Electronic Engineering

OCTOBER 1952

TWO SHILLINGS

CLASSIFIED ANNOUNCEMENTS

The charge for these advertisements at the LINE RATE (if under 1" or 12 lines) is : Three lines or under 7/6, each additional line 2/6. (The line averages seven words.) Box number 2/- extra, except in the case of advertisements in "Situations Wanted," when it is added free of charge. At the INCH RATE (if over 1" or 12 lines) the charge is 30/- per inch, single column. Prospectuses and Company's Financial Reports £14 0s. 0d. per column. A remittance must accompany the advertisement. Replies to box numbers should be addressed to : "Electronic Engineering," 28, Essex Street, Strand, London, W.C.2. Advertisements must be received before the 14th of the month for insertion in the following issue.

OFFICIAL APPOINTMENTS

ADMIRALTY : Electrical Engineers. The Civil Service Commissioners invite applications from men for Main Grade and Basic Grade Electrical Engineers for service in Admiralty. Candidates must have been born on or before 1st October, 1922, for Main Grade and on or before 1st October, 1927, for Basic Grade. They must have a University Honours Degree in Engineering or an equivalent qualification and a minimum of two years' practical training followed by practical experience in a responsible electrical engineering post of at least three years for Basic Grade and of eight years for Main Grade or such other experience as the Commissioners consider equivalent. Present London salary scales (somewhat lower in provinces). Basic Grade—Minimum £628 (at age 25) then according to age up to £875 at 34. Maximum £970. Main Grade—£870 by eight annual increments to £1,280. Exceptionally a starting salary above the minimum of the grade may be granted. Higher posts normally filled by promotion. The London salary scale of the next higher grade of Superintending Electrical Engineer is £1,331 × £50 — £1,536. Full particulars and application forms from the Civil Service Commission Scientific Branch, Trinidad House, Old Burlington Street, London, W.1, quoting S210/52. Completed forms to be returned by 16th October, 1952. W 2962

ASSISTANT (SCIENTIFIC) CLASS. The Civil Service Commissioners give notice that an Open Competition for permanent and pensionable appointment to the basic grade will be held during 1952. Interviews will be held throughout the year, but a closing date for the receipt of applications earlier than December, 1952, may eventually be announced either for the competition as a whole or in one or more subjects. Candidates must be at least 17½ and under 26 years of age on 1st January, 1952, with extension for regular service in H.M. Forces, but candidates over 26 with specialized experience may be admitted. All candidates must produce evidence of having reached a prescribed standard of education, particularly in a science subject and of thorough experience in the duties of the class gained by service in a Government Department or other civilian scientific establishment or in technical branches of the Forces, covering a minimum of two years in one of the following groups of scientific subjects: (i) Engineering and physical sciences. (ii) Chemistry, bio-chemistry and metallurgy. (iii) Biological sciences. (iv) General (including geology, meteorology, general work ranging over two or more groups (i) to (iii) and highly skilled work in laboratory crafts such as glass-blowing). Salary according to age up to 25: £236 at 18 to £363 (men) or £330 (women) at 25 to £500 (men) or £417 (women); somewhat less in the provinces. Opportunities for promotion. Further particulars and application forms from Civil Service Commission, Scientific Branch, Trinidad House, Old Burlington Street, London, W.1, quoting No. S 59/52. Completed application forms should be returned as soon as possible. W 2965

B.B.C. requires Engineer in Studio Equipment Section of Planning and Installation Department in London. Appointment will be in salary grade £795-£1,065. Duties include specification, ordering and testing of equipment used for transmission of films for television and for making films from television; planning complete installations including such equipment; liaison with manufacturers and supervision of contracts. Requirements include considerable practical experience in the use of high-grade cinematographic equipment and thorough knowledge of principles of its design and of associated techniques relating to lenses, film stock, film processing, etc.; good knowledge of principles of television, and preferably some experience of application of films for television purposes. A Degree in Electrical Engineering or Physics, or equivalent qualification desirable. Applications to Engineering Establishment Officer, B.B.C., London, W.1, giving details of qualifications and experience within 7 days. W 2945

B.B.C. requires a limited number of Technical Assistants, age 21 or over in Operations and Maintenance Department for service at Transmitter, Studio, and Television Centres throughout the United Kingdom. Knowledge of mathematics, electricity and magnetism to School Certificate Standard; experience in electrical or radio engineering an advantage. Salary £360 p.a. with annual increments to £470 p.a. maximum. Promotion prospects. Application forms from Engineering Establishment Officer, Broadcasting House, London, W.1 (enclosing addressed foolscap envelope). After completion, forms to be sent to B.B.C., c/o Ministry of Labour, 211 Marylebone Road, London, N.W.1, marking "T.A.11". W 2972

MINISTRY OF SUPPLY require experimental officer in Radio Department, Royal Aircraft Establishment, Farnborough, Hants, for experimental design of aircraft aerials for modern high speed aircraft. Thorough knowledge of properties of aerials, transmission line filters and matching units, with practical experience of measuring techniques and aerial development in V.H.F. wave band, essential. Knowledge of aircraft constructional materials and techniques, as far as these affect aerial design, is also required. Candidates should have Higher School Cert. (Science) or equivalent, but possession of higher qualifications in physics or engineering may be an advantage. Salary according to qualifications and experience within inclusive range: £597-£754 p.a. (Min. age 26.) Rates for women somewhat lower. Post unestablished. Application forms from Ministry of Labour and National Service, Technical and Scientific Register (K), Almack House, 26 King Street, London, S.W.1, quoting D.352/52A. Closing date 10th October, 1952. W 2948

MINISTRY OF SUPPLY require Experimental Officers in Research and Development Establishments. Most posts concern Guided Weapons, and require knowledge and experience of electronics. Minimum qualification H.S.C. (Science) or equivalent but higher qualifications in Physics or Electrical Engineering an advantage. Salaries according to age, experience, etc., within inclusive ranges: Experimental Officer (min. age 26), £597-£754. Assistant Experimental Officer, £264 (age 18)-£555. Somewhat lower for women. Posts unestablished. Application forms from M. L. and N. S., Technical and Scientific Register (K), Almack House, 26 King Street, London, S.W.1, quoting A233/52/A. Return within 14 days. W 2949

MINISTRY OF SUPPLY have vacancies at Research Establishment near Sevenoaks, Kent, in following fields: (1) Electronic circuit design, (2) Trials of experimental equipment, (3) Development of electro-mechanical devices, (4) Measurement of transient phenomena on electrical and explosive equipments, (5) Development work on electrical components, (6) Maintenance of laboratory electronic instruments. Candidates must possess Higher School Certificate (Science), or equivalent, higher qualifications in Physics or Electrical Engineering may be an advantage. Salary within inclusive ranges £597-£754 for Experimental Officer (minimum age 26) and £264 (age 18)—£555 for Assistant E.O. Rates for women somewhat lower. Posts unestablished. Application forms from Ministry of Labour and National Service, Technical and Scientific Register (K), Almack House, 26, King Street, London, S.W.1, quoting D.365/52-A. W 2962

RUNWELL HOSPITAL, Near Wickford, Essex. Applications are invited for the post of Senior Technician in the Department of Electro-encephalography. Previous experience essential. Applications should be sent to the Physician Superintendent. T. Fitzroy Kelly. Secretary. W 2952

SITUATIONS VACANT

The engagement of persons answering these advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18-64 inclusive or a woman aged 18-59 inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order, 1952.

A SENIOR COMMERCIAL APPOINTMENT is offered in the Equipment Division of Mullard Ltd., to an applicant having experience in the operational or systems planning aspects of radio communications and/or broadcast transmitters and systems. Candidates should have a University Degree or equivalent, an interest in the systematic organization and handling of various types of equipment and should be experienced in dealing with customers at all levels. Please forward personal details including salary required to the Personnel Officer, Mullard Ltd., Century House, Shaftesbury Avenue, W.C.2. Applications will be treated in confidence. W 2929

ADDITIONAL Senior and Junior Engineers are required by a small but progressive firm of electronic instrument manufacturers in Surrey for interesting development work on important projects. Applicants should possess a Degree in physics, and should have industrial experience and a practical mind. Both salary and prospects will be good for the right men. Apply Box No. W 2933.

ADMINISTRATIVE PERSONAL ASSISTANT to Research Director of Decca Radar Limited required. Scientists or engineers are invited to apply for this senior appointment where the successful applicant will be responsible for the administration of the Laboratory for recruitment, training and welfare of the personnel. Please write to Research Director, Radar Laboratory, 2, Tolworth Rise, Surbiton, Surrey. W 2973

AMBASSADOR RADIO and Television require Electronic Engineers for laboratory research and development work. Applicants must have had reasonable experience in electronic research and development. They should be Graduates in Physics, Telecommunications or Electrical Engineering, or hold the Higher National Certificate or City and Guilds Final in Radio subjects. Progressive positions are offered to men who can prove their ability. Commencing salary in accordance with qualifications and experience. Applications must be made in writing in the first instance, intimating availability for interview at Princess Works, Brighouse, Yorkshire. W 2879

AN ELECTRONIC ENGINEER is required to investigate Vibration Phenomena on Guided Missile projects. Applicants should be experienced in the use of, and capable of developing, Electronic Equipment for this purpose and should hold a H.N.C. or recognized equivalent, or have exceptional experience. Details should be sent to the Assistant Manager, (A) The Fairey Aviation Company Limited, Dept. E, Research and Armament Development Division, Heston Aerodrome, Hounslow, Middlesex. W 2931

AN ENGINEER required for Service Dept. Knowledge of electronic measuring instruments essential. Commencing salary according to age and experience. Write giving full details of qualifications and experience to Dawe Instruments Ltd., 130, Uxbridge Road, Hanwell, London, W.7. W 2966

AN EXCELLENT opportunity exists in a new section for a first rate engineer, thoroughly experienced in the development and design of high power radar modulators. This is a permanent position, carrying a substantial salary and superannuation facilities. The post calls particularly for a man with initiative and energy. Applications, quoting reference 921 D, from suitably qualified men will be welcomed by Central Personnel Services, English Electric Co. Ltd., 24-30 Gillingham Street, London, S.W.1. W 2953

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SITUATIONS VACANT (Cont'd.)

The engagement of persons answering these advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18-64 inclusive or a woman aged 18-59 inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order, 1952.

APPLICATIONS are invited for a post with a Company engaged in airborne geophysical surveying. Applicants should have a good knowledge of Radio and Electronics equipment, and be prepared to go abroad on flying operations. Previous flying experience an asset. Apply Box No. W 2944.

BELLING & LEE LTD., Cambridge Arterial Road, Enfield, Middlesex, require research assistants in connexion with work on electronic components, fuses, interference suppressors and television aerials. Applicants must be graduates of the I.E.E. or possess equivalent qualifications together with similar laboratory experience. Salary will be commensurate with previous experience: five day week, contributory pension scheme. Applications must be detailed and concise, and will be treated as confidential. W 138

CHIEF ELECTRONIC Engineer (between 35-45) required with mechanical engineering background for a Company engaged on an expanding development programme in Industrial Electronic production equipment and automatic special purpose machines and test gear. A.M.I.E.E. or equivalent desirable though extensive practical experience will rank higher than purely academic qualifications. Write Box No. W 2961.

CHIEF INSPECTOR required. Applicants must have a sound basic knowledge of Radio Theory and be conversant with **VHF** and Radar. Applications should be made in writing giving full details of experience and qualifications to Personnel Manager. Murphy Radio Limited, Welwyn Garden City. W 2980

DECCA RADAR LTD. invites applications from microwave, electronic and mechanical engineers to join the Company in its extensive work in a wide field of microwave link and radar development. The Company offers excellent starting salaries and first rate opportunities for men to exploit their initiative and to rise rapidly to responsible posts. Graduates without industrial experience who are prepared to undertake intensive training are also invited to apply for junior posts. Apply in writing to Research Director, Radar Laboratory, 2, Tolworth Rise, Surbiton, Surrey. W 150

DECCA RADAR LTD. require draughtsmen and junior draughtsmen for Research Drawing Office, preferably experienced in any of the following fields: Radar, radio and electronic circuits, electro-mechanical devices, light mechanical engineering. Knowledge of workshop practice essential, applicants must possess Ordinary National Certificate or equivalent. Positions are permanent and progressive; salaries based on A.E.S.D. rates. Tracers (female) also required. Write giving full details to Chief Draughtsman, Decca Radar Limited, 2, Tolworth Rise, Surbiton, Surrey. W 151

DESIGNERS required for Factory Test Apparatus. Experience in Pulse Techniques essential. Apply Personnel Manager, E. K. Cole Ltd., Ekco Works, Malmesbury, Wilts. W 2885

DEVELOPMENT engineer or physicist is required for work concerned with transistor and cold cathode valve circuitry. Degree or H.N.C. in electrical engineering or physics with electronics or telecommunications is essential. Previous experience would be useful. Appointment is at Stanmore. Apply to the Staff Manager (Ref. GBLC/S/671) Research Laboratories of the General Electric Co. Ltd., Wembley, Middlesex, stating age, qualifications and experience. W 2937

DRAUGHTSMEN: one Senior, one Junior, required for North London Manufacturers of Electro-Mechanical Scientific Instruments and Electrical Equipment. Early move to Stevenage where housing available. Write Box No. W 2963.

DRAUGHTSMEN. A large engineering company and drawing office in Central London has several vacancies for men who have a wide experience in the light electro-mechanical field. These are permanent and pensionable posts connected with both important defence projects and long term private development work. Applications are invited from men with sufficient experience and ability to justify from good salaries. Please write in confidence giving full details of past experience quoting reference L.19 to Box No. W 2977.

DRAUGHTSMEN required. Must have sound experience in Radio, Television or Electronic Design. North London Area. Knowledge of Government Department practice desirable. Special opportunities and pay in excess of accepted minima. C/o Newspaper. Write Box No. W 2887.

DRAUGHTSMEN. Senior and Junior Electro Mechanical and Circuit Draughtsmen required for work on electronic computing and training equipment, including Flight Simulators. Location near Waterloo station. Apply in writing to Mr. G. B. Ringham, Chief Engineer and Manager, Flight Simulator Division, Redifon Ltd., Broomhill Road, Wandsworth, S.W.18. W 2889

E. K. COLE LTD. (Malmesbury Division) invite applications from Electronic Engineers for permanent posts in Development Laboratories engaged on long-term projects involving the following techniques: 1. Pulse Generation and Transmission. 2. Servo Mechanism. 3. Centimetric and V.H.F. Systems. 4. Video and Feedback Amplifiers. 5. V.H.F. Transmission and Reception. 6. Electronics as applied to Atomic Physics. There are vacancies in the Senior Engineer, Engineers and Junior Grades. Candidates should have at least 3 years' industrial experience in the above types of work, together with educational qualifications equivalent to A.M.I.E.E. examination standard. Commencing salary and status will be commensurate with qualifications and experience. Excellent opportunities for advancement are offered with entry into a Pension Scheme after a period of service. Forms of application may be obtained from Personnel Manager, ECKO Works, Malmesbury, Wilts. W 2800

ELECTRICAL ASSISTANT required for an industrial metallurgical research laboratory in the S.E. London area, to help with problems connected with furnaces and control equipment. National Certificate in electrical engineering a minimum requirement, with some knowledge of electronics an advantage. Write giving full particulars to Box No. W 1568.

ELECTRICAL ENGINEERS are required for interesting and varied work in the Nelson Research Laboratories, English Electric Co. Ltd., Stafford. Applicants should have sound workshop and some drawing office experience and will be required to control the engineering of electronic, H.F. heating or vacuum equipment beyond the Laboratory stage and therefore, should have had experience in one or more of these fields. These posts offer ample scope for advancement to men with initiative and ability; salary according to qualifications and experience comparable with present-day levels. Please write, quoting reference 1016 and giving full details to, Central Personnel Services, English Electric Co. Ltd., 24-30 Gillingham Street, London, S.W.1. W 2950

ELECTRICAL ENGINEER or Physicist with Higher National Certificate or equivalent is required for the design of small quantities of special transformers for experimental apparatus. This appointment is at Stanmore. Apply to the Staff Manager (Ref. GBLC/S/638) Research Laboratories of The General Electric Co. Ltd., Wembley, Middlesex, stating age, qualifications and experience. W 2930

ELECTRONIC ENGINEER required with experience in microwave techniques and measurement. Salary according to qualifications and experience. Box No. W 1554.

ENGLISH ELECTRIC COMPANY LTD., Luton, invite applications for permanent posts in a department developing and engineering in a wide variety of specialized electronic circuits. Previous experience in such work would be an asset and, for one vacancy, some experience in optics or oscillography would be a recommendation. Salaries will be in accordance with qualifications and experience, up to £625 per annum. The laboratories are new and pleasantly situated. Please write, giving full details and quoting reference 1002, to Central Personnel Services, English Electric Co. Ltd., 24-30 Gillingham Street, London, S.W.1. W 2839

ENGLISH ELECTRIC CO. LTD., Luton, have a vacancy for an Electronics Engineer with drawing office experience for liaison between laboratory and drawing office. Higher National Certificate or equivalent an advantage, but not essential. Salary according to experience and qualifications in the range of £500 to £650 with good prospects. Please write, giving full details and quoting ref. 988A to, Central Personnel Services, English Electric Co. Ltd., 24-30 Gillingham Street, London, S.W.1 W 2947

ENGINEER, I.E.E. or equivalent standard wanted for interesting electronic development. Good prospects for engineer with wide outlook. Applicants must be British and between 25 and 35. Write stating details of experience, etc., to Works Manager, Revo Electric Co. Ltd., Tipton, Staffs. W 1558

ENGINEERS required for interesting work on components for Telecommunications and Television Transmission Equipment. Should be capable of undertaking development work without supervision. Scope for men with enterprise and imagination with suitable experience. Degree or equivalent desirable but not essential. Apply Box No. W 2834.

ELECTRO-MECHANICAL ENGINEERS required with good academic qualifications, apprenticeship, theoretical background and knowledge of production methods for development work. Experience in electrical methods of computation, servo theory and instrument design desirable. Apply with full details of age, experience and salary required to the Personnel Manager, Sperry Gyroscope Co., Ltd., Great West Road, Brentford, Middx. W 2904

ENGINEERING REPRESENTATIVES with contacts in industry required to obtain specific problems for group of consultants. Write in first instance. Box No. W 1566.

EXPERIENCED Radio Testers and Inspectors required for production of communication and radio apparatus. Also Instrument makers, wirers and assemblers for Factory Test apparatus. Apply Personnel Manager, E. K. Cole Ltd., Ekco Works, Malmesbury, Wilts. W 146

EXPERIENCED ELECTRONIC ENGINEER required by the English Electric Company Limited, Luton, for investigation into the nature of mechanical vibrations in connexion with guided missiles project. Position of responsibility in a new department is available for a well qualified man. Adaptability and ability to develop electronic measuring techniques required. H.N.C. or equivalent and some experience of vibration work essential. Salary according to qualifications. Please write giving full details of qualifications and experience and quoting reference "850 C" to Central Personnel Services, English Electric Company Ltd., 24-30, Gillingham Street, London, S.W.1. W 2846

EXPERIENCED MEN (ex-Service Radar Mechanics preferred) are required for duties in the Electronics Division of Saunders-Roe Limited. Applicants should be capable of intelligent assembly and wiring of a wide variety of electronic apparatus from circuit diagrams. Write, giving details of experience, age, etc., to the Personnel Officer, Saunders-Roe Limited, East Cowes, Isle of Wight. W 2895

EXPERIENCED DRAUGHTSMEN required in the following fields: A. Carrier Telephony. B. Electronic Instruments. C. Radio Receivers and Transmitters (From 10kW). Write stating qualifications, experience and wages required to Mullard Equipment Ltd., Brathway Road, Wandsworth, S.W.18. W 2943

EXPERIMENTAL ELECTRICAL ENGINEER, B.Sc., preferably Physicist with electronic experience. Capable of carrying out on his own initiative and to a satisfactory conclusion, development work in connexion with electrical discharge phenomena applicable to manufacturing processes. Well-paid permanent position with first-class Company, Northwest London area, offered to suitable applicant. Write giving personal details, qualifications, age, experience and salary required to Box No. W 2940.

EXPERIENCED COMPONENT engineers are urgently required by a large Midland firm for work of National importance. Applicants

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The engagement of persons answering these advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18-64 inclusive or a woman aged 18-59 inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order, 1952.

selected will be required to build up a new section specializing in selection and design of electrical and mechanical components for electronic equipment, together with associated light and medium heavy control gear, transformers and wiring. Applicants should have a full working knowledge of service specifications and type approval procedure, experience of component design and an understanding of ratings. Please write giving full details of experience and qualifications and quoting reference IHF to Box No. W 2951.

FERRANTI LTD., Moston, Manchester, have vacancies for: (1) Mechanical/Electrical Engineers of proved ability in the design and application of (a) Gyroscopic Instruments (b) Small Electric Servos and Analogue Computers. Candidates should be able to show proof of past achievement in these fields rather than high academic attainments. Salary in the range of £1,000-£1,250 p.a. (2) Mechanical/Electrical Engineers for development work on (a) and (b) above. Preference will be given to candidates who can show evidence of practical achievement. Salary in the range of £750-£850 p.a. The Company has a Staff Pensions Scheme. Application forms from Mr. R. J. Hebbert, Staff Manager, Ferranti Limited, Hollinwood, Lancs. Please quote reference H.N. W 2934

FERRANTI LTD., Edinburgh—invite applications from suitably qualified persons for the position of Research Engineer in their Small Transformer Department in Edinburgh. The duties involve investigations into new techniques and materials associated with transformers for use in electronic equipment with a view to their ultimate use in large-scale production. Candidates should preferably have a University Degree and experience in (1) Transformer design and development tendencies and/or (2) Electronic component research. Staff Pension Scheme and excellent conditions and equipment. Reply quoting Ref. T/RE and give full details of age, qualifications and experience to the Personnel Officer, Ferranti Ltd., Ferry Road, Edinburgh. W 2941

FERRANTI LTD., Moston, Manchester, have the following vacancies for work in connexion with the development of cathode ray tubes for television, oscillography and special purposes: (1) Senior Engineers and Scientists to take charge of research and development sections. Applicants should have a good Degree in physics, electrical engineering or glass technology, and have had experience in supervising development work. Salary according to qualifications and experience, in the range £750 to £1,250 per annum. Please quote reference GCT/1. (2) Engineers and Scientists for work in the following fields: Thermionic emission, vacuum techniques, electron optics, photoelectric phenomena, electronic circuits, glass technology and high-voltage techniques. Qualifications include a good Degree or equivalent. Previous experience would be an advantage, though not essential. Salary, according to qualifications and experience, in the range £450 to £1,000 per annum. Please quote reference GCT/2. (3) Mechanical or Production Engineers to undertake the development of machinery for mass-production of electronic devices. Qualifications etc. as in (2). Please quote reference GCT/3. (4) Technical Assistants for experimental work in the fields listed in (2) above. Qualifications are a degree or Higher National Certificate. Salary range £400 to £600 per annum according to age and qualifications. Please quote reference GCT/4. The Company has a Staff Pensions Scheme. Application forms from Mr. R. J. Hebbert, Staff Manager, Ferranti Limited, Hollinwood, Lancs. Please quote appropriate reference. W 2917

GRADUATE engineers or physicists are required for work at Wembley and Stanmore in connexion with (a) I.F. receivers (b) microwave and V.H.F. equipment (c) aerials (d) magnetrons. All vacancies are of an interesting experimental nature and men with a practical flair combined with good academic qualifications are needed. Apply to the Staff Manager (Ref. GBLC/679) Research Laboratories of The General Electric Co. Ltd., Wembley, Middlesex, stating age and record. W 2936

GUIDED WEAPONS DEVELOPMENT offers good opportunities for Senior and Junior Electronic, Electrical, Radio and Mechanical Engineers and Draughtsmen, Aerodynamicists, Technical Authors, and Computors (female); also for skilled and semi-skilled Fitters, Electronic Wiremen, Toolmakers and Machine Tool Operators. Apply, quoting reference S.P. and giving particulars, qualifications and experience, to the Employment Manager, Vickers-Armstrongs Limited (Aircraft Section), Weybridge, Surrey. W 2914

INSTRUMENT ENGINEERS required for the development of control systems for aircraft. Candidates must be British between the ages of 25 and 35, and be capable of carrying out development of electronic or electro-mechanical systems on their own initiative. Pension scheme in force. Salary range £550-£750. Apply, quoting Ref. A.A., to Box No. W 2954.

JUNIOR DEVELOPMENT ENGINEERS are required to assist in development of precision electronic laboratory instruments. Successful applicants will be engaged on interesting long-term projects concerned with the development of a wide range of equipment. The appointments are of a permanent nature, they carry considerable technical responsibility and offer scope for the exercise of individual initiative. Applicants should have had previous practical experience of development, preferably in the instrument field. Theoretical qualifications ranging from O.N.C. (or an equivalent standard) to a University Degree in Communications Engineering or Physics are acceptable. Salaries are in the range of £350-£650 p.a. and are dependant upon age, qualifications and experience. Applications should be made to Personnel Manager, Furzehill Laboratories Ltd., Boreham Wood, Herts. W 147

JUNIOR ELECTRONIC ENGINEER for test and development high grade instruments. Excellent opportunity for experience with prospects of advancement in small but enterprising firm. Surrey area. Box No. W 2969.

MAINS RADIO GRAMOPHONES LTD. have vacancies for development engineers for design work on domestic radio and television. The openings cover a wide field from basic technical research to construction of experimental receivers and models. The positions will be permanent, carrying Staff Status. Superannuation Scheme, etc., for suitable applicants. Application must be made by letter in the first instant, giving all relevant details, to: Mains Radio Gramophones Limited, 359, Manchester Road, Bradford. W 1569

MIDDLESEX HOSPITAL MEDICAL SCHOOL. Department of Physics Applied to Medicine. Laboratory Technician (Minimum age 26) required for maintenance and construction of prototype electronic equipment. Salary £410 p.a. rising to £475 plus £30 London weighting and family allowance, with superannuation. Apply immediately to Secretary, Barnato Joel Laboratory, Middlesex Hospital, W.1. W 1571

MURPHY RADIO LTD. have vacancies for designer draughtsmen in their Electronics Division. A varied programme ensures opportunity of widening experience with excellent prospects. Apply giving particulars of training and experience to Personnel Manager, Murphy Radio Ltd., Welwyn Garden City, Herts. W 2884

NELSON RESEARCH Laboratories, English Electric Co., Ltd., Stafford, have vacancies for two senior research scientists to study the influence of physical and metallurgical properties on the magnetic characteristics of ferromagnetic materials and the development of improved materials. Applicants must have a good Honours Degree and several years' post-graduate and industrial experience on the physics and metallurgy of magnetic materials. Previous experience of leading a group is desirable but not essential. Please write giving full details and quoting reference 310 C. to Central Personnel Services, English Electric Co., Ltd., 24-30, Gillingham Street, London, S.W.1. W 2958

PHYSICIST required for experimental work in Leeds upon development and test of gamma radiation detectors. Preferably a young graduate with some research experience, not necessarily in this field. Manipulative skill essential and experience of electronic equipment very desirable. Salary in range £400-£600 according to qualifications. Apply Box No. W 1572.

PHYSICISTS required by large electrical firm in South-West for vacuum tube development. Good salary according to qualifications and good opportunities for initiative. Five-day week. Pension scheme. Write, in confidence, giving full particulars of training and experience to Box N 6728 A. K. Advg., 212a Shaftesbury Ave., W.C.2. W 2946

PHYSICAL CHEMIST required having experience and an interest in the electrical properties of materials. Salary according to qualifications and experience. Box No. W 1560.

PHYSICAL CHEMIST required having experience and an interest in the electrical properties of materials. Salary according to qualifications and experience. Box No. W 1553.

PHYSICISTS AND ELECTRONIC ENGINEERS. Interesting and varied work on industrial application of measurement techniques. Vacancies exist for experienced staff in Research Department of West London Engineers. Please forward full details of age, education, qualifications, experience and salary required to Box A. 208, Central News Ltd., 17, Moorgate, London, E.C.2. W 2970

PHILIPS BALHAM WORKS, 45 Nightingale Lane, Balham, S.W.12, require young Electronic Engineer, minimum qualifications Higher National Certificate, for development of electro-medical and radiation instruments. Permanent appointment. Write stating age, training, experience and salary required. W 2938

REQUIRED, Laboratory Assistant for maintenance of electronic equipment in Aylesbury, Bucks. Experience in operation and maintenance of electronic equipment necessary. Skilled ex-R.A.F. tradesman would be considered. Salary £7 to £10 per week according to experience. Reply to Box No. W 1555.

RESEARCH ENGINEER required for Television Development Laboratory. Previous experience with reliable manufacturer essential. Write giving details of age, qualifications and salary required, to Personnel Manager, Vidor Limited, West Street, Erith, Kent. Applications treated confidentially. W 2966

ROYAL FREE HOSPITAL OF MEDICINE. Hunter Street, London, W.C.1. Electronics technician to work in Inter-departmental workshop on construction and repair of research apparatus. Salary £410 rising to £475 p.a. plus London weighting allowance and superannuation. Applications with full details and two testimonials to the Warden and Secretary as soon as possible. W 2968

SALES MANAGER'S Assistant required in Electronics Division of large Company, to take charge, without supervision, of sales correspondence, records and routine. Applicants should possess Degree in Electrical Engineering or Graduateship of the I.E.E. or Brit.I.R.E. and show successful sales record. Write giving full particulars of experience and salary expected to Box E.C.528 c/o 191 Gresham House, E.C.2. W 2956

SENIOR AND JUNIOR Electronic Engineers required for development of Guided Missiles and other work of national importance. Good academic qualifications, a thorough knowledge of low frequency electronic circuits including D.C. Amplifiers, and practical design experience of lightweight electronic equipment are desirable. The posts are pensionable, and offer good scope for a man to learn and develop new techniques and advance his position. Apply to the Personnel Manager, Sperry Gyroscope Co., Ltd., Great West Road, Brentford, Middx., giving full details of age, qualifications and experience and salary required. W 2906

SENIOR Electro-Mechanical Engineer with good academic and professional qualifications, and experience of modern production methods required for development of airborne equipment, including gyroscopic devices and instrument servo-mechanisms. Applicants should have at least 5 years' experience in this class of work. Excellent prospects. Write fully stating age, experience and salary expected to Box E.C.527, c/o 191 Gresham House, E.C.2. W 2957

CLASSIFIED ANNOUNCEMENTS
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SITUATIONS VACANT (Cont'd.)

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SENIOR ELECTRONIC ENGINEER required. Experience of Helicopter instrumentation and of analogue computors would be an advantage. Apply, stating experience, age, etc., to the Personnel Officer, Saunders-Roe Ltd., Southampton Airport, Eastleigh, Hants. W 2852

SENIOR TELEVISION DEVELOPMENT ENGINEER required for Research Laboratory by well-known manufacturer in South East London. Write, giving details of age, qualifications, previous experience and salary required to Personnel Manager. All applications will be treated confidentially. Box No. W 2967.

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continued on page 8

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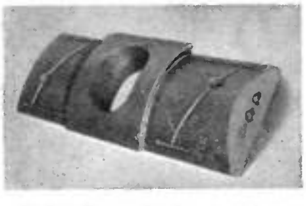

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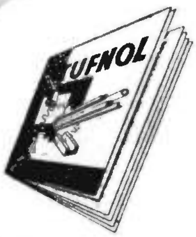

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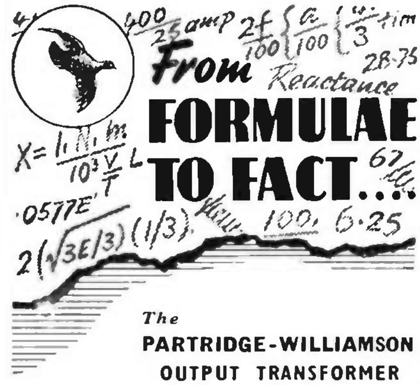

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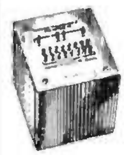

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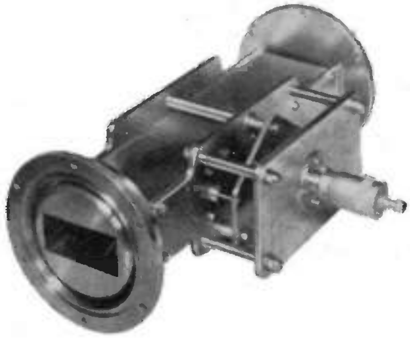

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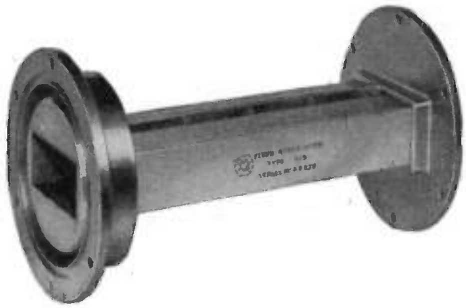

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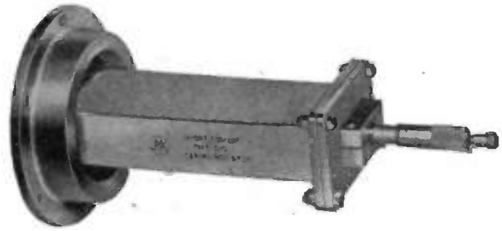

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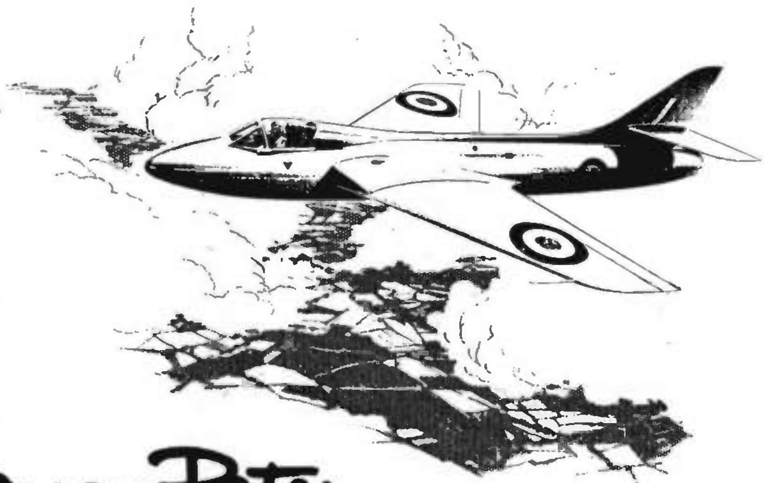

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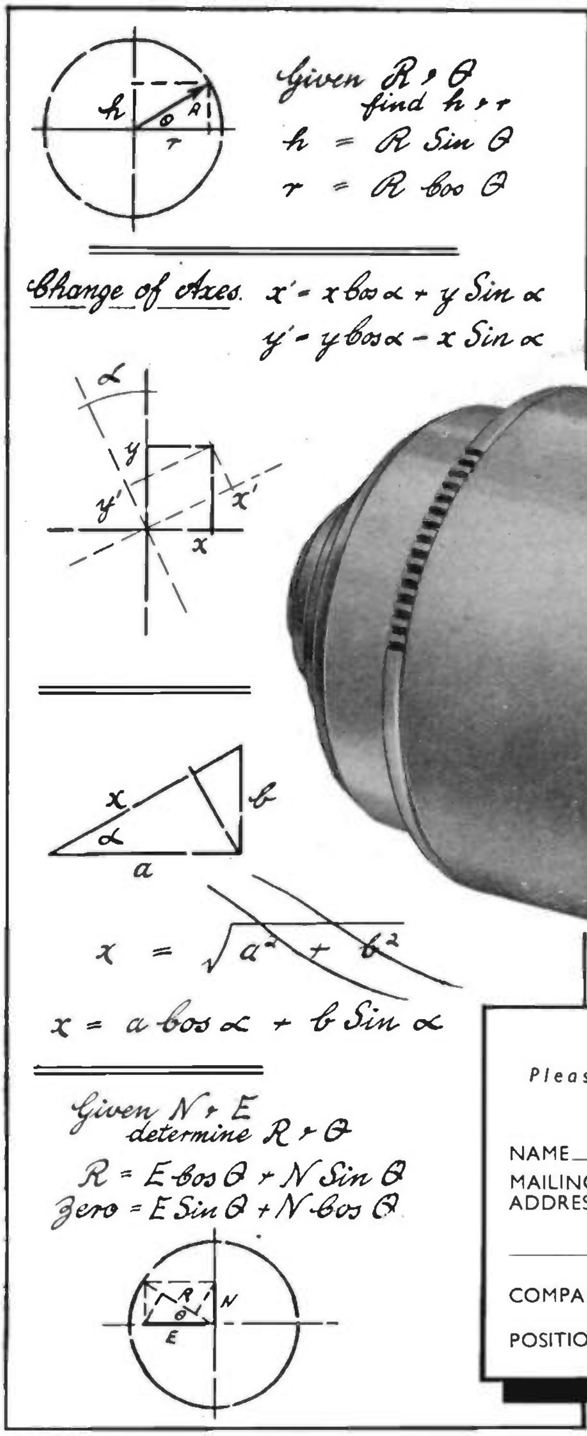

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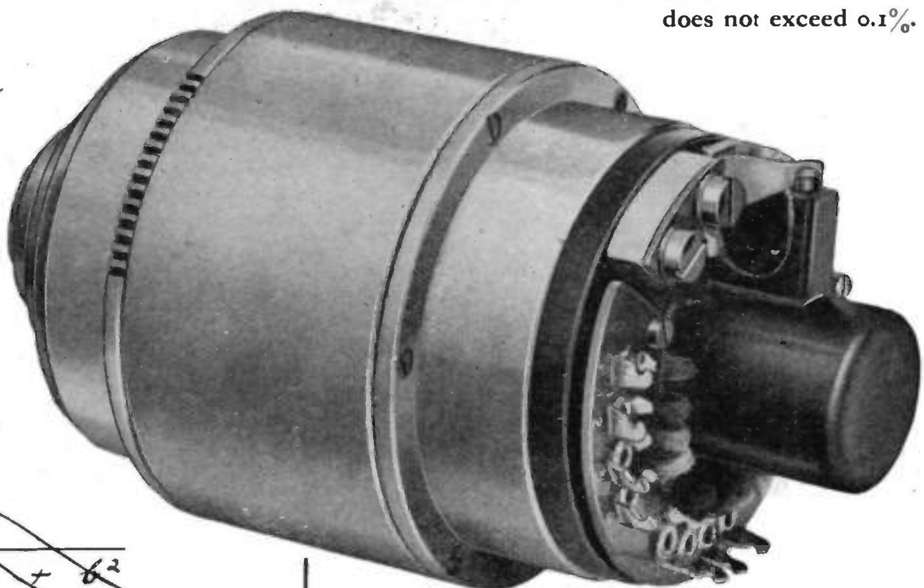

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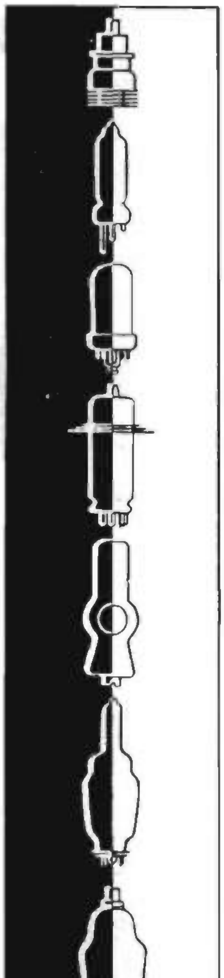

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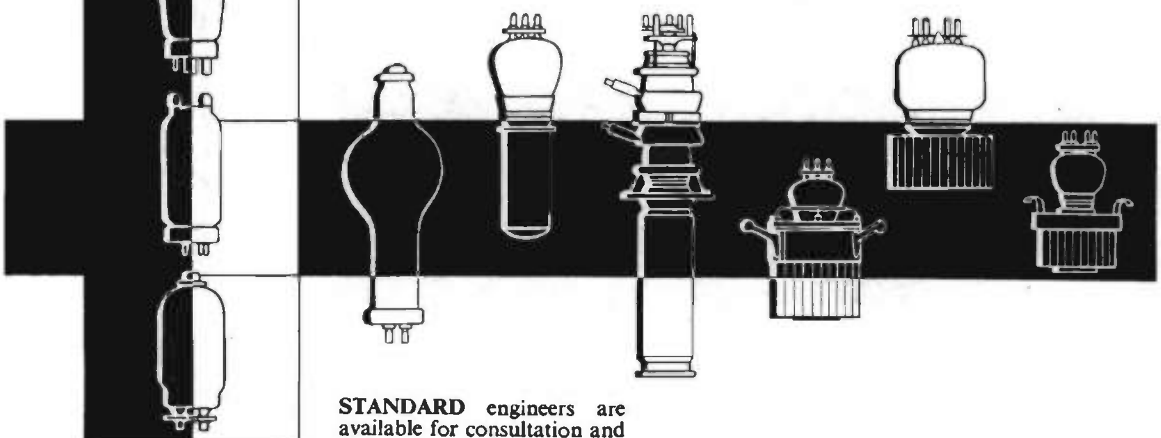

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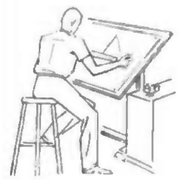

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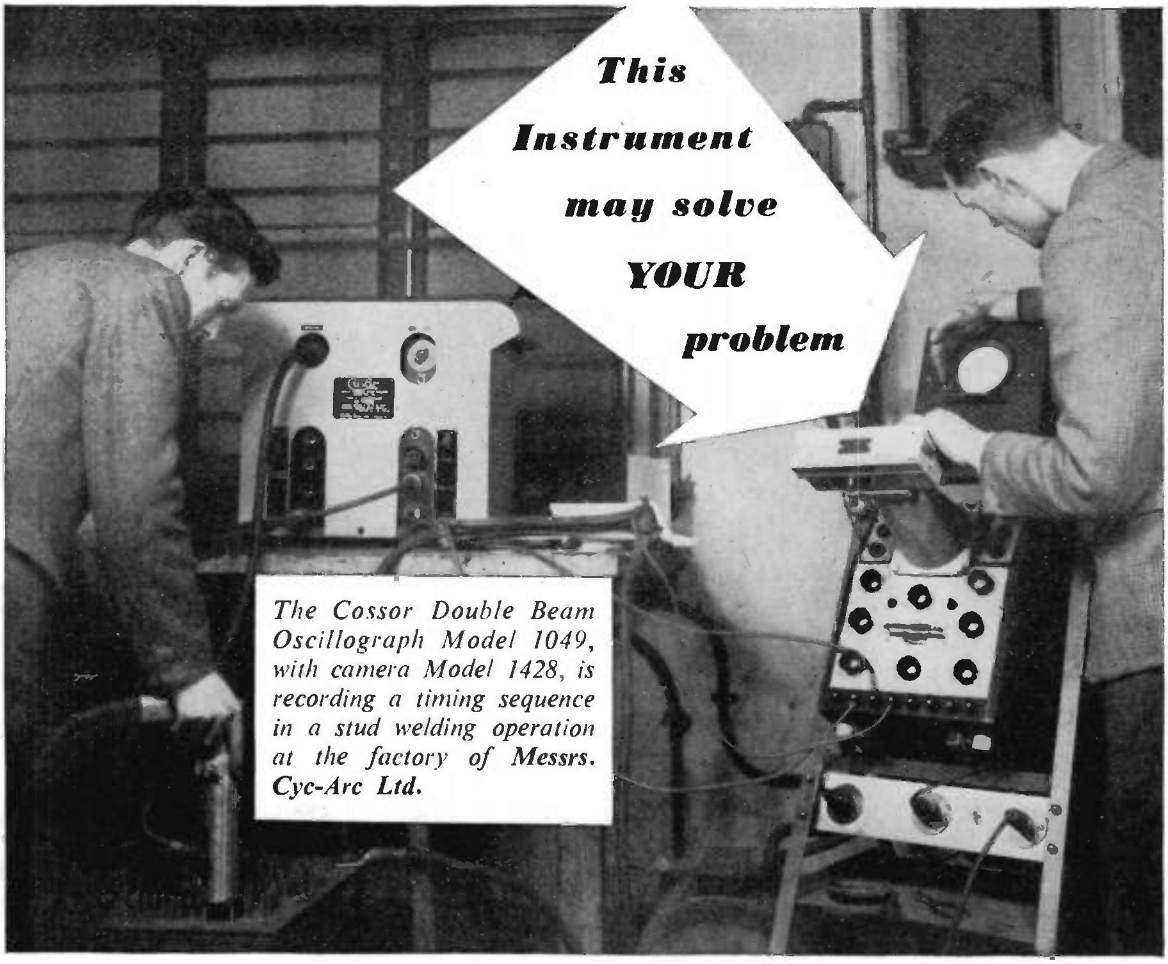

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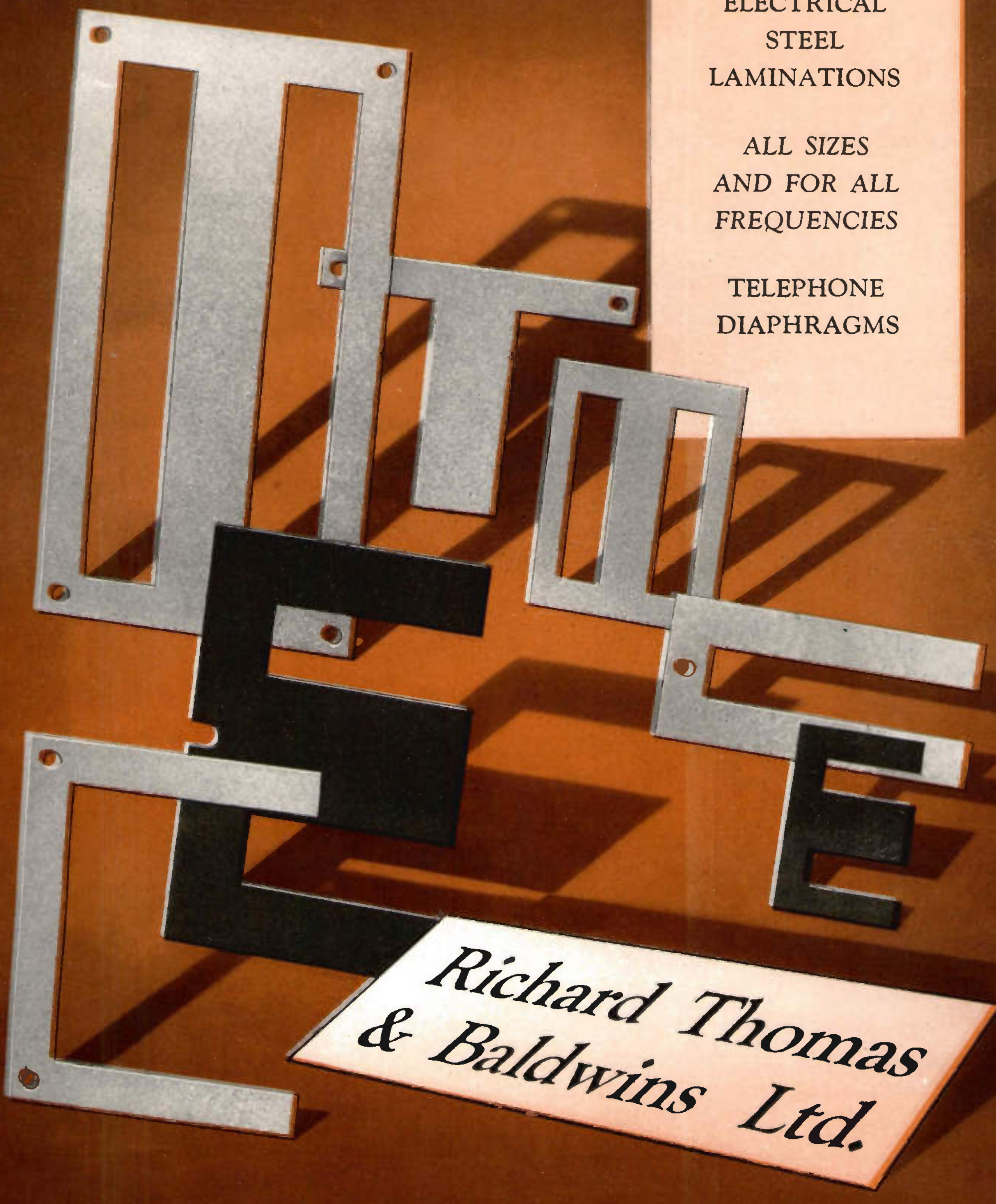

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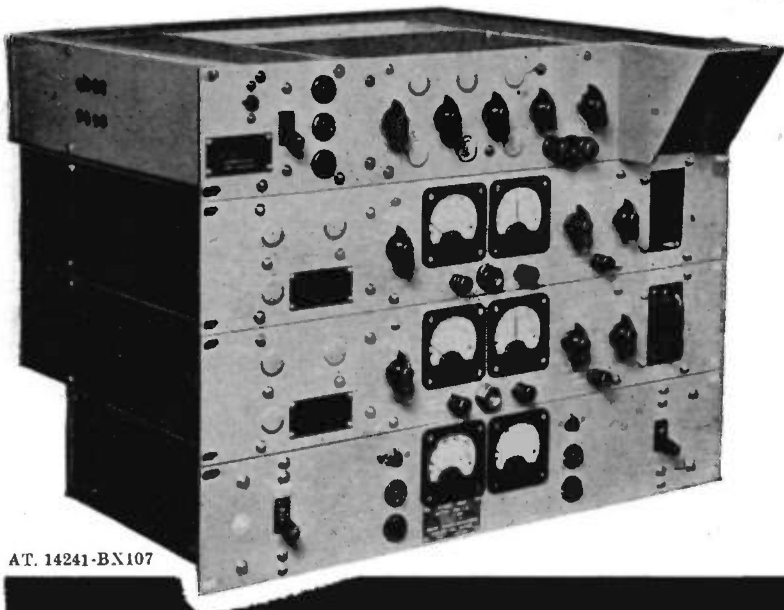


Type FSK.2. Keying Unit for frequency-shift keying is designed for conversion of any conventional communications transmitter for frequency-shift operation.

Type FSY.7. Receiving Terminal is for dual diversity shift reception. It includes a cathode-ray monitor unit with which the balance of the two aerials and receivers in a dual diversity combination can be checked visually, and with which the correct tuning point of the two receivers can be set up while a transmission is in progress. Other models are available for single receiver reception.

Both these units can be fitted on site by station engineers, any modification of radio equipment required being only of a minor nature.

AT. 14241-BX107

AUTOMATIC TELEPHONE & ELECTRIC CO. LTD.

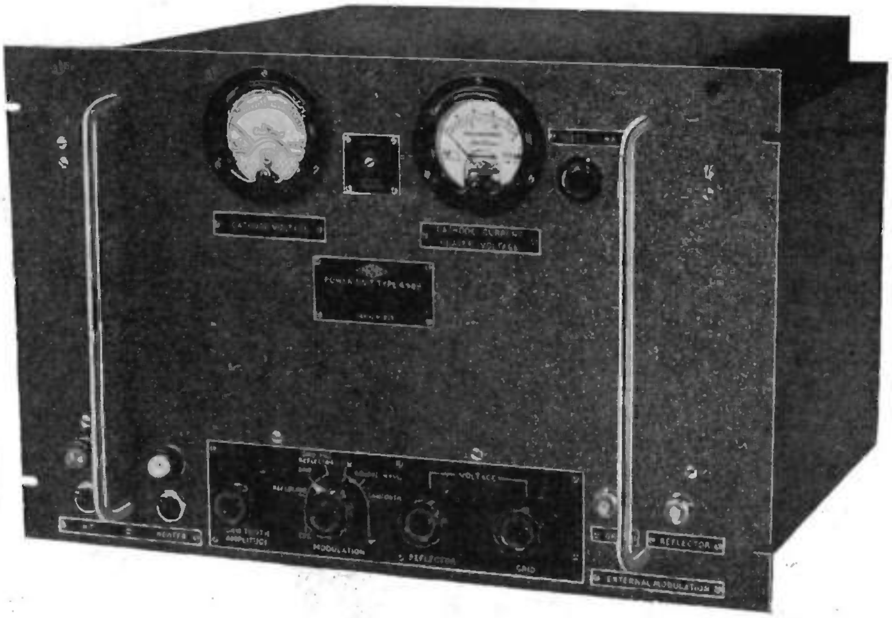
Radio and Transmission Division, Strowger House, Arundel Street, London, W.C.2.
Telephone: TEMple Bar 9262. Cablegrams: Strowgerex, London.

AIRMEC

POWER UNIT TYPE 698B

for

Klystron Valves



THE POWER UNIT, TYPE 698B, is designed to provide H.T. and L.T. supplies for high voltage Klystron valves. All the H.T. supplies are stabilised, the output voltage change being less than 0.5 per cent of the input voltage change. Internal oscillators provide square wave and sawtooth wave modulation, and switching enables either the internal modulation, or modulation from an external source, to be applied to the grid or reflector voltages. A switch position is also provided for operation under c.w. conditions.

STABILISED H.T. OUTPUTS

	Maximum	Minimum
Cathode Volts - - -	—2.4 kV	—1 kV
Grid Volts (relative to Cathode)		
Maximum - - -	—220V	—100V
Minimum - - -	0V	0V
Reflector Volts (relative to Cathode)		
Maximum - - -	—500V	—280V
Minimum - - -	0V	0V
Cathode Current (Maximum on load) - - -	18 mA	10 mA

Stabilisation	Output change of less than ± 200 mV for input change of 210-250V.
Ripple Voltage	Not greater than 20 mV R.M.S.
Regulation	Output Impedance less than 500 ohms at 10 mA.

L.T. OUTPUTS

Rating	4.0 V D.C. at 1.4A.
Ripple	Less than 150 mV R.M.S.

Full details of this or any other Airmec instrument will be forwarded gladly upon request.

AIRMEC LABORATORIES **LIMITED**

HIGH WYCOMBE - BUCKINGHAMSHIRE - ENGLAND

Tel.: HIGH WYCOMBE 2060 *Cables: AIRMEC HIGH WYCOMBE*

Electronic Engineering

Incorporating ELECTRONICS, TELEVISION and SHORT WAVE WORLD
Managing Editor, H. G. Foster, M.Sc., M.I.E.E.

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Contents

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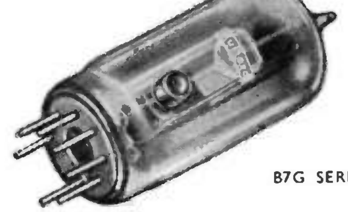
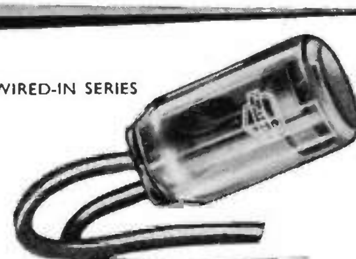
The Mullard range of all-glass photocells for industrial applications


B7G SERIES


B8G SERIES

WIRED-IN SERIES


DEVELOPED on the all-glass technique, Mullard photocells have the outstanding advantages of rigid construction and freedom from microphony, maximum ratio of cathode area to bulb size, high sensitivity and stability and positive location with uniform orientation. They are available on either the B7G or B8G base, with alternative cathode surfaces: caesium-silver oxide (C type cells) with a high sensitivity to red and infra red radiations; and caesium-antimony (A type cells) with a high sensitivity to daylight and radiations of blue predominance.

For applications where savings in space are a prime consideration, as for example, in compact photo-electric equipments, a small wired-in photocell, suitable for end-on incidence of illumination, is also available.

Brief technical details of the Mullard range of photocells are given below. Those who require more comprehensive information, including principles of operation, characteristic curves, and circuit details, are invited to apply for the revised edition of the Mullard publication "Photocells for Industrial Applications".

PRINCIPAL CHARACTERISTICS OF MULLARD INDUSTRIAL PHOTOCELLS.

Type	Base	Max. Anode Supply Voltage (V)	Max. Cathode Current (µA)	Max. Dark Current at Max. Anode Supply Voltage (µA)	Sensitivity* (µA/lumen)	Max. Gas Amplification Factor	Projected Cathode Area (sq. cm.)
20CG	B8G	90	5.0	0.1	150	10	6.7
20CV	B8G	150	20	0.05	25 (V_a = 100V)	Vacuum	6.7
58CG	Wire-in	90	1.5	0.1	100	9	1.1
58CV	Wire-in	100	3.0	0.05	20 (V_a = 50V)	Vacuum	1.1
90AG	B7G	90	2.5	0.1	150	7	4.0
90AV	B7G	100	5.0	0.05	45	Vacuum	4.0
90CG	B7G	90	2.0	0.1	125	10	3.1
90CV	B7G	100	10	0.05	20 (V_a = 50V)	Vacuum	3.1

*Sensitivity measured at max. anode supply voltage, with the whole cathode area illuminated by a lamp of colour temperature 2,700°K., and with a series resistor of 1MΩ.

Mullard

MULLARD LTD., COMMUNICATIONS & INDUSTRIAL VALVE DEPT., CENTURY HOUSE, SHAFTESBURY AVENUE, LONDON, W.C.2

MVT 125

Electronic Engineering

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Commentary

THE radio industry is facing a number of difficulties at the present moment with its pre-occupation with the rearmament programme and export markets, and doubt was expressed about the advisability of holding an Exhibition at Earl's Court again this year.

Sales of domestic receivers in the home market have been deliberately restricted since the Budget by an increase in purchase tax and by restrictions on hire purchase and the effect which this has created can be seen from figures recently published by the Radio and Television Retailers Association. According to the R.T.R.A. the hire purchase sales of radio receivers fell by 59 per cent from January to April this year, while the hire purchase sales of television receivers fell by 78 per cent.

These are startling figures, but they by no means indicate a decline in the radio and television industry which, on the contrary, is making an increasingly important contribution not only to the rearmament programme but to the economy of the country by a vigorous export drive.

On the rearmament side, security prevents comment, but the success of the British radio and television industry in the world's markets is readily apparent. From a very modest £2 million just before the war, the industry has increased the value of its exports to £22·3/4 million for 1951 and it is expected that this figure will rise to £25 million for 1952.

But judged on a basis of attendances figures, the nineteenth National Radio and Television Exhibition organized by the Radio Industry Council was most successful for no fewer than 290,000 visitors went to Earl's Court.

There were the added attractions, as far as the general public was concerned, of the large auditorium theatre in which the B.B.C. artists could be seen in the flesh, and the Fighting Services again co-operated by staging excellent displays. It is inevitable, however, that each succeeding Radio Show tends to become merely an exhibition to attract the buying public. Domestic receiver design is now so stabilized that this year's models will show only minor advances on last year's and until colour television and perhaps frequency modulation are here, the more scientifically minded visitor to Earl's Court finds less and less to appeal to him.

This is in no sense a criticism of the exhibition which is designed primarily to sell more domestic receivers, but it is a matter of regret to us that so little of the other activities of the radio industry were on view. It may well be, of course, that a more technical display of this kind would not combine with the present Radio Show.

* * *

The Flying Display and Static Exhibition of the Society of British Aircraft Constructors is held, in the words of the official programme "to promote the export trade of its member companies and to demonstrate the quality of British aeronautical products" and few people who attended Farnborough last month could doubt that this country has obtained an unchallenged leadership in the design and manufacture of high speed aircraft.

The development of the jet engine has added enormously to the speed of modern aircraft and no more convincing demonstration of this could be obtained than in the recent R.A.F. Fly Past over London to commemorate the Battle of Britain. This aerial procession was led as usual by the Hurricane—a type which played such a predominant part in the darks days of 1940 and had a top speed of 300 m.p.h. Yet the new Hunter which brought up the rear of the procession is easily capable of flying *more than twice* this speed. And this has all come about in less than fifteen years !

But it has not been a matter of adding jet engines to existing aircraft, for many fundamental problems in aerodynamics have had to be solved before the Canberra could cross the Atlantic there and back in eight hours and the Comet add something like one hundred and fifty miles an hour to the speed of the world's air liners. Basically new designs of aircraft have been called for and at Farnborough last month the first results of the British aircraft industry's approach to these problems were on display for the world to see and, we hope, to buy.

The contribution made by the radio industry is by no means insignificant and it is true to say that much of the research on supersonic flight would have been impossible without the aid of the electronic techniques developed very largely by the radio industry itself.

Here at Farnborough there was much to see and admire in the way of electronic apparatus, radio communication equipment and radar—an important side of the other activities of the radio industry to which we have earlier referred.

The Monitoring of High-Speed Waveforms

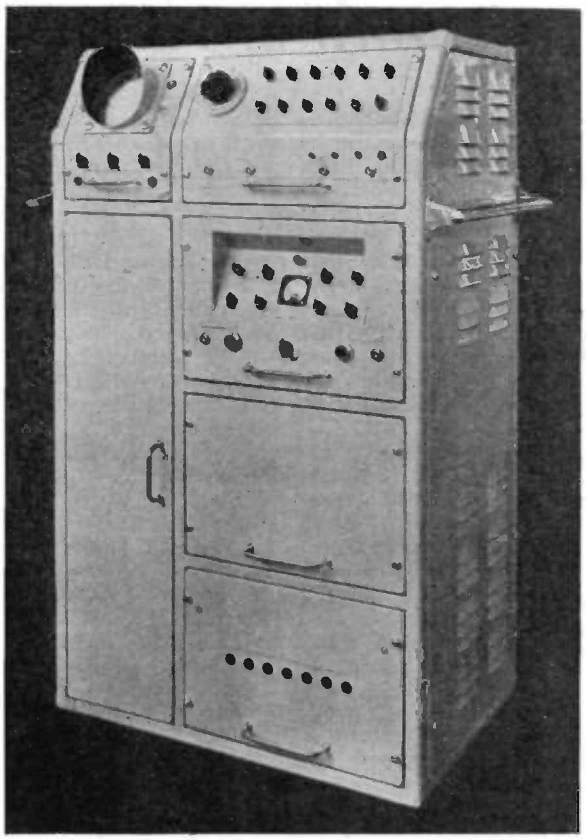
A Description of Techniques Incorporated in the Metropolitan-Vickers Recurrent Waveform Monitor Type 500 †

By J. G. McQueen*

THE instrument to be described has been designed to observe recurrent waveforms having frequency components up to 300Mc/s. Negligible loading is introduced on the circuit producing the waveform, and amplitudes as low as 0·1V are displayed without distorion. Two concurrent waveforms may be viewed simultaneously.

The monitor can only be used when the waveform is repeated continuously, preferably at a rate higher than about 100 per second. During each recurrence a measurement is made of the instantaneous amplitude of a selected point in the waveform. Each measurement is utilized to form one Y co-ordinate of a graph of the waveform, each co-ordinate being made to persist for a considerable portion of the time interval between recurrences. The graph is traced out relatively slowly by causing the selected point to occur at a slightly different instant during each recurrence. The X co-ordinates of the graph are produced by a deflexion in synchronism with the position of the selected point within the waveform.

The essential difference between this and other techniques is that the waveform under observation is not used to deflect an electron beam in a cathode-ray tube, but is, instead, applied to a circuit capable of measuring its instantaneous amplitude at a predetermined point. As many of the advantages of the system result from this difference, the means by which instantaneous amplitude measurements are made will now be briefly described.



The complete instrument

(The probe units which plug into the front panel are not shown)

Fig. 1 is a simplified circuit of the probe unit to which the waveform to be displayed is applied. The valve V_1 is normally cut off, its grid leak, R_1, being returned to a bias point. The waveform is applied to the grid of V_1 via the capacitive divider formed by the small series capacitor, C_1, and C_2 in parallel with the grid capacitance of the valve. As V_1 is normally cut off its grid input impedance is not modified by transit time effects.

At the instant selected for waveform amplitude measurement a very narrow negative going pulse (about 1 millimicrosecond wide) is applied to the cathode of V_1 causing a short pulse of current to flow in the valve. The amount of current depends on the instantaneous level then existing at the grid. The short pulse of current discharges the anode capacitance by a small amount (of the order of 0·5V) following which the anode capacitance recharges slowly to H.T. through the high value resistor R_2. The anode waveform of V_1 is thus a sharp drop whose amplitude depends on the instantaneous amplitude of the input waveform, followed by an exponential rise having a time-constant of the order of 20 microseconds. Although the steep edge is lost in subsequent amplification a pulse output is nevertheless obtained whose amplitude is a function of the instantaneous amplitude of the input waveform as measured in V_1. The means by which this pulse is converted into a suitable Y deflexion voltage will be described later.

The probe unit is normally placed very close to the circuit being monitored, and the terminal attached to the input plate of the series capacitor, C_1, is allowed to touch the required point in the circuit. C_1 represents the whole of the loading on the monitored circuit and is normally adjusted to a value of less than 1pF. C_2 and the grid capacitance of V_1 form a bottom capacitance of about 10pF resulting in an attenuation of at least 10:1. Very much greater attenuation is obtained by reducing C_1. The waveform amplitude required at the grid of V_1 depends on the amount of amplification following the probe unit, and this is limited by the effective noise level at the grid of V_1. This is found to be about 2 millivolts. Assuming a capacitive division of 10:1, 20 millivolts of noise (effectively) exist at the input terminal of the probe unit. If a larger setting of C_1 is tolerable a proportional decrease in the effective input noise level is obtained.

The following advantages are apparent from the above description:—

(1) The high speed waveform is confined to the grid circuit of the probe input valve.

(2) The probe unit may conveniently be placed very close to the circuit producing the waveform.

* Metropolitan-Vickers Electrical Co., Ltd.

† Patent applications have been made in respect of all techniques and circuits discussed in this article.

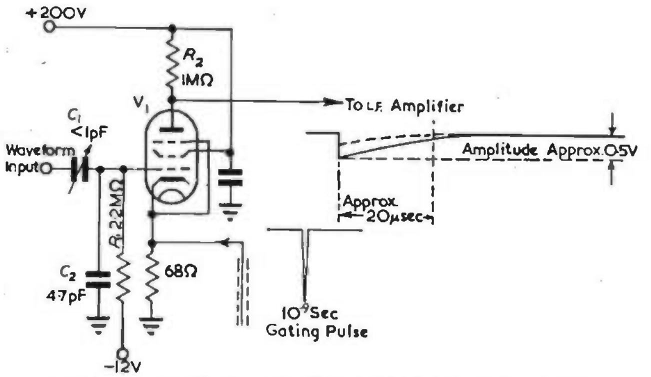


Fig. 1. Simplified schematic diagram of probe unit input stage

(3) The input impedance of the probe unit is high.
(4) Very low amplitude waveforms may be viewed.
(5) Due to the very narrow gating pulse instantaneous amplitude measurements of frequencies up to 300Mc/s can be made with negligible error.
(6) By the use of two probe units instantaneous amplitudes of concurrent waveforms may be measured.

The advantages listed above result primarily from the Y deflexion system, i.e., the production of a series of Y co-ordinates of the graph of a waveform rather than the utilization of the waveform itself as a deflecting potential. In addition to these there are several advantages associated more particularly with the X deflexion system.

(1) The X plates are fed with a series of co-ordinates rather than with the fast time-base of a conventional high speed oscilloscope.
(2) There is no necessity to produce a steep edged brightening waveform.
(3) Most important is the fact that means exist for providing a stable graph of a waveform in cases where the waveform is jittering with respect to its pre-pulse.

The anti-jitter operation indicated in the last paragraph adds considerably to the complexity of the instrument and, while certain monitoring requirements justify this complexity, there are many cases in which it is not necessary. Therefore the instrument has been designed to operate either with or without an additional unit containing the anti-jitter circuits. The anti-jitter system will be described later.

Normal Operation

Fig.2. is a block diagram showing the operation of the monitor when viewing a waveform which is not jittering with respect to its pre-pulse. Block 1 indicates a pre-pulse which must occur at least 0·5 microsecond before the beginning of the waveform to be monitored (Block 3). The instrument has been designed to monitor a waveform occurring up to 24 microseconds after the pre-pulse. When running on internal pre-pulse generation the instrument provides an output trigger pulse about 1 microsecond after the pre-pulse, this delay enabling the front edge of the output trigger pulse to be monitored.

Block 4 represents a manually variable delay which consists of a linear negative going sawtooth having a slope equal to 7 volts per microsecond. The sawtooth, which is triggered by the pre-pulse, is applied to the cathode of a diode whose bias is varied by an accurately calibrated control.

A further delay (Block 5) which varies at a relatively slow rate is introduced by applying to the anode of the same diode a slow sawtooth waveform generated in Block 6. At the instant that the diode conducts it passes a pulse to Block 9 which generates a negative going pulse of approximately 1 millimicrosecond width. This gating pulse is fed along a coaxial line to the probe unit (Block 10) in which, as previously described, a pulse is produced whose height is dependent on the amplitude of the monitored waveform at the instant of the gating pulse. Block 11 converts the output from the probe unit into a flat topped pedestal of upwards of 100 microseconds duration whose height is proportional to the measured instantaneous amplitude. A brightening pulse selects the top of each pedestal for display.

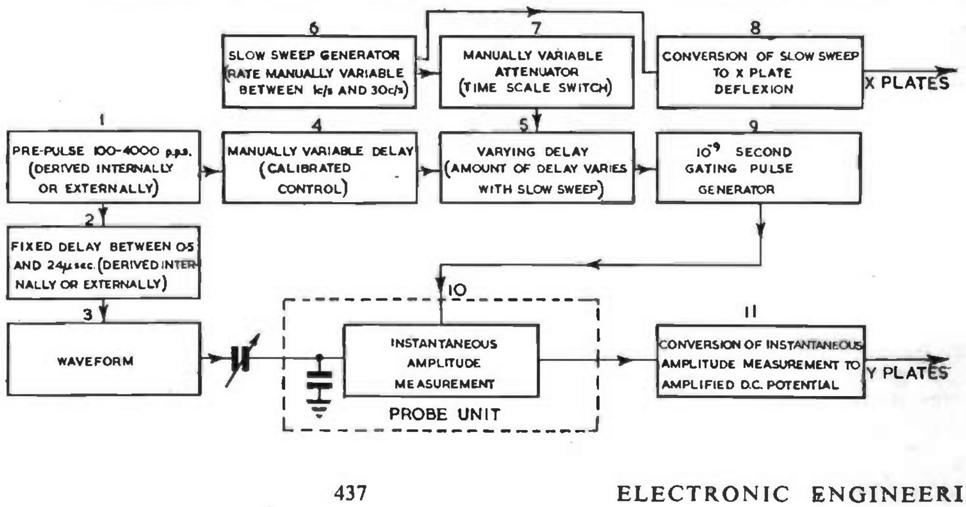
The position of each gating pulse within the monitored waveform is dependent on the free-running slow sawtooth generated in Block 6. The X co-ordinates of the graph of the waveform are therefore required to change in synchronism with the slow sawtooth, and, in Block 8, a suitable deflecting voltage is generated. The slow sawtooth is attenuated in Block 7 by an amount depending on the setting of the time scale switch; e.g. a 7 volt slow sawtooth waveform fed into Block 5 produces a microsecond movement of the gating pulse. A 0·35V slow sawtooth provides an effective time scale of 0·05 microsecond.

The manually variable delay (Block 4) controls the position of the time interval during which gating pulses occur, thereby providing horizontal movement of the displayed waveform. Calibration of this control in 0·01 microsecond divisions (fine adjustment) and 2 microseconds steps (coarse adjustment) enables the time scale of the display to be accurately measured. In addition the control is adjusted to provide a delay roughly equal to that between the prepulse and the waveform. An inherent delay of about 0·5 microsecond in Blocks 4 and 9 sets a limit to the earliest point following the prepulse which can be observed.

Anti-Jitter Operation

The difference between anti-jitter and normal operation is in the derivation of the X deflexion potential. In the operation just described the X deflexion is maintained in synchronism with the movement of the gating pulse relative to the pre-pulse. As long as the monitored waveform remains in fixed time relationship to the pre-pulse the X deflexion is therefore representative of the movement of

Fig. 2. Block diagram showing operation of high-speed monitor when waveform is not jittering with respect to pre-pulse



the gating pulse within the waveform. If, however, the waveform is produced erratically with respect to the pre-pulse it is necessary that each X co-ordinate of the final graph be produced by a direct measurement of the position of the gating pulse within the waveform.

Fig. 3. represents this operation. Block 2 indicates the irregular delay between the pre-pulse and the waveform. The variable delay represented by Block 4 remains substantially constant during the monitoring of a waveform. It is adjusted by an automatic means, to be decribed later, to cause the mean position of the gating pulses to be roughly in the centre of the portion of the waveform selected for viewing. As the waveform is jittering with respect to the pre-pulse the position of any particular gating pulse within the waveform cannot be previously determined. All that is now required of Blocks 4, 5, 6 and 7 is that a reasonable number of gating pulses be made to occur during the waveform. The position of the gating pulses during successive waveforms may well be entirely random.

The gating pulses produced in Block 9 are fed to the probe unit, Block 10, and the resulting series of instan- a small fixed amount before application to the time measuring circuit.

Block 13 is a manually variable delay which serves to select the interval of time (relative to the locking pulse) which is to be displayed. Assume that the locking pulse occurs 1 microsecond after the front edge of the waveform. It is then required that a gating pulse which occurs 1 microsecond before the locking pulse (i.e. on the front edge of the waveform) should give rise to an X co-ordinate at the left-hand side of the display, and, assuming that the displayed time scale is to be 0·25 microsecond, a gating pulse occurring 0·75 microsecond before the locking pulse should produce an X co-ordinate at the right-hand side of the display. Now, as the gating pulse is delayed 2 microseconds before being applied to the time measuring circuit, Block 13 should be set to give 1 microsecond delay to make the measured time interval zero when an X co-ordinate at the left-hand side of the display is required. The time scale switch (Block 15) which is a variable attenuator is adjusted, in the present assumed case, to provide a full scale movement of the X co-ordinate when the measured time interval is changed by 0·25 microsecond. As

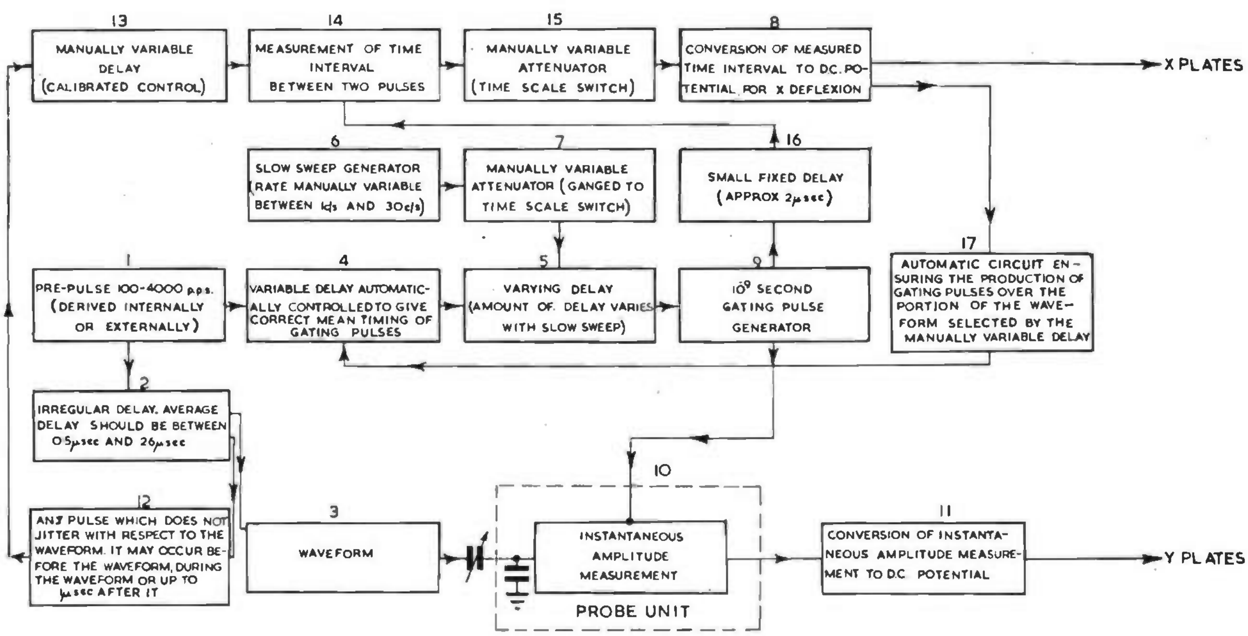


Fig. 3. Block diagram showing operation of high-speed monitor when waveform is jittering with respect to pre-pulse

taneous amplitude measurements are amplified and lengthened in Block 11 to produce Y co-ordinates.

Block 12 represents the generation of a locking pulse. This is a pulse which is produced externally to the instrument, the actual means by which it is generated depending on the circuit being monitored. The requirement is that the locking pulse should occur in fixed time relationship with the waveform under observation. It may well be the front edge of the waveform itself. It need not occur before the waveform; in fact provision is made for utilizing a locking pulse occurring up to 1 microsecond after the earliest point in the waveform being monitored.

Block 14 is a circuit which measures the time interval between the locking pulse and the gating pulse. The time interval measurements are converted in Block 8 into voltage pulses of similar duration to the Y co-ordinates, each voltage pulse forming an X co-ordinate of the display.

The gating pulses may occur either before or after the locking pulse. The time measuring circuit, however, requires that one pulse always occurs before the other. For this reason the gating pulse is delayed in Block 16 by adjustment of the manually variable delay (Block 13) has the effect of moving the displayed waveform horizontally it is used as a measure of the time scale.

The movement of the gating pulse within the waveform during successive recurrences is partially controlled by Blocks 4, 5, 6 and 7, while random movement is provided by jitter of the waveform with respect to the pre-pulse. It is required that the average position of the gating pulses should be near the centre of the displayed waveform. It has been seen that when the gating pulse occurs at or before the beginning of the portion of waveform selected for display, an X co-ordinate at the left-hand side of the display is produced. Similarly, gating pulses occurring at the end of or after the waveform produce X co-ordinates at the right-hand side of the display. Block 17 is a circuit which integrates all the X co-ordinates and provides a slow automatic control of the delay between prepulse and gating pulses (Block 4). If, for example, there is an excess of X co-ordinates at the left-hand side of the display, the delay (Block 4) is slowly increased until balance is achieved. This circuit does not shift the displayed waveform. It only ensures that points of the graph are plotted within the limits of the selected time scale.

Fig. 4 is an illustration of the efficacy of the anti-jitter system. The waveform is the front edge of the rectified output of a pulsed 3cm magnetron. Due to inherent jitter in the thyratron which is used in the generation of the magnetron driving voltage and further jitter in the build-up of magnetron oscillations, normal operation of the monitor provides the random distribution of co-ordinates shown in (a). Waveform (b) is the same as (a), but in this

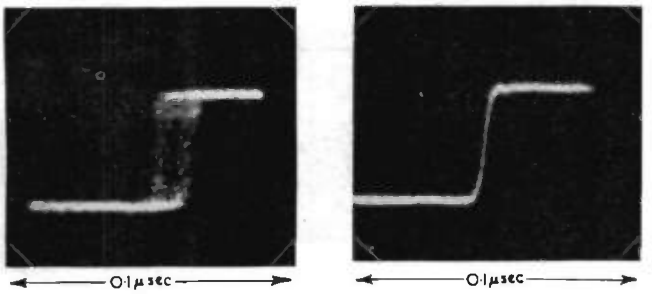


Fig. 4. Front edge of rectified magnetron oscillation (a) Normal operation of monitor (b) Anti-jitter operation of monitor

case anti-jitter operation is provided by using the waveform itself as a locking pulse.

The stabilizing of a time scale to a time instant occurring after its start is analogous in a conventional oscilloscope to triggering the time-base from the waveform itself and then delaying the waveform before application to the Y plates. The system described above has the advantage that the waveform is not delayed and is not subject to any distortion which such a delay might introduce.

Limiting Factors

The limitations imposed by various parts of the system will now be considered.

The monitored waveform must be recurrent and must be substantially the same shape each time it occurs. As only one element of a graph is produced each time the waveform occurs, 100 per second is considered about the lowest suitable recurrence rate. An afterglow tube is used to provide a constant display of the graph. The upper limit of recurrence depends on the ability to count down the prepulse and locking pulse (not the waveform). 4,000 per second is the highest rate at which the display circuits will work but very much higher recurrences may be handled by counting down. If the waveform is free running a pre-pulse within the specified limits must be derived, but, as already explained, jitter between it and the waveform is unimportant.

The limitation imposed by the timing and time measuring circuits is an extremely small pulse to pulse discrepancy in the positioning of the X co-ordinates (less than 0·3 millimicrosecond) resulting from valve noise.

The effective "speed" of the time scale is without limit. By causing each gating pulse to occur at exactly the same place while driving the X plates with the slow sweep, an infinite effective speed is obtained. The shortness of the time scale is no criterion of performance, as there is a limitation set by the frequency response of the monitor which makes a time scale shorter than about 50 millimicroseconds valueless.

The limitation in frequency response is due to two causes. Firstly, it is necessary to feed the waveform to the grid of a normally cut-off valve. The low-pass filter formed by the probe input lead and the grid of the valve has been found to have a cut-off frequency of about 380Mc/s with a substantially flat response up to 350Mc/s. It is thought that an improvement may be obtained by the use of a specially constructed probe input valve.

The second limitation to frequency response is due to the width of the gating pulse. It has already been explained that a pulse of current passes through the probe input valve, the amount of current depending on the amplitude of the waveform at the instant of the gating pulse. As the gating pulse is of finite width it is the mean amplitude of the waveform during the gating pulse which is measured.

The attenuation of a sine wave of frequency f which is measured by a series of gating pulses of width T can be derived as follows:—

In Fig. 5 a square gating pulse of width T is centred on point P of the waveform $V\sin\omega t$.

The mean amplitude of $V\sin\omega t$ during the period T is

$$\frac{1}{T}\int_{t-T/2}^{t+T/2} V\sin\omega t$$

$$= \frac{2V}{\omega T}\sin\omega T/2 \,.\, \sin\omega t$$

$$= V.\frac{\sin\pi f T}{\pi f T}\,.\,\sin\omega t$$

The resulting waveform, therefore, has an amplitude

$$\frac{\sin\pi f T}{\pi f T} \times \text{input waveform}$$

Assuming $T = 1$ millimicrosecond and $f = 300$Mc/s, the ratio of output to input is

$$\frac{\sin 0{\cdot}3\pi}{0{\cdot}3\pi}$$

$$= 0{\cdot}86, \text{ an attenuation of } 1{\cdot}3\text{db.}$$

Circuits

Most of the circuits used in the monitor follow standard practice, and will not be described in this article. The accurate timing of the gating pulse and the amplification of very low level pulses call for considerable care in the stabilizing of H.T. supplies and in the isolating of independent parts of the system. In particular it is found necessary to avoid any unintentional coupling between the slow sawtooth generator and the gating pulse generator or the Y deflexion system.

Two circuits are shown, for the reason that they do not follow standard practice, and were specifically designed for this instrument. They are (1) the complete circuit of the probe unit and the subsequent amplifying stages and (2) the derivation of the millimicrosecond gating pulse.

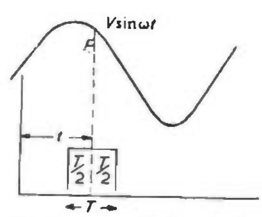


Fig. 5. Measurement of mean amplitude of sine wave during time interval T

Y. Co-ordinate Derivation

$V_{1, 2, 3, 4}$ in Fig. 6, are housed in the probe unit. The remaining circuits are in the main instrument. The operation of V_1 has already been described. The negative going pulse at the anode of V_1 is amplified in the low frequency amplifier V_2, and is fed to the main instrument. The circuit of V_3 and V_4 is an exact replica of that of V_1 and V_2, with the exception of V_3 grid, which is returned (via C_3) to earth and has no waveform applied to it. The gating pulse is fed to V_1 and V_3 cathodes, so that the output from V_2 and V_4 are identical except for the modulation on V_2 anode output due to the waveform at V_1 grid. V_4 output is inverted in V_5, and the two waveforms are then added so that on the slider of VR_1 only the modulation due to the monitored waveform appears.

The reason for this balancing circuit is to cancel out any noise or other unwanted waveform at the cathode of V_1. Thus small variations in the amplitude of the gating pulse have no effect. (It should be noted that as the gating pulse is about 10V in amplitude a variation of 1 per cent

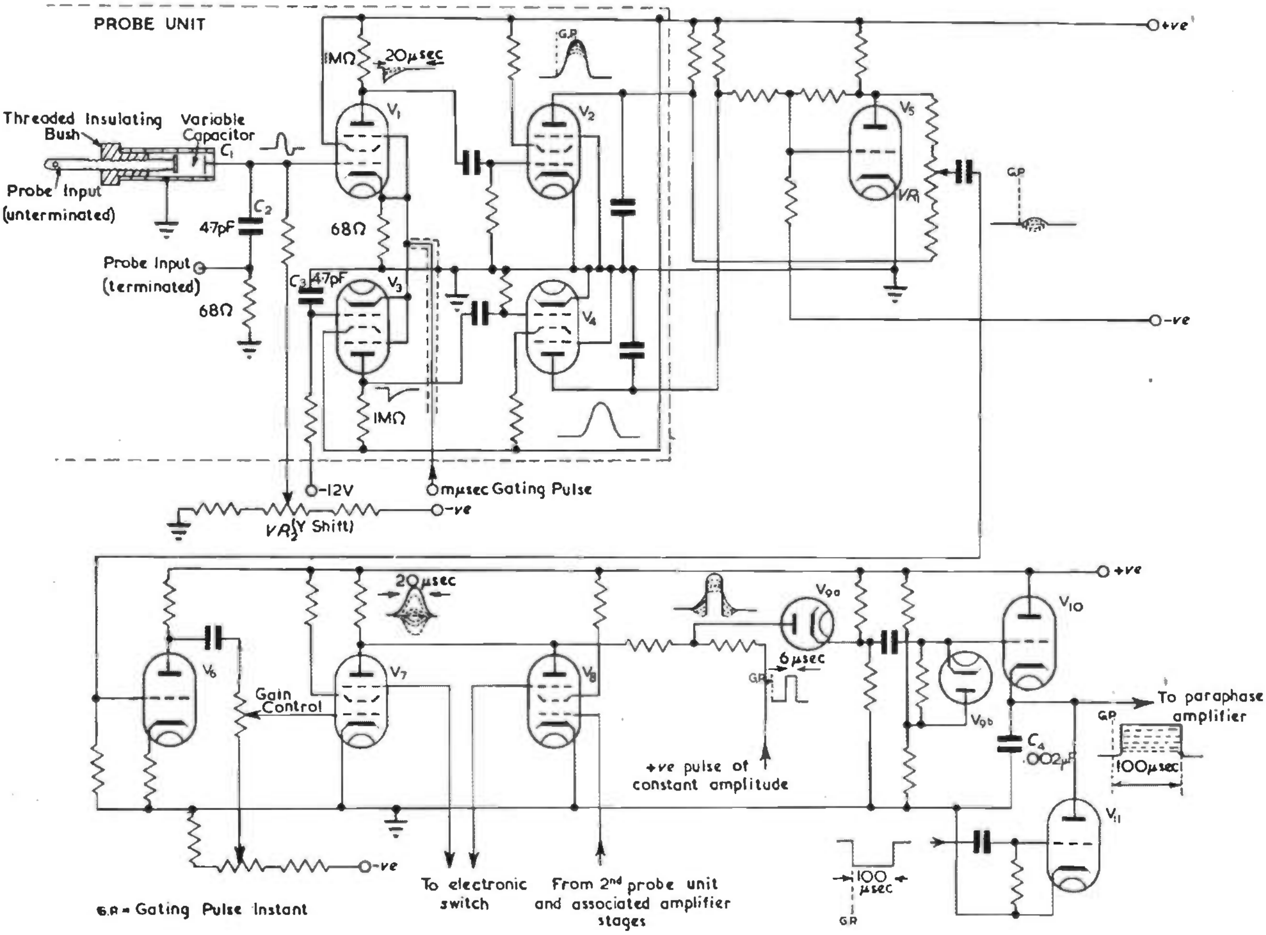


Fig. 6. Derivation of Y co-ordinate

produces the same change in V_1 current as a 0·1V waveform on V_1 grid, which is the normal working level.) Another unwanted waveform which might appear at the cathode of V_1 and which is effectively cancelled is that due to high frequency chassis currents which are normally troublesome when monitoring a waveform such as shown in Fig. 8. This waveform is only 0·5V in amplitude and occurs simultaneously with a 200kW thyratron pulse. In spite of this the interference is negligible.

The balanced output is amplified in V_6 and again in V_7. V_7 and V_8 have a common anode load, and V_8 is preceded by the same stages as V_7. By means of switching the suppressors of V_7 and V_8 electronically the outputs from two probe units can be fed into the common load during alternate slow sweeps of the X deflexion system.

It is required that the pulse lengthening circuit be provided with unidirectional pulses. Therefore, a constant amplitude pulse is added to the waveform at V_7 and V_8 anodes. D.C. restoration is carried out in V_9 and the resulting waveform is applied to the cathode-follower V_{10}, which charges C_4 to rather above the peak of the grid waveform. C_4 remains charged until V_{11} conducts after about 100 microseconds (or in the case of low repetition rates, after about 400 microseconds). V_{11} remains conducting until the next gating pulse occurs, when it again cuts off, allowing C_4 to charge to a new level.

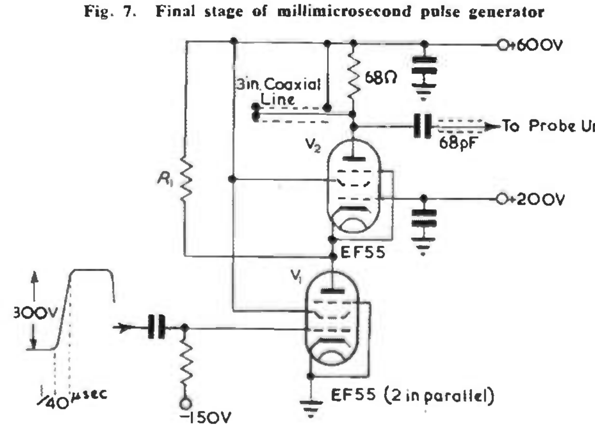
The resulting pedestals are fed to a paraphase amplifier and to the Y plates of a cathode-ray tube.

Amplitude calibration is carried out by adjusting the voltage calibrated control VR_2, which changes the grid potential of V_1, thereby introducing vertical shift. It is, however, still necessary to know the attenuation due to the input capacitive divider which is variable. This is measured by applying to the probe input a C.W. oscillation of known amplitude. A 3V and 30V peak-to-peak oscillation are available, and the resulting unlocked band of Y co-ordinates is compared with the calibrated shift, the ratio between the two being the attenuation for a given setting of the capacitive divider.

Millimicrosecond Pulse Generator

Fig. 7. is the circuit of the final stage of the millimicrosecond gating pulse generator. The basic requirement in the generator is the very rapid switching on of the valve V_2. The current in the anode circuit is caused to change from zero to roughly 2A in a time of the order of 1 milli-

Fig. 7. Final stage of millimicrosecond pulse generator



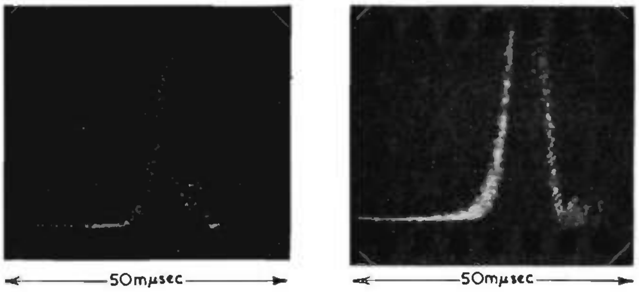


Fig. 8. T.R. cell "Spike" recorded on high-speed recurrent waveform monitor. (a) With "keep alive" voltage applied to cell. (b) "Keep alive" removed; same voltage scale as (a)

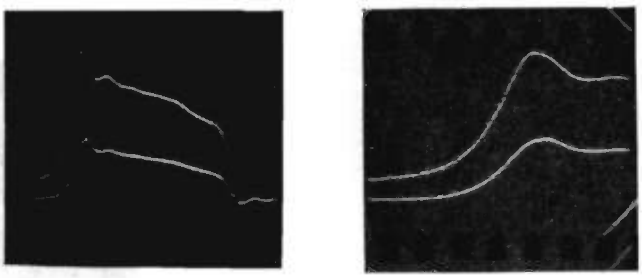
microsecond. The resulting negative edge travels along the piece of short-circuited line, and the returning inverted edge cancels the initial drop, the current in V_2 having by this time reached a constant value. A narrow pulse is thus formed at the anode of V_2, and is fed to the probe unit where the tip only of the pulse is used to gate the input valves as already described.

V_2 is switched on by a negative waveform applied to its cathode. Although this method has the disadvantage that the switching waveform has to provide the whole of the current for V_2, there are two overriding advantages:—

(1) It is a simpler matter to provide a fast negative edge than a similar positive one.

(2) A negative edge can be produced with a sharp transition from maximum rate of change of voltage to constant voltage.

Fig. 9a. Grid and cathode waveforms of a $\frac{1}{2}\mu$sec blocking oscillator pulse generator. The voltage scale of each wave form is the same. (b) The front edge of the above waveforms on a 0.1μsec time scale



V_1, shown as a single valve, though it is preferable to use two in parallel, is switched on fairly rapidly by a blocking oscillator pulse, the resulting current reaching a maximum of several amperes in about 5 millimicroseconds. By the time the current has reached its maximum it has discharged the anode capacitance of V_1 and the cathode capacitance of V_2 from 600V to about 200V at which point the bias on V_2 is overcome and the remaining negative going edge before V_1 bottoms switches on V_2 sufficiently rapidly for the present purpose.

Some Practical Applications

One application of the monitor has already been indicated in Fig. 4 in which the rectified build-up of oscillations in a magnetron is shown. An important waveform associated with the above is the break-through in a T.R. cell to which the magnetron output is applied. The break-through, shown in Fig. 8, is an example of the low amplitude, steep edged waveforms, in the monitoring of which the instrument is used to its best advantage. It would be an extremely difficult matter to reproduce the waveforms of Fig. 8 by any other means.

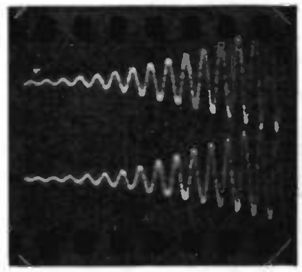


Fig. 10. Build up of oscillations in a pulsed 150Mc/s oscillator

Fig. 9. shows the waveforms associated with a blocking oscillator in which case use is made of the waveform mixing facility.

Fig. 10. shows a few cycles of build-up of a pulsed 150Mc/s oscillator. The two concurrent waveforms appear at the anode and grid respectively of the valve.

Many other applications will no doubt come to mind, and the usefulness of the technique in any particular case can be assessed in the light of the foregoing description.

Acknowledgment

The author is indebted to the Directors of Metropolitan-Vickers Electrical Co. Ltd. for their help and encouragement in carrying out this work and for their permission to publish this article.

Automatically Indicating the Termination of a Television Programme*

It is standard practice in television receivers in this country to apply the D.C. component of the picture signals to the cathode-ray tube and this allows dark and bright scenes to be reproduced as such on the receiver screen. When, however, the picture transmission ceases, the practice results in no raster being left visible on the television screen and with the cessation of the sound transmission in addition it sometimes happens that the continued functioning of the receiver passes unnoticed so that sets not switched off before the end of an evening's programme may become left on all night. This is wasteful, particularly of tube life of the receiver, and it is desirable to have some automatic indication that the receiver is still switched on although the programme has ended.

Indication by an automatic brightening of the raster appears to be a simple and appropriate form of indication and can be achieved in a very simple manner by greatly reducing the degree of the D.C. component applied to the cathode-ray tube. There is then, however, the disadvantage of insufficient discrimination between dark and bright scenes, and in particular dark effects, employed frequently on studio technique, fail to be reproduced. Moreover, there is the tendency to show return lines on the screen when the average picture brightness is small.

A more satisfactory method is to employ a control of the cathode-ray tube that does not depend on the picture brightness but on some characteristic of the transmission which is constant so long as the transmission lasts and then ceases with the transmission. Thus the sound carrier may be employed and a control applied to the cathode-ray tube, depending on the D.C. present in the sound detector circuit. Alternatively a control may be developed proportional to synchronizing impulse amplitude. Here the control can conveniently be obtained from the anode circuit of the separator valve. In accordance with the usual practice at present adopted synchronizing impulses are applied in a positive sense to the control-grid of the separator valve with the result that the valve is not strongly conducting on the average during a transmission, but becomes strongly conducting when synchronizing impulses cease. The ending of the potential of the separator valve and this can be used to increase the intensity of the cathode-ray beam so that with the ending of the transmission a suitably bright raster is shown on the screen of the picture tube.

* *Communication from E.M.I. Engineering Development Ltd.*

The Physical Realization of an Electronic Digital Computor

By A. D. Booth*, D.Sc., Ph.D., F.Inst.P.

It is the purpose of this article to complete the description of an electronic computing machine, using magnetic drum storage, which was commenced in the previous articles[1,2].
The principal components and control elements which remain to be discussed are:
(1) *the multiple shift instructions,* (2) *the multiplier,* (3) *the function table,* (4) *the control.*
and these will be taken in the above order.

Multiple Shift Instructions

As explained in a previous article[1], numbers are represented, for machine purposes, in binary form and it is assumed that the "binary point" occurs immediately at the right of the most significant binary digit (i.e. that the numbers are numerically less than unity) thus a number will appear as:

0·1100,000 . . . . (3/4 in decimal notation)

In this machine, as in most others at present operating or under construction, negative numbers are represented by complements modulo 2. (That is by subtracting the positive number from 2). Thus:

$- 3/4 = 2 - 3/4 = 1{\cdot}0100{,}0000$ . . . .

Now it will be seen that if several numbers are added together the sum will tend to increase. This means that, in a machine of the type under discussion where the numbers are of a limited number of binary places only, the result of a large number of additions will soon grow out of the range of the machine and digits will be lost from the most significant end. To avoid this, the register storing the number must be capable of shifting its contents to the right by any desired number of places. In a similar manner the operation of multiplication applied, as in this case, to numbers which are numerically less than unity, tends to decrease the size of the resulting numbers and consequently it is desirable to have an instruction which will shift the register contents to the left by any number of places.

A moment's consideration will show that the right shift "n" places instruction (R_n) is equivalent to division of the number held in the register by 2^n. Similarly the left shift "n" places instruction (L_n) multiplies by 2^n.

It is desirable that the sign of a number held in the register should not change as a result of a shift operation. This can be ensured by the following scheme:

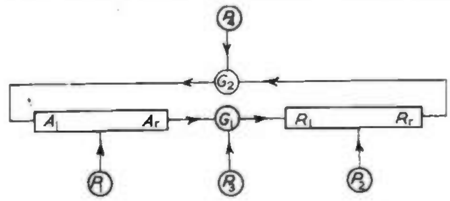
In right shift n, (i.e. division by 2^n) the most significant digit, F_1, of the original number remains unchanged and fills successive positions to its right after each shift. Thus:

Original	0·1101,0000	(13/16)	1·0011,0000	(−13/16)
1st shift	0·0110,1000	(13/32)	1·1001,1000	(−13/32)
2nd shift	0·0011,0100	(13/64)	1·1100,1100	(−13/64)
3rd shift	0·0001,1010	(13/128)	1·1110,0110	(−13/128)
etc.				

The Birkbeck College computing machines have shifting register units of the type shown in Figs. 9(b) and 10 of the previous article[2] and it will be seen that if no external connexion is made to F_1 and a series of shift pulses is sent to the gates G_n precisely the desired result is attained.

A left shift order is slightly more complex since no actual left shift gates are included in the register units. This situation may be overcome, however, by observing that if the head and tail of an "r" stage register are connected together to form a ring and (r-n) right shift pulses are applied, the result of the operation is effectively an n stage left shift.

In practice, the machine under discussion has two registers usually called A and R and for various reasons it is convenient to arrange for the tail of A to be connected to the head of R during shift operations. This means that



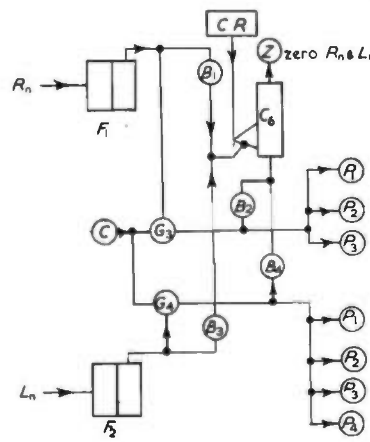


Fig. 1. Control for R_n and L_n

in fact, an n stage left shift is obtained by means of ($2r$-n) right shift pulses.

The details of the control circuits are given in Fig. 1, P_1 and P_2 are the shift pulsers for registers A and R respectively. P_3 connects A_r to R_1 and P_4, R_r to A_1. C_6 is a standard counter capable of being pre-set to any number indicated by the digits contained in part of the control register $C.R.$

It is worth mentioning at this point that this pre-setting of a counter is a simple substitute for a coincidence sensing device, thus if it is required to know when the contents of a certain binary counter of total capacity 2^p have reached q say, it is sufficient to preset the counter 2^p-q and to observe when carry occurs from the most significant stage. This trick could not, however, be applied to the main counter in the machine since in this case a continuous

* *Birbeck College Research Laboratory.*

record of the drum position is required and considerable loss of time would result from the adoption of the above simple coincidence sensing scheme. C is a source of clock pulses and F_1 and F_2 are the control flip-flops for R_n and L_n respectively. B_1-B_4 are diode buffers inserted in obvious places to prevent feedback from one operation to another. The operation of the circuit is as follows: when R_n is set up a D.C. step voltage is obtained from one anode of F_1, this operates a gate, via B_1, to pre-set C_6 to the number held in $C.R.$ (actually 64-n in the present machine). At the same time G_3 is set to emit subsequent clock pulses which pass, via B_2 to C_6 causing the latter to count, and to the pulsers P_1-P_3 causing A and R to shift and A_r to be sent to R_1.

When n pulses have passed G_3, C_6 emits an operation complete pulse which restores F_1 to its zero state and thus terminates the operation.

The operation of L_n is exactly similar except that C_6 is now pre-set to n and P_4 is also pulsed, via G_4 causing R_r to be sent to A_1.

The Multiplier

The design of multipliers for digital computing

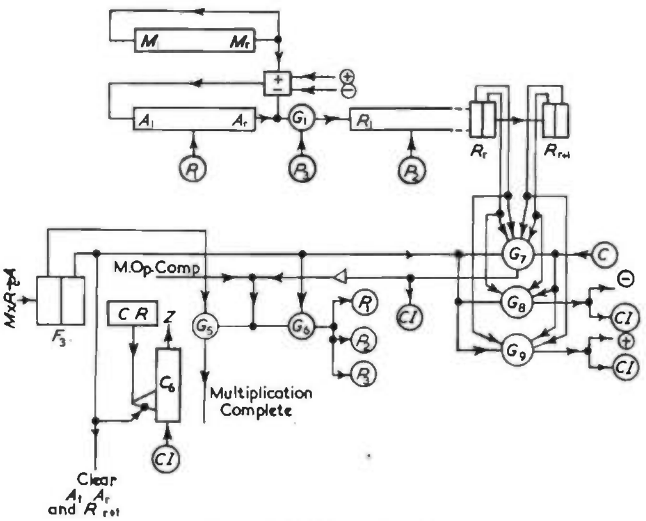


Fig. 2. Multiplier schematic

machines has been a subject of considerable controversy in the past. It is fairly easy to design a multiplier, either serial or parallel, which will deal with positive numbers; however, it is an irksome restriction in an all-purpose computing machine if numbers have to be tested for sign and converted to positive form prior to insertion into the multiplier and the result subsequently corrected for sign.

When numbers are represented in complement form an automatic multiplier, designed for positive operation only, would generate the following quantities if applied to non-positive quantities:—

(1) $+a \times +b = ab$

(2) $-a \times +b = 2b - ab$

(3) $+a \times -b = 2a - ab$

(4) $-a \times -b = 4 - 2a - 2b + ab$

so that in cases (2) and (3) corrections of $-2b$ and $-2a$ would have to be added to the result and in case (4) $2a + 2b - 4$. This can be done but results in fairly elaborate circuits and appears to be undesirable, especially in a serial machine of the type under discussion. As a result theoretical studies were undertaken with a view to finding a procedure which would need no prior knowledge of the signs of the numbers being multiplied and no corrections at the end. The mathematical details of this process have been given elsewhere[3] and it is necessary to mention now only the mechanical details. Referring to Fig. 2, the multiplier is held in the shifting register R and the multiplicand in M. The auxiliary counter C_6 is again used, this time to stop the multiplication process after the required number of operations. It should be noted that by presetting C_6 in a suitable manner any desired number of steps of multiplication can be carried out thus obviating wasted time when the multiplier is known to have less than n "live" digits. The process is as follows:—

(1) If $R_r = 0$, $R_{r+1} = 0$, shift A and R one place to the right so that $A_r \rightarrow R_1$ and $R_r \rightarrow R_{r+1}$.

(2) If $R_r = 1$, $R_{r+1} = 1$, exactly as in (1).

(3) If $R_r = 1$, $R_{r+1} = 0$. Subtract M from A and then shift A and R as in (1).

(4) If $R_r = 0$, $R_{r+1} = 1$. Add M into A and then shift A and R as in (1).

R_{r+1} is initially clear.

The shift is suppressed at the last operation.

When F_3 is sent into the excited state by the initiating pulse from the function table, A and R_{r+1} are cleared and the required priming number is set into C_6 from the control register $C.R.$ G_5 is closed so that the normal memory operation complete pulse, used to clear the add/subtract units, is inhibited, $G_6 \ldots G_9$ are opened. If $R_r = R_{r+1}$ (i.e., both zero or both unity) G_7 emits the next clock pulse from C, this goes to CI and causes C_6 to count.

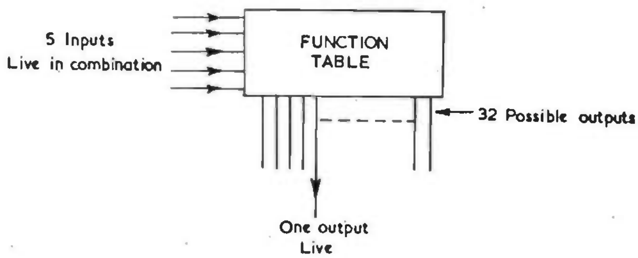


Fig. 3. Schematic of function table

After a delay |> to enable C_6, if necessary, to terminate the operation, the pulse passes via G_6 to P_1, P_2 and P_3 causing the required shift of A and R. If the process is, however, complete C_6 will have restored F_3 to zero state closed G_6 and opened G_5, thus allowing the pulse from G_7 and |> to appear as an "operation complete" signal. If $R_r \neq R_{r+1}$ either G_8 or G_9 will emit the clock pulse, G_8 stimulates the subtract unit causing M to be subtracted from A. G_9 stimulates the add units causing M to be added into A. Both gates cause C_6 to add one to its original contents. If the current operation is not the final one, the addition or subtraction complete pulse passes, via G_6, to the shift pulsers $P_1 \ldots P_3$, if it is the final one, however, C_6 will have zeroed F_3, closed G_6 and opened G_5, and an operation complete pulse will appear via G_5.

It will be seen that the circuit is very economical in components and also that it "shortcuts", that is, runs over any consecutive series of 0's or 1's in the multiplier without having to wait a full addition or subtraction time. A further property of the device is that a separate register M is not necessary, since M can be obtained directly from the store, this, however, slows up the operation very considerably in the case where a magnetic drum is used.

The Function Table

In this, as in most other computing machines, orders are represented in coded binary form, and since they are between 16 and 32 in number, any order can be represented by a 5 binary digit array. It is thus necessary to have means of obtaining a signal on a unique member of 32 output channels in accord with the combination set up on the five input channels, this is shown, schematically in Fig. 3.

Three general methods of engineering a function table exist:—

(1) By counting.

(2) By series elements.

(3) By parallel or matrix elements.

In the first method a counter causes a shifting register to move a single "1". If a five stage binary counter C_5 is used

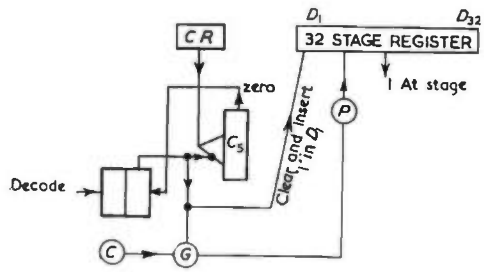


Fig. 4. Counting function table

together with a 32 stage register D as shown in Fig. 4 a "1" initially placed in D_1 will eventually reside in D_{32-n} where n is the number preset in C_5. This scheme has the advantage of using only standard components, but has the disadvantages of complexity and inherent slowness. A variant not requiring either C_5 or D is obtained by having the instruction word so long that each operation can be given a particular digit to itself, this is so wasteful of memory space that it is usually considered impracticable.

The second method is most familiar in the form of a relay "tree" or pyramid as shown in Fig. 5. Here only one conducting path between the 32 output lines and the earth exists for each combination of on/off of the 5 relays $S_1 \ldots S_5$. Although this circuit has been described in terms of relays it can be constructed from double triode valves, each anode corresponds either to an "on" or an "off" contact, the grids correspond to the coils and the cathodes to the centres. The scheme appears to be an excellent one and to have the sole disadvantage of

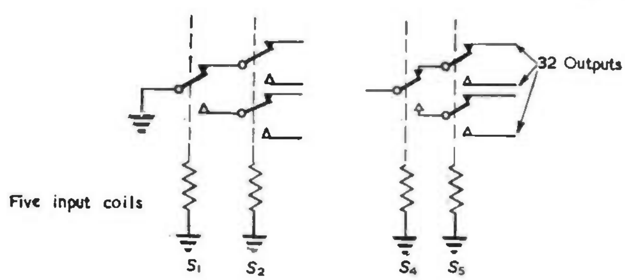


Fig. 5. Tree function table

requiring a large set of different voltage levels for correct grid biasing.

The third method uses a resistance or diode matrix as shown in Fig. 6. It will be seen that for resistive connexion the voltage in any output line is $1/3(\Sigma\ V_A)$ and that this can only reach $V_{A\,(MAX)}$ if all inputs to the line are at high potential. If diode connexion is used the output voltage is $V_{A\,(MIN)}$ unless all the inputs are high in which case it rises to $V_{A\,(MAX)}$. The diode matrix is thus clearly the most satisfactory but if germanium crystals are used a 5 × 32 table containing 160 elements is very expensive. It is hoped that the introduction of selenium rectifiers, of low capacitance, will in future improve matters.

Since a resistive matrix uses high value resistors the output step voltage has a very slow rise, to overcome this difficulty one of a set of gates $G_1 \ldots G_n$ is set up by the table and then used to transmit a standard sharp pulse from a clock source C.

The Control

In Fig. 7 is shown the control schematic for a machine of the type under consideration, and it will now be explained how this operates to guide the machine in the execution of its various functions.

Firstly it will be assumed that a group of order digits is just appearing at the digit output of M (the store) and that the binary element $C.F.$ is set in the excited position. The gate G_1 is open and the train of "n" clock pulses, coincident with the required word digits, are passed to the shift pulser of the control register $C.R.$ These pulses cause the contents of $C.R.$ to shift progressively to the right and, at each stage, one of the incident digits from M is absorbed. When the whole n digits have appeared these will be stored in $C.R.$ and the memory now emits an operation complete (Op. Comp.) pulse which restores

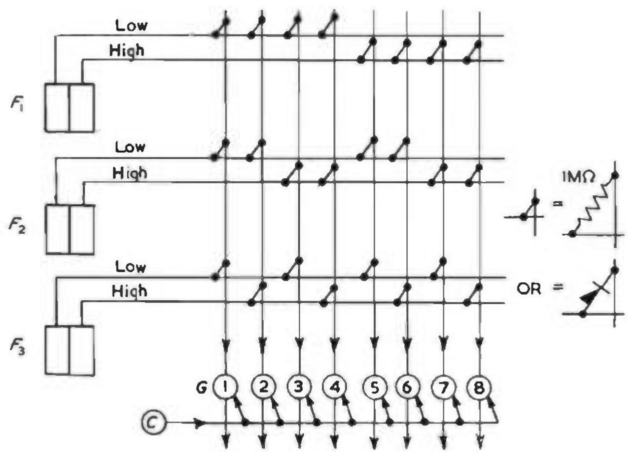


Fig. 6. 3 × 8 matrix decoder

$C.F.$ to its normal state. As $C.R.$ returns to zero a pulse is emitted, via line a, which gates the memory location digits of the number required in the following arithmetic operation to the memory location register $M.L.$ After a short delay |> to enable the decoder $D.C.$ to settle down on the contents of $C.R.$, a gating pulse is applied to $D.C.$ and one of its 32 outputs emits an operation pulse. At this stage several courses of action are possible: (1) Arithmetical orders not involving the memory (e.g., left and right shift). Here the operational output of $D.C.$ actuates the particular sequence line in the arithmetic unit $A.U.$ $A.U.$ performs its operation and emits an op. comp. pulse. This operation complete pulse advances the countrol counter ($C.C.$) one stage via line b and then, after a delay to allow $C.C.$ to settle down, causes $M.L.$ to absorb the position recorded by $C.C.$—via lines c and d. At the same time $C.F.$ is sent into its excited state (via c) and M is instructed (via c') to emit the order located in the position shown by $M.L.$ When M has reached the appropriate position clock digits are emitted and again pass via G_1 to repeat the cycle.

(2) Arithmetical orders involving transfer from M (e.g., +, −, ×, etc.). The gate pulse to $D.C.$ acts as before and $A.U.$ organizes itself to execute the required order. When it is ready it emits a "read" pulse via f to M. M when ready emits n clock pulses coincident with the digits of the given word, these pass to $A.U.$ which receives the incident digits and performs the required operation on them. When this is finished an Op. Comp.

pulse is emitted by M which, if appropriate (i.e., in + and in − but not in ×), is re-emitted by *A.U.* to initiate the same cycle as in (1).

(3) Transfers from the arithmetic unit to the memory. Here, as in (2), *A.U.* prepares itself for operation and then emits a "record" pulse to M via h. This causes M to emit clock pulses as before and these cause data to be shifted out of *A.U.*, via k, to M which now absorbs them in the given position. At the end of the cycle M emits its Op. Comp. pulse and the remainder of the cycle as in (1) and (2).

(4) Transfers of control. Two operations of this type exist in the single address type machine being described.

(a) Absolute transfers out of sequence.

(b) Conditional transfers out of sequence.

In the first *D.C.* emits a pulse to A.U. which is emitted directly, via m, this resets *C.C.* to a completely new location previously contained in the order stored in *C.R.*, and after a delay, to allow *C.C.* to settle down, sends the usual cycle pulse via c thus initiating the next cycle on the order located in the new contents of *C.C.*

In the case of conditional transfers (i.e., "if number in accumulator is positive proceed in sequence, if negative, however, transfer control to instruction located in memory position x"). The first condition causes a standard Op. Comp. pulse to be emitted, via b, while the second produces an output on m which operates as in absolute transfer.

(5) Input-output orders. If it is imagined that the input-output equipment is in *A.U.* the operation is seen to be identical with that described in (1), (2) or (3).

Other Types of Control

Those differences which will result from the substitution of a different sort of memory or arithmetic unit are more or less trivial. If a parallel operation memory is used the only change will be that, instead of M emitting "n" clock pulses, it will emit only one which will simultaneously gate all the digit outputs to the appropriate receptors, this means that k, o and p will become n digit channels.

Similarly, if a two address code is adopted, in which each order contains the location of the next, the only effect will be to eliminate *C.C.* and replace it by the multichannel connexion r, to connect b to c and d directly, and to perform conditional transfer on the channel t normally used for number locations. The latter opera-

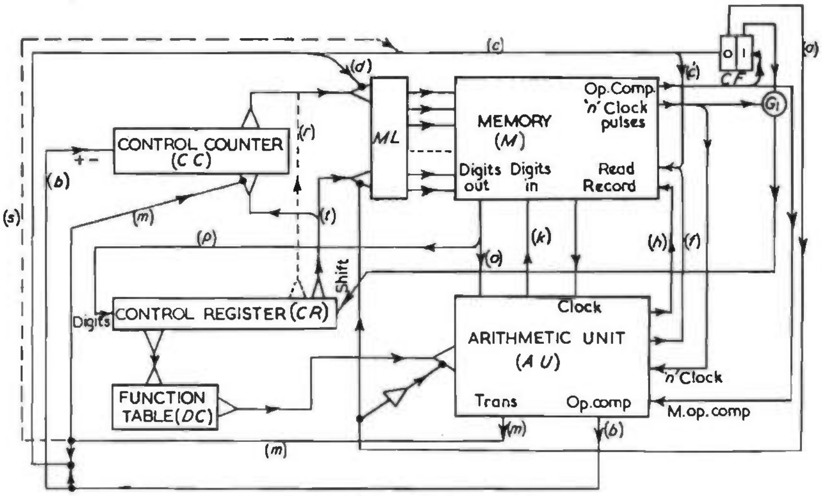


Fig. 7. Schematic of control

tion is performed by means of the connexion(s) which by-passes the gate channel d.

Conclusion

The final article in this series will deal with the input-output devices for computing machines which are at present under development in this laboratory.

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ELECTRONICS IN INDUSTRY

Supplement to Electronic Engineering

As announced on page 133 of the March 1952 issue of ELECTRONIC ENGINEERING the second supplement on *Electronics in Industry* will appear in next month's issue of this journal.

Like the first supplement which was published in April last, it will be printed on tinted paper and will be bound in with the issue.

Among the articles on the further applications of electronics to industry and industrial research will be contributions by qualified authors on the following subjects:

Vibration Studies in Aircraft Design.

Electronics in the Rubber Industry.

Nucleonics as an Aid to Industry.

Electronics in the Textile Industry.

An order form is enclosed in this issue for regular readers who may require additional copies and for readers who are not regular subscribers and who wish to secure a personal copy.

The price of the November issue, complete with supplement, will remain at 2s., and all inquiries relating to copies should be addressed to: ELECTRONIC ENGINEERING (Circulation Dept.), 28 Essex Street, Strand, London, W.C.2.

BBC New Automatic Unattended Transmitter Technique

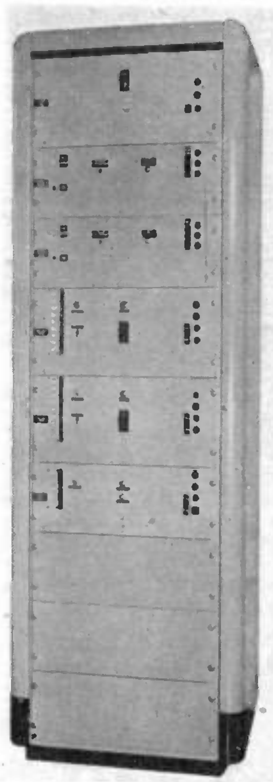
(Part 1)

By F. A. Peachey*, M.I.E.E.; R. Toombs*, B.Sc., A.M.I.E.E.; C. Gunn-Russell*, M.A.

SINCE the early days of the British Broadcasting Corporation, the general trend has been to extend the broadcasting service by increasing the power of the main medium and long wave transmitters. However, there are still localities where reception is poor, perhaps due to fading, or through interference after nightfall from stronger foreign signals in crowded frequency bands. The difficulty cannot be overcome by further increases in power on medium wavelengths, or by providing more high-power stations as there are insufficient wavelengths for the latter. Another method must be adopted and an obvious solution, though only a partial one until V.H.F. comes into general use, is to erect small-power, local stations for operation on shared wavelengths, in places where the main transmitters do not provide a satisfactory signal. Eight such stations have already been brought into service by the BBC, and four more are planned or in the course of construction. This represents an appreciable capital outlay, but more important are the manpower difficulties and the revenue charges, which are inevitably heavy at all manually operated stations. Some of these low-powered stations are already unattended, but are remotely controlled from premises which have to be staffed. This is an economic arrangement if the unattended station is not too remote from its "parent" station. If outside the limits of reasonable radio reception, these stations have, however, required a return programme channel for monitoring purposes, which is expensive. So far, the BBC has not accepted any arrangement as being sufficiently reliable without some programme monitoring check.

If a remote control system is used to operate a transmitter, the latter may be unattended, but is not necessarily fully automatic. Control and monitoring is effected by a parent station, sometimes using the Automatic Monitor described earlier[1].

Summarizing the situation, the BBC has already in service:



Automatic monitor unit for transmitters at unattended stations.

(1) FULLY STAFFED STATIONS

Such stations are fed by a programme signal line and a control line (one programme signal line per programme radiated and usually a control line common to the complete station).

(2) REMOTELY CONTROLLED UNATTENDED STATIONS

These are stations which are not staffed, but have a "return" programme signal line so that monitoring of the radiated signal from the transmitter may take place at the base supplying the programme signal. This is usually accomplished automatically by means of the "Automatic Monitor Minor". The latter provides an alarm if the programme signal radiated by the distant transmitter is outside reasonable limits of distortion. When this alarm is observed, an engineer at the originating station can make use of the remote switching facilities to ascertain which part of the system is faulty. He can then, by further remote switching, take some action to clear the trouble.

The BBC now proposes to try in service as an adjunct to the remotely controlled type, stations which are largely self-sufficient and possibly one hundred miles from the parent station. In this system the transmitter consists of two or three units each checked by its own self-contained automatic monitor; details of this part of the system will be given in Part 2 of this article. It is also necessary to check the performance of the line connecting the parent station to the remote station. A method of providing such a check without the need for a return programme line is described in this part of the article.

The Line Monitor

This is done by producing pulses from the rectified programme signal at the parent station and passing these signals over a phantom circuit derived from the normal programme circuit to the remote station. At the remote station similar signals are derived from the programme at that point and compared with those arriving from the phantom circuit. Any lack of correlation between these signals which indicates a sufficiently serious fault, will close down the transmitter until normal conditions are restored. By this means, two important advantages should accrue. As monitoring is achieved in this way and no return programme signal line is needed, the reliability of monitoring is nearly doubled. Possibly of greater importance is the saving in running costs. The capital cost of the automatic apparatus required for this purpose will, of course, depend on the source and method of manufacture, but it should certainly be less than the rental charge for one year of the line it saves. This will mean a revenue saving per station, after the first year of operation, of £1000 to £2000 per annum.

Emphasis should be given to the fact that reliability has throughout been regarded as of foremost importance and it is considered that the circuit arrangements about to be described fulfil that requirement. This has been achieved not only by providing duplicate monitoring and input equipment, but also by dividing the transmitter into several identical and self-contained units which normally operate in parallel. Incidentally, the transmitter output combining problems which therefore arise, are to be described in another article, to be published shortly.

As an automatic system cannot pass absolute judgement on programme quality, but must, by necessity, be provided with a source of comparison, some extra channel other than the programme channel must be provided. Such

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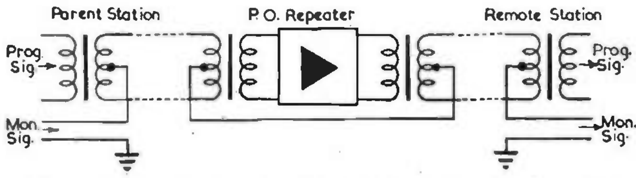


Fig. 1. Programme signal line and monitoring signal phantom circuit

a channel needs to convey only a small amount of information; in fact, it need not be wideband as long as the pulses derived from the programme signal are sufficiently slow and do not contain components that would interfere with the programme.

With a suitably designed message system, the phantom circuit derived from the programme line is adequate for conveying the monitoring signals[2]. This is shown in Fig. 1.

Slow speed messages, describing the condition of the programme, are provided by a detector which is shown in Fig. 2. This, it will be seen, is a two valve amplifier having a non-linear amplitude characteristic provided by back biased diodes in the negative feedback path. Below a certain volume these diodes are inoperative and the amplifier provides full gain, while at higher volumes the diodes conduct, increase the amount of negative feedback and so decrease the gain. The output from the amplifier is rectified and passed to relays which describe the volume of the programme. This is done in terms of three volume ranges, *A*, *B* and *C*, as shown in Fig. 3.

The detectors cause the operation of further relays, external to the unit, which apply distinctive D.C. signals to the phantom. Three signals are used, distinguished by magnitude or polarity, corresponding to the three ranges of programme volume considered.

The phantom circuit is, of course, fitted with low-pass filter networks so that the maximum frequency component which results from this D.C. switching is unlikely to cause interference on the programme channel. It will be appreciated that this alone places a restriction on the speed at which information is sent.

At the distant end of the line, that is, at the transmitting station, a similar detector assesses the rectified value of the received programme, but indicates only two level ranges, *A′* and *C′*, as shown in Fig. 3.

Now it will be seen that while there is correlation between the sending and receiving detector operation, i.e. *A* corresponds with *A′* or *C* corresponds with *C′*, conditions of transmission may be regarded as satisfactory. If, however, *A* corresponds with *C′* or *C* with *A′* it means that in the one case the programme has dropped in volume or in the other case that the programme has increased in volume. The former may occur if the line becomes broken and the latter, if some spurious source of signal, such as line noise, has arisen between the sending and receiving ends. The division between the level conditions is made at the value shown in Fig. 3 so that the monitor will be sensitive to the predetermined amount of noise at which action is deemed desirable.

The *B* volume range is provided so that the overall device shall not be too sensitive to small changes in transmission line equivalent. When the programme volume at the sending end is within this range, that at the distant end may be hovering between ranges *A′* and *C′*. In these circumstances monitoring should be temporarily suspended. This is effected by sending over the phantom a 'neutral' signal which prevents the distant monitor from taking executive action. This 'neutral' signal is also invoked to prevent the sending of false messages to the phantom, if a failure occurs in the monitoring equipment at the sending end. To provide for this, the detectors at the sending end are duplicated and their relays are interconnected. As long as they give the same signal as each other, the 'neutral' signal is sent only during the period that the programme volume lies within the *B* range, but it is

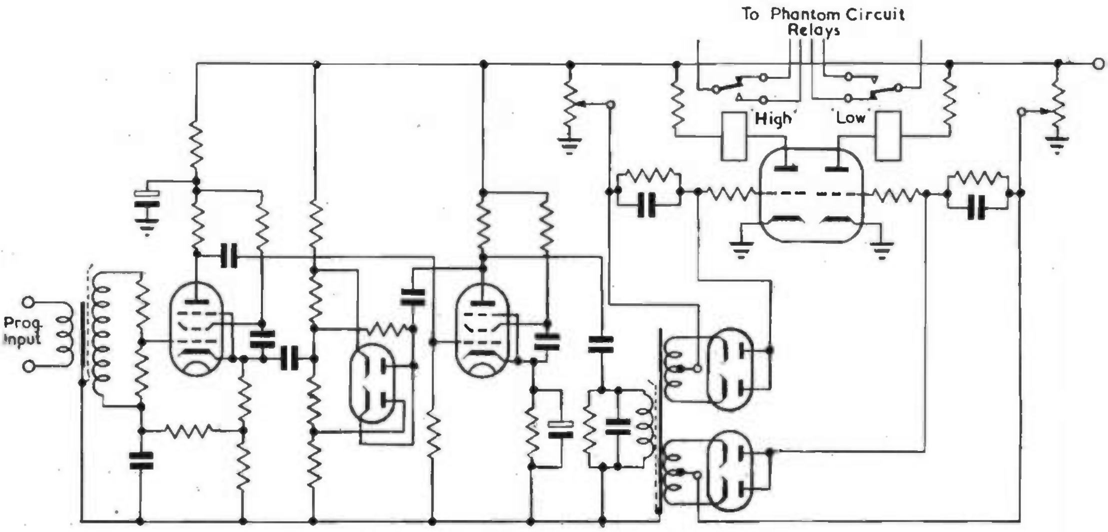
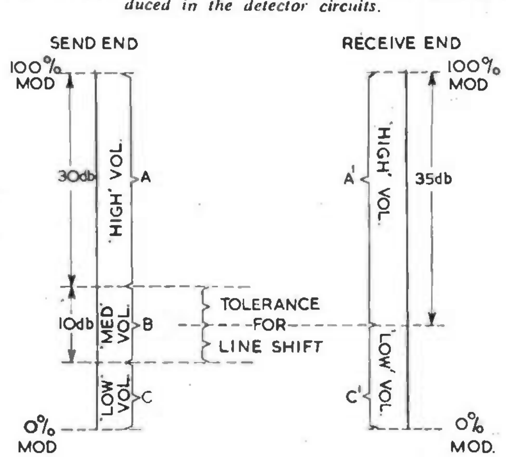


Fig. 2. Sending end detector (simplified diagram)
Receiving detector as above but one output receiver and relay circuit omitted.

Fig. 3. Showing volume of programme signal at which detectors operate
This is different for high and low frequencies as aural grading is introduced in the detector circuits.



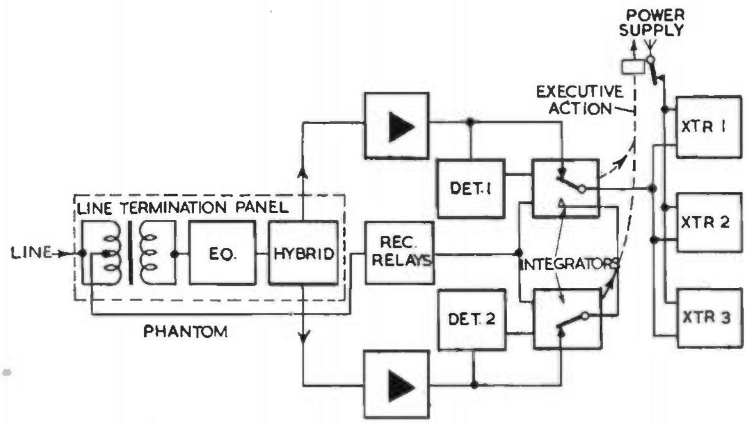


Fig. 4. Block schematic of equipment at receiving end

sent continuously if the indications from the two sending end detectors differ for an appreciable period. This latter condition produces an alarm at the sending end, indicating that the line monitoring has failed.

At the receiving end, the detectors are duplicated for a similar purpose but are used in a different way (see Fig. 4). The line, on entry into the transmitter building, is split into two independent chains and a separate detector is connected across each. The interconnexion of the detector relays and the associated integrator circuits is arranged so that if the signal from either detector differs from the sending end signal, the transmitter will be fed off the other branch from the line termination panel. This guards against incorrect action due to a fault on either detector, and also looks after a fault arising in the receiving line amplifier apparatus.

It will be appreciated that with this line monitoring system it is important that the relays at the two ends shall operate in the correct sequence. The criterion is that when the line with its associated equipment is not faulty, the receiving end shall never detect (except for a period, too brief to give operation) a condition of programme volume which is opposite to that signalled from the sending end. To satisfy this, the time-constants are so arranged that the sending end relays always "shadow" those at the receiving end if the programme is rapidly decreasing in volume. This is shown in Fig. 5. If the programme increases in volume, the "shadow" provided by the forward time-constants is sometimes cancelled by the time delay on the phantom circuit, but in such a case the period of error is too short to cause subsequent operation.

The time-constants are also such that the overall system may discern extraneous noise during intervals between words. It would, however, be quite wrong to close down a transmitter for a substantial period for just such a short period of noise. To avoid this, further discrimination, approximating more closely to the action of an engineer or operator at the station, is introduced by a special integrator device shown in Fig. 6. This receives signals in accordance with the correlation or differences between the sending and receiving detectors.

Capacitor C receives a discharge if the signals correlate at low-level and a charge if they differ at either high- or low-level. The discharge time-constant of this capacitor circuit is very long indeed—several hours—and so it keeps a continuous and stored integration watch on the detector operation. If, due to a profusion of "differences" in a given period the voltage on this capacitor increases sufficiently, the gas discharge tube V_1 will strike and executive action be taken in closing down the transmitter. Correlation assessment is not made at high signal volume as this is away from the maximum sensitivity of the detectors, and under fault conditions might produce undue dilution of the ultimate assessment. On the other hand, difference at high volumes can be registered. This also fits in with circuit convenience. It will be seen that the effect approximates fairly closely to the action of an operator who would not take the drastic action of closing down a transmitter unless the background noise were not only loud but persistent.

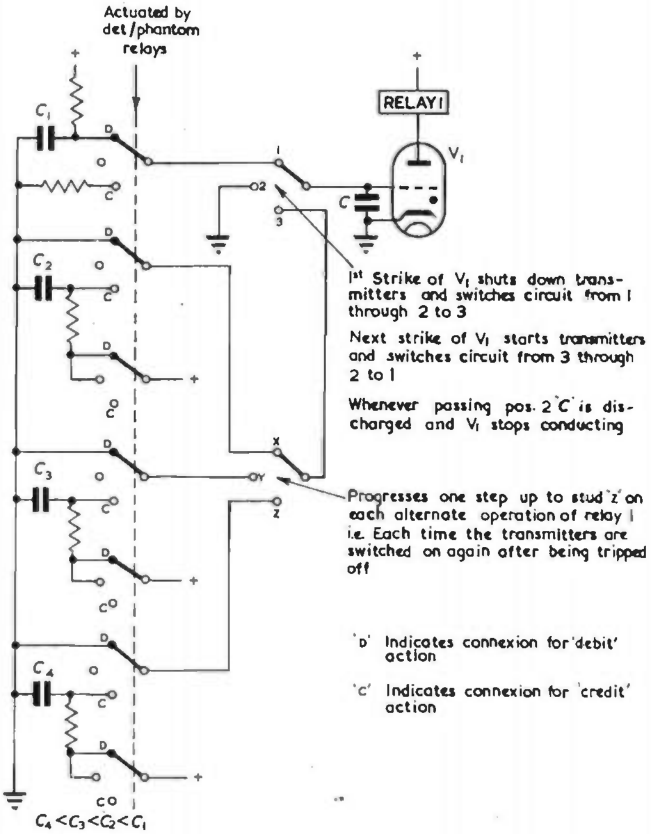
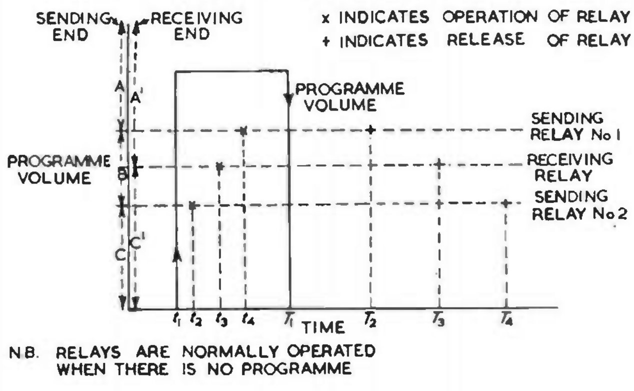


Fig. 6. Simplified circuit arrangement of "debit/credit" integrator

After the transmitter has been closed down by such means, this integrator capacitor is cleared of previous information and is virtually reversed in action. Whereas previously it was charged by "difference" signals (or "debits") by means of C_1 being switched to it, it is now charged from correlation signals (or "credits"), by C_2

Fig. 5. Relay operating sequence



being switched to it instead of the discharge leak. A 'debit' produces a complete short-circuit (for the period of the fault) on *C*, whereas a 'credit' is established by the discharge of a small capacitor on to a large capacitor, and for a given grade of fault it therefore takes very much longer for an overall credit charge to be established.

This in effect means that after the transmitter has been closed down due to line trouble, it can be restored, but the monitor has become more critical of fault condition. The circuits are so designed that a further switch-off due to a transmission fault in the same day, will produce even greater difficulty in restoration.

This obviates "fast and loose" operation on an intermittent line fault. In acting with increased caution after each shut down the equipment approaches the attitude of an engineer or operator. The stored information about any earlier switching operation is cancelled whenever the power supply to the equipment is broken. A time switch makes and interrupts the main supply at the beginning and end of the normal programme period so that the integration will be cleared at least daily.

Two such integrators are provided, so that if the first one becomes faulty, the second will automatically take over as a consequence of the first transferring the transmitters to the reserve local programme input equipment (see Fig. 4).

These several units and their associated relays are so interconnected that a normal fault on the monitoring apparatus either brings into use alternative apparatus or prevents the monitor from taking executive action.

A fault at the sending end while holding off the line monitoring also produces an alarm. The possible absence of monitoring at the receiving end may be discerned by another means which will be described in the second part of this article.

In some instances the line routings are such that two or more such small-power stations will be fed in tandem. This presents no particular problem, as the monitor signal generated at the sending end, or parent station, can be passed through to successive stations by simple relay equipment.

In designing systems for automatic operation of unattended stations, the general complication, if it can be considered such, arises from the need to provide alternative apparatus which takes over automatically if the normal equipment becomes faulty. It is estimated that the visiting by a service team should not have to be more frequent than once a month, but this largely depends on the reliability of the lines connecting the parent station to its satellite. Much experience has been gained regarding line reliability and with the co-operation of the Engineering Department of the General Post Office, there is every reason to suppose, that apart from the few inevitable and spasmodic mishaps, the need to close down a station through line trouble should be relatively infrequent. The monitoring apparatus is, of course, designed to be more reliable than the apparatus it is monitoring.

(To be continued)

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RANTZEN, H. B. PEACHEY, F. A. and GUNN-RUSSELL, C. The Automatic Monitoring of Broadcast Programmes. *J.I.E.E.*, **98**, Pt. III (1951); and also The Broad Principles in the Design of Automatic Monitors. *Electronic Engg.* **23**, 19 (1951).
2. British Patent No. 15480/52.

Atomic Exports

The Ministry of Supply have announced that Britain is now the largest exporter in the world of radio-active materials for peaceful purposes.

The only other competitors in the world market for these materials at present are the United States and Canada.

Owing to the growing urgency of demands from far away countries, B.O.A.C. have converted a fleet of Argonauts to carry the materials in their wing tips and are now considering suggestions for similar modifications to Comet 2 aircraft. This method reduces the cost of transport by over sixty per cent by cutting out the cost of heavy lead containers.

During the year which ended in June the Supply Ministry's Atomic Research Establishment at Harwell sent more than 3,000 consignments of isotopes to no fewer than 37 different countries.

Radio-active isotopes are still used mainly for medical purposes and new discoveries are continually being made to increase their scope; but they are also daily gaining more significance in scientific research and industrial applications.

Altogether 9,578 consignments were sent from Harwell in the year, of which 3,053 went overseas by air.

Another indication of the growing international interest in the by-products of Britain's atomic energy programme has been the steady flow of scientists to the Isotope School at Harwell, where the technique of using isotopes is taught. To date, 133 experienced scientists, doctors and engineers have passed through the School. Of these, 102 have come from Great Britain and the others from India, Australia, South Africa, Belgium, Egypt, Greece, Holland, Israel, Italy, Norway, Spain, Sweden and Yugoslavia. Nearly two-thirds of the total have been chemists and bio-chemists and the remainder has been made up of electrical, electronic and other engineers, physicists and medical men.

When the School first opened in March 1951 it was housed in a converted hut, but it has now been moved to a permanent brick-building outside the security fence in which all modern facilities and instruments have been provided for the specialized work.

Canadian Television*

The Canadian Broadcasting Corporation's first television network was officially opened on September 6th.

Both Toronto and Montreal have been equipped with two studios (one large and one small) and their control rooms, a master control room, and film projector room.

In the large studios are three complete Image Orthicon camera chains and, in each control room, all the vision mixing, distribution amplification, power supply, intercommunication, producers' and engineers' control equipment. The smaller studios are similarly equipped, but with only two Marconi Image Orthicon camera chains.

The master control rooms have studio picture monitors, waveform monitors and master control switching equipment, while the film and projector equipment will allow the two stations to televise 16mm films, slides and film strips.

The projectors can be remotely controlled from any of the control positions.

The two outside broadcasting vans incorporate the latest techniques in design. They are streamlined, and contain all the equipment normally found in fitted studios. Each is a three-camera station with full video, audio and radio link equipment.

All portable equipment can be stowed quickly and neatly, and just as quickly set up into operation. Producer and technicians can sit comfortably in the van for control purposes.

Representing the British company at the opening ceremony was Commander B. G. H. Rowley, the Marconi representative in New York.

**Communication from Marconi's Wireless Telegraph Co., Ltd.*

The Wien Bridge and Some Applications

By C. F. Brockelsby*, A.R.C.S., B.Sc., A.M.I.E.E

ALL modern alternating current bridge methods stem from the work of Max Wien, who published, in 1891, a description of apparatus and procedure which underlies the techniques now in use. Among the circuits described[1] is one for the comparison of two capacitors; this circuit, shown in Fig. 1, is that which today is usually known as the Wien bridge. It is seldom used for the measurement of capacitance; its importance now lies in the fact that balance occurs only at a particular frequency, determined by the values of the arms. The bridge is therefore useful for measuring frequency and, by appropriate circuit techniques, as a substitute for an inductance-capacitance tuned circuit in selective apparatus such as filters, tuned amplifiers and oscillators. In the following paragraphs, the operation of the bridge itself is developed and some examples of its application are explained.

The Wien Bridge

The balance condition can be written down in the usual way, by equating the ratios of the vector impedances of adjacent pairs of arms†, which gives

$$R_3/R_4 = (R_1 + 1/j\omega C_1)(1/R_2 + j\omega C_2) \quad \ldots\ldots (1)$$

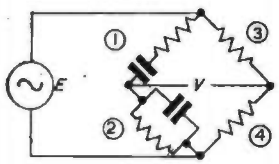


Fig. 1. The Wien bridge

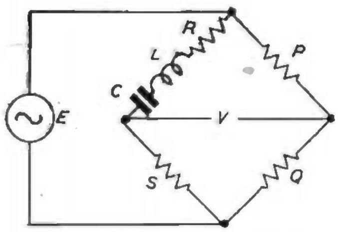


Fig. 2. Series resonance bridge

Separating the real and imaginary parts,

$$\left.\begin{aligned}\omega_0^2 C_1C_2R_1R_2 &= 1\\ R_1/R_2 + C_2/C_1 &= R_3/R_4\end{aligned}\right\} \quad \ldots\ldots\ldots\ldots (2)$$

If $R_1 = R_2 = R$ and $C_1 = C_2 = C$, Equations (2) reduce to

$$\left.\begin{aligned}\omega_0 CR &= 1\\ R_3/R_4 &= 2\end{aligned}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The physical basis of the bridge balance is easy to see. The phase-angle of arm 1 rises from $-90°$ at very low frequencies to zero at very high frequencies, while that of arm 2 falls from zero to $-90°$. At some frequency these phase-angles must, therefore, be equal; if the ratio R_3/R_4 is then made equal to the ratio of the impedances of arms 1 and 2, the bridge will balance. It is to be noticed that the balance frequency depends equally upon all four components of arms 1 and 2, being determined by the product $C_1C_2R_1R_2$. There is no essential relation between the values of these components; for example, making $R_1 = R_2$ and $C_1 = C_2$ is simply a matter of convenience. If this equality is only approximately maintained in practice, the effect will be a slight alteration of the frequency, according to the product of the values, and a slight change in the required ratio of R_3 to R_4. If these resistors are fixed in value, (this is necessary in some applications) deviations of the components of arms 1 and 2 from their ideal values will result in a slightly imperfect bridge balance.

* *Late of Marconi Instruments, Ltd.*

† *The suffices refer to arm numbers in Fig. 1.*

Frequency Response

The variation with frequency of the transmission through the bridge can be obtained as follows. Inspection of Fig. 1 permits us to write

$$V/E = R_4/(R_3 + R_4) - Z_2/(Z_1 + Z_2) \quad \ldots\ldots (4)$$

With $R_3 = 2R_4$ this becomes

$$V/E = (Z_1/Z_2 - 2)/3(1 + Z_1/Z_2) \quad \ldots\ldots (5)$$

With $R_1 = R_2 = R$ and $C_1 = C_2 = C$,

$$Z_1/Z_2 = 2 + j\omega CR + 1/j\omega CR \quad \ldots\ldots\ldots (6)$$

Putting in the angular frequency, ω_0, at which the bridge balances, $\omega_0 = 1/CR$,

$$\begin{aligned}Z_1/Z_2 &= 2 + j(\omega/\omega_0 - \omega_0/\omega)\\ &= 2 + jy \text{ (say)} \quad \ldots\ldots\ldots\ldots\ldots\ldots (7)\end{aligned}$$

Hence

$$V/E = \tfrac{1}{3} \cdot \frac{jy}{3 + jy} \quad \ldots\ldots\ldots\ldots\ldots (8)$$

The magnitude of the ratio of the input to the output voltage is therefore given by

$$|E/V| = 3\sqrt{(1 + 9/y^2)} \quad \ldots\ldots\ldots\ldots (9)$$

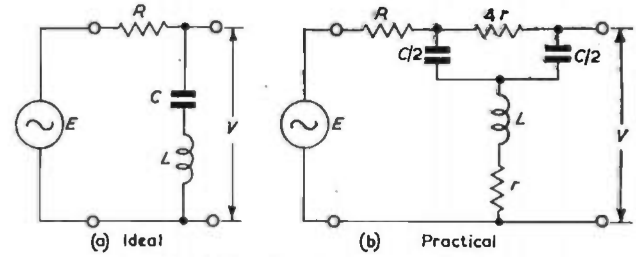


Fig. 3. Ideal and practical rejector circuits

The phase of V relative to E is ϕ, with $\cot\phi = y/3$.

Analagous Circuits

It is obvious that the transmission behaviour of the bridge bears a general resemblance to that of a tuned circuit: the series-resonance bridge of Fig. 2 is, in fact, an exact equivalent. The analysis of its frequency characteristic, on the lines of the above treatment of the Wien bridge, gives, for $R/S = P/Q = 2$.

$$V/E = \tfrac{1}{3} \cdot \frac{j2Qy}{3 + j2Qy} \quad \ldots\ldots\ldots\ldots (10)$$

where $Q = \omega_0 L/R$

The response is thus precisely the same as that of the Wien bridge if $Q = \tfrac{1}{2}$. In this sense, we may say that the "equivalent Q" of the Wien bridge is 0·5.

Equation (10) can be generalized by taking the resistance S as part of the series tuned circuit; this yields a new value Q' for the magnification of the coil: $Q' = \omega_0 L/(R + S)$. The frequency characteristic then becomes

$$V/E = \frac{1}{(n + 1)} \cdot \frac{jQ'y}{1 + jQ'y} \quad \ldots\ldots\ldots (11)$$

Where $n = R/S = P/Q$.

Equation (11) also describes the behaviour of a bridge containing a parallel-resonant circuit.

The simplest circuit having this frequency characteristic is shown in Fig. 3(a); it includes a perfect, loss-free tuned circuit. This is, of course, unobtainable in practice, but the circuit of Fig. 3(b) is equivalent in performance. The frequency characteristic of these circuits is given by

$$E/V = \frac{jQy}{1 + jQy} \quad \ldots\ldots\ldots\ldots\ldots \quad (12)$$

where $Q = \omega_0 L/R$. This characteristic is the same (apart from the insertion loss) as that of the Wien bridge if $Q = 1/3$, so that, in this more general sense, the "equivalent Q" of the bridge is $1/3$.

The frequency characteristic of the Wien bridge—and of the resonance bridge with the proper value of Q—is shown in Fig. 4, which also illustrates the effect of a slight departure from the ideal ratio R_3/R_4, making the balance imperfect. The residual signal at the best obtainable balance is proportional to the error in the ratio arms, being given approximately by

$$V/V_\infty = (2/3)p \quad \ldots\ldots\ldots\ldots\ldots \quad (13)$$

where V_∞ = output voltage at frequencies far removed from balance.

p = fractional error in resistance ratio.

Thus a ratio error of 0·1 per cent limits the suppression of the bridge to 62db; an error of 1 per cent, to 42db, and so on.

A polar plot of the transmission characteristic is informative; it shows both amplitude and phase characteristics.

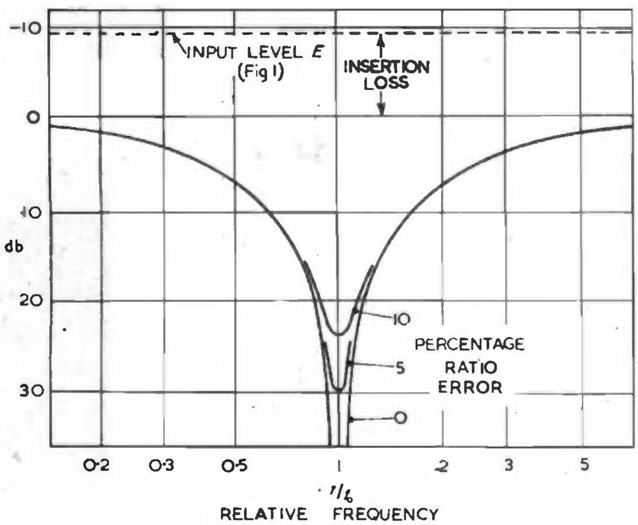


Fig. 4. Frequency characteristic of Wien bridge

What is required is to express V/E of Equation (8) in the form $r \exp j\theta$ and obtain a relation between r and θ from which the polar plot can be drawn.

Omitting the factor $1/3$, which represents only the insertion loss, from Equation (8),

$$r\epsilon^{j\theta} = r(\cos\theta + j\sin\theta) = V/E = jy/(3 + jy) \quad \ldots \quad (14)$$

Equating the real and imaginary parts gives

$$\left.\begin{array}{l} 3\cos\theta - y\sin\theta = 0 \\ y\cos\theta + 3\sin\theta = y/r \end{array}\right\} \quad \ldots\ldots\ldots \quad (15)$$

Eliminating y: $\quad r = \cos\theta \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (16)$

The polar plot is therefore a circle; it is shown in Fig. 5, which also shows the effect of maladjustment of the ratio arms.

When the ratio arms are correctly adjusted, Fig. 5 shows that the output voltage, at frequencies very near balance, is in quadrature with the input voltage. When the ratio arms are changed slightly, however, the bridge output voltage, at the balance frequency, is exactly in phase—or out of phase—with the input voltage, the sign depending upon the direction in which the ratio arms are altered.

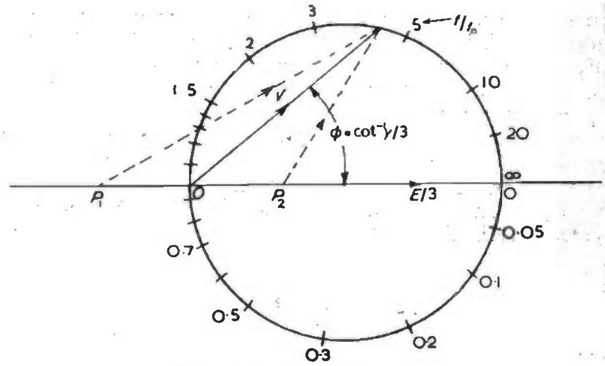


Fig. 5. Polar plot of V on $E/3$

Vector V rotates about O when $R_3 = 2R_4$; but about P when $R_3 \neq 2R_4$. P_1 is for $R_3 < 2R_4$; P_2 is for $R_3 > 2R_4$

Unbalanced/Unbalanced Connexion

In common with all other four arm bridges, the input and output connexions of the Wien bridge must be balanced to earth on one side, or both sides, of the bridge. When the bridge is used simply for the determination of frequency, this is no great disadvantage as a screened and balanced transformer can be provided. It is, however, difficult to construct transformers with a very wide frequency range and small phase shift; they are therefore inconvenient in many applications and must usually be excluded from negative feedback circuits. Where a power supply is available, the transformer can be replaced by a phase-splitting valve with the circuit of Fig. 6. The frequency response of this circuit is the same as that of the original Wien bridge (shown in Figs. 4 and 5). The insertion loss becomes very nearly zero because of the cathode-follower connexion. The valve will introduce stray capacitances which will normally have only a very small effect upon the balance frequency. The permissible amplitude of the signal is, of course, limited to that which the valve can handle.

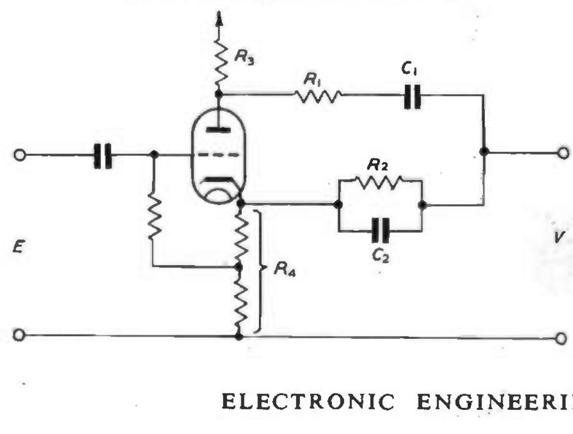
The foregoing discussion brings out the essential features of the behaviour of the Wien bridge and some applications will now be described.

Distortion Measurement

The total harmonic content of an approximately sine-wave signal is commonly measured by suppressing the fundamental and measuring the residual, i.e., harmonic, voltage. The tuned-circuit bridge of Fig. 2 and the bridged-T circuit of Fig. 3(b) have both been used for this purpose in successive models of the Marconi Instruments Limited Distortion Factor Meter type TF 142. In these circuits, the minimum Q to obtain a substantially equal response to all harmonics is about 3*.

** This is the Q of the bridge as in equation (11). The Q of the coil itself will usually need to be considerably higher.*

Fig. 6. Phase splitter and Wien bridge



It is therefore not possible simply to substitute the Wien bridge, which has an effective Q of about 1/3. This difficulty can be overcome by including the bridge in the closed loop of a negative feedback amplifier, which flattens the response at frequencies away from balance. The block schematic circuit diagram of Fig. 7 shows the connexions; writing A for the voltage amplification of the amplifier and n for the ratio of output to input voltage of Fig. 6, the overall amplification m of Fig. 7 is given by the usual negative feedback equation:

$$1/m = 1 + 1/nA$$

$$= 1 + \frac{3 + jy}{jAy} \quad \ldots\ldots (17)$$

Hence

$$m = \frac{jAy}{3 + j(A + 1)y} \quad \ldots\ldots (18)$$

$$|m| = \frac{Ay}{\sqrt{\{9 + (A + 1)^2 y^2\}}} \quad \ldots\ldots (19)$$

At extreme frequencies, $y \rightarrow \infty$

$$m \rightarrow m_\infty = A/(A + 1) \quad \ldots\ldots (20)$$

The frequency characteristic is therefore given by

$$|m/m_\infty| = \frac{(A + 1)y}{\sqrt{\{9 + (A + 1)^2 y^2\}}} \quad \ldots\ldots (21)$$

Equation (21) shows that the frequency characteristic is flat when $(A + 1)y \gg 3$; the droop is less than 5 per cent when $(A + 1)y > 9{\cdot}4$. At the second harmonic, $y = 2 - 1/2 = 1{\cdot}5$; an amplification A of only 5·3 is therefore sufficient to secure a flat response within 5 per cent for all frequencies from the second harmonic upwards. A single-valve amplifier is clearly capable of providing this over a wide frequency range and also gives the correct phase for negative feedback.

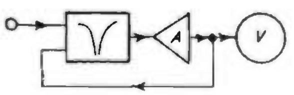


Fig. 7. Distortion meter

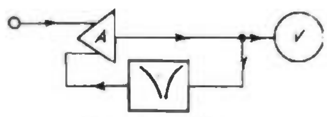


Fig. 8. Analyser

Wave Analysis

If the circuit of Fig. 7 be rearranged as in Fig. 8, putting the Wien bridge in the negative feedback path, its response curve is inverted by the feedback and a selective amplifier is obtained. It is quite practicable to build such amplifiers with a satisfactory performance for very many measurement purposes, including use as bridge detectors, but the application to wave analysis is limited by the difficulty of obtaining sufficiently rapid attenuation as the signal moves away from the tuned frequency.

(This difficulty can be overcome by using two selective amplifiers in cascade. This arrangement has other advantages; for example, a flat-top response curve can be obtained by staggered tuning).

In the Distortion Meter, discussed above, the fundamental is fully suppressed by the Wien bridge; only a little negative feedback is required to level off the response to all the harmonics. In the analyser, however, the minimum amplification is approximately unity (at frequencies far from balance) and the maximum amplification is simply that of the amplifier (at balance, when the feedback vanishes). The separation in amplitude provided by the selectivity of the system can, therefore, never exceed the gain of the amplifier. Thus, if it is desired to measure a component whose amplitude is only 0·1 per cent of that of the strongest component, the gain must be at least 60db. In practice, most measurements will be made with the wanted component only part of the way down the skirt of the curve of response to an unwanted component and the separation will therefore be less than the above.

The frequency characteristic of Fig. 8 is readily obtained by a method similar to that used for Fig. 7 and is given by

$$m_0/m = 1 + \frac{jAy}{3 + jy} \quad \ldots\ldots (22)$$

$$|m_0/m| = \left\{\frac{9 + (A + 1)^2 y^2}{9 + y^2}\right\}^{\frac{1}{2}} \quad \ldots\ldots (23)$$

where m_0 = amplification at tuned frequency, $y = 0$.

For example, when the bridge is tuned to the second harmonic, the response to the fundamental ($y = 1{\cdot}5$) has fallen by a factor

$$\left\{\frac{9 + (A + 1)^2 \times 2{\cdot}25}{11{\cdot}25}\right\}^{\frac{1}{2}} \sim \frac{A + 1}{\sqrt{5}}$$

that is, 5 for $A = 10$, or 45 for $A = 100$. The fundamental-suppression at the second harmonic is therefore about 6db less than the amplifier gain.

The sharpness of tuning near the bridge balance can be found by letting y become small (say, less than unity) in Equation (22), which reduces to

$$m_0/m \sim 1 + j\frac{A + 1}{3}y \sim 1 + j(A/3)y \quad \ldots\ldots (24)$$

This is the equation for the response of a tuned circuit

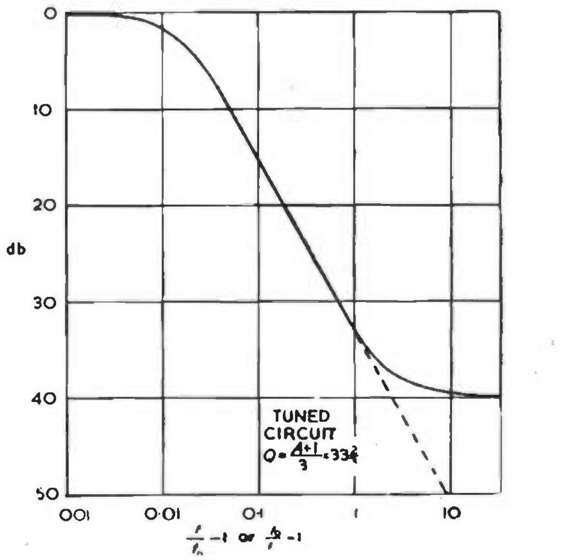


Fig. 9. Response of selective amplifier. $A = 100$

with $Q = A/3$. The effective Q of the selective amplifier is thus $A/3$; the negative feedback amplifier increases the effective Q of the bridge A times.

For very small mistuning Δf, $y \sim 2\Delta f/f$. Then

$$m_0/m \sim 1 + (2A/3)\,\Delta f/f \quad \ldots\ldots (25)$$

$$|m_0/m| \sim 1 + 2A^2/9\,(\Delta f/f)^2 \quad \ldots\ldots (26)$$

which is sufficiently accurate for mistuning up to about 15 per cent. The response falls by 3db for a percentage mistuning of $(150/A)$. per cent.

The response curve for $A = 100$ is shown in Fig. 9, with the curve for a tuned circuit ($Q = 33\frac{1}{3}$) for comparison.

Oscillator

It was shown, in connexion with Fig. 5, that a departure from the exact balance value of the ratio arms produces, at the tuned frequency, an output voltage from the bridge which is at 0° or 180° to the input voltage. If the connexions are like those of Fig. 8, in-phase voltage produces negative feedback and the out-of-phase voltage produces positive feedback. If this is of sufficient magnitude, the loop amplification will reach unity and the system will oscillate at substantially the balance frequency of the bridge. Output in the required phase is produced by increasing the value of R_3 in Fig. 6; the fractional increase required is $1/A$.

To make it possible to adjust the amplitude of oscillation smoothly down to a low value, at which the waveform will be good, it is desirable to put into the circuit an element which varies automatically with amplitude in such a way as to reduce the positive feedback when the amplitude increases. Perhaps the simplest arrangement is to include a metal-filament lamp as part of R_4.

The oscillation frequency will be that for which the phase-shift of the complete loop is zero, so the phase-shift in the amplifier must be small if the frequency is to be substantially that of the bridge. It is easy to show, from Equation (22), that a phase shift ϕ in the amplifier results in a small frequency shift given approximately by $\Delta f/f = 1{\cdot}5 \tan \phi/A$. For example, with $A = 30$, a phase shift of 11° produces a frequency shift of 1 per cent. The amplifier phase-shift can easily be made zero at any single frequency, but it is more difficult to maintain a high amplification with very small phase-shift over a wide frequency range. At high frequencies, moreover, it is no longer permissible to neglect "stray" reactances within the bridge network. Wien bridge oscillators thus find their main utility at frequencies betweeen a few cycles and a few tens of kilocycles per second.

Conclusion

The Wien bridge, especially when used in conjunction with a phase-splitting valve, is a versatile device capable of performing a number of useful functions in electronic circuits. The foregoing discussion, while not exhaustive, brings out the main features of the behaviour of the bridge and indicates the scope of three of its more important applications.

Acknowledgment

Acknowledgment is due to Messrs. Marconi Instruments Limited for permission to publish this paper.

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A Gain Stabilized Mixer

By M. Lorant

A new type of feedback mixer that will retain gain calibration over a reasonably long period of time has been developed recently at the U.S. National Bureau of Standards. The device helps correct the serious defect of long time calibration instability common to many units used for the continuous recording of radio field intensity. The mixer is equally applicable to other types of frequency selective measuring equipment.

In the operation of the circuit, gain stabilization is brought about by using, as negative feedback, the difference frequency voltage from the output of a superheterodyne mixer. As an approximate explanation of its performance, the mixer tube may be considered similar to a voltage feedback I.F. amplifier. When a high degree of feedback is maintained, excellent gain stability is achieved. The conversion gain is also stabilized to the extent that the conversion transconductance is linearly proportional to the average value of amplifier transconductance.

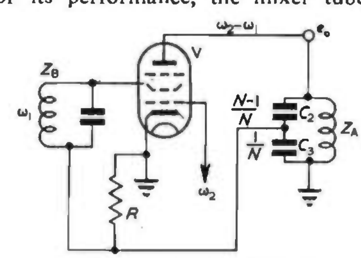


Fig. 1. Single valve feedback mixer

When a high degree of feedback is employed the gain is essentially not a function of the valve transconductances, but is approximately proportional to the ratio of two constants determined by the switching or modulating function of the mixer valve. One constant relates to the average value of amplifier transconductance and the other refers to the conversion transconductance. Variations in the constants are chiefly due to tube ageing, but are also effected by changes in circuit impedances, oscillator and supply voltage instability, etc. However, there is little effect upon the gain with feedback provided both constants are similarly changed by approximately the same percentages. This appears to be the case with valves such as the 6SA7 and 6SB7-Y. With other valve types there may be appreciable differences in the percentage change of the constants, resulting in a change in the centre frequency voltage gain which had not been anticipated. This effect may be considered as a limiting factor for stability improvements with some mixer valves. Fortunately, the valves used during the course of the experimental work did not appear to suffer appreciably from this possible limitation.

In an experimental single-stage circuit (Fig. 1) a 6SB7-Y was employed as the mixer tube. With an anode supply of 100 volts or greater (300 volts normal) and 26db of feedback, the gain variation was less than 5 per cent of that which would be experienced without feedback. This particular single valve mixer experiment indicated that a large change in conversion transconductance resulted in a relatively small change in voltage gain. It should be noted that in order to substantially improve the gain stability, a relatively high degree of feedback is required. For this reason a valve with a high conversion transconductance should be selected. In addition, the tuned anode circuit should have a high impedance and a high Q if a relatively narrow bandwidth is desired.

The gain stabilization principle may be extended to mixer couples (Fig. 2) or possibly to mixer triples as well. For example, if feedback is applied over two stages using practically obtainable coils of high Q, a relatively narrow bandwidth with improved flatness will result. The feedback voltage is derived from the capacitive voltage divider of a tuned anode circuit and is returned to the cathode of the first stage through a parallel resonant circuit. The cathode return is used to obtain the correct phase relationships. The resulting improvement in gain stability for the mixer couple operating at 3.75Mc/s with 23db of feedback is greater than that obtained in the single valve circuit.

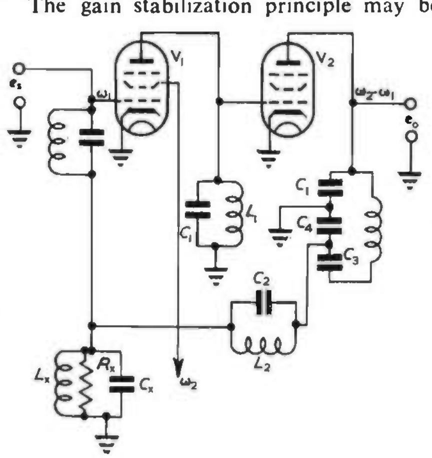


Fig. 2. An extension of the gain stabilization principle

When the mixer valve is operated with a fairly large cathode resistor, degeneration of both signal and oscillator voltages will be appreciable. To avoid this difficulty, the phase of the feedback voltage is reversed by suitable means and the feedback applied to the signal grid of the mixer. This circuit is similar to the mixer couple previously described except the feedback voltage returns to a junction between a parallel tuned grid circuit and a grounded shunt circuit composed of resistance, inductance, and capacitance. The purpose of this shunt-connected R, L, and C is to furnish the correct terminating impedance for the feedback circuit as well as to provide a sufficiently low impedance at the signal frequency to by-pass the grid return. This arrangement has been used to maintain a constant feedback ratio over a frequency range of 1 to 20Mc/s.

Compared to a cascade, synchronous, single-tuned mixer-amplifier arrangement, the new mixer couple provides improved gain stability, increased gain-bandwidth product and a gain-frequency characteristic which more nearly approaches an ideally rectangular shape.

The Clavioline

By G. H. Hillier

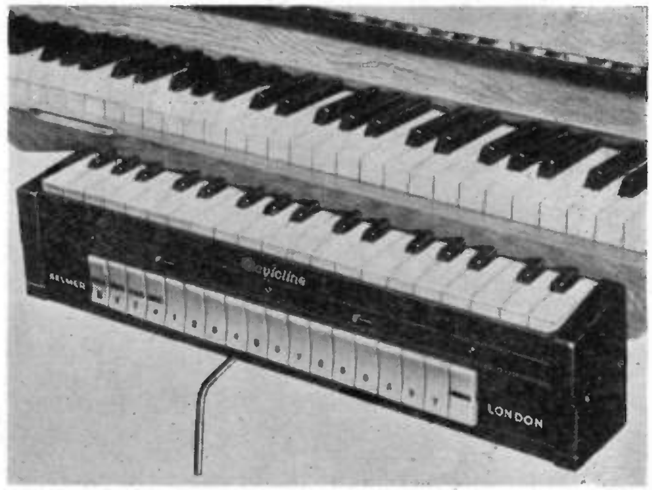


Fig. 1. The keyboard of the Clavioline attached to a piano

THE Clavioline[1] is a small electronic musical instrument manufactured in this country under licence from M. Constant Martin, a French inventor who has a considerable amount of work in the electronic musical instrument field to his credit.

The instrument is melodic, that is, it can sound only one note at one time. It is played from a small keyboard of three octaves, 20 in. in length, which is arranged so that it may be attached to a piano, and played therewith.

Many different tonal effects are obtained by manipulation of one or more of the 18 stop tablets which can be seen in Fig. 1 extending along the front of the keyboard, and the performer can soon learn to imitate a considerable number of different instruments. Three vibrato speeds, and two vibrato amplitudes contribute considerably to its effectiveness and, for use in the simulation of plucked strings, a separate tablet produces a percussion effect at the commencement of the tone. Control of expression is by means of a knee operated swell.

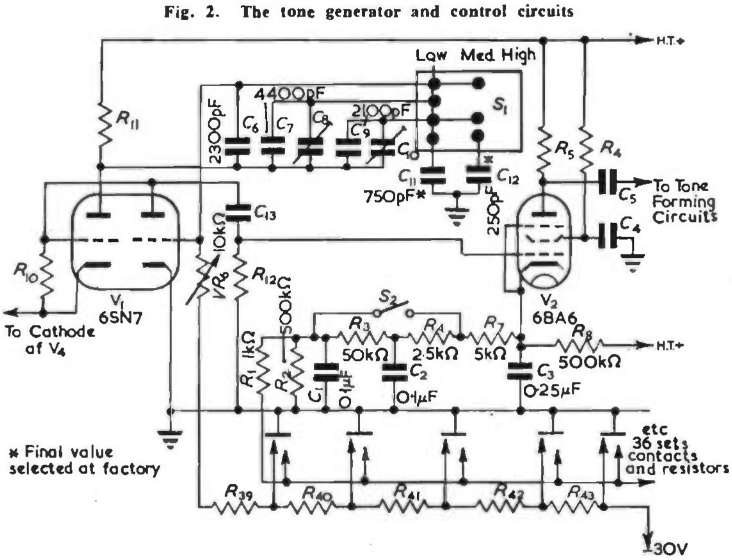
The complete tone generator, the vibrato oscillator and its buffer amplifier, together with a control valve, are in the keyboard unit, which also contains all the tone forming circuits. The amplifier, power supply and loudspeaker are carried in a separate case, into which the keyboard unit packs for transit. The whole equipment weighs approximately 46 lbs.

As the circuit diagrams show, the Clavioline is economically designed, and it is obvious that a considerable amount of thought has gone into it. Its simplicity and economy compared with the Hammond Solovox[2], for example, are marked, although one feature of the Solovox, octave coupling, is absent in the Clavioline.

The tone generator, Fig. 2, uses a 6SN7 as a multivibrator, the frequency of which is changed by altering the resistance in circuit between the grid of the right-hand triode and earth, ($R_{39, 40, 41, \text{etc.}}$), and by changing the capacitance in circuit between the anode of the left-hand triode and the grid of that on the right, (C_{6-10}). The value of the tuning resistors is such that each increment of the complete series placed in circuit by the key contacts will lower the frequency of operation of the oscillator by one semi-tone. Thirty-six sets of key contacts and resistors are included in order to cover the compass of the keyboard. The values of the capacitors C_{6-10} have been so chosen that operation of the switch S_1, either to the left or right of the centre position will transpose the pitch of the sound produced either down or up one octave. The control for this switch can be seen between the stop tablets and the keys in Fig. 1. The Clavioline therefore covers five octaves. The variable resistors VR_6 and VR_5, enable the performer to put the Clavioline in tune with the piano or other instruments with which it is to be played. Other pre-set controls, not shown in the figures, are adjusted during manufacture and tuning. Most of the capacitors and resistors used are close tolerance, high stability types in order that frequency drift may be minimized, the tuning resistors, for instance, being specially made to ½ per cent. As the power supply components are separate from the keyboard unit, there is no noticeable warming up drift after one minute's operation.

The oscillator is kept quiescent, when no key is pressed, by the application of 30V bias to the grid of the right-hand triode via the tuning resistors and VR_6.

Fig. 2. The tone generator and control circuits



Operating in conjunction with the tone generating oscillator is a vibrato oscillator, V_3, another 6SN7, and its buffer amplifier V_4 a L63 (Fig. 3). Normally inoperative, this oscillator is set in operation by S_3, S_4, or S_5, which respectively give vibrato speeds of 4·5, 5·5, or 6·5c/s, by selection of the resistor in the grid-anode, and grid-earth circuits. The output from this oscillator is passed to the cathode-follower buffer amplifier, V_4, via C_{16}, R_{23}, and S_6, and the output from this valve modulates the tone oscillator V_1, with which it shares a common cathode resistor, R_{25}. S_6 shunts the buffer feed resistor R_{23} in order to provide a measure of control over the deviation produced by the vibrato oscillator. A small amount of amplitude modulation is produced, but the greater effect is that of a frequency shift vibrato, which is more acceptable and natural.

From the tone oscillator, the signal is passed to the grid of the control valve V_2 a 6BA6. This valve is normally kept in a non-conducting state in a similar manner to the oscillator by the application of bias to the cathode via a high value resistor, R_8,

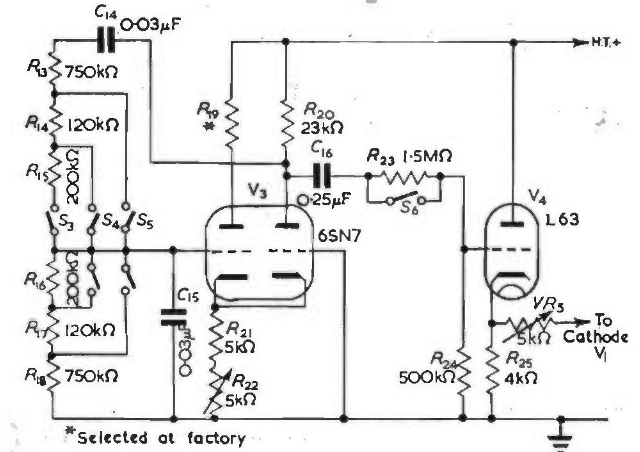


Fig. 3. The vibrato oscillator and buffer amplifier

from the H.T. supply. Associated with the cathode circuit of V_2 is a low-pass filter and delay network.

On pressing a key, two contacts are made, one shortly before the other. The first removes the bias from the oscillator by grounding the junction of two of the frequency determining resistors, and at the same time sets the amount of resistance in circuit in order to produce the correct note. The second contact removes the bias from V_2, which, after a delay determined by the time-constant of the cathode circuit, passes the signal to the tone forming circuits, via C_5, with the correct "attack". If two keys are inadvertently pressed, only the higher of the two notes will sound.

The switch S_2 (tablet "P") is included in order to reduce the time-constant of the circuit so that a definite transient appears at the commencement of each note. It helps to provide the plucked string effect when used in conjunction with the expression control. This control is a variable resistor, R_{32}, of special construction and grading, connected across the output from the control valve, and operated by the lever which can be seen in Fig. 1. The track is so graded that bowed and plucked string effects, for example, when "playing" the violin or guitar, may be obtained with a little practice.

The output from the control valve is trapezoidal in form, which as is well known, is composed of the fundamental, together with a long series of the natural harmonics thereof. Such a wave is easily modified to produce the characteristic tone colours of orchestral instruments. In the Clavioline this is effected by passing the wave through a set of resonant, high and low-pass filters (Fig. 4). These filters suppress harmonics of the fundamental which are not required, and also, by their resonant nature, exaggerate frequency bands in order to produce the characteristic formants required. Table 1 shows how these filters are selected by the stop tablets to give distinctive tone colours, and the writer, who has played the instrument, can say that the tones produced, in particular the strings and brass, are very realistic[3].

Fig. 4. The tone forming circuits

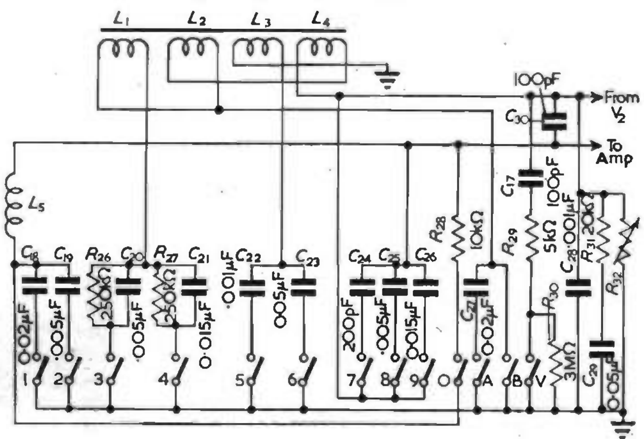


TABLE 1

Suggested combinations for some of the instrumental tone colours which can be reproduced on the Clavioline

INSTRUMENTS	NO.	LETTER	VIB.	AMP.	COUPLER
Violin	1	O or V	2	+	High
Viola	1	O or V	2	+	Medium
Tenor-Sax. ..	4	—	3	—	Medium
Trumpet ..	—	—	2	—	Med.-High
Trombone ..	3	—	2	—	Low
Horn	23	—	3	+	Low
Bassoon ..	37	—	—	—	Low
Cornet	6	—	1	—	Medium
Oboe	148	—	1	—	Medium
Flute	345	—	1	—	High
Piccolo	140	—	2	—	High
Hawaiian Guitar	146	P	2	+	Medium
Banjo	34	BP	—	—	Medium
Mandolin ..	368	P	—	—	High
Musical Saw ..	3	B	2	+	High

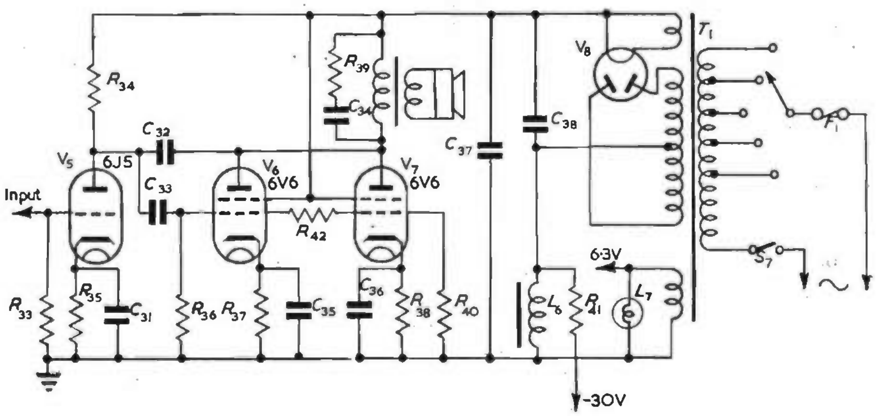


Fig. 5. The amplifier and power supply unit

From the keyboard unit the signal is passed to the amplifier, Fig. 5, which is designed to introduce a controlled amount of harmonic distortion, which adds to the realism of the sound produced. In the same way, the 10 in. moving-coil loudspeaker has been specially produced to add its measure to the distortion produced in the amplifier. Most of the distortion added in the amplifier and loudspeaker is 2nd harmonic.

In production, a number of the components in the generator, tone forming circuits, and the amplifier are hand picked in the finishing or voicing process.

Acknowledgment

The writer is indebted to Messrs. Henri Selmer and Co. Ltd, of London for their co-operation and help in producing this article, and to M. Constant Martin for permission to publish the circuit diagrams.

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A Study of the Characteristics of Glow-Discharge Voltage-Regulator Tubes

(Part 2)

By F. A. Benson*, M.Eng., Ph.D., A.M.I.E.E., M.I.R.E.

Vibration and Mounting

Current-voltage and striking characteristics have been obtained and measurements of initial drifts and life tests have been carried out with tubes mounted in a vertical position upside down and also with the axes of the tubes horizontal. All the results, including length of life, appear to be independent of the method of mounting.

Several tubes of each type have also been subjected to severe vibration tests. The tubes were mounted on a lever fixed at one end, the other end resting on a toothed wheel attached to a driving-motor shaft. They could, in this way be set in rapid vibration.

The tests indicate that vibration does not seriously affect stability. The changes in running voltages recorded were only of the order of 0·01 per cent. For best results, however, in applications where vibrations or sudden shocks are liable to occur, an anti-microphonic mounting should be used as specified by some manufacturers[16].

Photoelectric Effects

Baker[17] has observed certain photoelectric effects associated with several commercial neon glow lamps in America. He reports a case where moderate daylight reduced the striking voltage obtained for a tube kept in the dark by about 10 per cent.

It was, therefore, decided to examine all the glow-discharge tubes, at present under consideration, for such effects. The tubes were placed in the dark and then in moderate daylight. The striking voltages and running voltages were recorded for the two conditions.

No differences in the characteristics were observed with the tubes in the dark or in moderate daylight except for one tube of each of the types VR105 and VR150. In these two particular cases placing the tubes in the dark increased the striking voltages by about 12 per cent over those in normal daylight as already mentioned previously.

It appears, however, that, apart from these two types of tube, even where glow-discharge tubes are used under conditions where constancy of the striking voltage is important, it is unnecessary to keep the level of illumination within certain limits or to coat the envelopes with paint or other material to render them opaque. This also applies to the CV71 tubes for which an opaque coating is specified.

Operation with Reversed Polarity

For two reasons it was felt that a knowledge of the properties of tubes operating with the cathode potential positive with respect to the anode would be of interest. First, the author has experienced several cases where tubes have been accidentally used with reversed connexions. Secondly, glow-discharge tubes have been successfully applied to the stabilization of A.C. voltages in addition to D.C. ones. The striking and running voltage characteristics with reversed polarity have been determined for most tubes.

* *The University of Sheffield*

Striking Voltage

Table 5 shows the results obtained. It is difficult to draw any definite conclusions about striking voltage with reversed connexions. Even for tubes of the same type, in some cases the voltage is reduced, in others it is increased by reversing the polarity. For example, of the particular CV1070 tubes tested, the striking voltage was mainly lower with reversed connexions than when operating normally, only 3 out of 36 tubes striking at a higher voltage. The maximum decrease in striking voltage was 13V. For the 85A1 tubes, on the other hand, the majority struck at a higher value when reversed. The maximum increase was 28·5V, but a decrease of 7·5V was observed.

To explain the difference between the striking voltages in the two cases it is necessary to draw attention to the theory of striking for non-uniform fields.

TABLE 5—CHARACTERISTICS OF TUBES WITH REVERSED POLARITY

TUBE TYPE	STRIKING VOLTAGE VARIATIONS FROM TUBE TO TUBE (V)	RUNNING VOLTAGE FROM TUBE TO TUBE (V)	VARIATION FOR A SINGLE TUBE (MAX.) V.
CV1070 ..	103·5–119·5	85·0–112·0	16
85A1 ..	106·5–142	93·5–135·0	28
CV45 ..	‡	‡	‡
S130	‡	‡	‡
CV71 ..	130–160	132–187*	46*
KD60 ..	72–75.5	49–60.5	2.5
CV188 ..	100–115	78·0–95·5	14
G50/1G ..	58–75	48·0–51·5	2.5
G180/2M ..	172–197§	147–205§	58§
G120/1B ..	80–110	51·5–73	16
VR105 ..	122–132‖	103–157	54
VR150 ..	162–180‖	146–197†	27†
CV284 ..	80–117	64·5–86	16·5
NT2¶ ..	—	—	—

KEY FOR TABLE 5

* *0.4 to 4mA only.*
† *5-15mA only.*
‡ *Only one tube of each type tested as at a current of about 70mA tubes arc over.*
§ *One anode used only.*
‖ *In normal daylight.*
¶ *Electrodes are the same shape. The characteristics for normal and reversed connexions are almost the same.*

Theory of Striking for Non-Uniform Fields

In the case of non-uniform fields Townsend's theory gives the following condition for striking[18]:

$$\int_0^d \alpha_n \left[\frac{-}{e} \int_0^s (\alpha_n - \alpha_p) du \right] ds = 1 \quad \ldots\ldots \quad (5)$$

where the integration variables u and s, and distance between electrodes d are measured with the cathode as origin. α_n is often called the electron-ionization coefficient, and is the number of ions produced by collision by an electron per centimetre of path. If the polarity is reversed so that the anode is now the origin, the condition becomes:

$$\int_0^d \alpha_p \left[e^{-\int_0^s (\alpha_p - \alpha_n)du} \right] ds = 1 \quad \ldots\ldots (6)$$

where α_p is the positive-ion-ionization coefficient which is analogous to α_n.

Now α_n and α_p are not the same in general and so (5) and (6) are not satisfied at one value of applied voltage. Thus, the striking voltages for normal and reversed connexions are different.

Thomson's theory, based on the fact that positive ions liberate secondary electrons from the cathode leads to the same conclusions[18].

In this case:

$$\int_0^d \alpha_n \, ds = \frac{1 + \beta}{\beta} \quad \ldots\ldots\ldots\ldots\ldots (7)$$

or

$$e^{\alpha_n d} = \frac{1 + \beta}{\beta} = 1 + 1/\beta \quad \ldots\ldots\ldots (8)$$

where β is the number of secondary electrons liberated from the cathode per ion pair produced in the gas.

Now β is a function of the field strength at the cathode, hence value of α_n (and therefore of applied voltage) is different for normal and reversed connexions. It is to be expected that the field strength at the cathode will generally be greater when the cathode is the smaller electrode, i.e., with reversed connexions. Thus β will be the larger for this case and the applied voltage for striking smaller. That this is not always true may possibly be due to the fact that not nearly so much care is taken with the preparation of the anodes of the tubes as with the cathode surfaces.

Running Voltage

The results obtained are given in Table 5. It is seen that the regulation of all tubes is greatly increased by reversed polarity. The discharge becomes "abnormal" and the small "cathode" area becomes entirely covered by glow at quite a small current. The "abnormal" discharge gives the observed voltage rise with current over the working range.

Reversed-polarity running is generally accompanied by large random drifts, steps are still evident and hysteresis effects are very pronounced. In fact, if characteristics are taken several times, quite different values of running voltage are obtained at a given value of current, e.g. for the 85A1 type values of 8V are not uncommon.

Normal Operation after Running with Reversed Polarity

The striking voltages and running characteristics of the tubes were recorded with normal connexions after operation with reversed polarity to determine if the latter causes any permanent damage. Excluding the few tubes which arced (see Table 5), all others tested had the same striking voltage and running characteristics before and after operation with reversed connexions.

Effect of Reversed Polarity on Tube Life

Some tubes of Type CV1070 were run for a considerable time with reversed connexions. It was found that the running voltage increases very rapidly, in some cases more than 30 per cent during the first 200 hours of life.

Effects of Tube Age

Twelve tubes of the CV1070 type were tested on arrival from the manufacturer. Their age at that time was unknown. They were then stored and tested at intervals over a period of 3 000 hours. The striking voltages of the tubes were unchanged during this time. The running voltages were in all cases, however, increased, considerably during the first 1 000 hours and then remained nearly constant. The maximum increase in running voltage at a given value of current was 1·6V, the average value 1V and the minimum value 0·6V.

The increase of voltage observed is considered to be caused by contaminations of the cathode by gases from the glass walls which will take place to some extent whether current passes or not unless special precautions are taken as in the 85A1 tube. For these high-stability tubes, where any gases if produced are removed immediately by the molybdenum coating, the running voltage is almost constant with time during long resting periods. No results have been obtained for the other tube types, but it is reasonable to assume that they behave in a manner similar to the CV1070 samples.

Current Overloads

Peschel[19] has reported that accidental current overloads will frequently make glow-discharge voltage-regulator tubes entirely useless as regulators although they may appear to be functioning quite normally. His statements are misleading, however, as they give no details of the magnitudes or durations of the overloads in question.

The effects of overloads on the characteristics of tubes of the CV1070 and S130 types have been examined in some detail. Several CV1070 tubes were run with overloads ranging from 10 per cent to 700 per cent for periods between 15 seconds and 1 hour.

One important point arising from these tests is that. because of the large cathode area, the increase of voltage with current in all tubes is fairly small over a current range extending well beyond the maximum value.

It appears that overloads of 200 per cent can be applied for a period up to 1 hour without permanent damage to a CV1070 tube. The effect of larger overloads is to increase the running voltage for a given value of current, probably due to sputtering of the cathode by the discharge, but it is interesting to note that the regulation over the current range does not increase very greatly.

Changes in the characteristics of the S130 tubes become evident after overloads of 100 per cent applied for a few seconds only and the running characteristics move bodily by a few volts.

A slight overload (up to about 25 per cent) appears to do no damage to a tube of any type except that it reduces the useful life appreciably as discussed later.

Exposure to Magnetic and Electric Fields

All tubes are affected by exposure to stray magnetic and electric fields. In general, however, the effects of stray fields are not serious, but it is advisable not to place tubes near transformers or permanent magnets. Variations in running voltage of more than 20 per cent may be obtained by locating a tube close to a permanent magnet with a field strength of 1 500 oersteds. Fortunately tubes do not appear to be permanently affected by strong fields. Several tubes of the CV188 type operated in the gap of a 1500-oersted magnet for a short time gave their normal characteristics again when removed from the field.

Long-Term Tests

Variations in the characteristics of tubes of the CV1070, 85A1, S130 and KD60 types have been observed during the first several thousand hours of continuous operation. Each tube was run at an approximately-constant current and was exposed to small ambient-temperature changes. Mention has already been made of the observed increase in temperature coefficient of running voltage and the increase of initial drift with life. Attention has also been called to the effects of reversed polarity on life. It remains only to discuss the striking- and running-voltage variations with time and the effect of overloads on life.

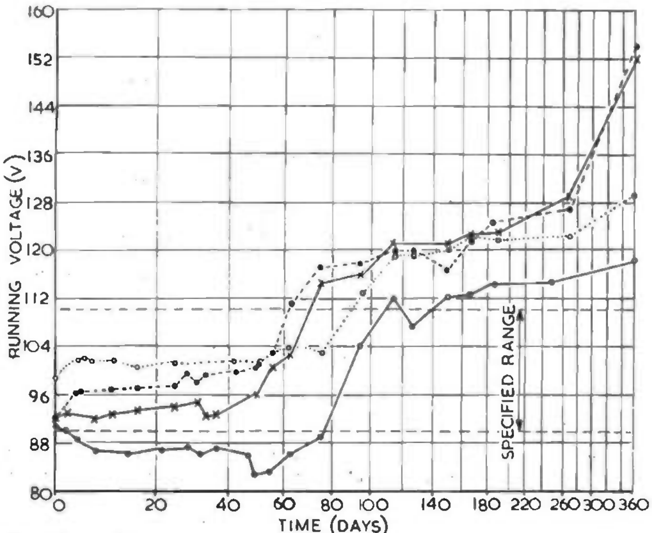


Fig. 15. Typical characteristics showing the variations of running voltage with time for tubes type S130 run continuously at approximately-constant tube currents of 5mA.

RUNNING VOLTAGE VARIATIONS

The CV1070 Tubes

Twenty-four tubes were run continuously at an approximately constant current of 5mA for about 10 000 hours. Some typical characteristics for the tubes are shown in Fig. 15. Other typical characteristics are given in Fig. 16 illustrating the voltage variations during the first 1 680 hours plotted to a larger scale than on Fig. 15.

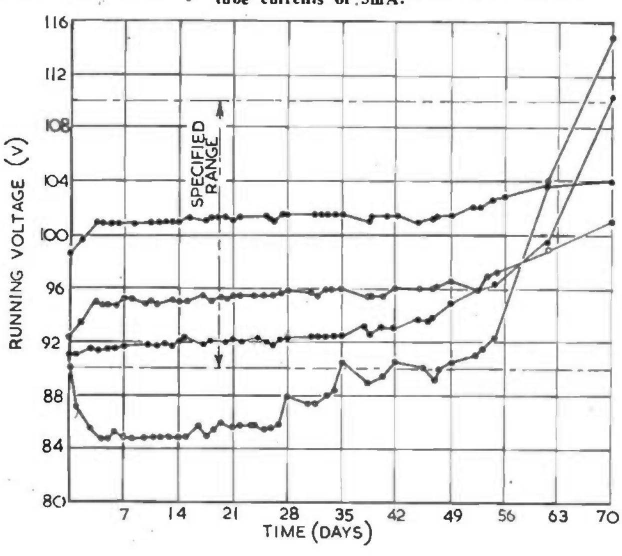
It appears that for this type of tube the running-voltage/life characteristics can be divided into three parts:—

(1) An initial "ageing" period during which the voltage may change fairly rapidly. The duration of this period is, in general, about 100 hours, but may extend to 300 hours. Voltage variations of up to ± 10 per cent are observed. It seems worth while ageing tubes before putting them into service to take them out of this period.

(2) An intermediate period lasting up to about 1300 hours from the start during which only small voltage variations of a random nature are observed. The maximum variation during this period is less than ± 2 per cent, but the change is generally considerably less than this figure.

(3) A final period where again large variations occur

Fig. 16. Typical characteristics showing the variations of running voltages with time for tubes type CV1070, run continuously at approximately-constant tube currents of 5mA.



and the voltage gradually increases even after it passes out of the specified range. It can be seen from Fig. 15 that after about 9 000 hours operation the running voltage may have increased by about 70 per cent. Apart from the fact that the glass envelopes darken with time the tubes appear to be running quite normally even after the voltage reaches its upper specified limit. Thus, it is advisable to replace tubes in any equipment before they have a chance of running into this final period of life.

All the tubes tested ended their useful life, i.e. reached period (3) at about 1300 hours within about 200 hours of each other. It does seem rather remarkable that tube life

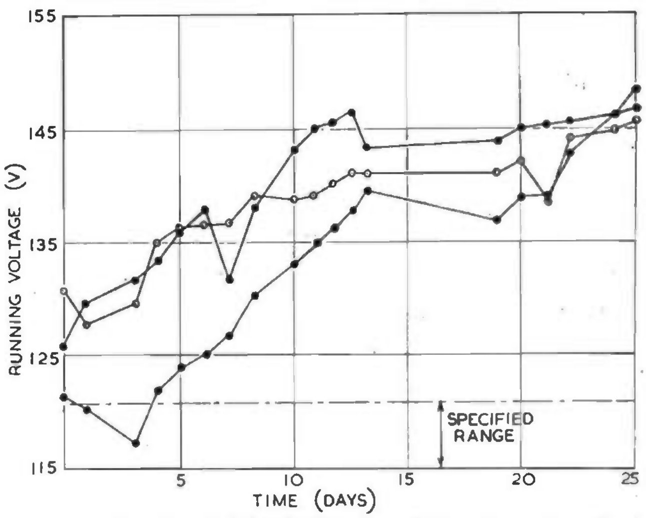
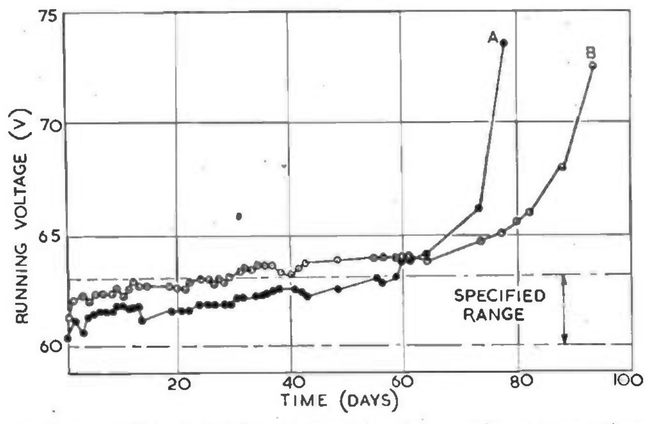


Fig. 17. Typical characteristics showing the variations of running voltages with time for tubes type S130, run continuously at approximately-constant tube currents of 50mA.

Fig. 18. Typical characteristics showing the variations of running voltages with time for tubes type KD60, run continuously at approximately-constant tube currents of 1mA.



can be predicted fairly accurately for a given operating current.

During the lives of the tubes the slopes of the current-voltage curves of Fig. 1 generally change considerably, the characteristics do not usually move parallel to themselves as might be anticipated.

The S130 Tubes

Twelve tubes were run continuously at an approximately constant current of 50mA. Some typical characteristics for the tubes are shown in Fig. 17. Large running-voltage variations are observed throughout the life of the tubes; there is no period corresponding to (2) as with the CV1070. Tubes which are within the specified range at the start soon pass out of it; voltage increases of up to 10 per cent during the first 150 hours seem usual and thereafter changes of 0·1V/hr are common. It will also be observed from Fig. 17 that large voltage drops occur quite frequently.

The KD60 Tubes

Two tubes only were available for life test so no generalizations can be made. However, the few results obtained are thought to be of some interest and are, therefore, included. The tubes were run at approximately-constant currents of 1mA. The characteristics obtained are shown in Fig. 18. An initial ageing period is evident during the first 50/100 hours. Thereafter the running voltage gradually rises until it passes out of the specified range. The time taken for this appears to vary considerably from tube to tube. After about 1500 hours operation the running voltage increases very rapidly with time.

At points A and B (Fig. 18) respectively the two tubes tested developed an oscillating glow. Records obtained by the manufacturer do show, however, that tubes of this type are capable of running satisfactorily for 5 000 to 8 000 hours depending on the current.

The 85A1 Tubes

Twenty-two tubes were run continuously at an approximately constant current of 5mA for about 10 000 hours. In contrast with the other types of tube these show little change of running voltage with time. There is an initial ageing period which lasts from about 50 to 200 hours. The maximum change of running voltage during this period was 0·5 per cent and the average change 0·3 per cent. After that, during the 10 000 hour tests the maximum change in running voltage was 0·6 per cent and the mean change 0·4 per cent. The variations are of a random nature. Even after 10 000 hours there is no evidence that the useful life of the tube is being approached.

STRIKING-VOLTAGE VARIATIONS

The striking voltages of the tubes were recorded at various stages throughout the long-term tests. The striking voltage increases with life, very considerably in many cases.

For the CV1070 tubes the striking voltage increases by from 8 to 90 per cent in the first 7 500 hours. At this stage the majority of the striking voltages were well outside the upper specified limit.

For the S130 tubes increases in striking voltage from 5-16 per cent are observed during the first 1000 hours of operation.

For the two KD60 tubes tested the striking voltage increase amounted to about 5 per cent in the first 1500 hours. There seems to be some evidence that the magnitude of the change of striking voltage with time for this type of tube is a function of the tube current, the lower the current the smaller the variation.

In the case of the 85A1 tubes the maximum increase in striking voltage is less than 5 per cent during the first 10 000 hours operation and after this time all the voltages are still well inside the specified limits. Many tubes of this type showed no change of striking voltage with time.

CURRENT OVERLOADS

A few CV1070 tubes were run continuously at an approximately constant current of 10mA (i.e. at 25 per cent overload). There is an initial ageing period in the running-voltage/life characteristics as before lasting from about 50 to 100 hours, during which the voltages change quite rapidly. These changes may be either increases or decreases. In contrast with the life characteristics obtained for currents of 5mA, however, there is no period where the voltage remains nearly constant. Instead the running voltage increases gradually, after the ageing period, in a random manner at a rate of about 5mV/hr for approximately 1000 hours and, thereafter, at a much faster rate.

No results have been obtained for other types of tube.

DISCUSSION OF RESULTS

During the life of a tube of the CV1070 or S130 type a visible deposit forms on the glass envelope. This is caused by sputtering of the cathode by the glow-discharge and is greatly accelerated by current overloads. Figs. 19 and 20 show photo-micrographs of portions of the cathode surfaces of a new CV1070 tube, and a tube of the same design after 2 000 hours continuous operation at a current of 5mA, respectively. The new tube shows a uniform cathode surface suggesting an oxide coating on a metal base. This coating has been completely removed in 2 000 hours by sputtering and explains the cause of the observed running-voltage variations for tubes of this type.

The deposit, during its formation on the glass envelope, will trap some of the gas in the tube and, therefore, will alter its pressure. However, the cathode drop in a discharge tube is substantially independent of the gas pressure. Liberation of gases from the glass walls by the glow-discharge may also be responsible for some variation of running voltage. These gases may contaminate the cathode or the original gas filling and increase the working voltage. It has been shown by Langmuir[20], and others[8,9], for example, that a discharge in neon liberates gases, in particular oxygen, from the glass walls. In the 85A1 tubes, which when run continuously for as long as 10 000 hours show quite small variations of running voltage, the molybdenum layer on the tube walls shields the glass from the discharge and prevents liberation of gases. It also acts as a getter. It is not sufficient, however, to introduce the

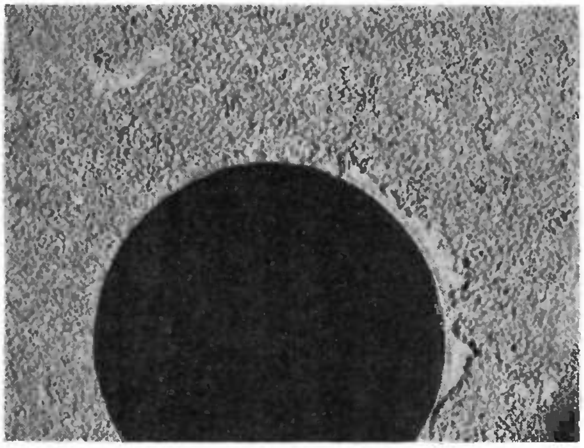


Fig. 19. Photo-micrograph of a portion of the cathode surface of a new CV1070 glow-discharge tube.

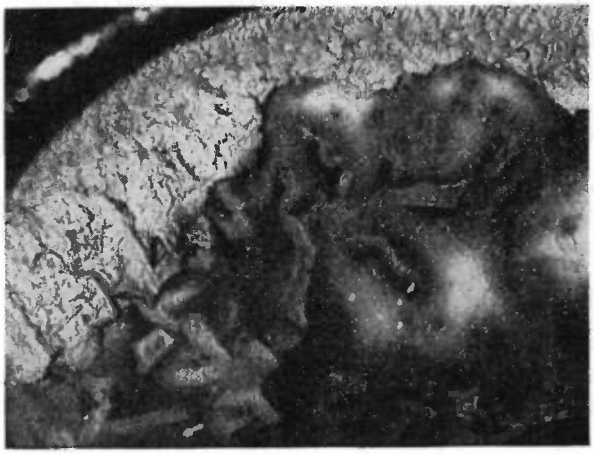


Fig. 20. Photo-micrograph of a portion of the cathode surface of a CV1070 glow-discharge tube after 2,000 hr. continuous operation at a current of 5mA.

molybdenum anywhere in the tube, it must be on the glass walls. Further, sputtering of the molybdenum cathode in an 85A1 tube does not appear to be troublesome.

Conclusions

It has been demonstrated that glow-discharge tube characteristics show considerable variations, not only from tube to tube of the same design, but also with the passage of time and with changes in ambient temperature. Many of these variations appear to have been largely unrecognized in the past. Tubes of the high-stability types show substantial improvements over the earlier designs. However, for use in high-stability power-supply or other precision circuits, it appears that glow-discharge tubes are not suitable unless they are specially chosen, and used under carefully-controlled conditions. A careful revision of tube specifications is necessary, particularly since in many cases they are somewhat misleading.

Acknowledgements

The work recorded in this paper has been carried out in the Department of Electrical Engineering at the University of Sheffield. The author wishes to thank Mr. O. I. Butler, M.Sc., M.I.E.E., for facilities afforded in the Laboratories of this Department and for the encouragement given during the preparation of the paper. The assistance of Philip's Electrical Ltd., Standard Telephones and Cables Ltd. and Ferranti Ltd., in supplying some of the tubes for examination is also gratefully acknowledged.

Appendix

TABLE A.—VARIATIONS IN STRIKING VOLTAGES OF TYPE CV1070 TUBES

(NOTE.—The tubes were not all obtained at the same time but in batches over a period of two years.)

SAMPLE	VOLTAGE	SAMPLE	VOLTAGE	SAMPLE	VOLTAGE
1	131·5	13	117·0	25	117·0
2	119·0	14	122·0	26	114·5
3	118·5	15	122·5	27	117·5
4	111·0	16	126·0	28	114·0
5	134·0	17	125·0	29	118·0
6	119·5	18	113·0	30	119·0
7	125·0	19	116·0	31	114·0
8	116·0	20	127·0	32	120·0
9	130·0	21	120·0	33	119·0
10	122·0	22	124·0	34	122·0
11	128·5	23	115·5	35	117·0
12	129·0	24	116·5	36	115·5

TABLE B.—VARIATIONS IN STRIKING VOLTAGES OF TYPE 85A1 TUBES

(NOTE.—The tubes were not all obtained at the same time but in batches over a period of two years.)

SAMPLE	VOLTAGE	SAMPLE	VOLTAGE	SAMPLE	VOLTAGE
1	112·5	13	113·5	25	113·5
2	115·5	14	113·0	26	114·0
3	113·5	15	112·5	27	113·5
4	112·5	16	113·5	28	114·0
5	112·5	17	116·0	29	116·5
6	111·5	18	115·0	30	111·0
7	112·5	19	113·5	31	110·5
8	114·0	20	114·5	32	111·5
9	114·5	21	112·5	33	112·5
10	112·5	22	115·5	34	113·0
11	113·5	23	112·0	—	—
12	112·0	24	111·5	—	—

TABLE C.—VARIATIONS IN STRIKING VOLTAGES OF TYPE S130. TUBES

SAMPLE	VOLTAGE	SAMPLE	VOLTAGE	SAMPLE	VOLTAGE
1	143·0	8	141·5	15	150·5
2	166·0	9	161·0	16	160·0
3	167·0	10	167·5	17	169·0
4	157·0	11	155·0	18	153·0
5	157·0	12	167·5	19	150·0
6	149·5	13	175·0	—	—
7	172·0	14	144·5	—	—

TABLE D.—VARIATIONS IN STRIKING VOLTAGES OF TYPE CV71 TUBES

(NOTE.—Independent of whether glass bulb is rendered opaque as required by specification, or not.)

SAMPLE	VOLTAGE
1	141–151
2	145–170
3	140–160
4	145–162
5	140–155
6	149–157

TABLE E.—VARIATIONS IN STRIKING VOLTAGES OF TYPE KD60 TUBES

SAMPLE	VOLTAGE
1	74·0
2	77·0
3	75·5
4	75·0
5	78·5
6	80·0

TABLE F.—VARIATIONS IN STRIKING VOLTAGES OF TYPE CV188. TUBES

SAMPLE	VOLTAGE
1	106·5
2	118·0
3	117·0
4	109·5
5	112·5
6	110·5

TABLE G.—VARIATIONS IN STRIKING VOLTAGES OF TYPE CV45 TUBES

SAMPLE	VOLTAGE	
	a	b
1	125·0	145
2	115·0	154
3	120·0	158
4	121·0	153
5	118·0	153
6	124·5	156

(a) Ignition electrode connected to 220V D.C. positive through a 54kΩ resistor
(b) Ignition electrode not connected.

TABLE H.—VARIATIONS IN STRIKING VOLTAGES OF TYPE VR150 TUBES

SAMPLE	VOLTAGE
1	160
2	154
3	157
4	131–147*
5	172
6	150

* *131 volts in ordinary daylight, 147 volts in the dark.*

TABLE I.—VARIATIONS IN STRIKING VOLTAGE OF TYPE NT2 TUBES

SAMPLE	VOLTAGE
1	72·0
2	62·0
3	61·0
4	65·5
5	67·0
6	62·0

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A Timed RC Circuit

By John P. German,* M.S.

OCCASIONALLY a unique circuit employing electronic components can be devised to produce a toy which appeals to both children and adults. The blinking-light toy (Fig. 1) makes use of the principle of a capacitor charging and discharging through a resistor to provide a reliable timing device for turning neon lights on and off in a definite pattern. Each neon bulb will fire in order, and continue in that direction until the capacitors of the circuit are unbalanced. After the steady-state operating condition of the circuit has been reached it is possible to change the direction of rotation by placing one's hand across any neon bulb or unbalancing the circuit by any convenient method.

Since the drain on the battery is in the order of a few microamperes the life of the battery should be several months.

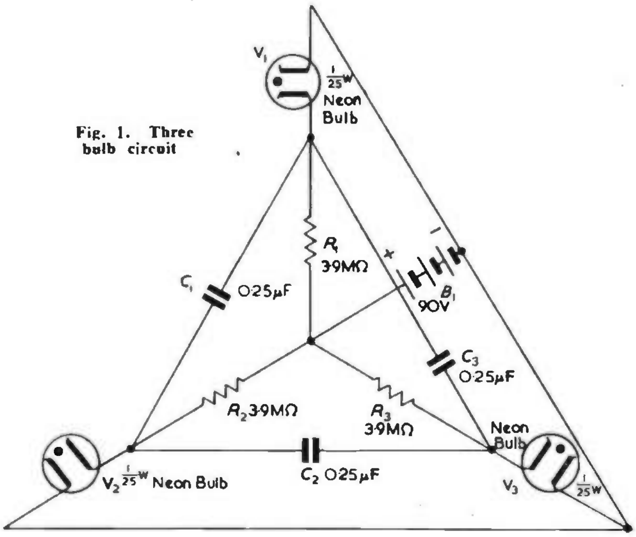

Fig. 1. Three bulb circuit

The neon bulbs will burn at a rate determined by the values of the capacitors and resistors used in the circuit. The rate at which the neon bulbs burn will be slower for large values of capacitance and resistance and faster if the size of the capacitance and resistance is decreased. If an uneven rate of firing is desired, the component values can be made unequal, but if the values become too different, some pattern instability may be experienced. The values given in Fig. 1 will provide a rate of fire which is reasonably slow.

The value of the resistors used will primarily determine the current drain on the battery. If the resistors are increased to too high a value—say, above 10 megohms—the current through each neon bulb will become so small that the glow will not be very bright. In addition to the dull glow at very low currents, the system may become unstable and a steady-state operation may seldom be reached. On the other hand, if the resistors are reduced too low—below one megohm—the battery current will increase to an appreciable value and the rate of firing will be so fast that the value of the capacitors will have to be increased to compensate for the loss of resistance.

The battery may be connected into the circuit with either polarity. The voltage must be reasonably high in order to provide sufficient potential to fire the neon bulbs. A 90-volt battery seems to work well.

An exact mathematical solution of the circuit is somewhat complex, so a more general discussion is all that will be attempted here. As soon as the battery is connected, the full 90 volts appears across each of the three neon bulbs. The bulb with the lowest breakdown potential will fire first. For purposes of discussion, say V_1 of Fig. 1. Electrons flow from the battery through V_1 and R_1 back to the plus terminal of the battery. At the same time there is a flow of electrons from the negative side of the battery through V_1, C_3 and R_3 back to the battery, and a flow of electrons from the battery through V_1, C_1 and R_2 back to the battery. This additional flow of electrons charges capacitors C_1 and C_3 at an exponential rate in such a polarity that the negative side of the capacitors C_1 and C_3 is toward V_1. Capacitor C_2 will have no charge built up on it as long as C_1 and C_3 each charge an equal amount. In an actual case there will be a slight charge on C_2 due to the unbalance of C_3R_3 and C_1R_2. As soon as the charge on either C_3 or C_1 reaches such a value that the potential across V_1 drops below its firing potential, then V_1 will stop glowing. At this instant, the full potential of the battery and the accumulated charge on C_1 and C_3 will appear across the two remaining neon bulbs V_2 and V_3, respectively. The next bulb to fire will be determined by the breakdown potential of the two remaining bulbs and by the potential across each. In this discussion say that the next neon bulb to fire is V_3. At this point the process begins to repeat itself, but the initial conditions are different since the two adjacent capacitors C_2 and C_3 do not have zero charge. Because of this initial unbalanced charge, V_2 will fire after V_3 goes out and the process will repeat itself, turning the bulbs on in a clockwise order. If the capacitors are suddenly unbalanced, the system may reach a steady-state operation in such a fashion that the bulbs fire counterclockwise.

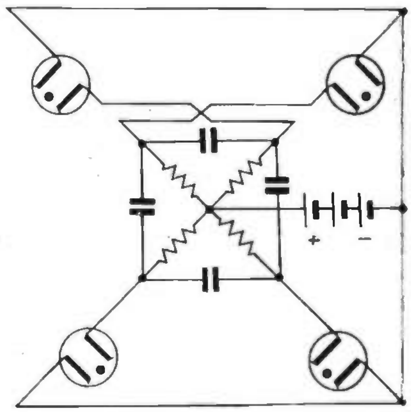

Fig. 2. Four bulb circuit

Fig. 1 may be expanded to provide a timing circuit for more than three neon bulbs. As an example, Fig. 2 shows the circuit for four neon bulbs. Since it is possible to obtain several operating modes as the number of bulbs is increased, it may be necessary to relocate some of the neon bulbs in the circuit in order to produce a clockwise or counterclockwise operation. In the four-bulb model it will probably be necessary to relocate two of the bulbs as shown in Fig. 2 in order to prevent the bulbs from firing diagonally across the square. As the number of bulbs is increased, the effective time-constant of the circuit is reduced, and the bulbs fire at a faster rate, so that it may be necessary to increase the size of the capacitors. In addition, it takes a longer time for a steady-state operating condition to be reached. When an eight-bulb unit was built by the author, it was found that if the lead to one side of the battery was disconnected and shorted to the other terminal, the capacitors could be discharged in a few seconds and, when re-connected, the circuit would reach a steady-state operating condition in a very short time.

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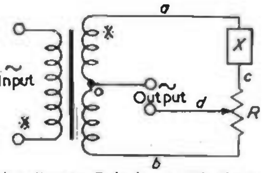
Changing the Phase of a Low Frequency Sinusoid

By P. Huggins*, A.M.Brit., I.R.E.

THERE are numerous electronic applications in which it is desirable to vary the phase-angle of a low frequency sinusoidal voltage by means of a manual control. For instance: phase shift control is usually required for delaying the firing point on thyratrons by varying the grid-cathode phase relationship with respect to the anode-cathode sinusoidal voltage[1]. In most instances the application is at mains frequency; although this is not always the case[2].

Manual Control

When analysed, most circuits used for this purpose are fundamentally of the basic type shown in Fig. 1. A number of authors have described the action of this circuit[3,4] so no more than a cursory description follows. T is a matching transformer, having a low resistance high impedance centre-tapped secondary. It is so connected, that primary and secondary voltages are in phase. This transformer feeds a series circuit consisting of reactance X and potentiometer R. The input E.M.F. is fed into T_1 primary. The output is taken from between the transformer centre-tap and the potentiometer slider. The manner of the phase shift can be understood best from the vector diagram (Fig. 2). When the slider is at c, the output voltage will have a magnitude oc and phase lag $\theta°$. When the slider is at mid point d, the output voltage will be of magnitude od and the phase lag is $\frac{1}{2}\theta°$. When the slider is at b the output E.M.F. will be that of one half the secondary winding and the phase displacement will be zero. Thus the total phase shift for the full traverse of the potentiometer slider is $\theta°$.



X Indicates Polarity of Windings

Fig. 1. Basic phase shift circuit

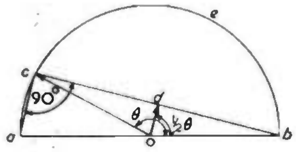


Fig. 2. Vector diagram for Fig. 1

The relationship between the design parameters is very readily obtained from the geometry of the circle diagram. These can most readily be summarized as

$$\theta = 2\cot^{-1} Q$$

where θ is available phase shift in degrees, and Q is the ratio $\frac{\text{Reactance}}{\text{Resistance}}$ of the series circuit.

CASE OF $\theta = 120°$

However, although the above equation is an expression for the general case, applications involving a 120° (variable) phase shift are common, because this figure is the "available firing angle" for most thyratrons (Fig. 3). In this particular case some simplifications can be obtained from the symmetry of the particular circle diagram (Fig. 4).

As will be seen from this diagram, since $\angle cob$ is 120°, the internal angles of triangle aoc are all 60°, and so the triangle is equilateral. *Hence the voltage across the reactance is equal to the voltage across one half of the transformer secondary.* This makes the experimental determination of optimum $X:R$ ratio for 120° phase shift relatively simple.

The other design parameter of interest is the minimum voltage to which the output drops (od). By the properties of similar triangles $od = \frac{1}{2}\, ao$. *Hence the magnitude of the output voltage will vary between the limits of the* E.M.F *across half of the secondary winding and 50 per cent of this figure*, being a minimum when the slider is in the mid position. This is true whatever the value of θ.

Limitations of the Standard Circuit

Two inherent disadvantages of the circuit are: the magnitude of the output E.M.F. varies as the potentiometer is adjusted; the rate of change of phase-angle for incremental changes of the slider, is non-linear.

The first of these can be overcome by connecting R purely as a variable resistance, instead of a potentiometer

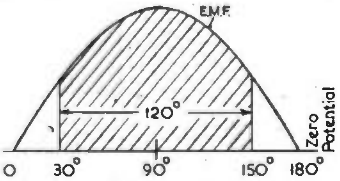


Fig. 3. Shaded area indicates optimum firing conditions for most thyratrons and ignitrons

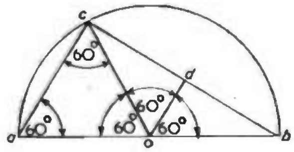


Fig. 4. Vector diagram where $\theta = 120°$

(i.e. disconnecting point b). The phase-angle swept will be $\theta°$ as before, but the locus of the variable vector will follow the arc ceb and thus have a constant magnitude. The penalty for stabilizing the magnitude of the output voltage is that when $R = 0$, the full secondary voltage appears across the reactance. Also the load on the transformer T is not a constant one.

The solution to the second disadvantage is to divide R into two equal resistances, making one a potentiometer (cosine law) and one a fixed resistor. It is necessary to have a two position range switch (D.P.D.T.) to interchange the relative positions of the resistor and potentiometer for each range.

The practical limit to the phase shift available is probably about 168° with this type of circuit. (Q = 0.1).

Over 180° Phase Shift

By having one phase shift network within another phase shift network (Fig. 5) it is possible to obtain double the phase shift available from one circuit. This can be seen from the series of circle diagrams shown in Fig. 6. The assumptions are: that T_2 is 1 : 1 ratio, and that the loading of the inner circuit is negligible ($k = 10$ say). The fact that the potentiometers are ganged will mean that the output voltage varies from rs to $r'o$ (Fig. 6), a total phase displace-

* *Sciaky Electric Welding Machines Ltd.*

ment of $2\theta°$. Thus the output voltage is halved and the phase shift doubled. By making T_2 a 2:1 step-up, the output voltage level can be maintained. Greater shifts (integral multiples of θ) are possible by extending the scheme[5].

Automatic Control

Of more importance, with the increasing application of variations of the fundamental circuit (Fig. 1), is the possibility of having an independent "automatic" control as well as, or in lieu of, the manual potentiometer.

Replacing R by metrosils, thermistors, or A.C. amplifiers has fascinating possibilities. Alternatively, it is possible to make the reactance the variable in the circuit. For instance, by making R a potentiometer, and X a saturable reactor, it is possible to have both a manual (R) and an automatic (L) control, and this system is used in various motor control schemes[6].

However, the latter method is only suitable where the automatic control is in the nature of a vernier control, or perhaps a compensation. For instance, if $R = 10X_L$

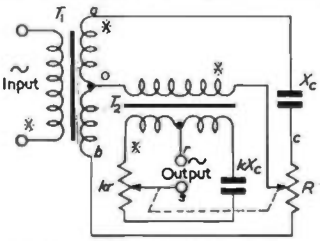


Fig. 5. Multiple circuit to obtain phase shift in excess of 180°

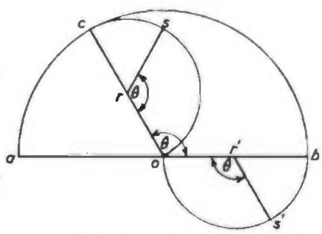


Fig. 6. Vector diagram showing overall phase shift of circuit (Fig. 5) is 2θ° > 180°

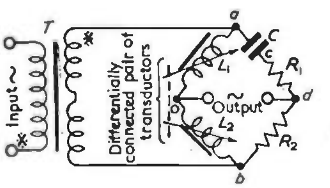


Fig. 7. A method of phase shift control where the variations can be governed by D.C. or electro-magnetic amplifiers

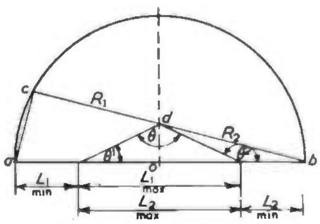


Fig. 8. Vector diagram for Fig. 7

where X_L is a saturated transductor, and R is the series resistance (including that of the reactor winding), the available phase shift will be in the order of 160° (actual figure depending upon reactor resistance). If now the saturating source be completely removed from the transductor and its reactance consequently increased say five times, the change in inductance will only produce about a 40° change in phase. Hence the automatic control is only about one quarter as effective as the manual one.

To increase the effectiveness of the automatic control the author has devised the following scheme:

C and $(R_1 + R_2)$ represent the usual series circuit (Fig. 7). One side of the output is taken from the junction of R_1 and R_2. The other side, however, is not taken from a centre tap on T, but from the junction of two identical saturable reactors (having high impedance low resistance A.C. windings). These saturable reactors are differentially connected, so that as the automatic control voltage is varied, one transductor increases in inductance as the other one decreases. Thus when the inductance of one transductor is a minimum, that of the other is at a maximum, and vice versa.

The circle diagram for the circuit is shown in Fig. 8. Providing the amount of current drawn is small, the output voltage will have a phase displacement varying from θ_1 to θ_2. The total phase shift will, therefore, be $\theta°$. Optimum values of the circuit parameters are most readily obtained by geometric construction. The smaller the Q of the series circuit, the greater value of θ.

The D.C. control of the transductors will be largely governed by individual requirements.

Combined Automatic and Manual Control

This can be tackled in two ways. The most flexible method is to have adequate electronic circuits preceding the two transductor primaries; and push-pull or see-saw types of D.C. amplifier stage can readily be adapted. Alternatively the output of two independent phase shift circuits (one for automatic and one for manual) can be fed into a common transformer (Fig. 9). The output is taken from T_2 secondary.

The individual phase shift ranges of the manual automatic circuits are derived as already outlined.

The combined output voltage at T_2 secondary will be of the form $E_0 \angle\phi$ where:

$$|E_0| = T\sqrt{[E_1^2 + E_2^2 + 2E_1E_2 \cos(\theta_1 \sim \theta_2)]}$$

$$\text{and} \quad \phi = \tan^{-1}\left[\frac{E_1 \sin\theta_1 + E_2 \sin\theta_2}{E_1 \cos\theta_1 + E_2 \cos\theta_2}\right]$$

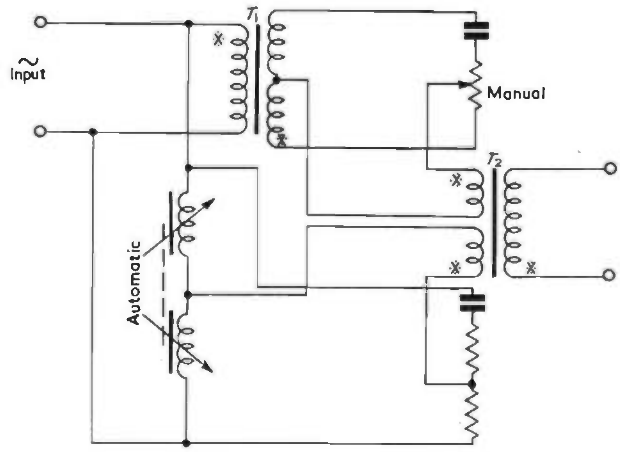


Fig. 9. Dual control circuit, suitable where a "manual" and an "automatic" adjustment of phase shift is required

T being the turns ratio (considering one primary), E_1 and E_2 being voltages of the individual outputs of the manual and automatic circuits (i.e. the input E.M.F'S. to T_2 primaries).

Providing the following circuit limitations are acceptable, the $E_0 \angle\phi$ calculations can be simplified:

(1) That the turns ratio of the manual section of the transformer be unity.

(2) That the manual circuit be connected so that its output E.M.F. (i.e. the input to T_2 primary) be always half T_2 primary E.M.F.

(3) That the turns ratio of the automatic section of T_2 windings be such that the virtual mean input E.M.F. to T_2 be equal to half T_1 secondary E.M.F. (this is reasonably possible, as in many cases there is not a very large swing in output voltage from the automatic circuit employed (cf Fig. 8).

Under the above conditions $E_2 \approx E_1 = \frac{1}{2}E_s$ (where E_s is the secondary voltage across T_1) and $T = 1$.

Hence

$$|E_0| \approx \sqrt{[E_1^2 + E_1^2 + 2E_1^2 \cos(\theta_1 \sim \theta_2)]}$$

$$= \sqrt{2E_1^2} \times \sqrt{[1 + \cos(\theta_1 \sim \theta_2)]}$$

$$\therefore |E_0| \approx 0{\cdot}707E_s \sqrt{[1 + \cos(\theta_1 \sim \theta_2)]}$$

which shows that the output voltage will vary between the limits of E_s (when $(\theta_1 \sim \theta_2) = 0°$) and $0{\cdot}707E_s$ (when $(\theta_1 \sim \theta_2) = 90$). And the expression for the resultant phase displacement will reduce to:

$$\phi = \tan^{-1}\left[\frac{\sin\theta_1 + \sin\theta_2}{\cos\theta_1 + \cos\theta_2}\right]$$

Conclusion

The phase shift circuits discussed in the above text are off-shoots of the basic form outlined in Fig. 1. The circle diagram technique is valid for complex circuits as for the basic circuit, but it must be borne in mind that if the circle diagram assumes certain properties or approximations, the designer must endeavour to meet these conditions. For instance, it has always been assumed that the voltages in the two halves of the centre-tapped transformer windings are in phase. This will only be so if the secondary resistance is small compared with its inductive reactance. Again, the series reactance has always been considered to be a pure one, and this assumption, too, must be scrutinized: particularly in the case of a saturable reactor. And, of course, the current drawn at the output terminals is considered to be comparatively small.

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A Design for a Constant Volume Amplifier

By G. J. Pope*

WHEN modulating a carrier wave, the highest efficiency and greatest signal-to-noise ratio are obtained at large modulation depths. The wide amplitude range of speech signals makes some form of compression desirable so that a reasonable modulation depth may be set without risk of overmodulation. The so-called constant volume amplifier is used extensively on overseas telephone circuits for this purpose.

Obviously, such a device is useful on any circuit requiring amplitude range limitation. The present circuit is designed to operate within some 10msec after the arrival of a strong signal and return to its previous state in 2-3 seconds.

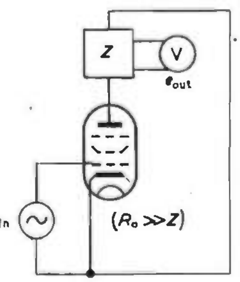

Fig. 1. Basic circuit of pentode and anode load

Principle of Operation

Fig. 1 shows, in skeleton form, an amplifier consisting of a pentode (a constant current generator) with anode load, the gain being given approximately by the equation:

$$e_{out}/e_{in} = g_m Z$$

where g_m = slope of valve in mA/V
Z = anode load in kΩ.

Changes of input voltage may be compensated by inverse changes of Z. The design to be described arranges for Z to be varied such that it is approximately inversely proportional to input amplitude changes within practical limits.

Any variable impedance would, of course, be suitable for the anode load, but it is believed that the use of a property of the cathode-follower is new in this particular application. The circuit to be described is simple to set up and reliable in operation, with results comparable to those of the more conventional circuits using metal rectifier bridge networks.

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The Cathode-Follower as a Variable Impedance

As is well known, the impedance presented by the cathode-anode circuit of a cathode-follower is given by:

$$Z = \frac{R}{1 + \mu}$$

and since

$\mu = g_m R$ where g_m = slope in mA/V
and R = anode resistance of the valve

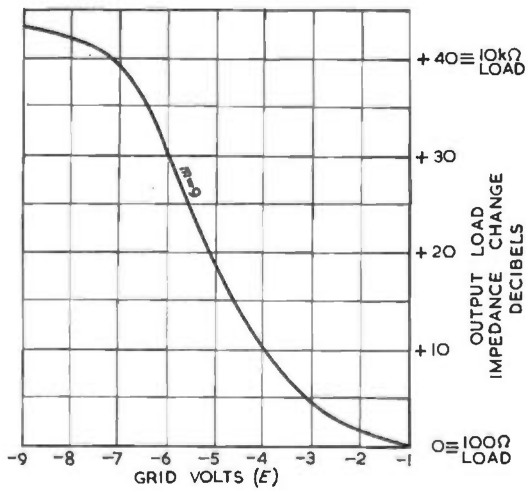

Fig. 2. The change of Z for variations of grid potential

then

$$Z = 1/g_m \text{ when } \mu \gg 1$$

Inspection of the curves of a triode-connected CV138 (EF91) shows that the product of its anode resistance and slope for various negative grid voltages is large compared with unity between values of zero and −7 volts. At voltages exceeding −7 on the grid, the g_m has become so small that this is no longer true.

The graph Fig. 2 shows the change of Z for variations of grid potential. Between grid voltages of −3 and −7, it will be seen that there is an approximately logarithmic relationship between the grid potential and the output impedance (measured in decibels). With the valve in question, a 37db change is obtained, the lowest impedance being some 140 ohms.

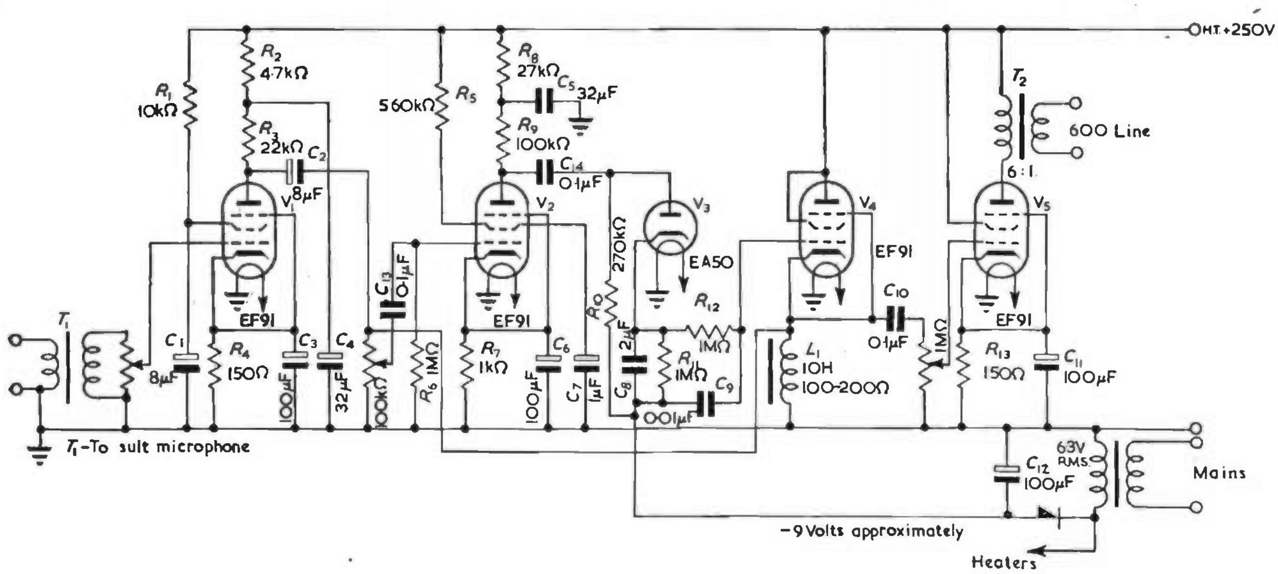

Fig. 3. The complete circuit

A 10 henry A.F. choke has been provided in the cathode circuit to prevent changes of grid voltage due to normal auto-bias action from affecting the cathode-follower characteristics. The highest cathode-follower impedance is some 20kΩ with maximum negative bias applied. The cathode and amplifier anode circuits which are, of course, in shunt, reduce this value to approximately 10kΩ at 1kc/s (see graph Fig. 2). At very low frequencies, the choke begins to shunt the cathode circuit, but the response for speech is adequate.

Fig. 3 shows an arrangement where the anode load of V_1 consists of a 22kΩ resistor shunted by the cathode-anode impedance of the cathode-follower V_4 biased towards cut-off. The anode of V_1 feeds a voltage amplifier V_2 whose output is rectified by V_3 to produce a positive going voltage to offset the standing bias on V_4.

It will be noticed that the feed for V_2 is taken from the output load and not from the input grid circuit of V_1. Using this method, incremental changes are more smoothly compensated, and the device has a better characteristic over a greater range. If the bias feed were taken from V_1 grid circuit, it would be necessary for the variable element to have an exactly reciprocal characteristic to any input change, that is for an input increase of 20db, the output load would have to decrease by 20db. As this condition is not fulfilled over any part of the range of the present cathode-follower element, either over or under compensation would result.

With no input signal, V_4 is non-conducting and presents an impedance of approximately 20kΩ to shunt R_3, the anode load resistor of V_1. As the input signal increases, V_2 develops a voltage which offsets the bias on the grid of V_4, so that the effective anode load of V_1 is reduced, with a resultant drop in gain of the device.

The resistor R_{12} and capacitor C_9 decouple the grid of V_4 to audio-frequencies without seriously affecting the operate time.

Sudden increases in input level are rapidly checked because C_8 charges quickly via the forward resistance of V_3, while decreases of output level are unchecked until C_8 has partially discharged via R_{11}. This means that the gain of V_1 (with the attendant background noise) does not increase appreciably during pauses in speech.

Performance

Fig. 4 shows the compression characteristic obtained and corresponding harmonic distortion figures are shown in Table 1. The distortion at low compression levels may seem excessive at a first consideration, but in practice is not noticeable, probably due to the fact that such a level may be tolerated on speech signals. Or again, the varying levels of speech continually carry the working point of

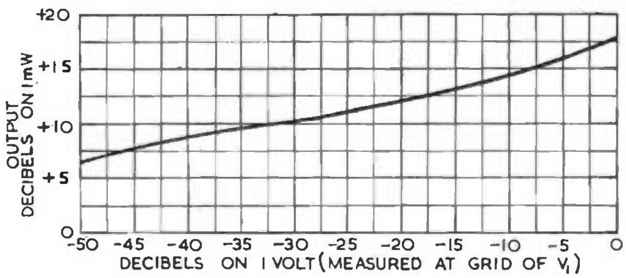

Fig. 4. The compression characteristic

the amplifier into the less distorting part of its characteristic, that is from zero to −20db in the table.

Input Relative to 1V (decibels)	Percentage Distortion
0	5
−10	6·5
−20	9·5
−30	10
−40	10
−50	6

Operation

The amplifier may well take the place of the usual pre-amplifier, the main modulator being fed by a 600 ohm line from the output transformer T_2. The input potentiometer VR_1 is set so that V_1 is not overloaded by the strongest input signals. It will, of course, have little other effect on the working conditions as any change of input signal to V_1 will be largely compensated. VR_2 may be adjusted to give a similar response to Fig. 4, by applying varying level tones.

VR_3 performs the function of normal volume control.

The cathode-follower bias supply should be between 8 and 9 volts negative. It is, therefore, important that the heater supply be reasonably constant, as this supplies the bias in the circuit described.

An Electronic Square-Law Circuit for Use with a Graphic Recorder

By M. J. Tucker*, B.Sc.

The circuit described uses the curvature of valve characteristics to produce an output voltage proportional to the square of the input voltage. It has been designed for graphic recording of the mean-square of a complex audio-frequency signal, but can be used to give the square of the voltage at any instant. A simple extension enables it to be used for multiplication. Fluctuations in the output zero after warming-up can be kept within 1 per cent (peak-to-peak) of the maximum output from a sinusoidal input by using simple power-supply stabilization.

A THERMOCOUPLE meter is a simple and satisfactory method of measuring the mean-square of an electrical signal, though its slow and not easily controllable speed of response might be a disadvantage in some applications. A thermocouple will not, however, give sufficient power to drive a pen recorder directly, so that either photographic recording or a rather elaborate D.C. amplifier would have to be used if a continuous record were required. Recording dynamometer meters which measure mean-square current are available, but these have a considerable inductance which limits their use to low frequencies and they require inconveniently large driving powers (of the order of 10 to 15 mean watts). Electronic square-law circuits thus have marked advantages where it is necessary to take a continuous record of the output.

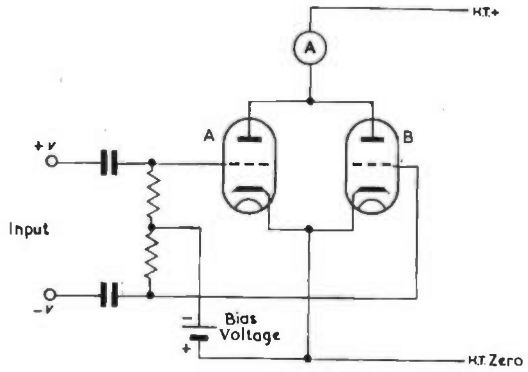

Fig. 1. Basic circuit

The squaring may be achieved electronically by using the curvature of valve characteristics[1,2] or the curvature of the characteristics of diode or metal rectifiers[3,4]. One recent circuit uses a series of diodes as automatic switches to produce an approximation to a square-law response curve by means of straight-line segments.[5] Another circuit[6] uses a temperature controlled diode in which the filament current is the sum of the A.C. input and a D.C. current which is controlled by a feedback circuit to keep the anode current of the diode constant, and is therefore a measure of the power of the input signal. Also, any multiplying circuit may be used as a square-law circuit by putting the same signal into both inputs, but such circuits are usually comparatively complicated.

The circuit described here is based on a principle similar to that described by Ross and Shuffrey[1], but it has been designed to avoid the use of special power supplies, to allow graphic recording of the output, and to give the maximum possible ratio of working range to instability of the output zero. Its performance has been examined in detail, and its theory is discussed in the Appendix.

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Principle of Operation

Fig. 1 shows the basic circuit and Fig. 2 the principle on which it operates. The input voltage is fed in push-pull to the grids of two valves whose anode currents are added. If the characteristic curves were straight lines, an input voltage would cause no change in the combined anode currents because the increase in one valve would be exactly balanced by the decrease in the other. In practice the characteristics are curved, and the increase in one valve will be greater than the decrease in the other so that the combined current increases. The combined characteristic is of the type shown in Fig. 2 and approximates to a parabola, or square-law curve, with a steady current added.

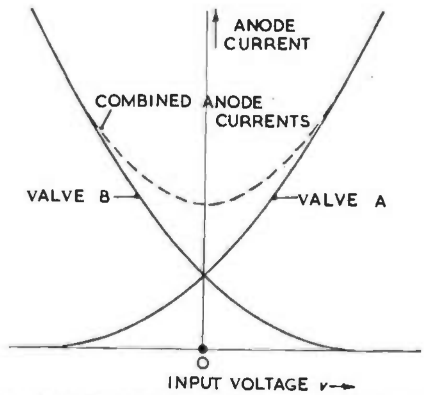

Fig. 2. This shows how the circuit of Fig. 1 combines two non-linear characteristics to give a square-law characteristic

The steady current is balanced against that through a similar pair of valves working under identical conditions but with no signal applied to their grids, and this arrangement gives comparatively good stability against changes in supply voltage and ambient temperature.

Connecting a resistor in place of the milliammeter in the triode circuit of Fig. 1 has the effect of straightening the combined characteristic and reducing the range over which the square-law is obeyed, and in the practical circuit pentodes are used to overcome this effect. Resistors in series with the cathodes or screens also tend to straighten out the characteristics, but are necessary if special voltage supplies are to be avoided. They are kept as small as possible by using common resistors for all four valves, with which arrangement their effective value is further reduced by the shunting effect of the balancing valves. The improvement in working range that could be obtained by supplying the screen and cathode voltages from a low-resistance potential divider is probably not worth the extra H.T. drain and the necessity of using high-power resistors. These effects are further discussed in the Appendix.

Circuit Details

The practical circuit is shown in Fig. 3. The input

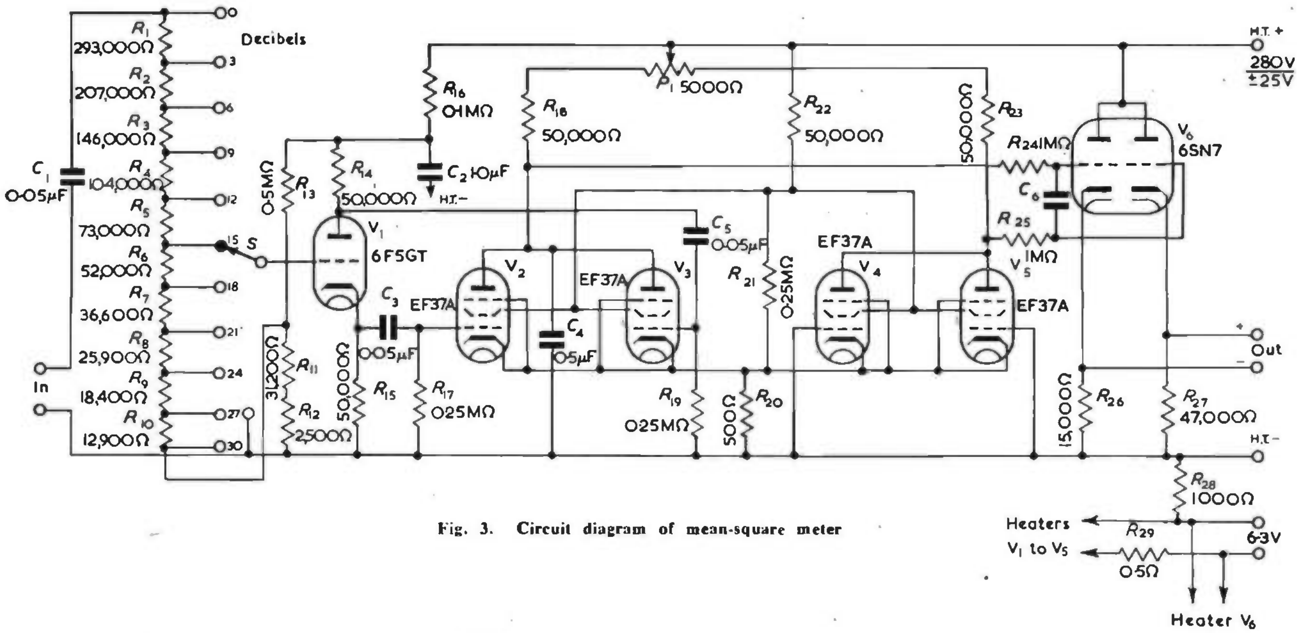

Fig. 3. Circuit diagram of mean-square meter

potential-divider sensitivity-control has $\sqrt{(2:1)}$ (3db) steps representing a 2:1 change in output, and feeds a cathode-follower phase-splitter which supplies the push-pull signal for the square-law valves (V_2 and V_3). V_4 and V_5 are the balancing valves. The signals from the two anode loads are taken through a suitable smoothing circuit to the two grids of a balanced cathode-follower output stage.

Because squares are always positive, the output voltage is always in the same sense: on application of a signal the current through the right-hand triode of V_6 increases and that through the left-hand triode decreases. The right-hand triode is therefore run with a low quiescent current and the circuit is arranged so that the currents through the two triodes are approximately equal at mid-scale output.

If the circuit is to be used to give the instantaneous square of the input voltage, the smoothing components (C_4, C_6, R_{24} and R_{25}) must be removed. It will also be necessary to balance V_2 and V_3 for the linearly amplified component (direct signal break-through) by inserting a pre-set potentiometer with its ends connected to the screen grids of V_2 and V_3 and its tapping point to the junction of R_{21} and R_{22}. This potentiometer should have the lowest possible resistance: 5000 ohms is probably sufficient.

H.T. Voltage

The H.T. voltage should be within about 25 volts of the specified value, otherwise the calibration curve may become slightly non-linear near the origin. The important factor appears to be the current through the square-law valves, and if an H.T. voltage outside the above limits has to be used R_{21} should be altered to bring the anode current of each valve to approximately 1·4mA. It will also be necessary to alter R_{26} to a value such that in the quiescent state it carries between 7 and 10mA and to make R_{27} approximately three times this resistance. Change in H.T. voltage has a comparatively small effect on the slope of the calibration curve.

Performance

A calibration curve using a sinusoidal input is shown in Fig. 4. The curve is linear within 1 per cent up to just under 50 volts output.

When measuring complex waveforms, the ratio of peak amplitude to R.M.S. amplitude will usually be higher than that for a sinusoidal waveform, and a smaller output range must be used. Using an output meter with a range of 15 volts full-scale the circuit can handle a peak amplitude of 2·5 times the R.M.S. amplitude without appreciable distortion, and this is probably an adequate margin for most purposes. It is therefore recommended that a resistor be placed in series with the recorder such that the full-scale deflexion is about 15 volts, which should include the voltage drop in the internal resistance of the circuit (about 700 ohms). The maximum output current is 5mA.

Two circuits have been built and tested. In the first, zero drift was negligible after a warming-up period of half an hour, but in the second circuit the zero drifted at the rate of between one and two volts per hour for about 2 hours after switching on. When the valves are new the zero drift is worse, and it is advisable to leave the instrument switched on for 24 hours before using it for the first time. Apart from any slow drift that may be present, the output contains fluctuations due to fluctuations in power supplies: variations in the heater voltage appear to have more effect than variations in H.T. To obtain the best balance against power supply changes some selection is necessary for V_2, V_3, V_4 and V_5. By selection of the best combination out of 5 aged valves that were available, the author was able to obtain a balance such that a 5 per

Fig. 4. Calibration of the square-law circuit using a 50c/s sinusoidal input

cent change in mains voltage produced less than a 0·4 volt change in the output zero (using a conventional simple power unit). The stability was improved by supplying the power unit through a stabilizing transformer, but these are very dependent on mains frequency and during the winter months when this is liable to fluctuate rapidly, they are not as effective as could be desired. However, even during the winter months the output zero usually kept within a range of 0·5 volts over a period of several hours after warming up, and this is probably adequate for most purposes. During the summer the fluctuations in output zero were considerably less and kept within a range of 0·1 volts.

For the first 100 hours or so of use the instrument settled down to a different zero each time it was switched on, the range initially being 1 volt. This effect slowly disappeared as the instrument aged.

Multiplication

To use the circuit for multiplication it is necessary to feed the grids of V_4 and V_5 from another phase-splitter similar to V_1. The sum of the two signals would be fed to V_1 and the difference to the other phase-splitter, the outputs then being given by:

$$(x + y)^2 - (x - y)^2 = 4xy$$

If mean products are required, a capacitor similar to C_4 should be connected between earth and the common anodes of V_4 and V_5. If instantaneous products are required, the smoothing circuits should be removed and fine balancing potentiometers inserted between the screens of V_2 and V_3 and of V_4 and V_5 in the manner described above under the heading "Circuit Details".

Conclusion

The instrument described is suitable for recording the mean-square value of an alternating voltage. The ratio of working range to output zero instability is not as good as could be desired, but is better than that of most similar instruments and is probably adequate for many purposes. The circuit is comparatively simple and requires no special power supplies.

Appendix

Theoretical Discussion

The most important factor in the performance of thermionic square-law circuits is usually the ratio of the range of square-law operation to the instability of the output zero. The push-pull method of operation increases this ratio by increasing the operating range.

It is convenient to represent the valve characteristic over the working range by the series:

$$i = a_0 + a_1 v + a_2 v^2 + a_3 v^3 + \dots\dots\dots \quad (1)$$

where i is the anode current,

v is the grid voltage.

For the sake of simplicity v will be taken as the change from the steady bias voltage, which means that the coefficients a_0, a_1, a_2 . . . are functions of the bias.

a_0 represents the steady anode current, $a_1 v$ represents the linear amplification (which has no D.C. component if the grid is fed through an RC coupling) and $a_2 v^2$ is the square-law term. The $a_3 v^3$ and higher terms represent distortion in the present application.

In the circuit of Fig. 1 valve A is fed with $+v$, and valve B with $-v$, so that the anode currents are given by:

$$i_A = a_0 + a_1 v + a_2 v^2 + a_3 v^3 + a_4 v^4 + \dots\dots$$
$$i_B = a_0 - a_1 v + a_2 v^2 - a_3 v^3 + a_4 v^4 + \dots\dots$$

and the combined anode current by:

$$i_A + i_B = 2\,(a_0 + a_2 v^2 + a_4 v^4 + \dots\dots) \quad \dots\dots \quad (2)$$

so that half the unwanted terms have disappeared.

It is usually possible to find a bias point on a valve characteristic such that either a_3 or a_4 is zero. In a single valve circuit it is probably best to choose a bias which gives a good compromise between a_3 or a_4, in which case both have an appreciable value. In the push-pull circuit, however, a_3 has no importance and the bias can be chosen such that $a_4 = 0$. The linearity of the curve of $i_A + i_B$ against v^2 is therefore improved, and hence the working range is extended. The absence of the $a_1 v$ term, which represents linear amplification, also means that the circuit will give instantaneous squares.

It should, perhaps, be pointed out that in some applications the odd power terms are not important. They produce no D.C. component in the output when the input has a symmetrical periodic waveform (i.e. waveforms with no even harmonics) or a statistically symmetrical non-periodic waveform such as thermal noise. It is also apparent that in circuits where the odd power terms are not eliminated, calibration with a sinusoidal input is not permissible if non-symmetrical input waveforms are likely to be used. All the even power terms produce a D.C. component in the output from a sinusoidal input; calibration with such an input is therefore a good measure of the performance of push-pull circuits.

It has been assumed so far that there are no resistors in series with the anodes or cathodes of triodes, or the screen grids or cathodes of pentodes. Resistors in series with the individual leads straighten out the characteristics and reduce the square-law coefficient a_2 compared with a_0 and a_1, which is an undesirable effect. Calculation of the effect of resistors in common leads is lengthy, but it can be seen that they produce a kind of negative feedback on the combined current and straighten out the arms of the combined characteristic curve, tending to make it into a V shape instead of the parabola desired. The effect of a resistor in the anode of a pentode is very small, unless it causes the anode voltage at some point of the characteristic to drop so low that the anode does not collect effectively all the electrons passing the suppressor grid.

To find the optimum bias point Ross and Shuffrey plotted the characteristic of a single valve on log-log paper and chose the centre of the range over which the curve is a straight line with a slope of 2. This method ignores the fact that the odd power terms are of no importance in the push-pull circuit, and in the author's experience it is quickest to find the best point by trial and error. If two curves similar to those in Fig. 2 are drawn for different biases, it is immediately obvious in which direction the bias should be adjusted and the correct value, which is not very critical, is quickly found.

Ross and Shuffrey improved the shape of the valve characteristic by applying the signal voltage to the suppressor grid of a pentode as well as to the control grid, the voltage applied to the suppressor grid being considerably greater than that applied to the control grid. In the author's experience the improvement in the shape of the characteristic is too little to compensate for the loss in sensitivity and the increase in complication involved.

The theory of diode and metal-rectifier square-law circuits may be treated in the same way. Draper and Tucker have described a circuit suitable for either of these elements[3], and in their theoretical discussion they have represented the characteristics by equations of the forms:

$$r = Ke^{-qv} \text{ for a metal rectifier if } v \text{ is small}$$
$$Ki = e^{qv} \text{ for a thermionic diode.}$$

Both these equations can be expanded into a power series of the type of Equation (1).

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2. Ragazzini, J. R. Boymel, B. R. A Square-Law Vacuum-Tube Voltmeter. *Rev. Sci. Instrum.* *11*, 312 (1940).
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Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

Advanced Theory of Waveguides

DEAR SIR,—In a review of "Advanced Theory of Waveguides", which appeared in your issue for May 1952, one of us (J.B.) stated that the equivalent circuit for the H-plane step, as given in section 5·1, was incorrect because of the neglect of the phase of the transmitted wave. We have recently discussed this point in detail and would like this opportunity of bringing our conclusions to the notice of your readers.

The method used for the analysis is based on the variational principle developed by Schwinger, but there are some minor differences. In such of Schwinger's work as has been seen by us, a suitable form for the equivalent circuit is selected and variational expressions are derived for the values of the circuit elements. This cannot be done for the H-plane step as it does not possess the required symmetry, and a slightly different procedure is used. A variational expression is obtained for the input impedance of the junction at some arbitrary reference plane, taken for convenience in section 5·1 as the plane of the step. From this an equivalent circuit can be deduced which will correctly describe the reflexion properties of the junction. To complete the specification of the equivalent circuit it is necessary to consider the phase of the transmitted wave. This can be most conveniently carried out by terminating the output guide in an arbitrary impedance: the input impedance then becomes a function of the position of this load and the equivalent circuit can be completely defined. An example of this procedure appears in section 5·3 dealing with the E-plane T-junction.

If the analysis of the H-plane step is completed in this way it is found to the degree of approximation used that the circuit in Fig. 5.2 is correct. The shift of the reference plane mentioned in the review does not appear until the approximation is carried a stage further, when it is found that a small quadrature component appears in the expression for the junction field. It is interesting to note that, owing to the slightly altered form of the equations for the E-plane step, the latter fails to exhibit this phenomenon, and the junction field is rigorously co-phased.

Yours faithfully,

L. LEWIN,
J. BROWN*

* Imperial College of Science and Technology, London, S.W.7.

Recording of Noise in Vehicles

DEAR SIR,—In the article on "Electronics in Automobile Engineering Research" in your April issue it is stated, in connexion with the recording of noise in vehicles, that "the recording and reproduction of intense low frequencies often causes considerable modulation noise although the same recording and reproducing heads and tape are quite satisfactory when used for speech or music. The Association is in close touch with the manufacturers concerning these problems."

The apparatus concerned, consisting of a commercially available tape deck with amplifier constructed generally in accordance with the instructions supplied by the manufacturers of the deck, was brought to us by two representatives of the M.I.R.A. Frequencies from 30 to 70c/s were fed into this apparatus and the distortion complained of made apparent. The same frequencies were then fed into our standard recording gear and reproduced, using the same samples of tape, without any sign of the trouble. The resulting waveforms were considered satisfactory by the M.I.R.A. for their purpose. The tapes used included both our own product and those of other manufacturers.

From these tests it was concluded that magnetic recording is capable of giving the desired response with our equipment which is, in fact, quite normal equipment; but it is also apparent that other commercially available equipment can give the low frequency distortion complained of.

Yours faithfully,

P. T. HOBSON,
Research Manager,
Magnetic Tapes Division,
Minnesota Mining and Manufacturing Co., Ltd.

The author replies:

DEAR SIR,—With reference to Mr. Hobson's letter concerning distortion in the magnetic tape recording of very low audio frequencies, I would point out that the article was written before we had contacted Mr. Hobson concerning this matter. So far as Mr. Hobson is concerned his letter is a correct statement. Although, to be frank, we do not know enough about the low frequency modulated noise referred to in the article to argue the matter in your columns, nevertheless, I would repeat that both recorder design and tape characteristics appear to be involved.

Yours faithfully,

J. R. BRISTOW,
Research Manager,
The Motor Industry Research Association.

A High Quality Power Amplifier

DEAR SIR,—I have read E. J. Miller's article "A Stable, High Quality, Power Amplifier" appearing in the August issue of ELECTRONIC ENGINEERING with great interest; it appears to me that it represents a straightforward, down to earth approach to a problem which has puzzled a good many amateurs and high-fidelity enthusiasts.

I would greatly appreciate your comments on the following two questions:—

1. Curve C in Fig. 3 shows the power output for 5 per cent total harmonic production. According to the data I have available on the 6V6 tube, the total harmonic distortion with 285 volts plate supply and a power output of 14 Watts is 3·5 per cent. In view of the 20db feedback in the pass-band, I would have expected a much lower distortion than the values given in the data sheets for the 6V6, which are of course for a straight amplifier without feedback. I am wondering whether there is a decimal point missing in this figure, 0·5 per cent being a value which I would consider as more probable.

2. Would you be kind enough to give me the characteristics of the EF37, or indicate what American tube is equivalent to it (I assume that it will be a 6J7 or 6SJ7).

Have you any data on the output impedance of the amplifier? This is in my opinion of great importance for good damping of the loudspeaker.

Yours faithfully,

WALTER RICHTER.
Milwaukee,
Wisconsin, U.S.A.

The author replies:

DEAR SIR,—Thank you for your letter and for the interest that you have taken in the amplifier.

Unfortunately Curve C in Fig. 3 showing 5 per cent total harmonic production, is correct. I have figures of power output for lower values of harmonic distortion, but I did not feel justified in publishing them. As you know, in this type of amplifier the onset of distortion with increasing input signal is rapid and thus the power output for 0·1 per cent, 1 per cent and 5 per cent total harmonic production is not so very different. Measuring low values of distortion, even where excellent signal generators and filters are available is always difficult and the results are often impossible to reproduce.

Exactly why valve manufacturers achieve much higher output for a given distortion is not apparent. Possibly the cause is that valves are tested under ideal conditions, e.g., purely resistive loads, fixed bias and perfect matching.

The EF37 is a near equivalent to the American type 6J7, however it has a somewhat higher mutual conductance. Use of the EF37, or the low hum version EF37A, has been standardized because, in my experience, this valve has the best, and by far the most consistent, microphony performance from sample to sample. In this particular application perhaps this is unnecessary, but in a pre-amplifier, to be published later, this feature is essential. I regret that I have no experience of American valves in this respect.

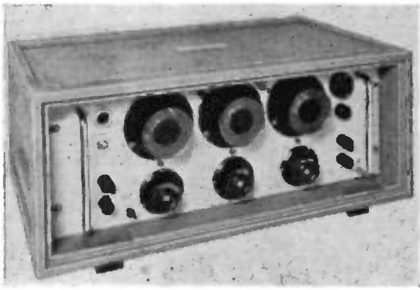
The source (or output) impedance of the amplifier has been measured and found to be 1·6 ohms for an amplifier having a 15 ohm termination. This should provide adequate damping.

Yours faithfully,

E. J. MILLER.

ELECTRONIC EQUIPMENT

A description, compiled from information supplied by the manufacturers, of new components, accessories and test instruments.



S.T.C. Industrial Counter

(Illustrated above)

THE Standard industrial counter type 74505A is an electronic counter capable of handling pulses at rates up to 5 000 per second. It has been designed for use in situations where mechanical and electro-magnetic types are too sluggish to count accurately or even to count at all, and can be used for batch selection, as a pulse divider and as a frequency-divider.

It owes its speed of response to the use of Nomotron decade counter tube. The tube is a cold-cathode gaseous-discharge device having ten possible states of equilibrium, i.e., the discharge can take place between the anode and any one of ten cathodes arranged in a circle. The glow of the discharge is visible through the end of the tube. Transfer electrodes are situated between adjacent cathodes, and these enable the discharge to be transferred from one cathode to the next in one direction only. If the tube is fed with a continuous train of pulses, the discharge can be made to rotate continuously, ten pulses being required for one complete revolution.

Three of the G10/240E tubes are used in the industrial counter—one for counting units, the second for tens, and the third for hundreds, so that any number between 0 and 999 can be indicated by the discharge positions in the three tubes.

The incoming pulses are first shaped and amplified, and then fed to the first (units) counter tube. At the end of each revolution on the units counter tube, i.e., at every tenth pulse, the discharge in the second (tens) counter tube is made to step round one position. At the end of each revolution on the tens counter tube, i.e., at every hundredth pulse, the discharge in the third (hundreds) counter tube is made to step round one position. Three switches are provided, one for each counter tube, for batch selection purposes. Each has a dial graduated from 0 to 9, and the principle of operation is as follows.

Suppose it is desired to count batches of 125; then the hundreds switch is set to "1", the tens switch to "2", and the units switch to " 5 ". When the 125th pulse arrives, a pulse of 150 volts is generated across the output terminals, and the discharges return to the "0" position on each tube. The process is then repeated, starting with the 126th pulse. The output pulse can be applied to a device for separating one batch from the next. For normal counting, the switches are all set to " 0 ", and a key is provided for manual resetting to the "0" position.

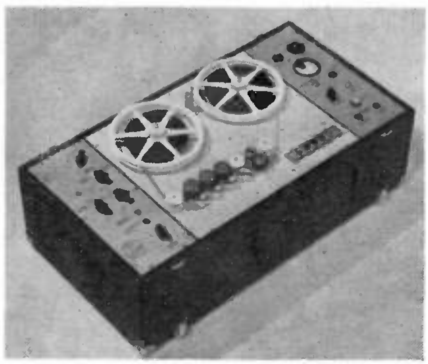
A minimum input pulse voltage of 25 volts is needed, and the output pulse voltage is 150 volts. The counter's power requirements are: 100-110V, 120-130V, 140-150V, or 200-250V, 40-60c/s single-phase A.C.

Standard Telephones and Cables, Ltd.,
Connaught House,
Aldwych, London, W.C.2.

Model DI Portable Recorder

(Illustrated below)

A NEW portable recorder has been produced by Electrical and Electronic Development, Ltd., in which the record and replay amplifiers, power pack oscillator and tape desk are housed in a case with a removable cover. The recorder is supplied with a desk type moving coil microphone and stand, microphone and main leads, a reel of recording tape and a spare reel.



On the left hand panel there are two inputs selected by a switch and a balanced feed microphone input of 15/30Ω, the second being a high impedance jack socket input requiring an input of 0·6V to modulate fully the tape. Separate record and replay volume controls are provided, as well as a selector switch for record, rewind and replay. There is also a compensation switch for 7½in. and 3¾in. per second.

On the right hand panel is placed a record level meter which works in a peak level valve voltmeter circuit, and a mains input socket with voltage tap board adjacent. A control is supplied for adjusting the bias to suit various tapes and, positioned over the internal 5in. speaker is a jack socket for an external speaker with a tap board giving impedances of 3, 7 and 15 ohms as required. Adjacent to this is a speaker muting switch which enables the operator to monitor with phones in place of the speaker if required.

The output of the amplifier is 3 watts with a low distortion factor. The frequency response is level with 2db from 70 to 10 000 cycles at 7½in. per second. The frequency response of the whole equipment is ±2db from 70 to 10 000 cycles, and can be extended when feeding a high quality amplifier from the monitor phones jack socket.

The tape desk incorporates brakes, fast forward and fast rewind, twin speed and erase, record and monitor heads.

The recorder measures 26½in. by 15½in. by 10½in., and weighs 52lb.

Electrical and Electronic Development, Ltd.,
Bickford Road, Witton,
Birmingham, 6.

Standing Wave Meter Model 2.

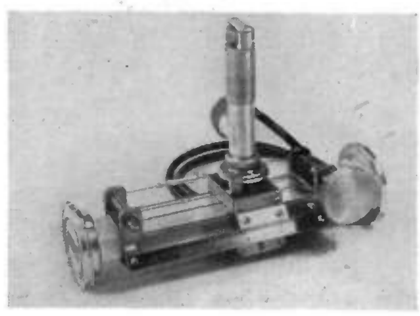
(Illustrated below)

THE standing wave meter model 2 is constructed on a selected waveguide held in a metal frame which carries the drive mechanism and scale. The vertical tuned line is held in place by a screwed ring and spring which enables the penetration of the probe into the waveguide to be varied from zero to 2mm. An engraved scale on the screwed ring indicates the probe penetration to within 0·1mm.

The travelling carriage rides upon the surface of the waveguide, accuracy of alignment and fitting rendering choke recesses unnecessary; a spring-loaded roller on the underside of the frame retains the carriage upon the waveguide.

Traverse is controlled by a multi-strand steel cord which is driven by a screwed drum. The drum moves across the frame as it is turned, thus keeping the cord on the centre line of the waveguide during the full travel of the carriage. One full turn of the control knob moves the carriage approximately 18mm. The carriage travel is 63·5mm approximately and is measured by a metric vernier scale to 0·01mm. The scale is of rustless steel and is standard at 20°C.

Tuning of the crystal detector, which uses a silicon crystal rectifier, is controlled by a knob at the top of the tuned line which has a piston movement of 22mm and tunes to 3·2cm wavelength near the centre of travel. At 3·4cm



tuning points are available near each limit of the piston movement. D.C. output from the crystal is taken via a screened cable to the indicating instrument. A 0-50 microammeter is recommended for this purpose.

The standing wave ratios are readable to better than ±0·1db. The instrument weighs 28oz.

Microwave Instruments, Ltd., West Chirton Industrial Estate, North Shields, Northumberland.

New S.T.C. Magnetic Material

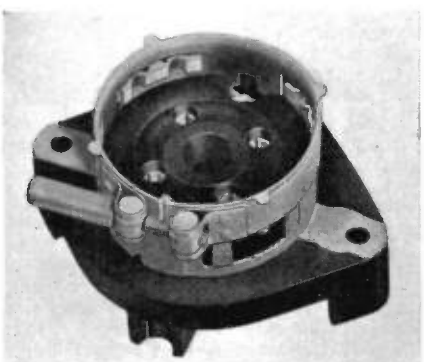
A NEW material has recently been added to the range of magnetic alloys manufactured by Standard Telephones and Cables, Ltd. This is Permalloy F, a nickel-iron alloy in which a rectangular hysteresis loop and a low value of coercive force are obtained by the method of domain orientation. It is, therefore, suitable as a core material for all types of saturable reactor. Permalloy F is produced in the form of toroidal cores wound from thin tape, and these cores are supplied in the fully heat-treated condition ready for winding. In common with all magnetic materials which have high permeability, Permalloy F is somewhat strain-sensitive and needs to be handled with care during winding and other processng if its high magnetic properties are to be retained fully. For some designs it may be advisable to place the core in a box before winding; this will serve both to avoid straining the core during winding and to prevent the penetration of coil-impregnating compounds into the core.

The magnetization characteristics are such that a flux density of nearly 14 000 gauss may be obtained in magnetizing fields of less than 0·1 oersted. From a maximum flux density of 13 500 gauss, the remanence is greater than 13 000 gauss, while the coercive force is less than 0·05 oersted, thus resulting in a hysteresis loss of only 210 ergs.

The specific gravity of the alloy is 8·4, and the electrical resistivity is 26 microhms per centimetre cube.

The core sizes which are proposed range from 2·25in. to 1·00in. outer diameter, 1·50in. to 0·50in. inner diameter, with a height of from 0·5in. to 0·25in., and a tape thickness of 0·004in. or 0·002in.

Standard Telephones and Cables, Ltd., Connaught House, Aldwych, London, W.C.2.



Arcolectric Toggle Switch

(Shown below)

A THREE position toggle switch with a true Q.M.B. action has been designed by Arcolectric (Switches), Ltd., in which each position is obtained with a positive snap.

The switch is provided with six terminals for connexion and will switch three separate single pole circuits. Alternatively it can be used to control two circuits, and either the end or central position can be the "off" position.

The contacts are of the self-cleaning low resistance type. The switch, Catalogue No. M.40, is rated 5A 250 volts A.C./D.C. Fixing is by means of two inserts tapped 6 B.A. at 1¼in. centres.

Applications for this switch include switching electric motors to give two speed and "off", and controlling electric elements to give two heats and "off".

Arcolectric (Switches), Ltd., Central Avenue, West Molesey, Surrey.

Ediswan Clix Valveholders

(Illustrated bottom left)

TWO new valveholders, type B4A and B4D, have been added to the Ediswan Clix range of components. These valveholders have silver-plated hardened beryllium copper contacts conforming to R.C.S.C. Specification 251.

The quartz-phenolic body has low moisture absorption, high surface and volume resistivity, low permittivity and low power losses. The silver-plated beryllium copper sockets are designed to provide good contact pressure and resistance, while the specified limit figures for insertion and withdrawal forces are attained with a wide margin.

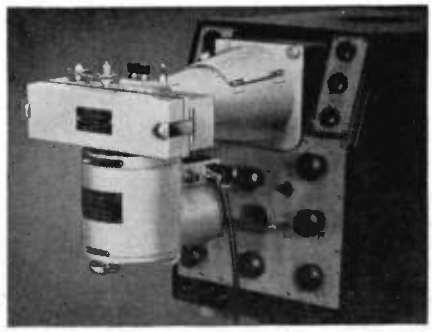
The Ediswan Swan Electric Co., Ltd., 155 Charing Cross Road, London, W.C.2.

Cossor Camera Drive Unit

(Illustrated top right)

DESIGNED for use with the Cossor camera models 1428 and 1432 when film drive becomes essential, this unit embodies a capacitor motor of ample power, which is worm coupled to a gear box having a range of nine speeds.

The model camera drive unit is arranged for film speeds in inches per second as follows: 0·05; 0·1; 0·25; 0·5; 1·0; 2·5; 5; 10 and 25. Gear selection is



effected by rotation of an engraved knurled knob and, by the positive action of the drive engagement lever, the starting and stopping of the film is, for practical purposes, instantaneous.

Switching of the motor is by push-pull type control mounted to the gear box. The drive unit may be operated from single-phase A.C. supplies of 110V, 200V, 225V and 250V through an auto-transformer which, with the motor capacitor, is housed separately and forms part of the mains lead to the unit.

For short records development may be carried out in a dish by "see-sawing" as with a standard roll-film, but where several feet have to be handled, it is almost essential to adopt some form of frame or drum processing technique.

A. C. Cossor, Ltd., Instrument Dept., Cossor House, Highbury Grove, London, N.5.

Morgan Megistor

THIS high value glass enclosed resistor was described on p. 345 of the July, 1952, issue of ELECTRONIC ENGINEERING. The following details are supplementary to the information given previously.

Change of resistance with applied voltage is small and reversible, and varies in magnitude with the resistance value. The voltage coefficient is expressed as an average percentage change per volt over the range 1 to 100 volts.

The limits are: —

Resistance	*Voltage Coefficient*
10^7 to 10^{10} ohms	Less than −0·1% per volt
10^{11} ,,	,, ,, −0·15% ,, ,,
10^{12} ,,	,, ,, −0·2% ,, ,,
10^{13} ,,	,, ,, −0·25% ,, ,,

The nominal resistance value is measured at 25°C. The change of resistance value with ambient temperature is small and reversible, and varies in magnitude with resistance value. The temperature coefficient is expressed as an average percentage change per °C over the range 0 to 60°C.

The limits are: —

Resistance	*Temperature Coefficient*
10^7 to 10^9 ohms	Less than +0·2% per °C.
10^9 to 10^{11} ,,	,, ,, +0·3% ,, ,,
10^{11} to 10^{13} ,,	,, ,, +0·4% ,, ,,

All Megistors are individually tested and it is claimed that the performance of all Megistors complies 100 per cent with the above specification and that in most cases the changes observed are considerably less than the limits shown.

The Morgan Crucible Co., Ltd., Battersea Church Road, London, S.W.11.

BOOK REVIEWS

Thermionic Valve Circuits

By Emrys Williams. 314 pp., 212 figs. 3rd edition. Sir Isaac Pitman and Sons, Ltd. 1952. Price 21s.

THE present volume is the third edition of Professor Williams book which was first published in 1942. It is based on lectures given to third year degree students, and provides a comprehensive survey of valve circuit theory.

In the first chapter the author deals with A.C. theory, circuit theorems, distortion, amplitude and frequency modulation, whilst in the second he deals with the construction and characteristics of thermionic valves of the conventional type.

The next two chapters are concerned with amplifiers. The various types of A.F. and R.F. coupling are discussed together with the analysis required to determine the maximum gain and power output in each case. Composite characteristics in push-pull circuits are also treated. Chapter IV contains much additional material on negative feedback and wideband amplifiers compared with the earlier editions.

Chapter V is devoted to regeneration and oscillation. The basic circuits of the common types of tuned circuit and relaxation oscillators are analysed. The extension of oscillators to the flip-flop and time-base circuits is included, together with an interesting original theorem relating to single frequency oscillators.

In Chapter VI detectors and rectifiers are described including phase sensitive rectifiers, and the use of a diode for the purposes such as A.G.C.

The author next deals with frequency changing and modulators commencing with the analysis of the equation of a modulated wave and following with frequency changer and modulator circuits. The principles of heterodyne and superheterodyne working conclude Chapter VII.

The last chapter is additional matter included in the book for the first time, and forms a very useful introduction to pulses and pulsed circuits. Pulse modulation, the formation and shaping of pulses, differentiation and integration, and electronic switching are all explained together with representative circuits. A short bibliography relating to this chapter is included.

The mathematical knowledge required of the reader does not extend beyond that necessary for simple differential equations, and the author develops very clearly the proofs of all the important results.

In the paragraph on distortion the author does not adhere to B.S.I. definitions, and ρ is used for the anode slope resistance in place of the more common symbol r_a.

It is inevitable in a book of this size that much must be omitted or drastically condensed. Thus only brief reference is made to band-pass circuits, to smoothing circuits, and to power rectifiers. In Chapter IV (Amplifiers) the reader learns that the anode efficiency in Class A cannot exceed a theoretical maximum of 50 per cent, but the practical limits are not given. This chapter covers a very wide range of subject matter and would probably have been improved, from the student's point of view, if it had been divided into two.

The book contains numerous diagrams, although some of them are disconcertingly small. Additional circuits in the chapter on oscillators would have avoided the necessity of detailing modifications in the text. Errors are commendably few.

It is evident that the publishers have endeavoured to keep the cost of production to a low figure, but the textual matter certainly seems to deserve better quality paper.

In conclusion, the criticisms made are of relatively minor details. Professor Williams has succeeded in presenting very clearly the theory of valve circuits, and the book can be confidently recommended to the serious student seeking an introduction to this subject.

J. E. F. Voss

Reports on Progress in Physics Vol. (XV)

Edited by A. C. Strickland. 338 pp. The Physical Society. 1952. Price £2 10s. 0d.

THE bulk of the contents of this book, which contains reports on nine physical subjects, lie outside the scope of this Journal. There are, however, three papers of considerable electronic interest—the review of ferrites by A. Fairweather, F. F. Roberts and A. J. E. Welch (pp. 142-172); of galvanomagnetic effects in conductors by D. K. E. MacDonald and K. Sargison (pp. 249-274) and of travelling wave tubes by R. Kompfner (pp. 275-327).

A historical method of approach has been adopted in all three reports, and in the second this necessitates some reference to later passages for the elucidation of the opening paragraphs. One does not expect reports of this nature to cover every detail of theoretical and experimental progress in each subject, and the present authors have confined themselves to a lucid account of the development of the field, and have presented only the basic theory. A comprehensive list of references is included for the student who wishes to make a more complete study of the subject.

In the paper on ferrites the authors describe the crystal structure and magnetic properties of various ferrites and their preparation, and include a subsection on the frequency characteristics of these properties. This topic is relevant to the use of ferrites in high frequency transformers of low loss. Dielectric and semi-conducting properties are also discussed and the outline of Neels' theory of ferromagnetism is given.

In the second report the authors refer to the pioneering work of Kapitza as the basis of experimental knowledge in the field of galvanomagnetic effects. His method of short-circuiting a high-powered generator enabled him to produce magnetic fields of the order of 3×10^5 gauss and so to make reasonably accurate measurements both on the Hall effect and the much smaller magneto-resistive effect. The fundamental difference between the origins of these effects is stressed by the authors. Whereas the Hall E.M.F. may be shown to be a direct result of the Lorentz force on the electrons, and should therefore be present to a certain extent in all conductors, the magneto-resistive effect is dependent on the dispersion of electrons from their forward motion through the conductor, which is in turn a function of the distribution of relaxation times among the electrons. Thus the latter effect is smallest when the relaxation times are most nearly equal.

The effects of temperature, crystal structure, and size are also discussed and a theoretical analysis of magneto-resistance given.

In the last of the nine reports the development of travelling wave tubes is traced by Kompfner from the early Klystron. The conventional triode, and to a lesser extent the Klystron, suffer from the defect that increasing power is drawn from the input as the time of transit of the electrons through the R.F. field becomes comparable with the period of oscillation. This restriction disappears if the R.F. field can be made to travel with the electron beam, and the author describes early experiments in which a helix is used to slow down the rate of propagation of the R.F. field to a convenient level. The development and performance of this type of tube is described, and such characteristics as attenuation in the helix, bandwidth, beam velocity, stability, gain and noise are discussed.

Various other structures which have been used to propagate slow waves are compared, and the report ends with a review of the important field opened by recent attempts to amplify microwaves by electron-electron interaction.

A misprint occurs on page 277 where a factor of 2 is missing from an equation in the text, and again at the foot of page 309 where two words should be interchanged. The word "Inference" on the eighth line of page 324 should read "Interference".

A cumulative subject index for volumes I to XV is included at the end of the book.

E. M. Deeley

Radio and Television Receiver Troubleshooting and Repair

By Alfred A. Ghirardi and J. Richard Johnson. 822 pp. Rinehart Books Inc., New York. 1952. Price $6.75.

THIS is yet another of the type of book which is intended to help engineers to service radio and television receivers quickly and properly. Like most American books of this sort it contains an enormous amount of information, but is padded out to such an extent that reading often becomes dull and boring. For instance, more than a page is devoted to the description and illustration of a "direct drive tuner" (a pointer on a knob) and a selection of knobs. It is stated that a likely fault is that the knob may become loose. Having shown that it is fixed by means of a set screw, it is suggested that the screw should be tightened to remedy the fault. Again, under the heading "10-10 Dead Receiver" it states "In a dead receiver, both the picture and sound sections are inoperative. This means that the trouble cannot be in a section which affects only one or the other, but must be somewhere in a section upon which both sound and picture sections depend."

Some illustrations are badly headed. For instance, on page 248 there is a diagram entitled "Fig. 7-19 Schematic Diagram of 2 filament type tubes with their filaments connected in series, showing how plate current as well as filament current pass through the filament circuit. Filament current is not shown in the diagram." A little care here would have made it so much clearer to the reader who, presumably, is reading the book to learn just this sort of thing; to leave out, and state it is left out, one of the things the diagram is intended, and stated, to illustrate, is very unfortunate.

As already stated the book contains an enormous amount of information, and this is presented in an orderly manner and very well illustrated throughout.

Chapter 1 describes typical components of a radio or television receiver, and the faults which may develop in them. It is very useful and complete and is most suitable material for the start of the book.

Chapters 2 and 3 cover points, the importance of which are not always appreciated. They include a systematic approach to repair work generally and perhaps most neglected of all the time saving which can be effected by means of a few questions put to the person actually making the complaint about the receiver. Suitable questions are given which can be time-savers.

Chapters 4 and 5 show the basic methods of static and dynamic testing, i.e., those tests which do not need a signal such as to A.C. and D.C. supplies, components and wiring checks, etc., and the method of signal tracing, or following a signal through a receiver until the faulty section is found. In practice both methods are used. Suitable test equipment is illustrated and described, and typical receiver circuits are shown. The points at which the various tests are applied are discussed and explained. The capacitor in the probe of a valve voltmeter is called an "isolating conductor capacitor" on page 132. Even a valve holder is shown from both sides to illustrate the relation of the pin numbers, top and bottom, to those on the circuit diagram.

Chapters 6-9 continue with more detailed general problems and those which mainly occur in certain types of sets such as A.C./D.C., battery, or communication receivers. The chapters also contain a number of charts which indicate where faults which cause certain symptoms are likely to be. In common with all the chapters in the book these are followed by a summary of the chapter and a list of "review questions". These summaries should be quite unnecessary and their contents would be much better in the chapters themselves. If it is thought that the questions are useful, then it would be best if some reference were made to the page upon which the answers could be found. The answers to the "odd" questions are given at the back of the book. The "evens" are left out.

Chapter 10 is a short one on trouble-shooting television receivers. It is difficult to see how the subject could be covered in 52 pages, but the authors make a brave attempt. This chapter, and Chapter 14 which covers alignment of television receivers, are the only ones devoted solely to this subject, but of course much of the basic writing is equally applicable to television servicing. After a brief mention of methods of taking receiver performance data in Chapter 11, come Chapters 12 and 13 which cover the alignment of A.M. and F.M. receivers.

Chapters 15 to 18 discuss the replacement of resistors, inductors, transformers and capacitors, and are quite thorough. How to choose a correct replacement can be quite a difficult matter if the faulty part is badly damaged or not the original, and these chapters show how to avoid "replacements" which will have short life. The remaining chapters deal with mechanical repairs such as drives, loudspeaker cones, record players and recording equipment.

As the book sets out to cover the entire subject, it is a pity that space could not be found for some details of minor cabinet repairs, retouching and repolishing etc., as it has become more and more important that receivers should be returned to clients looking satisfactory, and behaving accordingly.

A few errors were noticed, such as an electrolytic across the smoothing choke in Fig. 6-14 and a change of modulation depth of the bars on a C.R.T. which is intended to show line non-linearity. There is non-linearity, too, but the mark-to-space ratio change across the screen is much more noticeable.

The book is a good example of its type and should be of more help to the "troubleshooter" than the service engineer.

C. H. BANTHORPE

Television Principles and Practice

By F. J. Camm. 215 pp., 144 figs. George Newnes Ltd. 1952. Price 25s.

ON the jacket of this book it states that "this handbook is a necessity for . . . the technician, the student and the amateur." In this preface Mr. Camm says that he has dealt with the subject in "as non-technical a manner as possible". Taking Mr. Camm's statement as being the correct object of the book he can claim to have done the job competently.

It is a good and up-to-date review of present methods and trends in television, and will be of use to the layman or the amateur turning to television for the first time. It cannot, however, be considered as a book suitable for the serious student or technician.

BOOK REVIEWS (Continued)

Automatic and Manual Control

xi + 584 pp. Butterworth Scientific Publications. May, 1952. Price 50s.

A REVIEW of this book, which is a record of the very interesting and informative conference held at Cranfield in 1951, very rightly should contain a tribute to Professor Tustin for his pioneer spirit and his considerable labours, first in initiating the conference and, secondly, in compiling the book.

Being a contemporary of Professor Tustin in his student days, it is no surprise to the present reviewer to see the progressive spirit manifest in this work.

The conference itself was a signal success, bringing together as it did the leading personalities in this field from most of the civilized world, and the book is a faithful record of the papers presented and, also, the public discussion thereon.

A short account appears also of the demonstrations which were given after the sessions of lectures covering practical servo technique already developed and the hints for the future.

The speakers have something worthwhile to say; for example, Professor Gordon S. Brown, dealing with the educational problems involved in the new technique, is forthright in declaring the necessity of producing a new type of engineer as he says on page 6 "The solution is not to condense the old specialities and crowd them into a new curriculum, but to provide a new synthesis that will produce not a jack of all trades, but a master of a new trade, a specialist in the concepts and techniques of feedback system synthesis". Other speakers draw upon their recent and past experience and give of their suggestive thinking on both the theoretical and practical sides of machine and human servos and also on process control subjects. The range in size and power of mechanisms drawn upon as examples in the consideration of stability problems is from the smallest electrical and electronic devices up to ship stabilizers and to power supply systems involving many megawatts.

As indicated by Sir Ben Lockspeiser in his presidential address, one of the important events which has resulted from the study and development of control systems "is the emergence in recent years of a philosophy of automatic control, based on the recognition of a common pattern and a common basis of principle in a great variety of engineering devices."

The book is divided into nine sections, varying in length from two to 146 pages (580 pages in all). The largest section is on "General Theory" and comprises eight papers, dealing with stability, frequency response, feedback and design problems.

Other important sections deal with "Process Control," "Non-linear Problems," and "Systems working on Intermittent Data and Step by Step Servos", the first two each contain eight and the last five papers. The papers in these sections cover specialized theory and practice in their particular subjects, including stability, the effect of time, measurement, and transmission lags, on-off control, the effects of friction, backlash and resilience.

Smaller sections, each containing two papers, deal with "Educational Problems" and "The Human Operator" and a section of three papers covers "Particular Devices and Applications including Analogues."

The smallest section "Analysis of the Behaviour of Economic Systems" suggests a similarity between economic and servo systems, and the final section describes the demonstrations already mentioned.

A short bibliography or list of references occurs after each paper and is followed by the discussion relating to that paper.

The discussions contain valuable material particularly in the sections dealing with the design and stability of servos and, also, in the process control section.

A short but useful index is included with author and subject sections.

J. BELL.

Technological Applications of Statistics

By L. H. C. Tippett. 189 pp. Williams and Norgate, Limited, London. February, 1952. Price 18s.

THIS is an excellent book. The author has already written an introduction to statistics which is established as one of the best of its kind. He has now written a second book which deserves equal praise, although its aim is more limited. In the preface he says that it is a write-up of lectures given by invitation in America at the Massachusetts Institute of Technology. They were very good lectures. The author has the gift of enlightenment and restrained enthusiasm which one hopes from an expert combined with a simplicity of manner which is deceptive, and he makes skilful use of carefully chosen examples.

The first part, "The Routine Control of Quality", is an analysis of a number of controls already in use in industry to show how to apply standard methods, why these methods are chosen and the reasons for the particular manner of their use. The second part is entitled "Investigation and Experimentation" and the reader who forgives the second "-ation" will find there the uses of variance and correlation analysis together with the considerations which arise when an experiment is being planned.

G. J. KYNCH

PUBLICATIONS RECEIVED

B.E.A.M.A. GLOSSARY OF TECHNICAL TERMS AS USED IN INDUSTRIAL HIGH FREQUENCY HEATING has been compiled to clarify the meaning of new terms which have been loosely applied in this technique. British Standard definitions have been used or referred to except where the term used in the I.H.F. field has a different meaning. The glossary is obtainable from the British Electrical and Allied Manufacturers' Association, 36 and 38 Kingsway, London, W.C.2, price 2s.

CALIBRATION OF COMMERCIAL RADIO FIELD-STRENGTH METERS AT THE N.B.S. by F. M. Greene describes briefly the standards and methods used in the calibration of certain types of radio field-strength meters in the frequency range 10kc/s to 300Mc/s. It is available from the National Bureau of Standards, U.S. Dept. of Commerce, Washington 25, D.C., U.S.A., price 10 cents, postage extra.

BIBLIOGRAPHY ON GEIGER-MUELLER PHOTON COUNTERS by E. J. Walker includes references to most of the article on G.M. photon counters which have appeared in English and German, and a selection of those published in French, Russian and Italian. Where possible, the author's abstract, together with Mr. Walker's comments, are given. National Bureau of Standards Report 1050, U.S. Dept. of Commerce, Washington 25, D.C., U.S.A.

LABGEAR INSTRUMENT CATALOGUE gives full technical details and specifications of this Company's latest developments in the nuclear physics field. Labgear (Cambridge) Ltd., Willow Place, Cambridge.

INDUSTRIAL LUBRICANTS AND ENGINEERING SPECIALITIES is a booklet containing notes to explain the Regosine System of Industrial Oils and how it may be employed to obtain correct lubrication of all ordinary engines and machines. It covers general industrial lubrication, grease lubrication, listate lithium grease, cutting oils, heat treatment oils, drawing lubricants and process oils, lubricants, etc. The Ragosine Oil Co. Ltd., Minerva Works, Woodlesford, Near Leeds.

TIN AND ITS USES No. 26 contains an illustrated account of "Contact" plating with tin, whereby the tinning of the bores of fine tubes can be coated while the more accessible exteriors are being electro-tinned by ordinary electrolysis. It also includes articles on tinplate development, bronze specifications, and tin mining in Malaya. The booklet is issued by the Tin Research Institute, Fraser Road, Greenford, Middx.

ULTRASONIC SOLDERING EQUIPMENT describes the principles and methods of use of Mullard ultrasonic soldering equipment. This equipment makes possible the tinning of aluminium and other light metals without the use of flux. Suitable applications of the technique are dealt with in the booklet, and the use of the ultrasonic soldering iron for filling blow holes and other faults in light alloy castings is mentioned. The booklet is available from the Equipment Division of Mullard Ltd., Century House, Shaftesbury Avenue, London, W.C.2.

ELECTROTHERMAL VALVE RETAINER LEAFLET AND SHOWCARD have recently been issued by Electrothermal Engineering Ltd., 270, Neville Road, London E.7. Physical samples of the Electrothermal range of valve retainers are affixed to the showcard as an aid to draughtsmen to enable them to choose suitable retainers for various applications. The leaflet describes the standard retainers available, and mentions the fact that special constructions to suit design requirements can be supplied. Any manufacturers requiring a showcard and leaflet should send details of their requirements to Electrothermal Engineering Ltd.

WINSTON ELECTRONIC EQUIPMENT is a catalogue devoted to this firm's convertor equipment. It contains details of the properties of image convertor tubes and some typical applications. It then describes the Winston image convertor units and infra-red, ultra-violet, stroboscopic, slit-scanning equipments etc. Winston Electronics Ltd., 1, Park Road, Hampton Hill, Hampton, Middx.

This Order Form should be used for EXTRA copies of the November issue, containing the supplement " Electronics in Industry."

Details appear in the October issue, page 445

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Notes from the Industry

Radio Gramophone Development Co. Ltd., last year became a wholly-owned subsidiary of Automatic Telephone and Electric Co. Ltd. This company are continuing operations at the existing Bridgnorth factory under the name of A. T. and E. (Bridgnorth), Ltd., while those assets of the Radio Gramophone Development Co. Ltd., comprising the manufacture and sale of domestic radio receivers, etc., previously carried on at Bridgnorth have been assigned to a new company called Radio Gramophone Development Co. Ltd., with head office situated at 3-4 Hampton Court Parade, East Molesey, Surrey.

The South East London Technical College Evening Classes will be given on ten post-graduate subjects this session. These are: high voltage engineering; electrical engineering economics; communication engineering economics; vector analysis and fundamentals of electromagnetic theory; communication networks; advance laboratory work; fundamental theory of electric machines as the basis for design; electric circuit theory; applications of photography in engineering and industry, and elements of electric lighting practice. Most of these courses begin in October, and lectures are held on one evening per week.

In addition, four special short courses will be held on the following subjects: physical properties of modern materials; electric strain gauges and their application; power factor improvement and capacitor design, and principles of logic for engineers. These courses will also occupy one evening per week.

Full details of these and other courses in electronics and allied subjects are available in the prospectus available from the Principal, Department of Electrical Engineering and Applied Physics, South East London Technical College, Lewisham Way, London, S.E.4.

Brit. I.R.E. Premiums and Examination Awards for 1951. The senior award of the Brit. I.R.E., the Clerk Maxwell Premium, will be made to H. Paul Williams, Ph.D., for his paper on "Subterranean Communication by Electric Waves," published in the Institution's Journal, March, 1951. Dr. Williams was formerly with A. C. Cossor, Ltd., and is now with Fairey Aviation Company. This premium is for the most outstanding paper published in the Institution's journal during the year 1951. The award will be made at the Annual General Meeting on October 8th.

Other 1951 awards which will be presented at the same time, and which have just been announced by the General Council of the Institution are as follows:

R. E. Spencer, B.A. (E.M.I. Engineering Development, Ltd.), will receive the Heinrich Hertz Premium for his paper on "The Detection of Pulse Signals near the Noise Threshold" which appeared in the October, 1951, issue of the journal.

The Louis Sterling Premium will be presented to Emlyn Jones, B.Sc. (Mullard Research Laboratory), for his paper on "Scanning and E.H.T. Circuits for Wide-Angle Picture Tubes." This paper, first read at the 1951 Radio Convention, was published in the Journal of January, 1952.

R. G. Kitchenn, B.Sc. (Eng.) is awarded the Leslie McMichael Premium. His paper was on "An 8-channel Transmitter for an Experimental Carrier Wire-Broadcasting System." (August, 1951). Mr. Kitchenn was formerly with the Local Lines & Wire-Broadcasting Branch of the Engineer-in-Chief's Office, G.P.O.

The first award to be made of the Brabazon Premium is to G. E. Roberts (The Decca Navigator Co., Ltd.) for his Convention paper on "The Design and Development of the Decca Flight Log" (February, 1952). This premium is for the most outstanding contribution to the Institution's proceedings on radio or electronic aids to aircraft safety.

E. G. Rowe, M.Sc. (Brimar Valve Division, Standard Telephones & Cables, Ltd.), will be presented with the Marconi Premium, his paper being "The Technique of Trustworthy Valves" (November, 1951).

The Dr. Norman Partridge Memorial Award and the Students' Premium for 1951, have been withheld.

In addition, the following examination prizes will be awarded:—

G. R. Beswick (Birmetals, Ltd., Quinton, Birmingham), will receive the President's prize awarded to the most successful candidate in the Graduateship Examination in 1951. He will also receive the Electronic Measurements prize awarded to the most outstanding candidate who passed Part IV of the Graduateship Examination in 1951, in Electronic Measurements.

C. J. White (BBC. Daventry, and formerly R.A.F.), will be awarded the Mountbatten Medal as the most successful candidate who passed the Graduateship Examination in 1951, whilst serving in H.M. Forces.

The Council regrets that it has been necessary to withhold the S. R. Walker prize, and the Audio Frequency Engineering prize, as no candidate reached the required standard.

Supply Ministry Electronics Chief to Visit U.S., Canada. Mr. N. C. Robertson, Director-General Electronics Production, Ministry of Supply, left England by air on Tuesday, September 9th, for a four-weeks' visit to the United States and Canada. He is to exchange information on electronic manufacturing techniques and discuss standardization of equipment between Britain, Canada and the U.S.A.

During his journey he will visit Government establishments and industrial plants engaged on electronics production for the United States and Canadian forces.

Radio Export Record. The total value of exports of radio equipment of all kinds in July was £2,303,500, an increase of £721,000 as compared with the previous month.

Most striking feature was a total value of £878,800 for exports of capital goods, such as broadcasting and communications equipment, navigational aids and electronic equipment for industry. This does not include indirect exports of equipment such as that installed in ships and aircraft.

Exports of receivers jumped by £130,000 to £442,500 and components, not counting sound reproducing equipment, exceeded half a million pounds in value.

Ministry of Supply School of Electronics, Malvern. T. E. Goldup, M.I.E.E., a director of Mullard, Ltd., has been appointed Chairman of the Board of Governors of the Ministry of Supply School of Electronics, Malvern, in succession to Professor Willis Jackson, D.Sc., D.Phil., M.I.E.E., Professor of Electrical Engineering, City and Guilds College, London.

In addition to being a governor of the Ministry of Supply School of Electronics since 1949, Mr. Goldup is a governor of the Wandsworth Technical College, and a member of the Advisory Committee of the Norwood Technical College. He is also a member of the Radio Research Board of the Department of Scientific and Industrial Research.

Engineers Guild Ltd. Mr. Henry Nimmo, M.I.C.E., M.I.Mech.E., M.I.E.E., who has been chairman of the General Council during the past two years, has been elected president of the Engineers' Guild in succession to Mr. Robert Chalmers, O.B.E., B.Sc., M.I.C.E., M.I.Mech.E., whose term of office expires on September 30.

Mr. Nimmo is also chairman of the Southern Electricity Board and a part-time member of the British Electricity Authority.

Lanark School of Engineering is this year holding a series of six lectures on the American practice in colour television. The lectures deal with: the position of colour in the electromagnetic spectrum; fundamentals of colour television process; scanning methods; colour reproducers, and the various proposed systems, such as C.B.S. R.C.A., G.E.C., Vericolour, etc. The lectures take place at 7.30 p.m. on Wednesday evenings.

Courses are also available to cover electrical engineering practice, radio and radio servicing, telecommunications and television. Full details of these courses are available from the Principal, School of Engineering, Crawford Street, Burnbank, Hamilton, Lanarkshire.

Meetings this Month

THE BRITISH INSTITUTION OF RADIO ENGINEERS

Date: October 8. Time: 6.30 p.m.
Held at: London School of Hygiene and Tropical Medicine, Keppel Street, London, W.C.1.
Presidential Address.
By: W. E. Miller, M.A.(Cantab.).

Scottish Section

Date: October 2. Time: 7 p.m.
Held at: Department of Natural Philosophy, The University, Edinburgh.
Lecture: Recent Developments in Television—Methods of Picture Generation.
By: H. McGhee.

BRITISH KINEMATOGRAPH SOCIETY

Date: October 1. Time: 7.15 p.m.
Held at: G.B. Theatre, Film House, Wardour Street, London, W.1.
Lecture: The Viewing of Moving Pictures (Film and Television).
By: W. D. Wright, A.R.C.S., D.Sc.
Joint meeting with the Television Society

BRITISH SOUND RECORDING ASSOCIATION

Date: October 24. Time: 7 p.m.
Held at: Royal Society of Arts, John Adam Street, London, W.C.2.
Lecture: 78, 45 and 33⅓ Records.
By: B. E. G. Mittel.

Portsmouth Centre

Date: October 16. Time: 7 p.m.
Held at: Council Chambers, Portsmouth.
Presidential Address.
By: H. Davies, M.Eng., M.I.E.E.
Annual exhibition and open evening (exhibition open from 5 p.m. to 10 p.m.).

THE INSTITUTION OF ELECTRICAL ENGINEERS

All London meetings, unless otherwise stated, will be held at the Institution, commencing at 5.30 p.m.

Date: October 9.
Inaugural Address.
By: Colonel B. H. Leeson, O.B.E., T.D.

Date: October 20.
Informal discussion: The Institution and Current Affairs.
Opened by: The President.

Radio Section

Date: October 15.
Chairman's Address.
By: E. C. S. Megaw, M.B.E., D.Sc.

Date: October 27.
Discussion: The Impact of Television on Sound Broadcasting.
Opened by: G. Parr, B.Sc.

Measurements Section

Date: October 21.
Chairman's Address.
By: L. Hartshorn, D.Sc.

Cambridge Radio Group

Date: October 14. Time: 6 p.m.
Held at: The Cambridgeshire Technical College.
Chairman's Address.
By: K. N. Hawke, B.Sc.

Merseyside and North Wales Centre

Date: October 6. Time: 6.30 p.m.
Held at: Liverpool Royal Institution, Colquitt Street, Liverpool.
Chairman's Address.
By: W. A. Hatch, M.B.E.

North-Eastern Centre

Date: October 13. Time: 6.15 p.m.
Held at: Neville Hall, Westgate Road, Newcastle-on-Tyne.
Chairman's Address.
By: H. Leyburn, B.Sc.(Eng.).

North-Eastern Radio and Measurements Group

Date: October 20. Time: 6.15 p.m.
Held at: King's College, Newcastle-on-Tyne.
Chairman's Address.
By: D. R. Parsons.

North Midland Centre

Date: October 10. Time: 6.30 p.m.
Held at British Electricity Authority offices, Yorkshire Division, 1 Whitehall Road, Leeds, 1.
Chairman's Address.
By: H. S. Moody, B.Sc.

North-Western Centre

Date: October 7. Time: 6.30 p.m.
Held at: The Engineers' Club, 17 Albert Square, Manchester, 2.
Chairman's Address.
By: J. Prince.

North-Western Measurements Group

Date: October 28. Time: 6.15 p.m.
Held at: The Engineers' Club, Albert Square, Manchester 2.
Lecture: Telemetering for System Operation.
By: R. H. Dunn, B.Sc., and C. H. Chambers.

North-Western Radio Group

Date: October 22. Time: 6.30 p.m.
Held at: The Engineers' Club, Albert Square, Manchester 2.
Discussion: What Practical Benefits can Communication Engineers Expect from the Modern Information Theory?
Opened by: E. C. Cherry, M.Sc.(Eng.).

Northern Ireland Centre

Date: October 14. Time: 6.45 p.m.
Held at: The Presbyterian Hostel, Howard Street, Belfast.
Chairman's Address.
By: H. Weston.

North Scotland Sub-Centre

Date: October 8. Time: 8 p.m.
Held at: The Caledonian Hotel, Aberdeen.
Chairman's Address.
By: L. B. Perkins, B.Sc.

Date: October 9. Time: 7 p.m.
Held at: The Royal Hotel, Dundee.
Chairman's Address.
By: L. B. Perkins, B.Sc.

South East Scotland Sub-Centre

Date: October 8. Time: 7 p.m.
Held at: The Heriot-Watt College, Edinburgh.
Chairman's Address.
By: C. H. A. Collyns.

South-West Scotland Sub-Centre

Date: October 7. Time: 7 p.m.
Held at: The Institution of Engineers and Shipbuilders, 39 Elmbank Crescent, Glasgow.
Chairman's Address.
By: J. S. Hastie, B.Sc.(Eng.).

South Midland Centre

Date: October 6. Time: 6 p.m.
Held at: The Grand Hotel, Birmingham.
Chairman's Address.
By: K. R. Sturley, Ph.D., B.Sc.
Annual General Meeting and Conversazione.

Date: October 21. Time: 7.15 p.m.
Held at: The Winter Gardens Restaurant, Malvern.
Lecture: The Magnetic Fluid Clutch.
By: E. J. R. Hardy, B.Sc.(Eng.).

South Midland Radio Group

Date: October 27. Time: 6 p.m.
Held at: The James Watt Memorial Institute, Great Charles Street, Birmingham.
Informal Lecture: Why Quantum Theory Matters to Engineers.
By: D. A. Bell, M.A., B.Sc.

Southern Centre

Date: October 1. Time: 6.30 p.m.
Held at: British Electricity House, 111 High Street, Portsmouth.
Chairman's Address.
By: C. J. Turnbull, R.N.

Date: October 8. Time: 6.30 p.m.
Held at: The Dorset Technical College, Weymouth.
Lecture: Illumination.
By: S. S. Beggs.

Date: October 10. Time: 7.30 p.m.
Held at: The R.A.E. College, Farnborough.
Lecture: Introduction to the Theory of Information.
By: J. E. Flood, Ph.D., and L. R. F. Harris.

Western Centre

Date: October 13. Time: 6 p.m.
Held at: The South Western Electricity Board Offices, Colston Avenue, Bristol.
Chairman's Address.
By: A. C. Warren, B.Sc.

South-Western Sub-Centre

Date: October 16. Time: 3 p.m.
Held at: The Rougemont Hotel, Exeter.
Chairman's Address.
By: R. H. Cotton.

West Wales (Swansea) Sub-Centre

Date: October 16. Time: 6 p.m.
Held at: The Central Public Library, Swansea.
Chairman's Address.
By: D. L. J. Powell, B.Sc.

Irish Branch

Date: October 16. Time: 6 p.m.
Held at: Trinity College, Dublin.
Chairman's Address.
By: P. J. Dowling, B.E., B.Sc.

District Meetings

(Other than those held in the area of a Local Centre)

Maidstone

Date: October 6. Time: 7.30 p.m.
Held at: "The Wig and Gown," Maidstone.
Lecture: The Development and Design of Electrical Control Gear for Machine Tools.
By: A. R. H. Thorne.

Norwich

Date: October 20. Time: 7.30 p.m.
Held at: The Royal Hotel, Norwich.
Lecture: Technical Colleges and Education for the Electrical Industry.
By: H. L. Haslegrave, M.S., Ph.D., M.Sc.(Eng.).

Oxford

Date: October 8. Time: 7.30 p.m.
Held at: The Southern Electricity Board, 37 George Street, Oxford.
Lecture: Short-Circuit Testing Technique.
By: J. G. P. Anderson, B.Sc.

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Date: October 7. Time: 5 p.m.
Held at: The Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2.
Chairman's Address: Engineering and the Postal Service.

Informal Meeting

Date: October 29. Time: 5 p.m.
Held at: The Conference Room, 4th Floor, Waterloo Bridge House, S.E.1.
Vice-Chairman's Address: Some Aspects of Local Line Utilization.

THE PHYSICAL SOCIETY

Date: October 3. Time: 5 p.m.
Rutherford Lecture: The Atomic Nucleus and its Constituents.
By: Professor R. E. Peierls.

Date: October 29. Time: 5 p.m.
Lecture: The Stationary Waves in the Space Lattice of Crystals and their Experimental Proof.
By: Professor M. von Laue.

Acoustics Group

Date: October 13. Time: 5 p.m.
Held at: The Science Museum, London, S.W.7.
Lecture: The American Acoustical Scene.
By: A. T. Pickles.

Colour Group

Date: October 15. Time: 3.30 p.m.
Held at: The Institute of Ophthalmology, Judd Street, London, W.C.1.
Lecture: Colour Vision in the Central Peripheral Parts of the Retina.
By: Dr. E. N. Willmer and R. A. Weale.

Low Temperature Group

Date: October 16. Time: 5.30 p.m.
Held at: The Science Museum, London, S.W.7.
Lecture: Compressor Design and Characteristics.
By: Dr. A. J. Barnard.

PRESENTATION OF TECHNICAL INFORMATION DISCUSSION GROUP

Date: October 21. Time: 6 p.m.
Held at: University College, Gower Street, London, W.C.1.
Lecture: Colour Correction by Photographic Means.
By: F. Smith.

THE RADAR ASSOCIATION

Date: October 7. Time: 7.30 p.m.
Held at: The Bedford Corner Hotel, Bedford Square, London, W.1.
Radar Film Show.

SOCIETY OF RELAY ENGINEERS

Date: October 7. Time: 2.30 p.m.
Held at: 21 Bloomsbury Street, London, W.C.1.
Lecture: Television Wire Broadcasting—P.O. Testing of Licensed Systems.
By: C. F. W. Hawkins and G. H. Barlow.

THE TELEVISION SOCIETY

Main Society

Date: October 1. Time: 7 p.m.
Held at: The G.B. Theatre, Film House, Wardour Street, London, W.1.
Lecture: The Viewing of Moving Pictures.
By: W. D. Wright, A.R.C.S., D.Sc.

Date: October 24. Time: 7 p.m.
Held at: The C.E.A., 164 Shaftesbury Avenue, London, W.C.2.
Lecture: The Birth of a High Definition Television System.
By: S. J. Preston, M.A., A.M.I.E.E.

Presenting . . .

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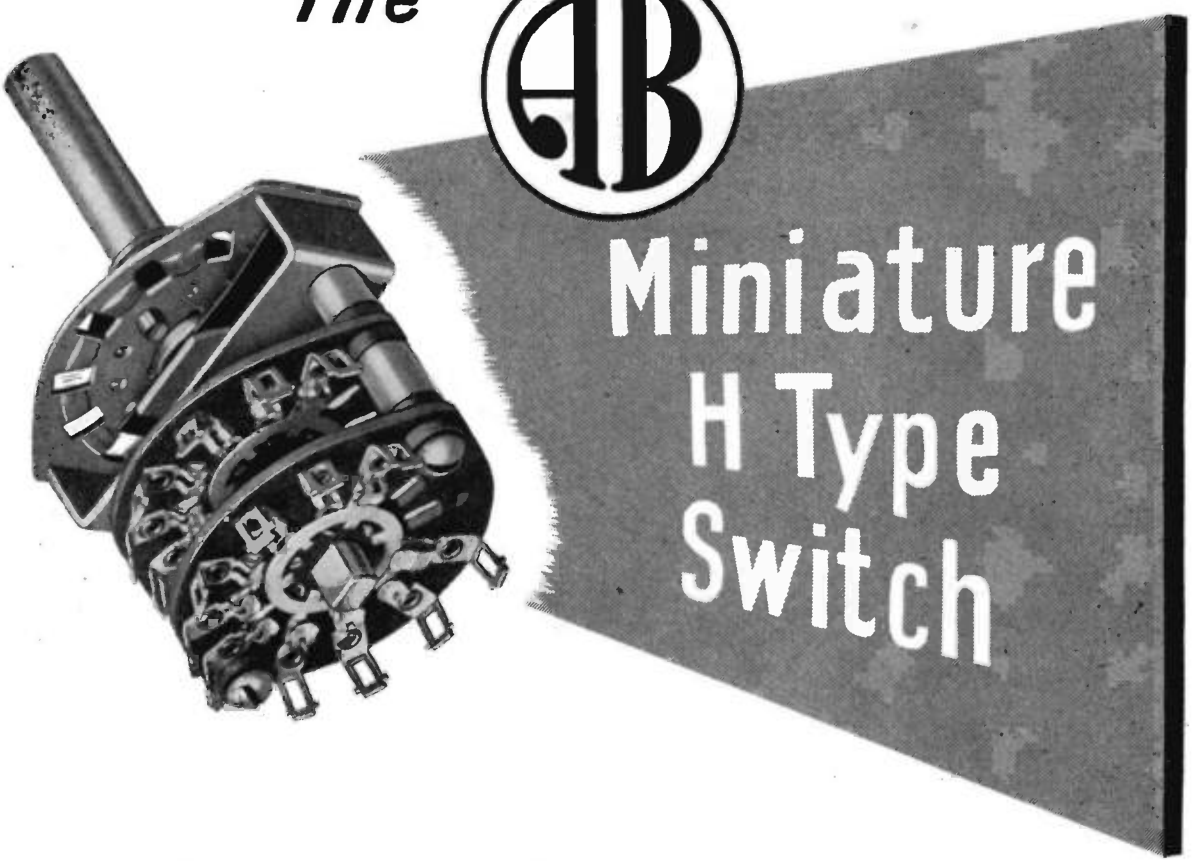

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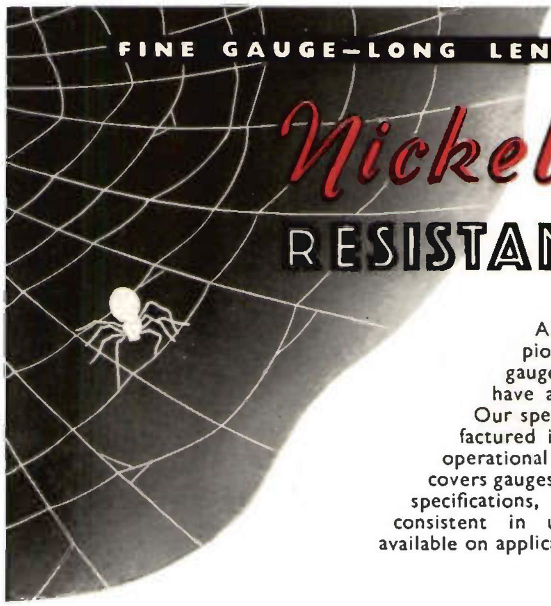

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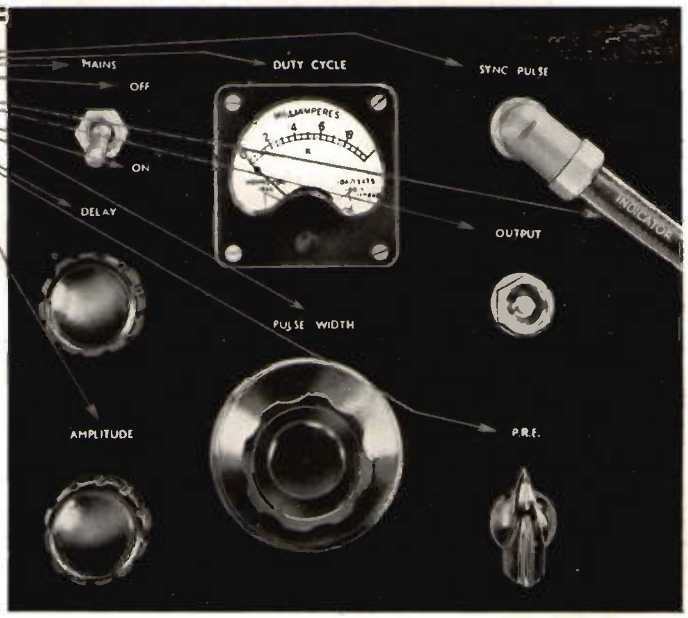

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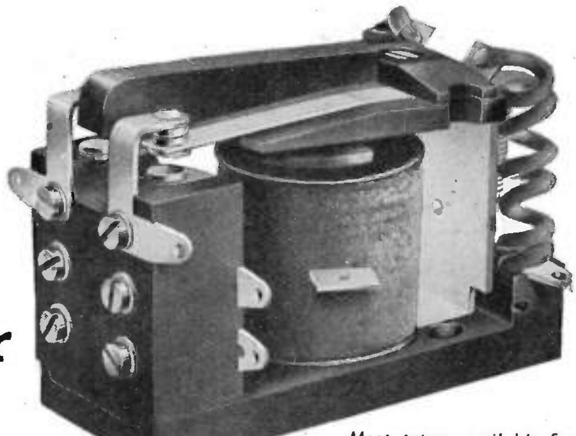

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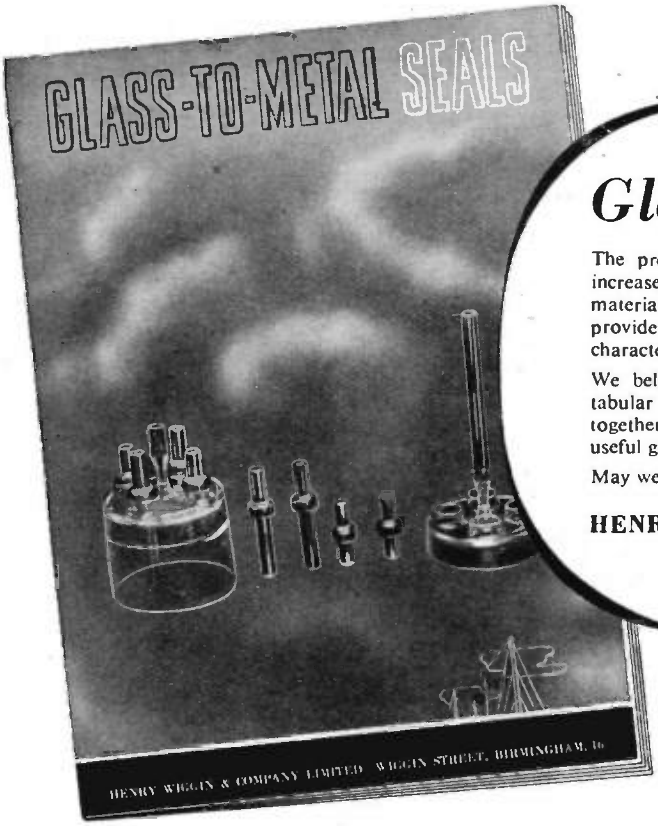

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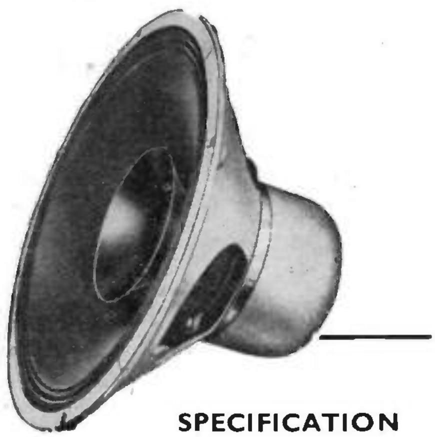

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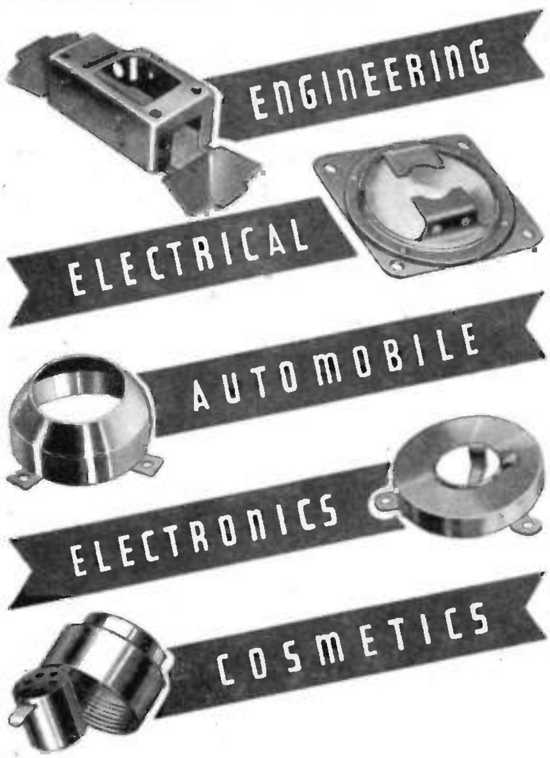

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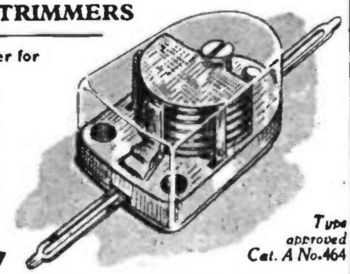


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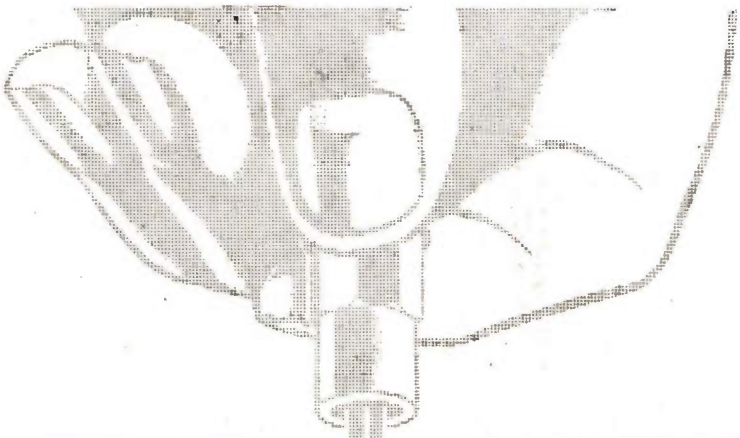

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