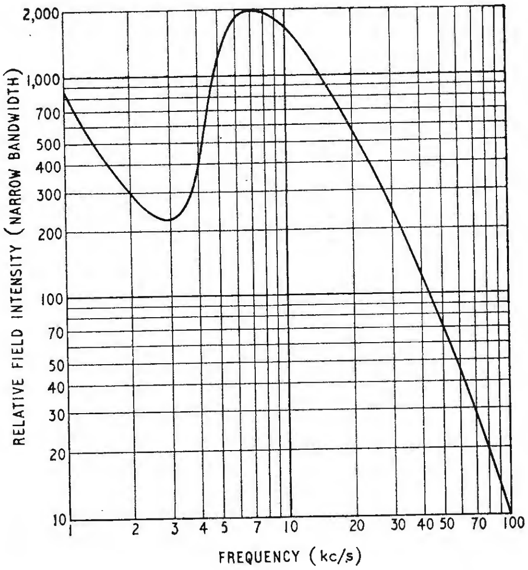


Fig. 5. Typical frequency spectrum of atmospheric noise envelope.

Artificial means of increasing the electrical length of the aerial is one possible approach to the easing of this restriction. This could be attempted for example by the introduction of suitable inductances into the aerial proper or by surrounding the radiator with a substantial amount of ferrite material.

Alternatively means can be sought to increase the path followed by the generating current, so that the current path becomes comparable with a wavelength. At least two major possibilities exist. The first is to raise a wire aerial to heights approaching a quarter of a wavelength by means of a balloon. This solution, which is at present under consideration, has many disadvantages and possible engineering difficulties. On the other hand the efficiency of such a system would undoubtedly be high and by choice of site (for example a small island or the end of a narrow peninsula) a highly efficient ready-made earth mat would be provided by the sea.

A further suggestion put forward independently by Prof. M. A. Morgan in the United States and Admiralty scientists in this country was that current paths of the order of a wavelength might be obtained by making use of certain naturally occurring geographical formations. For example, Prof. Morgan suggested that Deception Island in Sub-Antarctica might be excited as a slot aerial. The island, composed of badly conducting volcanic material, is formed in the shape of a horseshoe. It was proposed to feed current between the lagoon and the open sea by means of a cable running across the island at its centre. A similar proposal in which a cable was run between two Scottish lochs over a badly conducting peninsula is at present under investigation in the United Kingdom.

At the time of writing, reports of the American experiments are not to hand. Recent theoretical work has cast some doubt on the value of the method with the ground conductivities available and although the question is by no means finally decided, recent measurements in Scotland have not been encouraging.

Noise Reduction.—The presence of high noise interference in the v.l.f. band can be overcome to some extent by the use of directional receiving aerials. A highly directional receiving aerial would involve the use of spaced receiving elements separated by distances comparable with a wavelength; except for special applications this could hardly be justified. Gains of about 3 dB can be achieved by the use of a receiving loop having a figure-of-eight polar diagram.

A further measure particularly appropriate to applications involving low data rates, is the use of limiting, following wide-band amplification before the final filtering is applied. At times when a large noise burst is received the limiter is brought into operation and the noise is not integrated in the receiver; periods of particularly bad signal/noise ratio are therefore excluded. This technique is superior to simple filtering since with the latter some of the noise energy, eliminated in the former, would be integrated as a consequence of the ringing of the filter circuit to the impulsive energy. The technique is especially valuable where the information rate is low and little is lost by omitting short periods of received signal and associated noise from the integration process. The gain to be achieved is dependent on the character of the noise; the more impulsive this is the greater, in general, the advantage achieved. At the lower frequencies of the v.l.f. band, system gains of 20 dB are feasible.

Multi-channelling.—It will be recalled that since the v.l.f. spectrum is narrow there is a severe limitation on the number of independent services which can be accommodated without mutual interference. For any given system in which the modulation and detection technique has been specified, the maximum data rate for given noise conditions is directly related to the available power. However, it is possible to superimpose two or more such systems on to the same carrier such that the data rate in each is maintained provided the same power is used per channel. Thus, with a given system the information rate can be maintained with unchanged power requirements by multi-channelling techniques which result in compression of the bandwidth used. This technique of multi-channelling has the advantage of economy in bandwidth, thus freeing parts of the spectrum for use by other services. The disadvantage of the technique at v.l.f. is that on account of the insulation problems mentioned earlier transmitting aerials are often voltage limited. Although compression of bandwidth can be effected and the data rate maintained for the same radiated power, the maximum voltage occurring on the aerial rises with the number of channels which have been superimposed. Further multi-channelling, after the state of aerial voltage breakdown has been reached, can only be effected at the expense of reducing power per channel with consequent losses in either data rate, range, or both.

Conclusion.—The above review has outlined briefly the uses of v.l.f. electromagnetic waves and discussed some of the severe limitations associated with this band, together with techniques and proposals for improvement.

Further investigations are likely to be concerned with the Whistler mode of propagation, new modulation and noise discrimination techniques, phase stability investigations and an extension of research to even lower frequencies.

Acknowledgment.—This paper is published by permission of the Admiralty.

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CLUB NEWS

Birmingham.—T. J. Hayward (G3HHD) will be giving a lecture on aerials to members of the Slade Radio Society on April 6th. The club meets at the Church House, High Street, Erdington, at 7.45.

Dorking.—A demonstration of instruments will be given to members of the Dorking and District Radio Society by B. Bonehill (G3LHC) at their meeting on April 24th at the "Star and Garter." Meetings are normally held on the second and fourth Tuesdays of each month at 8.0.

Southampton.—Single sideband operation will be discussed by D. A. Pilley (G3HLW) at the meeting of the Southampton Group of the R.S.G.B. on April 14th. The meeting will be held in the Lanchester building of Southampton University at 7.0.

Stoke-on-Trent.—The North Midlands Mobile Rally, which will be held at Trentham Gardens on April 29th, is again being organized jointly by the Midland Amateur Radio Society and the Stoke-on-Trent Amateur Radio Society. Details of the rally, which will include amateur television demonstrations, are available from R. Palmer (G5PP), 22 Sherlock Road, Coventry, Warks.

Welwyn.—Jack Hum (G5UM), Murphy's well-known press officer, will discuss two-metre operation at the April 12th meeting of the Welwyn Garden City Group of the R.S.G.B. which will be held at 8.0 in Murphy's Conference room, Bessemer Road.

NOVEL MICROWAVE RESONATOR

USE OF TWO PERFORATED PARALLEL PLATES

By MICHAEL LORANT

DR. WILLIAM CULSHAW of the U.S. National Bureau of Standards has recently developed a new technique for probing millimetre waves—a largely inaccessible region of the radio spectrum—by treating them as light waves. The basic development—a reflector to resonate these waves—can be used with associated equipment to determine their wavelength or to investigate various materials when exposed to these waves.

Radio waves are normally resonated in a metal box. To achieve maximum resonance the box must be built to precise dimensions, depending upon the wavelength involved. The Bureau's new device, however, differs from previous resonators in that it has two perforated ends and no sides. The ends look like two small squares of pegboard except that they are made of polished brass or silver.

In the electromagnetic wave spectrum millimetre waves form a band of frequencies between microwaves and the infra-red. Millimetre waves are a rich field for research in that they are best suited for studying molecules and atoms which resonate at similar frequencies (a hundred thousand million vibrations per second). They can be used for studying the properties of superconducting materials and for studying the electron density of heavily ionized gases. Also, a better understanding of these frequencies will probably lead to new devices just as radar developed from the ability to handle microwaves.

The short length of millimetre waves also makes them very hard to handle. So far there had been no efficient way either to generate or resonate radio waves which are this short.

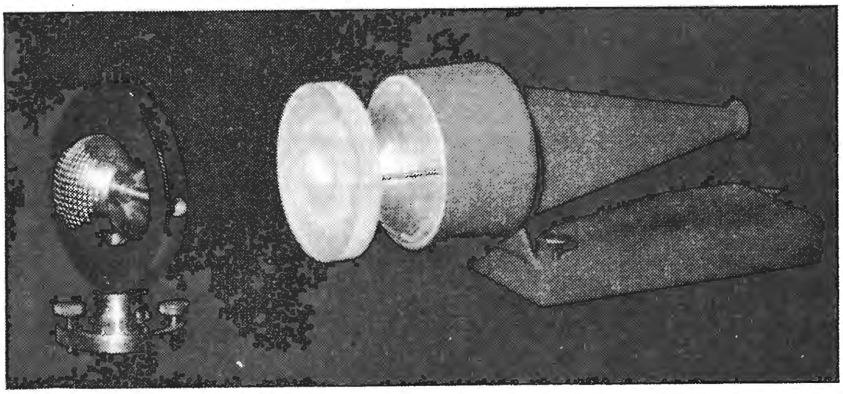
The length of a normal cavity resonator is about one-half of the wavelength being studied. This means that it is very difficult to build a cavity with the necessary precision for millimetre wavelengths because its surface irregularities must be only a small fraction of a wavelength and therefore they must be no larger than a few millionths of an inch. However, when a resonant cavity is used to study electrons, atoms, or molecules, the cavity must be big enough to allow sufficient interaction between them and the electric field inside the cavity. Until now such studies have been impossible at millimetre wavelengths, for the normal cavities are too small.

The cavity resonator developed at the Bureau consists of two perforated sheets of metal (normally six to twelve inches square). Plates made of perforated sheets of brass or films of silver deposited on glass have been used, and silver on quartz optical flats will also be tried. One of the plates is fixed but the other is movable so that the spacing between the plates can be precisely adjusted.

Electronically speaking the holes in these plates act as transformers to couple the millimetre waves into and out of the cavity while maintaining a high Q value inside the cavity. The effectiveness of the holes depends upon their diameter and spacing, and their optimum dimensions vary with the frequency. In an interferometer for 6mm wavelengths these holes are 0.0236in in diameter and they are spaced 0.057in between centres.

Resonance Build-Up

The two plates are placed parallel to each other and millimetre waves are beamed against the fixed end of this "box". Because the holes are so small, only a tiny fraction of the initial energy passes through the holes in the fixed plate. This energy strikes and is reflected by the second plate, with only a tiny fraction passing through it. (In one case the reflectivity of these plates was about 99.9%.) The waves that are "captured" inside the cavity are reflected back and forth and, when



Spherical cavity illustrating the design flexibility of the perforated cavities developed by the U.S. National Bureau of Standards. Millimetre waves are beamed by the horn (right) through two plastic lenses which focus the waves on the cavity (left). (In actual operation the two lenses are recessed into the horn.)

the plates are properly spaced, the cavity resonates. When the spacing between the plates is correct the transmission through the cavity is a maximum. Inside the cavity this condition creates an entire series of standing waves—one between each pair of holes at either end of the unit.

The perforated plates control millimetre waves much as semi-opaque mirrors control light waves. Present plates are flat and parallel to tenths of thousandths of an inch and thus the waves tend to be reflected back and forth (at the spacings used) with almost no loss of energy through the open sides of the cavity. Also, because there are no sides, the size of the cavity is adjustable over a wide range of frequencies; as the cavity is large in comparison with the wavelength, it is much more precise and easier to use than a conventional cavity.

To make the cavity resonate, the adjustable plate is slipped slowly away from the fixed plate. Maximum resonance (and output) occurs each time the distance between the plates is increased by exactly one half a wavelength. The plates are normally operated about six inches apart but are effective (depending upon their size and the frequency) at spacings up to two or three feet.

Cavity Uses

This type of cavity has been tested by using it as the resonant cavity for millimetre wave Fabry-Perot interferometer—an instrument whose basic design was originally developed for light waves. The interferometer is provided with a transmitting "horn" with plastic lenses to send millimetre waves into the cavity, a receiving horn to pick up waves coming out of the cavity, and instrumentation to record variations in the output signal.

The interferometer has already been used to measure the wavelength of millimetre waves with accuracies of better than four-hundredths of one per cent. This method of wavelength measurement, for these short wave lengths, gives the sharpest interference fringe maxima ever obtained with such an instrument (in radio or optics) and is thus more accurate than other available wavemeters. With further development it promises to give even higher accuracies.

Because of the cavity's ability to build up many reflections between the two plates with almost no energy loss its Q factor is extremely high. Until now this has been very difficult to obtain at millimetre wavelengths. In tests of waves which were about six millimetres long the cavity attained Q values of around 100,000—ten to fifty times better than the theoretical Q values which could be obtained by a normal cavity.

Such cavities become even more efficient at shorter wavelengths and are thus a practical and efficient tool for exploring the millimetre and submillimetre wave regions.

The cavities are relatively simple and easy to make and are not limited in shape. For example, a four-inch diameter spherical cavity, made of gold-plated silver, and with opposite portions of the sphere perforated with holes, has been operated at eight millimetres by focusing energy to the centre of the sphere.

Although the cavities are designed to resonate at a particular frequency, they have a wide bandwidth. This makes them applicable to the study of different materials and for use in masers.

A six-millimetre interferometer is being used to study various materials (such as plastics) by placing sheets of these materials in the centre of the cavity —parallel to the plates themselves. Since the radio waves must now be reflected back and forth through the substance being studied, there is a change in the length of cavity required for resonance. The amount of this change gives a measure of the material's dielectric constant.

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"Reflectors for a microwave Fabry-Perot interferometer", by W. Culshaw, *I.R.E. Transactions on Microwave Theory and Techniques*, vol. MTT-7, p. 221 (April, 1959).

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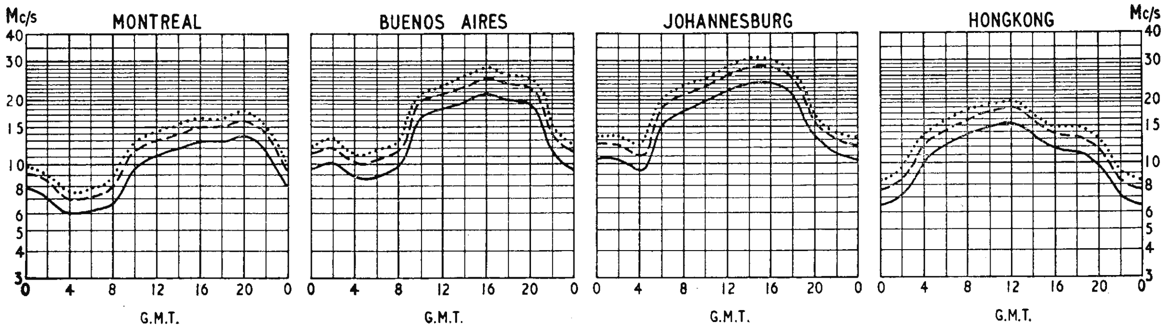
SHORT-WAVE CONDITIONS

Prediction for April



THE full-line curves indicate the highest frequencies likely to be usable at any time of the day or night for reliable communications over four long-distance paths from this country during April.

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

•••••••••• 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

Semiconductor Junction Capacitors

VOLTAGE-VARIABLE EFFECTS

By C. H. TAYLOR,* A.M.I.E.E.

SEMICONDUCTORS such as silicon and germanium can be made to conduct predominantly either by holes (p-type) or electrons (n-type) depending on the preponderant impurity type. If a p-type impurity is introduced into part of an n-type semiconductor, its type is changed where the p-type atoms out-number the n-type atoms, and a p-n junction is formed where there is an equal number of impurity atoms of each type.

P-n junctions exhibit a rectifier type characteristic and are used as diodes. Furthermore when a junction is reverse biased, i.e. when the p side of the junction has a more negative voltage applied to it than the n side, or when the junction is biased not more than a few tenths of a volt in the forward direction, it behaves as a capacitor, the value of which can be varied with the magnitude of the applied voltage. Such devices are known as variable capacitance diodes and are used in circuits such as parametric amplifiers where the voltage-variable effect can be used to advantage.

The following article describes, simply, why a p-n junction exhibits a voltage-variable capacitive effect; what can be done to make it insensitive to variation of applied voltage and what type of structure can be employed in order to obtain a non-polarized device.

P-n Junction capacitor.—The basis of operation of a semiconductor capacitor is that when a p-n junction is formed, a region adjacent to the junction is depleted of impurity current carriers and, as this region is sandwiched between two regions of high conductivity material, the effect of a parallel plate capacitor is produced. The depletion region or layer forms the dielectric and the junction has a capacitance equal to

$$C = \frac{k}{11.29W} \text{ pF/sq. cm.}$$

where k = dielectric constant of the semiconductor material (11.7 for silicon and 15.7 for germanium) and W = width of the depletion layer in centimetres.

The width of the depletion layer of a p-n junction is extremely small, typically being in the order of 10^{-4} cm in 5 ohm-cm germanium at equilibrium It varies with both the resistivity of the semiconductor and the voltage applied and can be increased by applying a reverse bias to the junction. This has the effect of further separating the " plates " of the capacitor and so reducing the capacitance. The capacitor is thus voltage sensitive.

These processes are illustrated diagrammatically in Fig. 1. In this figure, only the n- and p-type impurity atoms are shown, as the current carriers (electrons and holes) which these provide far outnumber those thermally produced in the silicon under normal working conditions. The impurity atoms, which are drawn in a regular array for clarity of presentation, are illustrated by a fixed charge (circled) and a mobile carrier (electron or hole) of opposite charge. In a real semiconductor the impurity atoms and current carriers are distributed throughout the crystal in a random manner.

Where a mobile carrier is attached to an impurity atom, the atom is electrically neutral but, when a carrier leaves an atom, the atom becomes either positively charged if an electron (negative charge) has left it, or negatively charged if a hole (positive charge) has left it.

In the zero bias condition (Fig. 1(a)) mobile carriers, electrons and holes, which crossed the junction due to mutual attraction when it was

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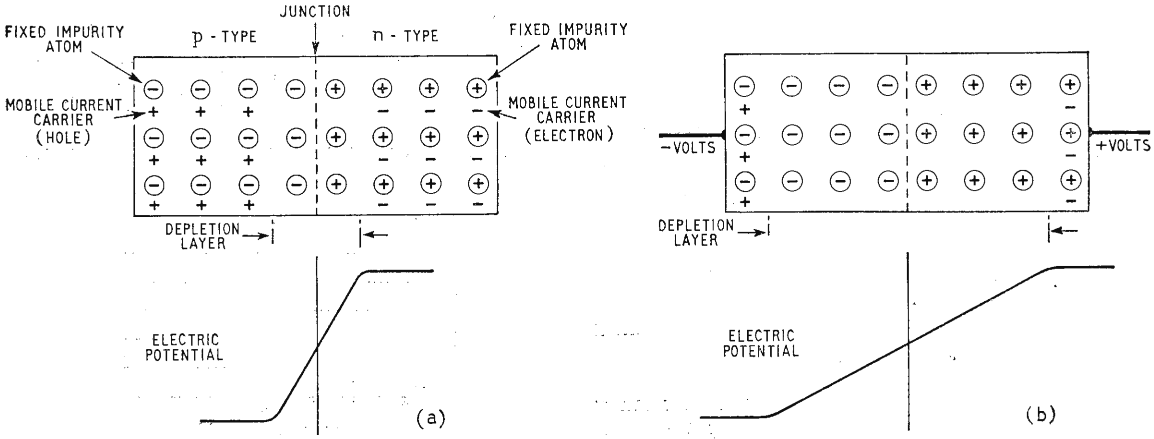

Fig. 1 (a) Diagrammatic representation of p-n junction with zero bias. (b) Diagrammatic representation of p-n junction with reverse bias.

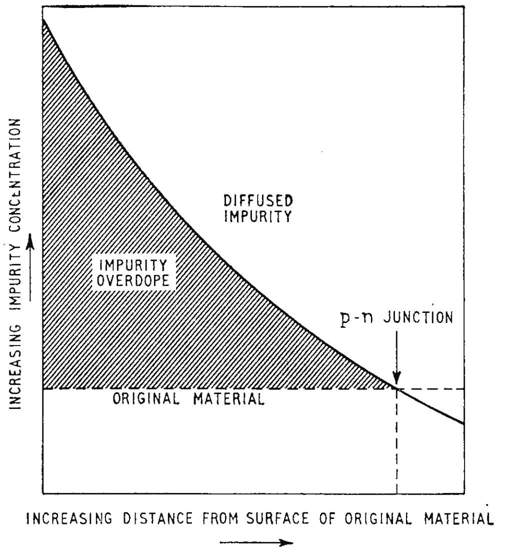

Fig. 2. Diagram illustrating typical impurity concentrations in vicinity of p-n junction.

formed, have neutralised opposite type carriers the other side and produced the depletion layer with an electric potential across it. This potential is sometimes called the "built-in" voltage and a maximum of about a volt of forward bias is required in the case of silicon to overcome it, the exact value depending on the temperature. Junctions in other materials produce slightly different built-in voltages.

The depletion layer is not necessarily symmetrical about the p-n junction, the proportion on either side being related inversely to a function of the net carrier concentration (i.e. balance of one type over the other).

If a reverse bias voltage is applied across the junction (Fig. 1(b)) mobile carriers are attracted away from it and the depletion layer widens, thus reducing the capacitance of the junction. As the resistance of the depletion layer is so high, virtually all the applied voltage is dropped across it.

The following relationship between capacitance and applied voltage holds for a p-n junction

$$C = \frac{K}{(V + V_o)^n}$$

where C = capacitance
K = constant
V = applied bias voltage
V_o = built-in voltage
n = a power which varies between $\frac{1}{3}$ and 1 according to the carrier gradient at the junction.

The built-in voltage for silicon is approximately 0.8 volts at 25°C, decreasing to 0.4 volts at 150°C.

From the above it is seen that the p-n junction capacitor is a voltage-sensitive capacitor for use with either d.c. or a.c. where the applied voltage does not forward-bias the junction by more than a few tenths of a volt.

Production of p-n Junction.—A p-n junction is produced by either alloying or diffusing a suitable impurity into a semiconductor material containing opposite type impurities. The impurities contribute either p- or n-type carriers (holes or electrons). Some p-type impurities are boron, aluminium and indium, while phosphorus, antimony and arsenic are n-type. Boron (p-type) is generally diffused into n-type silicon and the process takes place at a temperature in the region of 1200°C for a time depending on the required junction depth. The impurities are alloyed or diffused into the semiconductor at a higher concentration than the level of impurities which already exist in it. This overdopes the original impurity for a certain depth, usually less than 0.0005in, changing the conductivity type. (The type is determined by the impurity of which there is the highest concentration.)

A p-n junction is formed where the concentrations of the two types of impurity are equal. Fig. 2 shows a typical graded impurity concentration profile obtained with the diffusion process. The alloying process produces an abrupt change in type of carriers at the junction.

The greater the excess impurity concentration of one type over the other the lower the resistivity of the semiconductor. The following figures give an idea of the concentrations involved. In silicon there are in the order of 10^{23} atoms per c.c., and if it is n-type and of 10 ohm-cm resistivity, approximately 10^{15} of these will be an n-type impurity—that is, one impurity atom for every 10^8 silicon atoms. It therefore requires a p-type impurity concentration in excess of 10^{15} atoms per c.c. to overdope the n-type impurity and produce a p-n junction.

High Capacitance—Low Voltage Breakdown.—The lower the resistivity of the semiconductor near the junction the larger will be the capacitance per unit area produced. This is because the depletion layer for a given applied voltage is not so wide when the charge equilibrium is achieved as it is in higher resistivity material. The electric field across the depletion layer will however be greater and this results in a lower breakdown voltage. In a silicon diffused capacitor for example, it is possible to obtain a maximum capacitance of about 0.02μF/cm² with a breakdown voltage in the order of two volts.

Temperature Characteristics.—The variation of the capacitance with temperature of a typical silicon alloyed (abrupt) p-n junction capacitance[1] under three bias conditions is shown in Fig. 3. It should be noted that the capacitance becomes increasingly temperature sensitive at the lower voltages due to the large effect of the variation of "built in" voltage with temperature. The capacitance of a graded junction is virtually independent of temperature when more than about a volt of reverse bias is applied.[2]

Like all other types of capacitor, the p-n junction

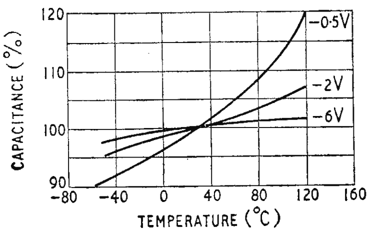

Fig. 3. Variation of capacitance with temperature of typical silicon alloyed p-n junction capacitor.

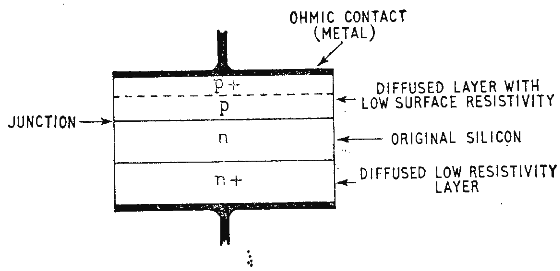

Fig. 4. Diagram of p-n junction capacitor showing conductivity types of various regions required.

capacitor has a leakage current which is due to thermally-generated current carriers in the silicon. This current is, however, substantially constant within the working voltage range of the capacitor and at room temperature is in the order of 0.01 microampere for a small silicon capacitor. The value approximately doubles for every eleven degrees centigrade increase in temperature in the case of silicon capacitors, and for every eight degrees increase for those made of germanium. The leakage current causes noise in these capacitors.

A maximum temperature for the operation of silicon capacitors is usually fixed at 150°C, as above this the junction will tend to be destroyed by excessive leakage current.

Design Considerations.—Silicon is preferred to germanium for making p-n junction capacitors for several reasons. First, capacitors made from it can be stored and operated at a much higher temperature —approximately 150°C as against 75°C; secondly, the leakage current is at least a thousand times less and, finally, for a given value of capacitance, a silicon capacitor will have a smaller area than one of germanium having the same breakdown voltage. Germanium, however, has a lower built-in voltage than silicon—about 0.4 volt as against 0.8 volt at room temperature and, as will be seen from the capacitance/voltage relationship stated earlier, capacitors made from it are slightly more voltage-sensitive, particularly at the lower applied voltages.

Particular attention has to be given to the design of connections to semiconductor capacitors, as to all semiconductor devices. Incorrectly chosen methods can result in high resistance or rectifying contacts being produced. A very low resistivity region at the surface of the semiconductor makes a low resistance contact to a suitable metal connection such as gold. If the surface resistivity of the semiconductor is too high, it can be reduced by alloying or diffusing a high concentration of an impurity of the same conductivity type into it. Evaporated gold, suitably doped, or aluminium are often alloyed into the surface of semiconductors for this purpose. Gold lead wires can then be bonded to this surface.

Fig. 4 illustrates diagrammatically a method by which a low resistance contact can be made to a p-n junction capacitor. The surface resistivity of the original n-type silicon is reduced by a low resistivity n-type diffused layer; the p-type diffusion which forms the junction already has a surface layer of sufficiently low resistivity to facilitate making a low resistance contact to it. The plus signs indicate a high impurity region which gives low resistivity.

In order to obtain the highest value of Q, $\left(\frac{1}{\omega Cr}\right)$ the internal series resistance of a capacitor must be as low as possible. A p^+-n-n^+ structure with a narrow base region can be employed for this purpose. One method of fabricating this is by diffusing an n-type impurity into one side of the n material and alloying a p-type impurity into the other (see Fig. 5). Low resistance contacts can then be made to the p^+ and n^+ regions. The abrupt junction results in a capacitor which is superior in both voltage sensitivity and capacitance range to one produced by diffusion. A p^+-n-n^+ structure is chosen rather than that of n^+-p-p^+ as approximately twice the Q value can be obtained due to the greater mobility of electrons than holes in the base material.

Non-polarized Capacitors.—In order to obtain a junction capacitor for use with an applied a.c. voltage which would forward bias a single junction greater than about 0.5 volt, a p-n-p structure can be employed. In this configuration one of the junctions is always reverse biased whichever way round the polarity of the applied voltage. The capacitance per unit area will be approximately half that of a single junction device of the same resistivity material though its value will still be dependent on the applied voltage.

Voltage Independent Capacitor

Where, as in certain forms of microminiature construction, a semiconductor p-n junction capacitor is required whose value is independent of applied voltage, it can be fabricated by making use of the following effect.

If a low resistivity p- and n-type layer are separated

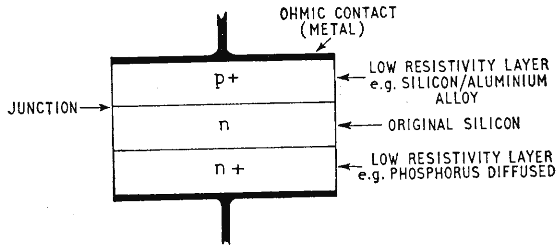

Fig. 5. Diagram of high-Q p-n junction capacitor showing conductivity types of various regions required.

by a thin layer of high resistivity (intrinsic) material, a p^+-i-n^+ structure is produced. When this is reverse-biased the depletion layer will extend through the intrinsic material and the capacitance per unit area will be determined by the thickness and dielectric constant of the high resistivity layer and will be independent of the applied voltage.

Availability and Application.—Because a p-n junction capacitor is necessarily a diode, there is no agreed nomenclature for these devices. For instance, some are listed in manufacturers' data sheets as capacitors, whereas others are called diodes, even though they have been designed with capacitance variation in mind. In yet other cases trade names are used.

The range of temperatures within which the commercially available silicon capacitors may be stored and operated is −65°C or −40°C to +150°C. If they are of the graded junction type, the capacitance variation over this temperature range, with several volts reverse bias applied, is a maximum of about 200 parts per million per °C.

Packaging is a very important aspect which can degrade the performance of a p-n junction capacitor by changing its capacitance value, increasing its leakage current and by decreasing its Q. The actual method of packaging depends on the application for which it is intended and can be either in a glass bead or metal can with a lead protruding from each end or, for higher frequency use, in a coaxial microwave fixture.

The following tables give examples of ranges of silicon p-n junction capacitors commercially available.

Hughes International (U.K.) Ltd.

Capacitance ±20% (at −4V d.c.) (pF)	Max Voltage (V.d.c.)	Typical Cap. Range (0.1V to max. voltage) (pF)	Typical Q at max. voltage	
			At 5Mc/s	At 50Mc/s
35	130	6 to 88	360	39
70	60	20 to 170	270	30
35	25	14 to 88	175	20
100	25	46 to 240	200	23

Max. leakage current 1.0μA at 25°C. 50μA at 150°C.

Microwave and Semiconductor Devices Ltd.

Junction at Zero	Capacitance Bias (pF)	Max. Voltage (V)	Min. Cut-off Frequency (Gc/s)	Typical Series Resistance (ohms)
Min.	Max.			
2.0	4.0	−4.5	30	2.4
0.5	1.0	−4.5	60	5.0
0.5	1.0	−4.5	90	4.0

There are many applications in which p-n junctions are used as diodes taking forward current, but we will confine ourselves here to some of their uses as variable capacitors.

The fact that p-n junction capacitors are physically small and electrically variable and that a low value of capacitance can be obtained, especially commends them for use in parametric amplifiers as pump elements. Their low noise and low power requirements are additional advantages.

Other possible applications are in voltage-tuned oscillators, amplifiers and filters. Since the d.c. power required to maintain the bias is small, low power feedback circuits can be employed to tune an oscillator in response to an error signal, as in a.f.c. circuits.

As an example of the use of p-n junction capacitors, a remotely-tuned radio receiver[3] is taken. A typical circuit for the remote tuning is illustrated in Fig. 6. The bias on the p-n junction capacitors, in both the oscillator and tuner tank circuits, is varied simultaneously by adjusting the remote potentiometer. The capacitance and so the resonant frequency of these circuits is thus adjusted by means of the potentiometer. It should be noted that in each circuit there are two capacitors connected back to back, producing, in effect, a non-polarized capacitor. This is necessary if the signal voltage is large compared with the bias voltage, as the signal would cause a single capacitor to be forward biased and conduct. The peaks of the signal waveform would then be chopped off, resulting in distortion. To prevent conduction under these conditions it would be necessary to increase the minimum reverse bias, but this would reduce the capacitance range of the capacitor and so the tuning range of the circuit.

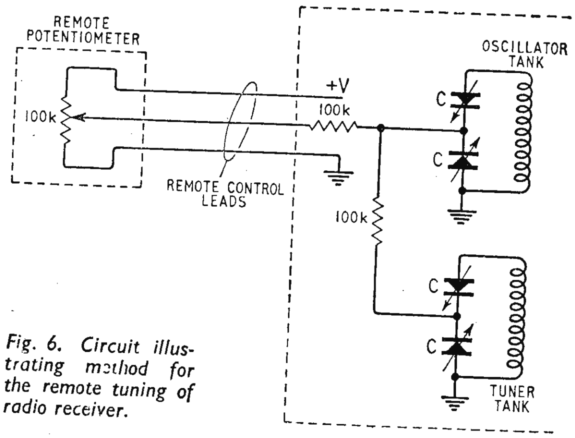

Fig. 6. Circuit illustrating method for the remote tuning of radio receiver.

Another application, for all types of p-n junction capacitors described, is becoming increasingly important; namely, in semi-conductor solid circuits. Here, as the material used is the same for the capacitor as for the rest of the circuit, capacitors can be an integral part of the circuit structure. An example of this was described by Bradshaw and Taylor[4]. In addition to the capacitive effect, distributed R-C networks can be produced by fabricating a p-n junction with one of the regions made of suitable high resistivity material. Connections are then made to two points in the high resistivity region (between these is the resistor) and one point in the low resistivity region (" common " point of the " capacitors "[5])

Some of the present possible applications of p-n junction capacitors have been described, but no doubt, many more will be discovered in the future, as the devices themselves are modified and improved.

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[2] Uhlir A. Jr., " The Potential of Semiconductor Diodes in High Frequency Communications," *Proc. I.R.E.*, June 1958, p. 1,099.

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TECHNICAL NOTEBOOK

Solid-circuit computer element made by Ferranti incorporates a complete logic circuit of six diodes, a resistor and a transistor in a can that would normally contain only one transistor. Transistors or diodes can be made by placing "dots" of the materials for the other electrodes upon a common base "slab" of silicon. After processing the slabs are usually diced into individual elements which have wires attached, are tested and then sealed into their cans. Ferranti, however, cut up the slab into blocks of six devices. The best device on test is used as the transistor and the next best *four* as diodes. The remaining diode is redundant; but it fulfils a valuable function: the chances are that out of every batch of units the largest number of "rejects" will have one junction faulty. This "extra" component thus saves the throwing out of the majority of imperfect assemblies. The other part of the circuit, consisting of two limiting diodes and a resistor, has the diodes formed in much the same way: the resistor consists of a bar of silicon. All the parts are then sealed into a can and form the completed logic element.

Tractor test recorder, developed by the National Institute for Agricultural Engineering, automatically plots a performance curve for a tractor being treadmill-tested. The drawbar pull is measured by a hydraulic dynamometer link, pressure from which moves the recorder plotting table. The link also moves the sliding contact of a potentiometer across which is a voltage developed from the treadmill. The potentiometer output voltage is therefore proportional to both the true speed and to drawbar pull, which product is available horsepower. A servo-amplifier is fed with this signal, and drives a pen. The wheel slip pen is operated by a balanced amplifier, the two inputs of which are derived from tachogenerators mounted on the treadmill and on the tractor driving wheels. The resulting plot displays curves for drawbar pull/wheel slip and drawbar pull/horsepower.

Unusual floating-drift-tube klystrons made by Elliott-Litton include some with an extra cavity tuned to the second harmonic (the original cavity being then used solely to pre-bunch the electron beam for the harmonic cavity). This allows roughly half the output power ($\gtrsim$ 0.1W) to be developed at this harmonic ($\approx$ 4mm). In another (prototype) klystron the drift tube between the two gaps in the single cavity is insulated from this cavity. By applying a suitable voltage to the drift tube the klystron can then have its frequency modulated by up to $\pm$30Mc/s (in 40kMc/s). Its output power is $\approx$ 1W.

Low-noise aerial design requirements are rather different than these for normal aerials, as was pointed out by C. R. Ditchfield in an article in the August 1961 issue of the *Journal of the Brit.I.R.E.* (p. 123). This is because the aerial must not "see" any of the relatively very noisy earth as distinct from the "quiet" sky: this means that great attention must be paid to reducing back lobes and other responses well off the axis, rather than to only the near side lobes and to achieving a high gain.

Read-out from a transistor counting decade must sometimes be obtained at the expense of counting speed, and the necessary decoding and display requires more power than can well be afforded. In an article by B. H. Harrison in *Electronics* for December 12, 1961, the use of photoconductors to dissociate the display from the counting operation is discussed. The output from the decade is provided by eight neon lamps, which do not affect the operation of the counter to any great extent. Over the lamps is placed a photoconductive decoder matrix with ten outputs, one indicator lamp or electrode being fed by each. The appropriate lamp feed path is completed by the counter neon shining on the relevant part of the matrix. The system proposed has the additional feature of a storage capability. If a gate is interposed between the counter neons and the indicator lamps, to be opened on the completion of each count, the display will remain constant during a counting period and change to the new reading when the cessation of counting triggers a gate-opening multivibrator.

Fail-safe switching system using solid-state devices has been developed by Lucas, and was described by F. H. Laishley and M. H. Roberts in the July 1961 issue of *British Communications and Electronics*. In this system signals are represented by continual switching between two states rather than, as is usual, by particular states. Any failure causes "sticking" in one of the states and thus does not give the required output signal (of switching between two states). In this system the two states are the forward and reverse magnetic saturation of a square-loop ferrite, and different pulse trains are used to switch alternately between these two magnetic states. The single basic AND/OR circuit used is designed so that any failure either prevents one train of pulses from being formed (so that the core is set in one state by the other train) or d.c. biases the core so that the pulses are no longer large enough to produce switching.

Twin-channel amplifier in the "Dataflex" series, by Bendix-Ericsson, provides a d.c. to 2-Mc/s response with high gain and low drift. One channel is a wideband amplifier arranged to have a response rising from d.c. to 45c/s where the gain is 10,000. The other channel handles d.c. at "i.f." and consists of a modulator, a.c. amplifier and demodulator, for which switching is provided by a 1-kc/s signal. At d.c. the two amplifiers are matrixed so that they are in series, but as the frequency rises the gain of the carrier system falls until the wideband amplifier has taken over completely.

Logarithmic characteristic is given over a wide range of current by the G.E.C. Type SXL63 diode. Thus to achieve a logarithmic response for an instrument it is only necessary to use one of these diodes in the signal path somewhere where the current through it will be between 3μA and 30mA.

Fibre faceplates for c.r.ts first made their appearance at last year's Physical Society's exhibition: recent work at the Royal Radar Establishment has shown that the light output available for photographic recording is 200 times greater than that obtainable by the use of an f4 lens and an ordinary tube. The faceplate itself consists of a bundle of fibres of about 12μ diameter made from glass having a high refractive index: these fibres are coated with low-index glass and then "fused" together. Following optical grinding of the resulting plate, it is fitted into a c.r.t. faceplate and the phosphor is deposited in the normal way. Light entering a fibre at less than the critical angle set by the ratio of the indices is totally reflected to appear at the other end, where the emulsion is placed in intimate contact with the fibres. The 12μ fibres used provide a resolution of about 140 cycles/cm. Microscope examination of the fibres shows a pattern of dark "marks" in the transmitted light: these are said to be complex "waveguide" propagation modes: these modes are under investigation in smaller fibres. A recent development in this field is a c.r.t. from Ferranti with a 3-in diameter faceplate composed wholly of the fibre material and using 5-μ diameter fibres. To avoid the possibility of leaks over this much greater area with many more fibres per unit area, the faceplate is given a very thin coating of glass. The resolution achieved is about 6,000 lines across the diameter.

Fixed store for computers described by J. Yamato and Y. Suzuki in the November 17th, 1961, issue of *Electronics* (p. 136) consists essentially only of a metal plate with holes in it corresponding to the information to be stored. The presence or absence of these holes considerably modifies the high-frequency ($\approx$ 1Mc/s) coupling between corresponding pick-up and excitation coils on opposite sides of the metal plate.

"Dot" miniature component packaging system giving a density of 3×10^6 components/cu ft is described by A. E. Hawley, E. A. Klein and S. Rubin in the December 1961 issue of the *I.R.E. Transactions on Product Engineering and Production*. The individual components are each in the form of small discs (0.03 in thick by 0.05 in diameter). These are inserted in circular holes of the same diameter spaced 0.1 in apart in a flat square wafer of suitable insulating material (e.g., beryllium oxide, aluminium oxide or anodized aluminium) of the same thickness. Connections are taken from the ends of the component at the sides of the wafer via copper strips along both sides of the wafer to two of its edges. (The other two edges are metallized and used to provide thermal dissipation.) "Hop-over" strip connections can be made after first depositing a thin ($\approx$ 0.005in) layer of insulating material over the affected area of the first layer of strip connections. A number of such wafers are vertically stacked together after interleaving with compressed rubber (0.005 in thick). This damps vibrations and resists lateral displacement between wafers. Interconnections between wafers are provided by an array of side-by-side copper strips laminated within a fluorocarbon strip: the copper being exposed at the required wafer edge contacts.

Electrostatic clutch, developed by I.C.T., has a history reaching back many years—an early wireless application was in the Johnsen and Rahbeck loudspeaker, for instance—but I.C.T.'s models use the latest techniques. The clutch consists of a metal drum on to which has been sprayed a 0.5×10^{-3}-in thick ceramic "dielectric" semiconducting layer: round this layer is wrapped a steel band secured at one end and connected to a return spring at the other. Under normal contact conditions there is an effective separation of about 5μ between band and drum. This allows the drum to rotate without dragging the band with it. When about 300V is applied between drum and band, the electrostatic forces drag the band on to the drum with a normal force of about 3kg/cm^2, so causing the band to be carried round with the drum. The only power taken from the 300V supply is that used to charge the capacitance between the band and drum. The work of moving the band and whatever it attached to it (a pen, switch contacts, or even a loudspeaker cone) is done by the drum. Research into flame-spraying of ceramic dielectrics has been done by G. V. Planer Ltd.

Transistorized instrumentation tape recorder made by Elliott uses a number of interesting methods to reduce wow and flutter. For example, the tape tension is kept constant by varying the torques on the take up and supply motors by means of magnetic particle clutches: the particles have their coagulation varied by means of exciting currents which are suitably derived from the reciprocals of the tape reel angular velocities; these are measured as the frequencies at which perforations in discs attached to the reels chop light beams focused on to these discs. To further reduce the wow and flutter a twin-capstan system is used to isolate the portion of the tape passing over the heads. Alterations in the length of this portion of the tape caused by any inequalities between the two capstan systems are eliminated because the consequently varying tape tension alters the pressure and thus the elastic indentations on the idler wheels produced by the capstans, thus temporarily varying the tape velocity.

APRIL MEETINGS

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

LONDON

2nd. I.E.E.—"Progress in aircraft aerials" by R. A. Burberry at 5.30 at Savoy Place, W.C.2.

3rd. I.E.E.—Discussion on "Design and application of read-only memories for digital computers" opened by D. M. Taub at 5.30 at Savoy Place, W.C.2.

3rd. Society of Relay Engineers.—"The selection of aerial sites and associated equipment for wire broadcasting systems" by A. Burke at 2.30 at 21 Bloomsbury Street, W.C.1.

2nd-4th. Brit.I.R.E.—Symposium on "Recent developments in industrial electronics" at the School of Pharmacy, Brunswick Square, W.C.1.

6th. I.E.E.—Discussion on "Analogues" at 6.0 at Savoy Place, W.C.2.

6th. Television Society.—"Scanning stabilizing circuits for four standards and colour receivers" by Dr. B. G. Dammers at 7.0 at the Cinematograph Exhibitors' Association, 164 Shaftesbury Avenue, W.C.2.

6th. Inst. of Physics & Phys. Soc.—One day meeting on "Electron diffraction with the electron microscope" at Imperial College.

9th. I.E.E.—"The impact of the epitaxial technique on semiconductor devices" by Dr. J. T. Kendall at 5.30 at Savoy Place, W.C.2.

11th. Brit.I.R.E.—"Long range v.h.f. air/ground communications" by E. H. Bruce-Clayton and D. B. Clemow at 6.0 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

16th. I.E.E. Graduate & Student Section.—"Switching and waveform circuits with long tails" by R. C. Foss at 6.45 at the Institution Building, Savoy Place, W.C.2.

17th. I.E.E.—"The use of closed-circuit television for inspecting fast-moving surfaces" by G. Syke and C. Burns at 5.30 at Savoy Place, W.C.2.

25th. Brit.I.R.E.—A discussion on "Television standards conversion" to be opened by A. V. Lord and B. Marsden at 6.0 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

26th. I.E.E.—The fifty-third Kelvin lecture on "Radiospectroscopy" by Professor B. Bleaney at 5.30 at Savoy Place, W.C.2.

27th. B.S.R.A.—"Transistor circuits for electrostatic microphones" by P. J. Baxendall at 7.15 at Royal Society of Arts, John Adam Street, Adelphi, W.C.2.

ARBORFIELD

16th. I.E.E. Graduate & Student Section.—"Computer techniques and projects" by D. Crowther-Watson at 7.0 at the Unit Cinema, Bailleul Camp, School of Electronic Engineering.

BASINGSTOKE

13th. Brit.I.R.E.—"Recent advances in low noise microwave valves" by Dr. D. G. Kiely at 7.0 at Basingstoke Technical College.

BIRMINGHAM

30th. I.E.E.—Annual General Meeting of the S. Midlands Electronics and Measurement Group at 6.0, followed by "Recent advances in semiconductor circuits including those for tunnel diodes" by Dr. G. B. B. Chaplin at the College of Technology, Gosta Green.

BRISTOL

18th. Brit.I.R.E.—"Applications and technology of piezo-electric devices" by A. E. Crawford at 7.0 at School of Management Studies.

COVENTRY
17th. I.E.E.—"The application of electronics to air traffic control" by Dr. E. V. D. Glazier at 6.30 at the Herbert Theatre. (Joint meeting with the Royal Aeronautical Society.)

EDINBURGH
3rd. I.E.E.—"The use of silicon transistors in industrial instrumentation" by M. K. McPhun at 7.0 at the Carlton Hotel.

GLASGOW
2nd. I.E.E.—"The use of silicon transistors in industrial instrumentation" by M. K. McPhun at 6.0 at the Royal College of Science & Technology.
11th. I.E.E.—"The potentialities of artificial earth satellites for radiocommunication" by W. J. Bray at 6.0 at the Institution of Engineers and Shipbuilders, 39 Elmbank Crescent, C.2.

LEICESTER
11th. Brit.I.R.E.—Address by R. L. Duthie, East Midlands Section chairman, at 6.45 at the University of Leicester, University Road.

LIVERPOOL
18th. Brit.I.R.E.—"Marconi and the early days of radio" by J. Lindsay Scott at 7.30 at The Walker Art Gallery.

MALVERN
9th. I.E.E.—"Radar observations of birds and 'angels'" by Dr. E. Eastwood at 7.30 at the Winter Gardens.

MANCHESTER
5th. Brit.I.R.E.—"Microwave valves" by C. R. Russell at 7.0 at Reynolds Hall, Manchester College of Science and Technology.
10th. I.E.E.—"The B.B.C. Television Centre and its technical facilities" by F. C. McLean, H. W. Baker and C. H. Colborn at 6.15 at the Engineers' Club.

MIDDLESBROUGH
18th. Society of Instrument Technology.—"Control systems design" by Dr. H. H. Rosenbrock (vice-president) at 7.30 at the Cleveland Scientific and Technical Institution.

NEWCASTLE-UPON-TYNE
11th. Brit.I.R.E.—"The design of high-quality sound reproducing equipment" by R. T. Lakin at 6.0 at the Institute of Mining & Mechanical Engineers, Neville Hall, Westgate Road.

NEWPORT, I. of W.
13th. I.E.E.—"Communication over a power network with special reference to power line carrier" by D. P. Howson and Dr. I. R. Smith at 6.30 at S.E.B. Showrooms.

SALISBURY
3rd. I.E.E.—"Bandwidth compression of speech" by K. Holywell at 6.30 at S.E.B. Showrooms, 17 New Canal.

SWANSEA
12th. I.E.E.—"Electronic analogue computers" by Glyn Jones at 6.0 at Velindre Works, The Steel Company of Wales.

WOLVERHAMPTON
18th. Brit.I.R.E.—Annual General Meeting of the West Midlands Section at 7.15 followed by "Electronic melody instruments" by K. A. Macfadyen at the Wolverhampton College of Technology.

UNBIASED

By "FREE GRID"

Bishops and Engineers

I NOTICED in our sister journal *Wireless & Electrical Trader* (23.12.61) that a correspondent, discussing the misuse of the honourable title of "engineer," states that it belongs only to a trained, qualified member of a Chartered Institution, and is not correctly applied to those employed as service technicians or mechanics.

This may be so in the opinion of "the duly qualified members of a Chartered Institution," but is not so in law. Anybody is free to describe himself as an "engineer," no matter whether he belongs to a Chartered Institution or not, or indeed, has any engineering qualifications at all. Personally, I agree it is all wrong that this should be so, but it is no use trying to hide the plain facts; rather should it be that we make an effort to get Parliament to alter this unsatisfactory state of affairs.

I think it is too little realized that there is no law to prevent my buying a clerical "dog collar" and giving myself the honorific title of "reverend," or even buying a bishop's outfit and styling myself "right-reverend." The only thing is that I must not attempt to deceive people into thinking I am a bishop of the Established Church or any other existing episcopal church of which there are several in this land of religious toleration.

It is the same with the title of "doctor," which, in the medical profession is a courtesy title. It was recently stated that in Cape Canaveral there are so many people entitled to the handle "doctor" that it was agreed that only the medicos should be called "doc."

Now it is no part of the job of us engineers to rally to the defence of bishops and doctors, but it really does seem time that we did something about the use of the title of engineer which should certainly be restricted to those really entitled to use it, or in other words the members of recognized engineering bodies.

But it is, surely, largely our own slackness in these matters that has allowed the title of "engineer" to be pirated by even the humblest user of tools. After all, no bricklayer's mate has so far designated himself as an architectural assistant, although I suppose there is no law against his so doing. But he would certainly be ridiculed if he did so, and ridicule is the greatest safeguard of all.

The word "engineer," coming as it does from the Latin *ingenium* (cleverness or ingenuity)—which is itself a Greek derivative—seems rather meaningless but it is sufficiently old and well established for us to ignore its origin. I can only hope that something will be done by engineers to protect their title, but I am quite sure it won't.

CQD—SOS

IT is just 50 years since the *Titanic*, the world's largest ship of those days, sank on her maiden voyage with the loss of over 1,500 people. She struck an iceberg at 11.40 p.m. (local time) on Sunday April 14th 1912, and sank less than three hours later at 2.20 a.m. It is interesting to note that at that period of history, the CQD call had just been superseded by the so-called SOS for distress messages, and actually the *Titanic* radiated both.

I well recollect that, at the time, the newspapers were full of a lot of nonsense to the effect that CQD meant "Come Quickly; Danger" and that SOS were the initial letters of "Save Our Souls." Actually CQ is the international call for "all stations" and is used for weather reports and any other information intended for all and sundry. D is simply the prefix for an urgent message of any sort. As I have pointed out before, SOS is a misnomer, since the symbol ···———··· represents no letter or letters in the international morse code.

I have been trying hard to find out some technical details of the *Titanic's* wireless apparatus. The records of Marconi's for that period are rather scanty but I understand she was fitted with a 5-kW rotary spark transmitter, and on the receiving side, a multiple tuner and magnetic detector; she also had a 10in coil emergency set. The most recent and most detailed book on the *Titanic* disaster, "A Night to Remember," by Walter Lord, published in 1956, gives no details whatever but simply mentions that the set of the *Titanic's* sister ship, *Olympic*, "was powerful." If Harold Bride, the survivor of the *Titanic's* two wireless operators, who, I understand went to the States some 40 years ago, is still with us he is the one man who could answer our queries.

I even visited the shipping exhibit on the second floor of the Science Museum in my search for information. I found one complete gallery devoted to the development of apparatus appertaining to the ship's engine-room department. But in an adjoining gallery where I might have expected to find several replicas of ships' wireless rooms over the past 60 years, I found the space filled with turret clocks and other apparatus. Over 10 years ago, the Marconi Company staged an excellent exhibition in the Baltic Exchange depicting ships' wireless cabins at various periods over the previous 50 years; surely something similar could be laid on at the Science Museum.

F.M. in the Dock

RECENTLY there has been quite a lot of correspondence in one of the more serious daily newspapers about the B.B.C's. v.h.f./f.m. service. On the whole the opinion seems to be that the service has not been as successful as it was anticipated it *would* be when it was first mooted.

The main object of the service was to give interference-free reception of the B.B.C's. programmes to those areas where the ordinary m.w. and l.w. transmissions were not satisfactory on account of intereference from Continental stations.

Of course, nothing ever does work as well as it is expected to do, and the v.h.f./f.m. service has not been any exception. But at the time of the scheme's inception I, for one, thought the B.B.C. was putting it forward too ardently as a sort of panacea for all the evils which attended the reception of those living well away from any of the existing B.B.C. transmitters. I was not the only one who held this opinion, and indeed, long before the service actually started there were many technical arguments in the columns of this journal by people who seemed to know what they were talking about; they pointed out many snags in the proposed system.

But despite all this it cannot be denied that the B.B.C's. v.h.f. sound broadcasting service has been a boon to many, and I don't want it to be thought that I am writing this merely to decry it. But admittedly it has not been quite the success that was anticipated in certain official quarters. The same will be true of the 625-line TV system if ever it is put into service in this country. If we are to uproot our existing 405-line service, let us at least put in its place something that is really worth while.

To return to the B.B.C's. v.h.f. service, there are many living in hollows who find they don't get much of a signal at all. What they do get, of course, is a reflected one, so that the programmes come in best with the aerial orientated in some abnormal direction.*

* There may also be standing-wave patterns, one for each of the Home, Light and Third wavelengths. It took me some time to find a position for the aerial (simple dipole) which coincided with antinodes of all three waves. It was found not on the roof of the house but in a tree in the garden, and in spite of low signal strength (about 10μV/m average) in a fringe-area hollow, I can now drive the limiter hard enough to get excellent noise-free reception of all three services. I am a satisfied customer.—ED.