Wireless World

AUGUST 1954 VOL. 60 No. 8

B.C.C.?

THE amendments made to the Government's television Bill during the later stages of its weary passage through the legislative machine deal with matters of detail rather than of principle; few of them hold any great interest for us or our readers. Nevertheless, there have been some thought-provoking asides to the main theme of the House of Lords debates. One of the most important of these came from Lord Balfour of Inchrye. In stressing the need for ensuring that the scheme for commercial television as outlined in the Bill will work, he expressed doubt whether our executive policy and administrative machinery are framed on a scale large enough or wide enough to cope with the rapid growth and competing demands of all branches of radio—not only of television. Criticizing the Post Office control, he asked "Is it likely that commercial applicants and mobile radio users are going to get from one interested Department, if not the fairest treatment, at any rate treatment on the widest basis of national interest?" The anomalous position of the P.M.G. was stressed.

Criticism of the Post Office, coming at the present time from a supporter of the Government, focuses attention on the desirability of a change in the organization of radio administration that many will consider to be long overdue. When this matter comes up, as it does periodically, comparisons are inevitably made between the G.P.O. and the Federal Communications Commission of the U.S.A. The F.C.C. sometimes comes under criticism, but at least it is not in the anomalous position of being, as is the G.P.O., in competition with its own licencees. If we had a B.C.C. it would at least be free of that anomaly. And, at a time when radio is becoming increasingly a party-political issue, anything that can keep its day-to-day administration out of the orbit of party politics is surely to be desired.

Electronics In Industry

AS complacency is not one of the besetting sins of those engaged in the electronic art, it was to be expected that both the art and its practitioners would come under some criticism at the successful convention on "Electronics in Industry" recently held by the Brit. I.R.E. In discussion, doubts were freely expressed as to whether all that should be is in fact being done to meet the needs of industrial users of electronic devices.

No doubt there are faults on both the electronic and non-electronic sides of the fence. Designers of equipment are sometimes unsympathetic towards the user, who, in his turn, often expects far too much. Then there is the thorny question of maintenance; to us it seems unlikely that electronic gear can ever be maintained except by specialists—and, if complex, operated by them as well. There is food for thought in a remark made by one of the convention speakers, who said, "It is better to train an electronic engineer to become, say, a chemist, than to train a chemist to become an electronic engineer."

The Law

THERE still seems to be some uncertainty as to the legal position of those who make recordings of broadcast programmes; this in spite of the effort made in our issue of December, 1953, to clarify the position. The gist of what we then said was that the private individual, making a recording for his private use for playing back in his own home for the benefit of his family or intimate circle of friends, runs no risk of falling foul of the law. On the other hand, those who make such recordings for financial gain, or play them back in circumstances that introduce an element of "public performance," are likely both to commit an offence under the Dramatic and Musical Performers Protection Act, 1925, and to infringe the law of copyright.

Very wide publicity was given to this interpretation of the legal position, but nothing has been brought forward to suggest that it was in any way inaccurate. Thus, until a ruling to the contrary is established by action in the Courts, it is safe to accept the basic correctness of the interpretation we offered last December.

Industrial Electronics

Is it Really Successful as an Aid to Production?

The British Institution of Radio Engineers recently held its third post-war Convention, on the subject of industrial electronics, at Christ Church, Oxford. Most of the technical papers put a strong emphasis on the actual applications of electronics, and as there were a good many representatives of various industries present the discussions tended to follow along the same lines. Appropriately, the whole proceedings were summed up in the last session by the President of the Institution of Production Engineers, Sir Walter Puckey, and his address was followed by a debate on the motion "Electronics is the key to improving and increasing production." We give here some of the opinions that were expressed at this final session and at other times during the Convention.

MOST electronics engineers to-day see the application of electronics to industry in the grandiose terms of a "second industrial revolution" which will completely change our methods of manufacture and even our way of life. Most people in industry, on the other hand, see nothing of the sort, and are not even convinced that electronics has anything to offer them. Why should there be such a great gulf in outlook between the two parties?

According to Sir Walter Puckey, who spoke at the Brit.I.R.E. Convention on industrial electronics, the fault lies with the electronics engineer himself. From his (Sir Walter's) observations the typical electronics engineer was not capable of understanding the wider implications of his work. He was a specialist, and something of a fanatic, concerned only with his own particular techniques and problems, and could not be bothered to explain his work to other branches of industry. Sir Walter felt that the radio industry put too much emphasis on the training of technicians when the real need was for men with a wider outlook. The technician was too much inclined to "plug" electronics as the only way of life when, of course, there were other ways of doing things. The proper criterion should be to achieve optimum results with the greatest simplicity.

Industrial electronics, continued Sir Walter, deserved better ways of demonstrating its abilities than it had at present. Static displays of equipment were not good enough. The important thing was what you did with the equipment, and exhibitions should be organized to show all the available techniques at work.

Another speaker at the Convention expressed the view that electronics would be more successful if a number of firms could collaborate to build a particular equipment instead of each individual firm trying to do the whole job itself. Each firm could then specialize in a particular type of "prefabricated" sub-unit and the whole group would be rather like component manufacturers supplying parts to the radio industry. It would be necessary, of course, to achieve a fair amount of standardization for this purpose, as in the component industry. A further speaker, however, felt that suggestion was premature at the moment because the necessary standardization would tend to stultify technical progress.

One topic which provoked a great deal of discussion was whether electronics should attempt to replace the human operator. The question arose out of a paper which suggested a method of doing simple mechanical operations (such as picking things up and putting them down somewhere else) so that the humans who are so engaged at the moment could be released for more interesting work. The suggested machine would not have a specialized function (unlike most electronic control devices), but would be flexible enough to be "programmed" by an input of information to do any job that was required.

On this some speakers took the view that electronics should not attempt to do what humans are already doing better. In any case, some sort of mechanization was the real answer. A more sweeping observation on the subject was that electronics is doing nothing more than changing the type of labour required in industry. Semi-skilled operators could be replaced by electronic devices but we needed skilled technicians to develop and maintain the apparatus, and the result was not a very economical arrangement. This speaker felt, however, that electronics would be of greater value in new industries and activities yet to be developed, such as nucleonic work.

An aspect of electronics which seemed to worry a great many of the potential users present was the reliability of equipment. All speakers agreed that equipment must be thoroughly reliable if the prejudices of industry were to be overcome. There was a considerable difference of opinion, however, on whether the electronics or the associated mechanical equipment was the more unreliable, and some speakers felt that an enquiry into the whole question was needed. One particular source of unreliability was considered to be miniaturized equipment, and it was felt that miniaturization had already gone far enough, if not too far. Another related problem was that electronic firms were not particularly interested in the servicing and maintenance of their apparatus after it had been developed and sold. Development engineers as a body were even less concerned, as they felt their only purpose in life was to create. This was shown up by the bad design of some instruments, in particular nucleonic instruments, which were very difficult to service.

It was pointed out, too, by a representative of industry that electronic apparatus is not usually maintained in the same way as other equipment: it is allowed to run until it breaks down and then is repaired, after a great deal of damage has been done. He said that it was up to the development engineers to issue some kind of checking schedule with the apparatus which would give an estimate of the likely breakdowns *before* they occurred. In this way serious trouble could be averted and the user would have more faith in the value of the apparatus.

WORLD OF WIRELESS

Import-Export Ratio
Jungfrau Television Station
R.A.E. Dates • V.H.F. Stations

Balance of Radio Trade

CAPITAL GOODS—transmitters, communication equipment and navigational aids—continue to provide the mainstay of the radio industry's exports. Of the total value of £10.97M exported during the first five months of the year, the "heavy" side of the industry accounted for £5.4M. Last year's figures were £9.26M and £4.11M respectively. It will be seen from the table that there has also been a marked increase in the value of exported components, p.a. gear and sound reproducing equipment.

There is, however, the other side of the picture. Whereas exports of valves and c.r. tubes have fallen by some £60,000 the imports of these accessories have risen during the same period from a little over half-a-million pounds in 1953 to £1,416,496 this year.

In answer to a question in the House of Commons recently, Mr. H. Strauss (parliamentary secretary to the Board of Trade) stated that in the first quarter of this year 2,078,000 electronic valves were imported against 771,000 in the corresponding quarter last year. When asked if he could explain the threefold increase he said it might be the very large increase in the demand for television sets.

Figures supplied by the Statistical Office of Customs and Excise show that in this total were 1,627,293 valves from Holland and 321,766 from Western Germany, making 1,949,059 for the two countries. As the cost of these was £301,092 the average price per valve was 3s.

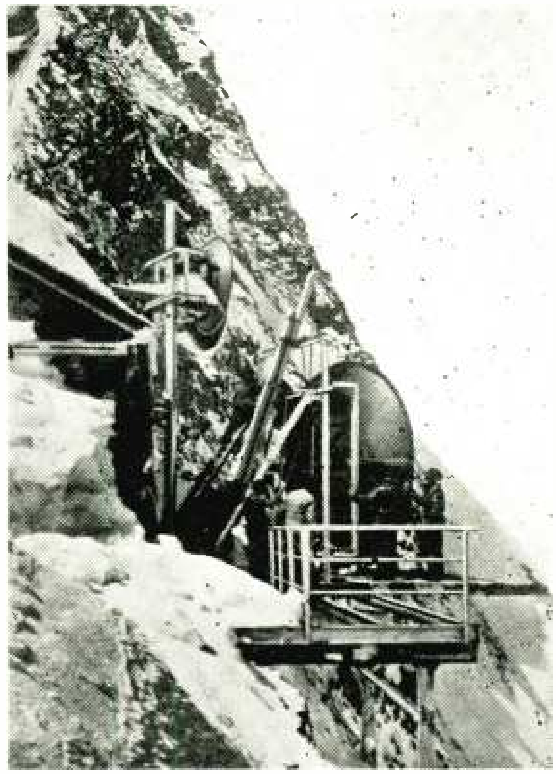
	Jan.-May	
	1953	1954
	£	£
Valves and stabilizing tubes	887,220	821,746
Cathode-ray tubes	44,304	49,640
Broadcasting and television transmitters ...	376,022	346,762
Radio communication and navigational equipment (including radar)	3,737,186	5,060,832
Domestic broadcast receivers	1,362,659	1,158,816
Radiograms	224,567	180,058
Television receivers	174,727	81,854
Public address equipment, and loudspeakers and microphones	255,144	299,209
Sound reproducing apparatus (electrical), not elsewhere specified	73,622	112,694
Components and parts, not elsewhere specified, including parts of valves and c.r. tubes	2,131,685	2,864,596
	£9,267,136	10,976,207

The position, moreover, is worsening, for the latest figures show that the number of valves imported during the first five months of the year increased from 1,287,542 in 1953 to 3,474,769 this year. The comparative figures for c.r. tubes are 72,212 and 194,227.

Electronic Control Research

A NEW Division of the National Physical Laboratory has been formed by the amalgamation of the Electronics and the Control Mechanisms Sections. The field to be covered by this Control Mechanisms and Electronics Division, as it is called, is the automatic control of industrial, administrative and experimental operations and the development of techniques and equipment for data processing and computation. Its terms of reference exclude radio and acoustic problems.

The officer-in-charge of the Division is R. H. Tizard, B.A., A.M.I.E.E.



Paraboloids, each weighing half-a-ton, being erected at the Jungfrau relay station. *(See "Trans-European TV")*

Trans-European TV

THE permanent Italo-Swiss-German television radio link used for the first time during the trans-European relays is of particular interest. This 125-mile link, from Chasseral in northern Switzerland across the Alps to Monte Generoso on the Swiss-Italian border, has but one relay station 12,000ft up on the Jungfrau.

The equipment for the relay station and the two terminal stations provides a one-way reversible television channel with a 5.5-Mc/s bandwidth. Two frequencies are actually used (1776 and 1848 Mc/s) to prevent feedback from the transmitter to the receiver at the relay station and frequency modulation is employed.

The repeater is of the non-demodulating type since this avoids the distortion which would be introduced into the video signal if numerous modulators and demodulators were used. The connection between the transmitter and receiver is made at the intermediate frequency (60 Mc/s).

Spun aluminium paraboloid reflectors 12ft in diameter are used at each station. The effective bandwidth of the aerials is 150 Mc/s and over this band the voltage standing wave ratio does not exceed 1.15. A gain of 34 db (relative to an isotropic radiator) is achieved at 2,000 Mc/s, the beam angle being 2 deg.

The equipment was installed by the G.E.C. and similar gear is to be provided by Hasler S.A. of Switzerland on behalf of the G.E.C. for the extension of the Swiss television network.

Amateur Examinations

ARRANGEMENTS have been made by the Post Office to hold the next Radio Amateurs' Examination on October 2nd at three centres, London, Edinburgh and Cardiff. Applications, enclosing the entrance fee of 25s, should be addressed to the Wireless Telegraphy Section, Radio and Accommodation Department, Union House, St. Martins le Grand, London, E.C.1, and must be received by September 4th.

Morse tests will be held during the first week in September at the Head Post Offices in Birmingham, Cambridge, Derby, Leeds and Manchester, provided there are sufficient candidates. Application forms are obtainable from the Radio Branch, Radio and Accommodation Dept., Post Office Headquarters, London, E.C.1, and these must be returned, with the 7s 6d fee, by August 20th.

V.H.F. Transmitters

FROM OUR NOTE in these pages last month, readers may have gained the impression that there are to be many more v.h.f. broadcasting stations than are actually planned for this country. Two transmitters will be operated in parallel for each programme, and, as shown in the map in our November, 1953, issue, the majority of the stations will radiate three programmes.

We understand that fourteen (not two) of the sixty-four transmitters on order for the B.B.C. have a power of 10 kW, thirty-eight will be rated at 4.5 kW and twelve at 1 kW.

As already stated, forty of the transmitters (two 10-kW and thirty-eight 4.5-kW) will be supplied by Marconi's and twenty-four (twelve 10-kW and twelve 1-kW) by Standard Telephones & Cables.

PERSONALITIES

Dr. Willis Jackson, F.R.S., director of Research and Education of Metropolitan-Vickers Electrical Company, has been elected a vice-president of the Institution of Electrical Engineers. Before taking up his present position with Metrovick in July last year, he was, from 1946, professor of electrical engineering at the Imperial College of Science and Technology, London. Dr. Jackson had previously occupied the Chair of Electrotechnics at Manchester University for six years, and prior to 1938 was a research engineer with Metrovick. He is a member of the technical sub-committe of the Television Advisory Commitee, and, since 1950, has been a member of the Radio Research Board of the Department of Scientific and Industrial Research.

Sir Gordon Radley, C.B.E., engineer-in-chief of the G.P.O., has been elected a vice-president of the I.E.E. for his second three-year term of office. Sir Gordon, who was knighted earlier this year, became engineer-in-chief in 1951, having previously been controller of research. He is chairman of the technical sub-committee of the T.A.C.

C. W. Oatley, M.A., M.Sc., who has been elected chairman of the I.E.E. Radio Section for 1954/55, has, since 1945, been a Fellow of Trinity College, Cambridge, and lecturer in the Engineering Department of Cambridge University. At the outbreak of the war he joined the Air Defence Experimental Establishment (later Radar Research and Development Establishment) of the Ministry of Supply, and was put in charge of basic work on radar transmitters and receivers. In 1942 he took charge of basic work in the whole establishment, and two years later became acting head of the scientific side of R.R.D.E. For twelve years prior to the war Mr. Oatley was a member of the staff of the Physics Department of King's College, London. He is chairman of the Power and Field Strength Measurement Committee of the Radio Research Board although not a member of the board itself.

C. W. OATLEY

Dr. R. C. G. WILLIAMS

Dr. R. C. G. Williams, B.Sc. (Eng.), the new vice-chairman of the I.E.E. Radio Section, has been chief engineer of Philips Electrical since 1948. He was general manager of the Electronics Division of Murphy Radio until 1946, when he went to the U.S.A. and was appointed executive engineer of the North American Philips Company. Dr. Williams has recently returned from a trade mission to the U.S.S.R. He has been for some time a member of the Comité International de Télévision, set up in 1947 to encourage international collaboration in the field of television techniques.

R. E. Burnett, M.A. (Oxon), A.M.I.E.E., A.Inst.P., principal of Marconi College, Chelmsford, and manager of Education and Technical Personnel, has also been appointed assistant to the general manager, and adviser on technical staff matters to the associated companies. In consequence, E. R. L. Lewis, M.A., A.M.I.E.E., has been appointed deputy manager, Education and Technical Personnel, and R. G. Hulse, B.Sc. (Hons.), deputy principal of Marconi College and director of studies.

Barry Z. de Ferranti, author of the article on storage systems on page 392, graduated B.Sc. from the University of Sydney in 1949. Two years later he received the degree of Bachelor of Engineering (electrical and mechanical) with honours in electrical engineering, the subject of his honours thesis being based on research work on the control of a magnetic drum memory for a digital computor. He came to England in the latter part of 1951 and underwent a two-year graduate apprenticeship course in telecommunications with the General Electric Company. Mr. de Ferranti is now investigating the applications of electronic computing techniques to automatic telephone exchanges at the Wembley laboratories of the G.E.C.

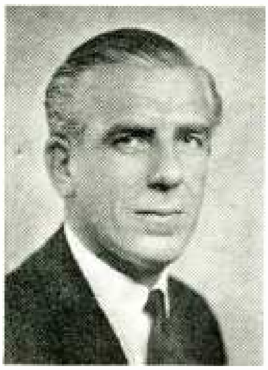
Douglas Walters has left Odhams Press after 22 years' service, where he was for seven years radio correspondent of the *Daily Herald.* From 1939 to 1945 he served with the R.A.F.V.R. as technical radar officer. Douglas Walters has been an amateur transmitter for 24 years—his call is G5CV—and is particularly interested in the radio control of models. His transistor r.t. transmitter was described in our December issue last year.

In order to foster the application by industry of results of research undertaken by the National Physical Laboratory, the director has appointed two liaison officers. They are, **E. I. Brimelow**, M.Eng., A.I.M., a metallurgical engineer, and **A. J. Garratt**, M.B.E., B.Sc., A.Inst.P., who was in the Civil Service from 1940 to 1951 and more recently has been in industry. He is a scientific adviser to the B.B.C. Television Service.

Marconi Marine announce the appointment of **Albert J. Locke** as manager of the company's Service Depot at Hong Kong, where he has been an inspector since 1950. Like all Marconi Marine depot managers, he commenced his service (in 1936) as a sea-going radio officer. He joined the shore technical staff in 1942 and went to Hong Kong in 1946. He succeeds A. P. Goodman who is returning to the U.K.

Air Commodore Michael Watson, C.B., C.B.E., who joined the Royal Air Force in 1929 and for the major part of his Service career specialized in signals, has retired at his own request and joined Decca Radar, Ltd., as head of the new Radar Systems Division. Since 1953 he had been director of Signals at the Air Ministry.

Peter O. Wymer, B.Sc., A.M.Brit.I.R.E., has been appointed press officer of Mullard's Publicity Division. He has held a similar position with the E.M.I. Group of companies since 1948, prior to which he had spent some years as a lecturer in radio-physics and on the radio staff of the B.O.A.C.



Air Comdre. M. WATSON

P. O. WYMER

H. John Dyer succeeds Peter Wymer at E.M.I. He was at one time editor of the *Wireless and Electrical Trader* and has been closely associated with public relations and publicity in the Radio Industry Council.

OBITUARY

Francis M. Colebrook, who, as recorded in our last issue, was appointed an O.B.E. in the Birthday Honours, died in hospital on June 21st after an operation. He was aged 61. A senior principal scientific officer at the N.P.L., which he joined in 1920, he was, at the time of his death, head of the Electronics Section which produced the automatic computing engine (A.C.E.). Before assuming control of the Section he was for some years deputy to Dr. R. L. Smith-Rose, superintendent of the Radio Division. Mr. Colebrook was a member of the editorial board of *Wireless Engineer.*

K. Higginson, affectionately known in the trade as "Higgie," who retired from the position of technical representative of the Dubilier Company last year, died on June 15th. Before joining Dubilier in 1934 he was chief engineer of Oliver Pell Control, Ltd.

H. D. Wilson, who had been with the Sifam Electrical Instrument Company, Ltd., for the past sixteen years, first as technical sales engineer and latterly as a director, died in June. He served his apprenticeship with Spagnoletti, Ltd., and prior to joining Sifam was with S. G. Brown, Ltd., and Measuring Instruments (Pullin), Ltd.

SHOW NUMBERS

Publication Dates

The next issue of *Wireless World* will include, in addition to the usual quota of articles and features, a stand-to-stand preview of the National Radio Show with a list of exhibitors and plan of the exhibition. The publication date has been advanced to August 23rd, two days before the opening of the Earls Court exhibition to the public.

In the October issue (published on September 27th) we shall include a review of the trends in design, written by the technical staff of *Wireless World* after examination of the exhibits at the show.

IN BRIEF

Licences.—The number of television licences current in the United Kingdom increased by 78,528 during May, bringing the total to 3,379,366. The total number of licences, including sound and vision and 231,848 for car radio sets, was 13,479,308.

White City TV Centre.—The first section of the new B.B.C. Television Centre at Wood Lane, London, has now been completed and occupied. Its main purpose is to serve as a vast workshop for the construction of scenery for studio productions, and it covers approximately one acre of ground. The block also contains some 200 offices for producers, designers, administrative staff, etc.

Aircraft Electronics.—The electrical section of the College of Aeronautics, Cranfield, is to be extended to have the status of a department. The course offered, which is at post-graduate level, has no equivalent at present; naturally, it tends heavily towards the electronics side.

I.E.E. Radio Section.—The new chairman of the committee of the Radio Section of the I.E.E. is C. W. Oatley, of Cambridge University, and the new vice-chairman is Dr. R. C. G. Williams (Philips Electrical). The new members of the Committee are N. C. Robertson, C.M.G., M.B.E. (E. K. Cole), L. Rushforth, M.B.E., B.Sc. (B.T.-H.) and A. M. Thornton, B.Sc. (S.T.C.). B. N. MacLarty, O.B.E. (Marconi's) has been co-opted to fill the vacancy created by Dr. Williams' election as vice-chairman before completing his term of office as an ordinary member. The only member of the Radio Section to be elected to the Council of the Institution this year is Dr. J. H. Westcott, B.Sc.(Eng.), lecturer in electrical engineering at Imperial College.

French Show.—The 17th French Radio and Television Exhibition organized by the National Federation of Radio and Electronic Industries of France (S.N.I.R.) will be held at the Musée des Travaux Publics, Place d'Iéna, Paris, 16, from October 2nd to 12th.

Radio Control.—More and more model engineers are turning to radio for control purposes and this aspect will again be featured at the Model Engineer Exhibition to be held at the New Horticultural Hall, London, S.W.1, from August 18th to 28th.

Nottingham Show.—Manufacturers have been invited this year to participate in the annual Nottingham Radio Exhibition, organized by the local members of the Radio and Television Retailers' Association, which will be held at the Ice Stadium, Nottingham, from September 6th to 11th.

Dissemination of Information.—Ten public library authorities in West London, in conjunction with many large firms and research establishments, have co-operated to provide a free technical, industrial and commercial information service for organizations and individuals in West London. Information regarding the Co-operative, Industrial and Commercial Reference and Information Service is available from the Acton Public Library. A similar service is provided by the Islington Public Libraries in North London.

Courses on crystal valves, transistors and transistor circuitry are among the many part-time **Higher Technological Courses** listed in the Bulletin for the autumn term, issued by the London and Home Counties Regional Advisory Council for Higher Technological Education. The Bulletin, which is obtainable from the Regional Advisory Council, Tavistock House South, Tavistock Square, London, W.C.1, price 1s 6d, lists some 20 radio and allied courses among the many specialized courses provided by colleges in the region.

The Department of Telecommunications Engineering, **Northern Polytechnic,** London, N.7, is introducing three courses covering Bands II and III receivers, convertors, test equipment and aerials. They are: a full-time two-week course, another necessitating one full day's attendance per week for three months, and evening classes. The courses, which will cover both theory and practice, commence during the week beginning September 27th and the fee for each is £2. Students must enrol by August 7th.

Evening Courses in radio and television servicing (Mondays and Tuesdays) and for the Radio Amateurs' Examination (Wednesdays) are again being held at Brentford (Middlesex) Evening Institute during the next scholastic year. The fee for each course is 15s.

International Aeradio, which operates aeronautical communications, control and allied services for international air transport, has just issued a booklet on its widespread activities.

British Large-Screen Television, made by Cinema-Television and operating on the French 819-line standard, was recently demonstrated by the Compagnie Française Thomson-Houston in the Palais de Chaillot, Paris.

PUBLICATIONS

"W.E." Editorials.—Professor G. W. O. Howe, technical editor of *Wireless Engineer*, has been contributing editorials to this, our sister journal, since 1926. An index to these contributions has now been prepared by the Electrical Engineering Department of Glasgow University, where Dr. Howe for many years occupied the James Watt Chair of Electrical Engineering. It includes chronological and subject indexes for the period January, 1926, to May, 1954, and an index to names and authors referred to. It is obtainable from Dr. A. J. Small, Electrical Engineering Department, The University, Glasgow, W.2.

CABMA Register.—The 1954-55 edition of this directory of British products and Canadian distributors, sponsored by the Canadian Association of British Manufacturers and Agencies, includes a buyers' guide of products under 3,750 headings, lists of proprietary names and trade marks and directories of British manufacturers and Canadian distributors. It is obtainable from our publishers, price 42s.

The bibliography of **Colour Television,** referred to on page 388 (incidentally, the price should be 2s 6d), is a reprint issued by the Television Society of the bibliography originally prepared by the librarian of Ultra Electric, Ltd., for private circulation.

Over 100 **Back Numbers** of *Wireless World*, some dating back to 1938, are offered gratis to a reader or organization by R. D. D. Langlois, of 2, Storey Road, Coventry, Warwicks. Interested readers are asked to send a stamped-addressed envelope for particulars.

EXPORTS

Pye U.S. Office.—Pye, Ltd., of Cambridge, have opened an office in Fifth Avenue Building, 200, Fifth Avenue, New York, 10, and William M. Cagney, formerly of the Link Radio Corporation, has been appointed regional supervisor of the activities of the Pye Group in the U.S.

An order for the supply of a large quantity of radio-telephone equipment has been received from the New Brunswick Department of Public Works by **Pye Canada.** It is to provide a province-wide communications scheme on 152-174 Mc/s for road maintenance vehicles and a point-to-point network on 72-76 Mc/s. The initial order is valued at 40,000 dollars.

British two-way radio relay equipment to carry television programmes between two Canadian towns—London and Windsor, Ontario—is to be supplied by the **General Electric Company** through the Canadian G.E.C. The chain will consist of four relay stations plus terminal equipment.

Another order from Canada has been received by **Marconi's W.T. Company.** It is to supply through its Canadian associate company telecommunications equipment for new Australasian and Far Eastern circuits being established by the Canadian Overseas Telecommunications Corporation. The equipment includes s.s.b. and double-diversity telegraph receivers and 30-kW s.s.b. transmitters. The transmitters are capable of handling four telephone channels and also provide facilities for either multichannel or normal frequency-shift telegraphy.

Gresham Transformers, Ltd., of Twickenham Road, Hanworth, Middlesex, now have in production a range of transformers conforming to the U.S. Service specification MIL/T.27.

INDUSTRIAL NEWS

The Plessey Company has formed a new division, which is being set up in Swindon for the development, manufacture and sale of electrolytic and paper capacitors and moulded-track potentiometers. The **Swindon Components Division,** as it is called, has as its general manager, O. G. Cox, who joined Plessey last year from A. H. Hunt (Capacitors), Ltd.

Richard Seligman, a partner and director of **Scope Laboratories,** Melbourne, Victoria, is on a two-months' visit to this country to introduce the Scope lightweight soldering iron. He plans to establish an agency before his return.

Decca Radar, Ltd., has formed a new section to be known as the Radar Systems Division which will cover the specialized applications of radar (other than marine) including military systems, civil air aids and meteorological radar. The head of the new division is Air Commodore Watson, who will be assisted by S. J. Kyte.

Advance Components' new signal generator for Band III was erroneously stated in last month's issue (page 41) to be externally modulated; it is designed for internal modulation only.

Solartron.—A new company to be known as Solartron Research and Development, Ltd., has been formed, which, together with the existing companies Solartron Laboratory Instruments, Ltd., and Solartron Engineering, Ltd., will be controlled by a new holding company, Solartron Electronic Group, Ltd., of Thames Ditton, Surrey (Tel.: Emberbrook 5611).

United Television Manufacturers, Ltd., has been formed to take over the servicing of all domestic radio and television equipment marketed by Pye, Ltd., Pam (Radio and Television), Ltd. and Invicta Radio. The head office is at St. Andrews Road, Cambridge (Tel.: Cambridge 3434). Five depots have been set up in London. Bristol, Birmingham, Salford and Glasgow.

Telephone number of Marconi House, Strand, registered office of the Marconi International Marine Communication Company, Ltd., has been changed to Covent Garden 1234.

Hudson Electronic Devices, Ltd., have provided the equipment for the thirteen engineers' vehicles, attached to the Dartford telephone exchange, which have been fitted with radio telephones.

Printed Circuit Television Set

New French Design Including Printed Coils and Capacitors

By CHARLES BOVILL,

A.M.I.E.E., M.Brit.I.R.E.

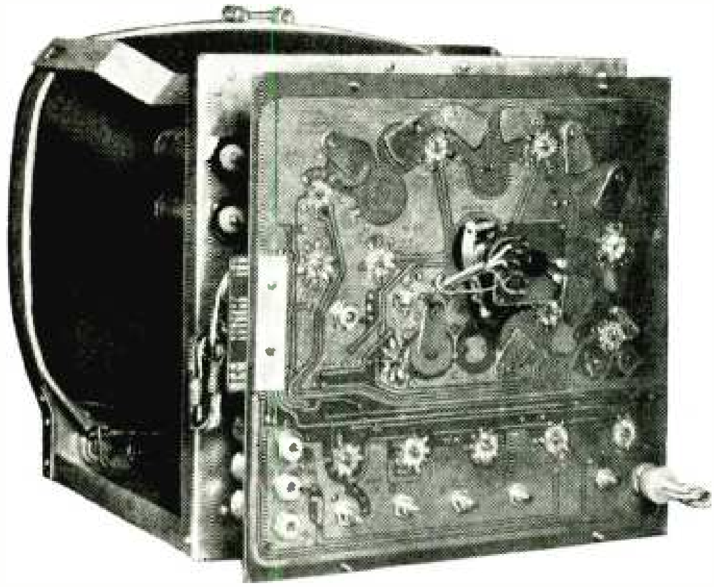


Fig. 1. Rear view of the set showing the printed receiver section with tuning slabs across the coils. The r.f. amplifier is on the right.

SINCE the E.C.M.E. machine* was first described by John Sargrove in 1947, and the possibilities of printed circuit and allied techniques were first revealed, there have been spasmodic appearances of items of radio and electronic apparatus made in this way. To many, it has been a surprise that so few equipments have been manufactured by printed circuit or photo-engraving methods, as it has the appearance of being an attractive way of constructing chassis involving complicated wiring. Similarly, for mass production and for reliable operation in service, this manner of making electronic devices appears to have considerable advantages over the normal wiring techniques.

In domestic sound receivers the question of to print or not to print is undoubtedly debated when new designs are under consideration, but it would appear that the method has been avoided for a number of reasons, such as the high initial plant costs which some of these techniques incur and the limited amount of printed circuitry which can be used in concurrent receiver designs year after year. This is probably in part due to the drastic changes in mechanical design of receivers each season which form a major part of modern design problems.

In the field of television receiver design, however, the position is somewhat different. For many years to come the existing standards and frequencies of transmission will be retained and no drastic change can be foreseen in requirements until the advent of colour, except possibly the necessity for a few additional channel facilities. It would appear, therefore, that a manufacturer can with safety design and put into production a long-term television receiver which could be marketed, over several years, without the danger of the necessity for anything but slight modification to meet new requirements.

Such a design is possible and, indeed, an attractive proposition if the latest techniques are used but, at the same time, not too much is attempted by printing methods. Perhaps not immediately apparent is the fact that with television signal and i.f. frequencies the coils can be printed, whereas this is difficult to achieve with sound broadcast frequencies involving high inductance coils. Similarly, in the average television set many more valves are used than in a sound receiver,

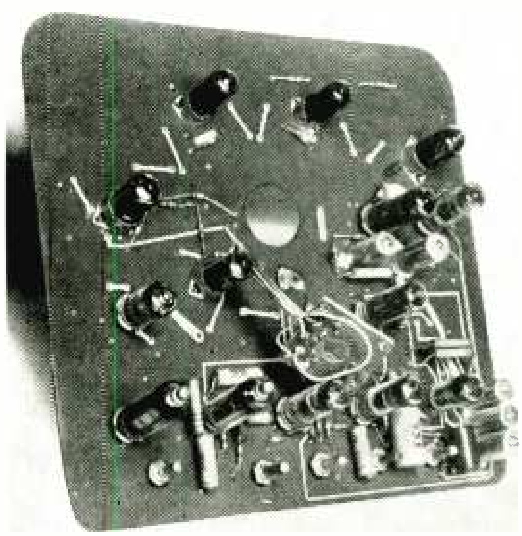


Fig. 2. Other side of the printed circuit panel, the r.f. amplifier now being on the left.

* Electronic Circuit Making Equipment.

and there is consequently considerably more wiring involved.

These considerations have evidently influenced the well-known French radio manufacturers, J. Visseaux S.A., in deciding to manufacture their television receivers by printed circuit methods. The first receiver to be put into production in the Lyon factory of this company is for single-channel operation on the 174-185 Mc/s band used in France, and is for the 819-line definition.

The techniques used have been developed by Visseaux and are less expensive in initial plant and processes than techniques which have been used previously. In the receiver now being marketed, the wiring, tuning and associated inductors in the local oscillator and the video and sound i.f. coils and the smaller capacitors are printed. Resistors, with their attendant complications, are not printed, and the normal types are used at all positions in the circuit. The power supplies are of conventional type. The chassis is mounted vertically and is designed to fit over the neck of the cathode-ray tube, with the valves pointing inwards towards the front of the set. This gives complete accessibility to the base contacts of every valve and facilitates servicing. The video i.f. amplifier and its associated valves and coils are on the top side of the chassis and the sound i.f. is immediately below the cathode-ray tube neck. The inductors for the r.f. amplifier and the local oscillator are on the right-hand side of the chassis. A multi-way plug is provided for taking a connector and cables either to the front of the receiver or to a remote control unit.

In the receiver it is necessary to connect the printed chassis to the power unit. This would normally require a plug and socket, but in the printed circuit this connector is simpler, consisting only of corresponding strips on the edge of the printed chassis and the connector, good contact being ensured by clamping the chassis and connector together. The arrangement is seen on the left-hand side of Fig. 1.

Altogether 14 valves (+1 rectifier) are used in the receiver of which seven are double-purpose types.

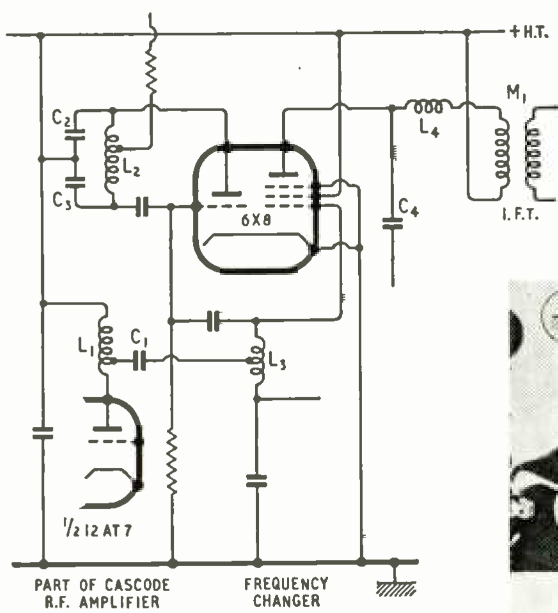
The layout of the receiver is of considerable interest and, in particular, the disposition of the input, r.f. amplifier, local oscillator and two i.f. channels and their associated inductors.

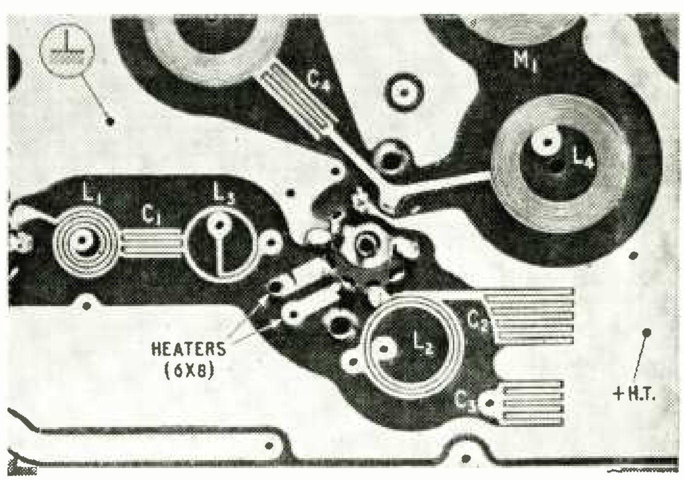
Some notes on the design of printed circuit inductors are given in the Appendix and this has an important bearing upon the layout of the chassis and its simplicity. For obvious manufacturing reasons the coils in all stages are printed on the same flat surface of the chassis and in consequence the coupling between them is very small indeed, even when their physical spacing is relatively close (see equation (6) in the Appendix). This makes it possible to design the layout without any inter-stage screening, particularly in an amplifier of the type used, which has a bandwidth of nearly 10 Mc/s to accommodate the 819-line transmission.

The accuracy of printed inductors and capacitors is of a very high order and they are easily mass produced to within 1% of the required value by the manufacturer. The stability of the inductors as a function of temperature and humidity is also good. A variation in inductance of 1% only is noted between 0°C and 100°C on production coils but the Q is reduced at 100°C by some 20%. At ambient temperature, humidity has no influence on the inductance value but the Q will be found to fall by about 3% under conditions of a water-saturated atmosphere. Fig. 5 shows the values of Q obtainable with practical types of printed coil used in the i.f. amplifiers.

In the production receiver illustrated the L/C values used in the i.f. amplifier make it necessary to provide trimming devices to allow for variations in capacitance in the valves associated with the coils in the r.f. and i.f. stages. These take the form of aluminium segments which provide an adjustment of capacitance. They can be seen in the view of the chassis in Fig. 1.

The local-oscillator coil is centred upon the required frequency corresponding to the received signal minus the heterodyne frequency, and fine adjustment for this circuit is provided by capacitance variation. The control for this adjustment is also made from printed circuit components and takes the





Section of the printed circuit (frequency changer) with corresponding section of the circuit diagram, indicating coils and capacitors which are actually printed.

form of a disc which has printed upon it a shaped vane which enables frequency to be changed in a linear manner with respect to the angular rotation of the disc. This part of the circuit is also very stable and after once being set up it does not require any further adjustment.

Using the printed-circuit techniques, better performance can of course be obtained from valves operating at the frequencies in the 180-Mc/s band owing to the unusually short leads which can be used in the r.f. stages, and this improvement is also noticeable in the i.f. stages. The Visseaux receiver has taken full advantage of the possibilities of the extra performance and the model described is in the fringe area category, having a sensitivity of between 40 and 60 microvolts for a signal-to-noise ratio of 26 db.

The Printing Process

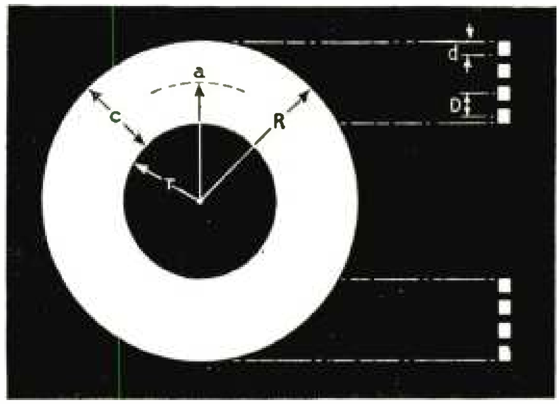
Before printing the chassis consists of a sheet of insulating material which has a coating of metal on each side, forming a metal-insulant-metal sandwich. The insulating middle section gives the strength and rigidity to the chassis, the metal coating being only between a ten-thousandth and a thousandth of an inch thick in most cases.

When the circuit is printed a photographic and chemical process removes the unwanted metal, leaving that required for the connections, components, etc. The insulation between the connections, between turns of the coils and plates of the capacitors is provided by the base plate in the middle of the sandwich.

A chassis upon which a circuit is to be printed is first coated with a film of material having photo-sensitive properties of a special nature, notably that it is entirely insensitive when wet, under which conditions it can be exposed to light and worked upon in a factory with normal lighting arrangements. The circuit to be printed is then photographed on to the film coating the chassis, either by projection or by contact. This part of the process naturally requires careful lining-up but is easily accomplished by the use of normal photographic techniques. The chassis with its exposed film coating is then submitted to Infra-red radiation, after which the film coating becomes very hard in the parts where no light has penetrated.

The chassis is then immersed in a tank containing a solution of acid in saturation and is at the same time subjected to intense vibration at a high ultrasonic frequency. This produces the effect of cavitation continually and at the same time causes the unwanted metal to fall away from the sandwich at all points on its surface where the film is not hardened, that is to say, where the light has penetrated the film coating. The process ensures a regular depth of metal in the printed circuit and also permits a very high resolution of the print. In practice, in the space of one inch, 125 lines each of 0.004 in. breadth can be printed under mass production conditions.

The time taken for the process is short, and a complicated wiring and component layout on both sides of a chassis one foot square can be produced in about four minutes when a metal coating thickness of just over 0.001 in. is being handled. The accuracy of the printing must clearly depend upon the master photograph from which the circuit is printed, but in practice coils and capacitors are not found to vary more than 1% due to the process.



Simplified sketch of printed coil, showing meaning of abbreviations used in the Appendix and in the captions to Figs. 3, 4 and 5. (a=mean radius, r=inner radius, R=outer radius, c=depth of winding, d=width of conductor, D=pitch of winding.)

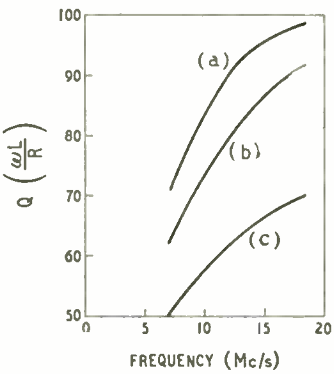


Fig. 5. Q values of various printed coils, all having r=4 mm, d=0.42 mm and D=0.96 mm. Coil (a) has 9 turns with a=0.8 cm and c=0.8 cm. Coil (b) has 7 turns with a=0.72 cm and c=0.64 cm. Coil (c) has 6 turns with a=0.67 cm and c=0.54 cm.

It does not require much imagination to realize how rapidly the basic chassis can be prepared for the acid tank and ultrasonic treatment, since this is akin to simple photographic exposure.

The Visseaux printed circuits use several forms of sandwich for the chassis. For the main chassis an American product called "Metal Clad" is used very successfully. This is supplied as a sandwich with metal faces of electrolytic copper of either 0.00135 in. or 0.0027 in. thickness. In this sandwich the metal is attached by heat treatment and pressure to the insulator. It is very strong and is suitable for dip soldering. It has very good dielectric strength and is to all intents and purposes practically non-hygroscopic.

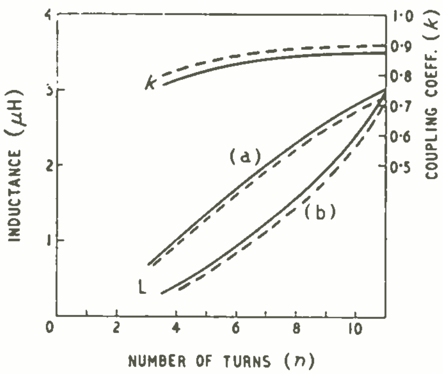
A simpler and less expensive chassis can be made up on a base of Paxolin insulating material between a hundredth and a tenth of an inch thick, depending upon the mechanical strength required. When Paxolin is used, a laminated copper metal surface having a thickness of between 0.002 in. and 0.001 in. is attached to one or both sides of the insulator.

The metal is made to adhere by a substance composed of synthetic resin and a stabilizing agent and a pressure process which does not involve heat treatment. The Paxolin chassis have about the same strength as those made of "Metal Clad" and slightly less dielectric strength, but the transversal resistivity is about as good as the American product, in spite of the greater absorption of water by Paxolin.

In both the materials there is, it will be appreciated, a limit to the temperature which can be applied to them. With "Metal Clad" the limit is about 120°C, which enables soldering operations to be carried out without undue trouble. The Paxolin-based material, however, tends to blister about 80°C, which makes dip soldering with tin and lead alloy solders rather difficult.

Visseaux are also making deflector coils by a printing process, although they are not yet used in the television receiver. The base material for these coils calls for some degree of flexibility, and the one used is actually P.V.C. A process of evaporation or sedimentation is employed to coat this with a very thin layer of metal in the first instance. The layer is then built up to the required thickness by an electrolytic method. This metal depositing, in the second stage, enables connections from one side of the material to the other to be made without the necessity of riveting or soldering.

One particular feature of these printed deflection coils is the accurate scanning which they make possible owing to the highly accurate printing of the position of the wires relative to each other, and this will improve the linearity of the picture on the screen of the television receiver.



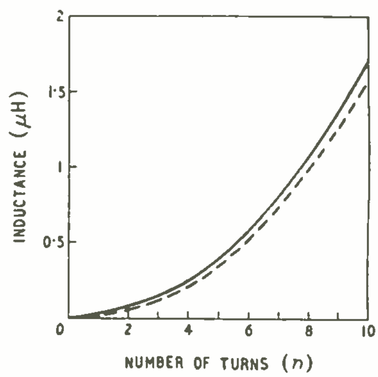


Fig. 3 (left). Inductance (L) and coupling coefficient (k) of printed coils with d=0.25 mm and D=1.025 mm. Full lines are calculated values and broken lines measured values. In curves k and (a), R is constant at 16 mm and r is variable; in curve (b) r is constant at 6 mm and R is variable.

Fig. 4 (right). Inductance of smaller printed coils with d=0.42 mm, D=0.96 mm, r=4 mm and R variable. Full line represents calculated values and the broken line measured values.

APPENDIX

The unusual condition met in printed circuits in which spirally wound coils are used involves the following special formulæ:

Calculation of Inductance

The value of an inductance is calculated with accuracy from the following formula:

$$L=4\pi a n^2\left[\left(\log\frac{8a}{c}-\frac{1}{2}\right)+\frac{1}{n}\left(\log\frac{D}{d}+0.155\right)\right]\times 10^{-9} \quad \ldots (1)$$

where: a = mean radius of the coil
c = depth of winding
d = width of conductor
D = pitch of the winding
n = number of turns.

L is in henrys and dimensions are in centimetres. From (1) the practical formula (2) is derived:

$$L(\mu H)=2.9\times 10^{-2}\, a n^2\left[\log\left(4.85\frac{a}{c}\right)+\frac{1}{n}\log\left(1.17\frac{D}{d}\right)\right] \quad (2)$$

Fig. 3 shows practical and theoretical results.

Calculation of coupling between two overlapping coils

The number of turns on each coil being the same, from the curve in Fig. 3, the following formula is derived:

$$k=1-\frac{1}{n}\times\frac{\log\left(\frac{2D}{d}\right)+0.155}{\log\left(\frac{8a}{c}\right)-\frac{1}{2}} \quad \ldots\ldots\ldots\ldots (3)$$

from which the practical formula is derived:

$$k=1-\frac{1}{n}\times\frac{\log\left(2.34\frac{D}{d}\right)}{\log\left(4.85\frac{a}{c}\right)} \quad \ldots\ldots\ldots\ldots (4)$$

Calculation of coupling between two coplanar coils

For two identical coils of which the centres are distant by l, the following approximation is used:

$$k\simeq 0.4\,\frac{a^3}{l^3}\times\frac{1}{\log\left(\frac{8a}{c}\right)-\frac{1}{2}} \quad \ldots\ldots\ldots\ldots (5)$$

or

$$k\simeq 0.4\,\frac{a^3}{l^3}\times\frac{1}{\log\left(4.85\frac{a}{c}\right)} \quad \ldots\ldots\ldots\ldots (6)$$

assuming that $\frac{a}{d}\leqslant\frac{1}{4}$, $\frac{a}{c}\leqslant 1$ which conditions are usually satisfied in practice.

Laplace Transformation Theory

ALTHOUGH the Laplace transformation theory has been used by mathematicians for well over a century it is only in recent years that engineers have begun to realize its usefulness in providing quick solutions to a great range of engineering and physical problems. B. J. Starkey, who is on the staff of the Royal Aircraft Establishment at Farnborough, has written a book* based on a series of lectures on the Laplace transform which he gave some time ago at the Signals Research and Development Establishment. In this work, which is issued by our sister journal *Wireless Engineer*, the approach is analytical, rather than purely mathematical.

* "Laplace Transforms for Electrical Engineers," by B. J. Starkey, Dipl. Ing., A.M I.E.E., 280 pages, published by Iliffe and Sons Ltd. price 30s.

Filters Without Fears

— or Tears, if You Have a Steady Head for Algebra

By THOMAS RODDAM

Eins within a space and a wearywide space it wast ere wohned a Mookse.

THERE are many readers of *Wireless World* who find that Zobel's classical papers on wave filters, and Mr. X's book on Zobel's papers, leave them with the same sort of feeling that they get from that quotation, the opening sentence of "The Mookse and The Gripes,"*. It certainly means something, but after reading about interaction loss, image attenuation, double *m*-derivation, *I could not feel moregruggy if this was prompollen.*

Other readers, of course, have broken through the wall of terminology and have realized that it is true to say of the wave filter:

Your feats end enormous, your volumes immense.

These are the readers who, from Ivory towers overlooking the park, write to tell the Editor that they sniff at pFs. There is nothing I can do about these people, because though I am free to quote John Donne ("Ask not for whom the bell tolls"), the tyrant of Dorset House will strike out the apposite quotation from Hemingway. Even those readers who are happy when required to design a crystal filter may have overlooked the possibilities of the simple algebraic approach to the simple filter. I am not going to plunge into the depths of the Darlington method, or the latest work of Guillamin and his group, but I propose to show how, with a knowledge of Ohm's Law and a steady head for algebra, you can design simple filters without ever introducing any of the special terminology.

But first of all, what is a filter? The simplest definition which we can find seems to be that it is a network which allows energy to pass freely from a source to a load over certain specified ranges of frequency, and effectively prevents the passage of energy over other ranges of frequency. A simple low-pass filter, for example, might be designed to pass frequencies up to, say, 1,200 c/s with less than 1 db attenuation, and to attenuate frequencies above 1800 c/s by more than 40 db. Such a filter has one pass band, 0-1200 c/s: one stop band, 1800-∞ c/s: and a transition region, 1200-1800 c/s.

* From "Two Tales of Shem and Shaun" by James Joyce (Faber and Faber, 19?2).

Secondly, why should we bother about this idea of filter design? Let us just guess the right sort of inductance and capacitance values to use, and fiddle about with resonant circuit Q-values until the thing produces the right response. The answer to this must, I suppose, be a matter of temperament. The empirical approach is inelegant, unreliable and far too much like hard work. It is, in my view, strictly for the birds. The egg-head approach is so much easier that no lazy man can afford to ignore it.

Before we actually get down to the business of filter networks themselves, there is one point of vital importance to consider. It is concerned with the nature of a wave filter and it must be clearly appreciated if a proper technique for defining and measuring a filter is to be accepted. A wave filter is a combination of pure reactances, or at least of elements which are close approximations to pure reactances. A pure reactance cannot absorb any energy, so that if energy is forced into the filter it must either come out at the far end, or be reflected back to the generator like those tennis balls bouncing back from the bucket at the village fete. A filter does not really attenuate at all, it just refuses to accept the energy. As the whole process is one of reflection, the impedances of the source and the load play an essential part in determining the behaviour of the system.

There are exceptions to the statement made at the end of the last paragraph. Filters used in association with valves may not be concerned with energy transfer at all. The algebraic approach which we are to consider is perfectly suited to this problem, and it enables us to work our filters with an open-circuit or a short-circuit at the ends, so that we have no "terminations" as such. Designs of this kind show up to six decibels profit compared with the standard wave filter.

And now to work. The filter network shown in Fig. 1, consisting simply of a shunt capacitance connected between a source which has an impedance R_1 and a load R_2 is only just a filter, but it forms a very convenient starting point. This "first-order"

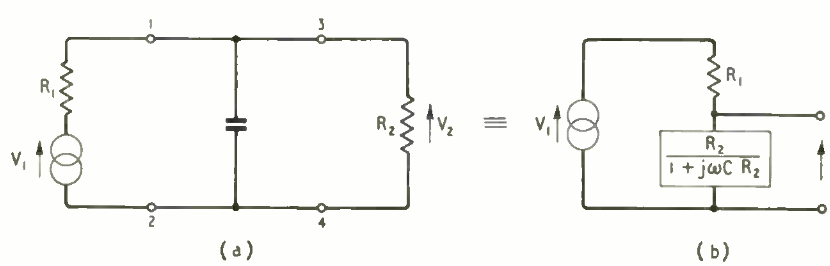


Fig 1. The behaviour of this rudimentary filter is very easily calculated by rearranging the circuit as a voltage divider.

filter, which is related to "real" filters in the same sort of way as the amoeba is related to the gentle reader, is defined by the following equation:

$$V_2 = \left[\frac{R_2}{1 + j\omega CR_2} \Big/ R_1 + \frac{R_2}{1 + j\omega CR_2} \right] V_1$$

For convenience, we rearrange this and manipulate it to the form

$$\frac{V_1}{V_2} = 1 + \frac{R_2}{R_1}\left(1 + j\omega CR_2\right) = \frac{R_1+R_2}{R_1}\left(1 + j\omega C\frac{R_1\ R_2}{R_1+R_2}\right)$$

Without the network, which is just C in this case, the equation would be

$$\left(\frac{V_1}{V_2}\right)' = \frac{R_1 + R_2}{R_1}$$

The insertion loss of the network is defined as

$20 \log_{10} \left| \left(\frac{V_1}{V_2}\right)' \Big/ \left(\frac{V_1}{V_2}\right) \right|$ which we shall write as $20 \log |N|$.

The quantity N is the function which defines the behaviour of the network, and for the first order filter is just

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

To save space, let use write $R_1R_2/(R_1 + R_2) = R$ so that $N = 1 + j\omega CR$.

The presence of j in this expression shows us that there is a phase shift introduced by the use of the filter. We can see that what happens is that there is an insertion phase shift of arc tan ωCR and an insertion loss of $20 \log |N|$, where $|N|^2 = 1 + \omega^2C^2R^2$, so that the insertion loss in decibels is $10 \log (1 + \omega^2C^2R^2)$. Now I have already pointed out that I am a thoroughly lazy man: I only do this for the money, in an attempt to keep up with the cost of living. So why should I draw more than one graph to illustrate this response? Let us define a frequency ω_0 such that $\omega_0 CR = 1$.

$$\text{Then } \omega CR = \frac{\omega}{\omega_0} \cdot \omega_0 CR = \frac{\omega}{\omega_0}$$

Now if we put $\frac{\omega}{\omega_0} = \sigma$ the insertion loss is simply $10 \log (1 + \sigma^2)$ and the insertion phase shift is arc tan σ.

All we need now is one pair of graphs, which are show in Fig. 2, and we can read off the insertion loss and insertion phase shift at any frequency. Features

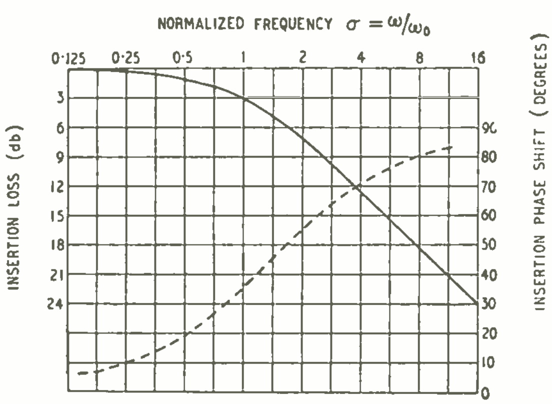


Fig. 2. Normalized insertion loss and phase shift characteristics for a "first-order" filter.

to note are that the insertion loss is 3db at $\sigma = 1$ where $\omega = \omega_0 = 1/CR$ and that the phase shift is 45° at this frequency. Futhermore, if σ is much greater than unity, so that $\omega >> \omega_0$ the insertion loss is very close to $20 \log \omega/\omega_0$.

Doubling ω will increase the loss by 6db: the slope of the asymptote is 6db per octave. The phase shift approaches 90°.

There are a number of special cases of interest which must be considered. The classical filter is based on equal source and load impedance, with $R_1 = R_2$. This gives us simply $R = R_1/2$ so that $\omega_0 = 2/CR_1$.

Working into the grid of a valve we may take $R_2 = \infty$ so that $R = R_1$ and $\omega_0 = 1/CR_1$.
Working from a pentode, we may take $R_1 = \infty$, so that $R = R_2$, and $\omega_0 = 1/CR_2$.

All this may seem rather a lot of fuss about a very simple circuit but let us now proceed to one form of the second order filter. This is shown in Fig 3 (a). It is not very difficult to work out the equation which describes the way this circuit behaves, by just putting $R_1 + j\omega L$ into the potential divider of Fig 1(b) in place of R_1. I do it by matrix algebra, which is really easier, but looks a bit too formidable. The result is

$$\frac{V_1}{V_2} = \left(1 + \frac{R_1}{R_2}\right) + j\omega\left(CR_1 + \frac{L}{R_2}\right) - \omega^2 LC$$

As before, we note that without the filter we have just $\left(\frac{V_1}{V_2}\right)' = \left(1 + \frac{R_1}{R_2}\right)$ so that the insertion loss coefficient

$$N = 1 + j\omega\left(C\frac{R_1\ R_2}{R_1 + R_2} + \frac{L}{R_1 + R_2}\right) - \omega^2 LC \frac{R_2}{R_1+R_2}$$

This expression can be made to look simpler by noting that it contains $\frac{R_1\ R_2}{R_1 + R_2}$, the effective parallel resistance R_p of R_1 and R_2, R_1+R_2 the effective series resistance R_s of R_1 and R_2 and $\frac{R_2}{R_1 + R_2}$ a ratio, k.

$$N = 1 + j\omega\left(CR_p + \frac{L}{R_s}\right) - \omega^2 LCk.$$

As before, we must get rid of j, and must consider

$$|N|^2 = (1 - \omega^2 LCk)^2 + \omega^2 (CR_p + L/R_s)^2$$
$$= 1 + \omega^2\left[\left(CR_p + \frac{L}{R_s}\right)^2 - 2LCk\right] + \omega^4 L^2C^2k^2.$$

The insertion loss is, of course, $10 \log |N|^2$

To save writing all those C's and R's, let us just look at the function $1 + \alpha\omega^2 + \beta\omega^4$. We are free to choose α and β, and we can do so in such a way that we get a Butterworth or "maximal flatness" response, or a Tchebycheff response. That sounds pretty horrifying, I know, but it isn't really as hard as it sounds. A Butterworth response is one which is as flat as possible for small values of ω, and has no humps and bumps. The mathematicians have shown that the form which $|N|^2$ must take for a response of this kind is simply $(1 + \omega^{2n})$ which here means that we must make $\alpha = 0$. The first-order filter can't help having a Butterworth response. A Tchebycheff response is rather more complicated and on reflection I have decided to come back to it an a later article.

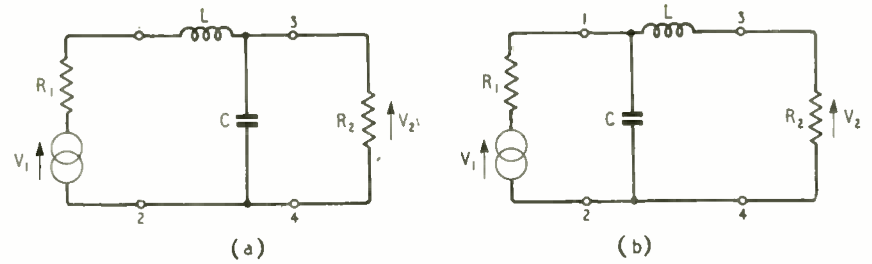


Fig. 3. The two ways of arranging the "second-order" filter.

For the Butterworth response we will make the coefficient of ω^2 equal to zero, so that

$$\left(CR_p + \frac{L}{R_s}\right)^2 = 2LCk$$

and the insertion loss is

$$10 \log \left(1 + \omega^4 L^2 C^2 k^2\right)$$

Let us choose a frequency ω_0 such that $\omega^2_0 \, LCk = 1$ and write $\frac{\omega}{\omega_0} = \sigma$ as before. Then the insertion loss is simply $10 \log (1 + \sigma^4)$. Again the response is 3 db down at $\sigma = 1$ or $\omega = \omega_0$ but now it approaches 12db per octave if ω is large. This second order filter is much squarer than the first order filter, as can be seen from Fig. 4.

Before going any deeper into this, which will involve us in finding the values of C and L, let us see what the second order filter of Fig. 3(b) gives us. A little quiet plodding on the back of an envelope leads to

$$\frac{V_1}{V_2} = 1 + \frac{R_1}{R_2} + j\omega\left(CR_1 + \frac{L}{R_2}\right) - \omega^2 LC \frac{R_1}{R_2}$$

so that the insertion loss coefficient N is

$$N = 1 + j\omega\left(C\frac{R_1R_2}{R_1 + R_2} + \frac{L}{R_1R_2}\right) - \omega^2 LC \frac{R_1}{R_1 + R_2}$$

Now if we call $\frac{R_1}{R_1 + R_2} = k'$ this is of exactly the same form as the result obtained for the other (3(a)) kind of second order filter, with k' written in place of k.

There are again some special cases which are of interest. If $k = k_1 = \frac{1}{2}$ so that $R_1 = R_2$, we shall have $R_p = R_1/2$ and $R_s = 2R_1$ and the condition for a Butterworth response becomes

$$\left(\frac{CR_1}{2} + \frac{L}{2R_1}\right)^2 = LC.$$

We must be rather careful in our substitution here. We have $\omega_0{}^2 LCk = 1$ so that, since $k = {}^1/_2$

$$LC = 2/\omega_0{}^2$$
$$C = 2/\omega_0{}^2 L$$

and the equation for the Butterworth condition is

$$\left(\frac{R_1}{\omega_0{}^2 L} + \frac{L}{2R_1}\right)^2 = \frac{2}{\omega_0{}^2}$$

Manipulating this, it becomes

$$\frac{\sqrt{2}R_1}{\omega_0 L} + \frac{\omega_0 L}{\sqrt{2}R_1} = 2$$

which is easily solved as

$$\frac{\sqrt{2}R_1}{\omega_0 L} = 1 = \frac{\omega_0 L}{\sqrt{2}R_1} \text{ or } \frac{\omega_0 L}{R_1} = \sqrt{2},\ L = \sqrt{2}R_1/\omega_0$$

From this we have $(L/R_1)^2 = 2/\omega_0{}^2$, which we can see from an earlier equation is LC. So $L^2/R_1{}^2 = LC$, and thus $L = CR_1{}^2$. This is a form we shall want to refer to later. Another result of some importance is obtained by substitution of this value of L in the equation $C = 2/\omega_0{}^2 L$, giving $C = \sqrt{2}/\omega_0 R_1$.

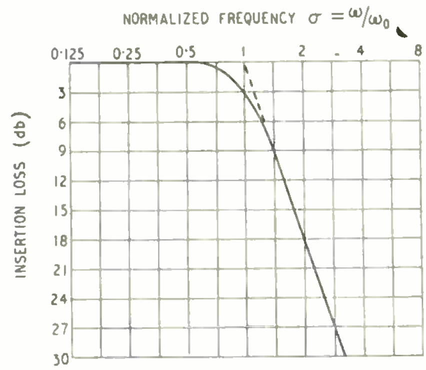


Fig. 4. Normalized insertion loss for a "second-order" filter of "maximal flatness".

We have now obtained the design equations for the simple second-order filter operating between equal resistances, and having a response which is 3db down at a frequency ω_0. They are

$$L = \sqrt{2}\, R_1/\omega_0$$

and $C = \sqrt{2}/\omega_0 R_1$. Our analysis applies to both the circuits in Fig. 3. What happens if R_1 is not the same as R_2? Take $k = 1$, so that either $R_1 = 0$, or $R_2 = \infty$. I shall leave the actual algebra to the reader, and merely give the results:

$$R_1 = 0, \quad L = 2CR_2{}^2$$
$$\text{and} \quad L = \sqrt{2}\, R_2/\omega_0$$
$$C = 1/\sqrt{2}\, R_2\omega_0$$
$$R_2 = \infty, \quad L = \tfrac{1}{2}CR_1{}^2$$
$$\text{and} \quad L = \frac{1}{\sqrt{2}} R_1/\omega_0$$
$$C = \sqrt{2}/\omega_0 R_1$$

Note that if $R_1 = 0$ instead of $R_1 = R_2$ the value of L is unchanged, but a different value of C must be used, while if $R_2 = \infty$, instead of $R_2 = R_1$ the value of C is unchanged but a different value of L must be used.

That last section, with $k = 1$, obviously applies only to the circuit of Fig. 3(a). The same algebra can be used for $k' = 1$, when either $R_1 = \infty$ or $R_2 = 0$. There is no difficulty in seeing what $R_1 = \infty$ means: it is just our friend the pentode. The case of $R_2 = 0$ looks like nonsense, but if we regard it as the limiting form of $R_2 \to 0$, and remember that $V_2 = I_2R_2$ where I_2 is the current flowing through R_2, we can see that it is the form we need for working into something like the emitter of a grounded-base transistor.

I do not want to spend any more time on the second-order filters, because we should take a look at the third-order filter of Fig. 5. For this we can,

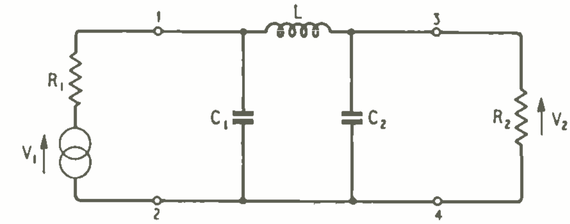


Fig. 5. The "third-order" filter.

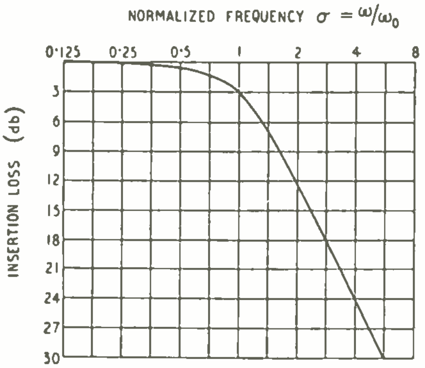


Fig. 6. Normalized insertion loss for a "third-order" filter of "maximal flatness".

without too much difficulty—it took me about 2 minutes—arrive at

$$\frac{V_1}{V_2} = 1 + \frac{R_1}{R_2} + j\omega\left[(C_1 + C_2)R_1 + \frac{L}{R_2}\right] - \omega^2 L\left(C_2 + \frac{C_1R_1}{R_2}\right) - j\omega^3 LC_1 C_2 R_1$$

$$\text{so that } N = 1 + j\omega\left[(C_1 + C_2)R_p + \frac{L}{R_s}\right] - \omega^2\frac{L}{R_s}(C_1R_1 + C_2R_2) - j\omega^3 LC_1C_2R_p.$$

As you can see, the expressions are getting to be rather bulky, but they are still the same sort of thing. We need the steady head for algebra, a large sheet of paper, and we can repeat the process of getting rid of the terms in j. The result, put in to show you that it can be done, is

$$|N|^2 = 1 + \omega^2\left[\left\{(C_1 + C_2)R_p + \frac{L}{R_s}\right\}^2 - \frac{2L(C_1R_1 + C_2R_2)}{R_s}\right] + \omega^4\left[\frac{L^2(C_1R_1 + C_2R_2)^2}{R_s^2} - 2LC_1C_2\left\{(C_1 + C_2)R + \frac{L}{R_s}\right\}R_s\right] + \omega^6 L^2C_1^2C_2^2R_p^2.$$

Formidable, but not impossible. For a Butterworth type of characteristic we put $\omega_0^6LC_1^2C_2^2R_p^2 = 1$ and make the coefficient of ω^2 and ω^4 zero. The insertion loss is then $10 \log(1 + \sigma^6)$ which is again 3 db down at $\omega = \omega_0$, but drops 18db per octave at values of $\omega >> \omega_0$. The response of this third order filter is shown in Fig. 6, and as you can see, it is still squarer than the second-order filter.

I shall deal with only one special case of this filter, the case when $R_2 = \infty$. This is the case where the filter operates directly into the grid of a valve. For this, $R_s = \infty$ and $R_p = R_1$ so that the two equations for the coefficients of ω are

$$\omega^2:\quad (C_1 + C_2)^2R_1^2 = 2LC_2$$
$$\omega^4:\quad L^2C_2^2 = 2LC_1C_2(C_1 + C_2)R_1^2$$

We must solve these two equations, which are the same as

$$(C_1 + C_2)^2R_1^2 = 2LC_2$$
$$2C_1(C_1 + C_2)R_1^2 = LC_2$$

Dividing one by the other $C_1 + C_2 = 4C_1$ so that $C_2 = 3C_1$ and then

$$L = \frac{2C_1(C_1 + 3C_1)R_1^2}{3C_1} = \frac{8}{3}C_1R_1^2$$

There is one more equation available. It is

$$\omega_0^6L^2C_1^2C_2^2R_1^2 = 1$$

$$\text{or}\quad \omega_0^6\frac{64}{9}C_1^2R_1^4.C_1^2.9C_1^2R_1^2 = 1$$

$$\text{or}\quad \omega_0 = \frac{1}{2}\frac{1}{C_1R_1} = \frac{3}{2}\frac{1}{C_2R_1}$$

Enough of algebra. I have chosen this particular solution of the third-order filter because it provides a convenient illustration of the way in which this sort of filter theory can be used for the treatment of problems which are slightly outside the ordinary run of filter theory. The problem here is to provide the maximum value of cut-off frequency, by which we mean the 3db point, for given values of R_1 and C_2. C_2 is usually limited because it is the input capacitance of a valve: R_1 is required to be as high as possible because it is the load of a preceding valve. For fixed values of C and R, we have, for our three types of filter:

first order, $\omega_0 = 1/CR$
second order $\omega_0 = 1.414/CR$
third order $\omega_0 = 1.5\ CR$

Between the last two there seems to be very little. But the third order characteristic is much squarer and if we choose the point at which the response is only 1db down we have:

$$10\log(1 + \sigma^{2n}) = 1$$
$$1 + \sigma^{2n} = 1.25$$
$$\text{so that}\quad \sigma^{2n} = 0.25$$

For the first order $\sigma^2 = 0.25$, $\sigma = 0.5$ $\omega_{1db} = 0.5/CR$
second order $\sigma^4 = 0.25$, $\sigma = 0.7$ $\omega_{1db} = 1/CR$
third order $\sigma^6 = 0.25$, $\sigma = 0.795$ $\omega_{1db} = 1.19/CR$

As you can see, increasing complexity gives increasing band width though the returns diminish rapidly. However, it's something to be able to find this out without really going beyond quite ordinary mathematics. I must confess that to go on to the fourth-order filter seems pushing the steadiness of my own head rather too far.

It is probably desirable to review the meaning of the mathematics so far. We have taken the ratio of source voltage to load voltage, which we can find by using Kirchhoff's Laws. We have then found the conditions that are needed for the amplitude ratio to be of the form $(1 + \sigma^{2n})^{1/2}$ which gives us a hump-free response of the kind known as "maximally flat." The limit of our algebraical equipment has been the simple knowledge that $|a + jb|^2 = a^2 + b^2$. I realize that to some readers it sounds as though I am saying that if you can put one foot in front of another you can climb Mount Everest. It really is not like that: if you can walk up Ludgate Hill you can walk up Beachy Head. In a later article I propose to show how all this mathematics can be used, just as it is, to design band pass filters.

ELECTRONIC TEST METER

For Measurement of Direct and Alternating Voltages and Resistance

By M. G. SCROGGIE, B.Sc., M.I.E.E.

THIS design is based on articles published in the January and March, 1952, issues; the former ("Valve Voltmeter without Calibration Drift") dealing with direct-voltage and resistance-measuring portions, and the latter with the additions needed for alternating voltage. The purpose of the present article is to put these separate pieces together to form a complete instrument.

The design provides seven direct-voltage ranges, from 1.5 to 1500 full-scale, plus a range of millivolts depending on the resistance of the meter incorporated. To cover the same ranges of alternating voltage (r.m.s.) it is necessary to use two types of diode; one up to 150V and the other for the 500V and 1500V ranges. The four resistance ranges have mid-scale values of 1kΩ, 10kΩ, 0.1MΩ and 1MΩ; and an "Insulation" range extends readings up to about 5000MΩ. The ranges of measurement can, of course, be modified to suit requirements or availability of components, especially the indicating meter.

First let us recapitulate the findings of the previous articles. The whole point of a valve voltmeter is the elimination, as far as possible, of the disturbing effects that connecting an ordinary meter is liable to have on the quantity being measured. Therefore the first requirement is a valve having as nearly as possible no input conductance. Valves in general do not meet this requirement nearly so well as is often supposed, and for good performance it is necessary to select a type having exceptionally high input resistance, and to use it under special conditions. These types and conditions are incompatible with the second requirement, which is that there shall be as nearly as possible no output resistance. Such resistance, being "electronic," cannot be relied upon to be sufficiently constant to be allowed to have a substantial influence on the current that operates the indicator or meter. A separate output valve is therefore needed, with sufficient negative feedback to reduce the output resistance of the combination to an amount that is small compared with that of the meter on the lowest range. A third requirement is that the "zero" shall be unaffected by changes in supply voltage. The most effective method of ensuring this is to duplicate the two-valve arrangement just described, and to connect the meter between the two balanced pairs.

These considerations led to the arrangement shown in Fig. 1, in which the balanced pairs are coupled by R_5, so that the pair V2 and V4 is not restricted to the merely static role of stabilizing the meter zero but serves as one-half of a push-pull system having 100% negative feedback. The result is that even with a meter requiring several milliamps for full deflection the output voltage V_o differs from the input voltage V_i by something of the order of only 1%, and by a slight elaboration even this difference can be eliminated. Consequently almost any voltmeter connected to the output terminals is converted into a valve voltmeter without affecting its calibration.

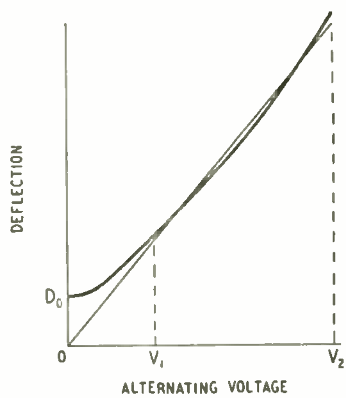


Fig. 2. Showing how the a.v. deflection/input characteristics are fitted closely to the linear d.v. scales by displacing the "zero" to D_0 and adjusting the slope. V_2 is full-scale voltage of the range in question, and V_1 is full-scale voltage of the next lower range. The curvature between these limits is exaggerated to show it clearly.

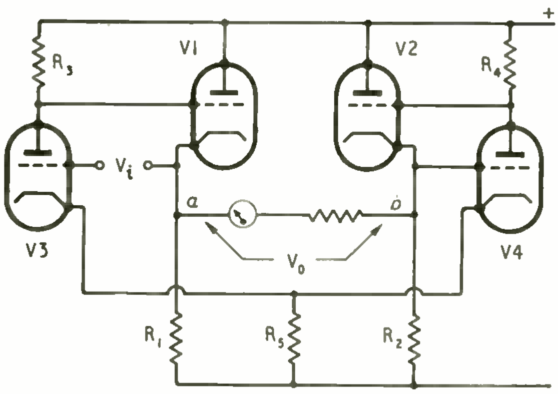


Fig. 1. Outline circuit of stable impedance "transformer" with 1 : 1 voltage ratio, which forms the basis of Fig. 4.

Resistance can be measured by connecting the grid of V3 to a point on R_1 that gives full deflection on one of the ranges. This connection is made through a standard resistance, and any conductive path then connected to the V_i terminals reduces the deflection. A suitable scale indicates its resistance relative to that of the standard. At half deflection it is obviously equal to the standard.

If the meter connected to the output terminals is provided with a metal rectifier for adapting it for alternating voltages, then the same valve system can be used for measuring a.v., at least at low frequencies; and the input conductance remains almost nil. But the valve circuits are not likely to be suitable for r.f.

(to say nothing of the metal rectifier) so to cover the wide range of frequency one expects from a valve voltmeter it is necessary to use a diode rectifier at the input. Although the circuit of such a rectifying unit is so simple and well known, consisting of only three components—diode, capacitor and resistor—its design presents a surprising amount of difficulty and complication.

One complication is the flow of current through the diode when the input voltage is zero, causing zero to be displaced to a voltage that depends on load resistance and cathode temperature. The most effective method of getting rid of this displacement is to back it off with an identical diode at the input of V4. But

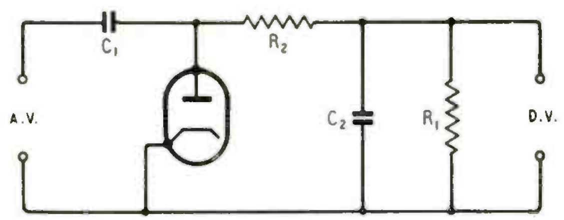


Fig. 3. Circuit of "probe" for adapting d.v. voltmeter to read r.m.s. values of sinusoidal a.v.

to enable the meter scales for d.v. to be used also for a.v., a certain amount of zero displacement is necessary, so the backing-off is deliberately made incomplete, the amount left being automatically adjusted for each range. In Fig. 2, V_2 denotes the full-scale voltage on one of the ranges, and V_1 the full-scale voltage of the next lower range. What happens to the calibration curve below V_1 is of no account, because such voltages can be measured on the lower range. So the policy is to adjust the initial deflection D_0 and the slope of the curve so that the part of the curve between V_1 and V_2 fits as closely as possible to the straight line corresponding to the d.v. calibration. If this has been done properly, there is a very small positive error at each end of the scale and a negative one in the middle, as shown exaggeratedly in Fig. 2. The only exception is the lowest range, the curved foot of which cannot be avoided, and either a calibration curve or a separate scale must be provided. Even so, it is convenient to displace the zero so that the upper part approximates to the linear calibration.

The appropriate displacement on each range is obtained by using a lower load resistance for the "dummy" diode than for the active one. The slope is adjusted for each range by means of R_2 in Fig. 3, which shows the circuit of the active diode. R_1 is a 15MΩ tapped range resistance across the d.v. input, and R_2 combines the roles of a.v. filter and reducing

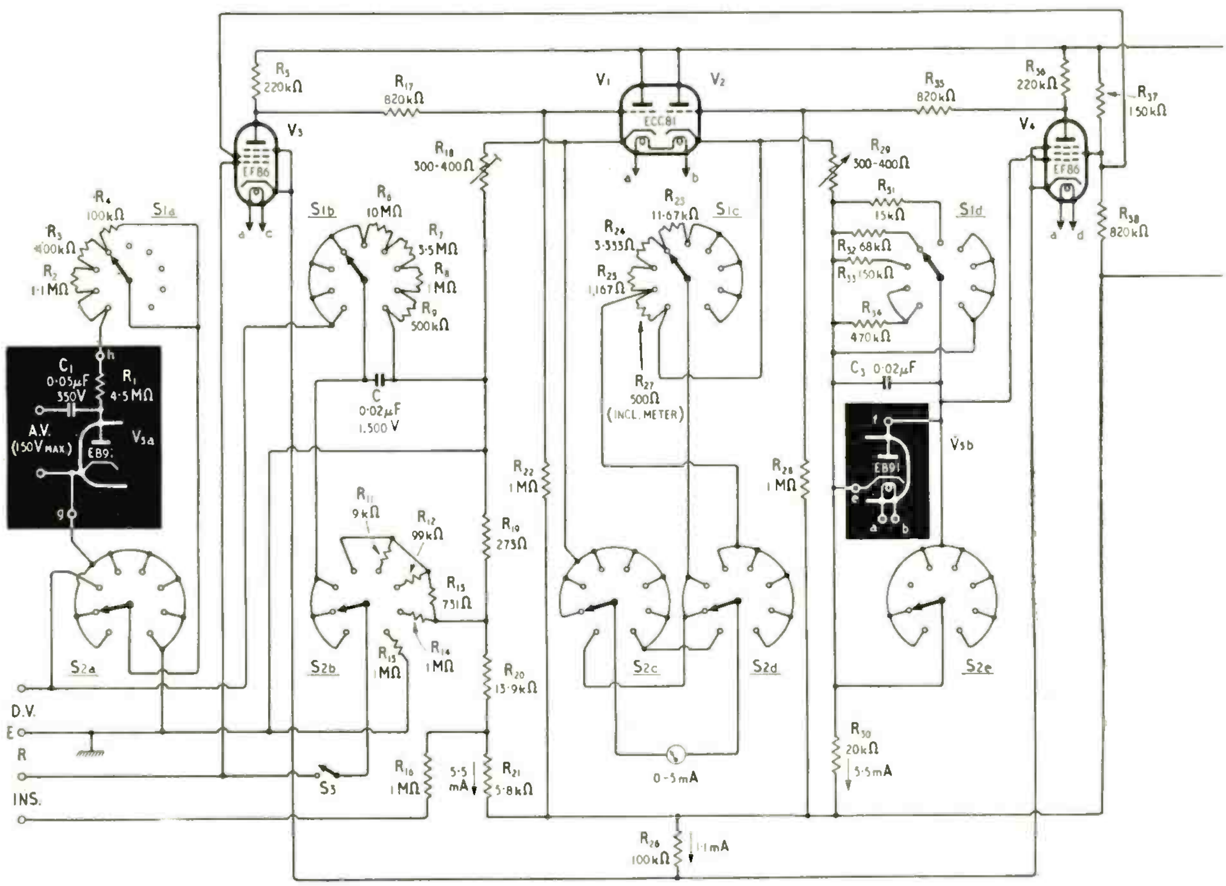
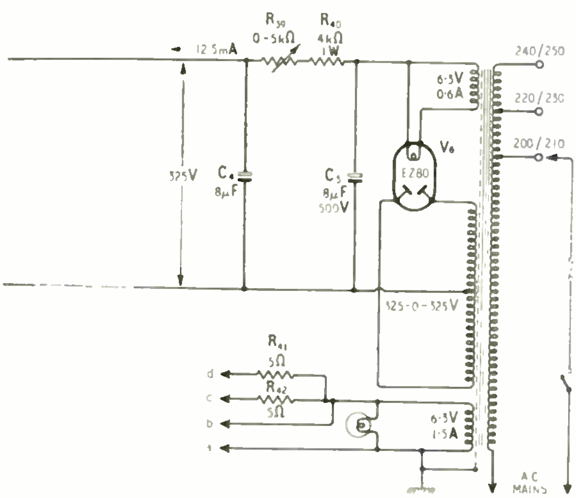
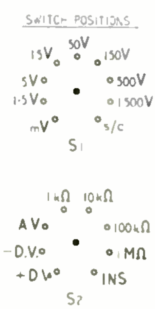


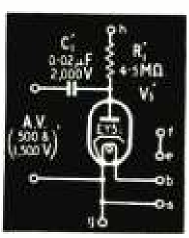
Fig. 4. Complete circuit diagram of electronic test meter. The alternative probe for the higher range of a.v. is shown in the

resistor to bring the rectified voltage, which approximates to the peak value, down to the r.m.s. value (on the assumption of sinusoidal input). With a perfect rectifier $(R_1 + R_2)/R_1$ would be equal to $\sqrt{2}$, which would make $R_2 = 6.2\text{M}\Omega$, but in practice it varies from about 4.5MΩ on the 1.5V range to 6.1MΩ on the 50V range and above.

If the type of input valve were not specially selected and operated, such high values of resistance in the input circuit could not be used without serious error due to grid current. With the valves recommended, much higher values *could* be used, but it is difficult to obtain such values to sufficiently close tolerances, and care is needed to avoid stray pick-up. The values specified are a suitable compromise for most purposes. Even though they may seem fairly high, it does not follow that as an alternating voltmeter the instrument would give accurate readings in measurements on circuits of the same order of impedance. As shown in the March, 1952, article, and in greater detail in the July, 1954, issue, the input resistance of the arrangement shown here in Fig. 3 is about one-quarter of R_1, or say 3.7MΩ with the values specified. It would seem that the error due to this would be limited to 1% if the resistance of the circuit being measured were not greater than 37kΩ; and if that is the dynamic resistance of a resonant circuit, so that the energy drawn by the voltmeter is averaged over the whole of each cycle, that is true; but if the circuit is non-resonant the open-circuit voltage is reduced by 1% when the circuit resistance is as low as 1/3000th the load resistance of the voltmeter, which in this case is approximately $R_1 + R_2$, so the maximum tolerable circuit resistance would be about 7kΩ. This may come as a surprise to those who supposed that valve voltmeters could be used to measure alternating voltages in circuits of very high impedance. The relationship is not linear, however; for 5% error the figure would be over 70kΩ.







detached black area, to take the place of the two attached.

Valve Types

Having recalled the main principles of the design, we can now turn to the full circuit diagram, Fig. 4. Originally V1 and V2 were SP61 valves and V3 and V4 were EF37A; as these perform at least as well as those now shown there is no reason why they should not be used if they happen to be available. But as they are now obsolescent, modern types are specified, which are much smaller and require no top-cap connections; moreover, the single ECC81 takes only one-quarter of the filament current of two SP61s, so develops much less heat.

The h.t. required is 12.5mA at 325V, and this is enough to ensure linear measurement up to 50V even when the mains voltage is 10% low. All ranges not exceeding 50V are therefore obtained in the conventional manner by switching resistance in series with a milliammeter. The necessary range resistors are shown as being switched by one section (*c*) of the master range switch S1, but if it is desired to make use of an existing multi-range voltmeter with its own range switch, this can be done provided one always remembers to set both range switches correctly. (Such a meter, if it has a.v. ranges, can be used to measure low-frequency a.v. in very high-resistance circuits, because no diode is needed.) To provide higher ranges at the meter would introduce serious design difficulties, so above 50V the ranging is done at the input by tapping down the 15-MΩ potential divider (S1*b*). The use of carbon resistors, provided they are of a reliable high-stability type, is now sufficiently established in measuring equipment to be used even in an instrument aiming at quite a good standard of accuracy.

The particular meter used was a 150-V "surplus" type in a 6½-in square Bakelite case, requiring about 3mA for full deflection. The values of R_{23} to R_{25} are specified for 3mA, and would need to be adapted for other full-scale current. R_{27} is of such a value as to bring the resistance of the meter itself (in this case 84Ω) up to 500Ω for the lowest (1.5V) calibrated range. Since the total output resistance of the valve system is only about 4Ω, any changes therein due to ordinary variations in valve characteristics have negligible effect on the calibration. An additional maximum-sensitivity range, for bridge detector use, etc., is obtained in the first position of S1, where it cuts out R_{27}; and even here the stability of calibration is very good by usual valve-voltmeter standards, so that this range could well be calibrated, say, 0-250mV.

Switching Facilities

The rectified output from alternating voltages makes the grid of V3 negative, so if the meter is connected the same way round for d.v. it reads only voltages that are negative with respect to the earthy terminal (E). To measure positive d.v. it is therefore very useful to have a meter-reversing switch. This could be a separate switch, but to ensure that it is always in the negative position for a.v. and resistance measurements it is shown incorporated in the function master switch S2. Although doing so admittedly adds two wafers to this switch it is worth it. Another valuable facility is S3, for disconnecting the input grid (of V3) from the potential divider, enabling real open-circuit d.v. measurements to be made, using the "R" terminals for connection. To obtain the full benefit of this, and of the capabilities of V3, it is essential for the valve holder and S3 to have ceramic or equivalent insulation. Although less essential, this is nevertheless desirable also for sections *a* and *b* of S1 and S2, for Paxolin is hardly good enough for these high-resistance input circuits. To use ceramic sections throughout would make these two switches unduly expensive, and the other sections are in fact Paxolin.

R_{18} and R_{29} are provided for eliminating the error of 1% or thereabouts due to voltage drop in the valve resistance. Ideally the meter current would be zero when they were equal, but since there is inevitably some inequality in the two halves of the valve system either of these resistors can be used as a zeroing adjustment.

Resistance Measurement

The resistance-measuring arrangements are controlled by S2*b*. S2*d* ensures that on all resistance ranges the voltmeter is on its 1.5V range, and the value of R_{19} is chosen so that the voltage drop across it due to the V1 cathode current (5.5mA) is 1.5V. In the "1kΩ" to "1MΩ" positions of S2, this voltage is connected to V3, so when the "R" terminals are unconnected the meter should read 1.5V. In order to set it precisely to this full-scale reading, the current through R_{19} is adjusted by R_{39}, which therefore serves as the usual preliminary ohmmeter adjustment. Although the voltmeter is immune from variations in mains voltage, the resistance-measuring voltage is not, so mains variations have to be taken up on R_{39}. This is perhaps a little annoying if the mains voltage is continually fluctuating and there are many resistances to be measured. But seeing that any need for re-setting R_{39} is shown by the meter the instant before connecting every resistance to be measured, the provision of voltage stabilization hardly seems justifiable.

In the "1kΩ" position, the 1kΩ standard resistance is made up of R_{13} plus the resistance of the voltage source, which is R_{19} in parallel with $R_{20}+R_{21}$. In the next position this is brought up to 10kΩ by R_{11}, and so on. For all these four resistance ranges the scale is of the standard ratio ohmmeter kind, reading from zero to infinite, with 1 in the centre, and the scale reading is to be multiplied by the value indicated by the range switch. Whatever resistance there is between the "R" terminals, the pointer is somewhere on the scale. But in the "Ins." position of S2 the test voltage is raised to 78, so unless the resistance connected to the "Ins." terminals has previously been ascertained to be at least 50MΩ the pointer may be driven off the scale. Not that any damage will result, for one of the advantages of the instrument is that in spite of its practically perfect linearity up to at least 4mA, no amount of misuse can make the current through the meter exceed about 6½mA. R_{16} limits the current that can be drawn from the −78V tapping to a far smaller amount. If a "guard" terminal is needed, to ensure that only the direct resistance between the "Ins." terminals is registered, "E" is the one to use. Still higher resistances can be measured as described later.

In the "A.V." position of S2, section *a* connects a diode rectifier in front of the d.v. system, and section *e* connects the balancing diode. S1*a* controls the value of R_2 in Fig. 3 to make the slope of the calibration curve fit the linear scale most nearly, and S1*d* controls the load resistance of the balancing diode, and consequently the voltage across it, to provide the most suitable displacement of the meter zero. The values of R_2 to R_1 and R_{31} to R_{34} may have to be adjusted slightly to obtain the best fit of the scales. The EB91 is a suitable type to provide both diodes together. The lowest frequency depends on C_1. For 50 c/s it should be at least 0.02 μF, and for 20 c/s at least 0.05 μF; preferably double these values. C_2 may be the same. But if these capacitances are more than 0.1 μF the meter action is unduly sluggish. Their insulation should be sufficient to give no perceptible reading when tested on the "Ins." range. The highest frequency depends on the layout of the connections to the active diode, and by keeping them to a minimum can be raised to several hundred Mc/s. Even for comparatively low frequencies the usual "probe" form is advisable; Fig. 5 shows a simple construction. If v.h.f. use is a main objective, an interchangeable C_1, say 100 pF miniature ceramic, should be substituted for the bulkier component needed for very low frequencies; or alternatively a special v.h.f. probe with germanium diode. Although the heater and "E" leads are nominally at the same potential, separate wires are used, to avoid introducing a small amount of heater voltage into the measuring circuit.

Alternative Diode Unit

The EB91 and equivalent type of diode are limited to 150 V r.m.s., so if it is desired to use higher ranges a different diode unit must be plugged in. The EY51 is rated to take up to 5 kV r.m.s., so is at least adequate in that respect. Owing to transit time its top frequency is limited to about 10 Mc/s. The zero displacement being negligible on these ranges, no balancing diode is needed, and the probe plug should be arranged to substitute a short-circuit; only three wires are required in the connection to the high-voltage probe. Its C_1 must be capable of taking up to 2,120 V peak; but since frequencies lower than 50 c/s are unlikely at the higher voltages, 0.02 μF would perhaps be sufficient. One must remember to make C_2 adequate for the lowest frequency and highest voltage on any range.

The power unit is conventional. A transformer to one's own specification can be obtained at a moderate cost from the Majestic Winding Co., 180 Windham Road, Bournemouth. In the layout of the instrument, it is advisable to keep the power circuits in a screened-off compartment. The remainder consists mainly of a sub-panel for the valves, and the switches S1 and S2, surrounded by resistors. These should be so mounted that adjustments can easily be made to them when the instrument is being calibrated.

After checking the general correctness of functioning, take a series of readings over each of the d.v. ranges against known voltages, and tabulate the errors. Anyone inexperienced in this should take note that it demands considerable care and patience. A small consistent error (high or low) on all ranges can be corrected by increasing or reducing R_{18} and R_{29} together (adjusting one of them shifts the zero).

Errors on individual ranges must be corrected by adjusting the range resistors concerned. Since only the *ratios* of $R_6 - R_9$ need to be precise, it is allowable to make all adjustments to them as increases. Multi-megohm high-stability resistors within 1% tolerance may not be readily obtainable; the alternatives actually used were ±5% types brought up to correct ratios by smaller values in series. As these form only a few per cent of the whole resistance they need not be special high-stability types nor particularly precise in value.

The resistance scale can be calculated from the voltage scale, using the formula $V = 1.5/(r+1)$, where r is the ratio of the standard resistance to the resistance between the "R" terminals, and the 1.5 is the voltage applied (Fig. 6); but it is wise to check it against known resistance ratios. If that has been done, and $R_{11} - R_{14}$ are correct within ±1%, all should be well on these ranges. Calibrating the "Ins." scale against known resistances is not practicable, and one must calculate it from $V = 78/(R+2)$, where R is the resistance in megohms between the "Ins." terminals and 78 is the voltage applied.

Finally, check the a.v. ranges, and make a calibration curve for the lowest range. Even greater care is needed in this than with d.v., for the r.m.s. scale relies on the assumption that the waveform is sinusoidal. There should be no heavily-loaded transformer in the calibration circuit, and never *any* transformer primary in series with resistance. If the accuracy is found to be insufficient, plot the calibrations against known voltage and see whether zero displacement or slope or both have to be altered to obtain a good fit.

The terminal common to "R" and "Ins." (and also the live "D.V." terminal) must be well insulated. This is more a matter of using the right material than a great deal of it; polystyrene or polythene is entirely suitable. If S3 is fitted, the insulation of the V3 grid can very easily be checked. Provide an input (d.v. or a.v.) to give about full-scale deflection on any range, say 50 V. Then open S3. If the deflection falls fairly slowly, taking at least several seconds to do so, then the insulation is probably of the MMΩ order ($10^{12}\Omega$), for the capacitance is only the circuit stray, which should not be more than about 20 pF. Note where the deflection ends up. To do so it may be necessary to reverse the meter, for the most likely leakage path with the single-ended EF86 is to the positive g_2. With top-grid valves such as EF37A the stray capacitance usually discharges to about zero.

Slowing the Discharge

If the discharge is rapid, try connecting a low-leakage capacitor to the "R" terminals. The writer had some wax-coated 500 pF samples, and connected two of them, identified as C_a and C_b, in turn, and then together, and in each case noted the time they took to discharge by a small percentage, over which the discharge curve can be regarded as linear. For example, if T is the time in seconds for the deflection to fall by one tenth after S3 is opened, then

$$CR \simeq 10\,T$$

where C is the capacitance in pF and R the leakage resistance in MMΩ. As usual, it was found that readings for each capacitor had to be taken several times before they settled down to a consistent figure. If R_a denotes the leakage of C_a, and R_b of C_b, and R_o the instrument leakage, then the three trials gave R_o in parallel with R_a, then with R_b, then with both; and from these three equations the values were found. (Actually they are much more easily calculated as conductances.) The results were surprisingly—and satisfactorily—high, considering that no special effort had been made to minimize leakage, other than the precautions already mentioned: R_a = 2,040 kMΩ, R_b = 1,270 kMΩ, and R_o = 287 kMΩ. These values were calculated on the assumption that the capacitors were discharging to zero, but it was found later that they were in fact discharging from −50 V to at least +50 V, so the actual resistances would be about double.

Resistances beyond the range of "Ins." can be measured by timing the fractional discharge of a known capacitance with and without the unknown resistance in parallel. If T_1 is the number of seconds to discharge one nth of the voltage of C without R_x in parallel and T_2 with R_x in parallel, then

$$R = \frac{nT_1 T_2}{C\,(T_1 - T_2)}$$

If C is in μF, R_x is in MΩ; and n is assumed to be at least 10.

To prepare the instrument for normal use, first

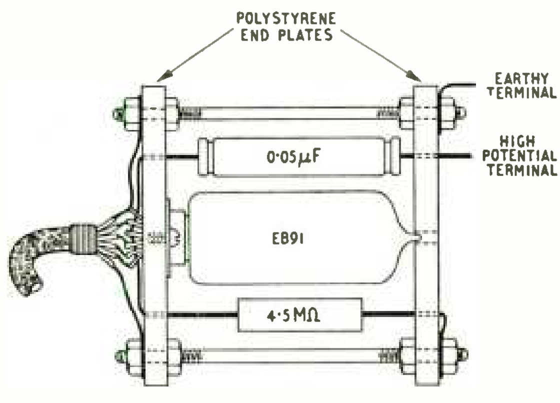


Fig. 5. Simple type of EB91 probe for voltages not over 150 r.m.s. A screening cover should be provided.

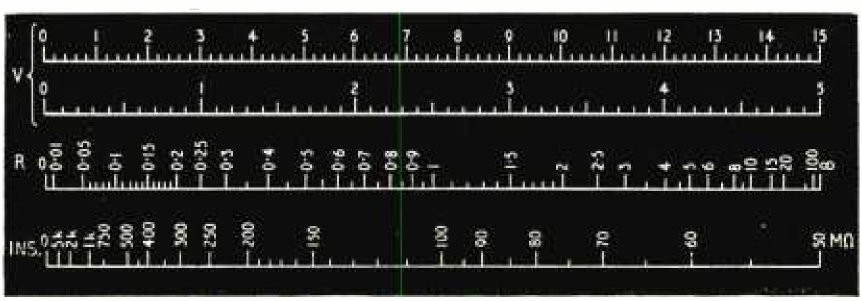


Fig. 6. Voltage and resistance scales, based on a 150-line meter.

check the zero adjustment of the meter. Then switch on and, after allowing time for warming up, switch to the lowest d.v. range and set the meter to zero by R_{29}. On this range a slight amount of drift will be perceptible during the first five or ten minutes, so if low readings are to be taken it is advisable to allow this time between switching on and checking the adjustment of R_{29}. The stability of this instrument being so very good, it should be found that if it is always given time to warm up little or no adjustment is needed after the first setting. Provided that the zero is correct, the calibration is unaffected even by large changes in valve characteristics or mains voltage. For resistance measurement, the meter must be set to full-scale deflection by R_{39} before connecting the unknown. On a.v. no attempt must be made to re-set the pointer to zero, for the displacement on the lower ranges is intentional; checking the zero must always be done on the lowest d.v. range.

List of Components

Switches.

S1 4-pole, 9-way; 2 poles ceramic-insulated
S2 5-pole, 8-way; 2 poles ceramic-insulated
S3 1-pole, 2-way; ceramic-insulated

Wire-wound resistors, precisely adjusted

R_{11}, R_{12}, R_{13}, R_{19}, R_{20}, R_{21}, R_{23}, R_{24}, R_{25}, R_{27}.

High-stability carbon resistors

Dubilier R.417, ±5%: R_2,* R_3,* R_4,* R_5, R_8†, R_9†, R_{14}†, R_{15}†, R_{16}, R_{17}, R_{22}, R_{26}, R_{28}, R_{30}, R_{31},* R_{32},* R_{33},* R_{34},* R_{35}, R_{36}, R_{37}, R_{38}.

Dubilier R.627, ±5%: R_1,* R_7†.

Dubilier R.850, ±5%: R1′,* R6†.

* Subject to adjustment for scale fitting.

† Adjusted or obtained to ±1% or better.

Capacitors

C_1 0.05μF, 500V.
C_1' 0.02μF, 800V a.c. TCC type 848.
C_2 0.02μF, 1500V d.c., TCC type 1545.
C_3 0.02μF, 350V.

NEWS FROM THE CLUBS

Birmingham.—At the meeting of the Slade Radio Society on August 20th J. E. Smith will speak on "Phase Shift in Tuned Circuits and its Application to D.F. Equipment." The society's club room at the Church House, High Street, Erdington, Birmingham, 23, where workshop facilities are available, is now open each evening. Morse and theory classes are being arranged. Sec.: C. N. Smart, 110, Woolmore Road, Erdington, Birmingham, 23.

Romford.—The Romford and District Amateur Radio Society continues to meet each Tuesday at 8.15 at R.A.F.A. House, 18, Carlton Road, Romford, but there will not be a programme of lectures during the summer months. The club transmitter, G4KF, is usually on the air in the top band on club nights. Sec.: N. Miller, 18, Mascalls Gardens, Brentwood, Essex.

B.A.T.C.—Although M. W. S. Barlow (G3CVO) is remaining as editor of *CQ-TV*, the magazine of the British Amateur Television Club, he has resigned the secretaryship. The new secretary is D. W. E. Wheele, G3AKJ, 56, Burlington Gardens, Chadwell Heath, Romford, Essex.

QRP Society is conducting a series of tests for transistor transmitters from August 15th to 17th. Stations G3IEE (A. Cockle, Kingston-on-Thames, Surrey) and G3JNB (V. Brand, Surbiton, Surrey) will transmit on 1875 and 1865 kc/s, respectively, from 21.30 to 21.45 B.S.T. each evening using c.w. Amateurs using transistor transmitters are invited to participate in the tests and are asked to communicate with V. Brand, 137, Surbiton Hill Park, Surbiton, Surrey. Short-wave listeners are invited to send reports.

NEW CAR RADIO RECEIVER

AN entirely new range of car radio receivers designed round a basic model, the CR152, has been introduced by E. K. Cole, Ltd. The basic set is a six-valve superheterodyne embodying permeability tuning and arranged so that either three stations can be pre-tuned for instant selection by a three-position rotary switch, or reception effected by manual tuning. Manual control is rather unusual, as the set has three independent drum tuning controls, two covering separate parts of the medium waveband and one the long. As shown in the illustration, a hinged cover normally conceals these drum controls.

The new Ekco car radio receiver Model CR152 with hinged cover dropped showing the three tuning drums.

The drum controls are independently calibrated and each is selected by one of the positions of the switch, the selected drum being automatically illuminated. If desired each can be pre-tuned to a station, the hinged cover closed and the stations selected by the switch. Alternatively the cover can be let down and stations tuned in manually on the drums after setting the switch to the one appropriate to the waveband required.

Flexibility of installation is provided by designing the set as three separate units; receiver, power unit and loudspeaker respectively, with various finishes to tone with different makes of motor car. Push-pull output is available in a de luxe model if desired, but the normal set has a single output valve with negative feedback.

The power unit employs a vibrator, well cushioned to eliminate all mechanical noise. The total consumption is 2.7 A at 12 V.

Including U.K. purchase tax, the price of set in its normal form is £26 10s.

"Live" versus "Recorded" Sound

ENCOURAGED by the response to his efforts in the provinces, G. A. Briggs has booked the Royal Festival Hall in London for 8 p.m. on November 1st for a lecture-demonstration on sound reproduction.

The audience will be invited to compare high-quality tape recordings with "live" performances of the same items by such distinguished executants as Denis Matthews (piano), Stanislav Heller (harpsichord) and Ralph Downes (organ).

The reproducing equipment will be of the same calibre as that used for high-quality sound reproduction in the home, and many may think it a bold experiment to attempt to demonstrate it in so large an auditorium. Early scepticism has already receded as the result of two successful rehearsals, and there can be little doubt that an enjoyable and instructive experience awaits those who can "make it a date." Tickets (3s 6d reserved, including tax) will be obtainable on and after August 16th, from the Festival Hall booking office, from dealers in audio equipment in the London area, or from Wharfedale Wireless Works, Idle, Bradford.

Inductance and Dynamic Resistance Meter

By G. G. JOHNSTONE,* B.Sc.

Testing Coils for Use in Medium-wave Receivers

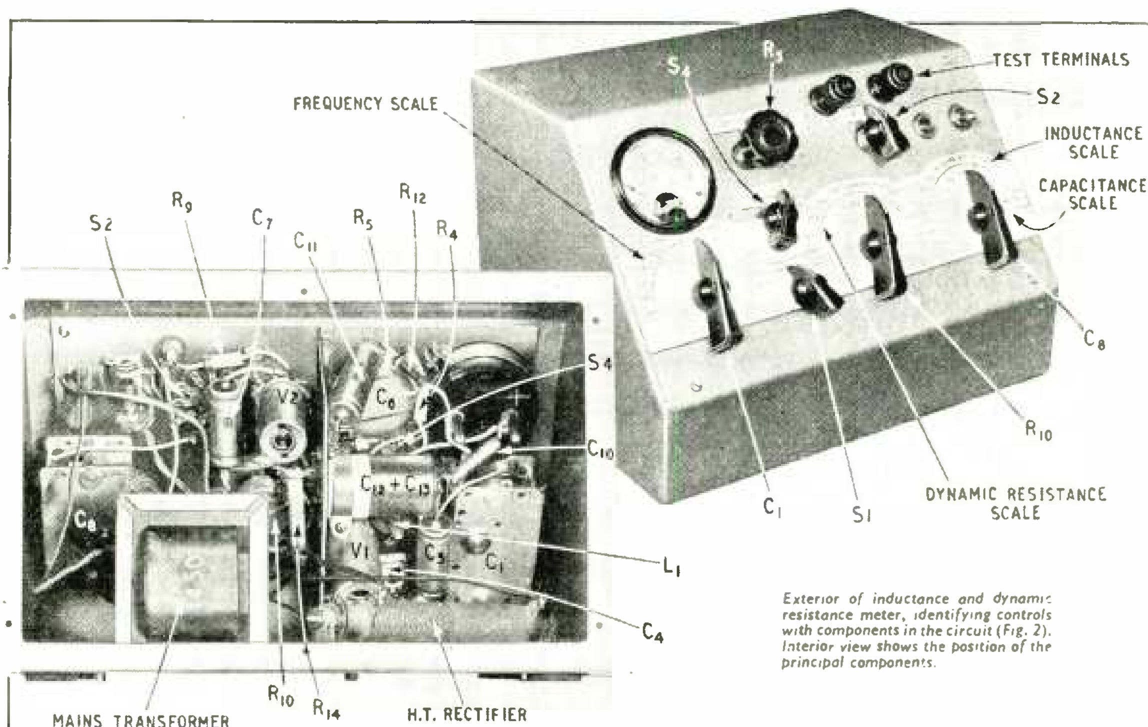
THE design of the instrument described here was prompted by the need of the author for a means of comparing the performances of various types of inductor for medium-wave use. Basically, what is required is an indication of the gain and selectivity which may be expected when a given coil is used in an r.f. amplifying stage of a receiver. For the former, it is desired to know the dynamic resistance R_d of the inductor when brought to resonance by a parallel-connected tuning capacitor; for the latter, the Q value of the coil is required. Without pursuing too closely what is actually meant by Q (the subject of much correspondence in *Wireless World* throughout 1949), we may define it for the present purpose from the relationship $R_d = QL\omega$ where L is the inductance of the coil. From a knowledge of two of the quantities R_d, Q or L, it is possible to find the third, for a given value of ω.

There are two fundamental ways of determining the quantities involved, which may, for convenience, be termed the constant voltage and the constant current methods respectively.

* B.B.C. Engineering Training Dept.

In the first, a known voltage, from a source the internal impedance of which is sufficiently low to be ignored, is connected in series with the inductor and the tuning capacitor, and a high-impedance voltmeter is connected across the inductor or capacitor. The voltage across either element at resonance is Q times the injected voltage. The inductance can be found from the value of the tuning capacitor required for resonance; if this value is C, the inductance can be found from $L = 1/\omega^2C$. If all measurements are made at a fixed frequency, the capacitor dial can be calibrated, and the value of inductance read off directly. Having thus determined Q and L it is then possible to calculate R_d. Alternatively, if the current flowing in the circuit can be measured, the reactance can be found from the ratio of the voltage across either element to the current flowing; the product of the reactance and Q gives R_d. However, the measurement of current in such a circuit is rather difficult.

In the second method, a known value of current, from a source whose internal impedance is sufficiently high to be considered infinite, is fed to the tuned circuit comprising the inductor and tuning capacitor



Exterior of inductance and dynamic resistance meter, identifying controls with components in the circuit (Fig. 2). Interior view shows the position of the principal components.

in parallel, with a high-impedance voltmeter connected in parallel with the pair. The dynamic resistance R_d can be found directly from the ratio of the voltage to the input current. If the circulating current can be measured, the value of Q can be determined from the ratio of the circulating to the input current. However, it is generally not convenient to measure the circulating current, and hence the Q value is generally found in this method by determining first the inductance L from the value of the tuning capacitor required for resonance, and thence by division of R_d by $L\omega$.

Because of the difficulty of constructing a low-impedance source, it was decided to concentrate on the second method, and a pentode is employed to give a good approach to a constant-current generator. To avoid the difficulty of measuring the alternating component of the anode current of the pentode directly, a variation of the circuit was evolved, shown in basic form in Fig. 1. In this arrangement, the inductor under test is connected in the anode circuit of a pentode, in parallel with the tuning capacitor, and a valve voltmeter is connected in parallel with both. A suitable voltage at a known frequency is injected at the grid of the pentode, and the anode circuit tuned for resonance. The grid voltage is then adjusted to bring the reading of the valve voltmeter to a calibration mark on its scale. The input voltage is next doubled, by means of a pre-set potentiometer, and a variable resistance is connected in parallel with the tuned circuit. The value of the variable resistor is now adjusted so that the valve voltmeter gives the same reading as formerly. If the alternating component of the anode current is doubled by the increased grid voltage, the effective anode load has therefore been halved by the action of the resistance, i.e., the resistance is equal to the dynamic resistance of the tuned circuit.

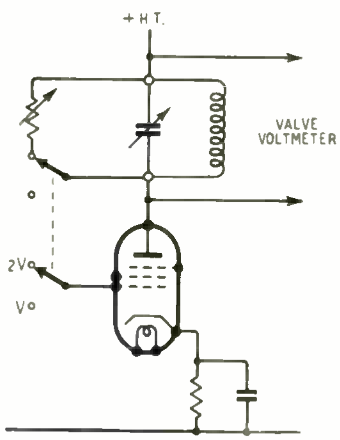


Fig. 1. (Left) Basic circuit for measurement of dynamic resistance.

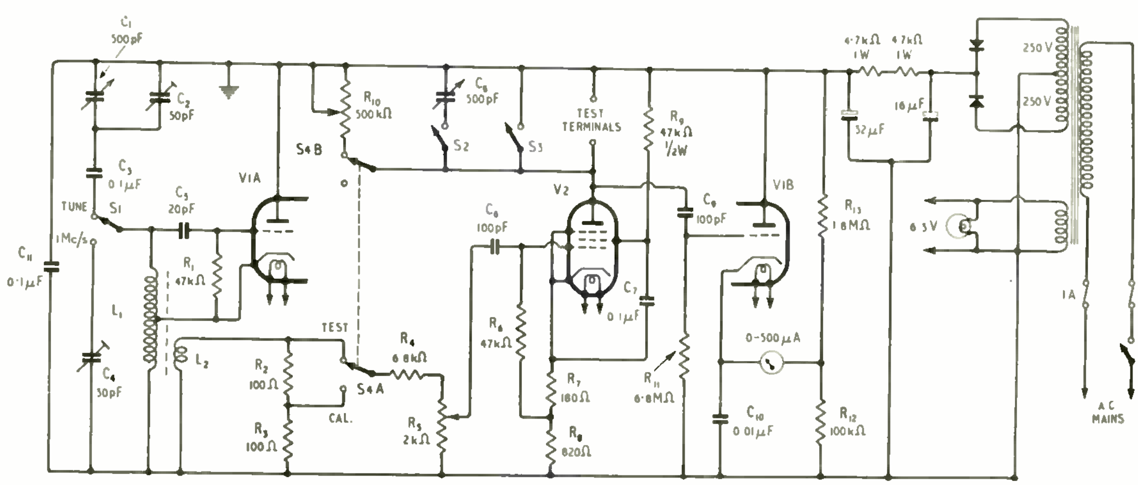
If the variable resistor is calibrated, R_d can be read off directly. The inductance is measured as before from a knowledge of the tuning capacitance employed and the resonant frequency, and hence Q can be determined indirectly. The principal advantage of this method is that the results are not dependent on the calibration accuracy of the valve voltmeter, which is used only to indicate one particular input voltage.

Since the inductor to be measured has to be connected in the anode circuit of a valve, it was decided to reduce the risk of shock by operating the unit with the h.t. line earthed. This means that one end of the coil is then connected to earth. It follows that the circuit arrangement has a somewhat unorthodox appearance, as will be seen from Fig. 2.

Two valves are employed in the unit, a 12AT7 (ECC81) and a 6AM6 (EF91). One half of the double triode is employed as a variable-frequency oscillator, whilst the other half is employed in the valve voltmeter circuit. The pentode is employed as the constant-current generator, feeding the tuned circuit under test.

The oscillator is connected in a cathode-coupled Hartley circuit. The oscillator coil L_1 is wound on a former enclosed in an iron dust pot. This type of coil is employed because fewer turns are required for a given inductance than with an air-cored coil; more important, the self-capacitance is much lower. By this means the oscillator can be made to cover the range 400 kc/s – 1.5 Mc/s, and this enables measurements to be made in the i.f. frequency band centred around 465 kc/s, as well as at all frequencies in the medium-wave band. The tuning capacitor C_1 is effectively in parallel with the tuning coil, since a low-impedance path between h.t. negative and earth is provided by C_{11}; the arrangement shown was adopted because the tuning capacitor is of the

Fig. 2. (Below) Circuit diagram of unit. Resistors are rated at ¼ watt unless otherwise stated.



standard type, having the rotating vanes connected to frame, and for obvious practical reasons it is desirable to have the frame earthed.

Provision is made for the oscillator frequency to be set to 1 Mc/s, by means of the switch S1, which introduces the pre-set capacitor C_4 in parallel with L_1. This facility is employed when measuring inductance values; with the frequency known, the inductance of the coil under test is calculable from the value of tuning capacitor required for resonance. It is implicitly assumed that the self-capacitance of the coil under test is negligible in comparison with the capacitance of C_8 at resonance. The choice of the frequency of 1 Mc/s ensures that this assumption does not introduce large errors with the type of coil normally employed for medium-wave working. Advantage has been taken of the arrangement to calibrate the dial of the capacitor C_8 in microhenrys as well as picofarads, the inductance scale being employed when the oscillator frequency is set to 1 Mc/s; the method of calibration is discussed later.

The oscillator develops a peak voltage in the region of 100 across L_1; the input to V2 must not exceed approximately 1 volt peak in the interests of linearity. Attenuation is obviously necessary between the oscillator and the input to V2. The coupling network used must satisfy the following conditions: (a) there should be provision for accurately doubling the input to V2; as it was desirable to use resistors for this purpose, these must be of small value so that shunt capacitance does not appreciably affect the division ratio; (b) the input must be independently adjustable so that the valve voltmeter can be set to the standard reading; (c) the oscillator must not be appreciably damped.

The output from the oscillator is taken from the small coupling winding L_2, and is fed to the two 100-ohm resistors R_2 and R_3. These resistors are of close tolerance, but the degree of matching is more important than accuracy of resistance value. By means of the switch wafer S4A, the output across R_3 alone or across the pair can be selected.

The voltage developed across R_2 and R_3 is sufficient to overload V2, but the coupling cannot be made small enough to avoid this without employing less than one turn. Therefore additional fixed attenuation is introduced by R_4 subsequent to R_2 and R_3. R_5 is a potential divider, and is pre-set at each measurement to give the desired valve voltmeter reading when the inductor under test is brought to resonance. The values of R_4 and R_5 are chosen so that at the maximum setting of R_5 the valve is not overloaded at either position of switch S4A, and also so that they do not appreciably shunt R_2 and R_3.

The cathode bias resistors R_7 and R_8 of V2 are not decoupled and produce negative current feedback. The feedback is employed for two reasons: first to increase the anode impedance of the valve, to make it a better approximation to a constant-current generator; secondly to improve the linearity of the stage. This is necessary to ensure, when the input signal is doubled, that the a.c. component of the anode current is doubled to a good degree of approximation. The screen dropping resistor R_9 is rather high (47 kΩ). This value is deliberately chosen so that if the anode of the valve is left with an open circuit, and all the cathode current flows to the screen, the screen dissipation limit is not exceeded.

The switch S3 (not shown in the photograph of the prototype) is fitted to enable the anode of V2 to be maintained at earth potential when no inductor is connected. Without this switch it is possible to obtain a shock when connecting a coil in circuit, by grasping the anode terminal and earth simultaneously. For preference, the switch should be of the spring-loaded type.

The tuning capacitor C_8 can be switched out of the circuit when it is desired to measure the characteristics of pre-tuned circuits; for example, i.f. transformers. In this it is of interest to note that the unit may be employed to determine coupling coefficients in tuned primary and tuned secondary transformers; the method of doing this is discussed later.

The valve voltmeter is of conventional design, employing a meter of 500 microamps full-scale deflection in an "infinite impedance" detector circuit. The value of the load resistor R_{12}, which determines the input voltage for full-scale deflection, is not critical since the voltmeter is used only for comparative measurements. The value chosen was 100 kΩ, giving full-scale deflection for an input signal of approximately 50 volts peak. The calibration mark employed is at half scale, representing an input signal of 25 volts peak, a convenient value for the range of dynamic resistances likely to be encountered in practice. If the dynamic resistance to be measured is relatively low, say less than 20 kΩ, the maximum value of the a.c. component of the anode current of V2 may not be sufficient to give a meter deflection to the calibration mark. In this case, a lower value of calibration mark can be employed. In the author's experience, the number of occasions when this has been necessary has been very few.

Calibration

The calibration of the unit is accomplished as follows. A resistor of, say, 1 kΩ is connected to the test terminals, and the anode terminal is connected via a small capacitor, say 10 pF, to the aerial terminal of a receiver, in parallel with the aerial. The receiver is then tuned to 1.5 Mc/s, and the oscillator tuning capacitor is set to minimum. The trimming capacitor C_2 is then adjusted until the oscillator output is heard, characterized by a "rushing" noise. The receiver is afterwards tuned to various stations in the medium waveband, and at each the oscillator is set to produce a zero-frequency heterodyne note. In this way the oscillator dial can be calibrated accurately over the whole medium waveband. At frequencies below 550 kc/s, it may be necessary to employ a signal generator to complete the calibration although it may be possible to complete calibration using the second harmonic of the oscillator. The signal generator output is also connected to the receiver aerial terminal via a small capacitor, and the oscillator frequency is adjusted to give zero-frequency beat note. If such a generator is available, it may be preferred to calibrate the whole oscillator range in this way.

When the oscillator dial has been calibrated, the oscillator frequency is set to 1 Mc/s, and the receiver is tuned to this frequency. Switch S1 is then thrown, and the capacitor C_4 is adjusted until the oscillator frequency is again 1 Mc/s.

When the oscillator has been calibrated as described above, a standard medium-wave coil is connected to the test terminals. A Wearite PHF2 is quite suitable for this purpose, its inductance being 170 microhenrys ± 1%; alternatively, an Osmor Type QA5 can be used; with the core removed, the inductance is 117 microhenrys. The oscillator frequency is then set in turn to the frequencies at which the capacitor is resonant with the inductor at convenient calibration values, e.g., 100, 150, 200 pF, etc. For the two coils mentioned above, the frequencies can be read off from the graph of Fig. 3. At each setting of the oscillator frequency control, the capacitor is adjusted for maximum meter deflection, and the scale marked accordingly. It will be seen that the curve does not extend to values of capacitance below 100 pF. This is because, for such values, an appreciable part of the total tuning capacitance is supplied by the inductor self-capacitance, and the error in assuming that the tuning capacitance represents the whole capacitance becomes serious. The limit of 100 pF is arbitrarily taken, on the assumption that the inductor employed has a self-capacitance of less that 10 pF; at this figure the capacitance calibration is in error by 10%, and this was felt to be the upper limit tolerable. Thus for inductors which require a smaller tuning capacitance than 100 pF at 1 Mc/s it is suggested that the capacitor should be set to a figure at which it can be reasonably assumed that it is very much greater than the self-capacitance of the inductor under test, and the resonant frequency found by varying the oscillator frequency.

In order to simplify the measurement of inductance at 1 Mc/s, the scale of the capacitor C_8 can be calibrated to read directly in microhenrys. The dial calibrations can be found from Fig. 4; it will, of course, be appreciated that this scale is only applicable at 1 Mc/s. At other frequencies, the inductance must be found by employing $L=\frac{1}{4\pi^2f^2C}$ where C is the value of C_8.

The calibration of the dial of R_{10} requires a suitably accurate meter or bridge. This can be done quite simply by connecting the measuring instrument across the test terminals with switch S4 set to introduce R_{10} in circuit; the unit should not, of course, be powered.

The method of measuring inductance and dynamic resistance is as follows. The inductor under test is connected to the test terminals, and the oscillator frequency is set to 1 Mc/s by means of the switch S1. The variable resistor R_{10} is switched out of circuit by setting switch S4 to its CAL. (calibrate) position. The output across R_3 alone is then fed to R_1. Switch S3 is opened, and the inductor is then brought to resonance by adjustment of C_8, indicated by maximum deflection of the meter. The value of the inductance can then be read off from the scale of capacitor C_8. If the value of the inductor is outside the range for which the dial is calibrated, i.e., its value is greater than 250 μH or less than 50 μH, a different test frequency must be employed, lower than 1 Mc/s if the coil value is too large, or higher if the coil value is too small. If this is necessary, the inductance calibration of the capacitor C_8 scale cannot be used, and instead the value of capacitance C required for resonance, must be noted, and the value of L found from the expression $L=\frac{1}{4\pi^2f^2C}$ where f is the test frequency. The expression can be simplified to $L=\frac{1}{40f^2C}$ which gives a value of L less than 2% in error; if f is in Mc/s, and C in pF, the latter expres-

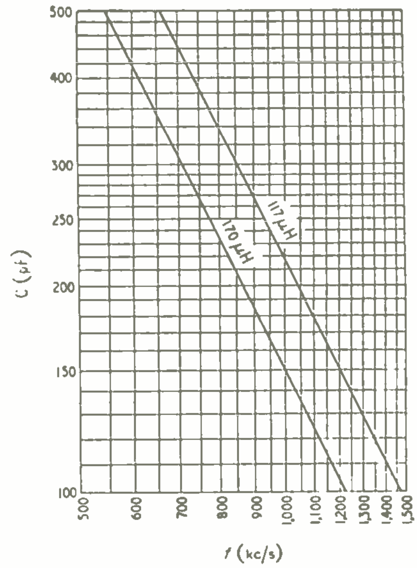


Fig. 3. Calibration curves for frequency scale (C_1) using 117 and 170-μH coils.

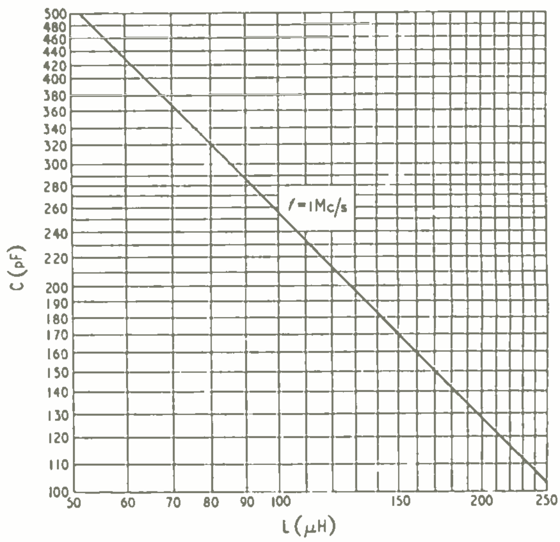


Fig. 4. Calibration curve for inductance scale (C_8) using a frequency of 1 Mc s.

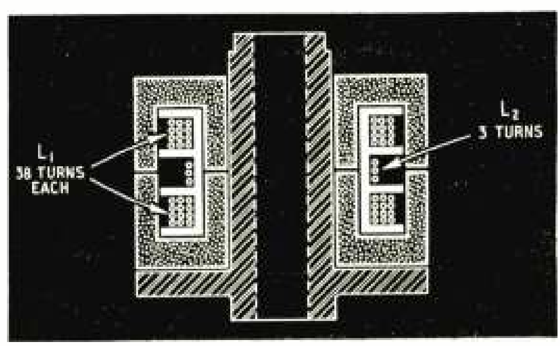


Fig. 5. Oscillator coil winding details. The coil and former are Neosid Type 10D.

sion simplifies to $L = \frac{2.5 \times 10^4}{f^2C}$ where L is in microhenrys.

To determine the dynamic resistance, the oscillator is set to the desired test frequency, switch S4 is set to CAL. With switch S3 open, the capacitor C_8 is then set to give maximum reading of the meter, and R_5 is adjusted until the meter is at the calibration setting. Switch S4 is then set to TEST and R_{10} is adjusted until the meter deflection is the same as formerly. A slight readjustment of C_8 may be necessary to keep the meter deflection at maximum as the setting of R_{10} is varied. The dynamic resistance is equal to the value of R_{10}, and can be read directly from the dial. If the Q value is required, it is then found by division from $Q = R_d/L\omega$.

Where a pre-tuned circuit is under test, the procedure is slightly different. The tuned circuit is connected to the test terminals, and C_8 is switched out of circuit. S4 is set to CAL. and the oscillator is set to the selected test frequency. Whether the oscillator is set to the existing resonant frequency of the tuned circuit (indicated by maximum meter deflection) or is set to a given frequency at which the tuned circuit is trimmed for maximum output depends, of course, upon the particular requirements. R_5 is then adjusted for the meter to deflect to the calibration mark. S4 is then set to TEST and R_{10} is adjusted to restore the meter deflection to the calibration mark; the tuned circuit should be retrimmed to keep the maximum meter deflection at each setting of R_{10}. If the circuit cannot be trimmed, the oscillator frequency must be adjusted with R_{10} to maintain the maximum meter deflection. The dynamic resistance of the tuned circuit is then equal to the value of R_{10}. If the tuned circuit is one of a pair of coupled circuits, and it is desired to measure the properties of either circuit alone, the other should be detuned whilst the measurements are made. In order to ensure that the coupled circuit is sufficiently detuned for its effect to be negligible, it is, in fact, best to break the coupled circuit.

In order to measure the coupling coefficient between two circuits, the primary winding is connected to the test terminals, the secondary circuit is broken and S4 is set to CAL. The oscillator is set to the working frequency and R_5 is adjusted until the meter deflects to the calibration mark. The secondary circuit is then restored, and tuned; at resonance the meter deflection falls to a minimum. The ratio of the meter reading in the first condition divided by that in the second is equal to $(1+n^2)$, where n is the coupling factor; where the circuits are identical, $n = kQ$, where k is the coupling coefficient. The accuracy of this type of measurement depends upon that of the valve voltmeter, and it is therefore advisable to select as large a reading as possible at the initial adjustment to minimize error.

The mechanical construction of the unit can be seen from the photographs. The unit was assembled in an instrument case bought for the purpose. However, it was found difficult to wire the components when mounted inside the case, and a sub-chassis was constructed which was fitted into the case after assembly and wiring. Since the controls have to pierce both the sub-panel and case, accurate registration of holes in the two was essential, and this involved some rather tedious constructional work. The oscillator and associated components were separated from the compartment containing valve V2 and its associated components by a screen; this was employed to prevent direct coupling from the oscillator to the test circuit, which would upset the correct operation of the circuit. The tuning capacitors used were of the 500-pF max type (Osmor). The oscillator coil was wound on a Neosid Type 10 D core and former, and the construction and details are shown in Fig. 5. The variable resistor R_{10} is a log-law type, whilst the meter was obtained in the surplus market.

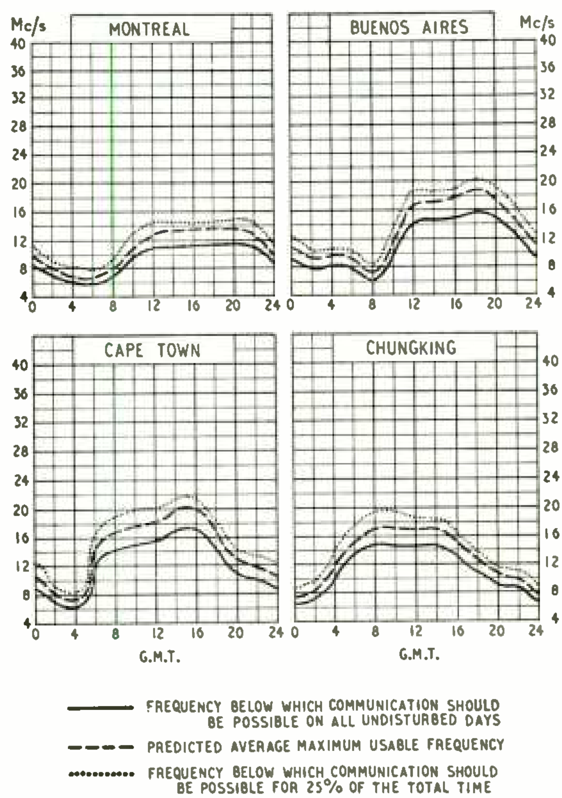
The power supply unit is entirely conventional, except that the positive terminal of the output is earthed, and not the negative terminal as is customary. This necessitates insulating the can of the electrolytic capacitors C_{12} and C_{13} from chassis. The total h.t. consumption is 16 mA at 240 volts and a full-wave selenium rectifier was employed, as this was to hand. The l.t. supply is 6.3 volts, the current being 0.6 amps.

Short-wave Conditions

Predictions for August

THE full-line curves given here 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 August.

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



LETTERS TO THE EDITOR

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

Cryptic Units

IN his otherwise excellent article on piezoelectric crystals (June and July issues) S. Kelly follows a growing practice of simplifying (?) units. Thus his coefficient *g* (p. 278, June issue) in volt-metres per Newton (whatever that may mean) is really a field (volts per metre) divided by a pressure (Newtons per square metre). Why not leave it as $\frac{V/m}{Newton/m^2}$, which is recognizable, and resists the schoolboy itch to treat it as a vulgar fraction?

As an awful warning of where all this may lead, I quote from a recent American textbook of acoustics. ". . . mechanical resistance R_m has the units of dynes/centimetres per second *or grams per second*"* (my italics). Shades of Fred Hoyle and the continuous creation of matter!

Hindhead. HENRY MORGAN.

*If you don't believe this, try substituting mass × acceleration (grams × cm/sec²) for force (dynes), and then cancel out.

"*Television I.F. Inquiry*"

I HAVE read with much interest the article in the July issue by G. H. Russell, but I feel that I must disagree with his conclusion in which he states ". . . that it is a great pity that the mainland of Europe did not adopt a certain well-tried system which uses 405 lines, . . . etc."

To me, it seems a great pity that we in the United Kingdom are at present tied to this "well-tried system" which gives, on all but the smaller receiver screens, a "liney" picture, and—may I say it—poor definition in all scenes with the exception of close-ups.

Another serious criticism which can be made against the 405-line system is the line-frequency whistle which this system induces in television receivers, the component from which this noise mainly emanates being the line output transformer, and which is a complaint peculiar to practically all British television receivers at the present time.

The foregoing remarks lead me to agree with your other correspondent, Charles A. Marshall (who writes about British colour television in the same issue), that compatible colour television may tie a weight around the neck of every receiver designer for the next century.

I therefore sincerely hope that when colour television is finally introduced we will have abandoned our present-day poor definition system and will no longer be annoyed with whistling line output transformers.

Belfast, N. Ireland. W. G. S. WRIGHT.

Ignition and Television Interference

THERE is one thing in *Wireless World* that I find very irritating: the regular tirade delivered by "Diallist" on ignition interference. In your June issue he elaborates the theme by adding a little polite blackmail: "If your engine is not suppressed, I won't buy your apples."

Surely such statements are quite out of place in a technical journal, in which more attention should be paid to the other side of the picture. As soon as television reared its head after the war regulations should have been made laying down the permissible radiation from a television receiver. In the absence of such regulations the market was flooded with cheap-jack receivers with a minimum of screening and the smallest number of overloaded valves doing the largest amount of work. Such receivers, radiating even the 20th harmonic of the line time base can and do cause devastating interference to reception of the 200-kc/s Light Programme transmission.

If "Diallist" will ponder awhile he may discover that the originator of "those d——d spots" has created an infernal weapon to use against the d——d whistles caused by the Random Radiations from his and his fellows' television sets.

St. Helens, Lancs. ARTHUR LINDON.

Transistor Interference

IT cannot be too widely known that the transistor circuit of Lorin Knight, published in your May issue, and many similar transistor "hook ups," if used on a normal wireless aerial, may cause serious interference to neighbouring broadcast receivers of the conventional type.

Things are quite bad enough without having a plague of hissing transistors thrown on the air.

London, S.W.16. B. S. T. WALLACE.

Advertisements

I DEAL extensively in sound equipment and allied lines, am regarded in the trade as highly skilled technically and purchase some £6,000 worth of equipment annually as well as operating a busy radio service business.

Most of the goods I handle are of British origin and the advertisement pages of *Wireless World* are to me of absorbing interest. Herein lie the causes of my protest and of my constant exasperation, under three headings.

(1) Absence of price in so many advertisements.

(2) Utterly inadequate technical information.

(3) Repeated failure to deliver goods advertised.

Under the first heading I ask, why omit the price? It is the most essential of all details to a prospective purchaser and surely the basic purpose of an advertisement is to sell the goods. The absence of a price or the naive "Prices on Application" gives rise in the mind of the possible purchaser that the price is prohibitive or that the advertiser is indifferent about selling.

Second heading: I frequently purchase microphones so I take this example. I look through *Wireless World* to see if there's anything new. I see one advertisement which tells me practically nothing except the frequency response. Now I know from experience that any microphone over the fiver in price will cover that side, as good as most users need it. But, before I can recommend that mike for a job I need to know a dozen other details. I want to know if it will suit my amplifier in output and impedance, whether it needs screened lead or if one is provided with it. Have I got to write to the advertiser and list all these questions? Have I got to write to *all* advertisers before I can judge which microphone is the best value and the most suitable for me? Not likely!

Lastly, deliveries. Taking one product at random, in February last an advertisement in your journal "whole-paged" a new product, no price, scanty details. The high reputation of the maker alone drew my attention. I wrote to him right away. A week later I was informed that the price was not yet fixed. Four weeks later I got the price and immediately ordered quite a number of the items advertised. I was told that "owing to unexpectedly high demand" supplies were short but that my order would be dealt with immediately supplies became available. I'm still waiting . . . or was until two days ago when I cancelled the order. And still the maker advertises this product and creates a demand which he cannot handle.

As a footnote might I ask a last question. Would it be too much to ask a manufacturer, when he supplies an expensive and highly technical product, to enclose with it a leaflet giving all possible uses for the product, together with every possible technical detail on it? It would save the user having to dismantle the unit to find out how it ticks or whether it will suit a certain purpose.

Ireland. "RAY."

Vector Diagrams Continued

An Improved Notation for Currents

By "CATHODE RAY"

THERE are two main motives for the study of any science. One is the desire to obtain some practical benefit, such as food, shelter, warmth—or entertainment. Where this motive dominates, there is *applied science*. The other motive is the enjoyment of order, design and beauty; and where that dominates there is *pure science*. It is a pity that people who are interested in one of these aspects of science often tend to be scornful about the other. It is a pity, because a starving scientist is unlikely to be able to give his undivided attention to the beauties of Nature, and the practical man is unlikely to do his best if he has a muddled and disordered mind.

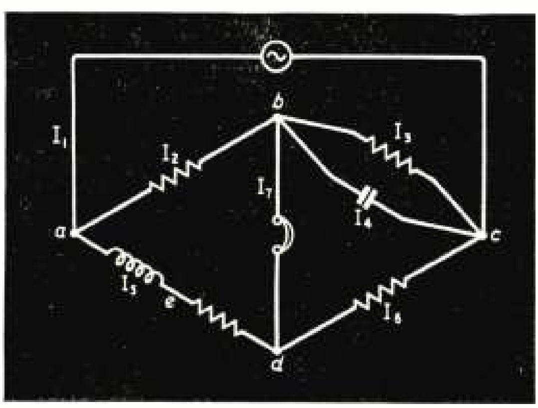
You may be wondering whatever this has to do with vector diagrams. What I am trying to say is that even strictly practical engineering is not only more enjoyable and interesting but is likely to be better done if we cultivate an appreciation of the design to be found everywhere in Nature and model our methods on it. Last month I criticized present practice in vector diagrams because, for one thing, it permits an almost endless variety of alternatives to represent a single circuit situation. The fact that the system I advocated has one correct "general" diagram for each situation satisfies a sense of order and in doing so also confers the practical advantage that its definite shape quickly becomes associated with what it represents. The present diversity of "correct" answers just makes things unnecessarily difficult, especially for the poor student.

Another practical advantage of the general diagram is that it gives a clear picture of the relative potentials of all the points in the circuit. This is because the corners of the vector diagram are labelled to correspond with the circuit diagram. If *a* in the vector diagram is above *b*, it means that (at the instant represented) the point *a* in the circuit is more positive than *b*. In other words, V_{ba} is positive and V_{ab} is negative. "V_{ba}" means the change in voltage on going from *b* to *a*. This way of writing the letters is the reverse of some people's, but is a logical result of the universal convention that "up" is positive and "down" is negative.

We hadn't time last month to deal with the corresponding notation for currents. Some people may have objected to my recommending a system of voltage notation that is the opposite of theirs, but they can hardly object to my recommending the following system of current notation to take the place of the existing lack of system. The usual practice of giving arbitrary numbers to currents does not deserve to be called a system. Take Fig. 1 for example. It is the circuit of the well-known Maxwell bridge for measuring inductance in terms of capacitance. There are seven currents, which have been numbered I_1, I_2, etc. But there are 5,039 other ways of allocating the numbers 1 to 7 to these currents! Another method is to label the circuit components, and then mark the currents accordingly: I_{R1} is the current through R_1, and so on. But a mixture of subscript letters and numbers is not advisable if it can be avoided (as the printer will probably agree) and anyhow it is unsystematic; is I_5 in Fig. 1 to be named after the inductor or the resistor? Then some people copy the voltage notation and refer to the current flowing from *a* to *b* as I_{ab}. But what do they do with I_3 and I_4 for these are both I_{bc}!

This is where the orderliness of Nature should come in again. Some time ago* we took note of the dual relationships between various electrical quantities, such as voltage and current. Equations and laws that are true for voltage can be converted into corresponding laws for current simply by exchanging

* "Duals," February, 1952.



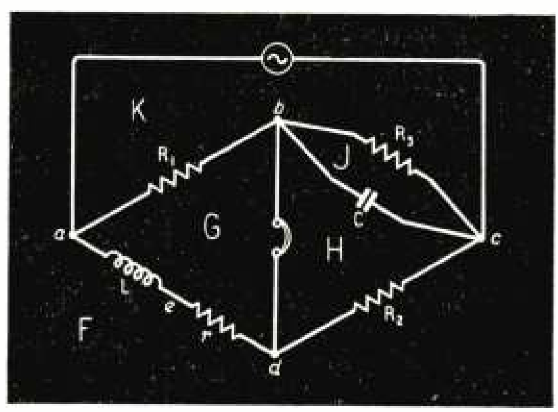


Fig. 1 (Left). Circuit diagram of the well-known Maxwell bridge for measuring inductance in terms of capacitance. There are seven potentially different currents, labelled here in the usual manner I_1 to I_7. Fig. 2 (Right). The same circuit as Fig 1, with its five meshes labelled F to K for systematic current identification.

resistance for conductance, series for parallel, and so on. An example is found in Kirchhoff's laws. Either of these is converted into the other by changing over current and voltage, and circuit points and circuit meshes. Circuit points and meshes are therefore " duals " of one another. We have already found that naming voltages after circuit points is a completely sound system, so the dual relationship should lead us to name currents after circuit meshes. It is surprising that this clear signpost has been missed all this time, especially as an analogous system (Bow's notation) has been in use by structural engineers for the last eighty years.

So in Fig. 2 (which is the same bridge circuit as Fig. 1) each mesh has been labelled with a large capital letter. These letters could of course be A, B, etc., but since *a* and A both sound the same it is perhaps better to use different letters. Every current in either direction can be unmistakably identified

Fig. 3. The convention adopted herein is that IAB is positive when flowing in the direction shown.

by a pair of mesh letters; for instance, I_{KG} is the current flowing through R_1. The only remaining requirement to make everything quite clear is an understanding as to which way it is flowing. Personally, I understand it to be from *a* to *b*, my rule being the anti-clockwise (or mathematically positive) direction with reference to the first-named mesh. This rule can be very easily remembered as in Fig. 3. Current in the opposite direction (*b* to *a*) is of course I_{GK} or $-I_{KG}$.

The only possible snag about this system is that it doesn't work very well if any wires cross. But by the time a circuit has been reduced to the parts that are essential to a vector diagram, it is very unlikely that it cannot be drawn without cross-overs. And if it can be so drawn it probably ought to be in any case, for the sake of clearness.

See now how nicely these notations fit into one another and the known laws of circuits to make a single consistent pattern. One of Kirchhoff's laws says that the sum of the voltages around any closed path must be zero. Take the closed path consisting of the mesh H in Fig. 2 for example. One thing about it that we can say at once is

$$V_{bc} + V_{cd} + V_{db} = 0$$

We should know this even without looking at a circuit diagram, because the subscript letters make a complete cycle from *b* back to *b*. The other Kirchhoff law says that the sum of the currents arriving at any point is zero. (A current leaving the point is reckoned negative). Taking *b* as an example,

$$I_{KG} + I_{GH} + I_{HJ} + I_{JK} = 0$$

Here again the letters make a complete cycle. Equations written down almost automatically on this letter-cycle principle give one a good start in solving most circuit problems. And we have already seen that in the recommended (or " general ") type of vector diagram the voltages around any closed path are represented by a closed figure. The three voltages around H would be represented by a triangle; the four voltages around G by a quadrilateral; and so on. It is obvious, then, that if we continue the same plan for currents, a closed figure in a current vector diagram represents all the currents meeting at a junction. And, whereas each point in the voltage diagram represents a circuit junction, in the current diagram it represents a mesh.

The best way to make all this clear is to draw the voltage and current vector diagrams for Fig. 2. The object of adjusting a bridge is to balance it, and the most important thing to know is the condition or conditions for balance. So let us draw the diagrams showing the balanced state. At balance, no current is passing through the phones; that is to say $I_{GH} = 0$, so G and H in the current diagram must coincide. In effect, GH is all one mesh, which corresponds with the fact that at balance the phone connection makes no difference. Since G and H are the same, the line joining G to F must be identical with the line joining H to F; which duly represents the fact that, because no current is coming or leaving via the phones, $I_{GF} = I_{HF}$.

Let us begin with this current, I_{GF} (or I_{HF}) as the reference vector, Fig. 4. The e.m.f. V_{cd} driving I_{HF} through R_2 must be in phase with it (remember, the e.m.f. is in the external circuit, through which it acts from *c* to *d*, driving current through R_2 from *d* to *c*). So we draw a voltage vector *cd* in the same direction as GF. V_{de} is also in phase, so it is appropriate to extend this line to *e* in the voltage diagram. The reason for dotting this extension is that *r* has no separate existence; it is the resistance of the coil being measured, of which L is the inductance. The e.m.f. V_{ea}, driving I_{GF} against the e.m.f. of this inductance, must be 90° ahead of I_{GF}, if the current is to lag the applied e.m.f. by 90°. So we draw the other dotted line *ea* to represent it. The voltage across the whole impedance of the coil can now be shown by joining *d* to *a*. The diagram for the lower half of the bridge is now complete, as in Fig. 4.

From the current point of view, as we have seen, balance means that no current flows between *b* and *d*. From the voltage point of view it means that *b* is at the same potential as *d*. This we represent on the voltage diagram by adding the label *b* to the point already located for *d*. (Fig. 5). This enables us to draw the

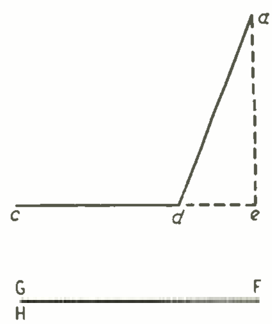


Fig. 4. Voltage and current diagrams for the lower half of Fig. 2 when the bridge is balanced.

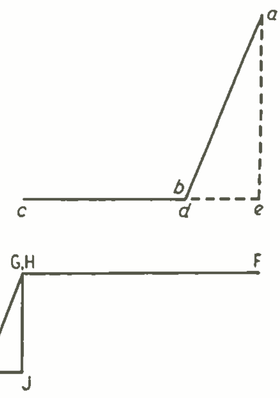


Fig 5. Completed voltage and current diagrams for Fig 2 at balance.

vector for I_{KG}, by putting K where a line drawn from it, parallel to *ba*, arrives at G. Lastly there are the two currents between *b* and *c*, one of them (I_{KJ}) being in phase with V_{cb}, and the other (I_{JH}) leading it by 90°. So there is no difficulty in drawing the corresponding vectors, to complete the triangle KJH.

By the way, K and H in Fig. 2 are not adjacent meshes, but an obviously correct interpretation of "I_{KH}" is the net current flowing between the meshes K and H, which is the total current flowing from *b* to *c* via R_3 and C. This is expressed in algebra as

$$I_{KH} = I_{KJ} + I_{JH}$$

Equally well it is the total current flowing between meshes K and H by any other paths—say via R_1 and phones, or generator and R_2.

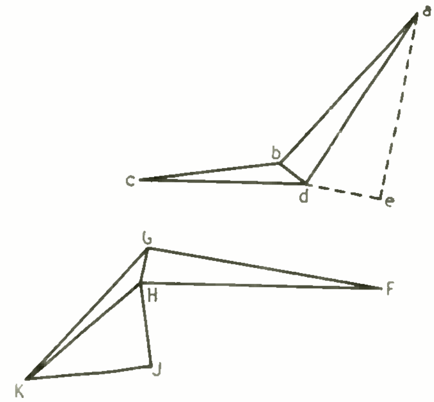
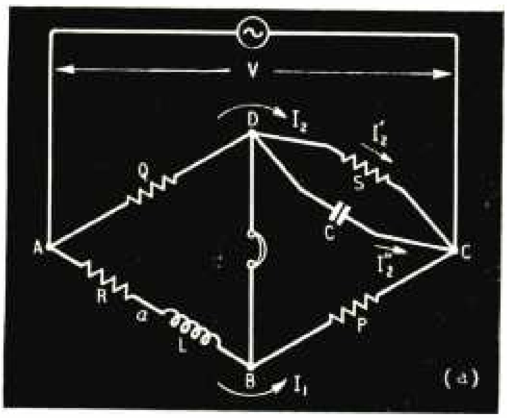


Fig. 6. (Above) One possible effect on Fig. 5 of unbalancing the bridge.



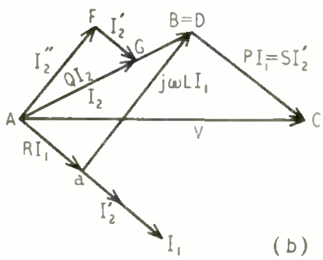


Fig. 7. (Left) Textbook version of Figs. 2 and 5.

Both current and vector diagrams are now complete except for the vectors representing the voltage and current of the generator. These would be shown by drawing in the lines from *c* to *a* and K to F, but they are usually of such little interest compared with the impedance arms of the bridge that it is probably better to leave them out, so as to focus attention on the conditions for balance.

Use for School Geometry

Even if our school geometry has become a little dim, we can hardly fail to notice the existence of two similar triangles, *dea* and KJH. The former refers to the inductance arm of the bridge, and the latter to the capacitance arm. Since current is the dual of voltage, and the current vector diagram is similar to the voltage vector diagram, we might guess that these two bridge arms are duals of one another. And of course that is so; for inductance is the dual of capacitance, and resistance in series is the dual of conductance in parallel. It is easy to see, too, that the power factor is the same in both arms, for Fig. 5 shows that the in-phase and quadrature components of the impedances are in the same proportion. I hope you are beginning to see how this type of two-fold diagram brings out as simply and clearly as possible the beauty of the natural electrical pattern in the circuit, and helps one to visualize its working principles. If not now, because of unfamiliarity with the method, it will come after closer acquaintance.

While we are at it, we might as well find the formula for balance. It can be deduced from Fig. 5, with the aid of the said school geometry.

Because the triangles mentioned are similar,

$$\frac{ae}{ed} = \frac{HJ}{JK}$$

Now *ae* and *ed* are proportional to the impedances, ωL and *r*, between those points; and HJ and JK are proportional to the admittances (i.e. 1/impedance) ωC and $1/R_3$. So

$$\frac{\omega L}{r} = \omega C R_3$$

$$\therefore \quad L = CR_3 r$$

We need another equation to determine L and *r*. Obviously at balance

$$\frac{cd}{da} = \frac{cb}{ba}$$

Because the same current is flowing from *c* to *d* as from *d* to *a*, *cd*/*da* represents not only the ratio of voltages between these points but also the ratio of impedances. The impedance between *c* and *d* is R_2 and we can call the impedance between *d* and *a* (consisting of *r* and ωL) Z_L. In the same way *cb*/*ba* is equal to Z_C/R_1. So

$$\frac{R_2}{Z_L} = \frac{Z_C}{R_1}$$

$$\therefore \quad R_1R_2 = Z_LZ_C$$

$$= \frac{da}{GF} \cdot \frac{cb}{KH} = \frac{da}{KH} \cdot \frac{cb}{GF}$$

Fig. 5 shows that *da*/KH = *de*/KJ, so

$$R_1R_2 = \frac{de}{KJ} \cdot \frac{cb}{GF} = \frac{de}{GF} \cdot \frac{cb}{KJ} = rR_3$$

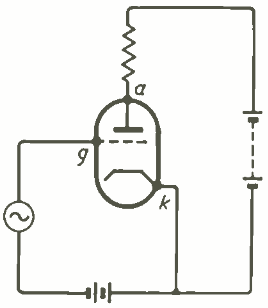


Fig. 8. Very simple valve circuit as a subject for vector diagrams.

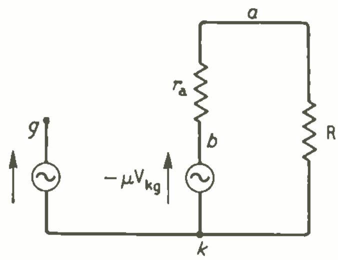


Fig. 9. A.C. equivalent of Fig. 8, with valve replaced by "equivalent generator."

We can therefore substitute rR_3 for R_1R_2 in the previous result, and get

$$L = CR_1R_2 \text{ and } r = R_1R_2/R_3$$

For the sake of comparison, Fig. 6 shows the diagram for the same bridge with the values of the impedances altered slightly so as to throw it off balance. On account of the inductive character of the phones, the current through them is shown as lagging the out-of-balance voltage by about 60°.

Also for the sake of comparison with the sweet simplicity of Fig. 5 is Fig. 7(b), which is an actual textbook version of the same thing, Fig 7(a) is a key to the symbols. It would be interesting to see the corresponding diagram for the unbalanced Maxwell bridge! (I have yet to find a textbook that dare show it.)

But now let us go on to something quite different—a valve circuit. Let us start with something really simple: Fig. 8. The first step is to convert the valve into its a.c. generator equivalent, without the d.c. accessories, which have no place in a vector diagram. There are actually two kinds of generator equivalent: the voltage generator, with the anode slope resistance in series; and the current generator, with the resistance in parallel* (dualism again!). Here in Fig. 9 we have the voltage generator circuit. Seeing this, readers who may have been watching for the opportunity to slip in under my guard will hardly be able to wait to point out that, after having poured scorn on those who rely on arrows in their a.c. diagrams, here am I falling into the habit myself. If so, they may not have noticed that in this example there is a rather special situation, viz., two or more generators related to one another in phase. Unless the phase relationship can safely be taken as understood (as perhaps it could be in diagrams of three-phase power-station generators) it is as well to show it unmistakably. As it happens, in this case practice is fairly evenly divided between two opposite methods: some represent the facts of valve behaviour as in Fig. 9; others prefer to show the anode generator developing $+\mu V_{kg}$ volts in the opposite direction. Among people who are accustomed to working with valve equivalent circuits, the minus sign in front of μV_{kg} should be enough to show where I belong, but it is just as well to make quite sure. If there were any better method than the arrows I would use it. At least they are an improvement on marking the terminals of both generators "+" and "−," for that can hardly fail to give the impression that they are d.c. generators, especially if "e_g" is written inside the circle instead of "∼."

Incidentally, one of my reasons* for preferring the $-\mu V_{kg}$ convention is that it doesn't upset the well-established convention of reckoning both grid and anode voltages with respect to cathode. The idea that the opposite direction ought to be adopted in order to make the signal current flow the same way in the anode circuit as the valve feed current is quite fallacious, because Fig. 9 does not depict a valve, having need of feed current and such things, but a purely a.c. system in which all talk of d.c. is irrelevant.

A Bankrupt Diagram

However, that is all by the way; let us get on with the job. Fig. 10 is one version of the vector diagram for this circuit, as given in a periodical for teachers. (I have taken the liberty of substituting "potential-rise" voltage notation, and r_a for a non-standard symbol.) It is a good example of the bankruptcy of contemporary vector diagram style. The ordinary rules of construction have broken down under the strain of all the vectors being in line, and the author has been driven to the expedient of extending the centre point into a little vertical line (though this is hardly in keeping with the geometrical definition of a point!) from which to start a second lot to the left. Even this does not make matters clear, because here we have in one diagram the two conflicting customs: along the lower track the vectors $-\mu V_{kg}$ and i_a both start from 0, so that the i_a vector falls on top of the $-\mu V_{kg}$ vector; along the upper track the $i_a r_a$ vector begins where the $i_a R$ vector leaves off, so there is no overlapping. But how is the poor student expected to know that! Presumably by having the thing explained to him! Then what use is the vector diagram, if it can only be understood when one knows the things it is supposed to reveal! And look at all those vectors pointing to the left; they all (except i_a) stand for voltages, so presumably they add up to one very big voltage; yet they are balanced by only one little voltage to the right!

We turn from this not very self-evident representa-

* "That Other Valve Equivalent," April, 1951.

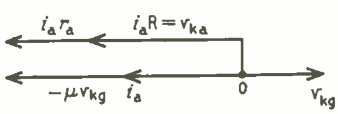


Fig. 10. One published version of the vector diagram for Fig. 9.

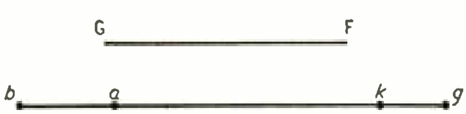


Fig. 11. General vector diagram for Fig. 9, for comparison with Fig. 10.

* "Circuit Conventions," April, 1947.

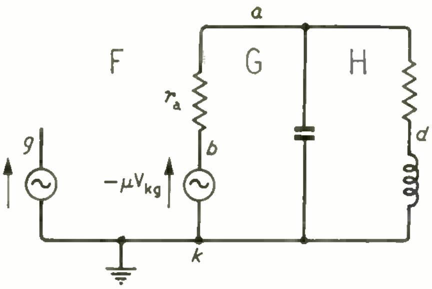
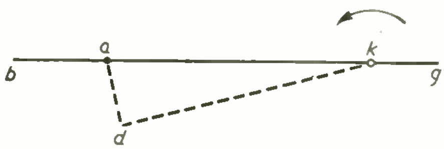


Fig. 12. Equivalent circuit of a valve with tuned anode.

Fig. 13. General current and voltage diagram for Fig. 12 at exactly the resonant frequency, so that the tuned circuit is equivalent to a high resistance.



tion to Fig. 11. Here, provided the simple rules for this type of diagram are known, no explanation is needed. There is no ground for mistake or misunderstanding. There is no alternative way, within the rules, of representing the same facts. There is no embarrassment or lack of clarity on account of all the vectors being in line. The relative potentials of all points in the circuit as the cycle proceeds are clearly seen by turning the diagram round. (Try getting this information from Fig. 10!) To do this turning properly, you should stick a pin through the point on the voltage diagram marked with the same letter as the earthed point on the circuit diagram. Usually this will be *k*, but the same diagram is every bit as valid for any other earthing point—just move the pin to alter the centre of rotation.

Suppose now we replace R by a tuned circuit, as in Fig. 12, and assume that this circuit is exactly in tune. As a whole, it is therefore equivalent to a resistance, and the vector diagram (Fig. 13) begins as before. The likelihood that the dynamic resistance of a tuned circuit will be high is shown by making GF rather short and *ak* rather long. The fact that the circuit is earthed at *k* is also indicated in the vector diagram. Only one thing remains to be done: to analyse the tuned circuit. The vector GH is easily filled in, for (neglecting capacitor losses) I_{GH} leads V_{ak} by 90°. The resistance of the coil is appreciable, however, so HF is less than 90° behind *ak*. The lower the resistance, the nearer 90° it is, and the farther off the point of intersection, H, must be. This represents the physical fact that the lower the tuned-circuit resistance the greater the current (represented by GH) circulating around it, in comparison with the current (represented by GF) fed in. The ratio of GH to GF is, in fact, the circuit magnification factor Q.

Although point *d* in Fig. 12 is, like *b*, fictitious, because the resistance and inductance of the coil are not really separate, the in-phase and quadrature components of the voltage V_{ak} across the coil can be found, by drawing the dotted lines respectively parallel and at right angles to HF. The fact that, owing to the resistance of the coil, *dk* cannot be in exactly the same direction as *kg*, is important. Suppose we want to obtain the driving voltage, V_{kg}, from the anode circuit, so as to make the whole thing a self-oscillator. There is no shortage of volts, for V_{ka}, the anode voltage, can hardly fail to be at least several times greater than V_{kg}. But it is exactly 180° out of phase. However, by coupling a second coil to the one in the tuned circuit, and connecting it the right way round, we can obtain an induced e.m.f in either direction. The snag now is that this "either direction" is relative to V_{kd}, so even when connected the right way the induced e.m.f. is not exactly in phase with V_{kg}. You see, it is the magnetic flux due to I_{HF} that generates V_{kd} (90° out of phase with current and flux), and it is the same flux that would generate the voltage we are proposing to feed back to *g*. We cannot bring it into phase with V_{kg} by eliminating all tuned-circuit resistance, but we can swing *kd* into line with *ka* by slightly mistuning the circuit.

To represent this required condition, let us redraw the vector diagram with *kd* in the right direction, as in Fig. 14. FH must be swung round through the same angle, to keep it still at right angles; and GF must be turned to keep it in phase with *ba*. GH must be turned to keep it at right angles to *ak*. This modified diagram shows us that the current I_{FG} fed into the tuned circuit must be made to lead the applied e.m.f. V_{kg}. This would happen automatically in practice, given sufficient coupling to make the inductively induced e.m.f. equal to V_{kg}, by oscillation taking place at a higher frequency than that to which the circuit was tuned. (At a higher frequency the capacitor offers a lower impedance than the inductor, so the net current is capacitive or leading.) The less the resistance, the less the difference between the two frequencies.

All this, and much more, is clearly demonstrable with the help of the vector diagram. In more complicated valve circuits, the help of the general voltage diagram in showing just when some point becomes more positive (or negative) than another is particularly valuable.

The coupled coils, and the introduction of magnetic flux, Φ, may be a reminder that it was a transformer

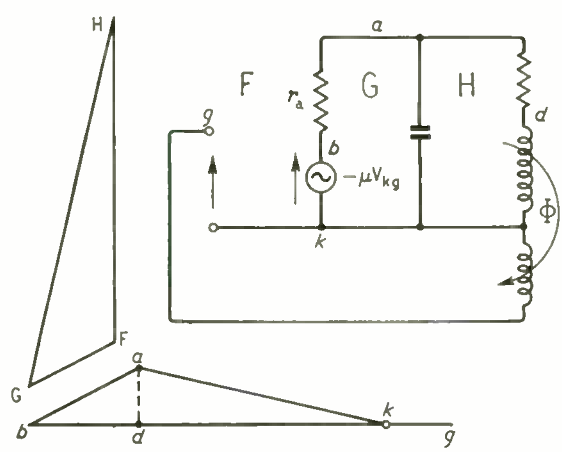


Fig. 14. Circuit and general vector diagram for the tuned anode circuit modified by back coupling, at the frequency giving the correct phase for self-oscillation.

problem that started all this. We have had a voltage notation and a current notation; how about flux notation? The usual practice is to call it just Φ, and leave it to be guessed (or explained somewhere) which flux is meant; and, if more than one flux is involved, to number them, Φ_1, Φ_2, etc. This seems to me pretty crude. The basic fact about magnetic flux is its being directly proportional to current, so that it is in phase with the current causing it. As a reminder of this, as well as a convenient notation, it seems a good idea to use the same label for the flux as for the current causing it. In Fig. 14 this is I_{HF}. So if we wished to distinguish the resulting flux we would call it Φ_{HF}. A further economy of effort conferred by the new system is that there is no need to show flux vectors; HF serves for both current and flux. If we want to call attention to the fact that a certain current is responsible for a significant flux, we can, if we like, mark the appropriate current vector with a "Φ".

One critic, while acknowledging the relentless logic of the general vector diagram, complained that it was not so good as the more familiar "star" type for comparing phase angles, still less for labelling the angles. I suppose it depends on one's eye whether HG in Fig. 14 can be seen at once to be at right angles to *ak* or not. If not, then far be it from me to insist that in no circumstances ought any other than the general type of vector diagram to be used. What I do emphasize about the general type is that it can claim to be the one logical basic type for representing a given circuit situation. If for particular purposes (such as high-lighting certain phase relationships) one then likes to derive a special vector diagram from it, with the vectors rearranged to suit, then by all means. But I still think it would be worth while to leave the general diagram there, too, as an unambiguous key to the situation.

Next month we shall tackle the transformer problem.

BOOKS RECEIVED

Amplitude-Frequency Characteristics of Ladder Networks by E. Green, M.Sc. Comprehensive treatise on the theory and design of broad-band couplings used in communication equipment. Pp. 156; Figs. 88. Price 25s. Marconi's Wireless Telegraph Company, Chelmsford, Essex.

Radio Research 1953. Report of the Radio Research Board and of the Director of Radio Research on work on propagation, atmospheric radio noise, ferromagnetic and ferroelectric materials and germanium point and junction diodes carried out under the Department of Scientific and Industrial Research at the Radio Research Station, Slough, the N.P.L. and the Universities of Cambridge, London and Wales. Pp. 40. Price 1s 9d. Her Majesty's Stationery Office, York House, Kingsway, London, W.C.2.

A Bibliography of Colour Television. References to articles (in chronological order) and books relating to the optical and electrical problems involved, with an authors index. Last entry Jan., 1954. Pp. 17. Price 2s. The Television Society, 164 Shaftesbury Avenue, London, W.C.2.

Proceedings of the National Electronics Conference 1953 (Vol. IX). Record of the papers read on circuit analysis and synthesis, valves, transistors, materials and components, instrumentation, computors, communications, ultrasonics, nucleonics, etc., at the Chicago Conference of Sept., 1953. Pp. 95 with numerous illustrations. Price $5. National Electronics Conference, 852 East 83rd Street, Chicago 19, Illinois, U.S.A.

Decibel Tables. Power and voltage ratios equivalent to steps of 0.1 db from 0 to 20 db, together with tables of db expressed as a percentage voltage ratio and of losses referred to 1,000 c/s for frequencies from 10 to 20,000 c/s for a slope of 6 db/octave. Reprinted from *B.S.R.A. Journal*. Pp. 6. Price 1s 2d by post. British Sound Recording Association, Hon. Librarian, S. W. Stevens-Stratton, 3 Coombe Gardens, New Malden, Surrey.

"At a Glance" Radio Valve and Television Tube Equivalents, by B. B. Babani. List of British, European and American valves and their equivalents, commercial equivalents of C.V. types (and vice versa) and television tubes, with remarks on possible replacements. Pp. 59. Price 5s. Bernards (Publishers), The Grampians, Western Gate, London, W.6.

Radio Control by F. C. Judd. Practical handbook on the design and construction of transmitters, receivers and auxiliary mechanisms for the remote control of model ships and aircraft. Pp. 135; Figs. 105. Price 8s 6d (cloth bound 11s 6d). Data Publications, 57 Maida Vale, London, W.9.

Principles of Mass and Flow Production by F. G. Woollard, M.I.Mech.E., M.I.Prod.E., M.S.A.E. Introduction to the study of quantity production. Deals principally with light engineering products and includes a description of the E.C.M.E. automatic machine for making broadcast receivers. Pp. 196; Figs. 102. Price 25s. Iliffe and Sons, Dorset House, Stamford Street, London, S.E.1.

Crystal Rectifiers and Transistors, compiled by E. Molloy and edited by M. G. Say, Ph.D., M.Sc. Survey of developments in the design and application of small diodes and transistors, with numerous representative circuit diagrams. Pp. 170; Figs. 145. Price 21s. George Newnes, Tower House, Southampton Street, London, W.C.2.

Practical Television Circuits by F. J. Camm. Collection of designs together with constructional details, including test apparatus and auxiliary equipment such as aerials and a spot-wobbler. Pp. 288; Figs. 156. Price 15s. George Newnes, Tower House, Southampton Street, London, W.C.2.

Fundamentals of Transistors by L. M. Krugman. Deals principally with the equivalent circuit and calculations involved in designing amplifiers, oscillators and switching circuits. Pp. 140; Figs. 110. Price $2.70. John F. Rider Publisher, 480 Canal Street, New York 13.

TV Picture Tubes by Ira Remer. Treatise for servicemen on the diagnosis of faults and the maintenance of American tubes and their accessories. Pp. 154; Figs. 93. Price $2.40. John F. Rider Publisher, 480 Canal Street, New York 13.

How to Locate and Eliminate Radio and TV Interference by Fred D. Rowe. Interference with and not by radio and television receivers. Pp. 122; Figs. 53. Price $1.80. John F. Rider Publisher, 480 Canal Street, New York 13.

Zirkonium by Dr. Werner Espe. Treatise (in German) on the production and properties of zirconium and its application in vacuum technique. Pp. 94; Figs. 14, and 20 tables. C. F. Winter'sche Verlagshandlung, Füssen-Allgäu, Germany.

Radio Trouble Shooting Guidebook, by John F. Rider and J. Richard Johnson. Description of a.m. and f.m. superheterodyne receivers, with an analysis of typical faults, their symptoms and remedies. Pp. 156; Figs. 55. Price $2.40. John F. Rider, Publisher, 480, Canal Street, New York 13.

WHY LINES?

By F. P. HUGHES

An Alternative to Rectilinear Scanning in Television

While we have doubts about the real practicability of the scheme proposed in this article, we are publishing it because we like the author's original and stimulating approach. We have, however, put a number of questions to him about the system, and these are printed, with his replies, at the end of the article.

CONSIDER the television scanning process. Starting from the top left-hand corner, the spot travels steadily to the right, eventually reaching a point one unit down the right margin. Here the transmitter, under the control of which the spot is travelling, closes down to signal to the spot to reverse its travel. And so the spot's direction of motion is reversed, with a relatively enormous expenditure of energy in the time base circuits. Reaching the left-hand margin again, the spot starts its journey across the screen once again, steadily to the right. Two hundred and two and a half times it does this to reach the bottom of the frame, and then it reverses its vertical direction of motion and travels to the top centre of the screen, where it begins the second half of its series of horizontal journeys, filling in the gaps in the lines drawn in the first half of the cycle.

Why?

Fundamentally because in the 1880's a gentleman by the name of Nipkow invented the disc which bears his name—the scanning disc. Mechanically, the simplest way to scan a rectangular image is by a series of lines, vertical or horizontal. Besides the Nipkow disc, man's genius has invented the mirror drum, the mirror screw, the double mirror drum (used by Scophony), the fixed line-mirror or Mihaly-Traub system, and various sorts of rotating slotted discs and cylinders have been suggested. All of these are ingenious—intellectually if not photometrically—and the perfection of the Scophony receiver, when I saw it demonstrated in 1938, was amazing—a full daylight picture about 3ft by 4ft!

But marvellous as these devices are, they are obsolete. Dilettanti such as myself may regret their passing, but they have been completely supplanted by the ubiquitous cathode ray tube. But still we use lines! And we invent spot wobble to cover them up. And geniuses spend their time devising æsthetic ways of recovering a little of the energy squandered by the time bases and converting it to e.h.t. And the system uses 10% of the transmitter's time which would, could and should be used to transmit detail.

Look on the sleeve of your jacket. You will probably find two or three buttons sewn there. They serve no particular purpose. They do not even undo. Why are they there? Because 300 years ago gentlemen sometimes took to their swords to settle an argument and it was useful to be able to roll up the sleeves for fighting. In these days we take to our slide rules to settle arguments, or refer to back numbers of *Wireless World*. Recognizing this, the tailor does not bother to make the buttons undo, but he puts them there just the same. Tailors may stick to tradition—our tradition must be to have none.

In Search of Simplicity

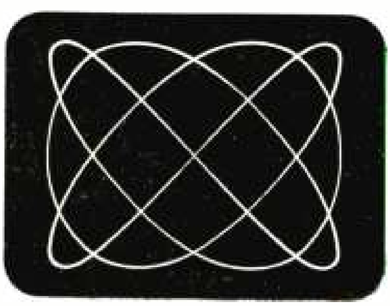
Let us recap. We scan images as we do because it involves the simplest of mechanical arrangements. It does not involve the simplest electronic arrangements possible. Mechanical scanning is obsolete; electronic scanning is unlikely to be superseded for some considerable time.

Is it possible to devise an electronic scanning system simpler than that at present used?

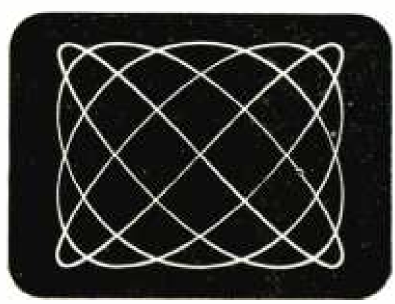
To answer this we must return to first principles and start by devising the simplest possible electronic scan.

What is the simplest pattern which can be drawn on a c.r.t. screen? A dot, in the centre of the screen. No scanning needed. Next simplest, a line, performing a simple harmonic motion vertically or horizontally. This involves a minimum of scanning circuitry—a simple oscillator. Also, a pure sine wave is pretty easily obtained (compared to an accurately linear sawtooth, that is). Third simplest, a Lissajous

This shows the type of scanning that would be given by a Lissajous figure, except that a very much finer pattern would be used. Pattern (a) is produced by a frequency ratio of 3:4 and pattern (b) by a ratio of 4:5, showing that the "raster" becomes more filled in as the two frequencies are brought closer together.



(a)



(b)

figure, drawn on the screen by two commensurable s.h.ms at right angles to each other.

All the textbooks give drawings of simple Lissajous figures, but only of commensurable frequencies. This is perfectly understandable, for if two incommensurable frequencies are so combined the eventual result is that a complete rectangle, of sides equal in length to the amplitude of the sine waves concerned, is filled in. This is of little interest for oscilloscope work. But it *is* the clue to the Simplest Scan!

If two alternating voltages of 100 and 101 c/s respectively are applied to the X and Y plates (or coils) of a c.r.t. the beam will trace a figure which will go through the following cycle of changes (assume for the moment equal amplitudes). Diagonal line, ellipse, circle, ellipse, diagonal line at right angles to the first, ellipse, circle and round again. It will repeat this cycle once a second. If the frequencies are 1,000 and 1,001 c/s respectively the visible result will be much the same. If the frequencies are 1,000 and 1,025 c/s the result will be a filled-in square to the eye but with a coarse line structure. If the frequencies are 10,000 and 10,025 c/s, the square will be filled with a fine line structure. The alteration of the square shape to the Golden Ratio beloved of the artists is elementary and in no way affects the argument.

What X and Y frequencies (we cannot say line and frame now) will give definition comparable to the present British 405-line system? To scan one British line takes 0.0001 second of time (nearly). It occupies 4/5 of the length of the screen diagonal. Therefore both X and Y scans must take 5/4 of 0.0001 sec. to swing the beam from edge to edge of the screen. The frequency required is half this, of course, or 10/4 of 0.0001 sec. or, say, 4 kc/s. Notice that in one complete round of the Lissajous figure every point of the image is scanned twice. So 4,000 and 4,025 c/s will give a picture under the suggested system comparable in definition to the present British picture.

Fitting in the Sync

Now that we have all the vision transmitter time used in sending picture detail, we have to put the synchronizing waveform somewhere else. The best place is probably on the sound carrier (as in the DuMont quadruple interlace system). Since the skirl of 4,000 and 4,025 c/s might be considered objectionable, it will be necessary to transmit a harmonic, say the fourth, with which a high-Q time base oscillator will readily synchronize. And since to split 16,000 from 16,100 c/s would be a triumph of filter design, perhaps the fifth would be a better harmonic for the higher of the two time base frequencies.

To summarize the system, at the transmitter two audio oscillators are maintained. These are applied directly to the deflection of the camera pick-up tubes and the monitors. They are also frequency-multiplied to a supersonic tone and set to modulate the audio carrier. At the receiver the a.f. is applied through a simple high-pass filter to oscillators driving the X and Y coils, in synchronization with the transmitter. One-valve oscillators should serve. Notice that this system provides its own flywheel sync.

There is only one complication. Owing to the difference in writing speeds between centre and edge, it will be necessary to modulate the output of the camera pick-up tube with the combination of the outputs of the X and Y oscillators in such a sense as to brighten the picture in the centre—to counteract centre-fading (to transpose a term). Since this can be done at a low level at the transmitter it is of small importance.

The advantages of the system would be:

1. All transmitter time would be employed in sending picture detail.

2. Owing to the random motion of the spot motion distortion would be minimized and subject-pattern distortion (e.g., horizontally striped frocks) would be impossible.

3. Scanning circuitry would be simpler.

4. The need for line elimination would be eliminated.

5. Interference would not upset synchronization.

6. And for the amateur television transmitter (who will be the only person likely to benefit by these ideas for some time) the necessity for a complex counter-down is removed.

Are not such advantages worth while thinking of?

* * *

Q. *Is it not a fact that with the Lissajous-figure scanning the line structure would be coarsest at the centre, just where the information content of the picture is most important?*

A. This is true, but look the bogy in the face. It means that during the first third of the *time* taken by the spot to travel from the centre of the screen to the edge, it would travel half the *distance* from the centre to the edge. This is surely not too bad, and it is a pretty even scan here—in fact, what has been described as the "middle cut" of a sine wave.

Q. *Would not the pattern show a bright spot wherever two lines cross? At these points the screen would be excited twice as often as elsewhere. Would not the picture be formed, in fact, by a series of points?*

A. Certainly the picture will be built up from a series of points, but they will be extremely close together. Consider for simplicity one scan down the diagonal of the frame. This line will cut (following the example given in the article) $\frac{4,000 \times 2}{25} = 320$ lines at right angles to itself, assuming the persistence of the screen to be of the same order of time (1/25 sec.) as the difference between the frequencies of the scans. Not only this, but next time round, since the scans are not locked exactly to 4,000 and 4,025 c/s, a closely similar but not identical set of points will be excited. This contrasts with rectilinear scans, where in a properly adjusted system the lines are superimposed, frame after frame. Critical examination of the screen only would divulge a series of crawling points.

Q. *Although scanning circuits would admittedly be simpler and less scanning power would be needed, what about e.h.t.? Would it not be necessary to use a lot more power than would be needed for scanning alone?*

A. I really do not see that generation of e.h.t., as by an r.f. oscillator, is going to use "a lot more power than would be needed for scanning alone." We have replaced five valves (at least) by two (at most), and so surely a simple pentode r.f. oscillator is not going to be a crushing electrical load?

Q. *How would you establish black level? Your* *argument that all the transmitting time would be utilized in sending picture detail overlooks the fact that periodical breaks in the transmitted signal are needed for this purpose and also for the operation of certain types of camera tubes.*

A. Touché! One edge of the picture will have to be darkened for reference purposes if we are to continue to run a level through the signal as of yore. But how did the black band get there? Because Mr. Baird stuck a black bar at the bottom of his picture to run his phonic wheel. Now I know this is a weak argument—and I give you best before stating it—but if the pioneers of television had used two tuning forks at right angles in two planes with polished faces on one tine of each to generate their rasters, how would the art have evolved then? Would not the problem of black level have been solved by now by some deadly simple method? Such as—I suggest on the spur of the moment—a slight variation in the difference between the two scan frequencies. There are as many ways of doing the job as there are electronic engineers capable of devising them.

Commercial Literature

Micro-Switches with locking action and with reset button for return of contacts after operation. These and many other new items listed in a mid-1954 catalogue of components and accessories from A. F. Bulgin & Co., Bye-Pass Road, Barking, Essex.

Glass-to-Metal Sealing with nickel alloy Nilo 475. Short illustrated description of process used in valve and c.r. tube manufacture, with information on new grades of nickel for valve electrodes Booklet from Henry Wiggin & Co., Thames House, Millbank, London, S.W.1.

Stabilized Power Units with output of 150-500V (variable in four ranges) at 100 watts, and stability of 0.02 % per volt change in input. Leaflets from Newtown Industries, Portmore, Lymington, Hants.

D.C. Potentiometer with built-in spot reflecting galvo, standard cell and supply battery; covers 10μV to 1.9V in three ranges. Leaflet from the Croydon Precision Instrument Co., 116 Windmill Road, Croydon, Surrey.

Meter Tester for helping to detect particles of dirt in movement; provides controlled rise and fall of deflection current so that hesitation in pointer swing becomes apparent. Description from Servomex Controls, Crowborough Hill, Jarvis Brook, Sussex.

Miniature Oscilloscope measuring 4¼in × 7¼in × 7¼in and weighing 6¼lb, with a 2¼-in c.r.t. The Y amplifier has a sensitivity of 50 mV/cm from d.c. to 100 kc/s and 500mV/cm from 20 c/s to 3 Mc/s. Specification on a leaflet from Industrial Electronics, Magnet Works, Derby Road, East Sheen, London, S.W.14.

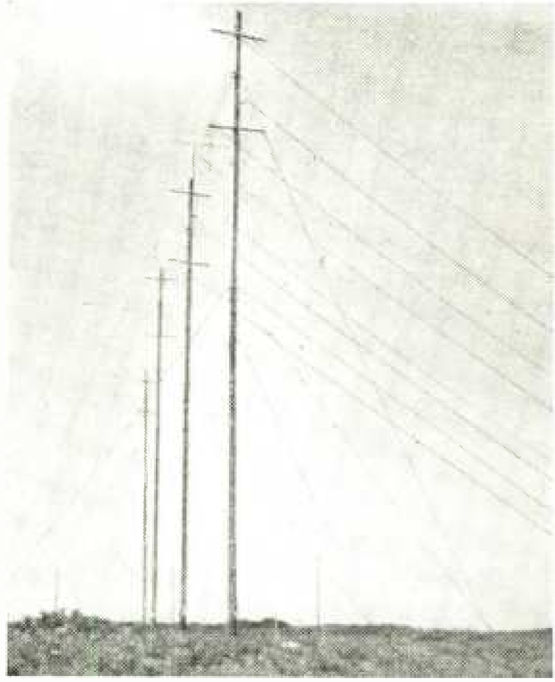
P.V.C. Sleeving in opaque colours. Price list for various gauges from Plasticable, Hawley Lane, Farnborough, Hants. Samples are sent on request.

Soldering Heat Guard for miniature irons; a steel cage attachment to prevent accidental burning of plastic insulation in congested equipment. Also a **Miniature Soldering Iron** with ⅛-in bit and 12-watt element. Leaflets from Light Soldering Developments, 106, George Street, Croydon, Surrey.

Composite Tubing, with main tube of one material and inner or outer sheathing of another. Various combinations of mild steel, stainless steel, copper, cupro-nickel, silver, Tufnol, Paxolin and glass. Booklet (in English and French) giving general possibilities and range of sizes from Accles and Pollock, Oldbury, Birmingham.

Germanium Junction Photocells, measuring $\frac{7}{32}$in diameter by $\frac{11}{32}$in, with sufficient output current to operate a Post Office type 3000 relay. Also **Germanium Junction Power Rectifiers** (20-100mA). Specifications on a leaflet from Standard Telephones and Cables, Warwick Road, Boreham Wood, Herts.

LONG-RANGE TELEVISION RELAY



AS exemplifying television working at extremely long distance, reception of the B.B.C. transmissions in the Channel Islands has been reported from time to time in these pages. But this occasional reception is a very different matter from a regular service, and it is a considerable achievement on the part of Rediffusion to obtain in Jersey a signal good enough for distribution by wire to subscribers in the town of St. Helier. This commercial service, which has just been formally opened, is ultimately to be extended over the whole island. Pictures from Paris, sometimes surprisingly good, are also being received experimentally, and, when the French television service is extended to the N.W. coast, it will be offered to Jersey subscribers as an alternative to the B.B.C. transmissions.

The receiving station at Les Platons, on the north side of the island, is certainly one of the most ambitious of its kind. There are three multiple tilted-wire aerial arrays, each with eight or 12 wires, carried on 80ft masts; one array for London, another for Wenvoe and the third for experimental reception of Paris. Distances are: London, 187 miles; Wenvoe, 150 miles; Paris, 200 miles. Each array has a three-stage low-noise masthead amplifier. Diversity switching between London and Wenvoe is manually operated; automatic control has proved impracticable.

Vision signals are passed from the receiving station to St. Helier, and thence to individual receivers, at a carrier frequency of 9.7 Mc/s. There are seven repeater stations in the line. Sound is transmitted and distributed at audio frequency; thus the subscribers' gear is somewhat less complex than an ordinary television receiver.

The technical development of the system has been carried out jointly by Rediffusion, London, and by the associated Jersey company, Television Research, Ltd.

Storage Systems

Methods of Holding Information for Computing and Other Applications

By BARRY Z. de FERRANTI,* B.Sc., B.E.(Hons.), Graduate I.E.E., Stud. I.E. Aust.

ELECTRONIC calculating apparatus, like the human being, cannot function without a memory or storage system capable of retaining many information patterns. In fact, storage systems are necessary to all automata (machines and animals alike) and, in particular, artificial automata or systems such as telephone exchanges, automatic computors and control systems call for a wide range of memory circuits.

Mechanization of long, tedious calculations was foreseen by Charles Babbage[1] of Cambridge in 1864, and although his computing engine would have been slow the design envisaged automatic access to operating instructions and data. This is necessary so that the whole calculation can be carried out, from the feeding-in of all instructions and data at the start to the production of the answer at the finish, without human participation. Thus the provision of a storage medium, and means for "writing" information into it and "reading out," has become fundamental to many modern electronic systems, not only computors, but many other machines capable of sustained automatic operation.

Memory in Computors

High speed automatic digital computors, many and varied, have been built in research and development centres all over the world.[2] The techniques used in their design, though differing in detail, may be represented as in the block diagram, Fig. 1. Data for the calculation, together with instructions detailing every step of the computation, are set up in the input unit. This may be done by punching a code into tape which is accepted and read photo-electrically by the machine. Then, on starting the machine, all these stored data and instructions are fed at clock-pulse frequency into the memory unit. The first instruction is fed to the control unit where it is stored temporarily until carried out, and is then replaced by the next. The instruction may call for transference of data from the memory unit to the arithmetic unit for temporary storage, while another piece of data is also moved there and the two are, say, added, the sum being transferred to the memory unit. After all operations are complete the final result is stored in the output unit, where it may be observed by, say, an automatic typewriter.

This simplified description shows that several kinds of storage are distinguished: first the input device, whose purpose it is to temporarily store information received at a slow rate and speed it up to the working speed of the computor, as given by the rhythm of the clock pulses. Other devices are required for temporary storage of current operating instructions, and in the arithmetic unit. These temporary storage devices may all be called "registers," and they retain blocks of information, usually a small number of "words" (a term used to describe ordered sets of digits of fixed length, characteristic of the computor and its rhythm). In contrast to these registers, there must be a main store, the memory unit of Fig. 1, capable of retaining a great number of "words." In fact, all the information necessary for the computation must be stored there and this may mean whole tables of special mathematical functions, all the experimental data, the programme of instruction, and the partial results of the computation.

Thus, in a comprehensive machine this main store might consist of two or more parts: a high speed section with short "access time" (the time taken to refer to a given piece of information in the store) and a slower auxiliary section whose data might not be required at such short notice but in larger quantity.

If storage of information could only be achieved by printed books it would be very difficult to devise means for referring to them quickly. Consider then the simplest means for giving information, the answer to a question "yes or no?" All facts can be defined by answers of yes or no to a series of questions, and thus we could measure the information necessary to convey a fact by the number of yesses and noes required to define it. This system of two alternatives is known as "binary," and in a binary system information is indicated by "words" made up from two characters which are usually "1" and "0." In electronic circuits this type of information can be repre-

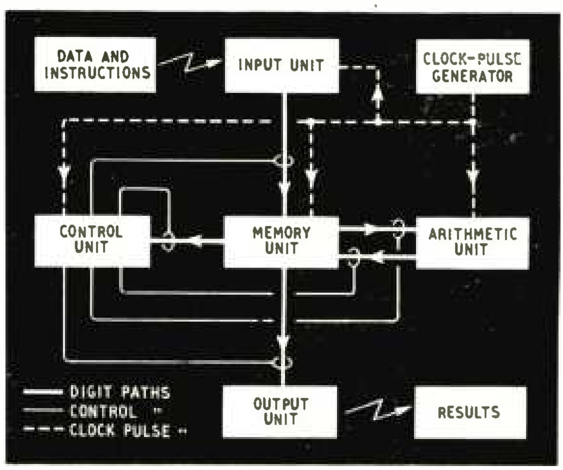


Fig. 1. Block diagram of a general-purpose digital computor, showing various functions of the memory unit.

* Research Laboratories, General Electric Company.

sented by the presence or absence of pulses at particular instants of time. In order that a "word" may be remembered for any length of time, some means must be provided to record this presence or absence of a pulse by a stable state—such as a switch which can stay "on" or "off" accordingly and which is then said to be "bistable." The total number of bistable elements necessary to define a total of n states has been shown by elementary information theory[3] to be the storage capacity

$$C = \log_2 n \text{ binary digits, or bits.}$$

Thus the medium which can provide a large number of bistable elements, economically, will make a good store. However, the merit of the store for a particular purpose will depend on the ease with which the state of its elements can be determined. A single such element may be called a binary cell.

Two-State Devices

Here it is interesting to think of that remarkable storage device, the human brain. In the brain there are some 10^{10} neurons (nerve cells), which are essentially binary cells. Thus some $2^{10,000,000,000}$ patterns of information might be stored. Nothing like this capacity has been provided for any single computor as yet, mainly for reasons of bulk and cost. A device with 10^{10} valves in it would be costly indeed! Thus it is vital that cheap storage means be found, and some of the methods to be described, although using several valves, may require as few as one valve for every thousand binary cells.

Electromechanical relays (e.g., Post Office type 3000) have long been in use as binary cells for storing incoming telephone subscribers' dialling pulses. They are reliable and circuitry has been well established. They take some few milliseconds to operate and may consume a watt or so of power. Other faster, more costly relays are also available.

The electronic valve may be used in a bistable multivibrator circuit, or "flip-flop" as it is generally called. Operation of this switch can be extremely fast, down to 0.1 microsecond, and the cost and power consumption are not much more than those of the relay. Its life may be shorter by a factor of 20, but would perform many, many more operations in that life. In the same way transistors may be used to achieve the same type of counter, with very much less power, smaller size and slightly slower speeds. A cold-cathode triode digital counter which lends itself to registers and circuits making up to some hundreds, perhaps thousands, of counts per second has been described by Peddle.[4] Polycathode counters, Dekatrons, etc., were described by "Cathode Ray" in *Wireless World* for October, 1951.

All these switches make use of the "all or nothing" type of action, in which the switch, once triggered, locks itself firmly to the single "on" current-carrying condition. Other more recent devices have been developed to use a characteristic of certain magnetic and dielectric materials called square-loop hysteresis. This term implies that the magnetic or electric induction in a material does not bear a linear relationship to the exciting energy as it is alternated, but follows a square-cornered loop on the B-H or D-E diagram. Thus, when the excitation is removed, the material remains in a positive or negative remanent state of induction, according to the reduction to zero from either positive or negative excitation. The condition may be tested by further excitation of fixed polarity, say a negative pulse (of H or E) which gives an output if the material is in the positive remanent state by traversing the loop but no output if in the negative remanent state, when the induction just remains at that negative saturated level.

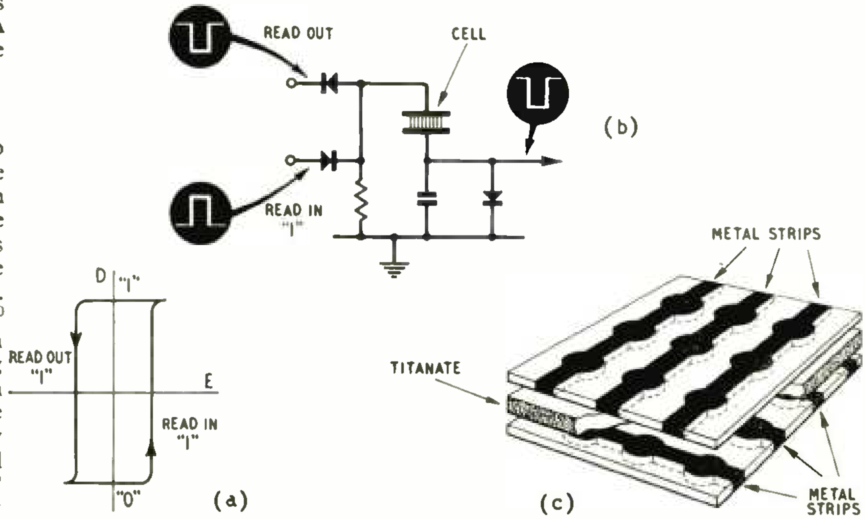


Fig. 2. Storage system using the hysteresis characteristic of a titanate dielectric. At (a) is the hysteresis loop and at (b) a capacitor type of storage cell based on this principle in circuit. At (c) is a matrix incorporating a large number of such cells.

One such device which shows promise of providing very compact storage is called the ferroelectric cell[5]. Certain dielectrics, such as barium, strontium and zirconium titanates (like magnetic materials and their permeability) show a non-linear dielectrical characteristic when biased with an electric field and display hysteresis. A capacitor using such a ferroelectric dielectric can therefore store a pulse. The voltage pulse to be stored may be positive, and when applied to the capacitor leaves it with a positive remanent induced charge, as indicated at "1" of Fig. 2(a). On the application of a negative pulse the change of polarity produces a negative pulse in the output circuit, whereas had the number "0" been required no change of polarity and no pulse would have occurred. Many of these cells may be incorporated in a matrix of electrodes separated by a sheet of the titanate, and in this way it is said that 256 bits of information per sq. inch may be stored. The system requires very little power for operation and it does not drift, but information is destroyed on reading out and the system is very sensitive to any change of environment.

Use of the non-linear characteristics of magnetic materials is well known in magnetic amplifier devices. The application of these techniques to magnetic delay lines and magnetic "shift registers" has been of great importance in computor storage development. (Shift registers are temporary storage units into part of which a pattern of information, say a binary number, may be introduced and along which the pattern as a whole may be shifted, one step per shift pulse.) Certain types of magnetic amplifiers may be connected in series to form delay-lines. These amplifiers utilize an immediate flux build-up in the magnetic core, made possible by the use of series rectifiers[6]. When applied to storage systems, each stage stores the input pulse for one half cycle of a driving waveform by means of the material hysteresis. Fig. 3 shows the simplicity of the circuit, in which the input pulse blocks the current in the input winding of the first toroid during the first half cycle of the driving waveform. Assuming the remanent flux is positive (clockwise), the second half cycle of the waveform is developed mainly across the middle resistor since the impedance of the output winding is low with the flux already set positive. This voltage then becomes the input pulse for the second toroid, and a pulse is given out after a further half cycle of driving waveform. Each stage of the line is thus responsible for a delay of the input pulse by one half cycle of the driving waveform.

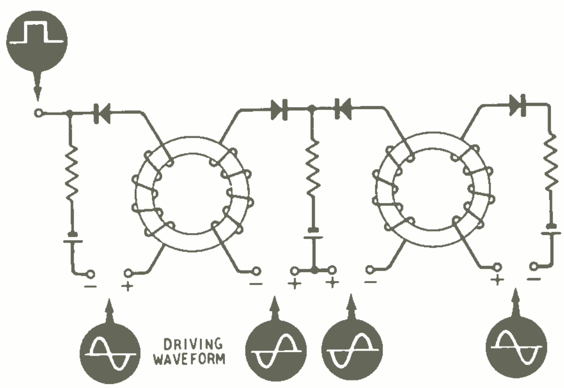


Fig. 3. Magnetic amplifiers connected in series to form a delay line. Each of the two stages delays the input pulse by one half cycle of the driving waveform.

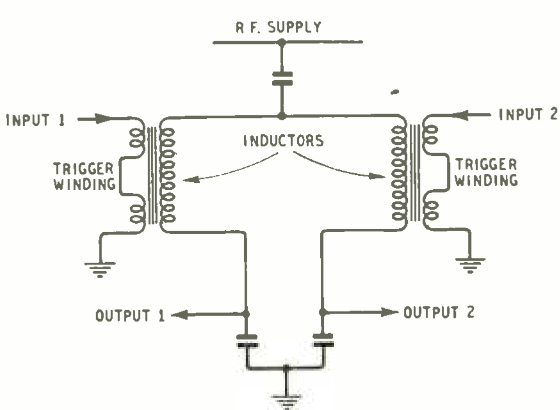


Fig. 4. Flip-flop type of storage circuit using resonance between saturable inductors and capacitors.

The magnetic shift register is an extension of this principle, using antiphase pulse trains instead of the driving waveform. Magnetic shift registers have been built[7] to work at up to 100 kc/s and, like the Fig. 3 circuit, they use toroids and rectifiers but require two shift-pulse trains to transfer the information along the line. These storage circuits are distinct from previous types, in that if the driving waveform or shift-pulse trains are suddenly stopped the information is not lost but is held in the core material remanence. In the Fig. 3 case, however, the pattern of pulses is repeatedly re-circulated and such delay lines can store information by continuous circulation. Interrogation may be made and the maximum time to wait for the information would be the line's basic delay period.

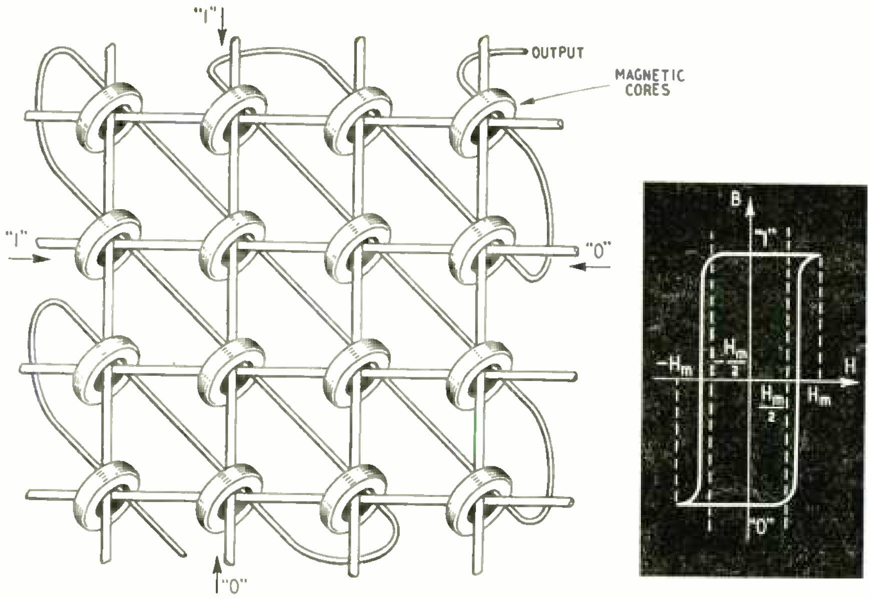
The foregoing systems are such that when interrogated any stored information is automatically erased, and continuous indication of this stored information cannot be given. An important device which overcomes this and may be built into registers of the type described under electronic relays is the "ferrestor." Ferroresonance is the condition which exists when a saturable inductor and a capacitor resonate so that the increased current at resonance keeps the inductor core saturated. Thus for a given supply frequency, a ferroresonant LC combination can have two stable states—a small-current state with an unsaturated high inductance and a large current state with a saturated low inductance which resonates with the capacitance.

A flip-flop using this principle[8] is shown in Fig. 4. The "ferrestor" inductors have trigger windings to change their inductance towards the saturation value which resonates with the circuit capacitance. Saturation is maintained by the resonant circuit current, irrespective of the trigger-winding current. Information may be stored in the same way as in registers using valve flip-flops or relays. Low power consumption, cheapness and fast operation are advantages although a special power supply is needed and a power failure would erase the stored information. Similar circuits may be built using ferroelectric materials.

"Warp and Weft" Memory

Most sensational of the magnetic type storage systems is the R.C.A. "Myriabit" magnetic-core matrix memory.[9] This 10,000-core matrix of 1/16in diameter manganese magnesium ferrite toroids (Fig. 5) depends upon the coincidence of current in two of the co-ordinate wires to give sufficient m.m.f. to take the material round the B-H loop and thus mark the toroid enclosing their intersection with remanent magnetic induction. The principle is similar to that used in the ferroelectric cell described above except that here the output is obtained in a third wire also passing through the toroid.

Discrimination against current in only one of the intersecting wires from putting the toroid in the "1" state is achieved as shown in the B-H curve at (b). The m.m.f. due to only one wire is half that required to saturate ($\pm H_m$) and this is only on the horizontal part of the loop, so that no change in induction, and therefore in output, results. The system unfortunately requires very heavy currents in extremely low impedances and although the core matrix itself is very compact the associated apparatus is bulky. Very high speeds are attainable.



(a) (b)

Fig. 5. Magnetic-core matrix storage system: (a) coincidence of currents in two co-ordinate wires affects the toroid at their intersection point; (b) hysteresis loop of the core material.

Perhaps the most compact of all the magnetic memory systems is the magnetic drum. This has now been well tried in commercial computors, particularly in the huge Manchester University machine,[10] and has been found most reliable. The recording medium, as in standard tape recording, is a thin strip of magnetic material on the surface of a non-magnetic drum on which a magnetic field is impressed at the small air gap of a magnetic recording head. The medium may be a 0.001-in layer of electrolytic nickel, or, as is now preferred, a sprayed coating of magnetic iron oxide of the same thickness. This material has a high figure of merit (coercivity over remanence) and allows a large number of digits to be written per unit length of recording strip. Fig. 6 shows the arrangement.

Digits may be represented by pulsing "cells" of the magetic surface in either polarity corresponding to "0" or "1" or by having a permanent magnetic bias representing all "0"s as shown in Fig. 6. Then if the drum is run at constant speed these cells will present themselves to the read/record head with a frequency which can be made to coincide with the clock pulses controlling the computor.[10] Then, by switching number pulse trains to one or several such read/record heads, a magnetic pattern representing that number will be set up on the rotating drum. This pattern may then be read without detriment within one revolution of the drum, and on the average will have an access time of half the period of revolution. The drums run at very high speeds, usually 3,000 or 6,000 r.p.m., whereas experimental units have run up to 75,000 r.p.m.

Thus with a digit spacing of up to 150 per inch on a 6in diameter drum, 12in long, running at 6,000 r.p.m., a million bits of information could probably be stored. This calls for extreme care in mechanical manufacture—very low friction and perfect balancing—but provides a very large capacity which requires only one or two valves per thousand digits when a million are stored.

As in the Fig. 3 type of register, delay-lines consisting of lumped-parameter units or distributed-constant lines may be used for storage. Here the pattern of pulses moves continuously through the delay medium, and after the basic delay time may be interrogated and the pattern must be then re-circulated. This may be achieved by using the misshapen output pulses to gate new "clock" pulses into the input. A pulse can be made to suffer a delay by passing it into a line of the type shown in Fig. 7 and delays of several microseconds can be obtained. The

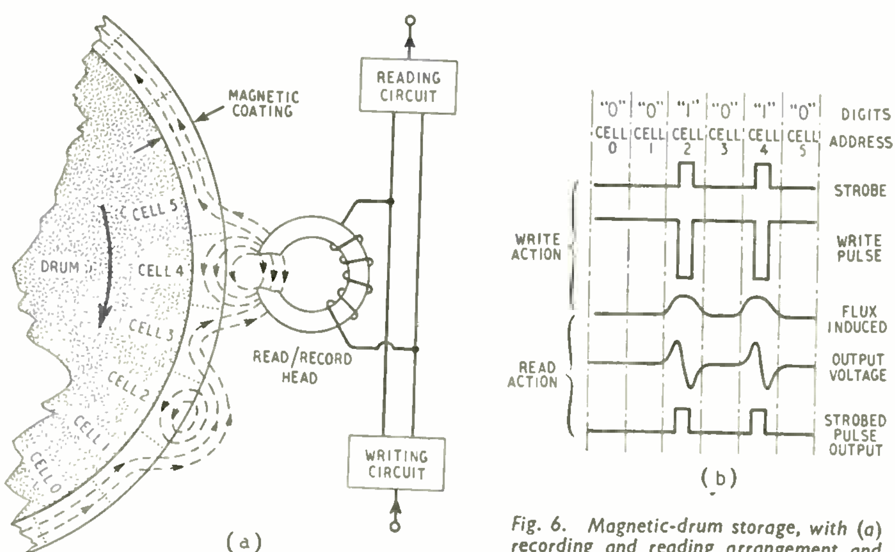


Fig. 6. Magnetic-drum storage, with (a) recording and reading arrangement and (b) waveforms representing the stored digits.

principle has been neatly applied to television sync-separation circuits and in radar systems.

Longer delays can be obtained by converting electrical pulses into acoustic pulses which propagate through a medium for the period of the delay and are then reconverted to electrical pulse form. One device used for this purpose is the mercury delay line. The information must be recirculated and is generally in the form of a pulse-modulated carrier of several megacycles. Mercury delay lines have been used with considerable success[12] and they provide delays from a few microseconds to about a millisecond. One disadvantage is their temperature sensitivity, which can be overcome by careful thermal control. They may require some eleven valves for a millisecond line and must be precision engineered. Solid materials, such as aluminium, have been used, but quartz, to which it is relatively easy to match a pulse transducer, shows promise as a high-speed solid delay line in which multiple paths are possible.

Considerable success has been obtained with another system, which utilizes the magnetostriction property of ferromagnetic metals like nickel. This is very simple, cheap and reliable, requiring fewer valves and no unusual temperature precautions. Delays of the same order are attainable[13] and one advantage of this method is that no carrier is required.

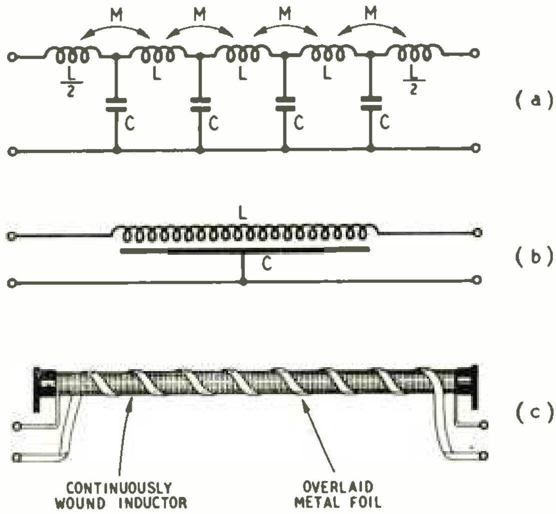


Fig. 7. Electrical delay lines: (a) lumped-constant circuit; (b) distributed-constant circuit with a practical arrangement at (c).

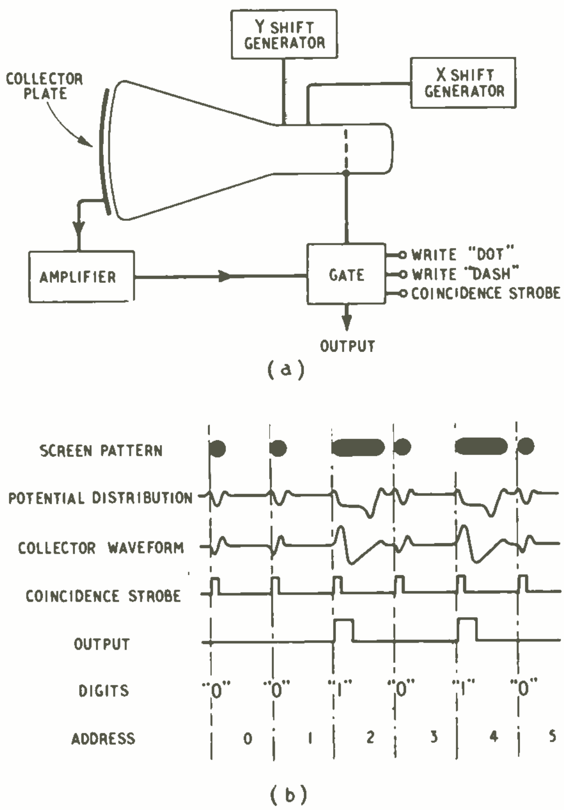


Fig. 8. Electrostatic storage system using a cathode-ray tube (a) with the associated waveforms representing digits at (b).

Electrostatic Storage

The capacitor is a very simple but effective means of storing information. By charging a capacitor through a diode, with low leakage, long storage periods are possible. This is the basis of a device using a matrix of capacitors, connected to "write" and "read" lines via diodes or neons.[11] The storage of information in the dielectric of an electrostatic system is also the basic principle of a very useful system developed by Professor F. C. Williams, of Manchester University.[10] A conventional cathode ray tube is used with its beam directed and modulated to write "dots" or "dashes" on the fluorescent screen, as in Fig. 8(a). The screen adopts a charge determined by the secondary emission characteristic. The resultant potential distribution, shown in (b), indicates whether the beam modulation was a dot or a dash. The pattern may be read out by means of a conducting "collector" screen placed outside the tube face to form a capacitor which indicates the fluorescent screen potential. A coincidence strobe which inspects this collector waveform can then produce an output positive pulse for a dash, or no pulse for a dot, so that binary numbers may be stored and read out with ease. Provision must be made in the programme for continuous regeneration of the stored pattern, interlaced with action periods. This type of storage is eminently suited to registers, and because of its ability to retain a pattern for more than a single cycle of regeneration high speeds of operation are possible, and regeneration circuits may be shared among several tubes. Other charge distributions are possible.[15] Several types of electrostatic memory tubes have been devised, including the Haeff tube,[15] which requires an additional electron beam to hold the face charge level, and the Selectron,[15] a specialized tube operating on a similar principle, which has been built specially as a digital store.

Many computors at present in operation utilize a combined storage system of several of the methods described. For instance, the Manchester machine uses c.r. tubes for the accumulator and control registers as well as for main high-speed storage, while the auxiliary 650,000-bit slow-access store is a synchronized magnetic drum. The N.P.L. Ace computor uses mercury delay lines for its high-speed section.

A comprehensive data handling system would probably best be served by a store using photographic storage[11] for some 1,000,000,000 bits, in conjunction with a magnetic drum with medium access time,[16] and with magnetostriction delay-line high-speed storage. Telephone exchanges call for simple, low running-cost units, and for this purpose cold-cathode tubes have been developed. Other circuits lending themselves to simple production for computor-type storage are magnetostriction delay lines and "ferrestors."

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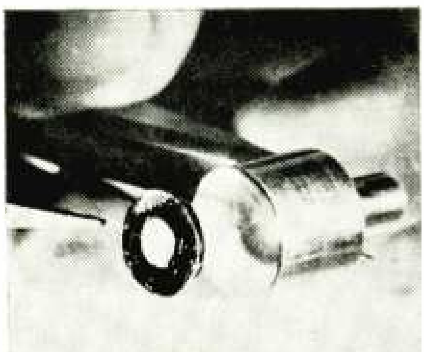
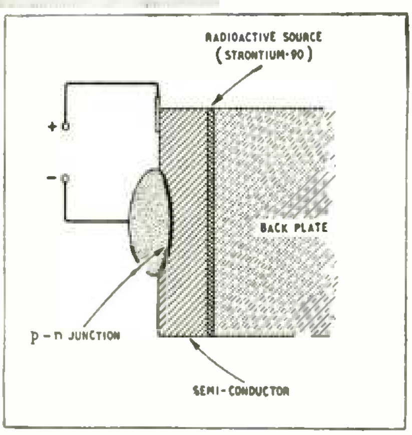
THAT ATOMIC BATTERY

Reasons for Thinking it May Have a Future



RECENTLY the Radio Corporation of America has demonstrated an "atomic" battery providing an output of one microwatt. The battery consists essentially of a germanium junction diode and a layer of radioactive material which emits beta particles. As you no doubt remember, a beta particle is just an electron, and it differs only from the other in being, like the breakfast food, shot from a gun. It is rather useful, however, to go on referring to the fast electron as a beta particle.



Component parts of the RCA atomic battery and (inset) diagrammatic section showing polarity.

The atomic battery uses strontium 90, which is produced as an end product in the "burning" of uranium in atomic piles, and which gives a plentiful supply of beta particles, with a long half-life; a further advantage is that, when purified, strontium 90 emits only beta particles and can easily be screened.

The operation of the battery is fairly simple, though it involves a new and very important effect. Obviously anything which shoots out electrons will finish up with a positive charge which can be "drawn off" to provide energy. The new atomic battery, however, makes use of the speed of the beta particles as well: each beta particle releases about 200,000 electrons as it passes through the semi-conductor. This multiplication effect converts the whole system from an interesting academic device to the makings of a practical battery.

One problem of fundamental importance remains unsolved. It is a basic problem in atomic energy application that the intense radiation damages any material exposed to the radiation: just how much the beta particles affect the germanium crystal and the junction region is not yet known.

It might seem that the whole thing is still just a physicist's toy, but if you recall the relatively short time which elapsed between the first detection, by very sensitive methods, of the phenomenon of nuclear fission and the production of large-scale fission devices (bombs to you) it is not unreasonable to hope that by 1960 we may have at least an atomic hearing aid.

T. R.

Inexpensive 10-Watt Amplifier

BY accepting reasonable limitations in the input and output stages, Mullard have produced a design for a high-quality amplifier which should be both easy and cheap to build.

Few would deny that the principal interest of high-quality enthusiasts at the moment is in the reproduction of gramophone records. The circuit has been designed for use with crystal pickups of which several makes are available giving a high standard of reproduction. In general the voltage output of crystal pickups is sufficiently high to make the provision of a multi-valve pre-amplifier unnecessary, and a single stage preceding the phase splitter is all that is required to make good the loss of gain due to tone-control and to feedback in the amplifier. Full output is given by an input of 600 mV to the input to the tone control. The sensitivity of the amplifier at the grid of the first valve is 50 mV.

A passive RC network provides variable bass and treble lifts up to approximately 10 db at 30 c/s and 10 kc/s, and cuts up to 10 db and 5 db respectively at these frequencies. The main compensation for differences between the recording characteristics of 78 r.p.m. and microgroove records is made by simple fixed equalizers, with values depending on the make of pickup used, inserted between the pickup and variable tone control.

It is perhaps superfluous to say that component values in the main amplifier are chosen to suit the characteristics of the valves selected from the current Mullard range. The first stage is the low-noise EF86, which is direct-coupled to a Schmitt-type cathode-coupled phase splitter (ECC83), thus reducing phase shift at low frequencies.

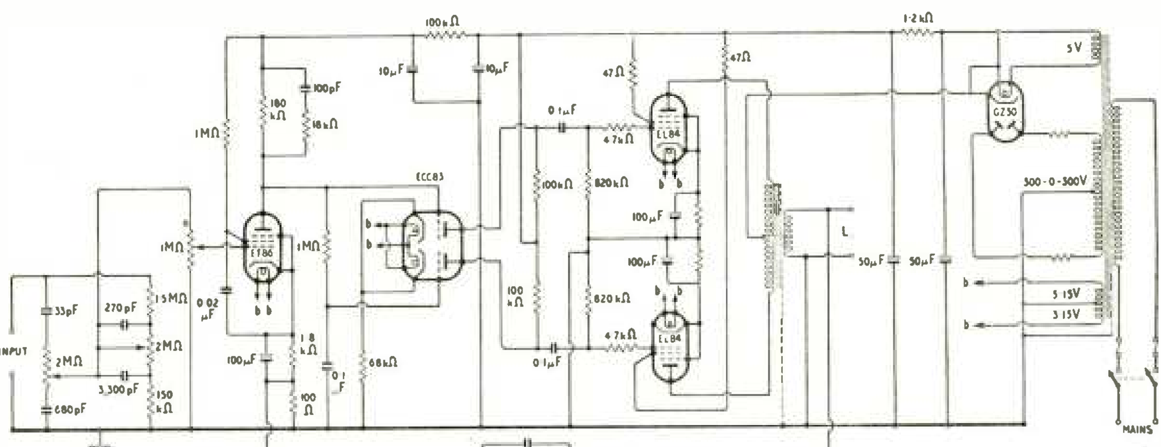
Two EL84 pentodes are used in push-pull in the output stage with separate bypassed cathode bias resistors. It is pointed out that under speech and music conditions, as opposed to steady-state sine-wave testing, a "low-loading" operating condition is preferable to the normal loading derived from the valve characteristics. This also results in reduced standing anode current, well within the rated maximum anode dissipation.

Details for winding the output transformer are available. Alternatively, a Partridge Type PPO can be used. Feedback (26 db) is returned to the cathode circuit of the first stage.

The rectifier is Type GZ30 which gives sufficient current to supply a radio feeder unit in addition to all demands of the amplifier under "normal" as well as "low-loading" conditions. The use of a 50-µF reservoir condenser, with no additional filtering for the output stage is unusual. It is economical and is capable of supplying adequately the transient current peaks of speech and music. No adverse effects on hum are evident, and the figure quoted by the designers for noise and hum for the amplifier as a whole is 73 db below the rated 10-W output.

This output is now generally accepted as ample for all requirements for domestic sound reproduction, and at this level the total harmonic figures quoted are 0.4 per cent at 40 c/s, 0.2 per cent at 400 c/s and 0.3 per cent at 2,000 c/s.

Complete details will be available shortly in a booklet to be issued by Mullard Limited, Century House, Shaftesbury Avenue, London, W.C.3. It is estimated that the cost, including valves, will be in the region of £12 10s.



Circuit of Mullard "5-10" amplifier. The values of the cathode resistors in the output stage are 270 Ω for "normal" loading and 437 Ω for "low loading". Feedback resistor and capacitor values depend on the output impedance of the loudspeaker used.

Skeleton Slot Aerial

Novel Design V.H.F. Aerial Having Interesting Possibilities

By H. B. DENT*

A NEW type of v.h.f. aerial has been the subject of discussion, and no little speculation, in amateur circles lately. It takes the form of a rectangular frame of metal slightly less than a half-wavelength long and about one third of this wide. At any rate this ratio of length to width has proved satisfactory on the 2-metre amateur band, but whether or not it holds good for other bands remains to be seen.

According to one account, the aerial was evolved by pruning away the metal surrounding a slot aerial with the object of ascertaining how far this could be carried without materially affecting its performance. Most surprisingly it was found that the surround could be reduced to a mere rim of metal and still the aerial behaved, or appeared to behave, as an effective slot aerial. The reason for this element of doubt regarding its mode of operation will be apparent later, but the essential fact remains that its performance was in all respects the same as that of a slot having a large surround of metal. In view of the way it was evolved the aerial has appropriately been christened a skeleton slot.

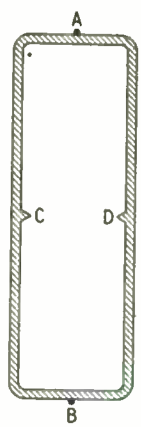
Pruning away most of the surround removes one of the main objections to a slot aerial for outdoor use; namely, its very high wind resistance even when wire netting or extruded metal is employed. This applies particularly in coastal areas, where the writer's station is situated, and also on elevated sites.

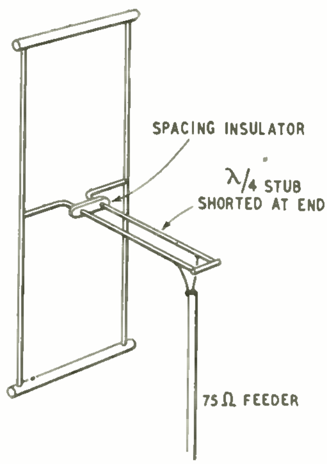
In comparison with a slot aerial the skeletonized version radiates, and receives, horizontally polarized waves when erected with its long sides vertical and the polar diagram is a figure-of-eight pattern in both the aximuth and vertical planes, and at right angles to the plane of the frame. The concentration of the high-angle radiation into more useful lower angles results in a useful power gain over a simple horizontal half-wave dipole aerial.

Mounting

Other respects in which the skeleton slot resembles a slot are that the mid-points of the two short sides, A and B in Fig. 1, are at zero r.f. potential and form convenient anchorage points for securing to a mast, and no insulators are required. The mid-points, C and D, of the long sides are at high impedance, about 600 ohms or so for a skeleton slot, and it is here that the feeder is connected. Feeders of this characteristic impedance are awkward to handle, especially on the amateur bands where generally it is necessary to arrange for the aerial to be rotated, but 75-ohm cable can be employed by interposing a quarter-wave stub, shorted at the far end, and tapping the feeder in at the appropriate point. It should be possible to achieve proper impedance match by fitting a quarter-wave transformer of the correct impedance, but owing to some uncertainty regarding the actual impedance at the feed points this method has not so far yielded very satisfactory results.

In Fig. 2 is shown one of the skeleton slots used for 2-metre communication at the writer's station and





Left: Fig. 1. The skeleton slot aerial. Right: Fig. 2. One method of matching a low-impedance feeder to a skeleton slot aerial.

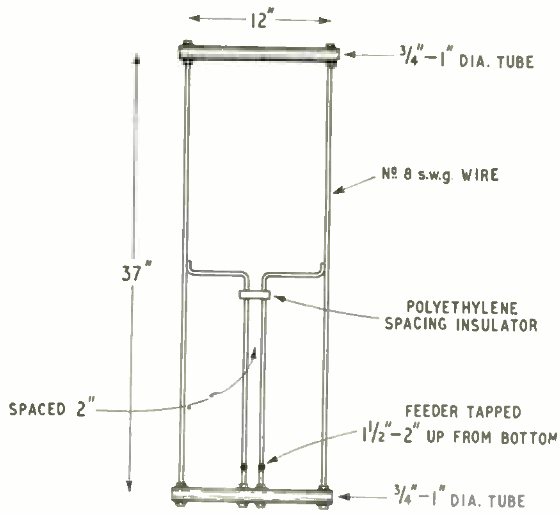


Fig. 3. An alternative method of arranging the matching section. Dimensions are for a working frequency of 145.1 Mc/s.

* Amateur radio station G2MC.

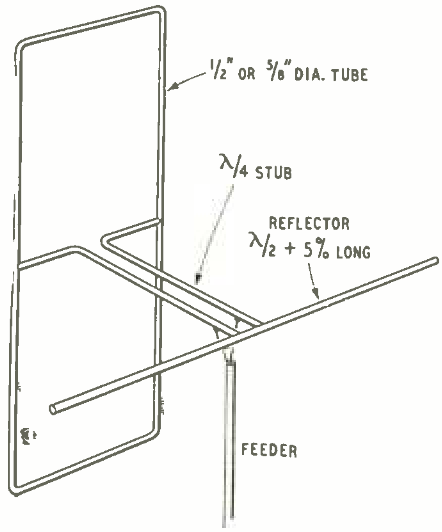


Fig. 4. A reflector can be mounted behind a skeleton slot in the manner shown here. Note this reflector is at right angles to the long sides of the slot.

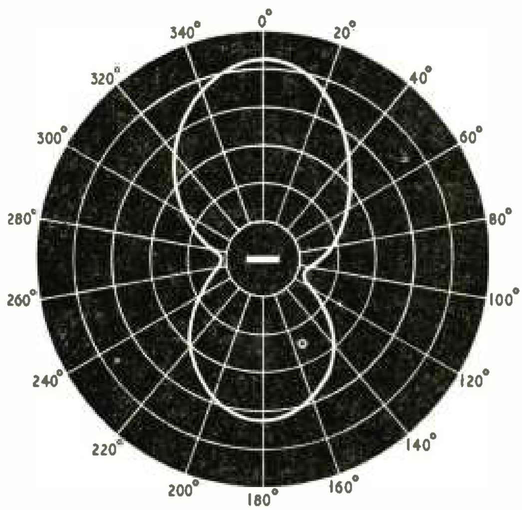


Fig. 5. Azimuth polar diagram of a skeleton slot, the reason for the asymmetry is explained in the text.

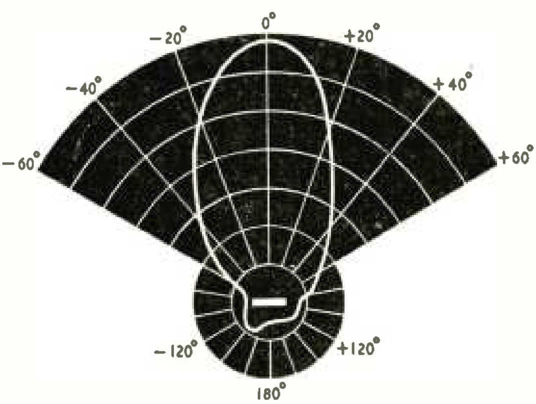


Fig. 6. The cddition of a reflector to a skeleton slot gives it unidirectional properties and improves the gain.

Fig. 3 a later version with the quarter-wave stub run down the centre of the slot and terminated at one of the short sides of the frame. In both cases 75-ohm feeders were used and there was no noticeable difference in the performance; the unorthodox way of installing the matching stub in Fig. 3 seems quite satisfactory. It also simplified erection as the supporting pole, a metal one, was clamped to the bottom and top tubes and by earthing the base of the pole the whole aerial was effectively protected against lightning. In a later model stouter side members were fitted and the pole fixed to the bottom tube only.

There is insufficient data available to say what the optimum thickness (if there be an optimum, not merely a minimum) of the surround should be, but some users say $\frac{3}{8}$ in to $\frac{5}{8}$ in is satisfactory on 2 metres. On the other hand the writer has been getting good results with quite thin side members and thicker end-pieces. The skeleton slots shown in Figs. 2 and 3 had 1-in diameter tubes for the ends (short sides) and No. 8 s.w.g. wire (0.160 in) for the long sides; this gauge wire is used also for the stub. The actual size of the slot is included in Fig. 3.

A reflector can be fitted behind a skeleton slot to give it unidirectional properties and one way of arranging it is shown in Fig. 4. The matching stub can take the form in Fig. 3, but Fig. 4 might be more convenient in some cases as the reflector serves also as the shorting bar for the stub and the pole can be clamped to this point without interposing insulators. If the pole is fitted at a point of balance an insulator must be used and the aerial is then not so convenient to earth.

A few measurements made with a skeleton slot constructed as in Fig. 3 provided the azimuth polar diagram of Fig. 5. The asymmetry in the front and back responses may be, and very like is, due to the use of a coaxial feeder without the customary "balun" coupling at the aerial end. Reflections from the feeder could account for this asymmetry.

Polar Diagram

Compared to a half-wave dipole at the same mean height the skeleton slot showed a marked gain. When a reflector was added the polar diagram took on the pattern shown in Fig. 6 giving an improvement of 2.5 to 3 db over the slot alone. Only approximate measurements have been made, but they serve to show the aerial has promising possibilities and is worthy of further investigation.

A comparison was made between the skeleton slot and a half-wave dipole connected alternately to the transmitter; both were erected indoors in the same room and at the same height and reports received from another 2-metre station about 50 miles distant. Signals with the skeleton slot and reflector were reported to be just under one "S" point better than the dipole, and assuming 6 db per "S" point this represents a gain of about 4 db over the dipole.

No data has been collected of the aerial's performance for any other purpose than 2-metre communication, but it was vaguely hinted in the earlier part of this description that it might have other applications. It would not be too unwieldy for example, for f.m. reception on 90-odd Mc/s as its length would not be greater than 5 ft and, of course, it would be erected vertically. The width of the frame and minimum thickness of the rim remains to be decided, but for an experimental model the ratio of 3 or 3.5 to 1 suggests itself as a good compromise between electrical requirements and mechanical rigidity. With a slight modification to the thickness of the surround the same general remarks would apply to Band III television (⅜ in tube being thought suitable) and also to Band IV (if it materializes) and for the 70-cm amateur communications and television band.

It remains to be seen whether or not there is an optimum shape for different frequency bands or if there is only a minimum width in relation to length for reasonable efficiency, and further information is needed on the exact feed-point impedance of different shaped skeleton slots and the effect of rim thickness.

Experiments have been conducted with vertically stacked slots and the results are most encouraging; it is said that two stacked skeleton slots with reflectors give a performance comparable to a well-matched pair of 3-element yagis stacked vertically.

Taken by and large there seems a lot to be learnt about this interesting aerial; one useful line of investigation would be into the exact mode of operation and whether it is behaving as a true slot or in some other manner. For example its polar diagrams closely resemble those of a pair of half-wave dipoles spaced a half-wavelength apart vertically and fed in phase; assuming for argument horizontal polarization.

Choosing a Television Standard

Advantages of 405 Lines

New Zealand has recently been considering the possibility of establishing a national television service, and it is interesting to note that 405 lines has been recommended as a suitable standard. This article is based on a lecture given by N. R. Palmer, M.Sc., A.M.I.E.E., to the Wellington sub-branch of the Brit. I.R.E., and we are indebted to the New Zealand journal *Radio and Electronics* for permission to use their published report of the proceedings. Mr. Palmer, an engineer of the New Zealand Broadcasting Service, was partly responsible for recommending the 405-line system, and in his lecture he discussed some of the technical considerations which led to this choice.

THE main consideration in choosing a television standard is the way in which it affects the economics of receiver manufacture. In spite of the high capital cost of transmitting and studio equipment, the highest cost to be faced by the public is ultimately the money expended in purchasing receivers. Thus, by far the most important aspects are those which have an effect on the manufacturing cost of receivers.

It is interesting to note here that the American 525-line standard was designed round the fundamental fact that the channel width of 6 Mc/s had been laid down in advance. The design of the standard thus consisted in attempting to make the best possible use of that channel width.

On this question of ether space it is, of course, necessary to maintain a responsible attitude. When there are other services requiring channel space we must not adopt a television standard which will be wasteful of bandwidth. As for the possible introduction of colour television, even if a 405-line system is put into operation it will not preclude the addition of colour at a later date, and when this comes about it will not take up any more bandwidth. Of all systems in operational use, the B.B.C. one is the most economical of channel space.

In determining the best picture frequency to use under given conditions, several things have to be taken into account. Perhaps the most important is the frequency of the mains in the greater part of the country to be served. In America, this is predominantly 60 c/s, while in Europe and England it is 50 c/s, as in New Zealand, so that America has decided on a picture frequency of 30 per second, while Britain and Europe, though their standards differ markedly in other respects, have chosen 25. There is also the question of whether or not the television picture frequency should operate in synchronism with the mains. From the point of view of flicker, the advantage of a high picture frequency is very much greater than in direct proportion to that frequency. Curves are available which relate the minimum observable flicker to the picture frequency, and these show that the reduction in flicker caused by raising the picture frequency from 25 to 30 a second enables the maximum brightness to be increased some five times without flicker being objectionable. Even so, a more important consideration still is that of running the system synchronously with the mains, since this has an important bearing on the amount of hum tolerable in a receiver. Synchronous working greatly eases the smoothing requirements in receivers and therefore renders them less costly.

How Many Lines ?

The question of the number of lines per picture has to be approached from two points of view. First of all, how many lines can be considered to produce a satisfactory degree of resolution for the purpose of home entertainment? With the acuity of the eye taken into account, together with the known preference of viewers for looking at the picture from a distance of between five and eight times the picture height, it is estimated that acceptable results can be produced with a balanced resolution of about 300 to 350 lines. This is the figure actually achieved in the British 405-line system with its normal video bandwidth of 3 Mc/s. If this is regarded as a minimum acceptable figure, then any increase in the number of lines must be evaluated in terms of the improvement in picture quality, as against the additional bandwidth necessary if equal horizontal and vertical resolutions are to be retained.

A decision on this point will be influenced by what the receiver manufacturers are able to accomplish in the way of providing overall bandwidth. It is noteworthy that, on the average, receivers built for the 525- and 625-line standards actually possess little more bandwidth than those built for the British 405-line system. This gives the 405-line system a considerable practical advantage over the other standards because of an insufficiently appreciated technical fact. This is, that *for a given bandwidth*, the horizontal resolution attained actually decreases rapidly with increase in the number of lines used, once that number exceeds the figure for which the given bandwidth provides balanced horizontal and vertical resolutions. In point of fact, for example, the horizontal resolution obtained with a bandwidth of 3 Mc/s is a maximum at approximately 350 lines for an actual line number of 400, and unless the bandwidth is increased as well as the number of lines horizontal resolution deteriorates rapidly. For instance, a 625-line system in which a receiver has a bandwidth of only 3 Mc/s will have a horizontal resolution of only 237 lines! Put another way, a 625-line system needs a bandwidth of 4.7 Mc/s to obtain *the same* horizontal resolution as a 405-line system with a bandwidth of 3 Mc/s.

On the economic side of the question, the consensus of opinion among receiver manufacturers everywhere is that if their sets have to give appreciably more bandwidth than they do at present it will make a considerable difference to their selling price. The conclusion has been reached that the 405-line system provides the best picture quality at the lowest receiver cost, so that, unless there is any good reason for modifying it, the British 405-line system is the one to be recommended. Some American engineers are not at all sure now that in departing from their pre-war standard of 441 lines they have done the right thing.

Type of Modulation

Other important matters are polarity of modulation and the type of sound modulation to be used. In America, where negative modulation is used, the picture is much more susceptible to loss of synchronism due to interference than in Britain, where positive modulation is used. On the other hand, negative modulation makes it a simpler matter to provide automatic gain control in the picture channel of a receiver, and this was probably a major reason for the American choice in this respect. In the U.S.A., where several transmitters serve the same area with different radiated powers and locations, automatic gain control is very desirable, but in Britain, where a given area is served by only one transmitter, the necessity is not so great. In this respect, New Zealand is much more likely to acquire conditions approximating those in the United Kingdom, and there is no real justification for recommending a change to negative modulation.

On the sound side there are arguments for and against f.m. sound, but the operative point is that the theoretical improvement over a.m. is realized only under the best possible conditions, in which the receiver's circuits are perfectly aligned. In practice, such conditions could be the exception rather than the rule. At the same time, an f.m. sound signal takes up more channel width than does a.m., and even where it is used the deviation is limited to 25 kc/s as against the 75 kc/s used in f.m. broadcasting. This again reduces the advantage of f.m. over a.m. Also, an f.m. sound section is more costly than an a.m. one in a receiver, so that unless something like the full advantage is actually obtained it is a poorer proposition economically.

Aerial Polarization

The existence of relatively different topography for the propagation of television signals in New Zealand has caused the following radio frequency channels to be recommended:—

Auckland	63 to 68 Mc/s
Wellington	48 to 53 Mc/s
Christchurch	58 to 63 Mc/s
Dunedin	53 to 58 Mc/s

At these frequencies the quasi-optical propagation of very high frequencies is minimized and shadow effects in places like Wellington and Dunedin will be less troublesome than at higher frequencies.

The only difference between the New Zealand recommendations and standard British practice is that for New Zealand horizontal polarization has been recommended. This has been done on the ground that the choice cannot affect receiving installations to any extent, whereas the choice of horizontal polarization does enable high-gain transmitting arrays to be more readily used, thus effecting a considerable saving of transmitter power or an increase in the service area for a given power. From the propagation standpoint each has its advantages and disadvantages and neither is markedly superior to the other.

An additional point about the British picture frequency of 25 per second is that it enables standard 35-mm motion picture film to be scanned at this same speed, causing only an insignificant increase in the speed of motion and in the pitch of the sound. Flying-spot scanners are used and these give such good results that the pictures are frequently indistinguishable from "live" programmes. In America, on the other hand, they have to resort to the iconoscope camera for scanning film because it is necessary to use a storage type of pick-up tube. This enables them to illuminate the film twice during one frame and three times during the next, the electronic scanning taking place while the film is in darkness and even while the pull-down is taking place. In this way the film can be run at 24 frames a second—its standard rate—while the television picture rate remains at the correct figure of 30 per second. On account of these difficulties films in America give substantially poorer quality pictures than live programmes.

Against that, however, it is a much simpler problem in America to produce high-quality film records of television programmes by photographing a special display tube. In Britain, this is difficult on account of the 1-c/s difference between the film rate and the picture rate.

"Plastic Circuitry"

Aid to Preparing Diagrams for Reproduction

By JOHN SCOTT-TAGGART,* M.I.E.E., F.Inst.P. and EDWIN J. MOYSE*

FOR the past year experiments have been made with a method of preparing circuit diagrams which aims at saving time, labour and cost, and giving better and more uniform reproduction.

In brief, the method consists in using very thin transparent plastic tape one side of which is sticky, the other side having a symbol (or, say, lettering) printed thereon. A reel of the tape would usually have only repetitions of the same symbol although two or three different symbols might be printed if desired. The draughtsman cuts off the required symbol and sticks it on a sheet of tracing cloth, tracing paper or plastic. Initially the draughtsman himself drew the lines joining the components of a circuit but in the developed system the lines and even the junction dots are printed on tape. Lettering and numbering of components are done with printed tape and the values of components are similarly inserted. Needless to say, only a large drawing office would have all the reels required for all the symbols that might be necessary. Many symbols (e.g., transformers) can (and, often, must) be built up of simpler symbols. The most commonly used symbols will be those representing resistors, capacitors, inductors and valves. Rare symbols would, like special wording, be normally prefabricated; i.e., the draughtsman's assistant would draw them individually on a short length of plain (unprinted) sticky tape.

There are objections to the older idea of using symbols printed on gummed paper although draughtsmen sometimes use adhesive strips of printed words or component designations (e.g., C2). Professional draughtsmen have always maintained that the printed-symbol scheme is messy and just not worth the bother. This view comes from a source that might be expected to react against any "mechanization" of the profession. However, there never seem to be enough draughtsmen nowadays and dilution in the field of electronic circuitry is likely to be beneficial. Circuit-drawing has always been a Cinderella of draughtsmanship and yet the use of inexperienced staff—even with the valuable aid of stencils—has not been a great success.

The authors are primarily interested in circuit-drawing from the technical handbook angle. This involves a reduction of size and it is important that the reproduction should be accurate; a broken line or the loss of a decimal point in printing may be the consequence of ill-considered draughtsmanship. The detailed planning of thickness of lines having regard to the final printed size of the circuit is a matter that is often neglected, and the use of what the writers venture to call "plastic circuitry" will do much to eliminate faulty work. The experimental work here described was done by E. J. Moyse (a leading draughtsman at Admiralty Signal and Radar Establishment) and was based on circuits drawn by the first-named writer. It is felt that much thought must still be given to the relative sizes of symbols, letters and figures and especially to the thickness of the lines.

The size of letters and figures is also of the greatest importance, but opinions on this matter differ.

The purpose of this brief article is to present an idea at a stage where Government Departments, industry, the Press, the teaching profession and the

* Admiralty Signal and Radar Establishment.

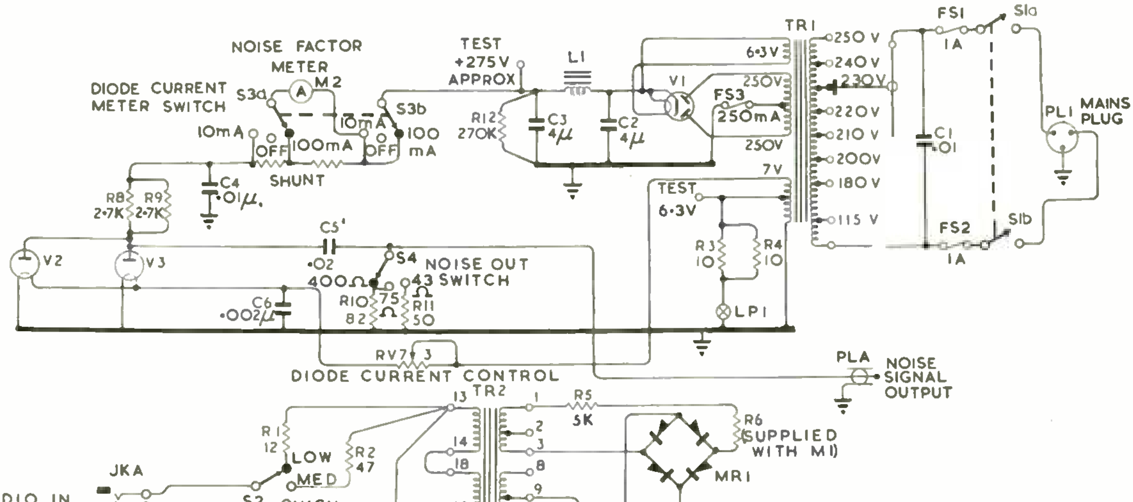


Fig. 1. Circuit diagram reproduced by the method described in the text.

public can assist by criticism or otherwise in the shaping of its future—if any. One adds the words "if any" because powerful forces are always arrayed against making anything "easier" and they might even be right for other reasons.

A complete circuit (of a noise generator) is shown in Fig. 1. All the parts of it (symbols, lines, etc.) were either printed on "Sellotape" or drawn by hand with Indian ink on blank "Sellotape." A considerable number of symbols have been printed by the makers of "Sellotape" but the lines, lettering and some items were drawn specially (and less successfully). It is part of the proposed scheme that even lines of the required thickness should be available "on the reel." The work of putting the circuit together is relatively unskilled but clearly the planning of the circuit should be done by the author, or at least by someone who understands the subject. A pencil sketch is sufficient but the arrangement should be correct. Too little thought is given to the clear presentation of a circuit; opinions differ as to how far this is the draughtsman's job.

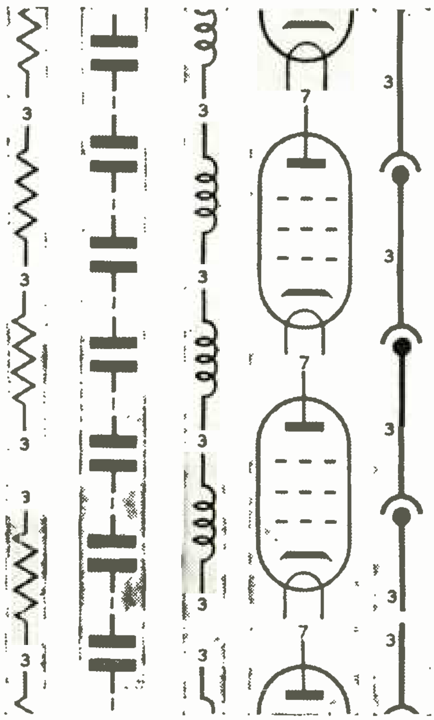


Fig. 2. Typical symbols printed on "Sellotape" strips.

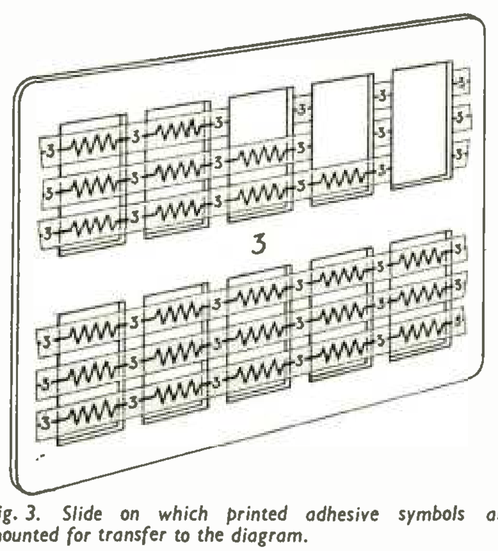


Fig. 3. Slide on which printed adhesive symbols are mounted for transfer to the diagram.

Fig. 1 is experimental. The component designations are not all standard because the manufacturer's own references had to be retained in this case. In the opinion of the present authors, the letters and figures are too large while the lines of some components (e.g., resistors) should be as thick as the junction lines.

Fig. 2 shows five pieces cut from "Sellotape" printed reels. The technique suggested is to cut off a symbol and stretch it across a hole cut in the celluloid slide shown in Fig. 3; the tacky surface of the tape adheres to the slide. If the slide is to accommodate a plurality of different symbols, the holes will be of different sizes; each hole is numbered and so is the tape at intervals; this arrangement takes care of symbols of different length. Several slides will be required. The slide filled with symbols is moved about over the work till the required symbol is in the correct position; the tape is then pressed down with the finger and cut at both ends with a penknife, care being taken to avoid cutting the tracing cloth or other base material. Mistakes are easily corrected by peeling off the tape and changes in the circuit are easily made in the same way.

Although tracing cloth or, better, tracing paper may be used as the base, the best material to obviate crinkling is "Kodatrace" tracing film which has one surface matt. A large sheet of this is placed over squared paper and affixed to the drawing board (by Scotch tape rather than drawing pins). The circuit is now roughly drawn on the "Kodatrace" with a "Chinagraph" pencil, the operator copying the author's sketch. Corrections can be made after wiping off errors with the aid of soap and water, carbon tetrachloride (e.g., "Thawpit") or petrol. The squared paper shows through the "Kodatrace" and so simplifies the drawing. The sizes of the component symbols are known but the spacing of them calls for some skill. A second sheet of "Kodatrace" is now placed over the first and held down as before. The "Sellotape" symbols are now placed in position over the "Chinagraph" symbols which show through. Lettering and numbering is the next process. The junction lines are now added and overlapping is usually desirable. Junction dots and radius lines (for corners) are put in last. The "Chinagraph" drawing on the first sheet of "Kodatrace" may be cleaned off with petrol and the sheet used again. Another system may be adopted if the author has drawn a well-balanced (though rough) diagram; the sketch is photographed and enlarged (by, say, a "Statfile" machine) so that the symbols are about the same size as on the "Sellotape"; a sheet of "Kodatrace" is then placed over the enlargement and the "Sellotape" affixed. The "Sellotape" on the main drawing appears to stick securely for an indefinite period; after a year there is no sign of peeling off, but it may be peeled off deliberately. Much practical experience has been gained but these few preliminary details may stimulate some interest.

This article is based on work done at Admiralty Signal and Radar Establishment.

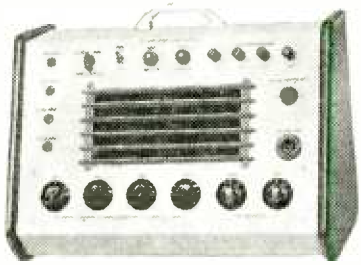
Manufacturers' Products

NEW EQUIPMENT AND ACCESSSORIES FOR RADIO AND ELECTRONICS

Portable P.A. Amplifiers

IN two new public address amplifiers made by Hifi, Ltd., Derry Street, Brierley Hill, Staffs, alternative low- and high-impedance outputs are provided, the latter for "100-volt line" working. Three-position treble and bass controls give cut and boost in addition to a normal level response. Sensitivity at the microphone input is stated to be 0.2 mV, and 100 mV at the gramophone input.

Type PA 25W uses two 6L6 output valves, is rated at 25 watts and costs £40. A battery adaptor (price £15) can be supplied for use with a 12-volt accumulator where a.c. mains are not available. In Type PA75W, two 807 valves in the output stage give a nominal 75 watts (60 watts with less than 3 per cent distortion); the price is £65 10s.



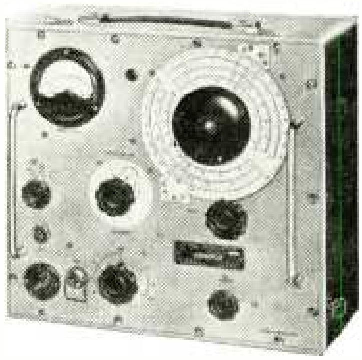
Portable p.a. amplifier by Hifi Ltd.

V.H.F. Signal Generator

SHOWN in the illustration is the latest addition to the Advance range of signal generators. It is the Type D1/D and covers 10 to 300 Mc/s in six switched ranges. A 50 : 1 reduction drive and vernier scale enable small and accurate changes in frequency to be made and also ensure exact re-setting to any given frequency. Each range has a separate scale calibrated in frequency and the scales are disposed over the whole of 360 deg of the dial.

The output impedance is 75 ohms and the signal is continuously variable from 1 μV to 100 mV by means of a five-position decade multiplier and a continuously variable attenuator calibrated in microvolts and in decibels. From 10 to 150 Mc/s the attenuation accuracy is $\pm$3 db and $\pm$1 μV and from 150-300 Mc/s it is 4 db and $\pm$2 μV. Triple screening of the oscillator is employed. The output can be pure c.w. or c.w. modulated 30 per cent by either a sine wave or a 50/50 square wave at 1 kc, $\pm$100 c/s.

Three models are available covering different supply voltages. Power consumption is 25 W, the weight 34 lb, the size $14\frac{1}{4} \times 12\frac{3}{4} \times 8$ in and the price £97. It is made by Advance Components, Ltd., Back Road, Shernhall Street, London, E.17.



Advance Components signal generator

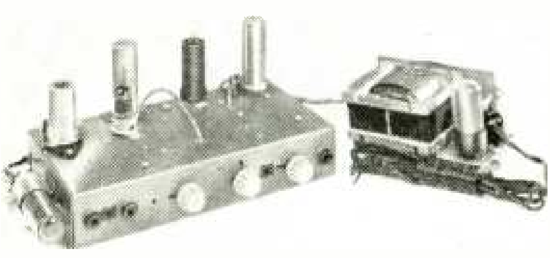
Tape Recording Amplifier

DESIGNED to work in conjunction with the Mark III tape deck, the Truvox Type C amplifier may also be used as a separate microphone or gramophone amplifier.

The power output is 4 watts, and the hum level is stated to be 50 db relative to this output. The rectifier and mains transformer are mounted on a separate small chassis. An erase voltage of at least 150 is provided by the 45-kc/s oscillator. Normal h.f. bias is approximately 80 V.

The recording characteristic is fixed to suit the Mark III tape deck, but the playback characteristic can be varied by a tone control. A "magic eye" level indicator is included.

Made by Truvox, Ltd., 15, Lyon Road, Harrow, Middlesex, the price will be in the region of £16 16s.



Truvox Type C recording amplifier

RANDOM RADIATIONS

By "DIALLIST"

Eurovision

DURING quite a bit of the eight-nation television programme exchange I was staying at a little place in a rather-worse-than-fringe area; hence I had to miss a number of the transmissions. But I did manage to see a good many of them, including those from Switzerland and Italy on the opening day. In common, I expect, with most other viewers I was most agreeably surprised by the quality and the steadiness of the pictures. Those of the Hungary *versus* Germany soccer match from Basle, for instance, were technically almost as good as our own O.B.s and I thought that the camera work was better than ours often is. The whole thing was a triumph for all concerned and must have meant a vast amount of hard work and hard thinking. When you consider the thousands of valves, each one a possible source of distortion, through which vision signals from the more distant places must have passed before reaching the control electrode of your c.r. tube you realize how almost miraculous a feat it was.

Fringe Area—But Only Just

It's something of an experience nowadays to find yourself in a town where your eye can travel over the roofs and chimney stacks of whole streets of houses without seeing a single television aerial. The little place I mentioned in the preceding paragraph is on the Suffolk coast, well over 80 miles as the e.m. wave waggles from its nearest TV transmitter at Alexandra Palace. I was told that there was only about a dozen television receivers in the place; and really I'm surprised that there should be as many, for the chats I was able to have with some of their owners disclosed that, even with the most elaborate of aerial arrays, there was no such thing as reception that you could bet on. If you got a picture at all, it was likely to be good; but more often than not there wasn't any picture. However, I heard no grumbles. The Coronation had come through splendidly; and that made up for a lot of disappointments. If you did get a programme it was an achievement to be proud of; if you didn't, it was just one of those things. Every one is hoping for great results from the Norwich transmitter, when it gets going, and I sincerely trust that these hopes may be fulfilled. The cheerful television adventurers of Southwold well deserve a lucky strike.

New Long-wavers

PROBABLY you've already heard the new Norwegian and Danish long-wave stations, each of which is rated at 200 kW. It's a considerable feather in our cap that both are British made: actually, each is a Marconi twin, consisting of two 100-kW transmitters working in parallel. The design and layout are very similar to those of the Third Programme transmitter at Daventry, which is also a twin with a possible power output of 200 kW. In this case, though, the output is kept down to 150 kW to conform with international agreements. This Daventry transmitter was, I believe, the first in the high-power class to be designed for unattended working and the first to be entirely air-cooled. Like it, the Norwegian and Danish stations will eventually be remotely controlled. In both the radio and the television fields our exports have increased by leaps and bounds since the end of the war—and this in face of very keen competition by other countries. Their earnings of foreign currency have, in fact, helped in no small way to bring back to our shops some of the things which till recently we hadn't seen for years.

Guaranteed

IT has always seemed to me a ridiculous business that a radio or television receiver should not be covered by a single, comprehensive guarantee. Such a guarantee is the usual thing in, at any rate, some other countries; but when *we* buy new sets we find the valves warranted for three months, the c.r. tube of a TV receiver for six months and the rest of the components for a year. It's a queer state of affairs after all these years of radio manufacturing history, for it almost suggests that while those who make transformers, capacitors, resistors, switches and so on now have a lot of confidence in their products, makers of c.r. tubes have less and those of valves very little indeed! Isn't it about time that the radio industry got down to straightening out the guarantee position? A twelve-months' guarantee for everything is what I'd like to see; but I'd rather have a comprehensive six-months' guarantee than the present fiddling arrangement. There must be plenty of figures available for the probable cost to valve and tube makers to be worked out and the necessary small increase in prices to radio and TV set manufacturers shouldn't add greatly to what the man in the street would have to pay for their products. The result would, I'm sure, be to improve sales, for the prospective purchaser would have a much greater feeling of security.

Illustrated News

OLD readers may recall that even before the war I was urging the B.B.C. to give us daily television news bulletins as an important part of the television service. Their coming is still a few days ahead, as I write; but it is great to know that at last we are to have them. I'm sure that television's real *métier* is to let us see events as they happen—or, *via* newsreels, as they happened shortly before. I've never been able to work up any enthusiasm for parlour games and the like; such things, if you want them, seem more the province of "sound" broadcasting.

Trust the Old Hand

WHEN I wrote a while ago that I had the idea of rigging up a broadcast receiver, based on J. L. Osbourne's design, for the lower compartment of my television console, I was severely taken to task by one reader. "For one thing," he wrote, "you don't need a.g.c. for local stations." And there were other things too. He didn't seem to have noticed that I wrote: "With certain small modifications. . . ." One of the certainties of wireless is that no old hand at the game could possibly make up another fellow's design without introducing alleged improvements of his own. I've cut out the a.g.c., for Home, Light and Third all come in without fading. Before finally fitting the receiver into its cubbyhole, I'm engaged in experimenting with different detectors just for the fun of the thing. I can see that I'll have to be firm with myself and set a time limit to these experiments, for otherwise the set is likely to remain in semi-finished form on my work bench instead of going to its proper place.

A Twicester

When a physicist living at Bicester
Was asked to explain the transicester
He replied with a sigh:
"I cannot comply;
Your query's too much of a twicester."

UNBIASED | By FREE GRID

Time the Great Healer

IT has often been said that the "Auntie Gertie" who answers letters on love and other imponderables which trouble readers of the women's page in some of our daily papers is really a man, and he has been depicted as a swarthy-looking individual smoking a very foul pipe, and the very antithesis of the sympathetic female to whom the girls and women think they are writing.

Auntie Gertie ?

I am quite sure, however, that this is not true—at any rate in one newspaper—as no man would be guilty of such a technically unsatisfying reply as was given to an enquirer recently who said that she was worried by a whistle—a common complaint by many girls, especially near an American camp. The whistle which worried her was a very high-pitched one which she could hear on the family TV set, although others couldn't.

The particular "Auntie Gertie" in this case started off very well by explaining that some people could hear frequencies above the normal range of audibility and she dealt also with the fact that the reproduction of the sound side of TV was, in theory at any rate, better in the matter of frequency response than that of ordinary sound receivers, although she rather implied that this was in some way due to the magic of TV and maybe she believed it herself.

However, I knew that "Auntie Gertie" was indeed a woman as she came a complete cropper in the matter of telling her correspondent how to set about filtering out the whistle. Actually she told her nothing, except that in time the unwanted sound would disappear, which is, of course, quite true as it is well known that as we get older the response of our ears to the higher frequencies falls off, and, to give "Auntie Gertie" her due, she does mention this fact.

She didn't even tell her to use her womanly wiles to wheedle her wireless dealer into doing something about it, such as boxing in the line transformer, which would probably be a complete answer to the maiden's prayer. But basically, of course, "Auntie Gertie" was right; all our earthly troubles will eventually be cured without our aid by what St. Francis of Assisi called "Brother Death."

"Coming Events . . ."

I HAVE often demanded a broadcast receiver with a built-in time switch and recorder. With it you could, when away from home or otherwise engaged, automatically bottle any programme you wanted for later consumption at your leisure.

Such a receiver has not yet appeared, although there is no *technical* barrier to its immediate marketing. I am glad to see, however, that a start has been made towards this ultimate goal by two firms. One of these has just produced a new receiver with a built-in clock which can be set to switch on at any time required. The other firm has marketed a simple receiving unit for attaching to a recorder for bottling local-station programmes. These things are, of course, a long way from what I have in mind but it is the thin edge of the wedge.

Ultimately, of course, both sound and TV sets will be available with built-in time switch and recorder and the vision programmes will be bottled without the complication of photographic recording on film; it will be tape for TV as well as sound.

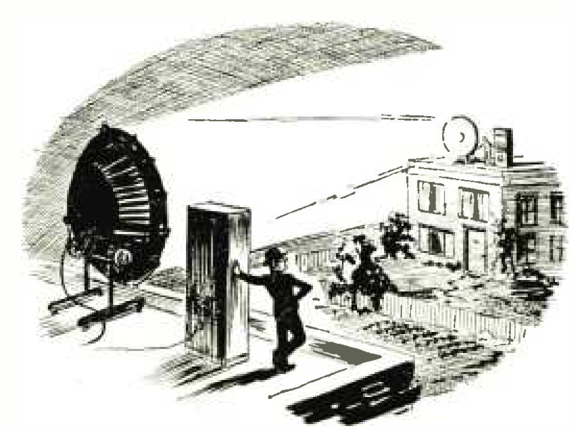
Legal Ruling

THE Editor's remarks about the new licensing regulations which came into force on June 1st made me wonder whether I shall find myself in trouble with the Post Office over a special wireless-telephone installation which I established a few months ago. It started as a simple photophone outfit installed on the roofs of two neighbouring houses for the amusement of some of the smaller components of my family who wished to talk by wireless to their opposite numbers next door.

As most — but possibly not all — *W.W.* readers will know, the photophone was well known as a scientific novelty in the days of our Victorian grandparents. It is—or was—a method of communication in which a beam of light is modulated by an electrically waggled mirror suitably connected to a microphone. In its simplest form it is not even electrically waggled as the sound waves are made to impinge directly on to the back of a suitably mounted mirror. At the receiving end the "detector" consists of anything which changes its resistance or generates an e.m.f. in sympathy with a varying beam of light falling on it; in Queen Victoria's time selenium was used as the photocell.

I soon found that children farther afield became interested and my installation has grown in power and range so that nowadays an ex-Army searchlight sends a powerful beam of light across the neighbouring gardens and quite a man-size a.f. amplifier forms the link between the mike and the modulating mirror.

Is this "apparatus for wireless telegraphy," within the statutory definition? A man who acts as his own lawyer has, as the saying goes, a fool for a client, but, from my reading of the Wireless Telegraphy Act I am satisfied that my photophone needs no licence. To me it is plain that the Postmaster-General's domain extends only up to 3,000,000Mc/s. I am well on the safe side; those who framed the Act allowed themselves plenty of latitude to cover possible developments, but, even so, the frequencies used in my communication system are hundreds of times greater than the upper limit of the wide frequency band over which the P.M.G. holds jurisdiction. That is just as well; otherwise anybody who gives a girl the glad eye and thereby uses electromagnetic-wave communication might put himself in peril of the law.



Photophone ; 1954 version