Electronic Engineering

SEPTEMBER 1955

TWO SHILLINGS

CLASSIFIED ANNOUNCEMENTS

The charge for these advertisements is 6d. per word. Minimum charge 12/-. Box number 2/- extra, except in the case of advertisements for "Situations Wanted," when it is free. Specially spaced advertisements per inch single column 42/6. 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 — ROYAL NAVAL Scientific Service. Engineers and Physicists (particularly with Electronics) required in Experimental Officer and Assistant Experimental Officer grades in Experimental Establishments in London, Portsmouth, Weymouth areas. Gloucestershire and Scotland. Qualifications: British subjects, minimum of H.S.C. (pass Degree, H.N.C or near equivalent an advantage). London salary (men) E.O. £750-£920, A.E.O. £302 10s.-£670 (according to age). Appointments unestablished, but opportunities to compete for established posts. Application forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A214/5A. W 3420

ADMIRALTY. Temporary Production Inspectors required with experience in either Mechanical, Electrical, Electronic or Marine Engineering for various places in the U.K. Duties involve work in connexion with the manufacture, inspection, test and installation of equipment in H.M. Ships. Inspectors with Radar and/or Radio experience particularly needed. Candidates, at least 25, should have recognized apprenticeship, or equivalent training, plus additional relevant experience with Industry or Government Department. They should preferably possess H.N.C. or O.N.C. in Mechanical or Electrical Engineering, or have reached at least an equivalent standard of technical education with qualifications in appropriate subjects. Appointments unestablished, but opportunities may occur later to compete for permanent posts. Inclusive salary scales £690 to £810 per annum; entry at minimum of scale less about £20 for each year by which age falls short of 30. Salaries outside London somewhat lower. Application forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting D 355/5A. Closing date 9th September, 1955. W 3501

AIR MINISTRY requires Scientific Officers for Operational Research in or near London. First or Second Class Honours Degree, or equivalent, in mathematics, physics or economics. Salary (London) £492 10s. to £885. Provincial rates and rates for women slightly lower. Opportunities for promotion. Application forms, quoting A384/54A from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1. W 3502

ATOMIC ENERGY RESEARCH ESTABLISHMENT, Harwell, Didcot, Berks, has a vacancy for an Engineer, for duties concerning the development of new types of instruments covering a wide and interesting field. This will entail the application of industrial control instruments and techniques to a wide variety of experimental plant. He will also have control of a small Standards Laboratory. Applicants should preferably have served a recognised engineering apprenticeship and be Corporate Members of the Institution of Electrical Engineers, or have exempting qualifications. The possession of an Honours Degree in Electrical Engineering is desirable, although candidates without an Honours Degree, but having had exceptionally wide experience, will be considered. Some knowledge of electronics would be an advantage. The successful candidate will be appointed within the salary scale £1065-£1,370 p.a. and he will be required to join the Authority's contributory superannuation scheme. A house will be available for the selected officer within a reasonable period if he is married and lives outside the radius of the Establishment's transport facilities. Requests for Application Form should be sent on a Post Card to the Establishment Officer, U.K. Atomic Energy Authority, A.E.R.E., Harwell, Didcot, Berks, quoting 2/103/373. W 3523

CHARING CROSS HOSPITAL Medical School (University of London). Applications are invited for the post of Research Assistant in the Department of Physiology for work on auditory physiology. The work will involve audiofrequency electronic techniques, and the design, construction and maintenance of such apparatus. Applicants should possess an honours Degree or equivalent qualification in electronics. Appointment for one year in the first instance. Salary £750 p.a. Subsequent re-appointment would be superannuable. Further details from the Secretary, 62 Chandos Place, London, W.C.2. W 3520

APPLICATIONS are invited for pensionable posts as Assistant Examiners in the Patent Office to undertake the official scientific technical and legal work in connexion with Patent Applications. There are a small number of similar posts in the Ministry of Supply. Applications may be accepted up to 31st December, 1955 but early application is advised as an earlier closing date may be announced. Interview Boards will sit at frequent intervals. Candidates must be between 21 and 28 years of age during 1955 (up to 31 for permanent members of the Experimental Officer Class) and have First or Second Class Honours Degree in physics, chemistry, mechanical or electrical engineering, or mathematics. Candidates taking their Degrees in 1955 may apply before the result of their Degree examination is known. Starting emoluments in London, including Extra Duty Allowance for 45½ hour week, between £532 and £729 (men) £642 (women) according to periods of National Service and post-graduate experience rising to £896 (men) and £799 (women). Promotion to Examiners—£934 to £1,279 (men), £820 to £1,144 (women); normally after 5 years (3 or 4 years in exceptional cases). Women's scales subject to increase under equal pay scheme. Good expectation of promotion to Senior Examiner. Candidates are recruited by selective interview. Application forms and further information from the Civil Service Commission, Scientific Branch, 30 Old Burlington Street, London, W.1, quoting number 128/55. W 3511

ELECTRONIC TECHNICIANS. The United Kingdom Atomic Energy Authority, Aldermaston, Berks, requires Several Technicians and Senior Technicians to be responsible for the inspection, testing, calibration to specification, fault finding and maintenance of electronic equipment such as oscilloscopes employing high speed time basis, pulse generators, video amplifiers and stabilized power supply units. Equipments involved are in small quantities of widely varying design and the testing is of a non-routine nature and attendance at A.W.R.E. outstations and at contractors' works for short periods will be required. Successful applicants for the Senior Technician posts will be required to lead a team of Technicians on the above duties. Applicants should have several years' approved practical training and experience on electronic testing and fault finding and possess technical qualifications in this field to at least O.N.C. standard for the Technician posts and H.N.C. for the senior Technician posts. Salary Senior Technician £710 (linked to age 30) to £830 p.a. (male), Technician £575 (linked to age 26) to £715 p.a. (male). Contributory Superannuation Scheme. Housing accommodation will be available on one of the Authority's estates within a reasonable period for married officers who live outside the radius of the Establishment's transport facilities. Alternatively the Authority may be able to assist successful applicants in the purchase of a house. Until permanent accommodation is obtained a lodging allowance may be payable. Requests for application forms by postcard to Senior Recruitment Officer, A.W.R.E., Aldermaston, Berks. Quote Reference 728/42. W 3535

EXPERIMENTAL OFFICERS/ASSISTANT Experimental Officers required by the Atomic Weapons Research Establishment, Aldermaston, Berks. To assist as Electronic Physicists in a group studying detonation phenomena. Applicants should possess minimum qualifications of H.S.C. in Science subjects, or equivalent, but for the higher post a pass Degree in Physics is desirable, and applicants should not be less than 26 years of age. Some experience in the electronic recording of high speed transients, in pulse circuitry and in the handling of explosive charges would be advantageous. Salary: Experimental Officer—£775-£945 p.a. (male), Assistant Experimental Officer—£310 (age 18) to £685 p.a. (male). Contributory Superannuation scheme. Successful married officers now living outside the Establishment's transport area will be eligible for housing on one of the Authority's estates; until housed a lodging allowance may be payable. Requests for application forms by postcard to the Senior Recruitment Officer at the above address. Quote reference 738/42. W 3540

GOLD COAST GOVERNMENT—Broadcasting Engineers. Applications invited for one vacancy in each post of:— A. Head of Engineering Training. B. Assistant in Engineering Training (Radio Frequency). C. Assistant in Engineering Training (Audio Frequency). Duties: Post A. Responsible for formulating and carrying through a training scheme in radio engineering for new entrants to the service, courses of training "on the job" for existing staff, and a course and examination approximately equal to the B.B.C.'s Grade C examination for Technical Assistants who wish to qualify for promotion into the Senior Technical Assistant Grade. Post B. Responsible under the Head of Engineering Training for the training of pupils scattered in small groups over wide areas by lectures and postal courses up to approximately the standard of the B.B.C.'s Grade C examination with emphasis on radio frequency subjects and on the theory and operation of radio frequency equipment. Will also be required to carry out some operational duties. Post C. Responsible under Head of Engineering Training for the training of pupils scattered in small groups over wide areas by lectures and postal courses up to approximately the standard of the B.B.C.'s Grade C examination with emphasis on audio frequency and power frequency subjects; also for specialized courses on the theory and operation of audio frequency and wired broadcasting equipment used in a broadcasting organization. Will also be required to carry out some operational duties. Qualifications: All posts. Candidates should have passed or have been exempted from Sections A and B of the Associate Membership examination of the Institution of Electrical Engineers or hold equivalent qualifications. Additionally as follows:— Post A. Have had previous teaching experience. Must be able to organize the training scheme in all its aspects, including postal courses, for its inception, and must have a thorough knowledge of the requirements for the engineering division of a broadcasting service. Post B. Candidates with exceptional experience but not so qualified may be considered for appointment. Candidates should have a thorough knowledge of transmitter, aerial and feeder systems, receivers, etc. and should also have a sound knowledge of the fundamental theory of audio frequency and power frequency equipment and be capable of lecturing on these subjects. Previous teaching experience is desirable. Post C. Have had appropriate experience in radio engineering. Candidates not so qualified but of exceptional experience may be considered for appointment. Candidates should have a thorough knowledge of studio apparatus and acoustics, tape and disc recording and power equipment and should also have a sound knowledge of the fundamental theory of radio frequency equipment and be capable of lecturing in this subject. Previous teaching experience is desirable. Terms of Service: The appointment will be on contract/gratuity terms of one tour of 18 to 24 months with extension provision to two tours. Salary in range £1,600-£2,050 according to age, qualifications and experience. Gratuity at rate of £37 10s. for each three months completed satisfactory service. Free passages appointment and on leave for officer; once each way for wife and up to three children under 13 years each tour. Vacation leave with pay 7 days for each months service. Kit allowance £30 may be payable. Basically furnished accommodation at £90 p.a. rental. Income tax at low rates Candidates in the United Kingdom should apply to the Adviser on Recruitment, Gold Coast Officer, 13 Belgrave Square, London, S.W.1, for a form of application. Other candidates should send full personal details and statement of qualifications, experience, employments, etc. with approximate dates, to that address. W 3493

OFFICIAL APPOINTMENTS (Cont'd.)

ENGINEER (Main Grade) required by The United Kingdom Atomic Energy Authority, Woolwich Common to control production of electronic and light mechanical equipment in a small production unit. To contribute to the design and engineering of electronic equipment and to liaise with sub-contractors on production difficulties and progress. Applicants should have served a recognised engineering apprenticeship and be corporate members of either the Institution of Mechanical or Electrical Engineers or possess equivalent qualifications. They must be well acquainted with modern light engineering machine shop practice and have first-hand knowledge of sheet metal work as used for electronic equipment. Knowledge of simple plastic processes an advantage. Salary £1,065 p.a.-£1,370 p.a. (male) plus a London allowance. Superannuation. The successful applicant will be required to join the Authority's contributory scheme. Requests for application forms by Post Card to Senior Recruitment Officer, A.W.R.E. Aldermaston, Berks. Quote reference 722/42. W 3522

HERTFORDSHIRE COUNTY COUNCIL. Hatfield Technical College, Roe Green, Hatfield. Principal: Dr. W. A. J. Chapman, M.Sc. (Eng.). Applications are invited for the post of Assistant Grade B in Electrical Engineering. Candidates should be graduates in Electrical Engineering, or possess equivalent professional qualifications, and have appropriate industrial experience. Preference will be given to candidates with experience in the U.H.F. field. Applicants should be able to lecture in Electronics and Telecommunications up to H.N.C. level and to develop work in these subjects to final Degree standard. The successful applicant will be required to commence duties as soon as possible. Applications (no forms issued) should be sent to the Registrar within fourteen days of the appearance of this advertisement, together with the names and addresses of two referees and copies of two recent testimonials. W 3534

SENIOR EXPERIMENTAL OFFICER required by the Atomic Weapons Research Establishment, Aldermaston, Berks. To assist in research and development on problems associated with high voltage, high energy electrical discharges. Applicants should be at least 35 years of age and have H.S.C. (Science) or equivalent, but possession of a Degree of H.N.C. in Electrical Engineering or Physics is desirable. Applicants should have a good basic understanding of electronics. Practical experience of the generation of high voltage pulses and the measurement of very short time intervals would be an advantage. Salary £1,090-£1,285 p.a. (male). Contributory Superannuation Scheme. Successful married officers now living outside the Establishment's transport area will be eligible for housing on one of the Authority's estates; until housed a lodging allowance may be payable. An initial period of detached duty at Fort Halstead, Kent may be necessary. Requests for application forms by postcard to the Senior Recruitment Officer at the above address. Quote reference 299/42. W 3541

SENIOR EXPERIMENTAL OFFICER (Electronics) required by the Research and Development Branch of the United Kingdom Atomic Energy Authority at Windscale, Sellafield, Cumberland, to take charge of a small section engaged on design and construction of various electronic equipment for the chemistry, metallurgy, engineering and physics laboratories. The range of work is extremely wide and interesting and provides considerable scope for initiative and ingenuity. Applicants must have at least a Higher School Certificate in science subjects, or equivalent qualifications, together with wide experience of the application of electronics. Possession of a Higher National Certificate or appropriate City and Guilds Certificate may be an advantage. Salary £1,090-£1,285 p.a. All new entrants under the age of 55 automatically join the Authority's contributory pension scheme. Suitably qualified persons are invited to send postcards for application form, to Recruitment Officer, Industrial Group Headquarters, Risley, Warrington, Lancs, quoting reference 1,048. W 3460

SENIOR TECHNICIAN and Technician for construction of prototype electro-mechanical apparatus in Department of Medical Electronics. Apply Personnel Officer, St. Thomas' Hospital, London, S.E.1. W 3484

SOUTHAMPTON UNIVERSITY. Applications are invited for a research studentship in Electronics on analogue computor work. Value £450 p.a. according to experience. The research is expected to lead to a Ph.D. thesis. Applications not later than 1st October to Secretary and Registrar, from whom further particulars may be obtained. W 3519

LABORATORY TECHNICIAN required at South East London Technical College, Lewisham Way, S.E.4, as soon as possible, for work in the applied physics laboratories. Salary scale: 77s. 6d. weekly at 16 to 108s. at 19; £303 15s. a year at 20; additional increments of £20 5s. for each full year of age above 20 years on entry (commencing salary not to exceed £384 15s.), rising by annual increments of £20 5s. to £425 5s. Holders of the intermediate certificate of the City and Guilds of London Institute in laboratory technicians work (or recognized equivalent) will be granted three additional increments, but not beyond the extended maximum of £479 5s. Further particulars and application forms (returnable within 14 days) available from the Secretary (1268). W 3547

THE ATOMIC WEAPONS Research Establishments, Aldermaston, Berks and Foulness, Essex. Have the following vacancies in the grade of Experimental Officer. Mathematical Physicists (Theroetical investigations: fluid dynamics, quantum theory, electronic computors), Electronic Physicists and Electronic Engineers (Nuclear measurements—development of neutron spectrometers and counters—telemetry and control—instrumentation), Metallurgists (To investigate the metallurgy of radio-active and toxic materials, processing, welding and fabrication—also beryllium research), Chemists (Analytical studies and explosive research — Physical, Inorganic and Radio Chemistry) Physicists (Climatic testing, research into explosive phenomena, also Health Physics and Instrumentation). Technical Administration and Information. Minimum Qualification is Higher School Certificate (Science) or equivalent, but a Degree or Higher National Certificate would be an advantage. In addition, applicants should preferably have some experience in the appropriate fields. Applicants not selected for appointment as Experimental Officers will be considered for posts as Assistant Experimental Officers. Salary: £775-£945 p.a. (male). Contributory Superannuation Scheme. Housing: At Aldermaston housing accommodation will be available on one of the Authority's estates within a reasonable period for married officers who now live outside the radius of the Establishment's Transport facilities. At Foulness Authority housing may be available at a later date. Alternatively the Authority may be able to assist in the purchase of a house and until permanent accommodation is obtained a lodging allowance may be payable. Requests for application forms by postcard to:— Senior Recruitment Officer, A.W.R.E. Aldermaston, Berks. quoting reference number WG/720/42. W 3499

UNIVERSITY COLLEGE LONDON (Gower Street, W.C.1) has vacancy for Electronics Technician for research and development work in speech communication. Interest in acoustics and ability to work independently an advantage. Salary up to £620 p.a. depending on experience and qualifications. Application forms from Secretary quoting Phonetics/6. W 3525

UNIVERSITY COLLEGE London (Gower Street, W.C.1) requires Electronics Technicians for research work in Anatomy Dept. Commencing salary up to £720 p.a., depending on age and qualifications. Good holidays. Application forms from Secretary, quoting Anatomy/8. W 3509

VACANCIES FOR SKILLED CRAFTSMEN in Government Department at Cheltenham. Applicants required with experience of:— (a) Maintenance and Installation of Teleprinters, Autotransmitters, Perforators, Re-perforators or experience in (b) Cabling, Wiring, Distribution frames, Jack fields or a knowledge of (c) Long distance radio communication systems, Line telegraph systems (e.e.V.F.) Multiplex and five-unit telegraph code. Basic pay: £7 18s. 10d. plus merit pay up to £2 10s., assessed at interview, based on ability and experience. Opportunities for permanent and pensionable posts. Five-day week. good working conditions—single accommodation available. Apply to: Personnel Officer, G.C.H.Q. (Foreign Office), 53 Clarence Street, Cheltenham. W 3302

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 DRAUGHTSMAN with mechanical design experience is required for the Electronics Division of Saunders-Roe Limited. Applications are invited from suitably qualified men, especially those with a basic knowledge of the principles of Electronics plus experience in the design of electromechanical transducers, servomechanisms and electronic assemblies. Housing assistance, pension and assurance schemes and other amenities can be offered. Those interested should write, quoting ref.: EE/36 and giving details of age, experience, etc., to the Personnel Officer, Saunders-Roe Limited, East Cowes, I.O.W. W 3490

AERONAUTICAL OPPORTUNITIES Guided Weapons. A well-known firm in the aircraft industry is starting a new project in a London Office. It is anxious to recruit staff to form an Assessment Group. Vacancies with unusual opportunities for rapid promotion exist to meet the following approximate requirements:— Assessment Group. Group Leader. Age 30/37. Science or Engineering Degree standard, experienced in aircraft, or G.W. project or assessment groups, with knowledge of performance and servomechanism problems and analysis of flight and laboratory tests. Personality is important. Section Leaders. Ages 27/35. Science or Engineering Degree standard, general experience as for Group Leader but to a lesser extent. Staff to fill these sections, with various capabilities from Computing to Honours Degrees in Science or Engineering. The age groups specified are given for guidance only and need not deter candidates outside these limits. Monthly staff appointments carry a compulsory Pension Scheme and Weekly Staff a voluntary Superannuation Scheme. Write in confidence, giving full details of age, previous experience, qualifications held, etc.; to:— Box A.C. 09768, Samson Clarks, 57-61 Mortimer Street, London, W.1. W 3462

A GRADUATE wishing to enter the field of guided missiles is offered a post in the system research laboratory of an advanced guided weapon project. Theoretical knowledge of general electronics, transistors, or servo mechanism is required, some practical knowledge would be an advantage. Write in detail, quoting Ref. 70, to:— The Personnel Manager (Technical Employment), de Havilland Propellers Limited, Hatfield, Herts. W 3479

AIRCRAFT RADIO AND RADAR Technician. Applications invited for the above pensionable staff position in the Experimental Department of Hawker Aircraft Limited, Dunsfold Aerodrome, near Godalming, Surrey. Applicants should have had sound experience of such work on modern aircraft in Royal Air Force or Fleet Air Arm, and should be able to arrange permanent accommodation within travel distance of Aerodrome. Commencing salary to be arranged according to age, qualifications and experience. Please write fully to the Personnel Supervisor, Hawker Aircraft Limited, Canbury Park Road, Kingston-on-Thames, Surrey. W 3530

CLASSIFIED ANNOUNCEMENTS
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Experimental Work
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Prototypes
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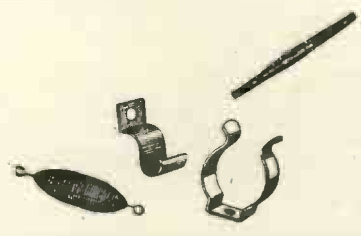
Bulk Production



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.

AN ELECTRONIC ENGINEER is required by Decca Radar to fill a key position in a Radar Systems Team. The post carries a substantial salary on a rising scale, and there are excellent prospects for further promotion. Applicants should be of H.N.C. or Degree standard and have had considerable previous experience in this field. There is a pension scheme in operation. British Nationality essential. Please write, quoting reference RLA.114, to Decca Radar Limited, Radar Research Laboratories, 2 Tolworth Rise, Surbiton, Surrey. W 3461

AN EXPANDING Instrument Company is in need of Physicists, Electronic Engineers, and mechanical Designers. The work to be undertaken by a newly-formed division of the Company is broadly in the field of process control and measurement devices. Qualifications are essential, but the chief requirement is interest in and enthusiasm for the work. These posts will appeal to men under 30 who are anxious to break out of the rut and assist in the development of new ideas. Please write giving brief details of qualifications and experience to Dr. D. H. Parnum, Industrial Division, Southern Instruments Ltd., Camberley, Surrey. W 304

A NORTH LONDON Electronics Company require a manager for their large Transformer Factory. The successful applicant, who will receive an adequate salary commensurate with his qualifications, will control a Planning and Progress staff, Supervisors and approx. 300 operators. Applicants should be familiar with modern manufacturing techniques as applied to Television and Radio transformers, chokes and coils and should have a good knowledge of Government Contract Requirements. Write giving age, qualifications and salary required, to Box No. W 3542.

APPLICATIONS are invited from engineers of inter-B.Sc., or Higher National Certificate standard for investigational and development work on thermionic valves. Five-day week, staff pension scheme, modern welfare amenities. Apply, giving full particulars of age, qualifications and experience to Personnel Superintendent, The Edison Swan Electric Co. Ltd., Cosmos Works, Brimsdown, Enfield, Middlesex. W 3537

APPLICATIONS are invited for the following vacancies in the development laboratories of a subsidiary company of a large well established electronic component manufacturer. (a) Graduate in Inorganic and Physical Chemistry for research and development work on oxide coated cathodes and other semi-conductor problems associated with the manufacture of modern electronic components. Knowledge of electronics would be a distinct advantage. (b) Graduate in Physics for work on the fundamental physical problems associated with the manufacture of the above components. Previous experience in vacuum physics and/or electronics is very desirable but not essential. The laboratories are situated on the South coast where the local authorities are very cooperative on housing problems. The posts are permanent and pensionable and provide excellent opportunities for advancement. Apply giving full particulars to Box No. W 3533.

A SENIOR Mechanical Designer is required by a Midlands manufacturer engaged in the complete engineering and production of a variety of electronic products. First-class men with experience of Design work in the Light Engineering Field are invited to write, giving details of career and qualifications to the Personnel Manager (Ref. S.M.D.). Box No. W 3402.

ASSISTANT ENGINEERS required for radio communication development work. Good prospects for men with H.N.C. or equivalent. Commencing salary according to age and experience. Apply in writing, stating age, experience, etc. to Siemens Brothers & Co. Ltd., Ref. 744/23, Woolwich, S.E.18. W 3548

A TECHNICAL assistant is required for secretarial staff of a Radio Manufacturers' Association in London. Good technical qualifications desirable and the ability to record accurately and dictate reports, etc. Commencing salary £550 to £600 p.a. or related to ability and experience. Apply Box No. W 1387.

AUTOMATION IS COMING! With it come new opportunities for designers of Jigs, Tools and special purpose machinery. Are you aged not less than 27? Have you a National Certificate? Can you claim practical Knowledge of Automation? If you can answer "yes" there is a future for you with Ford Motor Company Limited of Dagenham. From pay to pension, Ford is first in the first flight. Write to Salaried Personnel Department quoting reference JTA. W 3518

A VACANCY occurs for a Chief Inspector. Applications are invited from candidates with Engineering qualifications and experience in the Radio and Television Industry. Salary range from £800-£1,000. Apply giving full particulars of experience, etc. To Personnel Manager, Radio and Allied Industries Ltd., Hirwaun Industrial Estate, near Aberdare, Glam. W 1388

BIRLEC LIMITED, Tyburn Road, Birmingham, 24, have room in their modern drawing office for several Bright Young Men who like design work and enjoy following a project, personally, right through. Conditions are pleasant, pay is good and there is a free pension for those who recognize a good job and stay with it. Apply in writing to the Personnel Officer. W 3497

CIRCUIT DESIGN ENGINEERS are required by Decca Radar for positions created by the continued expansion of their Research Laboratories. These cover work in a wide field, embracing high and low power pulse, receiver, A.F.C., radar display, and test equipment design in standard and sub-miniature form. Applicants should preferably be of Degree or H.N.C. standard, and have had previous experience in this field. A pension scheme is in operation. British Nationality essential. Please write to Decca Radar Limited, 2 Tolworth Rise, Surbiton, Surrey, quoting reference RLA. 103. W 302

CANADA. Large Montreal Electronics company requires electronics Engineers, electronics Technicians, electronics Draughtsmen, Technical Illustrators and Gyroscope Technicians. High rates of pay; passage assistance; pension plan; group insurance; early September interview in United Kingdom. Write outlining qualifications to Department "A.C." Canadian Department of Labour, 61 Green Street, London, W.1. W 3471

COMMERCIAL T.V. Commercial television and F.M. broadcasting have resulted in vacancies becoming available for men interested in the development of V.H.F. tuners involving new techniques of design and manufacture. Salaries in the range £650-£1,000 are offered to engineers with the required experience, and prospects of future advancement are good. Write in confidence, giving full particulars of experience and qualifications to Box No. W 3475.

CHIEF DESIGNER required by company manufacturing electronic and mechanical measuring instruments for industrial and aircraft use. Salary £1,000-£1,200, housing assistance, pension scheme. Full particulars to Box No. W 3503.

COMPONENTS FOR COMMUNICATIONS. The Plessey Company have a considerable programme for the development of new components for application to communication and electronic equipment. Development engineers and designer draughtsmen who are interested in this type of work should write, giving particulars of experience and qualifications, to The Personnel Manager, The Plessey Company Limited, Ilford, Essex. W 3474

DESIGNER for varied, special-purpose, automatic and semi-automatic machines associated with induction heating processes. This is important work, contributing to productivity in a rapidly expanding field and offers great scope. Conditions are attractive and include a generous pension scheme. Applications are invited from men wishing to establish themselves in a progressive, senior position in a developing branch of industry. Apply in writing to Personnel Officer, Birlec Limited, Tyburn Road, Birmingham, 24. W 3498

DESIGN ENGINEER for electronic instruments capable of designing complete instruments to production stage. Experience necessary and a knowledge of production problems desirable. Academic qualifications Degree, national diploma, or equivalent. Permanent situation covered by Company's pension scheme. Apply to Technical Director, Advance Components Ltd., Marlowe Road. Walthamstow, E.17. W 1390

DETAIL DRAUGHTSMAN. Senior or intermediate for design work associated with commercial vehicle electrical equipment. Education up to O.N.C. level. Please apply Personnel Manager, Simms Motor Units Ltd., Oak Lane, East Finchley, N.2. W 1393

DEVELOPMENT ENGINEER (with Degree) required for telecommunication cables and testing equipment. Permanent and progressive position with pension scheme. Please apply, giving full particulars to Box No. W 1389.

DEVELOPMENT ENGINEERS and Technicians required in research department of a well-known firm of Precision Engineers, particularly for work in connexion with Servo Systems, Small Precision Motors, and Gyroscopic Instruments. Apply stating age, experience and salary required to S. G. Brown Ltd., Shakespeare Street, Watford, Herts. W 220

DEVELOPMENT ENGINEERS. A leading manufacturer of Domestic Radio and Television Equipment invites applications from qualified men with experience in this field for responsible positions in the Laboratories. Those interested should write, giving brief details of qualifications and experience, to the Personnel Manager (Ref. D.E.). Box No. W 3403.

DEVELOPMENT ENGINEERS & PHYSICISTS. Louis Newmark Ltd., have vacancies in their rapidly expanding research and development department for Engineers and Physicists for work on industrial and aircraft instruments. Degree or similar qualifications desirable. Salary according to experience and qualifications. Pension Scheme, excellent working conditions, etc. Please apply giving full details of career to: Personnel Officer, Louis Newmark Limited, Prefect Works, Purley Way, Croydon, Surrey. W 3495

DRAUGHTSMEN with experience in Electronic equipment are urgently required for work on Aircraft equipment by S. Smith & Sons (England) Ltd., at Cheltenham. High salaries for suitable applicants. Ideal working conditions in pleasant surroundings. Housing assistance. Pension scheme. Permanent positions. Apply Personnel Manager, S. Smith & Sons (England) Ltd., Bishops Cleeve, near Cheltenham quoting reference No. 63/EN. W 1404

CLASSIFIED ANNOUNCEMENTS
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SITUATIONS VACANT (Cont'd.)

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DRAUGHTSMEN: Vacancies for senior Draughtsmen with experience of Electronic and/or Electro-mechanical engineering required, preferably with experience of Ministry requirements. Excellent prospects with good commencing salaries; non-contributory Pension Scheme in operation. Applications will be treated in strict confidence and should give full chronological details of qualifications, experience and age to: John A. Smith Ltd., 24 Lichfield Street, Wolverhampton. W 201

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

ELECTRICAL DEVELOPMENT Engineer required for work on A.A. defence projects at the British associate company of the Hispano-Suiza group. Candidates must have Grad. I.E.E. or equivalent qualification. A sound knowledge of the fundamentals of electronics and applied mathematics and the ability to learn are of more importance than detailed experience of similar work. The successful applicant will work from the design office but will also be engaged in trials of prototype equipment in the factory and in the field. The post is a permanency and entitles holder to participation in superannuation scheme. Applications with details of age, experience, qualifications and salary required, by post only, to British Manufacture and Research Co. Ltd., Grantham, Lincs, quoting ref.: AWK/Staff/EE. W 1402

ELECTRONIC/ELECTRICAL ENGINEER required by London Component Manufacturers for test gear development and supervision of maintenance. Minimum age 30. A good salary can be offered to engineer with definite practical ability. Write full details experience and present remuneration. Box No. W 3446.

ELECTRONIC ENGINEER. An electronic engineer is required for a development laboratory on a guided weapon project. Degree or H.N.C. preferable. The applicant should be capable of working on his own initiative with a minimum of supervision. Experience of pulse circuitry an advantage. Write in detail, quoting Ref. 65, to: The Personnel Manager (Technical Employment), de Havilland Propellers Ltd., Hatfield, Herts. W 3463

ELECTRONIC ENGINEER required by a large food concern in London for the development and application of various forms of process control. Must have the ability to plan the layout, draw up specifications and supervise the installation. Experience in the design of electronic control and measuring equipment is desirable together with some workshop experience. Salary dependent on age and qualifications. Contributory pension scheme. Apply stating age, qualifications and experience to Box No. W 3508.

ELECTRONIC ENGINEER — an experienced engineer is required for the research and design of circuits with application to a Guided Missile System. He should have at least two years' experience and preferably be of Degree standard, although applicants with H.N.C. or C. and G. will be considered. The work is of great interest and importance, offering responsibility and good opportunities for promotion. Write in detail, quoting Ref. 68, to:— The Personnel Manager (Technical Employment), de Havilland Propellers Limited, Hatfield, Herts. W 3480

ELECTRONIC ENGINEER with good knowledge of H.F. measurements and interference suppression required for work in connexion with measurement of radio and television interference. Superannuation scheme. Write giving full details of age, qualifications, experience and salary required to Personnel Manager, The Telegraph Condenser Co. Ltd., North Acton, W.3. W 3257

ELECTRONIC ENGINEER required for Turbine Laboratory. Should possess a Degree in electrical engineering or suitable experience of instrument technology. Superannuation Scheme. Apply Personnel Officer, Sir George Godfrey & Partners Ltd., Hampton Road West, Hanworth, Middlesex. W 3527

ELECTRICAL LABORATORY ASSISTANT required for experimental work and electrical measurements. Superannuation scheme. Write stating age, qualifications and/or experience and salary required to Personnel Manager, The Telegraph Condenser Co. Ltd., North Acton, W.3. W 3258

ELECTRONIC ENGINEER.—Degree or equivalent, practical design experience of V.H.F. Transmitters and Receivers essential. Small but rapidly expanding organisation on South Coast. Near Southampton. Write full details, age, experience and salary expected. Box No. W 303

ELECTRONIC ENGINEERS and Physicists required for rapidly expanding Research Dept. Candidates should have experience of electronic instrument development. Experience in pulse circuits or ultrasonics desirable but not essential. B.Sc. or H.N.C. standard. Write full particulars to Glass Developments Ltd., Brixton. W 3517

ELECTRONIC ENGINEERS required for work on the application of Radio Valves for future Development. Work calls for vision and imagination combined with circuit experience. O.N.C. or Inter. minimum qualifications. Weekly or monthly staff vacancies available according to experience. Quote EE/3, Personnel Dept., M.O. Valve Co. Ltd., Brook Green, Hammersmith, W.6. W 3531

ELECTRONIC ENGINEERS with sound general electronic experience, required by firm with overseas connexions. Age about 30. Part of each year would be spent abroad. Good salary and allowances. Apply Box No. W 1392.

ELECTRONICS ENGINEERS. We are a young expanding section of a well-known organization in the S.W. London area, and we are engaged on Electronics. We are looking for a young man (completed or exempted from National Service) to join our team. He should have at least the H.N.C., preferably in Electronics, must understand pulse techniques, and the generalities of radar equipment. He must be able to design circuits, giving basic specifications. Such a young man would be encouraged to develop his ideas and improve his knowledge, and his prospects would be bright. The starting salary would be £450-£550 p.a. If you feel that you fit these requirements, and would like to hear more about the project, write fully and in compete confidence (all applications will be acknowledged) to Box No. W 3482.

E.M.I. Engineering Development Ltd., Instrumentation Engineers. An attractive vacancy exists for an electronic instrumentation Engineer (one senior and one junior), for the design and development of electronic instruments and instrumentation systems. Applicants should have a sound engineering background (preferably with a Degree) and appropriate experience in the design and development of electronic instruments and systems, or closely allied equipment, is essential. In the case of the Senior Engineer, experience in the supervision of small development teams is necessary. The posts are pensionable and offer excellent opportunities for engineers with an inventive and progressive outlook. Please send full details of training, qualifications and experience in confidence to Personnel Dept. (ED/253), E.M.I. Engineering Dev. Ltd., Hayes, Middlesex. W 3521

E.M.I. Engineering Development Ltd., Experienced Valve Engineer. An interesting vacancy has arisen at the Company's Feltham Laboratories for a Valve Engineer with 4-6 years' experience of both valve and micro-wave generators. Applicants who should be qualified, will have some knowledge of testing both in quantity, and for special purposes, will be able to design suitable test equipment, and have some applications experience. The salary offered for this pensionable post is attractive, and the prospects in this active Company are excellent. Please address your first reply to, Personnel Dept. (ED/252). E.M.I. Engineering Development Ltd., Blyth Road, Hayes, Middlesex. W 3526

ELECTRONIC HEATING. Senior and Junior development engineers and applications engineers required with experience of Induction, Dielectric or Plastic Welding equipment. Excellent prospects in an expanding division. Five-day week. Pension Scheme. Canteen. Write confidentially to the Chief Engineer, Industrial Electronics Division, Redifon Ltd., Broomhill Road, S.W.18. W 3546

ELECTRONICS ENGINEER.—B.Sc. or H.N.C. for laboratory development work on miniature transistors. Work in Slough/Marlow area. 5-day week, canteen, pension scheme. Wide scope for energetic, versatile man with progressive ideas. Full details of age, experience, salary required to Box No. W 3507.

ENGINEERS and Assistant Engineers required for research and development work on aircraft navigation and flight instruments, automatic pilots and electronics. Applicants should have H.N.C. or equivalent, or a degree in Electrical Engineering or Physics. Previous experience desirable, but not essential. Permanent positions with good prospects. Write stating salary required to Personnel Manager, S. Smith & Sons (England) Ltd., Bishops Cleeve, near Cheltenham, quoting ref. CHR.13. W 3383

ENGINEERS AND PHYSICISTS. Ferranti Limited in their new Laboratories are engaged in a programme of electronic development of great industrial importance. The work involves the use of digital computers to control machines and industrial processes and covers a wide and expanding field of application, offering long-term interest to those engaged in it. Development activity for these projects is taking place in the field of electronic circuitry (including pulse technique), digital computers, magnetic recording and servomechanisms. Engineers and Physicists having experience as well as interest in one or more of these subjects are invited to apply. The appointments are permanent and offer full scope for initiative in an expanding organization. A salary commensurate with the qualifications required will be paid. Staff Pension Scheme. Application Form will be sent on request (quoting Ref.: EP/AL) to the Personnel Officer, Ferranti Limited, Ferry Road, Edinburgh, 5. W 3225

ENGINEERS (Radio Valves) are required for all grades of work on Development, production and pre-production: Experience necessary for senior appointments. No previous experience needed for the Junior Posts but O.N.C. or B.Sc. (Inter.) minimum qualification. TA/8 Personnel Dept., M.O. Valve Co. Ltd., Brook Green, Hammersmith, W.6. W 3532

FERRANTI LTD., London Computer Laboratory. The Company invites applications for important positions in a new and rapidly expanding Development Establishment in the London Area from Engineering Design Draughtsmen (Mechanical and Electrical) age 25-40 for work on commercial and Government projects. The positions offer ample scope for initiative and eventual advancement to Engineer Status in the Engineering Design Group. The work is in the following fields:— 1. Process and Manufacturing Automatic Control Equipment, involving servo-mechanisms, gear systems, clutches, etc. 2. Experimental and Production Machines for automatic and semi-automatic circuit assembly. 3 Analogue and Digital Computers. 4. Computer Constructional techniques. 5. Magnetic Recording Equipment. 6. Digital Conversion Mechanisms. 7. Circuit Design and Layout Engineering. 8. Information Storage Mechanisms. Desirable qualifications are possession of Higher or National Certificate, or equivalent, some practical workshop experience and experience or interest in one or more of the above fields. A staff Pension scheme is in operation. Salaries will depend on age, qualifications and experience but will in general be based on excellent scales. Application forms from Mr. T. J. Lunt, Staff Manager, Ferranti Ltd., Hollinwood, Lancs. Please quote reference WSE/10/4. W 3390

CLASSIFIED ANNOUNCEMENTS
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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.

ERICSSON TELEPHONES LTD. have in their Research Laboratories a number of vacancies for circuit designers and equipment engineers to work on nucleonic instruments, and interesting new developments in electronic computing and switching; both senior and junior posts are available. Applicants should have a degree or equivalent plus several years' experience of appropriate work for the senior posts; correspondingly reduced qualifications and experience will be accepted for junior posts. Salaries will be in accordance with age, qualifications and experience. Applications, giving details of age, academic or other training and qualifications, experience, and starting salary required, should be sent to the Personnel Officer, Ericsson Telephones Ltd., Beeston, Nottingham. W 197

EX-SERVICE RADAR and Radio Technicians are invited to apply for posts as Test Engineers for work on Radar and other electronic products of a large Midland manufacturing organization. Further training will be given where necessary. Five-day week, excellent prospects. Apply giving details of experience to date, to the Personnel Manager (Ref. E.S.R.). Box No. W 3401.

FERRANTI LTD., Wythenshawe, have a number of vacancies for (1) Engineers and Physicists for Research and Development work in the following fields:— Radar, radio and electronic circuits. Microwave systems. Hydraulic control systems and servo-mechanisms. Relays and Electromechanical Devices. Test equipment associated with the above. Applicants should be graduates in Electrical or Mechanical Engineering or Physics, or hold equivalent qualifications. For these vacancies some previous experience is desirable. Salary range £800-£1,500. (2) Technical Assistants, possessing Degrees or Higher National Certificates in Electrical or Mechanical Engineering or Physics for experimental work in the fields listed in (1). Salary range £600-£900. The appointments would be to the permanent staff of the Company and offer the prospect of interesting work in Modern, Well-Equipped Laboratories in South Manchester within easy reach of Residential Districts. The Company operates a Staff Pension Scheme. Application forms from Mr. T. J. Lunt, Staff Manager, Ferranti Ltd., Hollinwood, Lancs. Please quote reference W (1) or (2). W 3485

FERRANTI LTD. (London Computer Laboratory), have a vacancy for an Inspection Engineer for electrical and mechanical inspection of prototype computers and allied equipment. The post involves considerable responsibility for immediate test and inspection work and for creating and equipping an inspection group. Essential qualifications are sound practical knowledge of electronic and mechanical measuring instruments and inspection procedure and Higher National Certificate, or equivalent, in Electrical or Mechanical Engineering. The work is of an interesting nature and working conditions are excellent. The Company has a Staff Pension Scheme. Application forms may be obtained from Mr. T. J. Lunt, Staff Manager, Ferranti Ltd., Hollinwood, Lancs. Please quote reference BGM 1. W 3458

FERRANTI LTD., London Computer and Information-Handling Laboratory. Applications are invited for vacancies as follows:— 1. Electrical Engineers and Physicists for a Magnetic Switching Group concerned with basic research, development and the application of techniques to specific projects. Applicants should preferably be of Honours Degree standard with interest in square-loop magnetic devices, ferro-resonant circuits, magnetic amplifiers or pulse transformers. Non-professionally qualified candidates with suitable experience would also be considered. For the more senior positions, post-graduate experience in this field is desirable. The pursuit of individual lines of investigation is encouraged and considerable emphasis is placed on the ability to make original contributions and to exercise initiative. (Ref. W.S.E./12). 2. Electrical Engineer to take a responsible part in a project including digital and analogue information-handling, electronic circuitry, magneto-strictive delay lines and magnetic amplifiers and storage. Knowledge and experience of the above techniques and awareness of the implications of information theory and statistics would be valuable, but an open mind and ability of original logical thought together with the enthusiasm to follow a lengthy project to a successful conclusion are essential. (Ref. W.S.E./13). 3. Electrical Engineers. Preferably with one or two years post-graduate experience, to take part in an information-handling project using both digital and analogue methods and including electronic circuitry, transistors, magneto-strictive delay lines and magnetic storage. (Ref. W.S.E./14). 4. Graduates of high quality capable of preparing programmes for and understanding the design of a new range of electronic computer projects. The successful candidates would probably have a mathematical background and some knowledge of electronics, but initiative and determination to succeed in an expanding field would be rated as highly as previous experience. (Ref. W.S.E./15). The positions are permanent and offer excellent prospects for advancement in a young and expanding organization with new and well-equipped Laboratories. Attractive salaries will be paid to the right men. The Company operates a Staff Pension Scheme. Application forms may be obtained from Mr. T. J. Lunt, Staff Manager, Ferranti Ltd., Hollinwood, Lancs. Please quote appropriate reference W 3438

IMPERIAL CHEMICAL INDUSTRIES LTD., Dyestuffs Division, has vacancies for Assistant Technical Officers (Physicists) to work on the development of special instrument and automatic controls for chemical plant using electronic, optical and other physical methods. Candidates should be aged 25-30 and hold a Higher National Certificate. Salary in accordance with training and experience. Applications in writing to Staff Dept. Hexagon House, Blackley, Manchester, 9. W 3536

INSTRUMENT DEVELOPMENT ENGINEER—Cambridge Instrument Company Limited, require in their Research Department at Cambridge a man to carry out interesting development work on electronic instruments for medical and other important but non-military purposes. The work will be backed by an organization producing instruments of the highest quality. Applicants should have a Degree or the equivalent but ability to produce results is even more important. The post is permanent and pensionable. Apply in writing giving full details of education, experience and salary required to Head of Research Department. W 1400

LOUIS NEWMARK Ltd., have further vacancies, both senior and junior, for Flight Trials of Automatic Control Equipment for aircraft and helicopters. Experience in Aerodynamics or Flight Test Department in an aircraft or guided weapons firm desirable but not essential. These important positions offer a very wide scope for establishing contacts with the entire aircraft industry and involve travelling for this purpose. The firm operates a scheme by which assistance can be given in the purchase of a house. Please apply giving full details of career and salary required (in strict confidence) to: Personnel Officer, Louis Newmark Ltd., Prefect Works, Purley Way, Croydon, Surrey. W 3496

JUNIOR ENGINEERS required for development of Television with large manufacturing company in N. London area. Excellent prospects for promotion in a large research and development establishment. Salary according to experience. Pensionable position. Write in confidence giving details of experience to Box No. W 3488.

JUNIOR ENGINEERS required for development of electronic instruments with large manufacturing company in N. London area. Excellent prospects for promotion in a large research and development establishment. Salary according to experience. Pensionable position. Write in confidence giving details of experience to Box No. W 3487.

JUNIOR ENGINEERS having H.N.C. or equivalent are required by long established progressive firm in Croydon area for varied and interesting planning and investigational work. Knowledge of electronic relay circuitry advantageous. Apply giving full details of experience, age and salary required to Box GX 3920 A.K. Advg., 212a Shaftesbury Avenue, W.C.2. W 3512

LABORATORY ASSISTANT required by Simms Motor Units Ltd., Oak Lane, East Finchley, N.2, for the research and development of electronic and electro-mechanical mechanisms associated with the commercial vehicle industry. H.N.C. or equivalent standard. Apply by letter stating age, qualifications and experience to Personnel Manager. W 1394

LABORATORY ASSISTANT required for test and calibration of Wireless, Radar, electronic measuring instruments. Should be capable of setting up basic calibration and experimental equipment. Five-day week. Write or 'phone Atkins Laboratories, Gowan Avenue, Fulham. RENown 5931. W 1396

MARCONI COLLEGE. Applications are invited for posts on the Lecturing Staff of Marconi College, Chelmsford. The appointments will be to the radio engineering section and candidates should have had experience in modern communications techniques, although applications will be considered from engineers trained in other branches of Electronics. Successful applicants will be required to instruct graduate engineers. The posts are permanent and pensionable. Five-day week. Excellent working conditions in new building. Please reply giving full details of age, qualifications and experience and quoting Ref. 2910 to Marconi's Wireless Telegraph Co. Ltd., Dept. C.P.S., 336/7 Strand, W.C.2. W 3465

MICROWAVE ENGINEERS are required by Decca Radar Limited for work on advanced microwave and millimetric aerial design in a rapidly expanding Aerial Group. Applications are invited from Electrical Engineers and Physicists of H.N.C. standard or above, having practical experience in microwave components; the prospects for men of ability are considerable. There is a pension scheme in operation. British Nationality essential. Please write, quoting reference RLA.108, to Decca Radar Limited, 2 Tolworth Rise, Surbiton, Surrey. W 300

MURPHY RADIO Limited have vacancies in their Electronics Division Laboratories for engineers and assistants on design and development work, and also on associated electro-mechanical problems. Applicants will be considered in the following categories: 1. Candidates with engineering or science Degrees or equivalent who have experience in industrial design. 2. Graduates who have completed Military Service but have no experience in design work. 3. Candidates with lesser qualifications but who have considerable experience in industrial design. 4. Candidates under 21 who are at present engaged upon H.N.C. part-time courses. The range of work involved is part of an interesting long-term programme in an expanding field and includes: 1. Navigational Aids. 2. V.H.F. and U.H.F. transmitters and receivers. 3. Pulse systems. 4. Magnetic information recording systems. These posts are permanent and pensionable, and offer good scope to men of ability. Applications giving full details of qualifications, age, experience, should be addressed to Personnel Department (EDL), Murphy Radio Limited, Welwyn Garden City, Herts. W 3466

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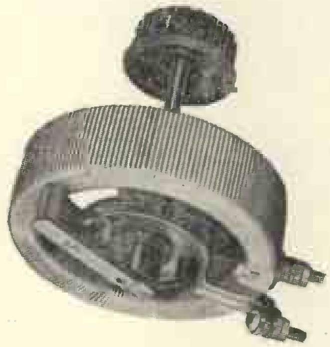
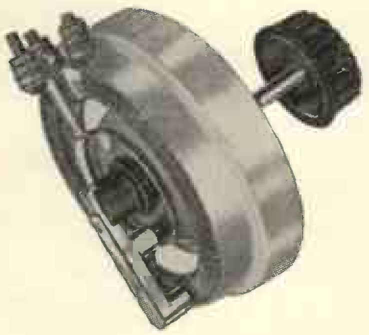
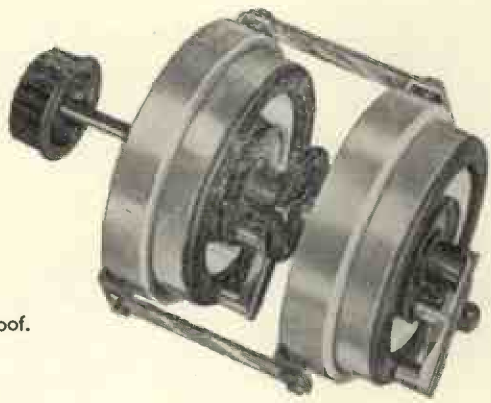
TOROIDAL RESISTANCES

Designed for Arduous Duty

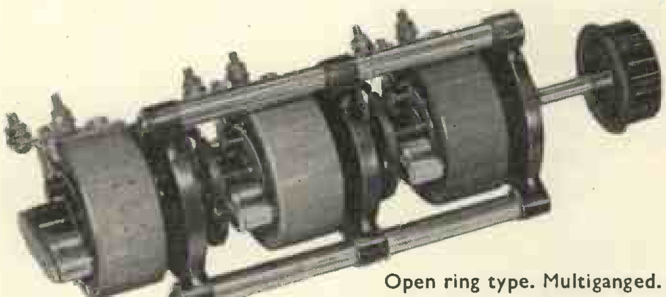


Open ring type.
Back of board mounting.





Embedded ring types. Single or multiganged.
Back of board mounting. Shock and Vibration proof.



Open ring type. Multiganged.
Back of board mounting.

Enclosed ventilated type. Front or back of board mounting.

For these and other Types
Write or phone

RESISTANCES Ltd.

30, OXFORD ROAD, LONDON, N.4. *Arc 2155*

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.

McMICHAEL RADIO LTD., Slough, Bucks, have vacancies from time to time for Electronic Engineers to be engaged on Government projects. Those wishing to be considered are invited to write fully to the Chief Engineer, Equipment Division. W 205

NEWCASTLE upon Tyne Area. Electronic engineers in all categories wanted for radar development and investigation work. Salary in accordance with experience and academic qualifications where requirements range from post-graduate successes in electronic courses to O.N.C. or C.G. certificates. Radar mechanics and technical clerks also wanted for associated work, where experience is desirable but not essential. The engineers and clerk positions will be superannuated appointments. Reply to Box No. W 1401.

OSRAM LAMPS Works, have vacancies for Technical Assistants for work on Cathode Ray Tubes. The two aspects of the work are: (1) Development, installation and maintenance of electronic gear and test equipment. (2) Development and pre-production of special type instrument CRTs. Qualifications required are O.N.C. or H.N.C. in (1) Electronics and (2) Chemistry. Previous experience in similar work is desirable but not essential. Apply giving details of age, qualifications and experience to: Personnel Officer, Osram Lamp Works, Horsenden Lane, Perivale, Middlesex. W 3469

PHYSICISTS or Engineers required for Design and Development work on thermionic valves. Science Degree or equivalent qualification desirable together with a least two years' experience. Applicants must have completed National Service or be exempt. The positions are permanent and offer opportunities for a progressive career. Attractive salary according to experience and ability. The Company operates a Staff Pension Scheme. Please write for further details, quoting Ref. No. LK. 10, to the Personnel Officer, Ericsson Telephones Limited, Beeston, Nottingham. W 3515

PLANNING ENGINEER required for medium-sized industry. Apply in writing giving details of experience and salary required to Personnel Manager, Simms Motor Units Ltd., Oak Lane, East Finchley, N.2. W 1395

RADAR, Television and Radio Testers. Practical men with a sound basic knowledge of electronics and preferably some experience in one of the above categories are required by the Test Department of a leading Midlands manufacturer. The work is of considerable interest and offers scope for technical advancement. Ex-Service technicians are particularly suitable. Applicants should write, giving details of experience to the Personnel Manager (Ref. R.T.R.). Box No. W 3400.

RADIO MANUFACTURERS in North London require Electronic Engineers and a Qualified Physicist for original work in connexion with Semi-conductor materials, circuitry, etc. (including transistors) and for development of wide range of Electronic devices. (a) Applicants for the Engineering posts should have (for senior appointments) Technical training to Degree standard with experience in research or development work of this kind. Or (b) Sound education and technical training to standard of City and Guilds full Technological Certificate or equivalent. In both cases consideration will be given to applicants who, whilst not possessing the above qualifications, can show to the company's satisfaction that they have equivalent knowledge and the ability to successfully pursue the projects contemplated. The concession applies mainly to those in the older age group who have correspondingly greater practical experience. Applicants should give full details of education, technical training, experience, age and salary required to Box No. W 3539.

RADIO VALVE ENGINEERS required for Senior positions on Development with London Company. Experience on this type of work essential. Starting salary ranging from £750 to £1,000 according to ability. Apply Box No. W 3529.

RADIO COMPONENTS. The Plessey Company Limited, Ilford, Essex. Components Division. Vacancies exist for Technical Design Staff with experience in the following field: 1. T.V. and F.M. Tuner Design. 2. Relays and Vibrators. 3. Radio and T.V. Circuit Application Work. 4. Acoustics. 5. Variable Condensers and Switches. 6. Senior Design Draughtsmen. Invitations are extended to applicants with the requisite experience to meet representatives of the company, without prior appointment, at the Charing Cross Hotel, Strand, W.C.2, for a confidential and informal interview. The representatives will be available on Saturday the 3rd September and 10th September, from 9.30 a.m. until 12.30 p.m. W 3473

SALES ENGINEER required with a good knowledge of the application of components and materials to the following: ultrasonic equipment; radar equipment; guided missiles. Preferably with commercial background in addition. Salary in accordance with experience. Excellent opportunity for progress in a rapidly expanding organization. Box No. W 3504.

R. B. PULLIN & Company Ltd., invite applications for the following vacancies in their recently formed and expanding Electronic Development Division—(a) Senior Development Engineers: Applicants should possess an Honours Degree or equivalent qualifications, and should have had several years' experience of the development of electronic circuits, preferably including work on electrical servos and magnetic amplifiers. (b) Development Engineers: Qualifications to O.N.C. or H.M.C. standard together with some previous experience of valve circuit design. The positions are of a permanent nature; they offer excellent prospects and the opportunity to work in a newly equipped Laboratory on a variety of projects requiring considerable individual technical responsibility and initiative. A commensurate salary will be paid. Contributory pension scheme, canteen and recreational facilities. Applications will be treated as confidential, and should be made to the Superintendent, Electronic Development Division, R. B. Pullin & Company Ltd., Phoenix Works, Great West Road, Brentford, Middlesex. W 3470

SCIENCE GRADUATE or equivalent required for development work on dielectrics. Knowledge of one or more of the following an advantage—statistical methods, polymers, electrical measurements, insulating materials. Very good prospects and conditions of service. Men interested to visit the works should write or telephone the Personnel Manager for an appointment. Telephone Manufacturing Co. Ltd., Sevenoaks Way, St. Mary Cray, Kent. Orpington 26611. W3528

SENIOR RADIO ENGINEERS required for the development of domestic radio receivers, including portables. Applicants should have had at least 5 years' previous experience and be capable of progressing designs up to Production stage. Knowledge of AM/FM technique advantageous. Write, giving full particulars of age, qualifications and salary expected to: Personnel Manager, Vidor/Burndept Ltd., West Street, Erith. Kent. W 3491

SENIOR DESIGN and development engineers required for work of an interesting nature in connexion with Microwave, electronic and mechanical development of guided weapons and associated equipment. The vacancies offer ample opportunity for advancement in a modern laboratory. The positions are permanent and the commencing salaries will be in accordance with experience and will be based on a generous and progressive scale. Degree or H.N.C. Please reply, in confidence, giving full particulars to: The Personnel Manager, The Plessey Company Limited, Vicarage Lane, Ilford, Essex. W 3505

SENIOR ESTIMATOR required by a large and progressive engineering company. This vacancy occurs owing to normal expansion of company business. Applicants should have a comprehensive experience of the light electro-mechanical engineering fields with special emphasis on Ministry contracts. This is an attractive vacancy and calls for a man with sufficient ability and initiative to justify a salary of up to £1,000 per annum. All staff privileges including superannuation and insurance scheme are available to selected candidate. Applications which should give full details of qualifications and experience should be addressed to Box No. W 3472.

SENIOR TECHNICAL Engineering Staff. A London engineering company invite applications from project engineers who are capable of taking charge of microwave, electronics and mechanical engineering development in connexion with guided weapon and other applications. These positions are permanent and offer ample opportunity for further advancement. The commencing salaries, which will be in the region of £1,000 per annum upwards according to qualifications and experience, will be subject to review on a generous scale Engineering Degree or H.N.C. Replies which will be treated in utmost confidence, should give full details of qualifications and experience and be addressed to Box No. W 3476.

SYLVANIA THORN Colour Television. Television Laboratories Ltd., require Circuit Engineers for research work on Colour Television Systems especially receiver display devices. 1. Senior Engineers. Must have had a number of years experience of actual design work on Electronic Circuits but not necessarily for Television. Academic qualifications to Degree standard preferred. Men of inventive character capable of making their ideas work are required. 2. Assistants to above senior men. Some experience of circuit work and at least H.N.C. or the equivalent essential. Salaries in line with present-day standard. Pension and Life Assurance scheme. Apply in writing to:— (Quote B2710), Sylvania Thorn Colour Television, Laboratories Ltd., Great Cambridge Road, Enfield. W 3492

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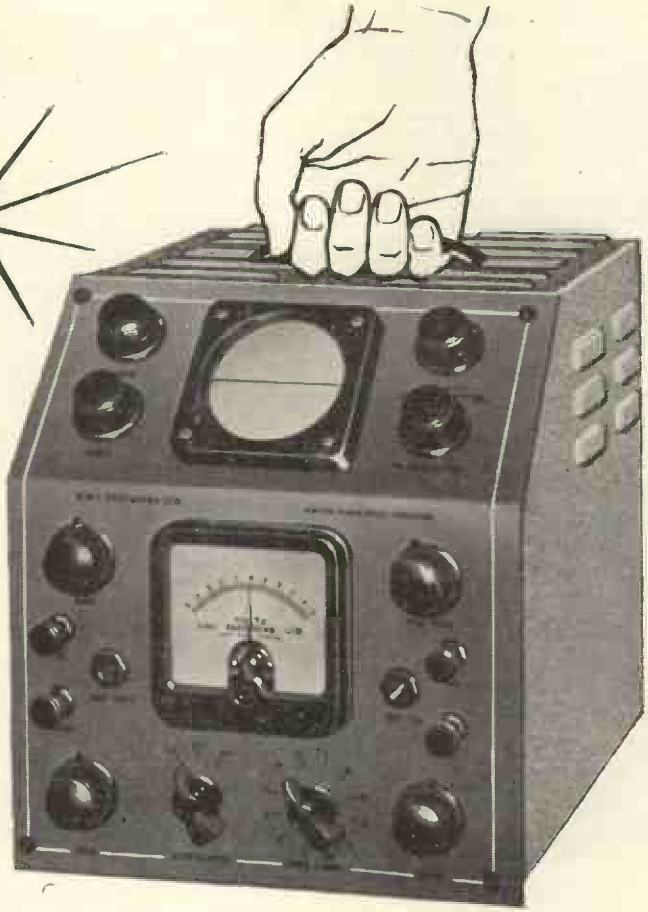
continued on page 12

Serves a dozen different ways



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EE 10

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.

SENIOR ENGINEERS required for development of electronic instruments with large manufacturing company in N. London area. Excellent prospects for promotion in a large research and development establishment. Four-figure salary. Pensionable position. Write in confidence giving details of experience to Box No. W 3489.

SENIOR ENGINEERS required for development of Television with large manufacturing company in N. London area. Excellent prospects for promotion in a large research and development establishment. Four-figure salary. Pension. Write in confidence giving details of experience to Box No. W 3486.

SOUND recording equipment maintenance and operating staff required. Essential qualifications —Higher National Certificate or equivalent, plus experience servicing amplifiers and allied equipment. Five-day week, pension scheme, permanent employment, generous salary. Write giving full particulars to Box No. W 1391.

SERVOMECHANISMS applied to Guided Missiles. An experienced engineer is required to work on the research and design of a complex servo forming part of a missile system. A sound theoretical knowledge, coupled with practical experience, is required. The work is of great interest and requires the use of advanced analysis and computing techniques. Write giving full details of qualifications and past experience, quoting Ref. 72, to:— The Personnel Manager (Technical Employment), de Havilland Propellers Limited, Hatfield, Herts. W 3478

SIEMENS BROTHERS & CO. LTD. Development and Research Laboratories. There are vacancies for:— Senior Engineers to take charge of long-term development in:— (a) New types of Mercantile Marine radio communication equipment. (b) Multi-channel carrier current telephone and telegraph equipment. (c) Carrier current terminal equipment for radio links, and submarine cable systems employing submerged repeaters. (d) Transistor applications. (e) Electronic switching and computing. (f) Electro-acoustics. (g) Design of new components including miniaturization. Assistant Engineers and Laboratory Technicians to carry out the detailed development for the above. Technical Sales Engineers for Carrier Equipment to undertake preparation of tenders, editing and writing technical publications, and training customers' engineers. Applicants with any of the following qualifications will be considered:— (i) Degree in Physics or Electrical Engineering with some previous industrial experience. (ii) Recent and prospective Science Graduates. (iii) H.N.C. Electrical or Telecom Engineering or A.M.I.E.E. (iv) O.N.C. or equivalent City and Guilds Certificates with practical industrial experience. All are pensionable staff posts with good prospects of advancement. Salary according to qualifications and experience. Apply in writing to Siemens Brothers & Co. Ltd., Ref. 744/21, Woolwich, S.E.18, stating age, educational qualifications, experience and salary required. W 3467

TECHNICAL LIAISON. Belling & Lee Ltd., Great Cambridge Road, Enfield, Middlesex, manufacturers of electronic components, receiving aerials, etc., require a man for this work, which includes attendance at technical committees, co-ordination of this function inside the establishment and drafting of specifications: there is a small amount of European travel entailed: permanent, pensionable position, age limits 28/42. Applications (in confidence) to the Secretary. W 3513

TECHNICAL OFFICER (Communications) required for Middle East service with large Oil Company. Not less than six years' experience Radio Transmission equipment; practical experience maintenance multi-channel carrier equipment and V.H.F. Radio equipment; knowledge V.F. Telegraph and Automatic Telephone Exchange installations (non-director) useful. Grad. I.E.E. or H.N.C. qualified. Age limit 35; bachelor preferred. Total minimum emoluments £1,600 p.a. and paid home leave with passages. Write quoting No. 503 to Box No. 8973, c/o Charles Barker & Sons Ltd., 31 Budge Row, London, E.C.4. W 3510

TECHNICAL WRITING. Ferranti Ltd., have a vacancy which will provide the opportunity for a Young Graduate in Electrical Engineering or Physics interested in Technical Writing to pursue this career at a high level of technical interest. The vacancy occurs in the Patents Dept. of the Company and involves close contact with research and development work in the many and varied sections of the Ferranti organization. There would be particular emphasis on Electronics. Training would be given in this specialized branch of technical writing and the successful candidate would be encouraged to qualify as a Patent Agent. Permanent staff appointment with Pension benefits. Application forms may be obtained from Mr. T. J. Lunt, Staff Manager, Ferranti Ltd., Hollinwood, Lancs. Please quote reference PD. W 3459

TECHNICAL SALES ENGINEER. The Manufacturers of "AVO" Electrical and Electronic Instruments invite applications from young men having completed National Service, for a post of Technical Sales Engineer. Applicants must have Ordinary National Certificate, City and Guilds Radio II, or similar qualification, and will, in addition to other duties, be expected to take a special interest in data relating to receiving valves. Applications to, R. E. Hill, Acweeco Ltd., Westminster, London, S.W.1, or phone VICtoria 3404. W 3543

TELECOMMUNICATION ENGINEERS (2) are required as Section Leaders for submerged repeater development by the firm which is manufacturing the major portion of the transatlantic telephone cable. Applicants should possess extensive experience of carrier telephone systems as applied to long-distance land cables. They should also have specialized knowledge on the selection of filters or feedback amplifiers. Minimum academic qualifications: Second class Honours Degree in Physics or Engineering. Ability to read technical German preferred. The work is interesting and in clean surroundings. Salary according to experience £800-£1,000 per annum bonus normally added after qualifying period. Applicants having the same academic qualifications but less experience will be considered for posts as junior engineers on the same work. Salary in the range £600-£800 per annum plus bonus. Women applicants will also be considered. Pension Scheme. five-day week, all welfare facilities. Write details to: Personnel Manager, Submarine Cables Ltd., Telcon Works. Greenwich, S.E.10. W 3500

THE GENERAL ELECTRIC CO. LTD., Brown's Lane, Allesley, Coventry, requires Mechanical Development Engineers, Designer-Draughtsmen and Draughtsmen, preferably with experience of Radar type equipments for work on Guided Weapons and like projects. Also required, Senior and Junior Electronic Development Engineers, particularly in the field of Microwave and Pulse Applications. Salary according to age, qualifications and experience. Apply by letter stating age and experience to the Personnel Manager. Ref. R.G. W 208

THE MULLARD LABORATORIES require Electronic Engineers for interesting design and development work on laboratory instruments and test equipment. Applicants must be capable of working on their own initiative and should have academic qualifications ranging from City and Guilds Final Certificate or fourth year National Certificate (Radio) to Degree Standard. Several years' experience in electronics is desirable and a good knowledge of pulse techniques is preferred. The positions offered are permanent, progressive and carry attractive salaries. Applications should in the first instance be addressed to the Personnel Officer, Mullard Research Laboratories, Cross Oak Lane, Salfords, near Redhill, Surrey, quoting reference VPL(C). W 3405

THE BRITISH THOMSON-HOUSTON Co. Ltd., require graduate Engineers and Physicists for the design, construction and processing aspects of magnetron and other electronic valve developments. The work is carried out in close association with a small Machine Shop and Pilot Production Unit, and every encouragement is given to the development of new ideas. It is work in which both practical and theoretical interests are desired. Applicants should write to The Director of Research, British Thomson-Houston Co. Ltd., Rugby, giving their age, qualifications and experience, and quote reference FT. W 3385

THE PLESSEY COMPANY Limited, Vicarage Lane, Ilford, Essex, require a senior electronics engineer for development work in an important field of industrial activity. Experience with servo-mechanisms, a varied background, and a real interest in experimental work are the important requirements. The position is permanent and pensionable, the salary is attractive, and future prospects are good. Replies, which will be treated in confidence, should be addressed to the Employment Manager. W 3418

TEST and Laboratory Engineers required for Gyro and Electro Mechanical Instruments. Apply stating age, experience and salary required to S. G. Brown Ltd., Shakespeare Street, Watford, Herts. W 216

THE MULLARD RADIO Valve Company Limited has a number of Senior Staff vacancies in the Television Tube Production Department of its Cathode Ray Tube Division. These posts are for Production Engineers who, in each case, will later be responsible for the overall efficiency of their section, including a complete range of duties within the production and management function against a highly technical background. It is felt these posts would have a particular appeal for young men who possess a good Honours Degree in the Physical Science or Engineering, coupled with a short period of industrial experience, (or who may be completing National Service), and now feel they wish to further their career in the production field. There are opportunities for promotion in this expanding field of Company activity. The commencing salary will be according to individual age, experience and qualifications and can be considered to be progressive. The hours of work will be forty-four in a five-day week. The Company provides a progressive Holiday Plan and Pension Scheme. Applications in writing, which will be treated with the strictest confidence, should be addressed to the Personnel Officer, The Mullard Radio Valve Co. Ltd., New Road, Mitcham, Surrey. W 3464

YOUNG MEN required of Intermediate B.Sc. standard with interest in electronic valve work. Applicants must have completed National Service or be exempt. Good salaries offered with first-class laboratory working conditions. The positions are permanent and the Company operates a Staff Pension Scheme. Please write for further details quoting Ref. No. LK.11, to the Personnel Officer, Ericsson Telephones Limited, Beeston, Nottingham. W 3516

TRANSISTORS—an engineer is required for the design and analysis of transistor circuits with application to a guided missile. Some experience of transistor circuit design is required, together with academic qualifications, consisting of a Degree, N.C. or C. and G. This is an opportunity to enter a small but expanding team working on these problems, where initiative and ability will be recognised. Write in detail, quoting Ref. 69, to:— The Personnel Manager (Technical Employment), de Havilland Propellers Limited, Hatfield, Herts. W 3481

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continued on page 14

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VACANCIES exist for engineers in Radio and Radar field at our various Depots. Applicants should possess 1st class P.M.G. wireless certificate or Ministry of Transport Radar certificate. Applications from long service naval personnel welcomed. Reply to W. H. Smith & Co., Electrical Engineers Ltd., 68 Grosvenor Street, Manchester 1. W 1403

VICKERS-ARMSTRONGS (Aircraft) Limited, have the following vacancies in their Guided Weapons Development Department:— (x) Calibration Engineer. An Engineer is required for work on calibration of electrical and electronic instruments and to investigate associated measurement techniques. Applicants for this position should have a Degree or equivalent in engineering or physics and preferably have experience in electrical measurement and allied techniques. (y) Engineer Draughtsman (Electronic). A Draughtsman is required to engineer equipment from laboratory circuit information to prototype stage. Adequate facilities are available for the development of original techniques. A knowledge of M.O.S. requirements is desirable. The minimum academic qualification required is Higher National Certificate in Electrical Engineering or equivalent. (z) Draughtsmen (Electrical). 2 Draughtsmen are required to engineer prototype electronic equipment under the direction of an engineer draughtsman. A knowledge of M.O.S. requirements is desirable. Minimum qualification Ordinary National Certificate or equivalent. Applications, quoting date and prefix letter of advertisement, to: Employment Manager, Vickers-Armstrongs (Aircraft) Limited, Weybridge Works, Weybridge, Surrey. Weybridge is 30 minutes from London on the main Waterloo/Portsmouth Line. Additional 'buses operate to and from the Works at starting and finishing times. Canteen facilities. Applicants should be in a position to arrange their own housing accommodation. Assistance can only be given with individual lodgings. Holidays already arranged by applicants this year taken into account. W 3443

V.H.F. Radio Link Engineer. Required for the maintenance of Multi-Channel Links. Previous telephone and radio experience essential. Apply, giving full details of experience, etc. to Personnel Manager, Pye Telecommunications Ltd., Ditton Works, Cambridge. W 3389

Further "Situations Vacant" advertisements appear in display style on pages 94, 103, 105, 108, 111, 112, 116, 117, 120, 122, 124, 128 and 134.

FOR SALE

COSSOR D.B. 339 'scope in excellent condition. New valves, links viewing hood, leads and instruction manual. £35 or nearest. Willis, "Briarfield", Clifton Road, Ilkley. W 1397

EXCLUSIVE. Sale of cabinets in bakelite for Television. Apparatus offered to Constructors for different countries. Apply Box No. W 1378.

EXTRUSIONS BY MARLEY Buyers requiring rigid and flexible tubes and sections in thermoplastic materials should ask for a quotation from Marley Extrusions Ltd., Dept. 127 Lenham, Maidstone, Kent. Harrietsham 381. W 224

FACTORY FOR SALE, Wolverhampton, 123,000 sq. ft. Modern Building, brick construction, central heating, electric lifts, offices, canteen. Freehold £85,000. Vacant possession. Full details from Chamberlain & Willows, 23 Moorgate, London, E.C.2. (Metropolitan 8001/8). W 3538

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FOR THE VERY BEST technique in V.H.F. design do please see the Eddystone "820" FM/AM unit at Webb's Radio, 14 Soho Street, W.1. (Gerrard 2089). Descriptive brochure post free on request. W 196

MAGSLIPS, SELSYNS and many other items connected with automatic and remote control mechanisms are marketed by Servo & Electronic Sales Ltd. Brochure available on request. See our display advertisement on page 123. W 202

METAL-GLASS SEALS. Single way hermetically sealed terminals for soldered connexions and fixing. Mostly 1kv and 2kv sizes. New: 65s. per 1,000 assorted. P. B. Crawshay, 94 Pixmore Way, Letchworth, Herts. Tel. 1851. W 215

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EDUCATIONAL

DIGITAL COMPUTORS, October 10th-14th, 1955. A short residential course at the Somerset Education Committee's College for Adult Education. Tuition by the staff of the Electrical Engineering Department, Manchester University. Inclusive residential fee £9. Final enrolment date, September 26th. Details from the Warden, Dillington House, Ilminster, Somerset. W 3514

THE POLYTECHNIC, Regent Street, W.1. Department of Mathematics and Physics. Advanced Electronics. The following series of lectures will be held on Tuesdays from 7.00-8.30 p.m. commencing on 27th September, 1955. A. Pulse Circuits 27th September to 1st November, 1955. B. The Physics of Semiconductors, 8th November, 1955 to 10th January, 1956. C. Semiconductor Circuit Elements, 17th January to 28th February, 1956. Fee for each series £1. Applications for prospectuses and enrolment forms should be made to the Head of the Department as early as possible. W 3264

FREE! Brochure giving details of course in Electrical Engineering and Electronics, covering A.M. Brit. I.R.E., City and Guilds, etc. Moderate fees. Write to E.M.I. Institutes, Dept. EE29, London, W.4 (Associated with H.M.V.). W 2674

LECTURES. Battersea Polytechnic, London, S.W.11. Electrical Engineering Department. A one-year evening course comprising lectures, tutorials and practicals on Linear Servomechanisms by Mr. G. L. Ashdown, A.I.Br., M.I.E.E., F.Inst.P. Mr. R. A. King M.A.(Cantab.), under the direction of Dr. G. L. d'Ombrain, Ph.D., D.I.C., A.C.G.I., M.Am.I.E.E., M.I.E.E., Consultant and Head of Department. Commences on the 3rd October, 1955, at 7 p.m. and on successive Monday evenings through the session. Particulars and enrolment forms on application to the Department. W 3494

THE POLYTECHNIC, 309 Regent Street, W.1. Department of Mathematics and Physics. The following courses of lectures have been arranged, starting in September 1955: (1) A second Course in Electronics on Monday evenings, 6.30-8.30. (2) Modern Electric Network Theory on Friday evenings, 7.00-9.00. Full particulars may be obtained on application to the Head of the Department. W 3477

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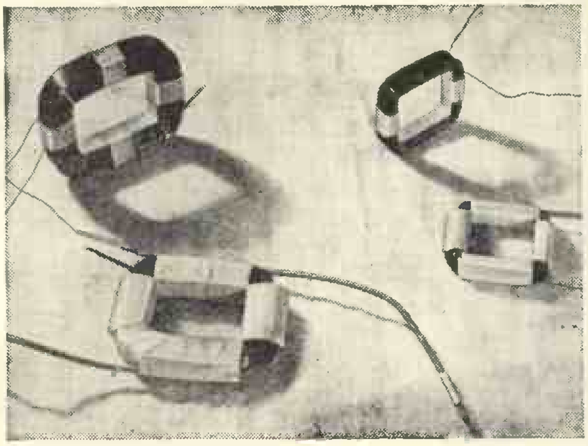

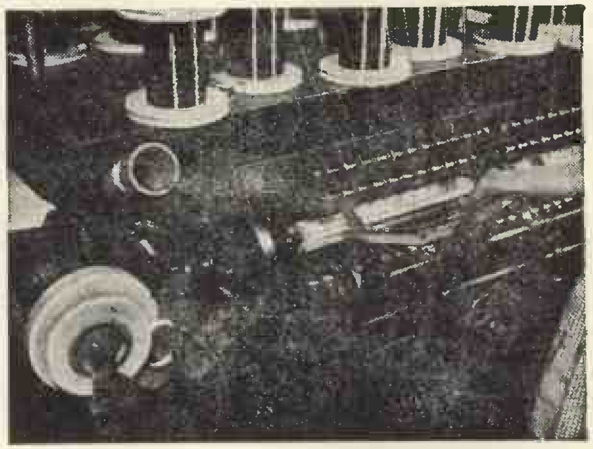

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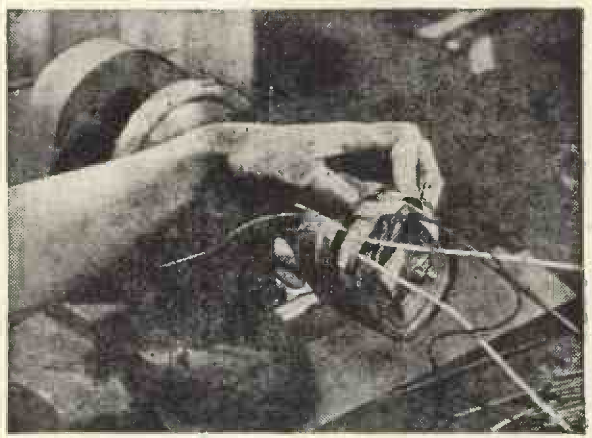

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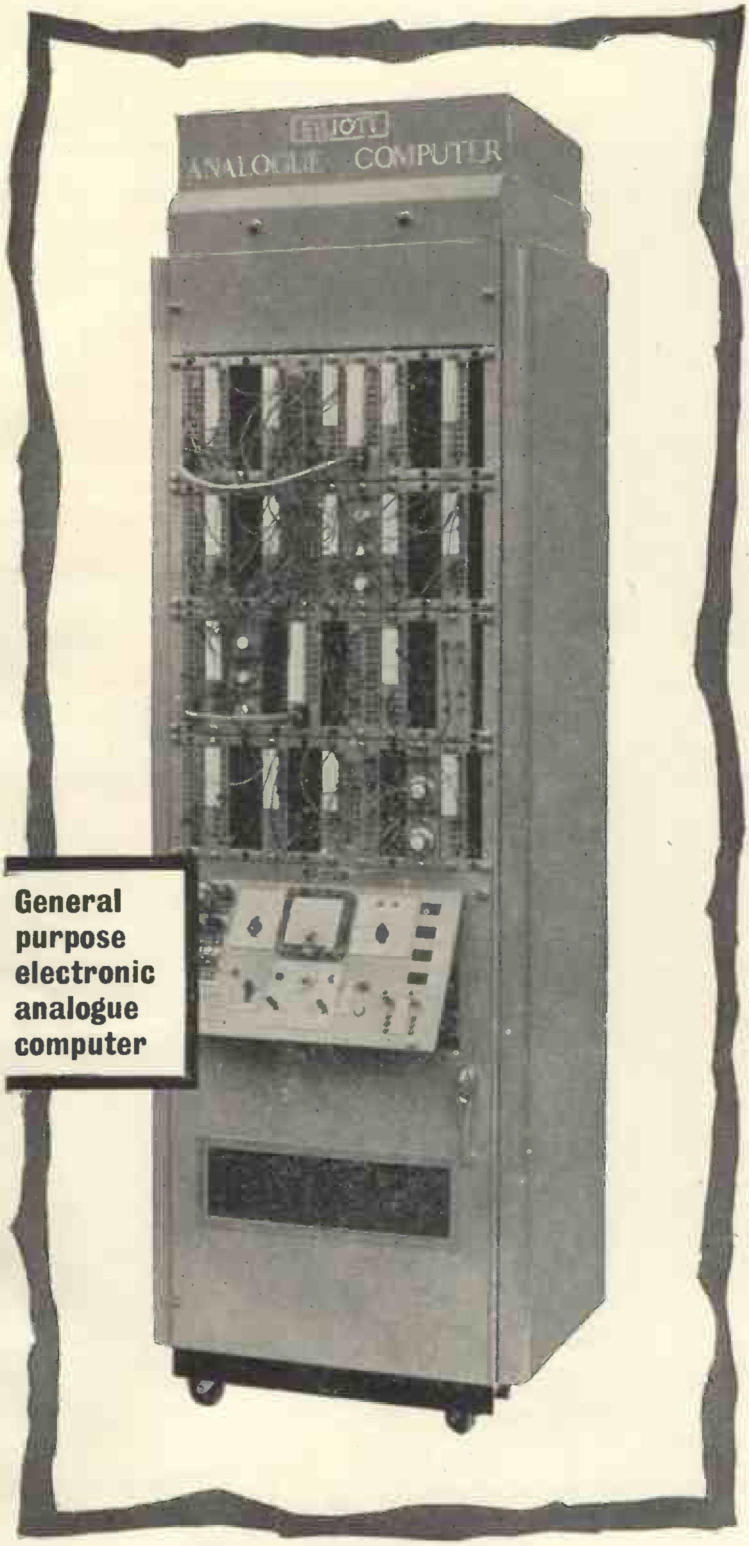

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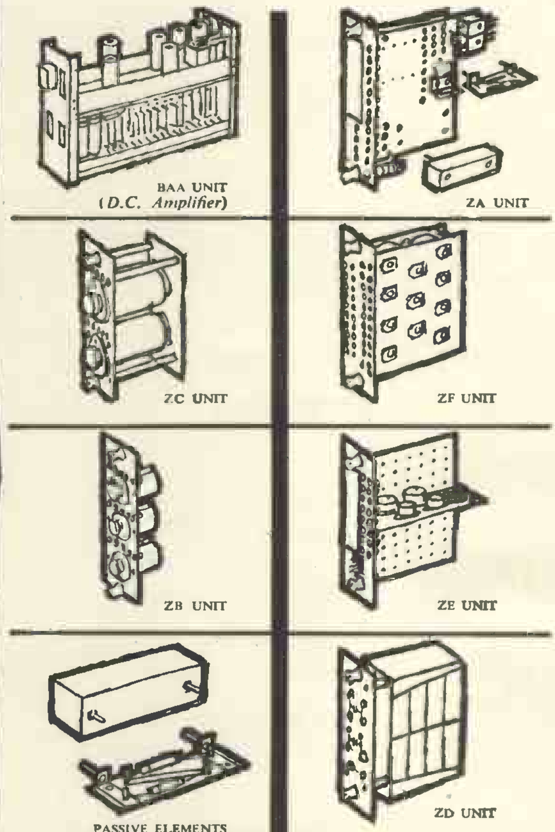

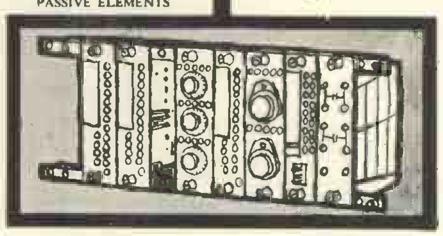

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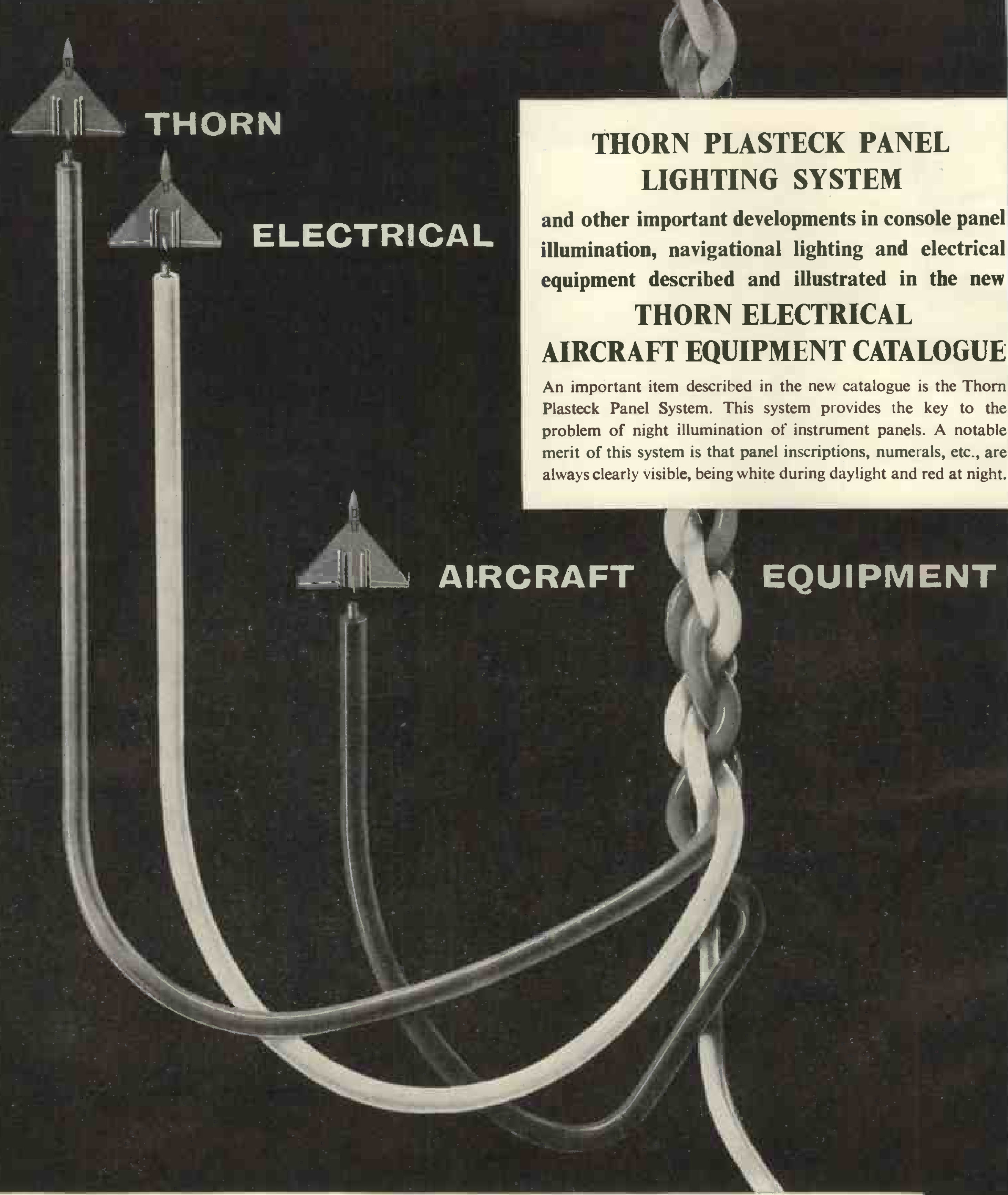

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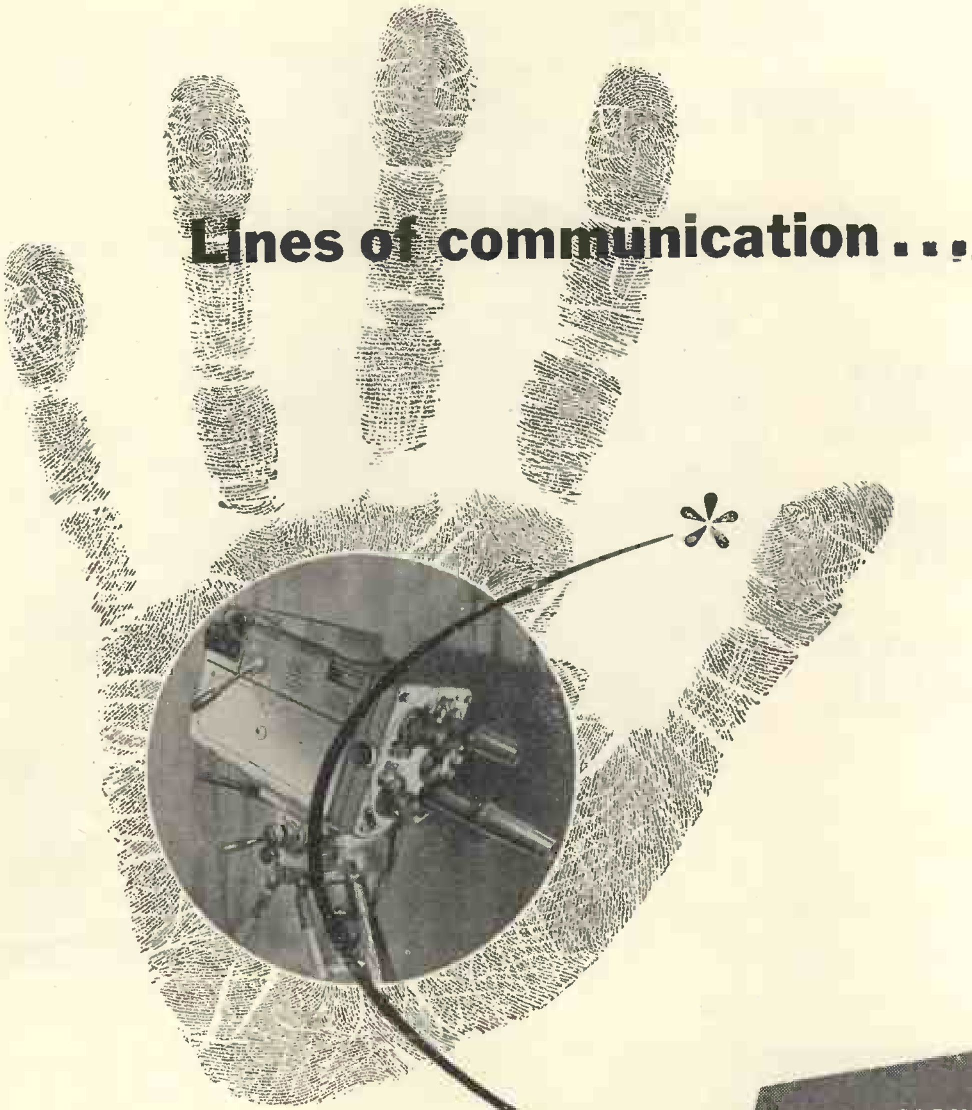

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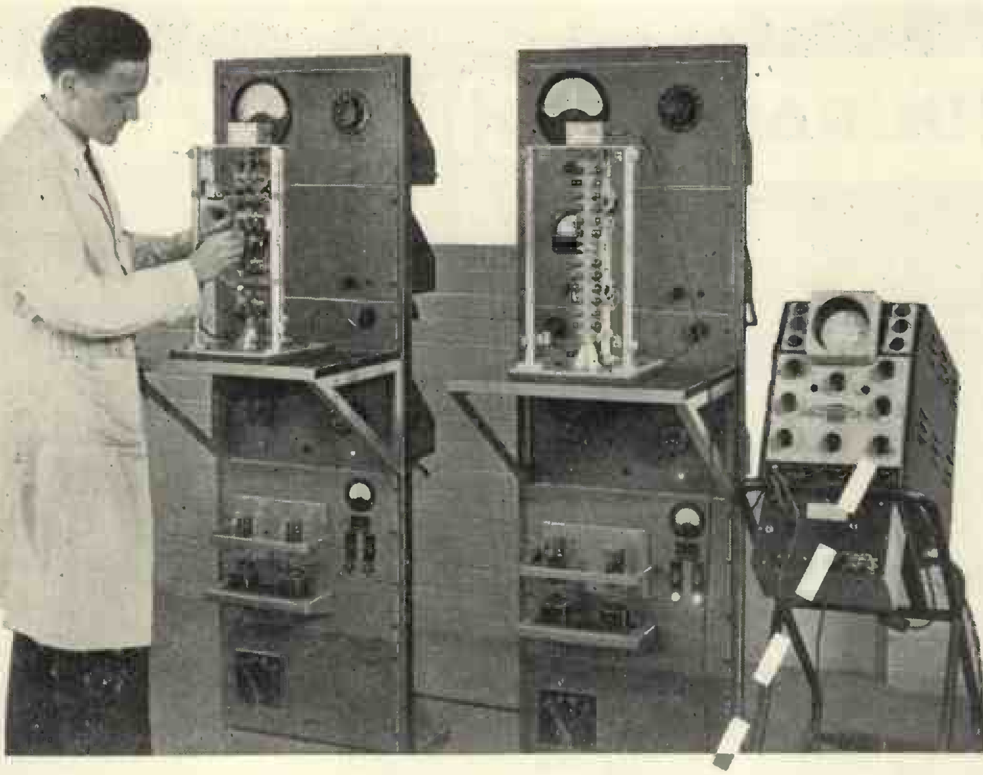
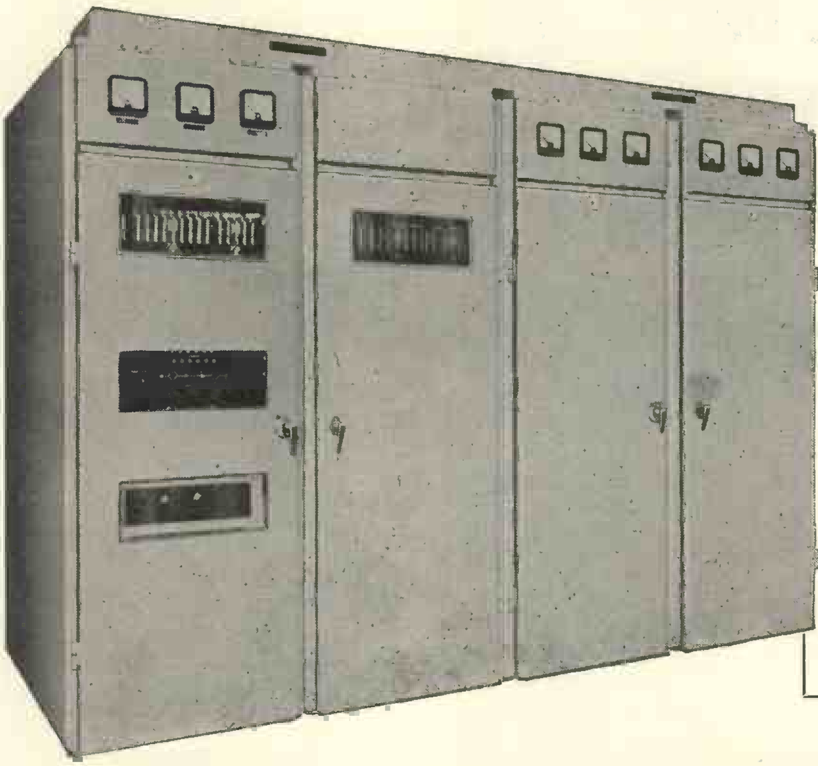


Marconi 6kW HF ISB Transmitters



TYPES
HS 71 AND HS 72

The assembly is enclosed by unit sections, as shown here, with access through front and rear doors. The two left hand bays house the rectifier and power equipment and the right hand bays the low power and auxiliary transmitting circuits and the main output stage.

These transmitters, designed in accordance with the most advanced practice, provide :—

(a) Telegraphy on CW and FSK (A1 and F1)
(b) Independent Sideband Operation (A3b)

The drive equipment is external and provides either ISB modulation or telegraph keying at 3.1 Mc/s and suitable RF oscillator signals for frequency changing in the transmitter. HS 71 is manually operated; HS 72 provides full automatic tuning and selection of any one of six pre-set frequencies.

FEATURES INCLUDE

- **Tuning over the whole range without change of components**
- **Air cooling throughout, with dust filtering.**
- **Double screening of power stages reduces indirect radiation and cooling air noise.**
- **Envelope feed back to reduce distortion.**
- **Compact assembly with good access for servicing and safety interlocking.**

More than 80 countries now have Marconi equipped telegraph and communication services, many of which, completed 20 years ago, still give trouble-free operation.

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LC12

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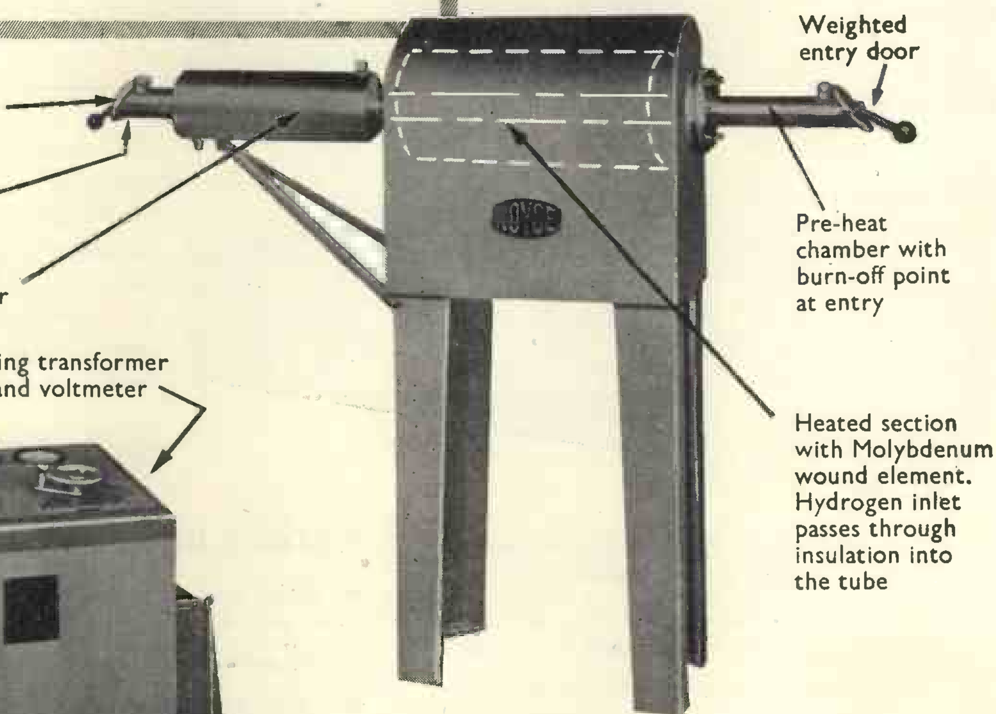
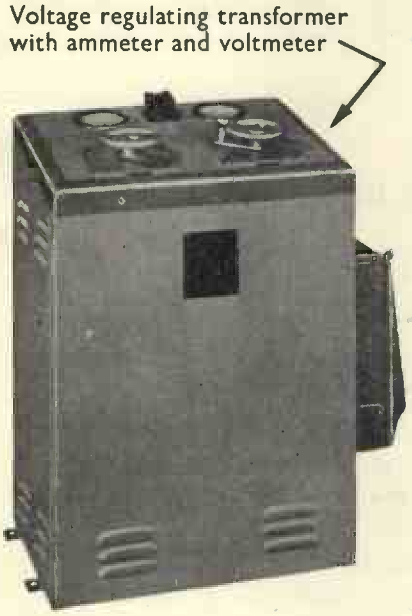
Molybdenum wound for temperatures up to 1750° C.





Royce Molybdenum wound tube furnaces are designed for sintering metals, including tungsten carbide, and for bright heat treatment of special steels. Long life of the heating element is obtained by a special method of winding. Operation is simple and maintenance easy. The furnace tube is fused alumina, wound with heavy section Molybdenum for temperatures up to 1750° C. It can also be supplied Platinum wound for 1550° C, Kanthal wound for 1200° C, and Nickel Chromium wound for 1000° C. Tube sizes range from 1" to 5" inside diam.

For full details write for publication R.F.5

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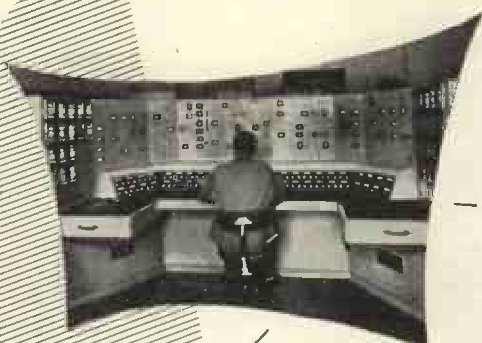

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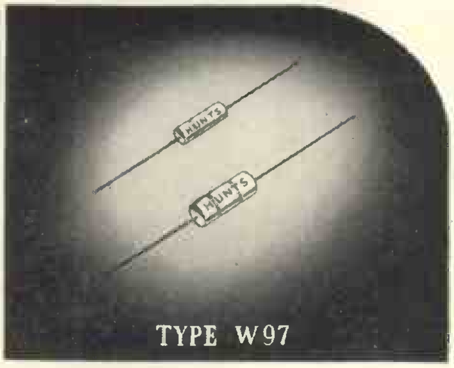

HUNTS "THERMETIC" MIDGET METALLISED PAPER CAPACITORS WITH A TRUE HERMETIC SEAL

FULLY APPROVED TO JOINT SERVICES STANDARD R.C.S.136/A CATEGORY 40/100, CLASS H.1.

TEMPERATURE RANGE : −100°C to +100°C

The W97 capacitor, although of diminutive size, is an extraordinarily robust unit. Most miniature units are prone to weakness in end connections and general mechanical flimsiness. Such undesirable features are eliminated in the W97 by the special processes used and extreme care in manufacture.

CAPACITOR UNIT

A single metallised paper is used to wind this unit which is made possible by the use of Hunt's Patent covering the "castellated" pattern. Recent development by Hunt on a special impregnating material gives the unit remarkable brackets of operating temperature.

CASING

Hunt's patented double metal tube, sealed with the special "Thermetic" compound, provides positive closure on the casing and lead entry, ensuring positive hermetic sealing.

INSULATION OF CASING

The capacitors are supplied without an insulating medium on the case. If specially requested they can be supplied with an approved plastic sleeve which increases the dimensions by 0.07" in length and 0.03" in diameter.

TERMINATIONS

The terminations are of 24 gauge tinned phosphor bronze wire having a nominal length of 1½". Special attention is paid to the retinning of the wires after the capacitor is fully processed. Connection is made to the unit by applying copper spray to the metallising. The pigtail is soldered to this bond giving a perfect connection of exceptional strength.

INDUCTANCE

W97 "Thermetic" Midgets have a very high self resonant frequency—the following figures are quoted as a guide. 50 pF at 600 volts, which is the lowest capacitance in the range, has a self resonant frequency of 280 megacycles. At the other end of the range, 0.04 μF 200 volts, which is the maximum capacitance, it is 8.5 megacycles.

INSULATION RESISTANCE

This is measured at working voltage at a temperature of 20°C. The minimum capacitance in the range, 50 pF at 600 volts, has an insulation resistance greater than 2,000,000 megohms. The maximum capacitance in the range 0.04 μF at 200 volts, has an insulation resistance greater than 25,000 megohms. The intermediate capacitances are approximately pro rata.

POWER FACTOR

Less than 2% at 1,000 cycles per second at 20 C.

CAPACITANCE TOLERANCE

Standard ± 20%. Closer tolerances are available, for capacitances exceeding 500 pF.

TYPE W97 STANDARD RANGE

LIST NO.	CAP μF.	DIMENSIONS (inches) L.	D.
	200 volts D.C.	Wkg.	
BM7	0.002	0.610	0.135
BM8	0.004	0.610	0.135
BM11	0.004	0.500	0.180
BM9	0.005	0.610	0.135
BM12	0.005	0.500	0.180
BM13	0.01	0.500	0.180
BM14	0.02	0.610	0.180
BM15	0.03	0.610	0.260
BM16	0.04	0.610	0.260
	400 volts D.C.	Wkg.	
BM4	0.0004	0.610	0.135
BM5	0.0005	0.610	0.135
BM6	0.001	0.610	0.135
BM18	0.002	0.500	0.180
BM19	0.003	0.500	0.180
BM20	0.005	0.610	0.180
BM21	0.01	0.610	0.260
	600 volts D.C.	Wkg.	
BM25	50 pF.	0.500	0.180
BM1	0.0001	0.610	0.135
BM26	0.0001	0.500	0.180
BM2	0.0002	0.610	0.135
BM27	0.0002	0.500	0.180
BM28	0.00022	0.500	0.180
BM29	0.00025	0.500	0.180
BM3	0.0003	0.610	0.135
BM30	0.0003	0.500	0.180
BM36	0.0004	0.500	0.180
BM31	0.0005	0.500	0.180
BM32	0.001	0.500	0.180
BM33	0.002	0.610	0.260
BM34	0.003	0.610	0.260
BM35	0.004	0.610	0.260

W97 IS A 'MUST'
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MAKERS OF ELECTRONIC EQUIPMENT

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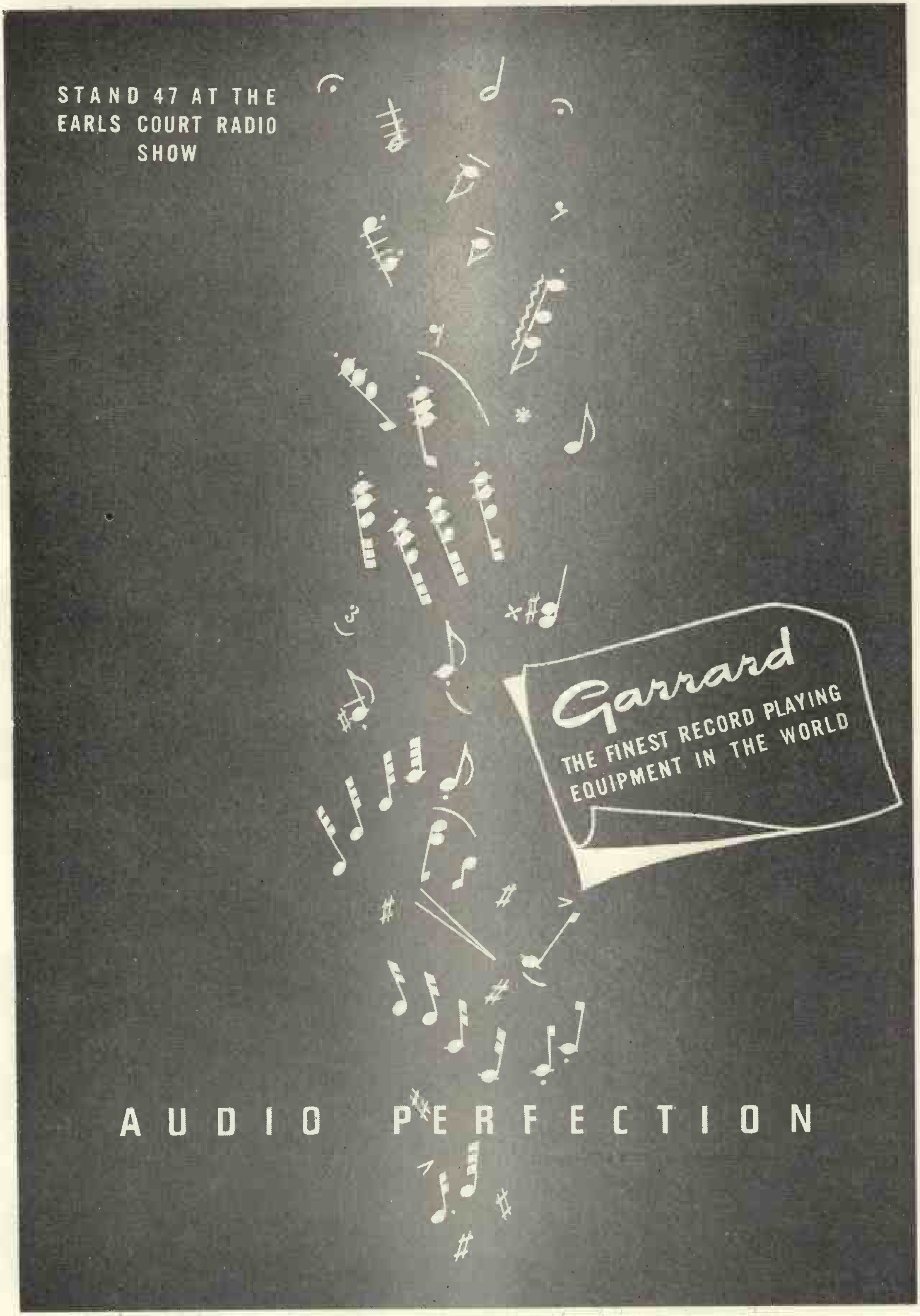
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THE FINEST RECORD PLAYING
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AUDIO PERFECTION

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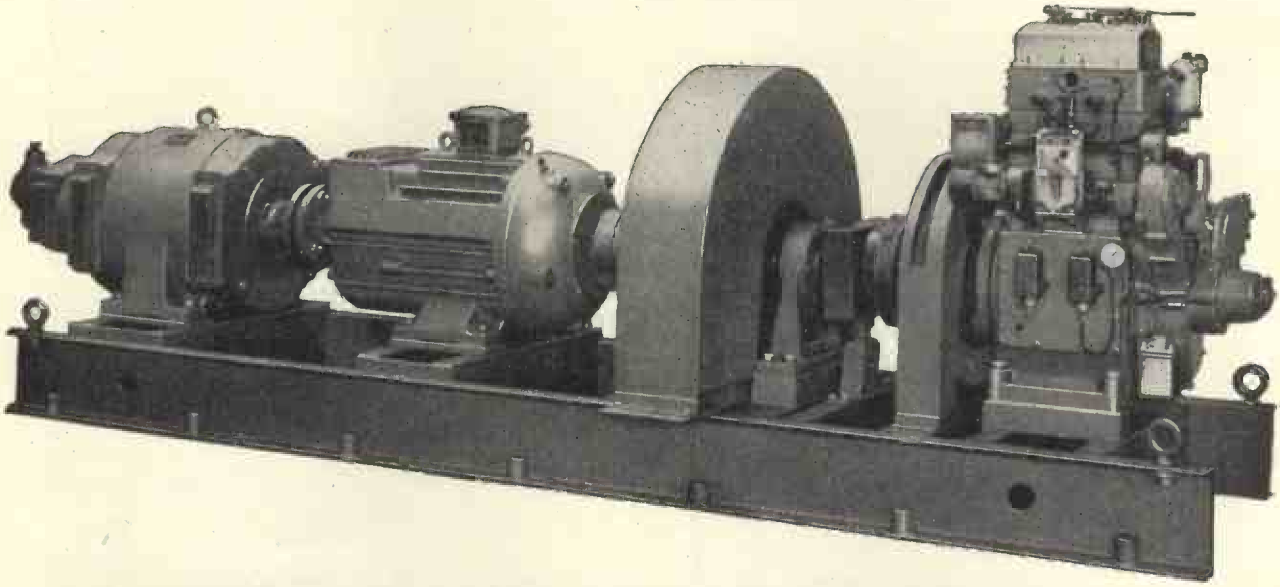

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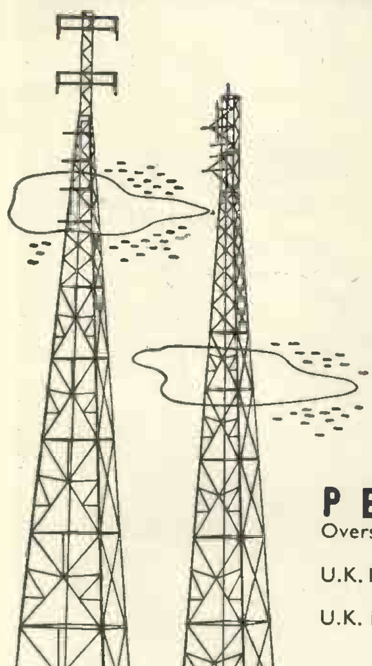

Recent developments in modern Telecommunications Systems have emphasised the necessity for an unfailing and constant supply of Electric Power. Any failure of supply, even for a very short period, could have far-reaching and serious consequences to the users of the System. The selection of the most suitable diesel engines and control gear, therefore, becomes a matter of supreme importance. Pelapone engines over half a century have earned a reputation for unfailing reliability and are now being widely adopted for this purpose. Close liaison with the leading manufacturers of Telecommunications Systems has resulted in the development of a range of Generating Sets and Control Gear suitable for all modern Systems. Recent contracts on which Pelapone equipments are being used include a Canadian Micro-Wave System, an East African Radio Telephone Link, The Eire Trunk Carrier System, a Japanese Micro-Wave System; for a Malayan V.H.F. Communications System and in conjunction with telecommunications in Nigeria and South Africa.

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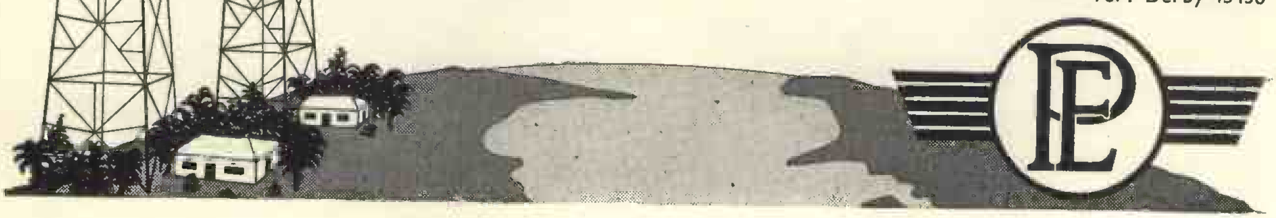

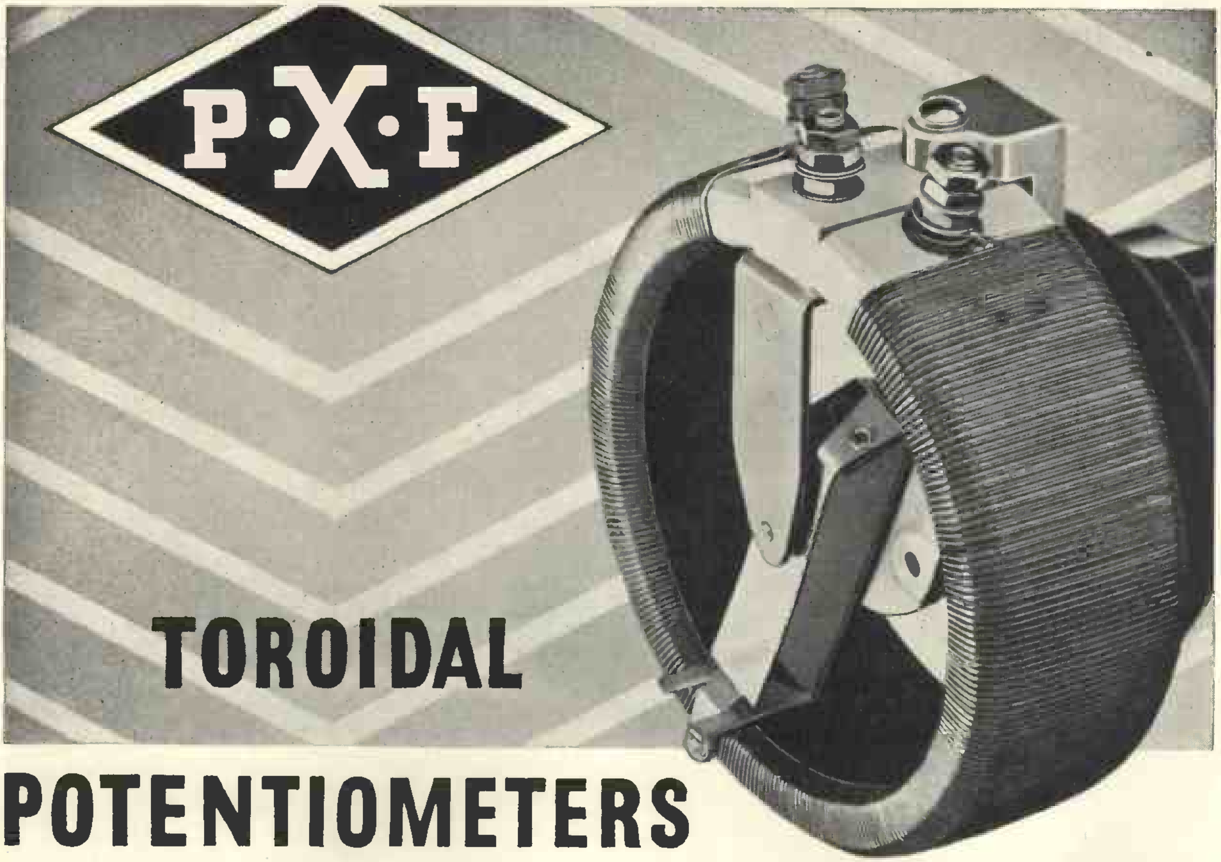

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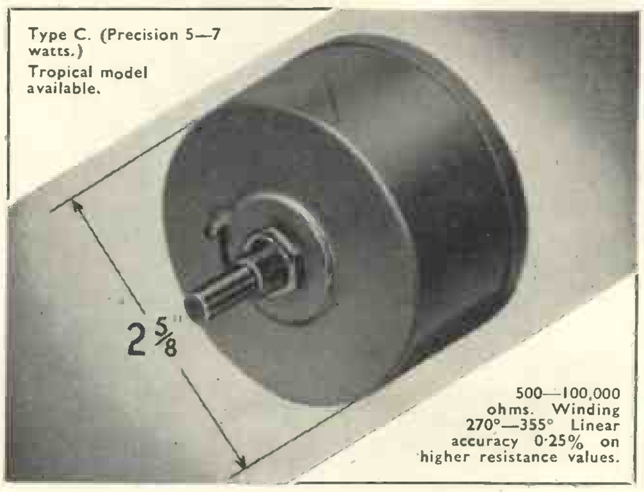

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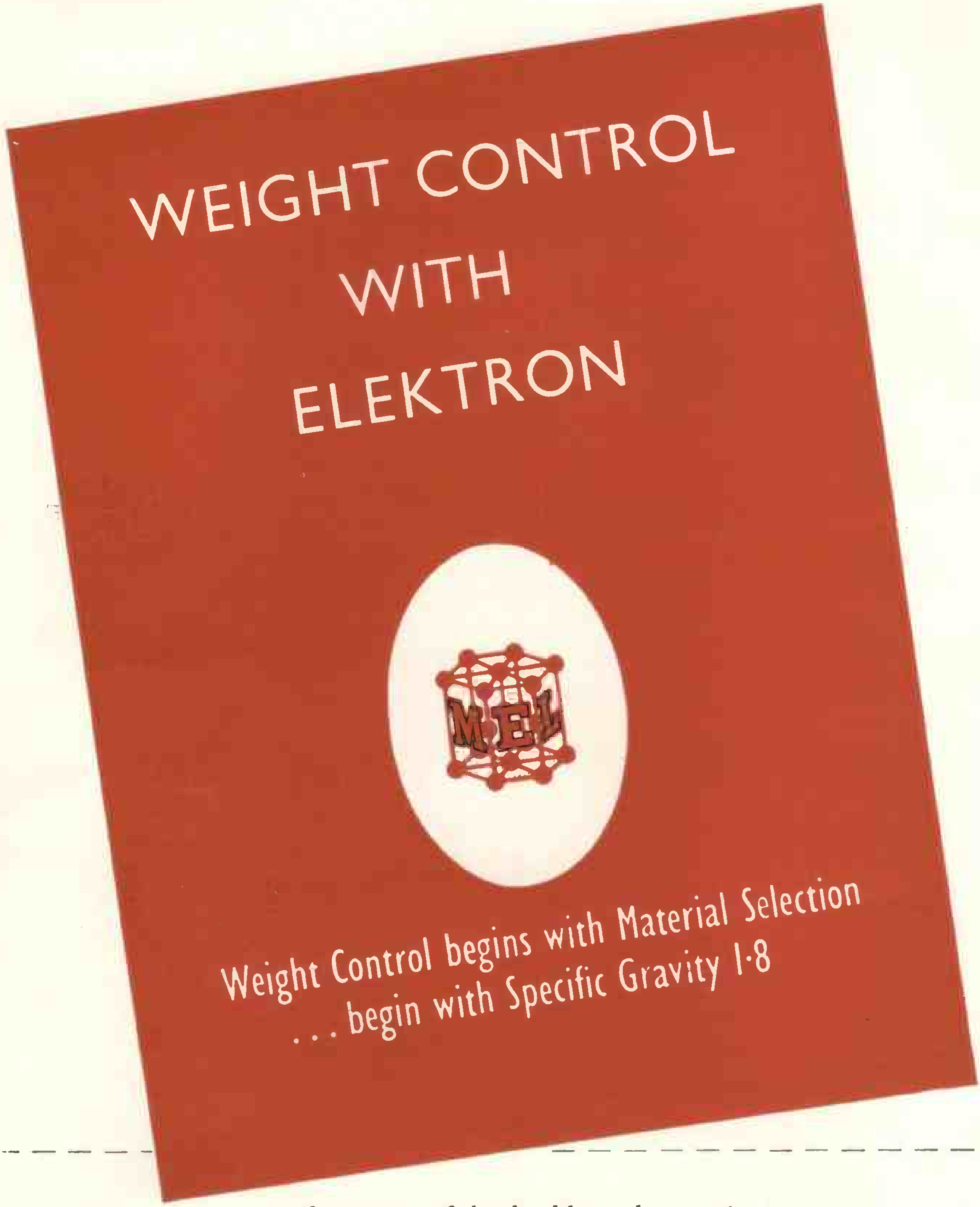
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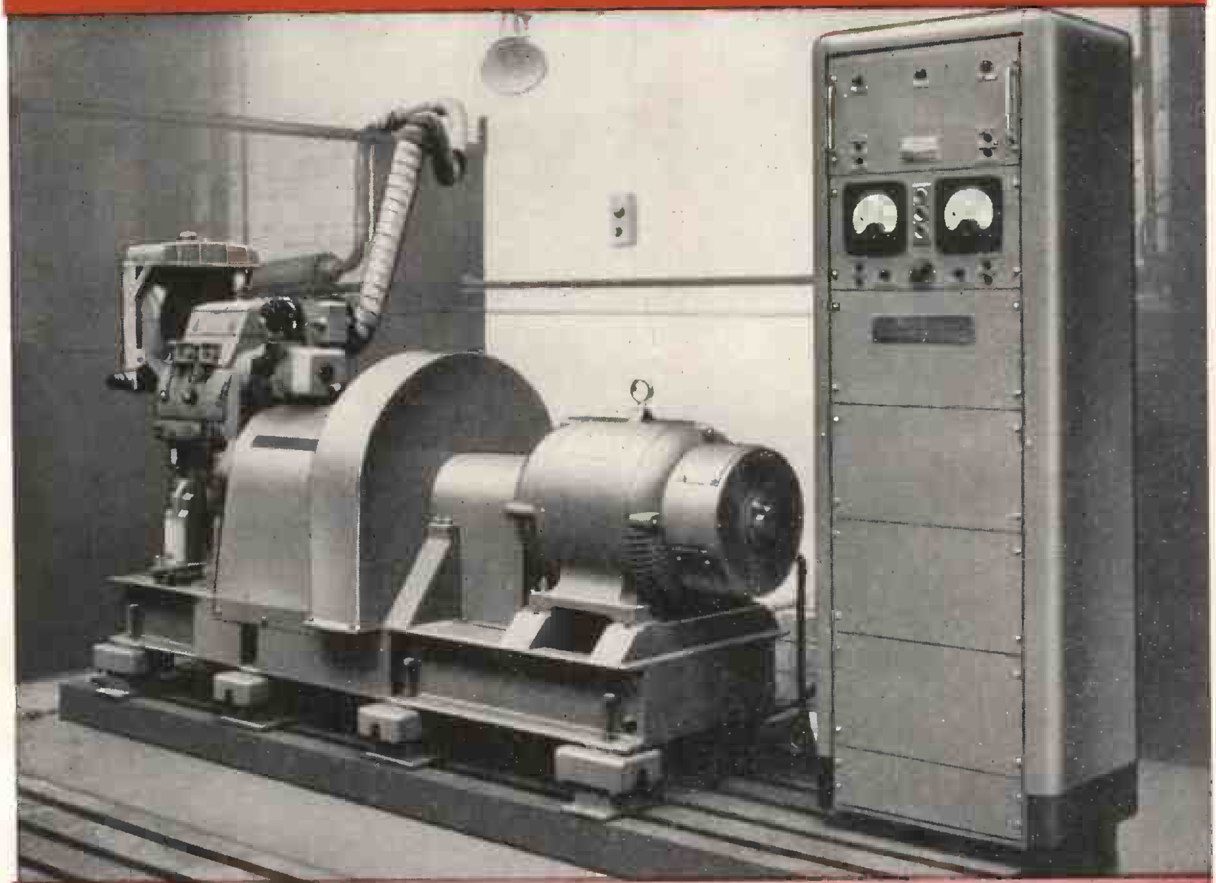
NO-BREAK ENGINE-ALTERNATORS

E.C.C. PATENTS



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These NO-BREAK Alternator Sets are arranged to operate in conjunction with existing A.C. mains to provide a continuous A.C. supply for essential services such as telecommunications, etc. Normally the vital service is fed from the supply mains and, under conditions of mains failure, from the diesel driven alternator set.

Under normal conditions the A.C. mains supply power direct to the load, the alternator operating as a synchronous motor driving a fly-wheel, with the diesel-engine stationary. Under mains failure conditions the alternator is driven by the diesel-engine to supply power to the load. On restoration of the ordinary supply mains the alternator synchronises automatically with these mains, the diesel-engine is again disconnected and the alternator operates as a synchronous motor.

Each set incorporates a Lister FREEDOM diesel engine and an E.C.C. synchronous induction motor/alternator. E.C.C. patent static excitation and control unit is incorporated in the control pillar.

E.C.C. patent ECCOSYNE automatic synchronising unit is provided for re-connecting the alternator to the mains on mains restoration. These sets ensure a continuous NO-BREAK supply both in attended and unattended stations.

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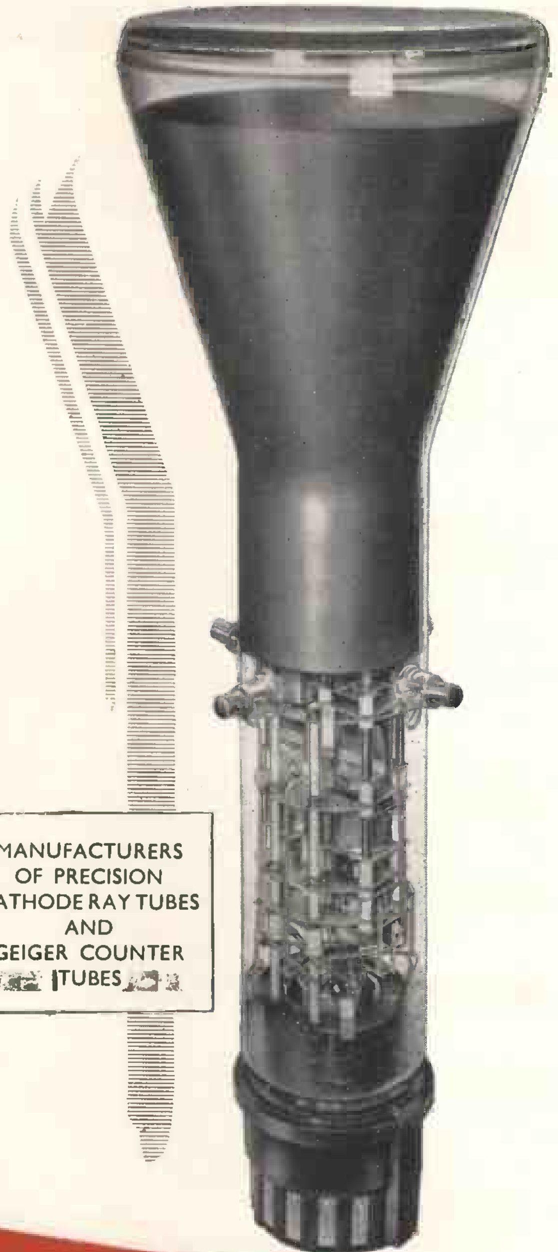
Double Beam Tubes

Series D.6 and D.4

These tubes employ two independent electron guns. All eight deflector plates are separately connected and interplate screening ensures complete absence of intermodulation. The traces can be superimposed and each gun has a useful screen area of at least 100 mm. × 80 mm. Independent connections to each grid, cathode and focus electrode permit optimum conditions of operation for each gun and each of the beams may be brightness modulated. Sweep speeds of 100 cms./μsec. may be recorded using the D6B or D4B.



Type		D.6	D.4
Diameter		6 in.	4 in.
Overall lengths (mms.)		480	370
Sensitivity	X	700	400
mm./V. x VA_3	Y	700	350
Y capacity		4μμf	4μμf
Heater volts		6.3	6.3
VA_3 max. KV		5	5
VA_1 max. KV		2	2
VA_2 (VA_3=2KV) volts		300	300
Vg for cut-off (average)		—45	—45
Drive for 20μa I_B		20v	20v

Screens:

D6B — Blue for photographic or visual use.
D6G — Green for visual observations.
D6P — Medium persistence.
D6F — Fluoride. Long persistence.
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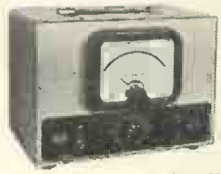
The L.101 is a well engineered and reliable instrument incorporating two identical Y amplifiers with sensitivities of 20 mV/cm over a bandwidth of 4 Mc/s. Full screen (10 cm) undistorted deflection is available with negligible interaction between channels.

The time base may be free running, synchronised or triggered and its velocity is variable between 0.1 μs/cm and 10 ms/cm. Calibration accuracies are: voltage ±5%, time ±10%.



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An a.c. amplifier instrument covering the range 0.5 mV to 300 V r.m.s. Frequency response constant to within 2% between 20 c/s and 1 Mc/s.

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A balanced d.c. amplifier instrument fed direct or via a probe, giving a level frequency response from 30 c/s to 100 Mc/s. Full-scale readings from 0.5V peak to 15 kV peak.

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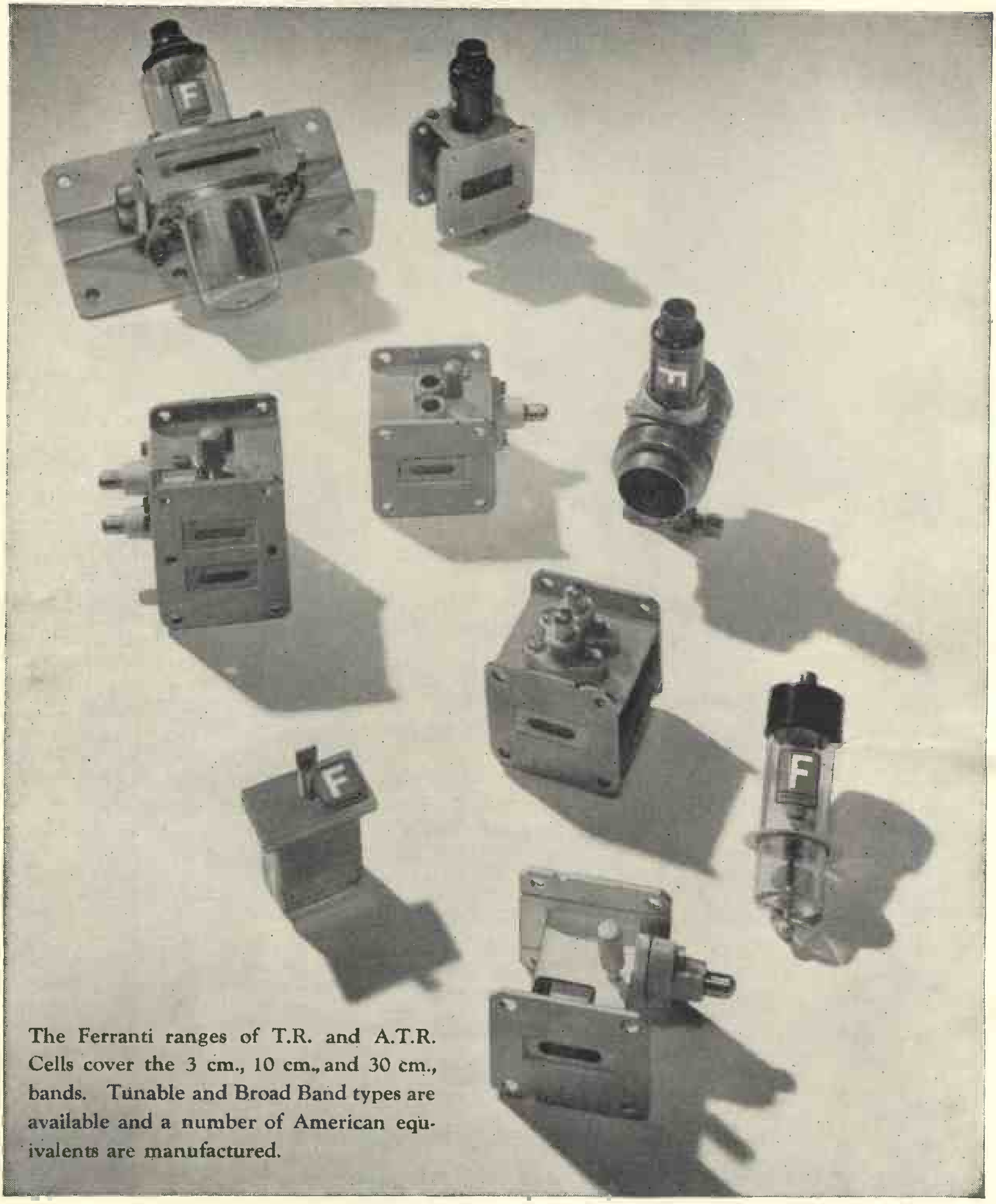

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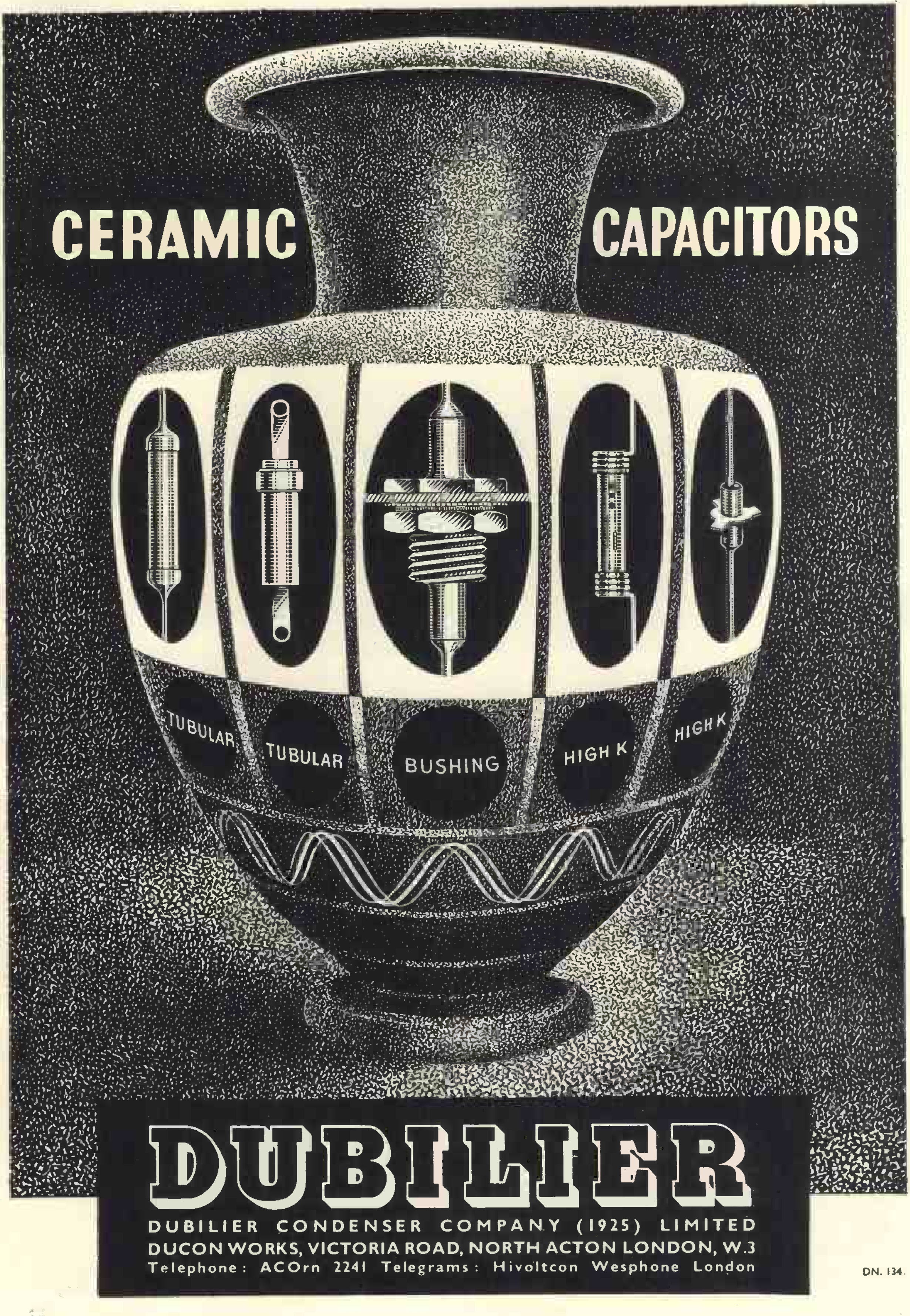
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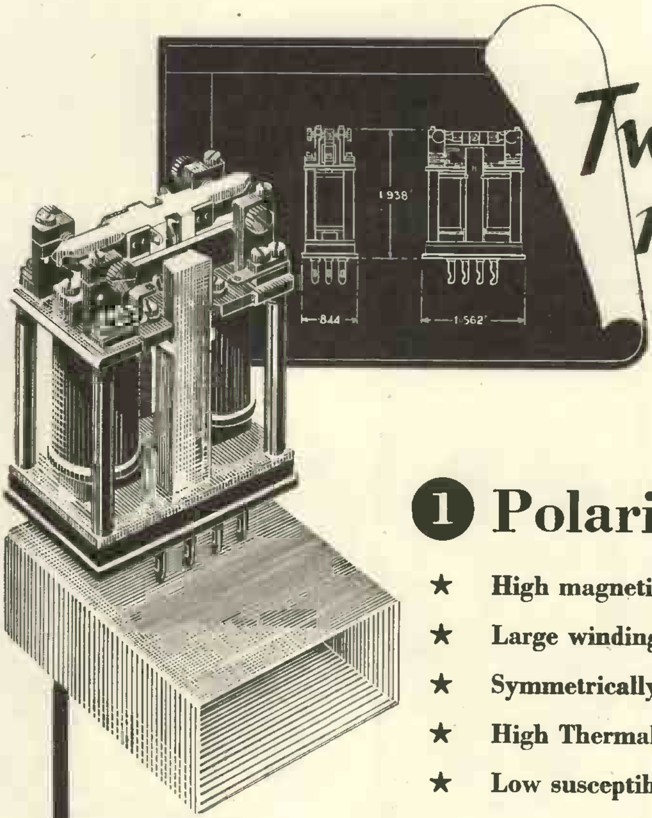

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- ★ Exceptionally high sensitivity
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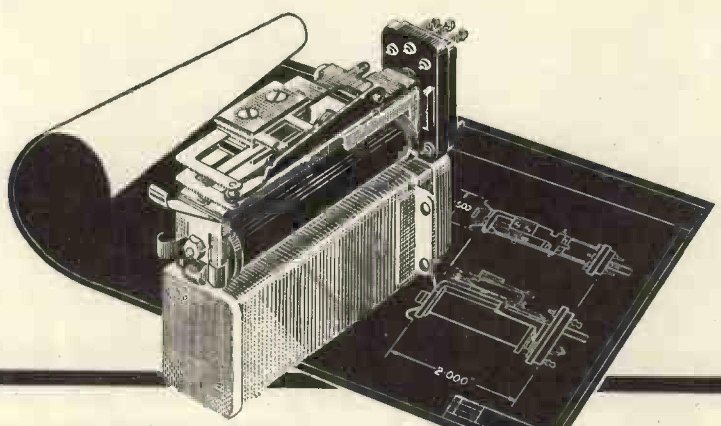

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SERIES 500

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Model 501
(fitted with end frames)

ABRIDGED DATA

(Further information on request)

	Data	Model 501	Model 502	Model 503	Model 504	Model 505
MAIN +VE Stabilizer	Output	200-500V 250mA	200-500V 250mA	0-500V 250mA	0-500V 250mA	0-500V 150mA
	Number of Ranges	2	2	4	4	1
	Voltage Stabilization	±0.02%	±0.002%	±0.1%	±0.002%	±0.1%
	Effective Output Resistance (max.)	0.2 Ω	0.02 Ω	0.5 Ω	0.02 Ω	0.5 Ω
	Output Ripple (rms. max.)	2mV	1mV	3mV	1mV	3mV
—VE Supply Stabilizer	Outputs	—	—	250V 25mA 0—250V 1mA	250V 25mA 0—250V 1mA	250V 25mA 0—250V 1mA
	Voltage Stabilization	—	—	±0.05%	±0.002%	±0.05%
	Output Resistance (max.)	—	—	1 Ω	0.01 Ω	1 Ω
	Output Ripple (rms. max.)	—	—	2mV	1mV	2mV
Unstabilized +VE H.T. Supply 250mA max.		470V 630V	470V 630V	320V 470V 630V	320V 470V 630V	630V
Unstabilized A.C. Supply		6.3V 10A	6.3V 10A	6.3V 10A	6.3V 10A	6.3V 10A
Price		£70	£91	£81	£99	£75

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EXTRAS. To convert from rack mounting to bench use the following extras are available :—

Polished hard-wood reinforced end frames ... ... £1 15 0 per pair

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Managing Editor H. G. Foster M.Sc. M.I.E.E.

Vol. 27 SEPTEMBER 1955 No. 331

Contents

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ELECTRONIC ENGINEERING

VOL. 27 No. 331

SEPTEMBER 1955

Commentary

A NEW extension to the Post Office transmitting station at Rugby has recently been opened and is briefly described elsewhere in this issue. The extension cost over £1M to build and it is claimed that Rugby is now one of the largest and the most up-to-date radio transmitting stations in the world. While one is chary of " biggest and best " claims, there is no doubt but that the new extension forms a very fine transmitting station and is a credit to British communications engineers.

The name " Rugby " is known to communication engineers the world over, while to many in this country the twelve 820ft masts, among the tallest structures in the world, are a well-known landmark that herald the approach to Rugby when travelling by rail from London to the North. The old and the new stations now straddle Watling Street, the famous Roman road, and together cover an area of some 1 600 acres, although the majority of this is still available for agricultural use.

It is now almost thirty years since the British Post Office installed their first telegraph transmitter at Rugby, for it was on 1 January, 1926, little more than 20 years after Marconi had first succeeded in spanning the Atlantic by wireless, that the first transmitter " went on the air " with the call-sign GBR. It had a power of 350kW and a frequency of 16kc/s. The purpose of this transmitter was to provide a world-wide telegraph service throughout the 24 hours of the day, thus supplementing the existing cable service, and to provide contact with ocean going liners.

In the meantime, radio telephony over long distances had proved practicable and in January, 1927, the first international public radio telephone service in the world was opened, to America. While at first a long wavelength was used, experiments with short-wave beam transmissions, with which the name of Franklin is so closely associated, showed the way to further development of the telephony service and in August 1928 a second service in the 16 to 32m band was established.

Now, in addition to the service to North America, there are radio telephone services from this country to destinations throughout the Commonwealth, South America, the Middle East and many other areas, as well as to a number of ocean going liners. Indeed, to the younger generation it must seem difficult to visualize how international commerce could have been conducted successfully without the long-distance telephone and telegraph; yet the present vast communications network has been built up in only about half a normal life-span.

In addition to its telephone and telegraphic traffic, Rugby has for many years broadcast accurate time signals, meteorological reports, standard frequencies and news to all parts of the world and to ships at sea; many ships' newspapers, descendants of the first ship's newspaper, *The Transatlantic Times*, published aboard the S.S. St. Paul with the co-operation of the Marconi Company in 1899, rely almost entirely on bulletins from Rugby.

With such a historic background it is fitting that, when new facilities were needed, a site adjacent to the original station at Rugby should have been chosen.

When the 28 transmitters in the new station are fully operational the total number in service at Rugby will be doubled but, due to the modern techniques of channel sharing, the traffic handling capacity will be trebled. While, on account of the elaborate system of remote control and monitoring installed, it will be possible for one man to control and supervise all 28 transmitters from a central control desk. It is, in fact, noteworthy that while the authorized staff of the old Rugby station was 128, the addition of the new extension has only increased this number to 167.

It is also interesting to note that, unlike most other services the cost of overseas telephone calls has decreased considerably with the passing of the years. For example, in 1927 the cost of a telephone call to the U.S.A was £5 per minute; a year later this was reduced to £3. In 1930 the cost fell to £2 and by 1936 to £1 8s., while in 1946 the cost was still further lowered to £1 per minute. This, of course, has been brought about largely by the vast increase in the number of radio telephone calls. In 1937 the number of calls via the United Kingdom was 50 929, while in 1954 the number was 143 160.

It is, in many ways, a pity that the communications side of the electronic engineering industry should have been rather thrust into the background by the more glamorous fields of computers, atomics, industrial control and the like, for there is no doubt it offers, and will continue to offer for many years to come, a satisfying and rewarding career for the young engineer starting out in life.

A Waveform Synthesizer

For Technical Training

By T. S. Fox*, B.Sc.

The equipment described was devised for educational purposes. It generates a fundamental sine wave and ten harmonic sine waves, each variable in amplitude and phase. By adding these, an infinitely variable waveform is available at the output terminals. Various educational applications are suggested.

FOURIER'S Theorem poses a difficult problem for those concerned with technical training. The subject ought to be full of fascination and interest for the student, yet too often he emerges from the classroom with a jumble of trigonometry in his head, and no clear mental picture of the processes involved. To provide the student with a picture—both visible and mental—the waveform synthesizer now described was developed at the BBC Engineering Training Department.

The equipment was designed to generate a fundamental frequency and a complete set of harmonics up to the tenth. Each harmonic voltage is continuously variable in amplitude and phase. A cathode-follower output tube and an adding circuit incorporates the fundamental and all the harmonics in a single output voltage. A fundamental frequency of 256c/s was selected, so that all frequencies should lie comfortably within the audio range, thus enabling the apparatus to be used for aural demonstration.

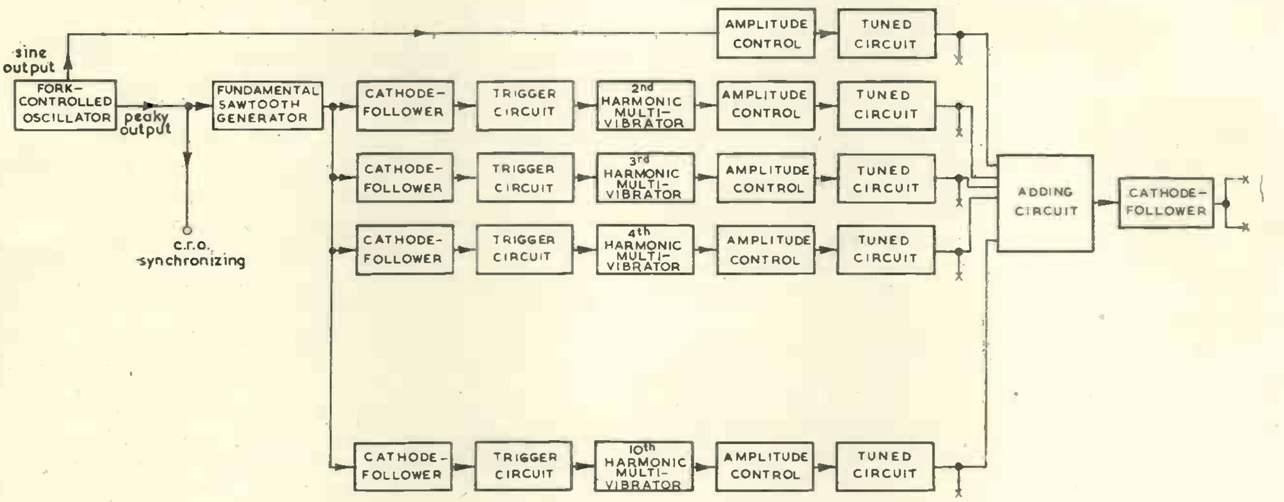


Fig. 1. Arrangement of the synthesizer

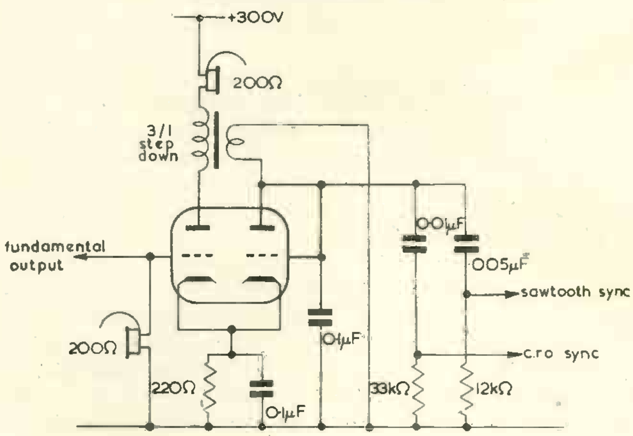
Block Schematic (Fig. 1)

The unit consists essentially of a set of locked multivibrators with resonant circuits to extract a sine wave at each frequency. A different set of synchronizing pulses at fundamental frequency is applied to each of the harmonic multivibrators. The pulses are derived from a variable-delay trigger circuit by means of which it is possible to shift the phase of the harmonic with respect to the fundamental.

Fundamental Oscillator (Fig. 2)

In an arrangement of this sort it is essential for the fundamental frequency to be well stabilized. A short term phase variation of 1° in the fundamental frequency will cause jitter in synchronizing the tenth harmonic to the extent of 10°. Long-term drifts in frequency will detune the resonant circuits and cause the multivibrators to fall out of synchronism. After some experiment, it was decided to use an electrically maintained tuning fork as the master oscillator. This was constructed on a sub-chassis and mounted resiliently in order to minimize sound radiation.

Fig. 2. Fundamental oscillator



* *The British Broadcasting Corporation*

The fork itself was bolted in a horizontal position on to a short length of angle iron while two 2 000Ω telephone earpieces were mounted near the ends on the prongs and parallel to them. The clearance was about one-tenth of an inch. With this arrangement it was found that one-half of a 12AT7 double triode was well able to start and maintain oscillation without the necessity of matching the coils. However, the amplitude was difficult to control, and was usually limited by physical contact between the prongs and the earpieces! To overcome this difficulty, a type of automatic gain control was introduced, whereby the second half of the 12AT7 was diode connected and fed from a transformer in the anode circuit of the amplifier. The rectified current so obtained was passed through a common cathode resistor. This arrangement naturally results in non-linear operation of the triode, but there is no disadvantage in this, because, owing to the very high Q of the tuning fork, the voltage in the grid circuit remains sinusoidal, and therefore suitable for providing the fundamental component of the synthetic waveform. Residual harmonics would, in any case, be rejected by the fundamental tuned circuit. The circuit was found to have the incidental advantage of providing a complex waveform at the second anode which, when differentiated, gave a peaky signal suitable for synchronizing the sawtooth oscillator and the display oscillograph.

Trigger Circuit (Phase Control) (Fig. 3)

A sawtooth voltage is applied to one grid of a multivibrator, while the other grid is held at a positive d.c. potential. Such a circuit gives a square wave output in which the falling edge of the square wave coincides with the falling edge of the sawtooth. The rising edge of the square wave, however, is timed by adjusting the d.c. potential of the second grid. To make the output suitable for synchronizing the harmonic multivibrators it is necessary to differentiate the rising edge and to suppress the falling edge. This is done by means of a *CR* circuit in which the time-constant depends on the polarity of the voltage step. Two WX6 metal rectifiers are used for the purpose.

If a perfect sawtooth waveform were available, it would in theory be possible to move the synchronizing pulse through 360°. In practice, for various reasons, the range available is not more than about 240°. However, this is ample since 240° phase change at fundamental frequency is equivalent to 480° (or $1\frac{1}{3}$ cycles) at the second harmonic frequency. For higher harmonics it is actually necessary to restrict the voltage variations on the second grid in order to obtain a smooth variation in phase over about $1\frac{1}{3}$ cycles of the harmonic in question.

The sawtooth oscillator may be regarded as a cathode-coupled version of a Puckle time-base circuit or as a multivibrator with a capacitor across its output. The oscillator was originally intended to be free-running, but for reasons already mentioned, it was synchronized to the tuning fork. Buffer stages must be inserted between the sawtooth oscillator and the trigger circuits, since the latter take appre-

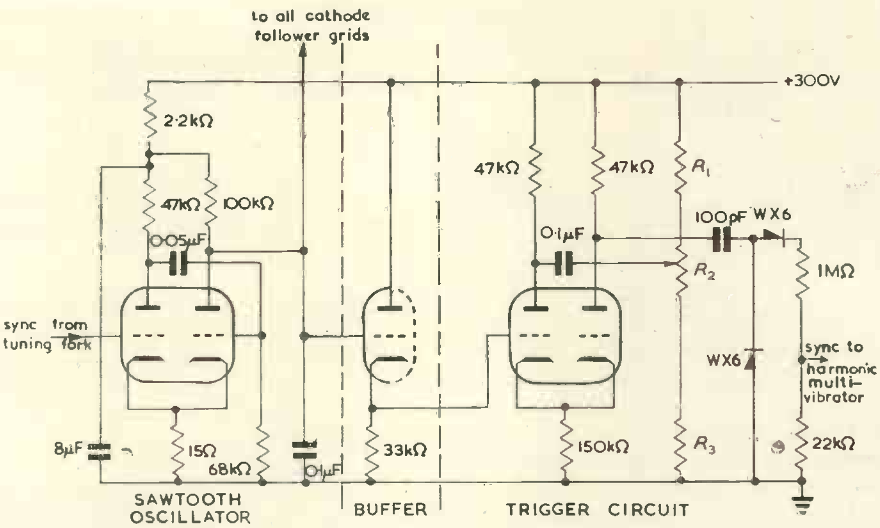


Fig. 3. Phase controlling unit

ciable grid current. Cathode-followers were used for this purpose, and by suitably choosing component values it was possible to use direct couplings.

To simplify wiring, layout, and replacement, it was decided to use a single type of valve throughout. The 12AT7 double triode was chosen on account of its compactness and versatility.

Component values for the trigger circuit are given in Table 1.

TABLE 1
Component Values for Phase Controlling Circuit

HARMONIC	R_1 (kΩ)	R_2 (kΩ)	R_3 (kΩ)
2nd	82	20	27
3rd	54	5	33
4th	56	5	22
5th	56	5	27
6th	56	5	33
7th	56	5	33
8th, 9th, 10th	56	5 shunted by 10	33

Harmonic Multivibrators and Tuned Circuits (Fig. 4)

Conventional cathode-coupled multivibrators were used pretuned by means of C_1 and R_4. A 5kΩ preset variable resistor was placed in series with R_4 to act as a frequency hold adjustment. In practice it has been found that this control very rarely requires adjustment once the unit has warmed up, and then only for harmonics above the 7th. It is, however, important that the control should be set correctly, for if the free-running frequency of the multivibrator differs appreciably from the harmonic frequency the phase control becomes jerky in its action.

The multivibrator output is controlled by a potentiometer ("Amplitude" Control) and a cut-key is wired in parallel. This facility is extremely useful for demonstration purposes, since it permits the amplitude to be pre-set. A buffer amplifier follows, use being made of the second half of the cathode-follower valve. (See Fig. 3.) R_5 is chosen so that the amplifier is not overloaded.

A resonant circuit follows, consisting of a dust-cored toroidal coil of inductance 100mH, tuned by C_2. The voltage appearing across the tuned circuit is taken to a

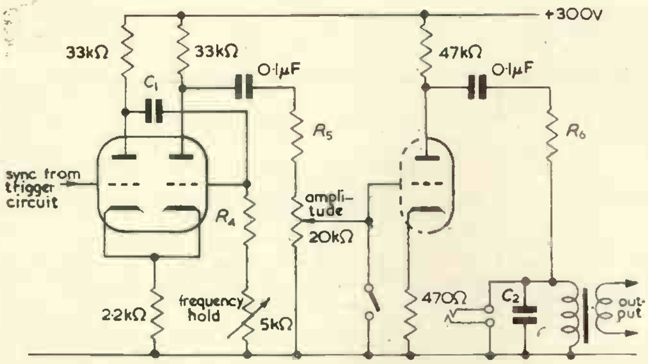


Fig. 4. Harmonic multivibrator and output stage

miniature jack on the front panel, where it is available for monitoring. R_6 is chosen so that the maximum voltage at the jack is about 2V.

The component values for the circuit of Fig. 4 are given in Table 2.

TABLE 2
Component Values for Harmonic Multivibrator and Output Stage

HARMONIC	R_4 (kΩ)	R_5 (MΩ)	R_6 (kΩ)	C_1 (μF)	C_2 (μF)
2nd	51	0·15	47	·008	1
3rd	22	0.51	100	·0087	0.44
4th	22	0.51	100	·005	0·25
5th	56	1·5	47	·003	0·16
6th	39	2·2	100	·003	0·11
7th	78	1·5	47	·002	0·082
8th	56	1·5	100	·002	0·62
9th	47	1·5	220	·002	0·05

Output Stages (Fig. 5)

The fundamental voltage is controlled in a similar way. In this case, however, care must be taken not to damp the tuning fork oscillator, and therefore the cut-key is placed across the tuned circuit. The toroidal coils referred to above carry a second winding of inductance 20mH. It was found that at 256c/s the voltage appearing across the tuned circuit was insufficient, and therefore, to improve the L/C ratio, the two windings were connected in series, thereby raising the inductance to approximately 200mH. At the harmonic frequencies, the Q of the 100mH winding was sufficiently high to give the required voltage output.

Voltage addition was effected by connecting the 20mH windings in series with the fundamental tuned circuit. The series chain feeds into a 500kΩ potentiometer, and under these circumstances no interaction could be detected between the tuned circuits.

Finally a cathode-follower gives a low-impedance (150Ω) feed to two parallel jacks. These were provided so that aural and visual displays could be given simultaneously; alternatively, one jack can be used to feed a voltmeter.

Layout and Power Supplies

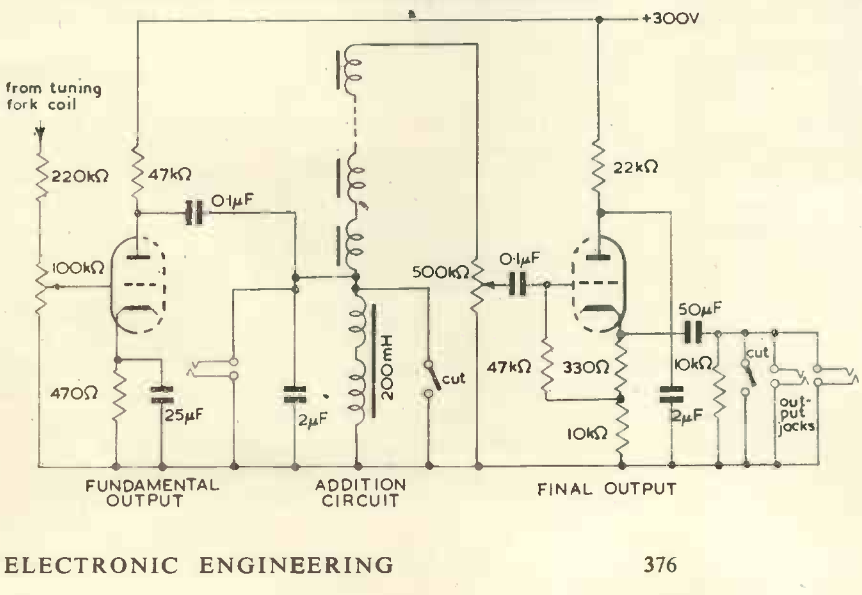
The synthesizer uses three double-triodes for each harmonic frequency, two for the fundamental frequency oscillators and one for fundamental output/total output. Thus 30 12AT7's were required altogether. These were laid out on a chassis measuring 20in by 11½in by 3in deep with a spacing of 2in (along the length of the chassis) by 2¼in (from front to back of the chassis). The front row of nine were the harmonic multivibrators, the second row were the triggering valves, and the third row were the cathode-follower and output valves. Two valves (the saw-tooth oscillator and the output valve) were mounted in a fourth row, the remainder of which was occupied by the tuning coils. The sub-chassis carrying the tuning-fork oscillator was mounted on pillars above the coils.

Fig. 6. The complete synthesizer

The arrangement of the panel, which measures 20in by 10¼in, can be seen from Fig. 6. The jacks and cut-switches are mounted below the chassis, and the potentiometers above. The chassis is housed in a well ventilated metal case.

A separate power pack supplies 175mA at 300V and 4·5A at 12·6V (centre-tapped to earth). This employs a choke-input, two-stage filter. No special stabilization has appeared to be necessary.

Fig. 5. Fundamental output, addition circuit, and final output stages



Applications of the Waveform Synthesizer

In the first place the equipment may be used to compare the effects of odd and even harmonics, i.e. whenever an even harmonic is present the positive and negative half-cycles are dissimilar. The importance of phase relationships is also readily demonstrated.

Before attempting to build up a specific complex waveform, it is advisable to have at hand the appropriate Fourier analysis. The amplitudes are then adjusted to the correct level, either by means of a valve voltmeter in the output circuit, or by measurement on the cathode-ray oscillograph. This procedure saves a great deal of time which might otherwise be wasted in trial and error adjustments. Once the amplitudes are correct, the phase controls

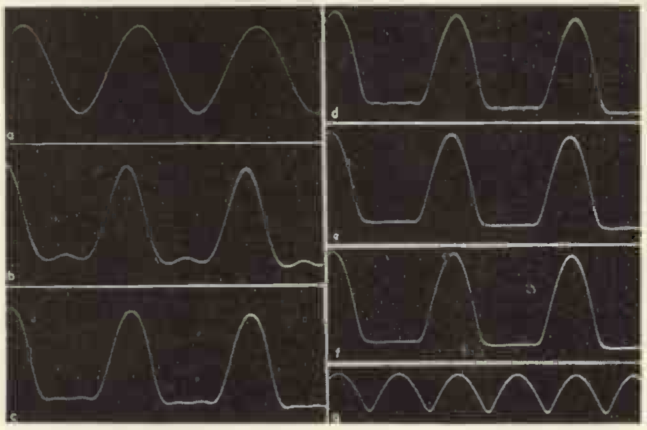


Fig. 7. (a) Fundamental ; (b) Fundamental + 2nd ; (c) Fundamental + 2nd + 4th; (d) Fundamental + 2nd + 4th + 6th ; (e) Fundamental + 2nd + 4th + 6th + 8th ; (f) Fundamental + 2nd + 4th + 6th + 8th + 10th ; (g) Half-wave rectified sine-wave with fundamental suppressed

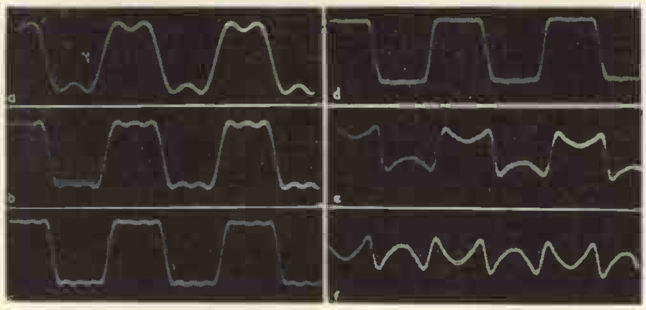


Fig. 8. (a) Synthesis of square wave : Fundamental + 3rd harmonic ; (b) Fundamental + 3rd and 5th harmonics ; (c) Fundamental + 3rd, 5th and 7th harmonics ; (d) Fundamental + 3rd, 5th, 7th and 9th harmonics : (e) As (d) but with fundamental amplitude reduced ; (f) As (d) but with fundamental suppressed.

are easily adjusted by inspection, and the synthesis can be demonstrated by introducing the harmonics in succession. Figs. 7 to 9 illustrate some of the results obtained.

In the synthesis of a half-wave-rectified sine wave (Fig. 7) the Fourier coefficients are as follows:

Harmonic	1	2	3	4	5	6	7	8	9	10
Relative Amplitude	100	42	0	8·5	0	3·8	0	2·0	0	1·3

After this demonstration, it is instructive to deduce the Fourier series for a full-wave rectified sine-wave. This is done simply by suppressing the fundamental frequency (Fig. 7(g)).

Fig. 8 shows the progressive synthesis of a square wave, the amplitude coefficients are in this case: —

Harmonic	1	2	3	4	5	6	7	8	9	10
Relative Amplitude	100	0	33	0	20	0	14	0	11	0

When the square wave has been built up, the fundamental amplitude may be reduced, as illustrated in Fig. 8(c). This waveform may be compared with the output from an amplifier having a poor low frequency response.

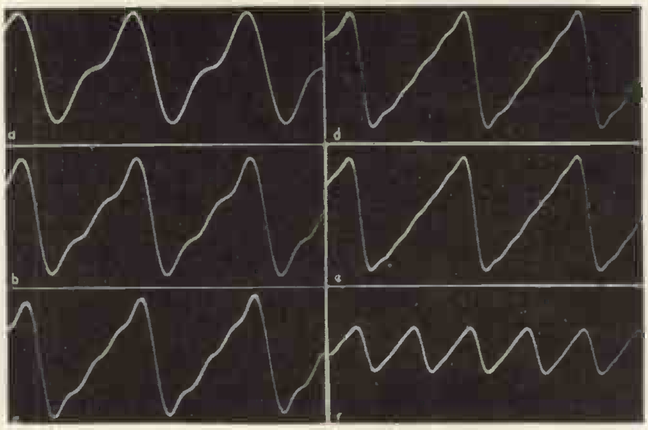


Fig. 9. (a) Fundamental + 2nd ; (b) Fundamental + 2nd + 3rd ; (c) Fundamenta + 2nd + 3rd + 4th ; (d) Fundamental + 2nd + 3rd + 4th + 5th ; (e) Fundamental + harmonics up to 6th; (f) Fundamental and odd harmonics suppressed from sawtooth

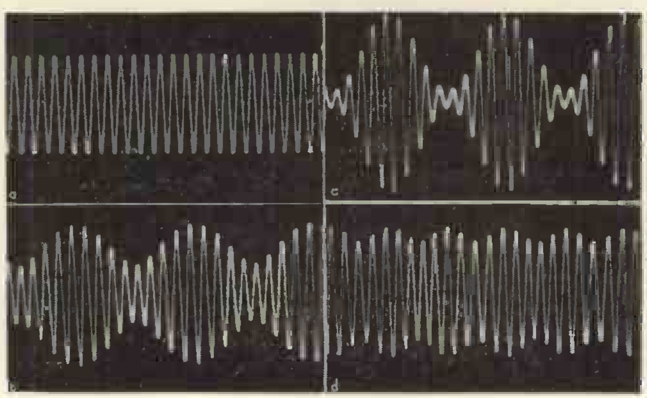
For a sawtooth waveform the amplitude coefficients are as follows:

Harmonic	1	2	3	4	5	6	7	8	9	10
Relative Amplitude	100	50	33	25	20	17	14	12	11	10

The first six frequency components are successively added in Figs. 9(a) to (c). The fundamental and odd harmonics are seen to constitute a square wave, as in Fig. 8, and if these are removed the waveform of Fig. 9(f) produced, i.e. a sawtooth wave of double frequency.

Another type of demonstration refers to the synthesis of modulated waves. Fig. 10(a) shows the 9^{th} harmonic which represents an unmodulated carrier. If 40 per cent of 8^{th} harmonic is added the waveform of Fig. 10(b) results. On casual inspection this appears to be an example of simple amplitude modulation, but in fact the envelope is seen to be non-sinusoidal. Also, the frequency is seen to vary from cycle to cycle. This is explained by reference to Fig. 11(a) in which the 8^{th} harmonic voltage is represented as a vector rotating clockwise at fundamental frequency on the end of the (stationary) carrier vector. V_T represents the instantaneous value of total voltage. This is seen to vary in amplitude by ± 40 per cent, while the instantaneous frequency varies from a minimum (at maximum amplitude) to a maximum (at minimum amplitude). In Fig. 10(c) the upper sideband, consisting of 40 per cent of 10^{th} harmonic has been added, resulting in pure amplitude modulation. The corresponding vector diagram is shown

Fig. 10. (a) Carrier (9th harmonic) ; (b) 9th harmonic and lower amplitude (8th harmonic) ; (c) Carrier + 2 sidebands (9th + 8th and 10th) ; (d) A.M. wave with carrier turned through 90° (showing f.m.)



in Fig. 11(b), in which the upper sideband is represented as a vector rotating at fundamental frequency in an anti-clockwise direction. The resultant of the two sidebands consists of a stationary vector parallel to the carrier, the length of which varies sinusoidally at fundamental frequency. The depth of modulation is seen to be 80 per cent.

If now the carrier phase is shifted by 90°, the oscillogram of Fig. 10(d) is produced. This shows the first stage in the synthesis of a pure frequency modulated wave. The residual amplitude modulation is in a positive sense and occurs at twice the fundamental frequency. The vector diagram is shown in Fig. 11(c). The resultant of the two sidebands

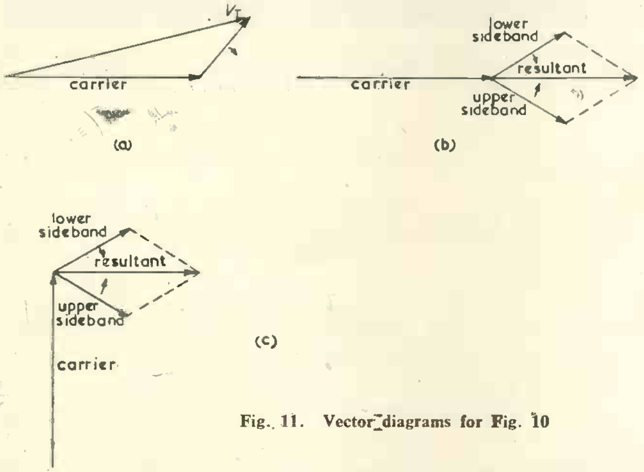


Fig. 11. Vector diagrams for Fig. 10

now acts in quadrature with the carrier, and at the instants when this resultant is a maximum the total waveform has a frequency equal to that of the carrier. The amplitude is then $\sqrt{(1^2 + 0{\cdot}8^2)} = 1{\cdot}3$ times that of the unmodulated carrier. At those instants when the resultant of the sidebands is zero, the frequency of the total waveform is alternately maximum and minimum, while its amplitude is equal to that of the unmodulated carrier. Further stages in the synthesis of a pure frequency modulated wave require higher harmonics and are therefore beyond the scope of the present equipment (unless a lower carrier frequency is chosen—in which case the envelope shapes become confused).

The waveform synthesizer also finds application in the teaching of sound. It may, for example, be shown that the ear is insensitive to phase distortion, and that the apparent pitch of a note may be affected by its harmonic content. The waveforms of musical instruments can be synthesized with a fair degree of success, although the typical character of many is apparent from transients rather than from a sustained note. This applies particularly to stringed instruments (including the piano).

Table 3 gives a list of harmonics amplitudes for different wind instruments. These can all be produced quite recognizably.

TABLE 1
Harmonic Amplitudes for Various Wind Instrumeats

	RELATIVE AMPLITUDES									
HARMONIC	1	2	3	4	5	6	7	8	9	10
FLUTE ..	100	100	10	20	15	2	1	1	—	—
CLARINET	100	—	50	10	60	30	50	30	10	1
SAXOPHONE	100	70	12	50	9	1	—	2	5	—
HORN ..	30	100	60	15	—	—	—	—	—	—
TUBA ..	100	70	9	2	1	—	—	—	—	—
TROMBONE	100	100	50	60	10	2	—	—	—	—

Other uses of the waveform synthesizer will no doubt suggest themselves to those concerned with teaching, and there is little doubt that the student can learn a great deal by experimenting with it at his leisure.

Acknowledgments

In conclusion, the author's thanks are due to Mr. A. W. Pickering for constructing the apparatus, to Dr. K. R. Sturley for his help and encouragement and to the Chief Engineer of the BBC for permission to publish this article.

An Inexpensive Dekatron Scaler

By G. A. Kerkut*, M.A., Ph.D.

The circuit is given of an inexpensive dekatron scaler for use in nerve physiology. A total count of up to seven figures is possible.

NERVE physiologists often require to know the way in which the activity of a preparation varies under specific conditions. One way of achieving this is to film the oscillograph record of the activity and then to count the filmed potentials. This is both tedious and expensive. It is often preferable to use a pulse counter. In some early experiments a commercial scaler of the type normally used in conjunction with a Geiger counter was used and proved to be most satisfactory. Later experiments demanded the use of additional scalers and the problem of cost arose. Details of a scaler that cost less than £25 to build are given in this article.

* *Department of Biochemistry and Comparative Physiology. The University of Southampton.*

The circuit of the scaler is shown in Fig. 1. The nerve impulses after amplification are monitored on the first beam of an oscilloscope and led to the scaler input. They are then fed on to a diode which can be switched to pass either the positive or negative phase of the impulses. The diode is supplied with a variable bias controlled by the 200kΩ potentiometer, so allowing pulses above a given voltage to pass to the first triode. In this way the diode filters off the background potentials and allows single units to be studied. Pulses passing to the first triode are monitored on the second beam of the oscilloscope so that one can determine what is being counted. The first triode (which like all the other triodes mentioned is half of a 6SN7) acts as a phase invertor to the negative phased pulses. The pulses are then led to the scaler proper.

The scaler proper consists of three Ericsson Dekatrons GS10C each being fed through a triode. The value of the anode resistance of these triodes and the values of the capacitors leading to the Dekatron guides are critical if one is to obtain a smooth count. The values indicated on the makers' pamphlet were found to be unsatisfactory and the ones shown in the circuit diagram substituted. These supplied by an 8μF capacitor. The three Dekatrons and the counter give a total of seven figures. The Dekatrons were zeroed by making cathodes 1 to 9 positive so that the discharge jumps to cathode 0. This was found to be much more satisfactory than making cathode 0 more negative than the other cathodes. A 50c/s input was available for use in calibrating the scaler.

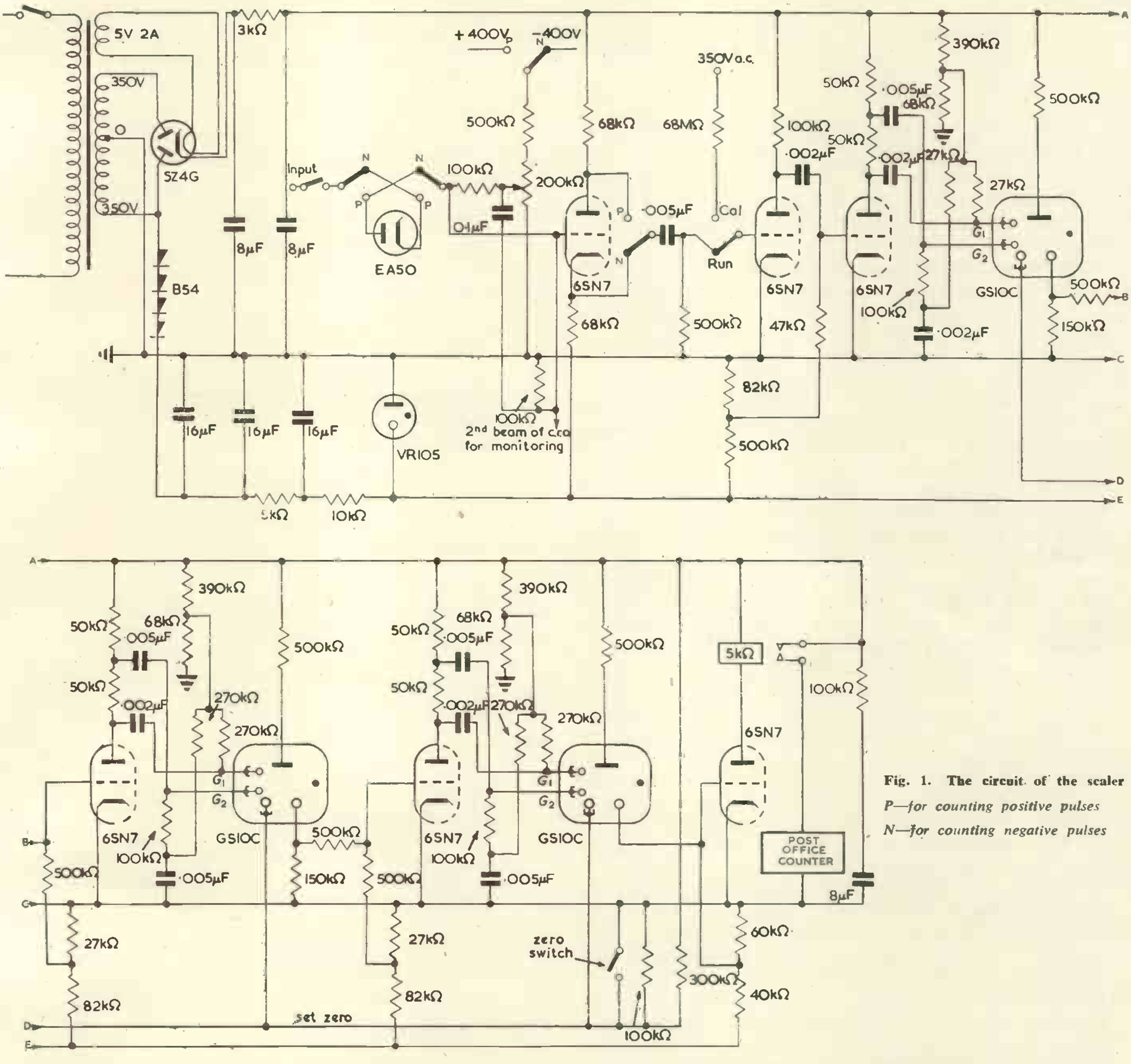


Fig. 1. The circuit of the scaler
P—for counting positive pulses
N—for counting negative pulses

gave smooth regular counting. Some preliminary trouble was found in getting the first Dekatron to trigger the second Dekatron via the intermediate triode. The fault was found to lie in the height and decay time of the pulses coming from the capacitors attached to the anode resistor of the triode. Care has to be taken to avoid stray capacitances in this region. The third Dekatron leads to a relay that drives a Post Office type counter, the relay acting as the anode load of the last triode, while the counter is

The scaler has been in daily use for over a year and has required no maintenance or modification. In a series of preliminary runs the performance of this scaler and a commercial model were compared, both being used to measure the activity of the isolated nerve cords of cockroaches. The machines gave identical counts.

Acknowledgment

The author's thanks are due to Dr. K. A. Machin and Mr. D. Le Croisette for their help.

The Design and Performance of A Simple V.L.F. Oscillator

R. A. Seymour* and J. S. Smith*, B.Sc.

A description is given of the design and performance of a simple oscillator of good amplitude and frequency stability covering the range 0·01 to 100c/s in finite steps. A maximum output of 6V r.m.s. into a 6kΩ load is obtainable.

A NUMBER of circuits have been developed for amplitude-stabilized v.l.f. oscillators, based variously on *RC* phase-shift networks[1], analogue computer methods[2], and counting-down systems, with amplitude control effected by means of thermistors or clipping devices; as all these arrangements are somewhat complicated and require a considerable amount of equipment, it was considered worthwhile to investigate the performance that could be obtained with a straightforward oscillator circuit, using the non-linear characteristic of the valve for amplitude limiting.

A resistance-capacitance frequency control is an obvious choice for the frequency range concerned, both on physical and electrical grounds, particularly as the voltage loss introduced by an *RC* network need not vary as the frequency setting is altered. The simplest form of *RC* network adequate for the purpose is the Wien type, illustrated together with its frequency characteristic in Fig. 1; this network has a minimum voltage attenuation of 9·6dB and zero phase-shift when the angular frequency ω is equal to $1/CR$.

The next requirement of the oscillatory circuit is a driving amplifier giving zero phase-shift between input and output with a gain slightly in excess of the voltage attenuation of the *RC* network, namely 9·6dB. It is also desirable with very low frequency oscillators to avoid the use of a.c. couplings owing to the considerable physical size of the capacitors required, and difficulties due to leakage currents. These requirements are admirably met by the cathode-coupled double-triode amplifier having the form and characteristic given in Fig. 2. The maximum anode current is stabilized by the high value of cathode load resistor permitted by the positive bias on the grids, the slope of the characteristic tends to be rendered more stable by the constant current working conditions imposed. By adjusting the relative bias between the two grids the amplifier is operated at the point of symmetry of the output/input voltage characteristic, this enables even harmonic terms in the oscillator output to be considerably reduced.

With the oscillator in action, equilibrium is established such that the effective loop gain at the fundamental frequency is maintained at unity. Any variation of loop gain will cause the equilibrium amplitude to change in such a way that the change of effective fundamental-frequency gain through the amplifier, due to the non-linear nature of the output/input voltage characteristic, makes up for the initial variation of loop gain.

Let the amplifier output voltage:

$$V_o = a + bv - dv^3 \quad \ldots\ldots\ldots\ldots (1)$$

where v is the amplifier input voltage about the point of symmetry, and a, b and d are positive constants related to the valve and circuit parameters.

* *Post Office Engineering Department.*

If v is assumed to be a sine wave $E \sin \omega t$, a useful approximation if E is small, expression (1) becomes:

$$V_o = a + bE \sin \omega t - dE^3 \sin^3 \omega t \quad \ldots\ldots\ldots (2)$$

which can be expressed in the form:

$$V_o = a + E(b - \tfrac{3}{4}dE^2) \sin \omega t + (dE^3/4) \sin 3\omega t \quad \ldots (3)$$

from which the voltage gain α at the fundamental frequency can be obtained:

$$\alpha = V_{ot}/E = b - \tfrac{3}{4}dE^2 \quad \ldots\ldots\ldots\ldots (4)$$

It will be seen that an increase of input voltage causes a reduction in amplifier gain at the fundamental frequency; without this property the oscillator output would not find an equilibrium level.

From equation (4):

$$\delta\alpha/\delta E = -(3/2)\, dE$$

and:

$$\delta E/E = -(\delta\alpha/\alpha)\, ((2b/3dE^2) - \tfrac{1}{2}) \quad \ldots\ldots (5)$$

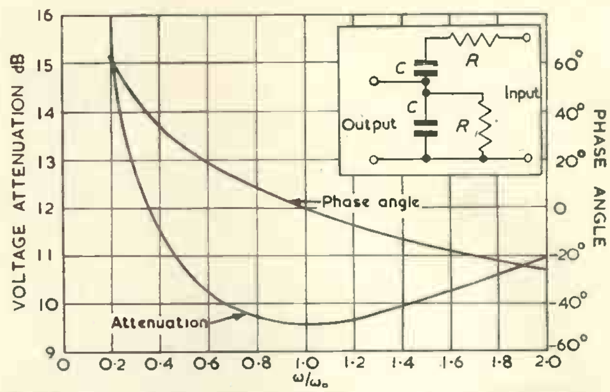
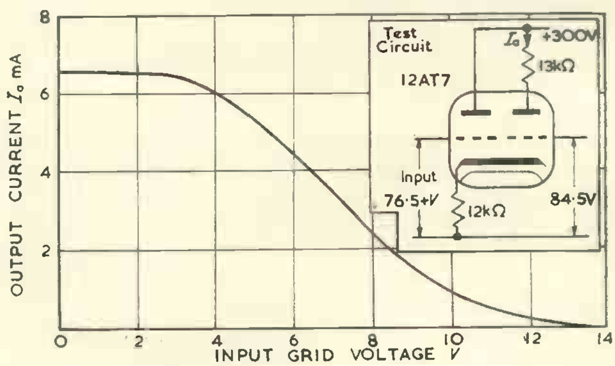


Fig. 1. Attenuation and phase angle/frequency characteristic of basic frequency control network at a given setting $\omega_o = 1/CR$

Fig. 2. Transfer characteristic measured on the given double-triode cathode-coupled amplifier



This expression shows that for a given change of gain $\delta\alpha/\alpha$, the amplitude change $\delta E/E$ becomes very large when the input voltage becomes small; unfortunately this is also the condition for minimum harmonic content as shown from expression (3). The purity of oscillator output obtainable will therefore be limited by the degree of amplitude stability required and the inherent stability of the oscillator loop gain. For example, if a 1 per cent or 40dB third harmonic content is required, then from equation (3):

$$\frac{dE^2}{4(b - \frac{3}{4} dE^2)} = 0{\cdot}01$$

and:

$$b/dE^2 = 25{\cdot}75 \quad \text{.................. (6)}$$

substituting equation (6) in equation (5):

$$\delta E/E = -(\delta\alpha/\alpha)\ 16{\cdot}6 \quad \text{.............. (7)}$$

This shows that a change in loop gain of 0·01dB will cause a 0·17dB change of output, if the oscillator has been adjusted to have a 3rd harmonic 40dB below the fundamental. To achieve the best output level stability stabilized power supplies are required, and switched pre-set components used in the frequency determining network to eliminate ganging difficulties.

To provide an efficient d.c. coupling from the oscillator stage to the output stage a neon filled voltage reference valve is used[3,4], which operated at approximately 2mA d.c. has an incremental resistance of the order of 200Ω.

The output stage is designed to meet the following general requirements:

(1) To remove the d.c. component.

(2) To provide control of output level with a fixed output impedance.

(3) To be stable and relatively free from harmonic distortion.

These conditions can be met by using a cathode-follower stage feeding an output attenuator, and having a similar stage to back-off the d.c. component; stability is further enhanced by having high values for the cathode load resistors permitted by the use of a high value of positive grid bias. In addition, the impedance of the output attenuators is made high compared with the incremental cathode resistance of the valves. For convenience of operation the negative line of the h.t. supply is left floating, thus permitting one side of the output circuit to be connected to earth. To improve the utility of the oscillator it was felt that some means of monitoring the output level should be incorporated; this function could, of course, be performed by means of a d.c. voltmeter at the lower end of the frequency range, but above 2 or 3c/s due to the inertia of the meter movement the readings would become increasingly inaccurate. A solution that has been employed before is to incorporate a small oscilloscope, but a simpler method involves the use of two trigger circuits arranged to give neon lamp indications when the peak of the generated signal lies between two pre-determined voltage limits. Thus, when the signal level is correct one neon flashes at each positive peak of the signal, both neons flash when the level is greater than normal, and neither flash when the level is too low. For this purpose a most convenient and reliable type of trigger circuit is that due to O. H. Schmitt[5], which has the form shown in Fig. 3, this also shows the type of transfer characteristic obtained with the given circuit. The output anode current remains constant as the input voltage varies from (a) towards (b), but between (b) and (c) the output current falls very rapidly to zero by regenerative action, causing a neon indicator lamp (not shown) to ignite. As the grid voltage decreases the output current remains at zero until the point (d) is reached, when the current rapidly returns to the initial value and the neon indicator extinguishes. The overlap or backlash between the transitions serves a useful purpose in increasing the duration of the flash from the neon indicator. The upper current limit is well stabilized by means of the high value of cathode load resistor permitted by the use of a high positive grid bias value. The total grid voltage at which the transition from (b) to (c) takes place can be adjusted by varying the bias applied to the grid of the output triode.

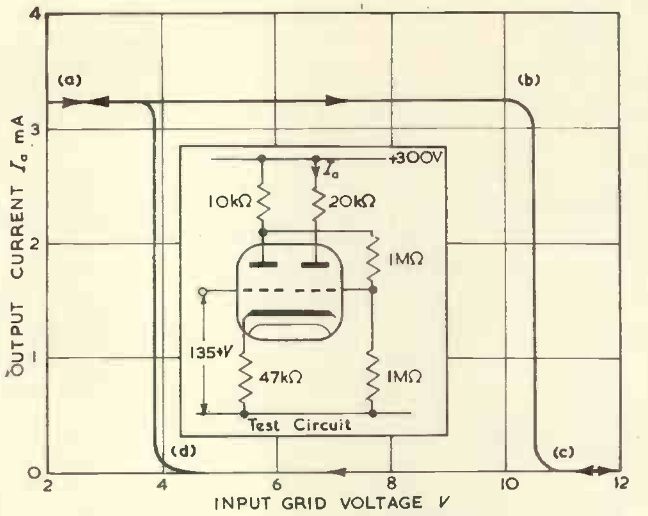


Fig. 3. Measured transfer characteristic of Schmitt-Trigger circuit

Description of Circuit

The schematic circuit of the complete oscillator is given in Fig. 4. Valve V_1 provides the driving amplifier for the oscillatory loop circuit, which is completed via the frequency control network N_1; manual control of loop gain to a limited degree is provided by means of the pre-set control VR_2. The voltage reference valve V_3 provides the stable bias to the grids of V_1 required by the use of a high value of cathode load resistor. The 1·8kΩ resistor between point C and V_3 is incorporated to improve the calibration accuracy of the frequency control network, and its resistance is approximately half that presented by the amplifier at point A. Potentiometer VR_1 permits a relative adjustment of bias at the grids of V_1, to ensure that the excursion of anode current due to the generated oscillation is symmetrically placed on the straight portion of the transfer characteristic, even harmonics being reduced to a minimum in the process.

The detailed circuit diagram of the frequency control network is given in Fig. 5. The chosen network design employs equal values of capacitors and resistors in the series and shunt arms, the resistors being selected by switch S_1, which is calibrated in 1c/s steps from 1 to 10c/s, and the capacitors by means of switch S_2, which is calibrated as a multiplier in decade ranges from "divide by 100" to "multiply by 10". A feature of the design is the provision of facilities for keeping the capacitors in the series arm of the network charged to the normal working d.c. voltage when not in use, by means of the 120kΩ resistor from point

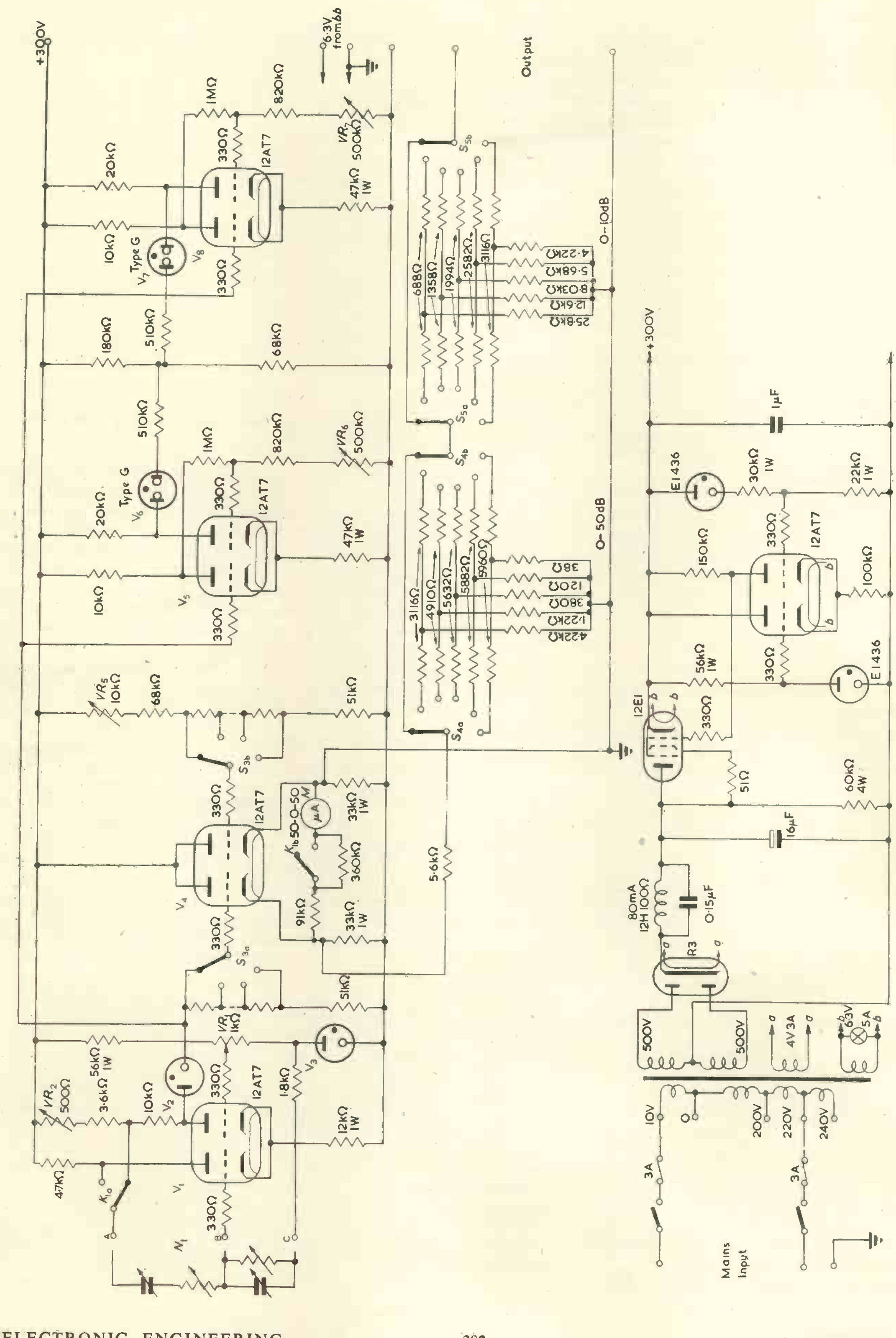


Fig. 4. The circuit of the oscillator

Switch S_3: wafers a and b each have 23 series resistors of the following values starting from the high potential end, namely 6 × 620Ω, 6 × 820Ω, 5 × 620Ω. Resistors high stability ½ watt carbon, unless otherwise stated. Grid resistors ¼ watt carbon, rod type.

A, thereby reducing the transient disturbance when changing range, and hence reducing the time required to reach steady-state conditions.

Returning to Fig. 4, the d.c. coupling from the anode of V_1 to the input grid of V_4 is provided by the voltage reference valve V_2, which operates at 2mA d.c. and gives a d.c. voltage drop of 85V; its incremental resistance is of the order of 200Ω. At the grid of V_4 the peak value of the combined a.c. and d.c. components are monitored by means of the Schmitt trigger circuits V_5 and V_8, the indicator neon V_6 firing when the input voltage to V_5 reaches a predetermined positive value, and V_7 firing if the input voltage to V_8 reaches a given upper limit. The input voltage at

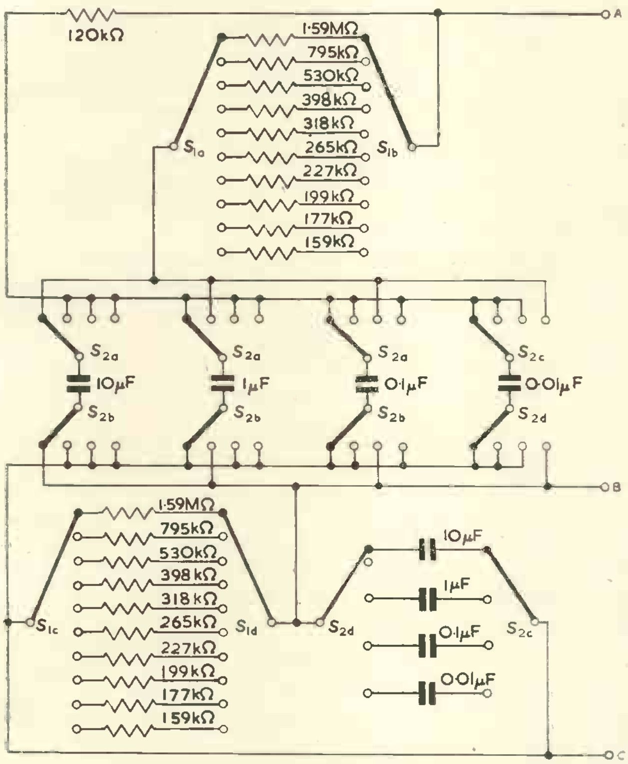


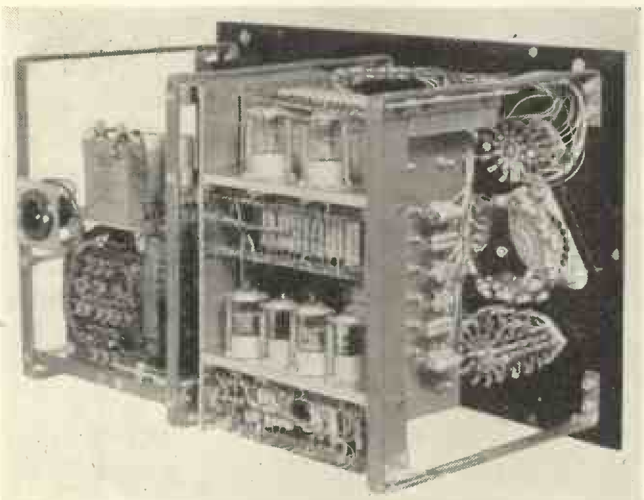
Fig. 5. Circuit of frequency control network
±1 per cent tolerance on component values.

which the trigger circuits operate can be adjusted by means of the variable resistors VR_6 and VR_7 for their respective circuits.

The cathode-follower output stage, utilizing the input triode of V_4, is fed from the fine output control switch S_{3a}, which covers a range of 2·3dB in steps of 0·1dB. An output circuit resistance of the order of 6kΩ is used to obtain an adequate degree of negative feedback to secure constancy of loss between input and output voltages with low harmonic production. Another circuit of identical form utilizes the output triode of V_4 to remove the d.c. component from the oscillator output, the balancing adjustment being accomplished by means of the variable resistor VR_5 and observed on the meter M, a null deflexion being achieved.

The sensitivity of the meter is increased during the adjustment process through the operation of the key K_1, this also suppresses the oscillation by transferring the input side of the frequency control network from its normal connexion to the anode of the input triode of V_1, which has a similar d.c. potential; thus any d.c. changes between the input grid of V_1 and the point of measurement at the cathode of V_4 are taken into account, and the presence of any leakage current through the series capacitors of the frequency control network can be detected. The resistor chain on switch S_{3b} is identical to that on S_{3a} and is required to prevent upsetting the d.c. adjustment when the fine output control is operated.

The complete oscillator



A rear view of the oscillator

The output is taken via variable attenuator pads controlled by switches S_4 and S_5, giving a total range of 60dB in steps of 2dB, and an impedance of 6kΩ. As the negative line of the h.t. supply is floating, the common side of the output circuit is connected to the oscillator frame, and can be earthed at the output terminals.

The power unit is of a conventional type employing a choke input filter tuned to resonate at 100c/s, and with a 60kΩ bleeder resistor to reduce the voltage rise at low values of load current. The stabilizer consists of a 12E1 series regulator valve controlled by a double-triode amplifier, to which the error voltage is fed by means of the two neon stabilizer valves across the output circuit.

Performance

Frequency

At all frequency settings the actual frequency is within ±2 per cent of the nominal, and with a mains variation of ±5 per cent the frequency change is less than ±0·01 per cent.

Output Level

The maximum output level is 6V r.m.s. into a 6kΩ resistive load with variations not exceeding ±0·3dB as the frequency settings are altered without re-adjustment of level.

An increase in mains voltage of 5 per cent from nominal, causes a decrease of 0·5dB in output level; this is largely due to variations in heater voltage and an improved performance could be obtained by stabilizing the heater supply.

D.C. Component in Output

Without re-adjustment, a ±5 per cent change of mains voltage results in a ±1V variation in the d.c. component at the oscillator output when terminated with 6kΩ, and with the output controls set to maximum output level.

Harmonic Production

With the maximum output level at 6V r.m.s., and with the even harmonics reduced to a minimum, the relative harmonic levels obtained are: 2nd −50dB, 3rd −38dB, 4th −60dB, 5th −65dB.

Hum

The hum level is 50dB below the signal for the majority of frequency settings; at 50 and 100c/s settings, a beat of 1 per cent of signal amplitude occurs at the difference frequency.

Trigger Circuits

If the generated signal level is held constant, a 5 per cent increase in mains voltage causes the trigger circuit to indicate an apparent decrease of 0·2dB in signal level.

Power Unit

The h.t. output has an incremental resistance of about 22Ω up to 60 mA, and a ±5 per cent change of mains voltage does not cause more than a ±0·1 per cent change in output voltage. The mains hum components are: 30mV r.m.s. at 50c/s, 350mV r.m.s. at 100c/s and 280mV r.m.s. at 200c/s.

The normal load on the unit consists of 33mA at 300V

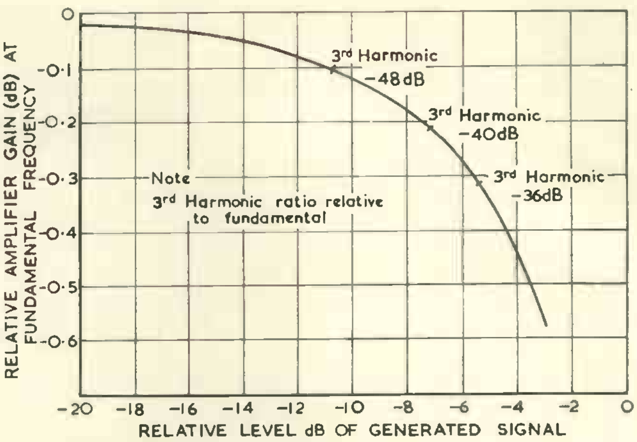


Fig. 6. Measured relationship between amplifier gain at the fundamental frequency and the amplitude of the generated signal

d.c. and 1·2A at 6·3V a.c.; with this loading the total consumption of power from the mains is 80W.

Check of Amplifier Characteristics

Fig. 6 shows a measured curve relating change of loop gain at the fundamental frequency component to oscillator output level; the level of third harmonic relative to that of the fundamental component for several values of the latter is also given. It can be seen from these results that the assumption of a cubic law for design purposes is reasonably justified.

Acknowledgments

Acknowledgment is made to the Engineer-in-Chief of the General Post Office for permission to make use of the information in this article. The photographs are reproduced by courtesy of British Telecommunications Research Ltd. who carried out the mechanical design of the model illustrated.

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Rugby Radio Extension

At the end of July a new extension to the G.P.O. radio station at Rugby was opened. The new site comprises some 700 acres on the opposite side of Watling Street to the old site.

The 28 transmitters in the new station are housed in three transmitter halls built in the plan of a letter T. At the junction of these is a glassed-in central control position from which the control engineer has complete supervision over every transmitter, being able to start, stop or change to any one of six operating frequencies on each of them or to change the aerial. The aerial selector switches under his control are divided into two groups, each group controlling up to a maximum of 40 aerials and 14 transmitters. At this control position information on the performance of each transmitter carrying traffic is continually displayed, and further facilities are provided for a more detailed check of any particular transmissions.

Transmitter Drive and Monitoring Equipment

The signals arriving at the station by land-line from London are translated into forms suitable for application to the transmitters by two types of drive unit; one for telephony, multi-channel telegraphy and picture transmission, and the other for different types of telegraphy. The drive units deliver low-power signals centred on a frequency of 3·1Mc/s to the transmitters.

Each drive unit includes a monitoring receiver which is used in conjunction with other apparatus for comparing automatically the signals arriving at the station with those leaving the transmitter. If the two signals do not agree, within a given tolerance, an indication is given at the central control position.

Transmitters

All 28 transmitters are of the same type, the Marconi type HS.51, which has previously been described in some detail[1]. This transmitter operates in the band from 4 to 27·5Mc/s and has a peak envelope power of 30kW; it is designed for operation on independent sideband telephone

The central control desk

or frequency-shift and on-off telegraph services. Since both sidebands are used each transmitter can deal with, for example, four telephone channels or two telephone channels and six telegraph channels. Third order inter-modulation products are not greater than −36dB relative to either of two equal testing tones for any power level up to full peak envelope power and harmonic radiation is less than 20mW.

All the valves in the transmitters are air cooled and each transmitter can be pretuned to six spot frequencies, any one of which can be remotely selected by motorized controls.

Aerials, Transmission Lines and Selector Switches

The majority of the 58 aerials so far provided are multi-wire rhombics. The aerials are connected to the building by open-wire transmission lines, but inside the building balanced coaxial feeders are used, the connexion between the two being by four wire exponential lines.

The aerials are connected to the transmitters via two interconnected motor-driven twin coaxial aerial switches which have been described by Gillam[2]. Each of the 14 transmitters associated with a switch is connected to a separate horizontal switch deck, and up to six of the aerial feeders which descend vertically on both sides of the switch can be connected to any one deck. Any one of these six aerials can be selected from the central control deck. Cross-connexions between the two switches can also be made. Electrical interlocking with the normal transmitter protective circuits is provided and, in addition, a special safety interlock system is used in which a low air pressure is maintained in each group of feeders. Release of this air pressure, when any feeder coupling is loosened, trips the power contactor of the associated transmitter. By means of a portable switch unit, having plug-in connexions, it is possible to operate any one deck locally instead of from the

The aerial selector switch

A group of telephony drive units

One of the transmitter halls

remote position for the purpose of testing or servicing. The use of this local test unit automatically opens the interlock circuit of the associated transmitter.

Design and Construction

The station as a whole was designed by the Engineering Department of the General Post Office who also provided the external and some of the internal plant. The buildings were designed by the Ministry of Works and constructed by Messrs. Foster and Dicksee. The transmitters and most of the associated equipment, including the aerial switches and central control position were designed and manufactured by Marconi's Wireless Telegraph Co. Ltd, to Post Office specifications.

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The Design of Hard-Valve Binary Counters

By D. M. Taub*, M.Sc., A.M.I.E.E.

A conventional counting circuit is considered. Tolerances on component values, valve characteristics and supply voltages are discussed and a method of design proposed in which these tolerances are taken into account. The method is valid at counting speeds up to several kc/s and may be used where coupling between the stages is carried out with hot-cathode or selenium diodes.

ONE of the commonest circuits in electronic switching and counting applications is the Eccles-Jordan or bistable circuit[1] shown in Fig. 1. Several papers on its design have been published during the last few years[2,3]; they give methods of obtaining the necessary steady-state conditions and maximum operating speed with given tolerances on the supply voltages, resistor values and valve characteristics.

A more complex case occurs when several circuits of this type are connected together as shown in Fig. 2 to form a binary counter. Here, in addition to the above considerations, each stage must be designed to produce a great enough triggering pulse to operate the succeeding stage. Where hot-cathode diodes are used as the coupling elements this presents no difficulty, and a common design rule has been to make R_N about three times as great as R_M. For operation at speeds not exceeding a few kc/s, however, it is possible to use miniature selenium rectifiers, thereby considerably reducing the number of hot-cathode valves required. Considerations of speed are now no longer important, but the high forward resistance of the rectifiers increases the difficulty of obtaining an adequate triggering pulse, and makes the steady-state conditions more difficult to analyse. The design of the circuit under these conditions is considered in the present article. A similar design procedure could be used with germanium rectifiers as the coupling elements. In this case, however, it might be necessary to consider the reverse resistance of the rectifiers, though the forward resistance could generally be neglected.

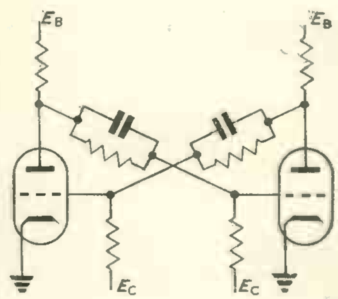

Fig. 1. Eccles-Jordan circuit

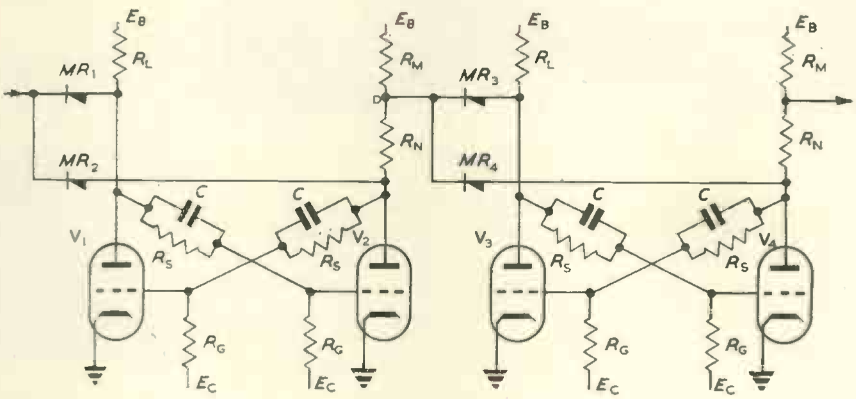

Fig. 2. Binary counter

Tolerances

H.T. Supply Voltages

Counting circuits can generally be designed to tolerate an h.t. voltage variation of about ±5 per cent. This figure is easily obtained with conventional stabilizer circuits.

Resistors

The tolerance figure used in design calculations must take account of the following factors:

(a) initial selection tolerance,

(b) voltage coefficient,

(c) temperature coefficient,

(d) drift during life.

Values of (b), (c) and (d) may be obtained from Specification RCS 112 of the Inter-Service Standards for Radio Components[4]. In the case of carbon rod resistors, changes in resistance of about 20 per cent of the nominal value may occur, making them unsuitable in many cases. Cracked carbon resistors are more satisfactory; their stability depends on the wattage rating, value and climatic conditions. Typical figures for ½ watt resistors covering factors (b), (c) and (d) are ±2 per cent for temperate conditions and ±5 per cent for tropical and arctic conditions.

Capacitors

The value of the cross-coupling capacitor C is not usually critical. Where figures for temperature coefficient and drift are required they may be obtained from specifications RCS 132 and 133 of the Inter-Service Standards[4].

Valve Characteristics

Unfortunately there is little published data on the initial spread of valve characteristics and the deterioration to be expected during life. In the case of valves used by the Services some useful guidance can be obtained from the C.V. Specifications[5], but the information provided there is not usually adequate. The only course, therefore, is to make an estimate based on experience, and the following method is suggested.

* Ericsson Telephones Limited.

Two characteristics of the valve are required:

(a) the anode current/anode voltage characteristic when the valve is conducting,

(b) the cut-off value of grid potential, i.e. the value which reduces the anode current to a negligible magnitude.

Consider first a valve in the conducting state. The supply voltages and resistor values are so proportioned that if no grid current flowed the grid potential would not fall below earth. However, because of the initial velocities of the electrons and the grid circuit resistance, the grid reaches an equilibrium potential of about $-0{\cdot}5$V. The characteristic required is thus the anode current/anode voltage curve at this grid potential.

The characteristic for an average new valve may be obtained from the manufacturer's data. Let it be plotted as shown by curve OA in Fig. 3. It may then be assumed that the maximum anode current at any anode voltage will be 30 per cent greater than the average, as shown by OB, and that the minimum, making due allowance for ageing, will be 50 per cent less, as shown by OC. A figure of 60 per cent less is sometimes used, but this is thought to be necessary only when the valve is used near its maximum rating.

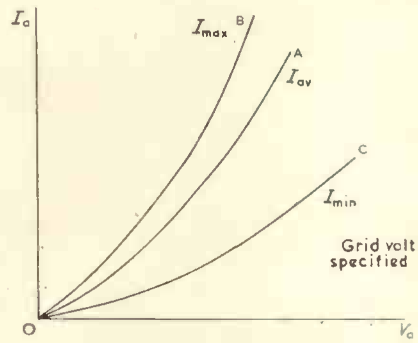

Fig. 3. Valve characteristics

For the cut-off potential a value some 30 per cent higher than that given in the manufacturer's curves should provide an adequate safety margin.

Design Procedure

In designing the circuit the following basic requirements must be met.

(1) When one valve in a stage is conducting, the grid potential of the other must be below the cut-off value.

(2) The grid potential of a conducting valve must not be less than zero (neglecting grid current).

(3) Each stage must produce a great enough triggering pulse to operate the succeeding stage.

A rigorous approach to the design would be to translate these requirements into a set of simultaneous equations. The equations would, however, be difficult to handle because of the complexity of the circuit, and the fact that the valve and rectifier characteristics cannot be accurately expressed in a simple mathematical form. Instead, the method used is to sub-divide the requirements in such a way that each can be stated in terms of one or two variables. The design can then be built up stage by stage as follows.

First a value is chosen for the maximum anode potential of a valve in the conducting state. It is then possible to determine R_S and R_G (see Fig. 2) to fulfil condition (1). From these and the valve characteristics a suitable value for R_L and $(R_M + R_N)$ is obtained. The triggering conditions are then analysed and a figure obtained for the minimum amplitude of triggering pulse; the relative proportions of R_M and R_N to produce this pulse are then found. Finally, the following checks are carried out to ensure that the coupling between stages does not cause any departure from the acceptable steady-state conditions. Referring to Fig. 2, suppose that V_1 and V_4 are non-conducting and V_2 and V_3 conducting. Current then flows through MR_4 lowering the anode potential of V_4 and the grid potential of V_3. It must be verified that, neglecting grid current, the potential of this grid cannot fall below earth, in accordance with requirement (2). The current through MR_4 also causes the effective anode load resistance of V_2 to be less than $(R_M + R_N)$. It must be verified that this effective resistance is not so low as to enable the anode potential to rise above the permitted value.

Details of the design procedure are set out later. For simplicity of expression they are given as a set of rules, each rule being followed by the relevant calculations. It should be noted that the terms "greater than", "less than", "maximum" and "minimum" are used there in the algebraic sense, e.g. when dealing with negative quantities, -95 is considered to be greater than -100.

Principal Symbols

The various voltages and currents in the circuit are identified by a suffix letter which indicates the point in the circuit at which they occur, and where necessary by a figure which differentiates between the values at a particular point under different circumstances. Capital letters are used for steady-state values, and small letters for instantaneous values. The principal symbols are as follows:

E_B = potential of positive h.t. supply line.

E_C = potential of negative h.t. supply line.

$\pm x$ = fractional tolerance on h.t. voltages (assumed to be the same for both supplies).

$\pm y$ = fractional tolerance on resistor values (assumed to be the same for all resistors).

$\pm z$ = fractional tolerance on capacitor values.

E_{A_1} = maximum anode voltage of a conducting valve.

E_{A_2} = minimum anode voltage of a conducting valve.

E_{A_3} = minimum anode voltage of a non-conducting valve.

I_{A_1} = minimum anode current of a conducting valve at an anode voltage E_{A_1}.

E_{G_1} = maximum grid voltage of a non-conducting valve.

E_{G_2} = minimum grid voltage of a non-conducting valve.

Δe_{A_6} = minimum amplitude of triggering pulse at the anode of the coupling rectifier.

R_L, R_M, R_N, R_S, R_G, C: nominal values of components as shown in Fig. 2.

Design Calculations

Given: E_B, E_C, x, y, z, valve characteristics and limit characteristics of the coupling rectifiers.

(1) Assume a value for E_{A_1}. Where this is not dictated by external conditions it may conveniently be $\frac{1}{4}$ to $\frac{1}{3}$ of E_B.

(2) Determine values of R_S and R_G to ensure that when one valve in a stage is conducting the grid potential of the other is below the cut-off value, E_{G_1}. The most adverse limits on voltage and resistor values are shown

in Fig. 4. The required condition is given by:

$$\frac{R_G(1+y)}{R_G(1+y)+R_S(1-y)}\,[E_{A_1}-E_C(1-x)]+E_C(1-x)<E_{G_1}$$

which simplifies to:

$$(R_S/R_G)>\frac{1+y}{1-y}\cdot\frac{E_{A_1}-E_{G_1}}{E_{G_1}-E_C(1-x)}\quad\ldots\ldots\ldots(1)$$

R_S and R_G are usually of the order of several hundred kilohms. Where high operating speeds are not required the larger of the two may conveniently be 1MΩ.

(3) Determine the minimum potential E_{A_3} at the anode of a non-conducting valve to ensure that the grid potential of the other valve in the same stage does not fall

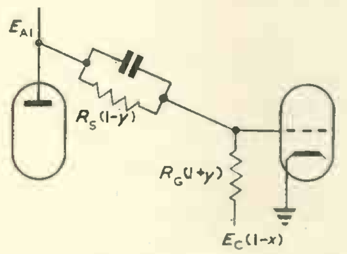

Fig. 4. Limits for determining R_S and R_G

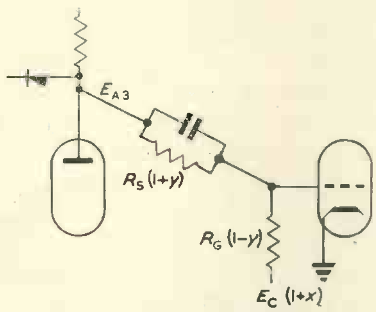

Fig. 5. Limits for determining E_{A_3}

below earth. The most adverse conditions are shown in Fig. 5. E_{A_3} is given by:

$$\frac{R_G(1-y)}{R_G(1-y)+R_S(1+y)}\,[E_{A_3}-E_C(1+x)]+E_C(1+x)=0$$

from which:

$$E_{A_3}=-\frac{(1+y)(1+x)}{(1-y)}\cdot\frac{R_S\;E_C}{R_G}\quad\ldots\ldots(2)$$

This quantity is used later in the calculation (step (11)). As a rough interim check it should not be greater than about $\frac{1}{4}E_B$, to allow for the voltage drop in R_L or (R_M+R_N) due to current flowing through the coupling rectifier.

(4) Determine the minimum limit value of anode load resistance, R_K, to ensure that the anode potential of a conducting valve does not exceed E_{A_1}.

With the anode potential of a conducting valve at E_{A_1}, determine the minimum current I_{S_1} flowing in the associated potential divider chain R_S, R_G. This occurs under the conditions shown in Fig. 6, giving:

$$I_{S_1}=\frac{E_{A_1}-E_C(1-x)}{(R_S+R_G)(1+y)}\quad\ldots\ldots\ldots\ldots(3)$$

At an anode potential E_{A_1} the valve takes a minimum current I_{A_1} as determined from valve characteristic (Fig. 3). The minimum current through R_K is thus $I_{A_1}+I_{S_1}$, which must produce a voltage drop $E_B(1+x)-E_{A_1}$. Thus:

$$R_K=\frac{E_B(1+x)-E_{A_1}}{I_{A_1}+I_{S_1}}\quad\ldots\ldots\ldots\ldots(4)$$

(5) Determine R_L and (R_M+R_N) as follows.

Referring to Fig. 2, when V_2 or V_4 is conducting its effective anode load resistance is made up of R_M, R_N, the forward resistance of a coupling diode, and the load resistance of the non-conducting valve in the next stage. The minimum limit value of this resistance must not be less than R_K. The minimum value of (R_M+R_N) i.e.

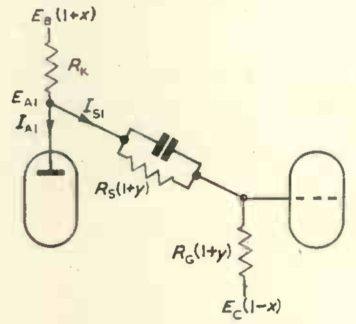

Fig. 6. Limits for determining I_{S_1} and R_K

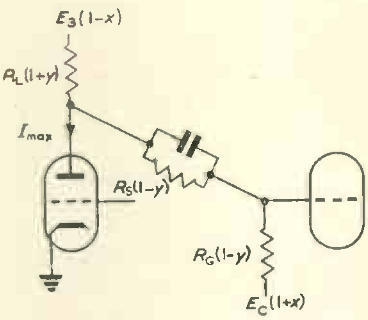

Fig. 7. Limits for determining E_{A_2}

$(R_M+R_N)(1-y)$ must therefore be at least, say, αR_K, where α is a factor greater than 1. For each stage to be symmetrical R_L should be equal to (R_M+R_N), and so, from equation (4):

$$R_L=(R_M+R_N)>\alpha\frac{E_B(1+x)-E_{A_1}}{(1-y)(I_{A_1}+I_{S_1})}\quad\ldots\ldots(5)$$

An accurate value of α cannot be obtained until the relative proportions of R_M and R_N are known. In practice, however, α is seldom greater than about 1·1, and R_L and (R_M+R_N) should be calculated using this value. When R_M and R_N have been determined an accurate check of this point must be made as shown later (step (12)).

(6) Determine the minimum potential E_{A_2} at the anode of a conducting valve. This is obtained when the conditions in the circuit are as shown in Fig. 7. Applying Thevenin's theorem, the anode may be considered to be returned through a resistance:

$$R_L'=\frac{1}{\dfrac{1}{R_L(1+y)}+\dfrac{1}{(R_S+R_G)(1-y)}}\quad\ldots\ldots(6)$$

to a potential:

$$E_B' = \frac{(R_S + R_G)(1 - y)}{(R_S + R_G)(1 - y) + R_L(1 + y)} \times [E_B(1 - x) - E_C(1 + x)] + E_C(1 + x)$$

$$= \frac{E_B(1 - x)}{1 + \dfrac{R_L}{R_S + R_G}\dfrac{1 + y}{1 - y}} + \frac{E_C(1 + x)}{1 + \dfrac{R_S + R_G}{R_L} \cdot \dfrac{1 - y}{1 + y}} \quad \ldots\ldots\ldots\ldots\ldots (7)$$

A load line is now drawn on the valve characteristics in Fig. 3, intersecting the E axis at E_B' and the I axis at E_B'/R_L'. The intersection of this line with the I_{max} characteristic gives the required value of E_{A_2}.

It will be seen that this value is obtained only when the limits of voltage and resistance are as shown in Fig. 7, and similarly that the maximum anode voltage E_{A_1} is obtained only with the limits shown in Fig. 6. However, to simplify the following calculations it will be assumed that the values depend only on the valve, and apply throughout the range of supply voltage and resistor values. Provided that R_L is not less than 2 or 3 times the anode resistance of the valve, the resulting error is not serious and is in such a direction as to provide a small margin of safety. Similar simplifying assumptions are made elsewhere in the calculation.

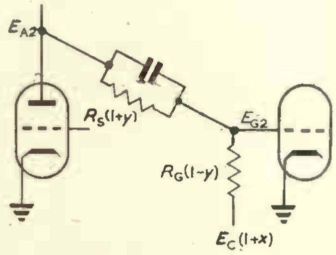

Fig. 8. Limits for determining E_{G_2}

(7) Determine the minimum potential E_{G_2} at the grid of a non-conducting valve. The appropriate limits are shown in Fig. 8, giving:

$$E_{G_2} = E_{A_2} - \frac{R_S(1 + y)}{R_S(1 + y) + R_G(1 - y)} [E_{A_2} - E_C(1 + x)]$$

$$\doteq \frac{E_{A_2}}{1 + (R_S/R_G) \cdot \dfrac{1 + y}{1 - y}} + \frac{E_C(1 + x)}{1 + (R_G/R_S) \cdot \dfrac{1 - y}{1 + y}} \quad \ldots (8)$$

(8) Determine C as follows:

To facilitate triggering C should be made as large as possible consistent with allowing the circuit to reach a steady state between successive triggering pulses. The time taken to reach a steady state may be taken as about four times the time-constant of the grid circuit. Generally R_S and R_G are large compared with R_L and the anode resistance of the valve; the maximum value of the time-constant is then given approximately by:

$$\tau = \frac{C(1 + y)(1 + z)}{(1/R_S) + (1/R_G)}$$

If t is the minimum interval between triggering pulses, then:

$$\tau < t/4$$

giving:

$$C < \frac{t}{4(1 + y)(1 + z)} [(1/R_S) + 1/R_G)] \quad \ldots\ldots (9)$$

(9) Determine the minimum pulse required at the grid of a conducting valve to initiate triggering.

Referring to Fig. 2, suppose V_3 to be non-conducting and V_4 to be conducting. The trigger pulse lowers the grid potential of V_4 causing its anode potential to rise. This rise is transmitted through the cross-coupling network to the grid of V_3 causing anode current to flow in this valve and the anode potential to fall. The fall in potential is transmitted through the second cross-coupling network to the grid of V_4.

Strictly, the minimum triggering pulse required is that which brings the circuit to a state where the loop gain is unity. This value would be very difficult to calculate, but a close enough approximation may be made by stipulating that the current flow in V_3 must cause the grid potential of V_4 to fall at least to the cut-off value E_{G_1}. This assumes a loop gain somewhat greater than unity, providing an extra margin of safety.

To cause the grid potential of V_4 to fall from zero to E_{G_1} the anode potential of V_3 must fall by some greater amount depending on the attenuation in the cross-coupling network. At the frequencies under consideration, i.e. up to several kc/s, C may be made large enough to ensure that the time-constant of the network is long compared with the duration of the triggering process. The attenuation then depends only on the ratio of C to the effective grid-cathode capacitance C_{G_1} of V_4. Taking account of the Miller effect this capacitance will be given approximately by:

$$C_{G_1} = C_{GC} + \mu C_{GA} \quad \ldots\ldots\ldots\ldots\ldots (10)$$

where C_{GC} is the grid-cathode capacitance with no anode current flowing,

C_{GA} is the grid-anode capacitance, and μ is the amplification factor of the valve.

The required change in potential at the anode of V_3 is then:

$$\Delta e_{A_4} = \left[1 + \frac{C_{G_1}}{C(1 - z)}\right] E_{G_1} \quad \ldots\ldots\ldots (11)$$

To produce this change the grid potential of V_3 must be raised to some value e_{G_3} which may be estimated from the valve characteristics. A generous allowance should be made for variation between individual valves, and for ageing. Clearly the required change in the grid potential of V_3 is greatest when the potential is initially at its lowest possible value E_{G_2}. The change is then:

$$\Delta e_{G_4} = e_{G_3} - E_{G_2} \quad \ldots\ldots\ldots\ldots\ldots (12)$$

Where short grid base valves are used e_{G_3} is often small enough to be neglected in comparison with E_{G_2}.

The change in potential Δe_{G_4} is produced by a change Δe_{A_5} in the anode potential of V_4. It is again necessary to consider the attenuation in the cross-coupling network, so that Δe_{A_5} must be greater than Δe_{G_4} by an amount depending on C and the effective grid-cathode capacitance of V_3. This capacitance will be rather lower than in the case of V_4 mentioned above, since V_3 passes no current while the grid potential rises from E_{G_2} to the cut-off value. Over this part of the grid voltage excursion therefore, the grid-cathode capacitance is not increased by Miller effect. By considering the relative values of the grid voltage excursion in the non-conducting and conducting regions it is a simple matter to estimate an effective value for the capacitance. Calling this value C_{G_2}:

$$\Delta e_{A_5} = \left[1 + \frac{C_{G_2}}{C(1-z)}\right] \Delta e_{G_4} \quad \ldots\ldots\ldots (13)$$

$\frac{C_{G_2}}{C(1-z)}$ will usually be much less than 1, and so a moderate error in the estimate of C_{G_2} can be tolerated.

The change Δe_{A_5} in the anode potential of V_4 is produced by the triggering pulse applied to its grid. This pulse must lower the grid potential to some value e_{G_5} which may be estimated from the valve characteristics, again making due allowance for individual variations and ageing. The triggering pulse is attenuated by the cross-coupling network, so that by analogy with equation (11) the triggering source must produce a pulse at the anode of V_3 given by:

$$\Delta e_{A_6} = \left[1 + \frac{C_{G_1}}{C(1-z)}\right] e_{G_5} \quad \ldots\ldots\ldots\ldots (14)$$

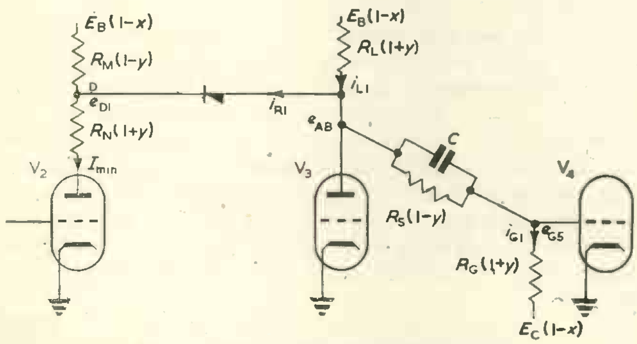

Fig. 9. Limits for determining R_M and R_N

It should be noted that e_{G_5} and Δe_{A_6} are negative quantities.

(10) Determine values for R_M and R_N to produce the above magnitude of pulse under the most adverse conditions. These conditions are shown in Fig. 9. It should be noted that the limits shown there do not agree in all respects with those used in calculating the amplitude of the triggering pulse, e.g. the value of E_{G_2} used above was based on a negative h.t. voltage of $E_0(1 + x)$, [equations (8) and (12)], whereas for the present calculation a value of $E_C(1 - x)$ is taken, the same value of triggering pulse still being assumed. This provides a further small margin of safety.

Referring to Fig. 9, assume as before that V_3 is initially non-conducting and V_4 conducting. The anode voltage of V_3 is then:

$$E_{A_7} = \frac{R_S(1-y)}{R_S(1-y) + R_L(1+y)} E_B(1-x)$$

$$= \frac{E_B(1-x)}{1 + (R_L/R_S) \cdot \frac{1+y}{1-y}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (15)$$

As soon as the triggering pulse is applied the potential at this point must change by Δe_{A_6}. Its value is then:

$$e_{A_8} = E_{A_7} + \Delta e_{A_6}$$

Substituting from equation (15):

$$e_{A_8} = \frac{E_B(1-x)}{1 + (R_L/R_S) \cdot \frac{1+y}{1-y}} + \Delta e_{A_6} \quad \ldots\ldots (16)$$

The current i_{L_1} through R_L is then:

$$i_{L_1} = \frac{E_B(1-x) - e_{A_8}}{R_L(1+y)}$$

$$= \frac{E_B(1-x)}{R_S(1-y) + R_L(1+y)} - \frac{\Delta e_{A_6}}{R_L(1+y)} \quad \ldots (17)$$

At the same time the grid potential of V_4 falls from zero to e_{G_5}, so that the current i_{G_1} through R_G is:

$$i_{G_1} = \frac{e_{G_5} - E_C(1-x)}{R_G(1+y)} \quad \ldots\ldots\ldots\ldots (18)$$

Since no current now flows to the grid of V_4, i_{G_1} is also the current in the parallel circuit R_S, C. The current i_{R_1} that must flow through the coupling rectifier to produce the above changes is thus:

$$i_{R_1} = i_{L_1} - i_{G_1}$$

Substituting from equations (16) and (17):

$$i_{R_1} = \frac{1}{1+y}\left[(1-x)\left(\frac{E_B}{R_S(1-y)/(1+y) + R_L} + \frac{E_C}{R_G}\right) - \frac{\Delta e_{A_6}}{R_L} - \frac{e_{G_5}}{R_G}\right] \quad \ldots (19)$$

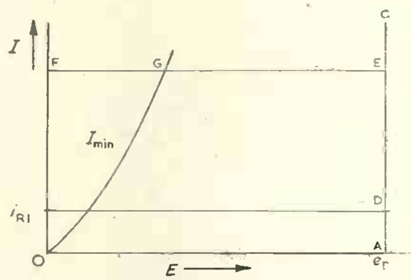

Fig. 10. Construction for determining R_M and R_N

At this value of current there will be a maximum voltage drop e_{R_1} in the coupling rectifier, whose value may be obtained from the manufacturer's data. The maximum permissible potential at D on application of the triggering pulse is thus:

$$e_{D_1} = e_{A_8} - e_{R_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots (20)$$

Suitable values of R_M and R_N are now obtained as follows. Plot the I_{min} characteristic of the valve as shown in Fig. 10. Set off lengths OA $= e_{D_1}$ and OB $= E_B(1 - x)$ along the voltage axis. Draw a line AC parallel to the current axis, and set off a length AD $= i_{R_1}$ along it. Then select a trial value for R_M, say approximately $(R_L/2)$, and set off a length DE $= \frac{E_B(1-x) - e_{D_1}}{R_M(1-y)}$ along DC. AD represents the current through the coupling rectifier and DE the current through $R_M(1 - y)$. AE is thus the current through $R_N(1 + y)$, which divides between the valve and the resistor chain $R_S R_G$. The current through the chain is generally small enough under the transient conditions to be neglected in comparison with the valve current. Now draw EF parallel to AO intersecting the valve characteristic at G. FG then represents the voltage across the valve, and GE the voltage across $R_N(1 + y)$. Thus, for the given value of R_M the maximum value of $R_N(1 + y)$ to produce the required pulse is (GE/AE); R_N is then given by:

$$R_N < \frac{1}{1+y} \text{(GE/AE)} \quad \ldots\ldots\ldots\ldots (21)$$

If the sum of R_M and the maximum value of R_N permitted by equation (20) is less than R_L, the process is repeated with a higher value of R_M; if it is greater, the process is repeated with a lower value, until a pair of values is obtained whose sum is equal to or just less than R_L.

(11) Check that the grid potential of a conducting valve cannot fall below zero.

The lowest value is obtained at the grid of V_4 under the conditions shown in Fig. 11(a), with V_2 and V_4 conducting, and V_3 non-conducting. As shown previously, it will exceed zero provided that the anode potential of V_3 exceeds E_{A3}. Fig. 11(a) may be replaced by the equivalent circuit shown in Fig. 11(b). Applying Thevenin's theorem to R_M and R_N the cathode of the coupling rectifier may be considered to be returned through a resistance:

$$R_W = \frac{1}{\frac{1}{R_M(1+y)} + \frac{1}{R_N(1-y)}} \quad \ldots\ldots\ldots\ldots (22)$$

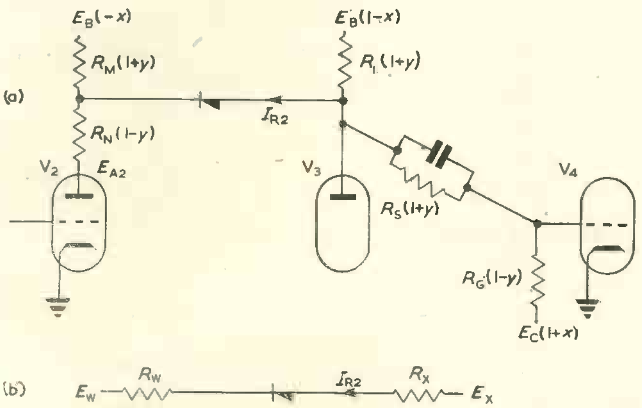

Fig. 11(a). Limits for checking lowest grid potential of a conducting valve (b) Equivalent circuit

to a potential:

$$E_W = E_{A_2} + \frac{R_N(1-y)}{R_N(1-y) + R_M(1+y)}[E_B(1-x) - E_{A_2}]$$

$$= \frac{E_B(1-x)}{1 + (R_M/R_N)\frac{1+y}{1-y}} + \frac{E_{A_2}}{1 + (R_N/R_M)\frac{1-y}{1+y}} \quad \ldots (23)$$

Similarly the anode of the coupling rectifier may be considered to be returned through a resistance:

$$R_X = \frac{1+y}{(1/R_L) + (1/R_S)} \quad \ldots\ldots\ldots\ldots (24)$$

to a potential:

$$E_X = \frac{R_S(1+y)}{R_S(1+y) + R_L(1+y)} E_B(1-x)$$

$$= \frac{E_B(1-x)}{1 + (R_L/R_S)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (25)$$

The rectifier current I_{R_2} may then be obtained by drawing a load line corresponding to $R_W + R_X$ on the characteristic of a low impedance limit rectifier as shown in Fig. 12. The potential at the rectifier anode, i.e. at the anode of V_3 is then $E_X - I_{R_2}R_X$, and so, for the grid potential of V_4 to exceed zero:

$$E_X - I_{R_2}R_X > E_{A_3} \quad \ldots\ldots\ldots\ldots (26)$$

(12) Check that the minimum effective anode load resistance of a valve is not less than R_K.

The minimum value occurs at the anode of V_2 under the conditions shown in Fig. 13(a) with V_2 and V_3 conducting and V_4 non-conducting. This may be replaced by the equivalent circuit Fig. 13(b), the equivalent resistances and potentials being derived as for Fig. 11. The cathode of the coupling rectifier is considered to be returned through a resistance:

$$R_Y = \frac{1-y}{(1/R_M) + (1/R_N)} \quad \ldots\ldots\ldots\ldots (27)$$

to a potential:

$$E_Y = \frac{E_B(1+x)}{1 + (R_M/R_N)} + \frac{E_{A_1}}{1 + (R_N/R_M)} \quad \ldots\ldots\ldots (28)$$

and the anode, through a resistance:

$$R_Z = \frac{1}{\frac{1}{(R_M + R_N)(1-y)} + \frac{1}{R_S(1+y)}} \quad \ldots (29)$$

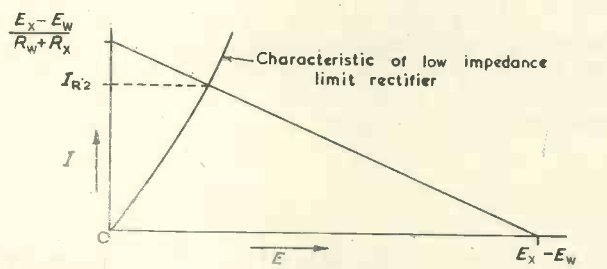

Fig. 12. Construction for determinig I_{R_2}

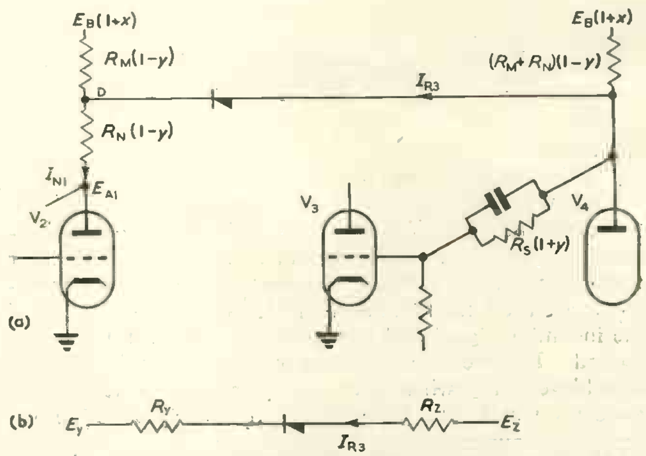

Fig. 13(a). Limits for checking minimum effective anode load resistance (b) Equivalent circuit

to a potential:

$$E_Z = \frac{E_B(1+x)}{1 + \frac{R_M + R_N}{R_S} \cdot \frac{1-y}{1+y}} \quad \ldots\ldots\ldots (30)$$

The rectifier current may be obtained as before by drawing a load line corresponding to $R_Y + R_Z$ on the characteristic of a low-impedance limit rectifier. Calling the value under the present conditions I_{R_3}, the potential at D is $E_Y + I_{R_3}R_Y$. The current I_{N_1} through $R_N(1-y)$ is then:

$$I_{N_1} = \frac{E_Y + I_{R_3}R_Y - E_{A_1}}{R_N(1-y)}$$

and substituting the value of E_Y from equation (28):

$$I_{N_1} = \frac{E_B(1+x) - E_{A_1} + R_M I_{R_3}(1-y)}{(1-y)(R_M + R_N)} \quad \ldots\ldots (31)$$

The effective load resistance R_J is the resistance between the valve anode and the h.t. positive supply that would allow the same valve current to flow. Thus:

$$R_J = \frac{E_B(1 + x) - E_{A_1}}{I_{N_1}}$$

and substituting the value of I_{N_1} from equation (31):

$$R_J = \frac{R_M + R_N}{\dfrac{1}{1 - y} + \dfrac{R_M I_{R_3}}{E_B(1 + x) - E_{A_1}}} \quad \ldots\ldots\ldots (32)$$

The required condition is thus:

$$\frac{R_M + R_N}{\dfrac{1}{1 - y} + \dfrac{R_M I_{R_3}}{E_B(1 + x) - E_{A_1}}} > R_K \quad \ldots\ldots (33)$$

Conclusions

It can be seen that even for the relatively simple circuit considered above, much calculation is necessary to ensure that it will operate satisfactorily under the conditions of component and supply voltage variation encountered in practice. Where apparatus has to operate reliably over any length of time it is essential that these calculations be carried out; failure to do so is probably responsible for the reputation of unreliability still associated with electronic apparatus in some quarters. In this connexion a point which cannot be over-emphasized is the necessity for valve and component manufacturers to provide more detailed and comprehensive information on the limit characteristics of their products; no mechanical designer would be expected to work with components on which the dimensional tolerances were incompletely specified, and the analogy between these and electrical tolerances on valves and components is very close.

Acknowledgments

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A Receiver for Submarine Cable Telegraph Signals

By J. W. Thompson,* B.Sc., A.M.I.E.E.

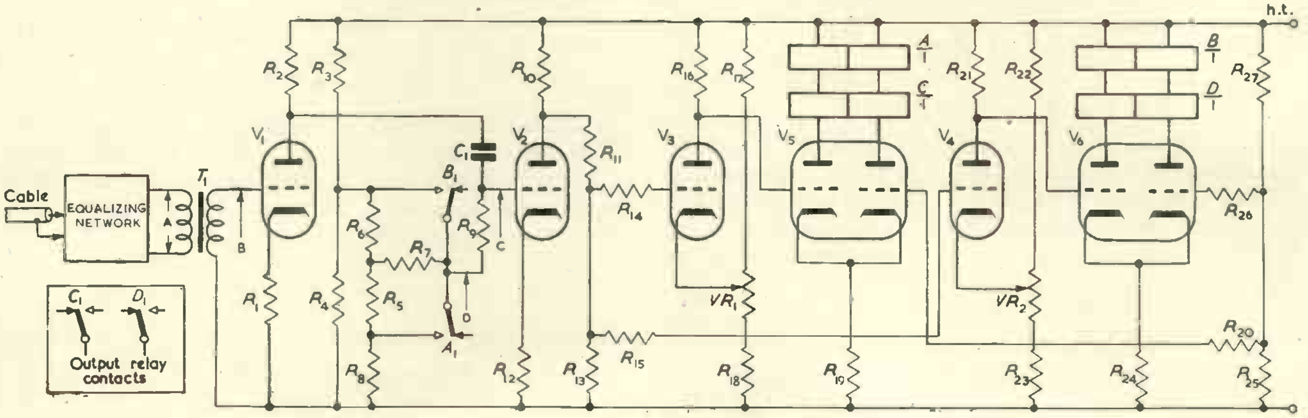
An electronic receiving amplifier for submarine cable telegraph signals is described. A.C. couplings are used in the amplifier and the circuit is arranged to restore the legitimate d.c. component of the signal.

RESONANT moving-coil instruments are widely used as prime receivers in submarine cable telegraph systems, and an important reason for their success is the ease of adjustment of their characteristics, which are very suitable for equalizing signal distortion. In most cases two such instruments are used, the first and more sensitive of which detects the incoming signal and passes it in amplified form to the second. Experience has shown that good signal definition is achieved only when both instruments are tuned to frequencies which are proportional to the speed of transmission and at the same time are heavily damped. The overall sensitivity is therefore inversely proportional to approximately the fourth power of the signalling speed, and this feature has made the system quite unsuitable for use on the high speed loaded cable circuits.

In the case of the widely used three position cable code[1] it is necessary for the direct component of the signal to be present at the output of any receiving device. Conventional direct coupling throughout the receiver achieves this aim, but allows the unwanted and slowly changing natural currents introduced by the cable's earth return to

* *Mervyn Instruments, formerly Cable and Wireless Ltd.*

Fig. 1. Simplified circuit of the amplifier



be amplified also. This interference, which is normally of very low frequency, is known as the "earth current," and undergoes daily cyclic variations. In the moving-coil system the signal bias caused by an earth current is automatically detected and corrected. The method by which this is done is fairly complicated, but the corrector is highly effective and is able to compensate for all but the very rapidly changing earth currents which sometimes occur during magnetic storms.

A simple way of dealing with all but the most troublesome earth currents is due to S. G. Brown, though it has not been convenient to apply his method to the moving-coil receivers as they are used today. The principle of the method is to employ a form of coupling somewhere in the receiving chain which severely attenuates all but the higher frequencies necessary to define the signalling cross-overs, and to restore the direct component later in the circuit. If a single *RC* coupling is employed the response to unit function input is of the form Ae^{-kt}, and if the leading edge of this waveform is used to initiate a rising potential of the form $(1-Ae^{-kt})$, and the two are added in the proper phase, the unit function input is faithfully reproduced. The rising potential is called the "correcting voltage" and the system as a whole is known as "local correction." If a changing potential which moves smoothly through unit amplitude in a time which is long compared with $1/k$ is superimposed on the unit function it will not appear in the output. It is clearly not essential for the response to give a truly exponential decay; the only necessary conditions are a complementary and properly phased correcting voltage.

It will be seen that the application of this principle to an electronic receiver can overcome two disadvantages of the coil system, in that the receiver imposes no upper limit to the speed of signalling and gives a simple and reliable method of eliminating earth current interference. Such an amplifier has been in use for a number of years on the London-Sydney loaded cable circuit[1]. Experimental work has recently been carried out to simplify and modernize this amplifier, and the way in which it has been achieved is described below.

A simplified electrical circuit of the amplifier is shown in Fig. 1. The received signal from the cable is passed through a suitable equalizing network and connected to the first amplifying stage by a transformer which has a time-constant of about one second. The amplified signal appearing at the anode of V_1 is fed to the control grid of V_2 via C_1. R_2 is small compared with R_9, and the time-constant of the coupling is therefore very nearly equal to the product R_9C_1. A typical value for this figure is 80msec. The signal is amplified again by V_2 and directly coupled to the grids V_3 and V_4. The limits of grid potential between which these last two valves can amplify is separately controlled by VR_1 and VR_2. V_5 and V_6 are double triodes which each operate two relays, one of which switches on the local correction voltage, the other delivering the signal output of the amplifier. The point at which these pairs of relays change over is controlled by the settings of VR_1 and VR_2.

The time-constant R_9C_1 is much the shortest in the system, and the response at the grid of V_2 to a unit function input therefore approximates closely to an exponential of the form $A\exp[-t/(R_9C_1)]$. VR_1 and VR_2 are adjusted so the leading edge of this decaying signal causes the appropriate relays to change over and apply a direct potential to the lower end of R_9. Since R_9 is large compared with R_2 an exponentially rising potential appears at the grid of V_2, having the same time-constant as the decaying signal. When the relative amplitudes are correctly set the two voltages add and maintain a constant resultant potential until a further signalling change takes place.

The behaviour is similar, though somewhat more difficult to analyse, when a cable code signal is received. The situation is complicated by the rise time of the signal, which should remain short compared with the time-constant

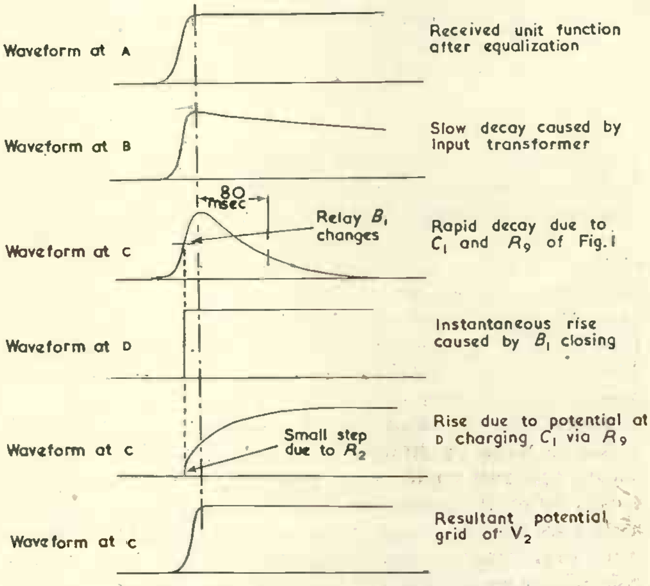


Fig. 2. Waveforms in circuit when unit function is received

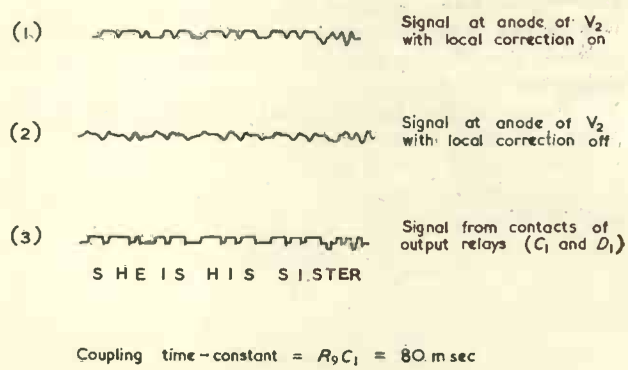


Fig. 3. Specimens of three position cable code signals

of the decay. It will be seen that the overall effect of this arrangement is to restore only the legitimate direct component of the signal; any slowly changing potentials due to earth currents do not pass the transformer and *RC* coupling. The waveforms at different points in the circuit are shown in Fig. 2. Specimens of actual cable code signals as they appear at the anode of V_2 are given in Fig. 3. The effect of disconnecting the local correction is illustrated and the signal from the output relays is shown.

Acknowledgments

The work described in this article was carried out at the experimental department of Cable and Wireless Ltd, and the writer wishes to thank the Engineer-in-Chief for permission to publish it.

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A Magnetron Microwave Diathermy Apparatus for Reanimating Rats from 0°C.

By W. J. Perkins*, A.M.Brit.I.R.E.

When the body temperature of rats falls below 15°C the heart stops beating and respiration ceases. It has been shown, however, that rats could be resuscitated from body temperatures as low as 0°C, by applying heat to the cardiac area and giving artificial respiration. A microwave apparatus is described which provides sufficiently rapid rewarming of the heart without burning the skin. A device for providing artificial respiration automatically is also described.

ONE great limiting factor in cardiac surgery is that the part to be operated on is moving, the heart is beating[1]. The rate and amplitude of movement may be and commonly are reduced by cooling the patient down to 25°C to 30°C. Cooling below this temperature to a point where heart and respiration actually cease would be highly desirable if the method of resuscitation were dependable. Furthermore, at lower temperatures the brain and other sensitive tissues would be less likely to suffer irreparable damage from lack of oxygen during circulatory arrest.[2]

Recent work by Andjus on hypothermia in animals has shown that rats could be resuscitated by heating the chest locally after the deep body temperature had been taken as low as 0°C. Sufficiently rapid warming from temperatures near freezing was, however, impracticable without risk of burning[4,5]. To further Dr. Andjus' work in the Division of Experimental Biology at the National Institute for Medical Research the use of radio frequency diathermy as a means of resuscitation was investigated.

With this type of apparatus, heating of deep tissues is obtained through the absorption of energy in the loss component of the dielectric. The power required to heat a given material can be calculated by considering the case of an imperfect capacitor (Fig. 1).

Applied e.m.f. $e = E \cos \omega t$.

The quantity of heat is proportional to the power loss and the time.

$$Q = Pt/J = \frac{EIt \cos \phi}{J}$$

$$Q = I^2Rt/J\left[\frac{1}{1 + \omega^2C^2R^2}\right] \qquad (1)$$

where Q = heat produced in calories

J = Joules' equivalent

If σ = specific resistance of the material

k = permittivity of the material

then:

$$Q = I^2Rt/J\left[\frac{1}{1 + (k^2\sigma^2/\lambda^2 \times 2{\cdot}78 \times 10^{-8})}\right] \qquad (2)$$

$$P = I^2R\left[\frac{10^8}{10^8 + (k^2\sigma^2/\lambda^2 \times 2{\cdot}78)}\right] \qquad (3)$$

For biological specimens k is in the region 75 to 85.

Thus assuming a value of 80 and inserting in equation (3):

$$\text{Power/amp/cc} = \frac{5630\sigma}{5630 + \sigma^2/\lambda^2} \qquad (4)$$

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For wavelengths of 30m and above the heat production is proportional to σ.

For wavelengths of about 10m the heat production is proportional to σ for low values and is then sensibly independent of σ.

For the very low wavelengths the heat production falls off with increased σ.

In the experiments using this apparatus it was desirable that the rate of heating should be fairly rapid and that the heart should be preferentially heated. By using microwaves it was possible to focus the beam to a smaller area

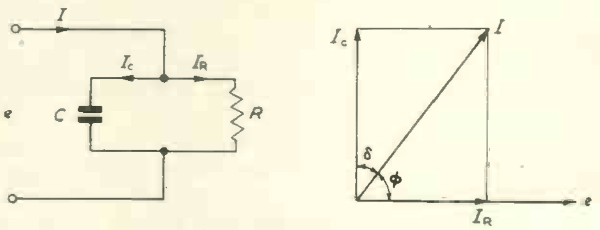

Fig. 1. Calculation of required power

than for the r.f. diathermy. As the specific resistance of the skin is much higher than for blood or the heart, thermal injury to the peripheral tissues could also be avoided. The depth of penetration is very nearly proportional to the wavelength but, as it was only intended to carry out these experiments with rats, the penetration was sufficient with a wavelength of 10cm.

A magnetron microwave generator had already been built, in collaboration with Dr. Lovelock, for the rapid heating of blood samples and this apparatus was, therefore, adapted for resuscitation experiments on rats.

The magnetron used was a continuous wave type with an output power of 500W, operating at a frequency of 3 000Mc/s. A circuit diagram of the complete apparatus is shown in Fig. 2. The magnetron was connected through a transformer section to a standing wave detector operating in the H_{01} mode and then to a termination section. The standing wave detector, although essential for the initial requirement of thawing samples of blood frozen at −79°C, was not necessary for the animal experiments, except to check the effects of various terminations. The power supplies required for the magnetron were 3·5kV d.c. at 3kW with 11V 24A for the heaters. A full wave voltage doubler circuit was used with a variac in the input circuit of the h.t. transformer, so that the power output of the magnetron could be controlled. To safeguard the magnetron filaments, they were switched on initially at reduced power, using a 240Ω resistor in series with the primary of the filament transformer and, at the same time, a delay circuit was completed which shorted out the resistor after a two minutes delay. A second contact of the delay relay completed the circuit of a second delay, which prevented the h.t. being applied to the rectifiers before the filaments had been heated, and also ensured that the h.t. could not be applied to the magnetron before its filaments had been heated. The delay circuit used was a bimetal strip operating two relays, the second relay being closed when the strip returned to the cold position. The circuit is shown in Fig. 3.

In order to obtain preferential heating of the thorax, the animal was placed under a grid extension of the waveguide (a), so that its chest lay beneath a 1in diameter aperture in the lower wall. To provide a more even distribution of energy, a horn radiator (b) was used with the same grid extension. Fig. 4 shows the rise of temperature in different parts of a rat corpse and it can be seen that the maximum input of energy occurs in the chest region. The approximate mean energy input to the animal was of the order of 4·5cal/sec, with the magnetron being run at reduced power. Fig. 5 shows the rate of increase of temperature for a corpse, and a revived animal. In the first case the heart and colonic temperatures rose at different rates and, therefore, gradually diverged, but in the case of the revived animal the heart commenced to beat when the temperature was approximately 15°C; the heart rate then rose steadily and the two temperatures converged. The preferential heating of the thorax thus decreases as the heart rate increases due to the improved thermal conduction with circulation. Later a taper section (c) with a distrene insert was fitted and this also proved satisfactory, but no statistical results are available.

Artificial respiration was carried out during the rewarming until spontaneous breathing was re-established. In order to standardize the procedure and to avoid the necessity of keeping the operator's hands in the beam, an automatic artificial respirator was used, which also had the additional advantage of saving the operator's time. The apparatus consisted of an air inlet valve connected to a compressed air line and operated from a thyratron timer, which could be adjusted for different respiration rates. The timer circuit is shown in Fig. 6.

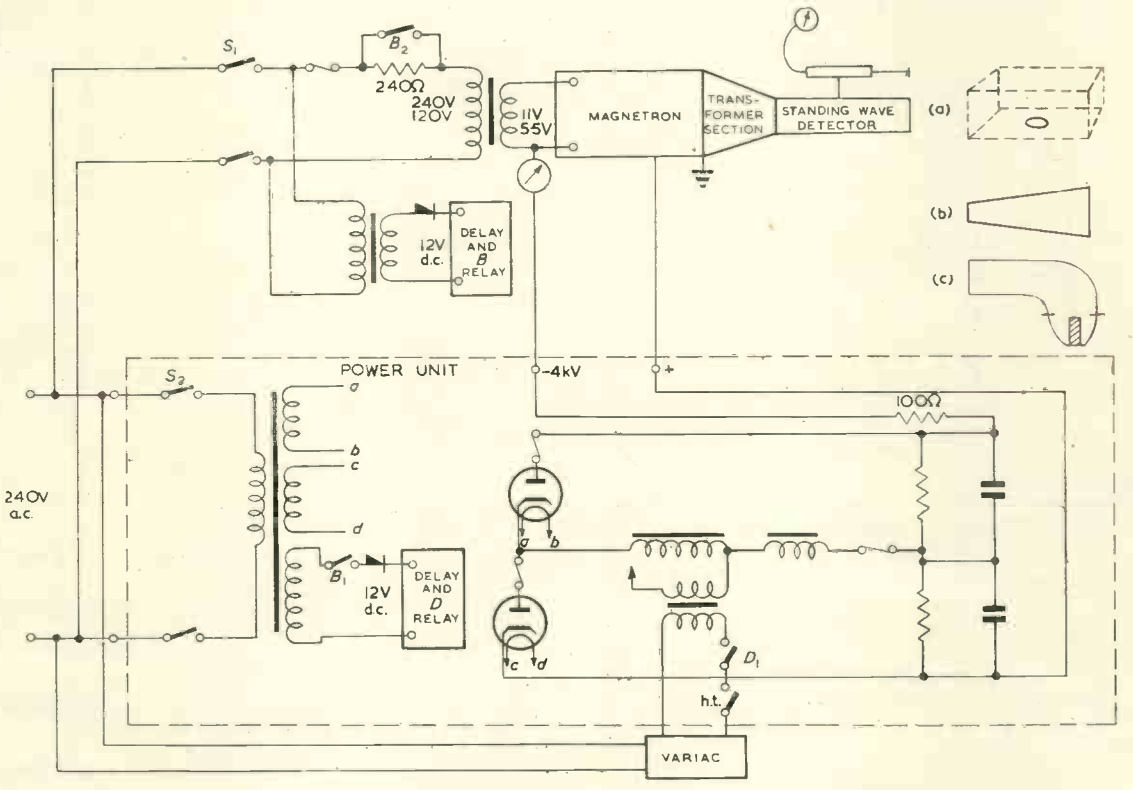

Fig. 2. General Layout of Apparatus

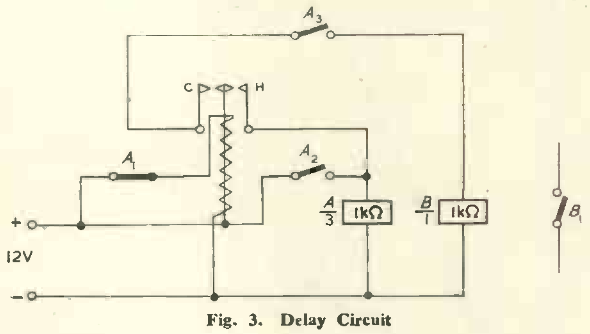

Fig. 3. Delay Circuit

When the thyratron conducts, the relay closes and C_1 charges from the voltage developed across C_2, cutting off the valve. The relay then opens and the negative charge on C_1 discharges through R_1R_2. When the charge on C_1 has fallen sufficiently, the thyratron again conducts and the cycle is repetitive at a rate determined by C_1 and $R_1 + R_2$.

A cardiograph was also constructed, so that the heart rates could be recorded both during the cooling process and after rewarming with the microwave apparatus. This proved particularly useful during cooling at the lower temperatures when the heart beats became very spasmodic.

The apparatus described has proved successful for re-warming small animals from body temperatures around 0°C and it has been possible to achieve 100 per cent survivals in a series of experiments, without any thermal injury to the animals[6].

For the larger animals the penetration using microwaves is not sufficient and the more conventional h.f. diathermy apparatus would be required.

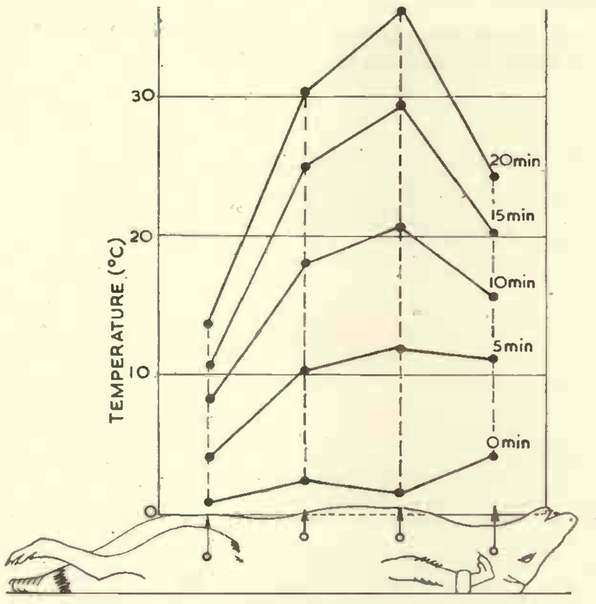

Fig. 4. Temperature rise plotted for different sections of a rat corpse when placed in the beam

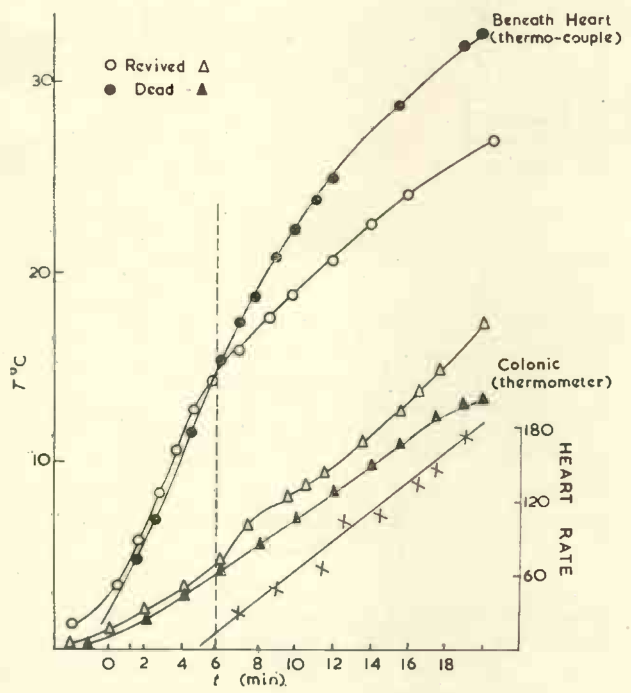

Fig. 5. Comparative temperature rise in a corpse and a revived animal

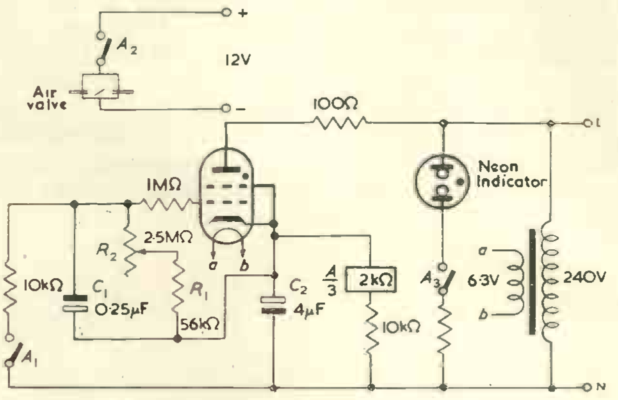

Fig. 6. Circuit used to provide automatic artificial respiration

Acknowledgments

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GLASS MANUFACTURING PLANT

A new glass manufacturing plant for cathode-ray tube components at the works of Pilkington Brothers Limited, St. Helens, began production in March. It is the only plant of its kind in Britain and cost nearly £1 000 000 to build.

The new equipment operates under licence from the Corning Glass Company of the U.S.A. who have been manufacturing cathode-ray tubes for many years.

The components are the largest high quality pressings that have been produced in this country and come off the machine at a rate of approximately one every six seconds—a speed more than twice as fast as by the hand methods of the older plant. The new plant can be adapted to produce in quantity, components of any size likely to be needed by any British set manufactured. It can make at least 2 000 000 units a year.

Each component is checked to ensure that all internal stresses have been removed. The inspection is done on a polariscope which enables the operator to compare the strain pattern in the sample with that of a good standard model by his side.

A very high standard is essential for the screens since the slightest defect might affect the image. Each component is critically examined for defects, surface imperfections and dimensions. Any screens requiring surface treatment are transferred to the grinding and polishing section.

Triggered Microsecond Sweep Generators

By D. P. C. Thackeray*, B.Sc.

Two feedback linearized sweep generators are described, one having a balanced output, the other single ended, both capable of providing a 450V sweep of 1μsec duration, using a single receiver type valve such as the CV173 (EF55) or CV2127 (6CH6) in the sweep generator stage. The designs have been developed from conventional hard valve feedback sweep generator circuits to provide sweeps up to this speed for a synchroscope used as a pulse monitor in high speed photographic applications.

THE practice of fast oscillography is well enough established as a technique to find immediate use in a number of physical investigations. For instance, the demands of an optical laboratory may frequently involve the display and measurement of shutter pulses to image convertor equipment[1], of light pulse waveforms both visible and in the ultra-violet, including those used in Schardin methods of photography, and of electrical waveforms required in image dissection silhouette photography[2]. None of these calls for a particularly elaborate cathode-ray oscillograph, the main requirements being (a) a cathode-ray tube, having an efficient phosphor, worked at high accelerating voltages, (b) a triggered linear sweep generator having a range of sweeps from 1 to 100μsec and (c) a simple trigger generator and time calibrator. It is the purpose of this article to describe two time-base circuits filling the requirements of (b).

The basic approach to obtaining high rates of change of voltage across the deflecting plates of a cathode-ray tube is that of making best use of an electronic switch, for example, a thermionic valve, to charge (or discharge) a capacitor. It is clearly to best advantage firstly that the switch should be used so that a high constant charging current should be obtained during the sweep, and secondly that the capacitor should be as small as possible. An ultimate limit to the first requirement is usually set by the characteristics of the valve to be used, and to the second requirement by valve, cathode-ray tube and lead capacitances. Examination of a typical linear sweep generator with a favourable performance at sweeps down to about 10μsec, for example the sanatron circuit of Fig. 1, shows that a number of other limitations may play a part. Here the charging valve V_1 is gated by a waveform applied to its suppressor grid, and the valve must be run with a low screen grid voltage in order not to exceed the allowable maximum screen dissipation during the comparatively long periods when the anode current is cut off. Although this voltage rises when the valve is gated it cannot do so faster than the rate associated with the charging of stray capacitances through the screen resistor, so that a fast sweep may well be over before the screen voltage has risen to a suitable value. This defect may be overcome, as suggested by Williams and Moody[3], Sayre[4] and Puckle[5], by applying the gating pulse to the screen grid instead, thereby transferring the period of highest screen dissipation to the duration of the sweep itself, which is commonly a small fraction of the time interval between sweeps. During the sweep the screen voltage may be pulsed to the recommended maximum value for the valve used and a high mutual conductance and availability of anode current obtained, without subjecting the valve to excessive mean screen dissipation. Examination of the sanatron circuit also shows that the gating waveform is obtained by partial differentiation (C_gR_g) and amplification (V_2) of the sweep waveform. This imposes on the anode circuit of the charging valve V_1 a shunt capacitive load, formed by the input circuit of V_2, which may be of the same magnitude as the unavoidable stray capacitances and the output

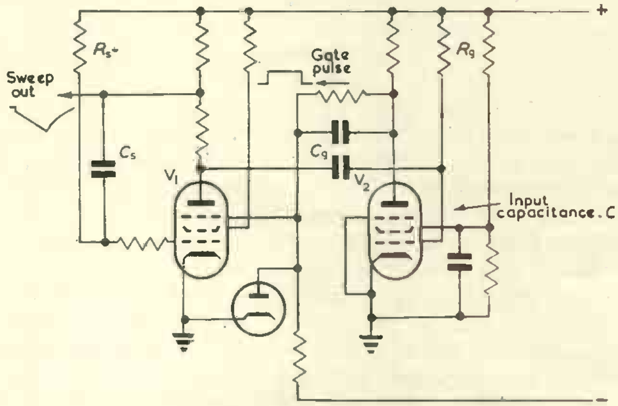

Fig. 1. Suppressor gated sanatron sweep generator
V_1 sweep valve
V_2 gate amplifier

capacitance of V_1. This undesirable loading may be avoided by the use of the sanaphant circuit[3], in which the gating waveform is obtained by amplification of the voltage developed across a small resistor inserted in the cathode circuit of the charging valve. This circuit has certain disadvantages of its own[4], and might suffer in the conversion to screen gated operation.

It can be seen from these considerations that for high sweep rates the development of the sweep generating circuit must start with the intent of operating the valves under conditions where they are able to develop high mutual conductance and high current handling capacities, and must avoid the introduction of any components liable to increase capacitances at points where the rates of change of potential are high.

To this end it is usually convenient to generate a gating pulse, locked to the available trigger waveform, by means of a separate circuit, and then to use this pulse for the double purpose of brightening the trace on the associated cathode-ray tube and of gating the sweep generating circuit. Bartlett and Davies[6] have developed a sweep generator in which these considerations are implicit. A form of the 'bootstrap' circuit is used to provide negative feedback linearization of the sweep waveform, and the waveform is

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positive going, which permits the attachment of a simple paraphrase amplifier, also described, so that symmetrical deflexion of the cathode-ray tube may be obtained. The device of driving the screen and suppressor grids of the gating valve to follow the rising anode potential minimizes the loading of the output capacitance of this valve upon the grid of the sweep generating valve. Moody[7] uses a similar feedback arrangement to linearize sweeps as short as 1μsec though his circuit also provides inductance linearized sweeps down to 0·1μsec, being then similar in form and performance to that adopted by Kelley[8]. Yu *et al*[9] in a synchroscope attaining sweep velocities up to 800in/μsec utilize a control grid gated tetrode to give constant current charging of capacitive anode and cathode loads, an elegant method of obtaining a push-pull output from the charging tube itself, while Winter and Fundingsland[10] employ inductance linearization of a capacitor discharge, using only the initial, nearly linear, portion of the voltage waveform available.

Single Ended Screen Gated Sweep Generator

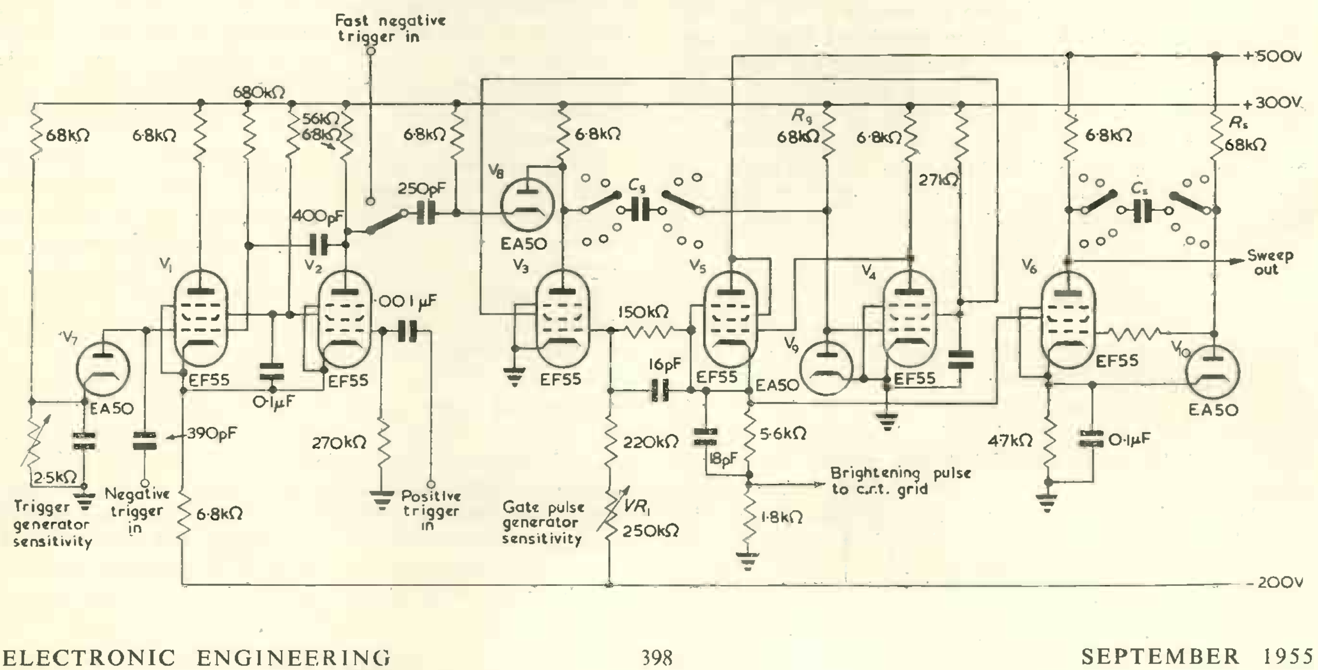
For many purposes it is not inconvenient to employ a negative going sweep and asymmetric deflexion. The use of a screen gated Miller integrator sweep generator permits this with no greater degeneration of performance than is usual with single ended deflexion systems, and requires only one valve, which is nearly cut off during quiescent periods. The first circuit to be described is of this form and will produce a 350V sweep waveform of 1μsec duration. The gating pulse is generated in a monostable anode to grid coupled multivibrator employing a pair of video pentodes, and having a third similar valve used as a cathode-follower output stage. This multivibrator may be triggered by a fast rising step of 20V or so, but since in general laboratory use it may be required to trigger from waveforms of a poorer shape, a cathode coupled monostable multivibrator is included to shape input pulses before they are fed to the gate pulse generator. It will then trigger from waveforms of either sign rising at not less than 0·1V/μsec.

The circuit is shown in Fig. 2. V_1 and V_2 form the shaping trigger generator feeding a short fast pulse to the gate pulse generator formed by V_3, V_4 and the cathode-follower V_5. Each input trigger therefore causes to appear at the cathode of V_5 a positive rectangular pulse 300V high and duration determined by the product of C_g and R_g. This pulse supplies screen power to the sweep valve V_6, the anode of which then performs the usual Miller rundown at a rate determined by C_s and R_s. Values of capacitors C_g and C_s are wired to a two gang switch to provide the sweep speeds required. The sweep circuit has the advantage of great simplicity and could, with suitable valve types and adequate available screen power be driven to very much greater sweep rates than here required.

Circuit Performance

Gate pulse generator waveforms, both free and driving the sweep generator and cathode-ray tube grid, were viewed, after attenuation, on the Y2 plate of a Cossor oscilloscope type 1035 and photographed by means of a Cossor c.r.o. camera on Ilford green recording film type RG91 (Fig. 3). The trace repetition frequency was 1000/sec. The waveforms are seen to be free of jitter. Notable are the fast rise of the 1μsec gating pulse and the distortion at the end of the pulse caused by the loading of the sweep generator once it has completed its sweep. The sweep waveforms, similarly recorded, are seen to have reasonable linearity for synchroscope use (Fig. 4). A more revealing test is that of displaying a regular waveform, generated by a pulsed oscillator locked to the time-base, on the synchroscope itself. Such a trace was photographed, both as a single non-recurrent sweep, and as the superimposition of 4 000 successive sweeps by means of a Zeiss Contax 35mm camera at nominal apertures of $f/1·5$ and $f/4$ respectively, at a reduction ratio of 2·5 : 1. These, reproduced in Fig. 5, show clearly that the first and last twentieths of the 1μsec trace are not linear, being due to the initial fast drop usual in Miller waveforms, and to the anode bottoming, respectively. The writing speed of the spot in the X direction is about 50mm/μsec and the two exposures were taken at different settings of the "brightness" control, and with the pulsed sinusoid at different phasings.

Fig. 2. Single ended feedback sweep generator



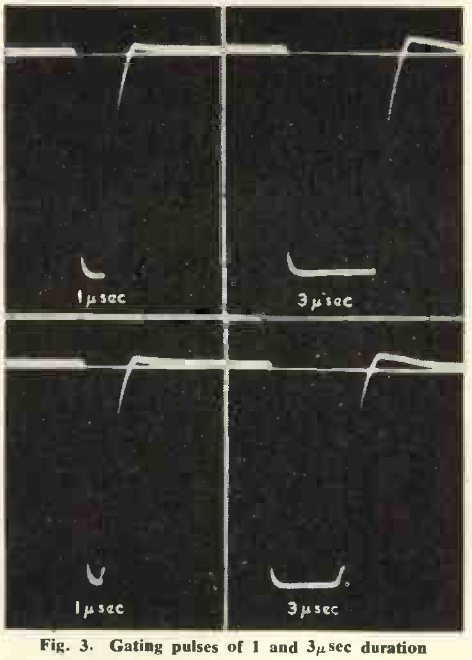


Fig. 3. Gating pulses of 1 and 3μsec duration

Top: Gate pulse generator unloaded. Bottom: Gate pulse generator driving single ended sweep generator and cathode-ray tube.

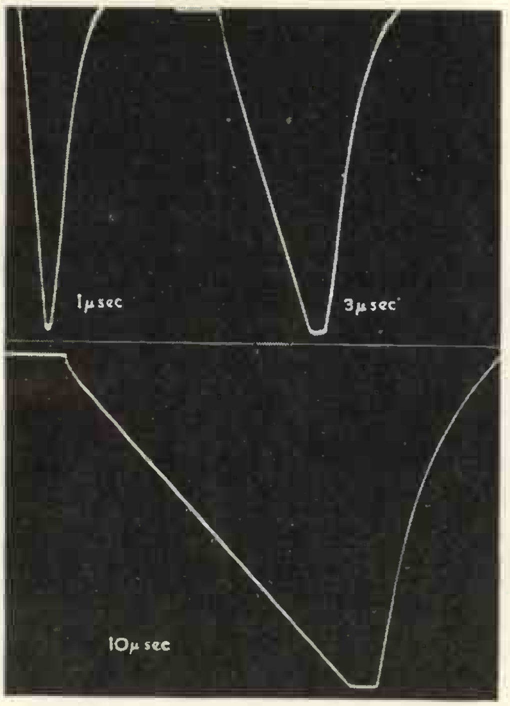
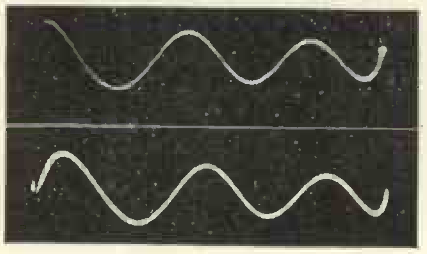


Fig. 4. Sweep waveforms from single ended sweep generator of 1, 3, and 10μsec duration

Fig. 5. Pulsed sinusoid displayed on 1μsec single ended sweep

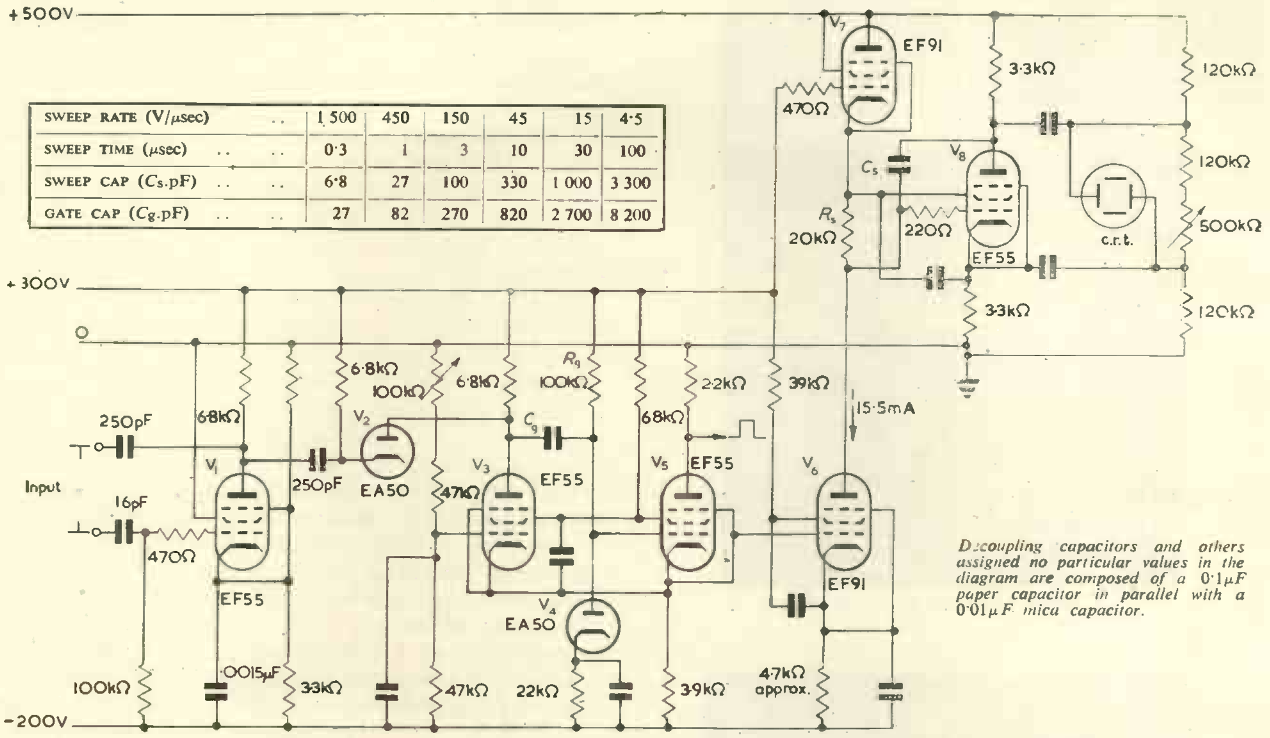
Top: One sweep. Bottom: 4 000 successive sweeps superimposed



Push-Pull Sweep Generator

Although this performance appeared satisfactory for many of the applications suggested, it was found that the display of signal waveforms having rates of rise greater than about 5 000V/μsec invited X axis distortion due to capacitive coupling between X and Y plates of the cathode-ray tube. By lessening the difference in impedance between each X plate and earth, the use of a push-pull deflexion system more nearly equalizes the amounts of signal injected into the two X plates, and reduces the resultant distortion. It should be noted that fast synchroscope sweep generators are commonly built with a push-pull output, even if only to supply full screen deflexion on the cathode-ray tubes used, a 900V sweep requiring the use of a two valve output stage if the h.t. line remains at 500V, as it must when valves such as the CV173 are used.

Since it is not easily possible to drive a phase invertor stage from a fast negative going sweep waveform, such a modification to the single ended sweep generator was not investigated. However as the sweep requirements were now known to be within the capabilities of a single valve it was thought likely, considering the "duality" of the Miller and bootstrap circuits[11], that a single valve with equal anode and cathode resistors could be employed as a feedback sweep generator. Although the arrangement necessitates control grid gating of the sweep valve, the arrangement works well and is capable of further development if faster sweeps are required. The circuit is shown in Fig. 6. V_1 is a trigger shaping valve and may be dispensed with if short negative triggers of sufficient amplitude are available. V_2 will pass negative triggers into the cathode coupled gate pulse generator formed by valves V_3 and V_5. Since again a monostable arrangement is used, the recovery time of the multivibrator is determined by the time-constant of C_g and R_g. With the component values indicated, a positive pulse of amplitude about 50V, used for brightening the c.r.t. is available from the anode of V_5, and a negative pulse of the same duration from its cathode. The latter is used to cut off V_6, a valve which normally carries about 15mA anode current to maintain the grid voltage of V_8 at or below that of the earth line. During sweeps this current charges C_s, at a rate which is maintained constant by strapping the cathode of V_8 to the high potential end of the charging resistor R_s. The connexion to this point of the screen grid of V_8 ensures that the cathode-screen voltage of the valve is held at a constant value during the sweep. Since the remote end of C_s is taken to the anode of V_8, the anode waveform is linearized by Miller integrator feedback action. V_7 is used as a cathode-follower clamp to determine the initial screen voltage of V_8, is cut off during the sweep by the rising of its cathode voltage, and recharges the bootstrap coupling capacitor rapidly at the termination of the sweep. Direct coupling between V_5 and V_6 determines the charging current available through R_s and keeps it constant to a few parts per cent over long periods. Values of C_s and C_g are again wired to a two gang switch to maintain the gate pulse a little longer than the sweep time at any setting of the switch. If the arrangement were redesigned, two circuit improvements could be effected. Firstly, V_7 could be used more effectively by taking the "bootstrap" connexion to its grid rather than its cathode. This would reduce the cathode current demand from V_8 during the sweep as it would then be working into a high impedance instead of having to supply screen power directly. The



SWEEP RATE (V/μsec) ..	1 500	450	150	45	15	4·5
SWEEP TIME (μsec)	0·3	1	3	10	30	100
SWEEP CAP (C_s.pF)	6·8	27	100	330	1 000	3 300
GATE CAP (C_g.pF)	27	82	270	820	2 700	8 200

Decoupling capacitors and others assigned no particular values in the diagram are composed of a 0·1μF paper capacitor in parallel with a 0·01μF mica capacitor.

Fig. 6. Push-pull feedback sweep generator

cathode of V_8 would also be relieved of the capacitive loading of the cathode of V_7 particularly if V_7 also has its screen grid strapped to its cathode. Secondly, the screen and suppressor of V_6 could also be driven from the cathode of either V_7 or V_8 as in the circuit published by Bartlett and Davies, though regrettably this makes the input impedance of V_6 to the gating pulse severely capacitive. This should not be troublesome as the rising edge of the gating pulse would have cut off V_6 before the sweep itself has started, and in this gate pulse generator the cathode output impedance of V_5 is very low. A third improvement would be to use a valve type such as the CV2127 (6CH6) throughout as the pentodes drawn, as these valves have much smaller inter-electrode capacitances than the CV173 (EF55) and will pass considerably more current than the CV138 (EF91) within their negative grid base.

Such a circuit is suggested in Fig. 7. Cathode injection of the gating pulse has been included as a useful variant of the original arrangement. Clearly the d.c. power supplies may need to be elaborate. The bootstrap arrangements are reminiscent of the circuits employed to amplify fast rising edges, for instance that shown in Fig. 8. V_1 and V_2 form a long-tailed pair providing a high input

Fig. 7. Sweep generator embodying the improvements discussed in the text
V_7 cathode-follower clamp
V_8 sweep valve
V_6 gate valve

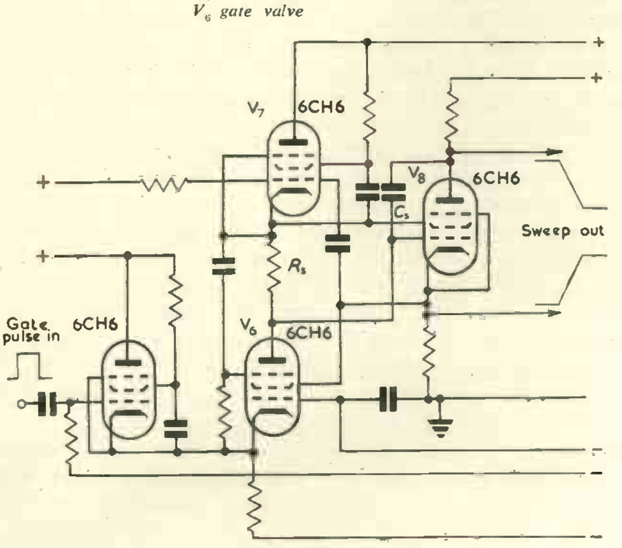
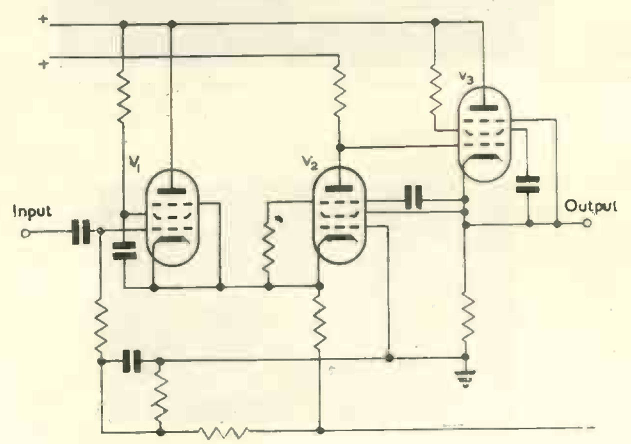


Fig. 8. A pulse amplifier

The output capacitance of V is effectively reduced by feedback, allowing a faster rate of rise of output waveform than would normally be obtained. By connecting input to output, a monostable multivibrator possessing the feature is obtained.



impedance for the input signal, while V_2 provides a cathode-follower output capable of driving the screen and suppressor grids of V_2 to follow the rise of its anode voltage, in order to allow the latter to rise at the maximum possible rate once the valve has been cut off by the rising edge of the input waveform.

Performance

Reverting, however, to the sweep generator of Fig. 6, it was thought reasonable not to over-elaborate by the addition of these refinements if satisfactory performance were obtained without them over the range of sweep times from 1 to 100μsec across the screen. This proved to be the case, and the circuit shown will also produce a 0·3μsec sweep, although at this speed the rising edge of the cathode-ray tube brightening pulse is becoming inadequately fast for single sweep working, taking about 0·05μsec to bring the cathode-ray tube to full brilliance from blackout. Fig. 9 shows a typical waveform, 1·25μsec long and 450V high, obtained from this sweep generator, displayed against the 3μsec single ended sweep generator first described, both generators being triggered at about 1 000/sec. About 1 000 traces are here superimposed. Fig. 10 shows separately, the triggering pulse used, and the anode and cathode waveforms of V_8 displayed on a 10μsec sweep. Fig. 11 shows some typical waveforms displayed against the push-pull sweep at various speeds. The sweep length on the screen of a cathode-ray tube type 908 C.A.R.A. was measured to be 55mm when the tube was run with a final anode to cathode voltage of 4kV, and with 4kV between the final anode and the post deflexion accelerator.

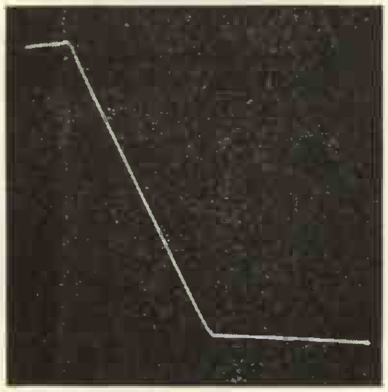


Fig. 9. 1·25μsec. 450V sweep, from push-pull generator, 1 000 sweeps superimposed

The horizontal time-base, of about 3μsec duration, on which the sweep is displayed, is single ended and produces noticeable trapezoidal distortion.

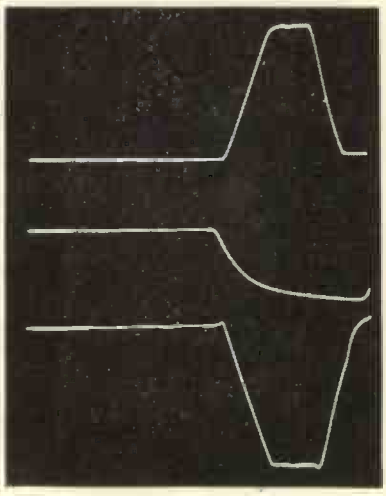


Fig. 10. 1·25μsec push-pull generator waveforms displayed on a 10μsec horizontal timebase

Top: V_8 cathode rise. Centre: Trigger pulse into gate pulse generator. Bottom: V_8 anode fall. In this oscillogram the "bottomed" condition of V_8 has been exaggerated in duration, by increasing the value of C_g.

Conclusion

In this article it has been shown how conventional circuits enable sweep rates of greater than 450V/μsec to be attained using a single pentode of ten watts anode dissipation as the sweep valve, employed either single ended or in a balanced arrangement, using either or both of two methods of feedback linearization. This rate of sweep is about an order of magnitude faster than is available from the ordinary general purpose laboratory oscilloscope, and may, if necessary, be improved by the employment of a larger valve.

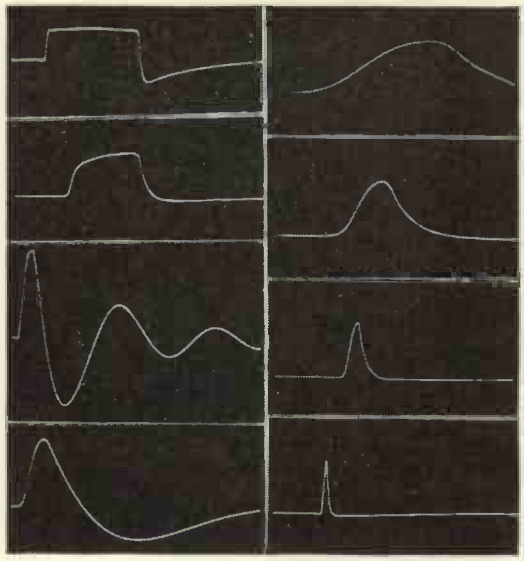


Fig. 11. Some blocking oscillator waveforms displayed on the push-pull generator sweeps

Right: A 0·2μsec pulse displayed on sweeps of 0·3, 1, 3, 10μsec duration. Pulse amplitude about 100V across 500Ω. Left: A 4μsec pulse on a 10μsec sweep. A 1μsec pulse on a 3μsec sweep. A rung waveform on a 3μsec sweep. A waveform showing overshoot on a 1μsec sweep.

Acknowledgments

The author would like to thank Dr. J. S. Courtney-Pratt for instigating effort on this item of development and for encouragement and criticism of the work, the Ministry of Supply (Air) for support, and Mr. S. A. Barton for much of the constructional work involved.

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The Response Functions and Vector Loci of First and Second Order Systems

By David Morris*, D.Sc., A.M.I.E.E.

(Part 1)

These articles, to be published in four parts, review the simple theory of electrical and mechanical networks, with the conventional approximations reorganized to allow for the treatment of very-low-Q systems.

Part 1 summarizes techniques for applying a frequency calibration to the loci of first order systems. These techniques are extended in the later articles to second order systems.

MUCH of the design of automatic control systems is concerned with the consideration of stability, and is regulated by the application of Nyquist's stability criterion. This criterion is formulated in terms of a vector locus, frequency being the variable parameter.

Alternatively, the vector locus can be replaced by separate gain and phase characteristics, plotted logarithmically between cartesian co-ordinates, frequency being the abscissa. In the responses of many linear physical systems the gain and phase characteristics are related, and criteria of stability can be derived, expressed in terms of the gain characteristic alone, as described by Bode. Control system design can then follow routine lines familiar in the design of speech transmission systems, in which phase in itself is not important.

However, in dealing with control systems, a clearer physical insight can sometimes be obtained if the responses of the system components are formulated in the same way as Nyquist's original criterion, i.e. in terms of vector loci. The vector loci convey simultaneous direct data concerning both gain and phase, and any redundancy in the information is not unhelpful when inventive activity is required.

A few basic loci enable the pattern of response from zero to infinite frequency to be visualized as a whole. Full advantage is not always taken of some of the features of these loci, and a review may therefore be useful. The present article is concerned only with first order systems, which operate according to equations of the first degree in frequency. Second order systems will form the subject of subsequent articles.

First Order Systems

First Order Response Functions

Fig. 1 illustrates a four-terminal network consisting of a loss-free inductor L and a resistor R. If a voltage V_1 of constant magnitude and variable frequency is applied to the input terminals, the output voltage V_2 is given in terms of the input voltage by the transfer function:

$$V_2/V_1 = \frac{R}{R + j\omega L} = \frac{1}{1 + j\omega T_0}$$

where $T_0 = L/R = 1/\omega_0$. If we introduce a "relative frequency" $\gamma = \omega/\omega_0$ the transfer function becomes:

$$V_2/V_1 = \frac{1}{1 + j\gamma} \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

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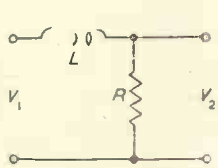
Similarly, if the input voltage is varied in such a manner as to maintain the output voltage constant as the frequency is varied, the required input voltage in terms of the output voltage is given by the function:

$$V_1/V_2 = 1 + j\gamma \quad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

The frequency-dependent functions (1) and (2) are dimensionless, and have unity value at zero frequency. Function (2) also equals Z/R, and thus describes the input impedance in terms of its zero-frequency value. Similarly, function (1) equals Y/G where $G = 1/R$, and thus describes the input admittance in terms of its zero-frequency value.



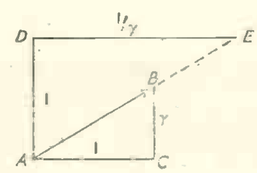
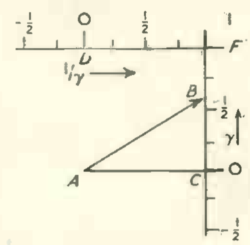


Fig. 1. (Above) a simple first order system

Fig. 2. (Top right) the derivation of the scale of relative periods

Fig. 3. (Right) vector locus of $(1+j\gamma)$



The Vector Locus of the Function $(1 + j\gamma)$

In Figs. 2 and 3, the vector AB represents the function $1 + j\gamma$, AC corresponding to the "real part" and CB to the "imaginary part". As γ varies, the tip B of the vector follows the straight-line locus CB. The locus CB can be calibrated with equally spaced graduation marks representing relative frequency, the unity mark corresponding to a value of 45° for the phase-angle CAB. To determine the phase-angle for very high relative frequencies, a frequency scale of undue length would be required. For high frequencies it is therefore more convenient to employ a scale of relative periods $1/\gamma$, as shown by DF in Fig. 3. The basis for this scale is illustrated in Fig. 2. If AD is drawn of unit length vertically, and then DE is drawn horizontally to cut the line of the vector AB at E, it follows from the geometry of the figure that $DE = 1/\gamma$, and the length DE is therefore proportional to the relative period. Any line parallel to AC may be used as a scale of relative period, provided that the scale factor is adjusted to give a phase-angle of 45° for the unity point. Similarly, the frequency scale need not coincide with the vector locus, but may be replaced by any parallel line provided that the scale factor is suitably adjusted. In Fig. 3 the scales are shown calibrated for both positive and negative frequencies, because frequencies that are formally negative are required for some constructions[1].

The Vector Locus of the Function $1/(1 + j\gamma)$

To obtain a vector locus representing the function of equation (1), the triangle ABC from Fig. 3 can be reproduced as in Fig. 4, the size being proportioned to maintain AB constant as γ varies. Then $1/(1 + j\gamma)$ equals the vector ratio AC/AB. Since angle ACB is a right-angle, C follows a circular locus, and further $\gamma = BC/AC = B'D/AB'$. Hence $B'D$ serves as a scale of relative frequencies, and can be used by drawing a construction line from the pivot or pole A, through the operating point C, to cut the scale at D. Similarly, EF can be used as a scale of relative periods,

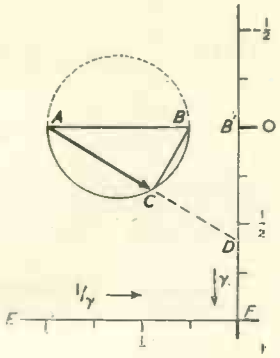


Fig. 4. Vector locus of $1/(1+j\gamma)$

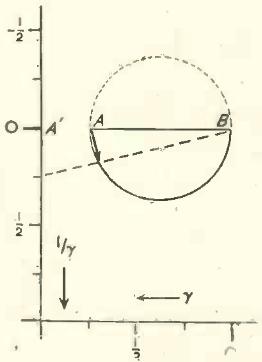


Fig. 5. Alternative scales for the locus of $1/(1+j\gamma)$

in conjunction with the same pole A. If the points on the locus had to be fixed by use of a frequency scale alone, a very long scale would be needed for fixing the high frequency points. The two scales in conjunction on the other hand, although occupying limited space, enable the construction line to be drawn for all frequencies from zero to infinity. Similarly, points could quite easily be determined on the semi-circle shown dotted, which corresponds to frequencies that are formally negative.

The construction line ACD in Fig. 4 is convenient for locating points on the right-hand half of the circle. A construction line drawn to the left-hand half of the circle, however, crosses the locus at an obtuse angle, which makes the precise point of intersection difficult to locate. An alternative procedure is to use the zero-frequency point B as a pole, in conjunction with scales constructed as shown in Fig. 5. By this means, points on the left-hand half of the locus can be fixed accurately. All points can be accurately located by using a frequency scale from zero to unity as in Fig. 4, and a period scale from unity to zero as in Fig. 5.

It can easily be shown (see Appendix 1), that any point on the circumference of the circle can be used as a pole, provided that the scales are suitably orientated. A particularly compact arrangement is obtained if the minus-unity point is used as a pole, as shown in Fig. 6. The frequency and period scales can then be inserted inside the circle, and share a common unity point at U. The construction line then cuts both the locus and the scale sufficiently acutely at all frequencies.

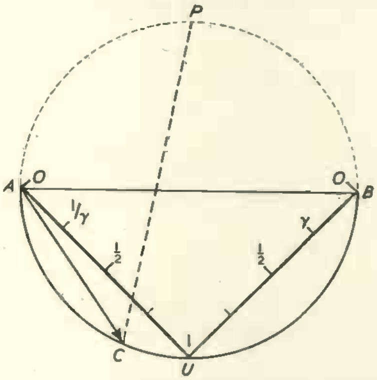


Fig. 6. The use of the minus-unity point as a pole for the frequency and period scales

The disposition of the frequencies on the circular locus has symmetry about two axes. In the first place, as with the loci of all real systems, there is symmetry about the real axis AB, the negative frequency points being reflections of the positive frequency points (points X and X' in Fig. 8). In the second place, there is symmetry about the vertical line joining the plus-unity and minus-unity points. Relative frequencies to the right of this line correspond to relative periods to the left, and vice-versa (points X and X'' in Fig. 8). The product of relative frequencies of points lying symmetrically left and right of this axis is always equal to unity. (See Appendix 2.)

Appendix 1

The Pole of the Frequency Scale

If a circular locus is known to have a frequency scale associated with a particular point on the circumference used as a 'pole', the pole can be moved to any other point on the circumference, provided that the scale is always made parallel to the line joining the pole to the infinite-frequency point on the locus[2].

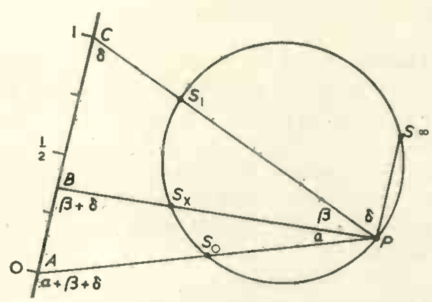


Fig. 7. Illustrating general relationship between pole and scale

Fig. 7 shows an existing scale ABC, and construction lines drawn from the pole P through the points S_0, S_1, S_∞ and S_x on the locus. The points represent respectively frequencies of zero, unity, infinite and arbitrary value. If P is moved to any other point P' on the circle, while the points S remain unchanged, the segmental angles α, β and δ are unaltered. If the scale is redrawn parallel to $P'S_\infty$, the angles at A, B and C will be unchanged. The figure $PABC$ is therefore of unchanged shape, and the ratio AB/AC is also constant, so that a uniform calibration for AC remains valid.

APPENDIX 2

THE SYMMETRY OF THE CIRCULAR LOCUS

In Fig. 8:

$$AX/AB = \frac{1}{1+j\gamma} = \frac{1-j\gamma}{1+\gamma^2}$$

$$DX/AB = \frac{1}{1+\gamma^2} - 1/2 - \frac{j\gamma}{1+\gamma^2} = \frac{1-\gamma^2}{2(1+\gamma^2)} - \frac{j\gamma}{1+\gamma^2}$$

Dividing top and bottom by γ^2 and letting $\tau = 1/\gamma = T/T_0$

$$DX/AB = \frac{\tau^2 - 1}{2(\tau^2+1)} - \frac{j\tau}{\tau^2+1}$$

Thus the expression for DX in terms of τ is the same as that in terms of γ, except that the real part is reversed in sign. Hence the $1/\gamma$ points are reflections in WU of the corresponding γ points.

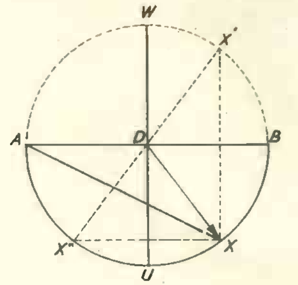


Fig. 8. Concerning the symmetries of the circular locus

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(To be continued)

A High Speed Decade Counter Using Germanium Diodes in the Feedback Loops

By H. R. Joiner*, B.Sc. and D. R. Woodward*

A description is given of a simple decade counter which will operate at frequencies of up to 500kc/s. The use of germanium diodes has resulted in a relatively simple circuit capable of working at high frequencies. The circuit was originally designed to work, in conjunction with a 1 second gate, as a frequency measuring system, but numerous other applications are possible.

The performance of a decade scaler may be considerably improved by using germanium diodes in preference to thermionic diodes. Apart from the small physical size and the absence of a heater, the main advantage of germanium diodes is that their shunt capacitance is lower than that of a thermionic valve; their use reduces the response time of the feedback network and hence greatly increases the resolution of the counter.

Choice of Diodes

The diodes have to feed back selected pulses to preceding stages while preventing the feed forward of unwanted pulses: for this a high ratio is needed between their "back" and "forward" resistances. The diodes used in this counter are subjected to a reverse e.m.f. in excess of 100V, and must present a back resistance, found experimentally to be not less than 200kΩ.

All germanium diodes suffer to some degree from the "hole storage effect", an effect which is in some ways analogous to the "transit time" of a valve.

While an "n" type germanium diode is conducting, a large number of "positive holes" are distributed in the semi-conductor. After the application of a reverse voltage, a finite time elapses before the hole concentration decays, and during this time a large reverse current may flow. The delay time varies with the forward current from 1 to 10μsec or more. This effect makes germanium diodes difficult to use in conventional high speed pulse circuits.

In this circuit the diodes do not conduct during most of the cycle so that the hole densities never become very large, and reverse current pulses are too small to affect the operation of the counter.

It may be noted that another version of this circuit using germanium crystals as coupling diodes, and designed to work at frequencies of up to 1Mc/s, was found to be unreliable at lower frequencies. It would appear that the reverse pulse was able to trigger this more sensitive circuit since the diodes were then conducting for longer periods.

The G.E.C. crystal diodes type GEX54/4 were selected for this circuit. They have ample back resistance and will withstand a reverse voltage exceeding 170V. They do, however, suffer rather badly from the hole storage effect, but not sufficiently to affect this circuit.

The properties of the crystals change with age, but published reports show that these changes are seldom great enough to make this scaler unreliable. The diodes will, however, become unreliable at temperatures in excess of 70° C due to a general decrease in resistance.

Circuit

The circuit diagram of this scaler is shown in Fig. 1: the two feedback paths are via C_9, MR_1 and C_{14}, MR_2.

The circuit consists of four cascaded Eccles Jordan stages using Grosdorff[1] couplings. The feedback networks feed pulses back to former stages causing a change of state equivalent to the introduction of input pulses. Thus one pulse fed back from the third to the second stage via C_9, MR_1 reduces the necessary input, for a complete cycle, from 16 to 14 pulses. If now one pulse per cycle is fed back from the fourth to the third stage, the required number of input pulses becomes $16-2-4=10$, for a complete cycle.

The feedback system was adapted from Fergusson and

* Sir W. G. Armstrong Whitworth Aircraft Ltd.

Fraser[2]. A resistive summing network may be connected to A_1, A_2, A_3, A_4, and the accumulated output amplified, and displayed on a meter or c.r.t.

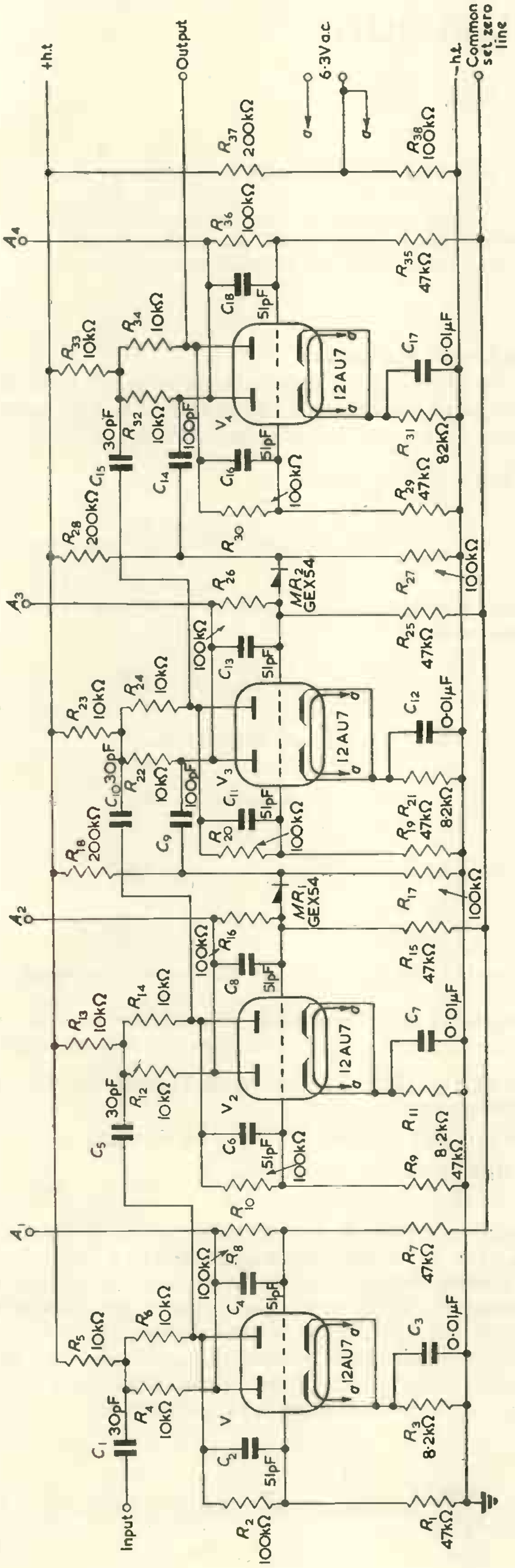

Fig. 1. Circuit of the counter

Construction

The four-stage counter may be arranged compactly on a chassis 8in × 2in (Fig. 2). The method of construction employed is to mount the anode resistor and the anode to grid coupling components vertically on a moulded nylon "turret" (originated in 1951 at Armstrong Whitworth Aircraft Ltd) concentric with the valve base (Fig. 3). The grid and cathode returns are wired directly from the valve pins to tags on the chassis, keeping all leads very short. Five per cent tolerance components should be used for anode and grid circuits.

Fig. 2. Chassis of the counter

Fig. 3. The "turret" assembly

Valve replacements will not affect the scaler unless the two halves of the twin triode are seriously asymmetrical.

It is essential to keep the circuit well cooled. Holes should be punched in the chassis between stages, and in very compact assemblies a fan may be needed. The chassis temperature should never exceed 40° C.

Performance

The counter may be triggered by a negative going transient of about 50V/μsec and of 30 to 70V amplitude.

The scaler will operate at any repetition rate up to 500kc/s, for the above method of assembly, and rather less if a "tagboard" construction is used.

A considerable number of these units have been built over the past year and have given trouble free service.

A stabilized 300V power supply is recommended, although operation is quite satisfactory with an h.t. variation of ± 20V.

Acknowledgments

Thanks are due to the Chief Scientist, Ministry of Supply, for permission to publish this article.

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Quantitative Noise Reduction in Pulse Time Modulation

By Jajneswar Das*, M.Sc.

Quantitative value of signal-to-noise ratio with input signal above threshold, in typical p.t.m. systems, is determined. Calculations have been based on the method shown by Daloraine, Labin and Goldman, and an improvement in the output signal-to-noise ratio due to the limited audio frequency bandwidth is shown. With input peak signal-to-noise ratio equal to 6dB, the output signal-to-noise ratio is found to be 35dB for a typical p.l.m. system and 47dB for a typical p.p.m. system. Comparison with experimental results are shown.

VARIOUS authors [1,5,7,8,9] have analysed the noise performance in pulse modulation systems. Jelonek[7] has shown the most rigorous results, but the detailed method is not yet published. It has been found more convenient to follow the steps indicated by Daloraine, Labin[5] and Goldman[1] in analysing the noise performance in p.t.m. (which includes both pulse-length modulation and pulse-position modulation). An attempt has been made here to present the results more rigorously in the case of a particular system. An important point regarding the improvement in signal-to-noise ratio in the output due to the limited bandwidth of the audio amplifier of the pulse-receiver has been included in the analysis below.

It has been assumed that the slicing level in the pulse receiver is above the peak noise amplitude and the sliced pulse is of infinitely small height and contains the noise in the form of pulse-edge modulation only. Noise within the width of the pulse is neglected and only random noise is considered in the analysis below. Comparison with the experimental results obtained by Moskowitz[8] and others is also given.

Analysis

After efficient slicing, the residual noise in a pulse time modulated system is due only to the time shift of the pulse edges by the noise voltage. Due to the noise voltage N (Fig. 1), the time shift of the pulse-edge, $\Delta t = N \cot\theta$. Now $\tan\theta = 2f_c A_0$ (approx), where f_c is the cut-off frequency of the transmission system.

Then:

$$\Delta t = N/2f_c A_0 \quad \ldots \quad (1)$$

= noise time-modulation of the pulses[1].

If the rise time of the pulses is small compared to the width, the Fourier-series expansion of the repetitive pulses may approximately be written as (assuming rectangular pulses):

$$f(t) = (A_0 d_0/T_0) + \sum_{n=1}^{\infty}(2A_0/\pi n)\sin\left(\frac{\omega_R n d_0}{2}\right)\cos\omega_R nt \quad (2)$$

where A_0 = maximum amplitude of pulses

d_0 = width of pulses

f_0 = pulse repetition frequency

$T_0 = 1/f_0 = 2\pi/\omega_R$

$\omega_R = 2\pi f_0$

n = number of p.r.f. harmonic.

* *Indian Institute of Technology, Kharagpur, West Bengal.*

Pulse Length Modulation

It is evident that the time duration of pulses in equation (2) will be modulated by the noise voltage and the resultant Fourier expansion of the waveform will be[2]:

$$F(t) = \frac{A_0(d_0 \pm \Delta t)}{T_0} + \sum_{n=1}^{\infty}(2A_0/\pi n)\sin\frac{\omega_R n(d_0 \pm \Delta t)}{2}\cos\omega_R nt \quad \ldots (3)$$

Further the random noise can be expressed in terms of Fourier series[3] as:

$$N = \sum_{q=1}^{\infty} C_q \cos((2\pi qt/T) - \phi_q) \quad \ldots \quad (4)$$

where T is the total time of observation.

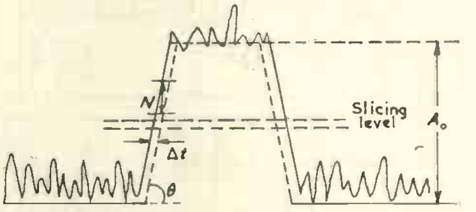

Fig. 1. Time shift of the pulse edges due to noise voltage

This shows that noise voltage will have infinite frequency components with random phase relations between them.

Noise Output Due to Amplitude Modulation of Zero Frequency Component

The first part of equation (3) can be re-written as:

$$\frac{A_0(d_0 \pm \Delta t)}{T_0} = \frac{A_0 d_0}{T_0} + \frac{A_0 \Delta t}{T_0}\cos(\omega_q t - \phi_q) \quad \ldots (5)$$

Where ω_q ranges from zero to f_c and ϕ_q is random in phase. The above equation is equivalent to a direct voltage plus a noise voltage with the amplitude $(A_0 . \Delta t)/T_0$ and frequencies up to f_c. Since noise powers are additive and the noise energy accepted by the audio-frequency amplifier is proportional to its bandwidth F_a, then the peak audio frequency noise power in the output contributed by the above amplitude modulation is proportional to:

$$\frac{A_0^2(\Delta t)^2}{T_0^2} \times F_a/f_c$$

i.e.: $\propto \frac{N^2 F_a}{4T_0^2 f_c^3}$ (substituting the value of $\Delta t = (N/2f_c A_0)$

$\ldots \quad (6)$

Noise Output Due to Phase Modulation of the P.R.F. and its Harmonics

The second expression in equation (3), given by $\sum_{n=1}^{\infty}(2A_o/\pi n)\sin\left[\frac{\omega_R n(d_o \pm \Delta t)}{2}\right]\cos \omega_R nt$, shows that the p.r.f. and its harmonics are phase modulated by the noise time-shift Δt, and will produce infinite harmonics causing an addition to the output audio-frequency noise in the receiver. Total number of harmonics of p.r.f. accepted by the receiver is equal to f_c/f_o and the contribution of each of the harmonics has to be added to give the total a.f. noise output. From the expansion of the phase modulated wave it is found, with the help of the Bessel functions[4] that the amplitude of each sideband is given by:

$$(2A_o/\pi n)\, J_m\left(\frac{\omega_R \,.\, \Delta t \,.\, n}{2}\right)\cos(\omega_R d_o n/2) \quad \ldots\ldots (7)$$

As Δt has frequency components from zero to f_c an infinite number of sidebands of each harmonic will be produced, but the a.f. amplifier will accept only the equivalent noise power proportional to F_a/f_c for each p.r.f. harmonic.

Further calculation of noise-sideband power on a generalized basis is highly involved and recourse is taken to a numerical example which shows the method of approach to the final result. Consider a p.l.m. system, where $f_c = 1\text{Mc/s}$, $\omega_R = 2\pi \times 10^4\text{c/s}$, $d_o = 2\times 10^{-6}\text{sec}$, $F_a = 3\text{kc/s}$, the slicing level $= A_o/2$, i.e. maximum $N = A_o/2$ and Δd = change of pulse length $= 2\times 10^{-6}$sec due to signal modulation.

For this system:

$$\Delta t_{max} = \frac{N_{max}}{2f_c A_o} = \frac{10^{-6}}{4}$$

$$\text{and}\ \frac{\omega_R \,.\, \Delta t \,.\, n}{2} = \frac{2\pi \times 10^4 \times 10^{-6} \times n}{4 \times 2} = (0{\cdot}008)n \quad \ldots\ldots (8)$$

[with $\Delta t = \Delta t_{max}$]

so long as $x \leqslant 0{\cdot}2$, $J_1(x) = 0{\cdot}5x$ and $J_2(x)$, $J_3(x)$ etc. are negligible[4]. Moreover, the sideband energies are only due to the first order sideband frequencies and not more than 1 per cent of the carrier energy. In this example, the value of x is within this approximation limit up to the 25th harmonic, i.e. for $n = 25$ in equation (8).

After the 25th harmonic, the second order sideband frequencies have to be considered and $J_2(x)$ may be approximated as $0{\cdot}125x^2$. Up to the 100th harmonic of p.r.f. is accepted by the receiver in the example, so the following approximation can be made with very little error.

$$\left.\begin{aligned} J_1(x) &= 0{\cdot}5x \\ J_2(x) &= 0{\cdot}125x^2 \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots (9)$$

The amplitude of the 1st order sideband frequencies is therefore given by:

$$(2A_o/\pi n)\, J_1\left(\frac{\omega_R \,.\, \Delta t \,.\, n}{2}\right)\cos\frac{\omega_R \,.\, d_o \,.\, n}{2}$$

$$= 0{\cdot}005\ N \cos\frac{\omega_R \,.\, d_o \,.\, n}{2}$$

And the total 1st order sideband power is proportional to:

$$\sum_{n=1}^{100}\left(0{\cdot}005\ N\cos\frac{\omega_R \,.\, d_o \,.\, n}{2}\right)^2$$

$$\text{i.e.}\quad \propto 12{\cdot}5\ N^2 \times 10^{-4} \quad \ldots\ldots\ldots\ldots (10)$$

The amplitude of the 2nd order sideband frequencies are given by:

$$(2A_o/\pi n)\,.\,J_2\left(\frac{\omega_R \,.\, \Delta t \,.\, n}{2}\right)\sin\left(\frac{n\omega_R d_o}{2}\right)$$

$$= \frac{\pi N \times 10^{-4}}{32}\,.\, n \,.\, \sin\left(\frac{n \,.\, \omega_R \,.\, d_o}{2}\right)$$

And the total 2nd order sideband power is proportional to:

$$\sum_{n=1}^{100}\frac{\pi^2 \,.\, N^2 \,.\, 10^{-8} \,.\, n^2}{(32)^2}\,.\,\sin^2\left(\frac{n\omega_R d_o}{2}\right)$$

i.e.:

$$\propto 0{\cdot}15\,45\ N^2 \,.\, 10^{-4} \quad \ldots\ldots\ldots\ldots (11)$$

Total peak noise power contributed by the above three factors is proportional to:

$$\left[\frac{N^2}{4T_o^2 f_c^2} + 12{\cdot}5\ N^2 \times 10^{-4} + 0{\cdot}155\ N^2 \times 10^{-4}\right]$$

And the peak noise power accepted by a.f. amplifier is portional to:

$$F_a/f_c\left[\frac{N^2}{4T_o^2 f_c^2} + 12{\cdot}5\ N^2 \,.\, 10^{-4} + 0{\cdot}155\ N^2 \,.\, 10^{-4}\right]$$

i.e.:

$$\propto (F_a/f_c) \times 12{\cdot}905 \times 10^{-4} \times N^2 \quad \ldots\ldots (12)$$

$$\text{since}\ \frac{1}{4T_o^2 f_c^2} = 0{\cdot}25 \times 10^{-4}$$

Actually the above noise power in the audio frequency output is to be doubled since the noise frequencies above and below the p.r.f. and its harmonics will produce lower sidebands equally. Hence the total effective audio noise voltage in the output is given by:

$$\sqrt{(2 \times 12{\cdot}905 \times 10^{-4} \times N^2 \times (F_a/f_c))}$$

$$= 5{\cdot}08 \times 10^{-2} \times N \times \sqrt{(F_a/f_c)} \quad \ldots\ldots\ldots\ldots (13)$$

For a 100 per cent modulated p.l.m. system, the r.m.s. audio signal output is given by:

$$\frac{A_o \,.\, \Delta d}{T_o\sqrt{2}} = \sqrt{2}A_o \times 10^{-2};\ \text{where}\ \Delta d = d_o \quad \ldots (14)$$

$$\text{Therefore}\ \frac{\text{r.m.s. signal}}{\text{effective noise}}\ \text{in the output}$$

$$= \frac{\sqrt{2}A_o \times 10^{-2}}{5{\cdot}08 \times 10^{-2}N}\,.\,\sqrt{(f_c/F_a)}$$

$$= A_o/N \times 5{\cdot}08$$

For $A_o/N_{pk} = 2$; $S_{rms}/N_{eff} = 10{\cdot}16$ .... (15)

The above r.m.s. signal-to-noise ratio in the output is further improved due to the fact that in the calculation the peak value of noise voltage has been considered. But the probability of this peak voltage is very small, and Daloraine[5] and others have shown that for practical results, the r.m.s. noise voltage is the effective noise voltage. Theory and experiments show that the "crest factor" (= ratio of amplitude of highest peaks to r.m.s. value of the amplitude) of random noise lies between 3:4 and 4:5. Taking a mean value of 4 for the "crest factor" and keeping the slicing level equal to N_{pk}, the output r.m.s. signal-to-noise ratio becomes 40·64. Moreover, the signal and noise amplitudes, that have been considered to be in phase during our initial calculations, are in random phase relationship with each other, and Kretzmer[6] has shown by the autocorrelation method that the mean effective value of the time shift in p.t.m. is equal to 0·7 times the maximum time shift. The r.m.s. signal-to-noise ratio is, then, further improved to the value of 58·07 (=40·64/0·7). This output r.m.s. signal-to-noise ratio is equivalent to 35·28dB for the input peak signal-to-noise ratio of 6dB only. The above calculations have been made for the single-edge modulation of the pulses. Noise modulation on the other edge can be eliminated by proper circuit arrangements. The assumption of Fourier series expansion of a rectangular-pulse may not be true for practical cases where bandwidth limitation is severe. But analysis of frequency components of trapezoidal pulses with appreciable rise time shows that the amplitude of higher harmonics of p.r.f. decreases more rapidly than that of the rectangular pulse and hence the audio noise contributions by the higher harmonics will be less than that in the case considered here.

Pulse Phase Modulation

Calculations, similar to the above for pulse length modulation, may also be made for pulse phase modulation. Considering equation (1), the pulse-phase shift caused by the noise is given by:

$$\Delta\phi_N = 2\pi\,(\Delta t/T_o) = \frac{\pi N}{f_c A_o T_o}$$

The general principle of detection of pulse phase modulated signals is that the p.p.m. signal is converted to a single-edge pulse length modulated signal and the resultant p.l.m. signal is filtered to produce the audio output signal. This shows that the general method of calculating noise output will be exactly similar to the case of p.l.m. with the only difference that the change of pulse length, Δd, will be dependent on the pulse shift of the p.p.m. signal. Considering a case where the pulse duration is 2×10^{-6}sec and the maximum time shift of the pulses due to the signal modulation is $\pm 8 \times 10^{-6}$sec, it is found that the resultant converted p.l.m. signal has a mean pulse duration of 10×10^{-6}sec $[= (8 + 2) \times 10^{-6}]$ and the maximum change of pulse length Δd is equal to 8×10^{-6}sec.

Examining equations (5) and (6), it is seen that the peak audio frequency noise power in the output, contributed by the amplitude modulation of the zero frequency component of the pulses is independent of the pulse length and hence is proportional to:

$$N^2 F_a / 4T_o^2 f_c^3 \quad \ldots\ldots\ldots\ldots\ldots \quad (6)$$

From equations (10), (11) and (12), the noise output due to the phase modulation of the p.r.f. and its harmonics is found to be proportional to:

$$F_a/f_c\left[\sum_{n=1}^{100}\left(0{\cdot}005\,N \,.\cos\frac{\omega_R \,.\, d_o \,.\, n}{2}\right)^2 + \sum_{n=1}^{100}\frac{\pi^2 \,.\, N^2 : 10^{-8} \,.\, n^2}{(32)^2}\,.\,\sin^2\left(\frac{\omega_R \,.\, d_o \,.\, n}{2}\right)\right]$$

The only difference between the p.l.m. and p.p.m. systems considered is that in the present p.p.m. system, the value of $\frac{\omega_R \,.\, d_o \,.\, n}{2}$ is equal to $(0.31416n)$, whereas in the p.l.m. system considered, the value of $\frac{\omega_R \,.\, d_o \,.\, n}{2}$ was equal to $(0{\cdot}0628n)$. The total 1st order noise sideband power is therefore proportional to:

$$\sum_{n=1}^{100} [0{\cdot}005\ N \cos(0{\cdot}31416\,n)]^2$$

i.e. proportional to:

$$12{\cdot}5\ N^2 \times 10^{-4} \quad \ldots\ldots\ldots\ldots\ldots \quad (16)$$

And the total 2nd order noise sideband power is proportional to:

$$\sum_{n=1}^{100}\frac{\pi^2 \,.\, N^2 \,.\, 10^{-8} \,.\, n^2}{(32)^2}\,.\,\sin^2(0{\cdot}31416\,n)$$

i.e. proportional to:

$$0{\cdot}165\ N^2 \cdot 10^{-4} \quad \ldots\ldots\ldots\ldots\ldots \quad (17)$$

Hence the total peak noise power accepted by the a.f. amplifier, given by equations (6), (16) and (17), is proportional to:

$$F_a/f_c\left[\frac{N^2}{4T_o^2 f_c^2} + 12{\cdot}5\ N^2 \,.\, 10^{-4} + 0{\cdot}165\ N^2 \,.\, 10^{-4}\right]$$

i.e. proportional to:

$$(F_a/f_c) \,.\, N^2 \,.\, 12{\cdot}915 \times 10^{-4} \quad \ldots\ldots\ldots \quad (18)$$

Taking into account the factors given in equation (13), the total effective audio noise voltage in the output is given by:

$$\sqrt{[(2F_a/f_c) \times 12{\cdot}915\ N^2 \times 10^{-4}]}$$
$$= 5{\cdot}08 \times 10^{-2} \times N \times \sqrt{(F_a/f_c)} \quad \ldots\ldots \quad (19)$$

For the p.p.m. system considered, the r.m.s. audio signal output is given by:

$$\frac{A_o \,.\, \Delta d}{\sqrt{2}T_o}$$
$$= \frac{A_o \times 8}{\sqrt{2} \times 100}$$
$$= 4\sqrt{2}A_o \times 10^{-2} \quad \ldots\ldots\ldots\ldots\ldots \quad (20)$$

Therefore: $\frac{\text{r.m.s. signal}}{\text{effective noise}}$ in the output =

$$\frac{4\sqrt{2}\,A_o \times 10^{-2}}{5{\cdot}08 \times N \times 10^{-2}} \times \sqrt{(f_c/F_a)} = 20{\cdot}32\ A_o/N$$

For $A_o/N_{pk} = 2$;

$$S_{rms}/N_{eff} = 40{\cdot}64 \quad \ldots\ldots\ldots\ldots\ldots \quad (20)$$

As in the case of p.l.m. signals, the probability of r.m.s. noise voltage is maximum and the phase relations between signal and noise amplitudes are random. Hence the above signal-to-noise ratio is further improved to the value of $\frac{(40{\cdot}64 \times 4)}{0{\cdot}7}$ i.e. 232·3. This output signal-to-noise ratio is equivalent to 47·32dB for an input peak signal-to-noise ratio of 6dB only. Due to the fourfold increase in modulation of the pulse-edge in p.p.m., the improvement in the output signal-to-noise ratio is 12dB approximately over the previous p.l.m. system.

Discussion

From the above analysis, theoretical curves can be drawn showing the signal-to-noise ratio in the audio output above the input threshold signal value of 6dB over the peak noise level. Fig. 2 and Fig. 3 show the theoretical ratios in decibels in p.l.m. and p.p.m. systems. Moskowitz and Grieg[8] have made an experimental study of the signal-to-noise ratios in a p.p.m. system and their curves are given in Fig. 4. The characteristics of this system, as given in Fig. 4, are similar to those of the system considered above. Comparing the curve of Fig. 3 and curve c of Fig. 4, it it seen that there is enough corroboration between the two curves. The slightly inferior behaviour of the experimental results of Fig. 4 is due to the fact that the bandwidth in this

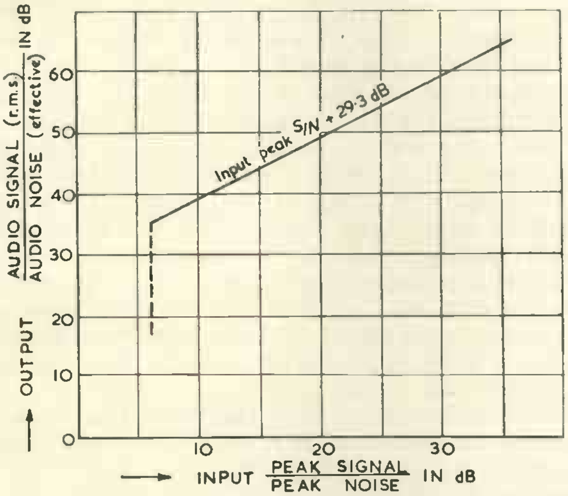

Fig. 2. Theoretical signal-to-noise ratio in p.l.m.

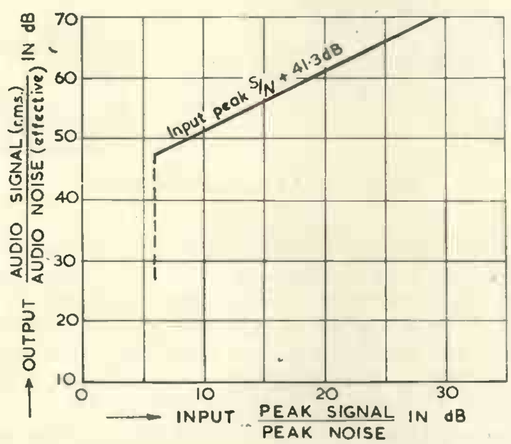

Fig. 3. Theoretical signal-to-noise ratio in p.p.m.

system was 700kc/s instead of 1Mc/s as considered in the theoretical curves. The theoretical results are slightly higher than practicable due to the fact that the sliced pulse has been considered to be infinitely small in height and contains no noise except in the form of pulse-edge-modulation. Both these assumptions are rather extreme. But the analysis, as given here, is simple in comparison with those indicated by Jelonek[7] and others and even then, the results are quite good.

Goldman[1] has shown that the effective audio noise output is given by $(N/2f_cA_o) \cdot \sqrt{(2F_a/f_c)}$, which gives an output signal-to-noise ratio of 10·3 ($\equiv$ 20·26dB) only when applied to a p.l.m. system and a ratio of 41·3 ($\equiv$ 32·32dB) only for the p.p.m. system, with input peak signal to peak noise ratio of 6dB. Gouriet[9] has shown that in p.l.m. with 1Mc/s bandwidth, the improvement in signal-to-noise ratio in the audio output is only 10dB over an a.m. system. These values are rather low compared to the values obtained here.

However, the following conclusions can be drawn from the foregoing analysis. (1) If the slicing level is above the peak noise amplitude, the signal-to-noise ratio in the audio output is proportional to the input signal-to-noise ratio, and the improvement in the output ratio (measured in dB) is constant. (2) If the time displacement of the pulse edge is made to be the same in p.p.m. and p.l.m., the audio signal-to-noise ratio in the output will be the same for both the systems for the same input ratio. This result was also shown by Jelonek. (3) From equation (1), it is seen that the noise-time-modulation of the pulses is inversely proportional to the video bandwidth. But due to the limited audio bandwidth, the signal-to-noise ratio in the output is further modified as seen in equations (6), (10), (11) and (12). (4) Even though the results are not

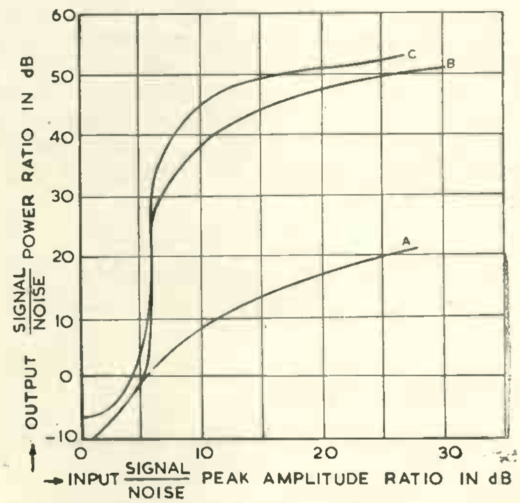

Fig. 4. Experimental signal-to-noise ratio in p.p.m.

P.R.F. = 12kc/s. Modulation displacement = ±8μsec. Pulse build-up time = 0·75μsec. Pulse decay time = 1·5μsec. A.F. modulating frequency = 400c/s. Demodulated a.f. passband = 100-3 000c/s. CURVE A *is with a double gate limiter.* CURVE B *is with two double gate limiters separated by a differentiator.* CURVE C *is with three double gate limiters separated by two differentiators alternately connected.*

generalized in the final form, the analysis indicates a method to calculate the noise performance of any typical p.t.m. system.

Acknowledgment

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Electronic Music Generators

(Part 2)

By Alan Douglas, M.I.R.E.

IN Part 1, a music generator of general utility was described, and this is a basic unit which is complete in itself, but can be extended in various ways. Perhaps the most obvious addition is an octave coupler. This term is sometimes loosely used to describe a means of raising the normal pitch of the whole register by one octave, but it should be self-evident that the octave pitch is not produced to the exclusion of the normal pitch, but added thereto, if the device is correctly to be termed a coupler.

Such an arrangement acts on all tonalities equally, but opens up a new field of combinational possibilities which become still more useful as other extensions are added to the instrument. The octave coupler is a mechanical device but since it only introduces an additional set of contacts the touch is unaffected so that, unlike old mechanical action organs, it is no harder to play with the coupler in action.

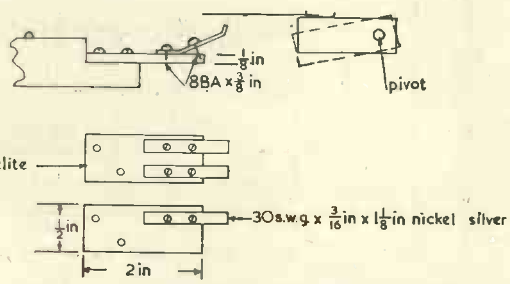


Fig. 14. Octave coupler key wipers and contact wires.

Examination of Fig. 8 will show that the tail end of the keys extends beyond the pivot pin. This can be used to carry a bakelite strip supporting the extra contacts called for. Fig. 14 shows the details of this part. It will be noted that unless an extra octave of oscillators is provided at the top of the compass, the coupler will cease to be effective above C_3. Whether these extra generators are thought worthwhile or not is left to the constructor; they can only be used with the coupler in action. Details of the coils for this additional octave are given in Table 3. The other circuit elements remain the same as before, but the soft iron tuning strips must be replaced by one thin strip of Stalloy only, and this can be cut from a number 39 lamination, using the outer legs.

TABLE 3. Top octave coil details

Coil, $\frac{3}{8}$ in. × $\frac{3}{8}$ in. stack M & E alloys no. 39 stalloy.	
Winding.	900.0.900 turns × 39 s.w.g. enamel for first 4 coils.
	600.0.600 turns × 39 s.w.g. enamel for last 2 coils.
Tuning capacitors. ·002μF to ·0002μF.	
Frequency range 2217·4 to 4186c/s.	

To revert to the coupler. Without the extra generators, 49 strips and 79 contact pieces will be required; if the generators are extended to C_5 (=4 186c/s) there will be 61 strips and 93 wiper contacts. These latter can be made from 30 s.w.g. × 3/16in wide nickel silver strip[11] and are attached by 8B.A. × $\frac{1}{8}$in cheese head brass screws[4]. The method of adjustment is similar to that of the main key contact plates. To carry the 28 s.w.g. hard silver contact wires requires a strip of Bakelite or Perspex 1in wide, $\frac{1}{8}$in thick, and reaching from CC to C_3 for 49 notes or the whole length of the keys for 61 notes. The CC end is supported by a 1in Mecanno spindle (5/32in diameter hole) set near to the rear of the strip and housed in the keyframe. See Fig. 15. Place a washer of thin felt between the strip and the wood of the frame. If the extra generators are used, the upper or C_4 end of the strip is similarly mounted, but this will necessitate slotting the frame. If the coupler stops at note 49 (=C_3) then the spindle must be held in a bracket screwed to the back of the keyframe as in Fig. 15. Take care that the edge of the bakelite strip nearest the keys is about 1in from, and quite parallel with, the keytails.

If now we assume the long bakelite rocking bar to be mounted and the short strips complete with wiper contacts attached to the keys, it is possible to mark off from the wipers for the setting of the contact wires and their securing

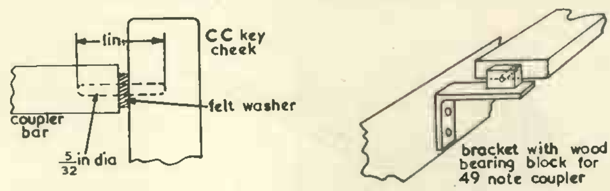


Fig. 15. Coupler bar mounting details

tags on the rocking bar. The proper level of this bar with respect to the keys is when a piece of silver wire, laid on the bar, lies horizontally when its other end touches a wiper contact, if these are set to half their travel by the adjusting screw and with the keys up. Mark off with a steel rule from the centre of each wiper to the bakelite strip, one contact for CC, two for CC♯, one for D, two for D♯ as with the manual keys. Suitable solder tags are then inserted near to the front edge of the bar to take the silver wires, now 1·3in long, and soldered thereto, leaving about $\frac{1}{2}$in projecting towards the front of the keys over the contact edge. All these wires should lie evenly on the wipers when attached, and this is very important.

To connect the wipers use very fine flex, 3 or 7/0076 is ideal. Fig. 16 shows how these loops are formed, for they must bend as the keys move; but the movement is very small at the rear of the keys. The ends of the two sets of loops are brought out to a two-way tag strip at the rear of the keyframe and marked + and B, as in Fig. 16.

So far we have not mentioned any means for operating the rocking coupler bar. Owing to the offset pivot, only a small movement is needed and this can be done mechanically by coupling to a standard stop key. A more elegant way is to use a small solenoid supplied with 12 volts from a full wave metal rectifier. No smoothing is required and details of a solenoid are given in Fig. 17. A light spring or a weight should return the coupler bar to the "off" posi-

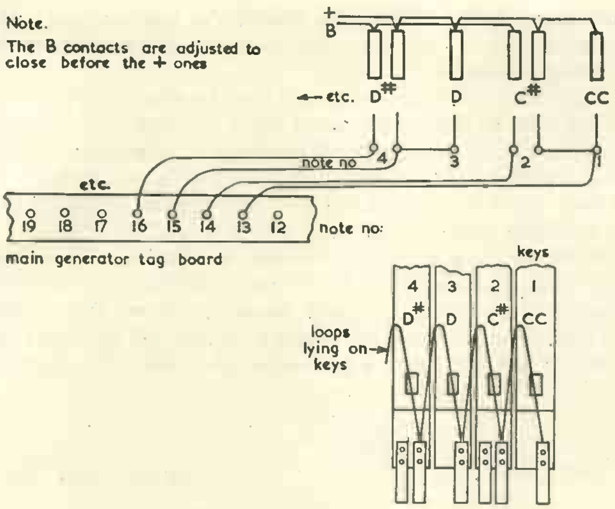


Fig. 16. Coupler connexions

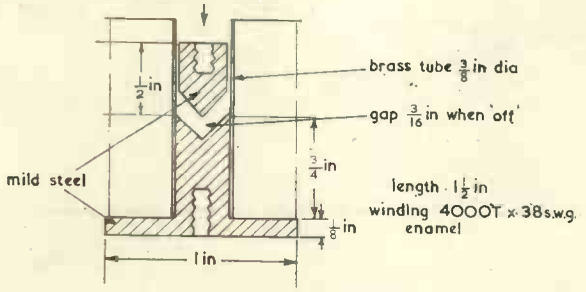


Fig. 17. Solenoid

tion, which is such that no wiper can touch a contact when a key is depressed. A stop should be screwed to the CC key check to fix the position. It has been found on several instruments which have been built with different wiring routes that no interference is caused by the solenoid and no suppression is needed. If direct mechanical operation of the bar is preferred, the details of the links will depend on the arrangement of the stops, and must be left to the constructor; but the actuating lever should come near to the centre of the bar.

Very fine wire is used to connect the coupler to avoid imposing any drag on the action. 36 s.w.g. single silk and enamel is suitable and the method of wiring will be clear from Fig. 16. Each set of contacts is taken to the main generator tag strip one octave above and it will be evident that if the + and B outlets are parallel, depression of the rocking bar will connect any key to the generator one octave higher, thus sounding this pitch as well as its normal or unison pitch.

The octave coupler is extremely useful with the flute, forming a small chorus of a pleasant quality. The effect of the viole is greatly enhanced, particularly with the tremulant, and the addition of the octave to the tibia results in a full and brilliant ensemble. It increases the power of the reeds and appears to have the effect of almost doubling the tonal output of the instrument. This is the most useful and versatile extension for a negligible outlay.

Next perhaps we should consider a bass generator. All sustained tone keyboard instruments have an organesque character, but this fact only emphasizes the need for a suitable bass. By providing a separate generator for the 16ft tones, that is, notes one octave lower in pitch than the corresponding ones on the keyboard, we have the advantage that an independent bass is available, but further, by a very simple arrangement we can obtain all the manual tones on the pedals as well, singly or in combination. The gain is thus out of all proportion to the cost.

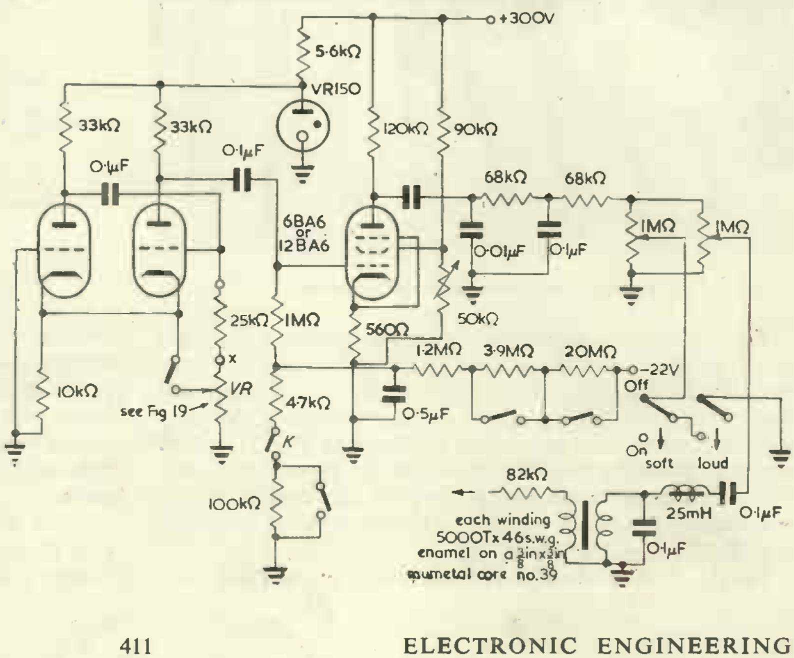
While in a full-scale organ it would be worthwhile to provide a separate generator for each note or pair of notes, we must satisfy ourselves with a monophonic generator which is continuously re-tuned to the correct pitch. Such a circuit is simple, inexpensive and suitable for the purpose envisaged. The rare occasions on which it is necessary to sound two pedal notes at the same time do not justify the cost of a polyphonic generator.

The circuit used is shown in Fig. 18. This includes the attack control valve, tone forming circuits, coupling transformer, transient suppressor and power supply. The generator is an unsymmetrical multivibrator due to R. Calvert, and not only provides a better waveform for tone shaping than the more usual circuits, but tuning is easier. One capacitor covers the required range.

The start of the wave is rapid and this would lead to a click, but apart from this it is an advantage to have the rate of attack under control. The circuit shown combines this function with that of pre-amplifier. The small transients which inevitably exist are removed by the rest of the circuit which combines this function with a certain smoothing of the waveform which, in combination with the tone filter, yields a smooth and natural bass which is most essential in an average size of room.

Everyone who has heard a pipe organ is aware of the pervading nature of the bass notes. If one were asked to identify the nature of the sound this would prove very difficult, except for tones of considerable power and special definition. It is this kind of bass which is ideal for the smaller keyboard instruments. We obtain it in two grades

Fig. 18. Pedal note generator and controls



of power, the levels of which can be set independently; but the tones are not identical. The quieter one has a greater harmonic content than the louder one. So sufficient contrast is available for any combination of manual tone-colours. The tuning of the circuit is carried out by Egen pre-set resistors[12]. Originating in a 10kΩ wire-wound rheostat, which is the pitch control for setting the top note, each successive semitone is fixed by adjustment of the pre-set units. Fig. 19 shows part of the tuning circuit, with a list of the resistors required. The whole tuning stack, as a series string, is the element *VR* in Fig. 18.

So far we have not considered how the notes should be keyed or operated. Many will consider a standard organ pedalboard the proper answer. Others will think this unnecessary and prefer short permanently attached keys as in Fig. 20, which shows this part of a recent American instrument for the home. But in either case the compass should not be less than 25 notes from CCC and for serious work the compass should be 30 notes. This point is not only of importance musically, but because it affects the number of tuning resistors required.

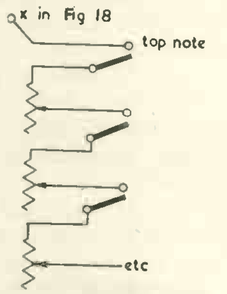


Fig. 19. Pedal tuning stack

Resistors:
from C to CCC, 25 *notes: all* 25*k*Ω *max.*
from F' to CCC, 30 *notes: first* 5, 10*k*Ω *max.*

No guidance as to the construction of the pedals[13] can be given because of space considerations, but the contacts required for both pedal unit and the manual to pedal coupler are shown in Fig. 21. Since the bass contacts are part of the resistive element of the oscillator, a low and constant contact resistance is essential. For this reason the contact faces should be Rhodium plated[9]. The coupler and control valve contacts[6] may be silver alloy or even phosphor bronze and are cheaply obtainable.

Fig. 20. Pedal arrangement of Organsonic

For the manual to pedal coupler we require a duplicate set of manual contacts actuated by the pedal keys, but since these have a longer travel they may be larger altogether and the pattern referred to above is recommended. An easy way to connect the two circuits is shown in Fig. 21, which also illustrates the speaking contact *K* on the control valve. This must be set to close *after* the bass unit contact, and is easily made from two leaves of a springset taken from any type 3000 Post Office relay.

Pedals, if of normal construction, are made detachable and simply pull out from the frame. An intermediate lever called a jack is used to couple the pedal key movement to the contacts as in Fig. 21.

For those who feel they would like the effect of a plucked string bass, as well as sustained tones, another form of control circuit can be used[14]. A final word on pedals; do not be deterred by the seeming complexity of a pedalboard. It is very easily made and standard size timber ready planed is available at a very modest cost[15].

Now we come to the stop switch mechanism. There are two ways of doing this. Either microswitches can be purchased[16], or sliding contacts made up from P.O. relay springs. The microswitches are s.p.c.o., so will serve for all circuits; in some cases, e.g. trumpet and oboe, two must be

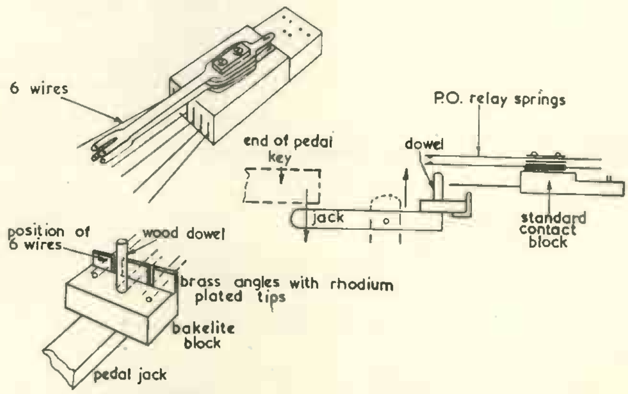


Fig. 21. Pedal generator, coupler and attack control contacts

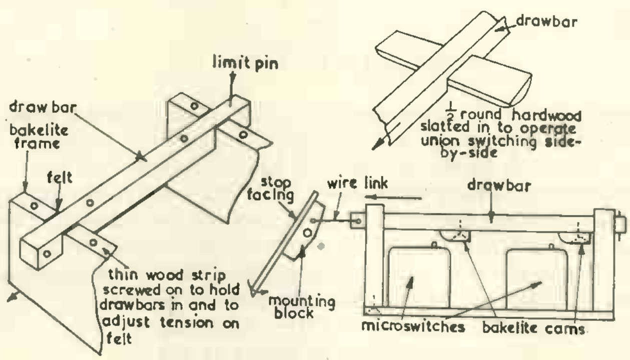


Fig. 22. Stop switches using microswitches

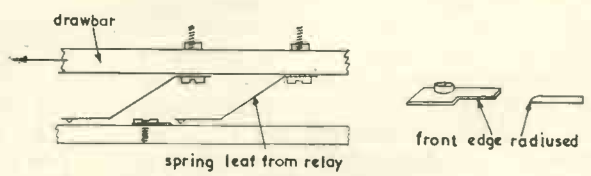


Fig. 23. Alternative arrangement using sliding contacts
All draw bars 8in long

mounted side by side and these can be operated by little bakelite cams on the drawbars as in Fig. 22. The pairs require a shaped piece of hardwood as shown. Stop key facings, suitably engraved, are inexpensive[17] and it is usual to have tonal stops white with black lettering, and non-tonal stops such as tremulant, couplers etc., black with white letters.

If it is decided to make up sliding switches, Fig. 23 gives most of the essential details. These are, of course, much cheaper but take a good deal of time to set for effortless operation. The fact that the silver tips are in contact with the base when "off" prevents the formation of any oxide so that there is never any hesitation in making contact with the nickel silver pieces.

The last remaining extension is a solo or melodic generator on a separate keyboard. In this way a most inexpensive two manual instrument can be made, and while its uses are limited there is no doubt of its value for the more romantic school of music. Of course such commercial instruments as the Solovox, Univox, Clavioline etc., are well known; but their compass is only three octaves, and it is thought that the full compass of five octaves is more useful, particularly if the unit is to be built in with the main generator keyboard. It is also considered more in keeping with normal playing technique to have stops representing fixed tonecolours instead of a variety of harmonic switches which can be combined as desired. Certainly if an instrument of this kind is to be installed in a small church or hall (for which it is very suitable), a strange player would feel at home with it at once.

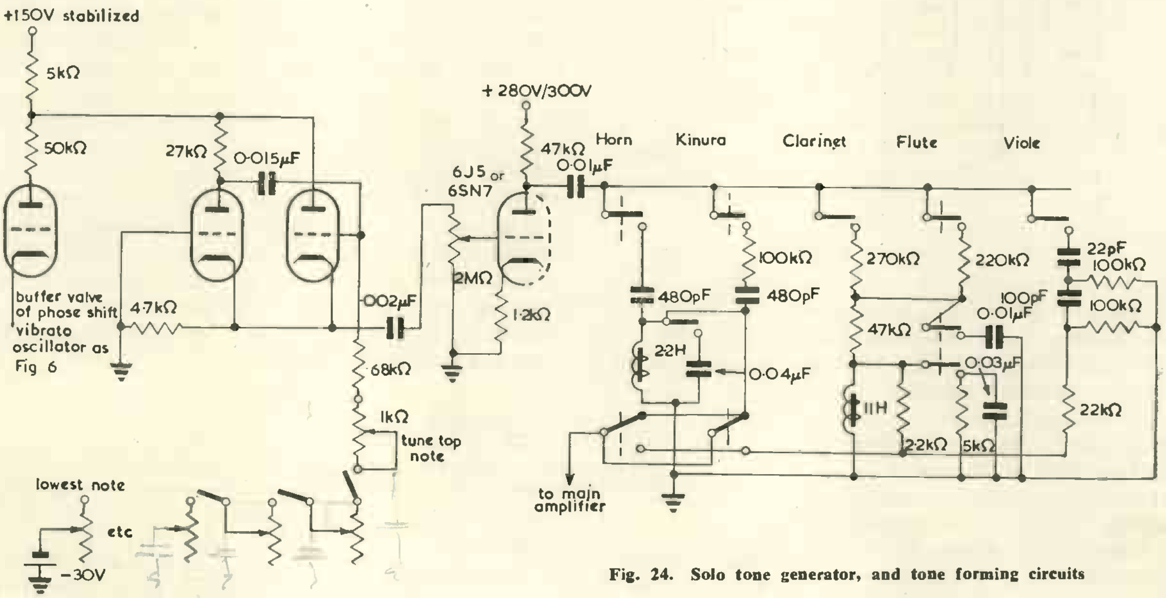


Fig. 24. Solo tone generator, and tone forming circuits

To cover the range of five octaves with only one variable circuit element restricts the tone oscillator to a pulse generator. True, a gas tube oscillator could be used, but there are certain good reasons why it is difficult to obtain satisfaction from these. The circuit of Fig. 24 represents careful study of all available methods, bearing in mind the paramount requirement of the home constructor—simplicity.

A number of useful tones can be formed from the cathode pulse, all of musical value, but as would be expected, the flute has some trace of stringiness in the lower two octaves. The tuning is set initially to the highest note (C_4 = 2 093c/s) by the 1kΩ variable resistor, which spreads the control over a wide range. All other notes are set from this by the Egen pre-set resistors. There are 20 at a maximum value of 1kΩ, 20 at 5kΩ and 20 at 10Ω, but the lowest six notes require a series resistor of 5kΩ.

The output from this oscillator is surprisingly uniform over the pitch range.

At the time these articles were written, no frequency dividers were fitted to the melodic generator in view of the fact that its compass was five octaves. It is appreciated that the chorus effect due to the addition of sub-octave pitches to the unison pitch is a considerable asset for the performance of certain kinds of music and the dividers now to be described have been used with success.

So we encounter the problem of deciding to what extent division should take place. Dividers can be cascaded and the most satisfactory arrangement is to alter the basic oscillator pitch to 4ft instead of 8ft. Then two dividers will give 8ft and 16ft pitches, which are far more useful than 16ft and 32ft from a basic pitch of 8ft. In addition, we have an extra top octave. The change in frequency is accomplished by halving the value of the 0·015μF capacitor in the pulse generator.

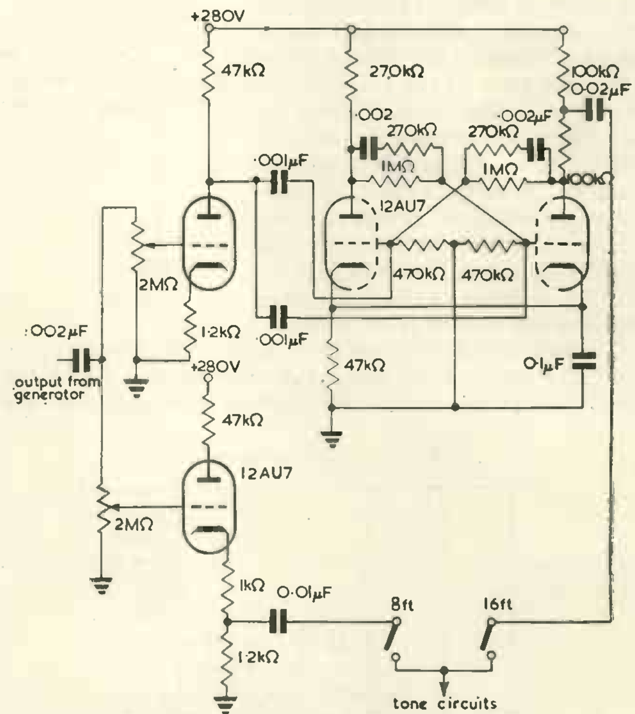


Fig. 25. Frequency divider and isolating valves

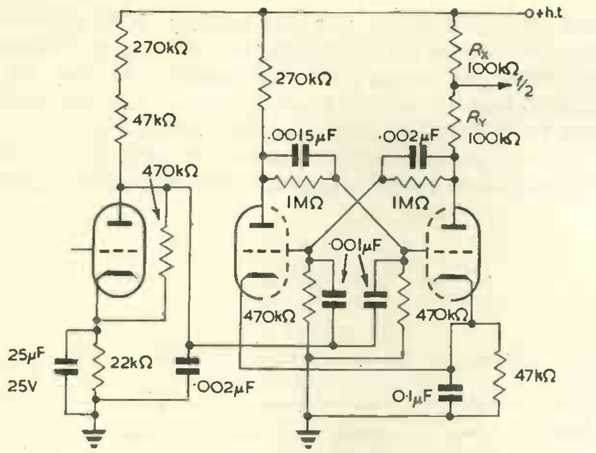


Fig. 26. Alternative divider

Since the output from this is a triangular wave and that from the dividers is a reasonably square wave, the tones obtained from the existing filters change to some extent with the pitch. By judicious selection of the part of the keyboard used, some additional effects can be obtained.

Many frequency dividers exist for musical instruments, but all are to an extent frequency dependent except some form of the Eccles-Jordan circuit. Such modifications as are to be found in adaptations of this circuit are directed to controlling the shape of the divided waveform. In view of the shape of the input pulse, the divider shown in Fig. 25 is found very suitable. If fed directly from the generator cathodes through a ·002µF capacitor, no additional circuit elements are required to drive a second divider. If fed as shown in Figs. 26 and 27, a shaping or isolating stage between the dividers is desirable.

The cascaded divider due to W. Bode, Fig. 28, is very useful. The output from this divider will be found to be of greater amplitude than that from the generator and the values of R_X and R_Y can be adjusted to set the level. The divided signals can be injected into the grid of the 6BA6 valve and another way of doing this is to tap the unison, 8ft and 16ft signals into a potential divider between the grid of this valve and earth, at points found by trial. These points are switched to isolate any particular pitch not required.

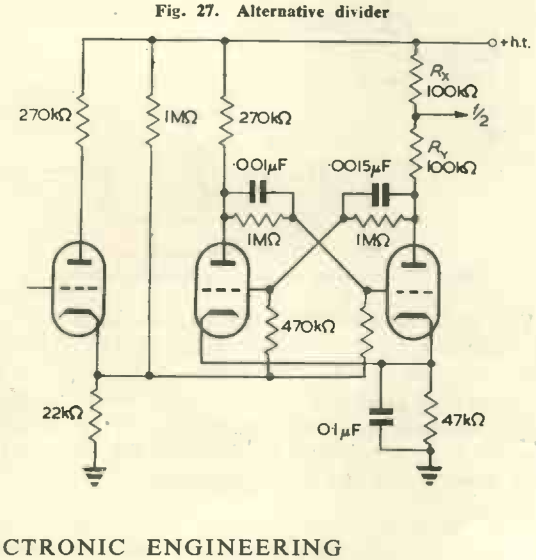


Fig. 27. Alternative divider

Stabilization of the h.t. line is necessary and a single VR150 has proved adequate except on the very worst mains; here, a simple valve stabilizer would be preferable. It should be noted that if the two music generators described are combined in one instrument, the h.t. for the solo and pedal generators must be derived from a separate transformer and rectifier. If branched off from the VR105 line, transients will appear in this latter circuit, affecting the attack of the main generator, which is smooth and natural. The percussion circuit previously mentioned[14] can be applied to the solo generator for special effects and, of course, the key contacts are much simpler, being single pole for each note. The mains switch, supply plug, valveholders and tag strips, as well as microswitches, may be obtained from A. F. Bulgin[16].

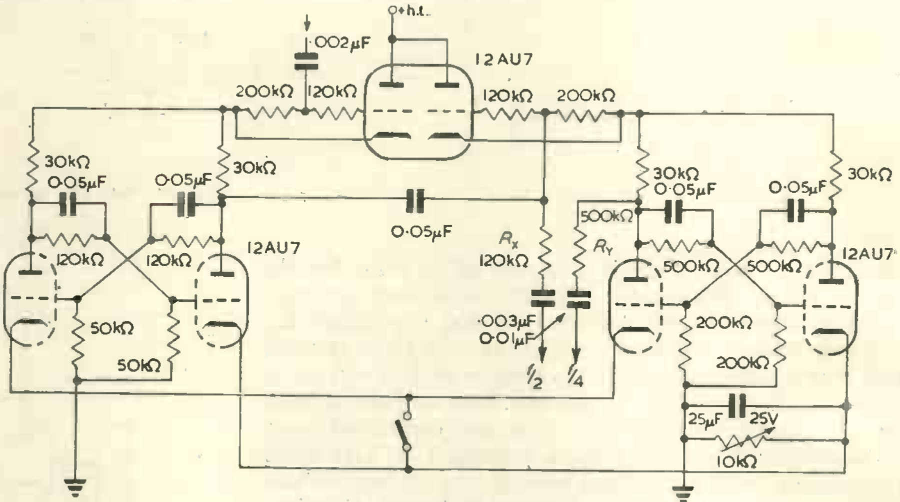


Fig. 28. Cascaded divider

It is hoped that the musically inclined reader will find this description sufficient to provide him with a simple instrument capable of giving endless pleasure. Although many circuits and methods are possible, those outlined are simple, truly musical, devoid of any trace of "synthesis", and inexpensive. Their advantages outweigh their shortcomings, and after all, every keyboard instrument has its limitations. Long experience has taught the author that in comparatively small rooms a special type of tone quality is preferable to that associated with larger buildings, and to achieve a sense of fullness without loudness or forcing, it is necessary to compound a tonal spectrum which is neither too thick nor too thin, as it were. A sufficiently large sample of light and classical musicians has endorsed the appeal of these simple generators to justify this viewpoint.

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12. Egen Electric Ltd., Canvey Island, Essex.
13. Ellingsworth and Mears, The Science of Organ Pedalling. Musical Opinion. 26, Hatton Garden, London, E.C.1.
14. Simple Electric Musical Instruments. Norman Price (Publishers) Ltd., 385, City Road, London, E.C.1.
15. Northern Timbercraft Supplies, Beverley Street, Livesey, Blackburn, Lancs.
16. A. F. Bulgin & Co., Bye Pass Road, Barking, Essex.
17. Clearmold Plastics Ltd., Commercial Street, Lenton, Nottingham.

BOOK REVIEWS

Advances in Electronics and Electron Physics Volume VI

Edited by L. Marton: 538 pp. 60 figs. Demy 8vo. Academic Press Inc., New York. 1955. Price $11.80.

THIS volume maintains the reputation of the series under a change of title; the addition of "electron physics" to the title indicates the growing concern of the physicist in this field. Of the eight reviews of developments in electronics included in this book, three are concerned with magnetic materials and magnetism, one with metallic conduction, one with space charge effects, and one each with the rapidly advancing electronic techniques employed in semiconductor devices, travelling-wave tubes and electron microscopy.

In the first review, A. B. Pippard relates progress made in applying high frequency techniques developed originally for radar purposes to the problems of metallic conduction at low temperatures. These include the finite resistance of superconductors to very high frequency currents and the anomalous skin effect.

The next two reviews, the first by E. Abrahams and the second by J. Smit and H. P. J. Wijn, deal with non-conducting ferromagnetic materials (especially ferrites) and their behaviour when subjected to high frequency fields. The first concerns relaxation processes in ferromagnetism, and the second the physical properties and uses of ferrites, which now include high as well as low power applications.

The fourth article is a comprehensive review by H. F. Ivey of the theory of space-charge limited currents. This is the longest and probably the most important part of this book; it includes sections on space-charge in beams, cavities and semi-conducting solids.

The next contribution is from W. M. Webster, who compares the behaviour of transistors and gas-filled tubes and estimates the maximum ratings possible for transistors of the future.

M. E. Haine, writing on electron microscopy, reviews the present state of our knowledge of electron optical techniques and the recently renewed progress towards a resolution which could make visible the structure of atomic lattices.

The article on travelling-wave tubes by R. G. Hutter classifies and reviews the rapidly-growing number of devices in this field; the experimental developments of the last ten years are just beginning to lead to practical uses for tubes of this kind.

The last article, by J. van den Handel, is on paramagnetism and includes sections on paramagnetic resonance, adiabatic demagnetization and antiferromagnetism.

The whole book can be recommended to any who want a short succinct account of the present state of affairs in the various branches of electronics covered. The lists of references at the end of each article are well chosen and are in themselves of no little value. The number of references included is often over a hundred and indicates the difficulty of writing comprehensively on such topics; the editor is to be congratulated on finding authors who have done so well in the face of such odds.

C. D. CURLING.

Elektronische Halbleiter

By E. Spenke. 379 pp. 70 figs. Demy 8vo. Springer Verlag, Berlin. 1955. Price DM.34·50.

SEMICONDUCTOR and transistor physics has become a topical subject treated by several recent books. Since the now classical volume by Shockley, none of these has dealt with the subject adequately.

Here the present book is a laudable exception. Its arrangement shows a certain similarity with that adopted by Shockley. The first part, dealing with the conduction mechanism in semiconductors and the physics of transistors and diodes, forms an excellent survey of the subject. It is clearly written and the subject matter is systematically arranged. The author has well succeeded in introducing the energy band concept, positive hole and lattice imperfection on a non-mathematical but rigorous basis.

The chapters on devices, i.e. p-n junction diodes and transistors might have been more detailed and advanced. Unfortunately they stop short at the basic phenomena.

The second part treats the fundamental principles of semiconductor physics presenting a most readable account of this complex subject. Unlike in so many works, mathematics is introduced to help rather than to baffle the reader who might be a little unfamiliar with the more complex theories of quantum physics.

Thus the theory of the homopolar bond, the energy band model, Brillouin zones, Zener-breakdown, Fermi-levels, etc., lose their formidable aspect and become tractable and helpful concepts, easily understandable.

The book deals successfully with problems associated with a life time of minority carriers and the elementary theory of surface states and metal-semiconductor contacts.

There has been for some time a great need for a book precisely of this kind and hence it must fill a serious gap on the shelf of every physicist and engineer concerned with transistors. It is unfortunate that no equivalent books exists in English.

Production, clarity of print and illustrations are of the high standard which one usually expects for Springer publications.

K. HOSELITZ.

ELECTRONIC EQUIPMENT

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

Q Meter

(Illustrated below)

THE Advance Q Meter is a.c. mains operated and provides a convenient method for making r.f. measurements of circuit magnification (Q), inductance, capacitance and power factor at frequencies between 100kc/s and 100Mc/s. A signal from the internal oscillator is injected into an inductive loop across which the voltage is metered and adjusted to a set level. A fraction of the loop consists of a stout bar from earth to one of the test terminals, and thus provides a signal with very low input impedance to the test circuit. The coil under test is in series resonance with an internal low loss, variable capacitor. The voltage across the capacitor indicates the Q, and is detected by a valve voltmeter calibrated

directly in terms of circuit magnification. The oscillator is modulated at 50c/s 50 per cent, so that d.c. amplifiers need not be used in the valve voltmeter, thus eliminating zero setting.

An unknown capacitor may be connected in parallel with the standard capacitor, and its capacitance and power factor then obtained by substitution.

In order to simplify calculations of inductance and impedance, the variable capacitor is calibrated with three scales. The first scale is calibrated in picofarads; the second scale is calibrated to read Z_t so that the impedance in ohms may be obtained by dividing the reading by the frequency in Mc/s. The third scale is calibrated to read L_t^2 so that the inductance in microhenrys may be obtained by dividing the reading by the square of the frequency in Mc/s.

Advance Components Ltd,
Marlowe Road,
Walthamstow,
London, E.17.

Portable Centrifuge

(Illustrated above right)

THIS centrifuge has been designed principally for testing components to be used in guided missiles.

With a range of between 0·25 and 100g, the speed of the table is controlled to within 0·25 per cent by means of a hybrid circuit which is similar to both

Velodyne and Ward-Leonard controls. The circuit is such that there is a high degree of stabilization against changes in supply voltage.

The space occupied by this instrument is only 32in × 25in while the overall height with guard mounted is less than 16in.

The table itself is of S.R.B.P. which by reason of its lightness cuts the time normally required to run up to speed. Up to four components with a total weight of 12lb can be tested at one time; in addition facilities are provided for the connexion of both electrically and air operated components under test.

Graseby Instruments Ltd,
Hook Rise,
Tolworth,
Surrey.

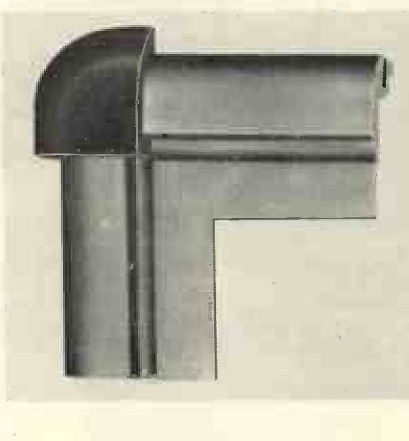
Cabinet Construction System

(Illustrated below)

ALFRED IMHOF LTD are now marketing a new "make-it-yourself" cabinet construction system.

This new product is known as the Imhof-Elliott system, and Imhofs are appointed sole world distributors.

Fundamentally, the system consists of two different units, each interlocking one with another. These two units shown in the accompanying illustration are the corner-connector, which governs the shape of the projected case or framework, and the alloy extrusion frame-member which may be cut to any size within the standard 12ft length.



As will be seen from the illustration the triple-pronged corner-connector corresponds in section with that of the frame-member. Thus these two units interlock precisely and simply. Allowance is, of course, made for screw tapping or similar fixing: and the rebated edge on the frame-member provides for a clean flush fitting of panels of any suitable material.

Alfred Imhoff Ltd,
112-116, New Oxford Street,
London, W.C.1.

Oscilloscopes

THREE new oscilloscopes have recently been announced by Nagard. Brief details of these are as follows.

MODEL DT103 (Illustrated above)—High sensitivity, low frequency oscilloscope covering the range from d.c. to 100Mc/s in two identical channels. Sensitivity 1cm/250μV. Noise level of the order of 10μV.

Amplifiers calibrated for voltage measurement over 2mV to 300V within 5 per cent and $\pm$100μV for smaller signals. Balanced inputs with high discrimination.

Wide range time-base with versatile triggering circuits, calibrated for time measurements and giving continuously adjustable sweep speeds from 20sec to 200μsec per 10cm.

Sweep expansion on either one or both beams, enabling magnification of portion of waveform while seeing the whole on the other channel.

Independent X shifts enable the two traces to be aligned as desired for comparison.

MODEL DS103—A less sensitive version of the Model DT103 incorporating a two-channel amplifier covering the frequency range of d.c. to 250kc/s. Sensitivity 1cm/8mV. Voltage calibrated.

Time-base is the same as for the Model DT103.

MODEL DE103—Wide band d.c. to 10Mc/s with identical amplifiers in each of two channels, driving a 6in c.r.t. with two separate gun systems. Time-base calibrated for time measurements to 2 per cent. Speeds continuously adjustable over range of 0·2sec to 2μsec per 10cm. Independent X shifts enable the two traces to be aligned as desired for comparison.

Amplifiers provide for voltage measurements over range of 200mV to 300V to 5 per cent and ±10mV for signals below 200mV.

Signal delay line for pulse leading edges, and cathode-follower probe, are both available as external units.

Any of the above instruments can be supplied trolley mounted, as illustrated.

Nagard Ltd,
18, Avenue Road,
Belmont,
Surrey.

High Voltage Triode Control Valve

(Illustrated above)

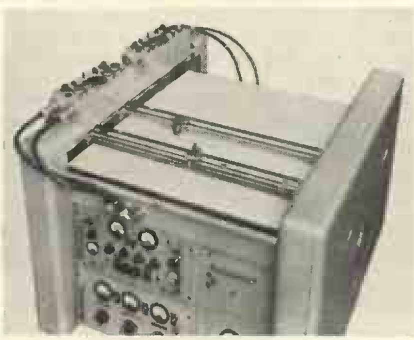
THE triode control valve type TV501 was developed for use in medical X-ray apparatus but it is likely to be of considerable interest for other purposes.

The principal features are:

- Maximum anode voltage, 70kV.
- Peak emission, 3A.
- Anode dissipation, 1·2kW continuous; 10kW for 1sec at a time
- Cut-off characteristic at $V_a = 70$kV. $I_a = 100\mu$A for $V_g = -400$V.

The overall diameter of the valve is 4¾in and the overall length approximately 12in.

Solus Electronic Tubes Ltd,
15-18, Clipstone Street,
London, W.1.



Medium Speed Plotting Table

(Illustrated above)

THIS instrument was originally developed to record one variable (X) in relation to another (Y) on a plotting area measuring 30in × 18in. Further developments have been made and it is now possible to apply up to four variables to one table measuring 30in × 30in, or larger if need be. This may take the form of three independent Y motions against a common X motion, or, alternatively, X_1 against Y_1 and X_2 against Y_2. An example of this latter application would be to plot the path of a target and on the same sheet of paper the path of an interceptor. The plotting table is self-contained for operation from 50c/s mains.

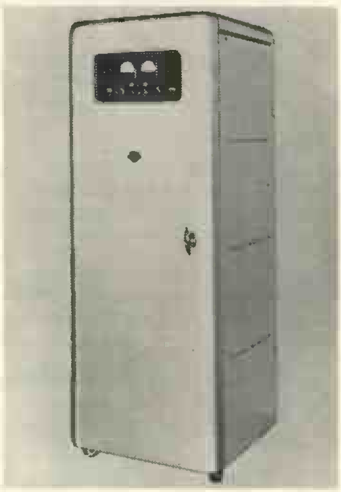
Dobbie McInnes Ltd,
191-3, Broomloan Road,
Glasgow, S.W.1.

Ultrasonic Generator

(Illustrated below)

THE Mullard low frequency ultrasonic generator type E7696 is a new general purpose equipment with an output power of 2kW in the frequency range 10kc/s to 30kc/s. It has been designed as a power source for magnetostrictive transducers used for ultrasonic cleaning, degreasing, soldering, tinning and drilling. Robust construction, conservative ratings, automatic protection circuits, and simple controls, make the generator suitable for everyday industrial use.

A variable frequency *RC* oscillator of the Wien bridge type feeds an amplifier, followed by a driver and push-pull output stage which is transformer-coupled to the load. The output current and the anode currents of the output valves are moni-



tored. Output power is controlled by a variable attenuator in the amplifier stage.

In the power pack, h.t. for the output stage is derived from a bridge rectifier using gas-filled valves with a short warming up time. Vacuum type rectifiers are used for the other h.t. supplies, and a variable low voltage d.c. polarizing supply is derived from a bridge circuit using metal rectifiers.

Mullard Ltd,
Century House,
Shaftesbury Avenue,
London, W.C.2.

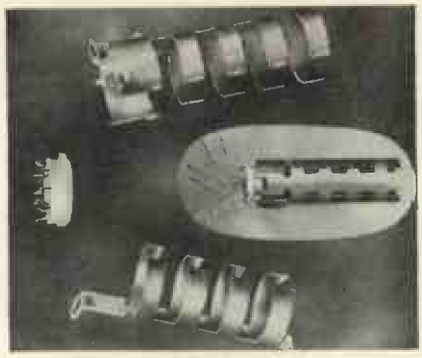
Flying Lead Valveholder

(Illustrated above right)

THIS valveholder is intended for B7G and B9A special purpose valves with flying leads.

The valve is seated on a p.t.f.e. ring which carries the appropriate number of terminal lugs to which the valve and the circuit leads are soldered.

The valve envelope is retained by the split clamp which, in addition to providing mechanical support, conducts much of the valve heat to the chassis. A special design of clamp ensures good thermal contact to bulbs of rather irre-



gular shape and makes a lower operating valve temperature possible.

The McMurdo Instrument Co. Ltd,
Victoria Works,
Ashtead,
Surrey.

Solder Thermometer

(Illustrated below)

THIS enables the temperature of solder, on an iron or in a bath, to be quickly determined.

The instrument is completely self-

contained and comprises a meter movement which is connected to a thermocouple mounted at the end of a tube attached to the meter. A scale is graduated in degrees Celsius and Fahrenheit and the maximum temperature to which the instrument should be subjected is 400°C (752°F).

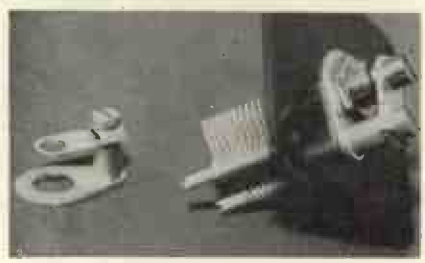
Multicore Solders Ltd,
Multicore Works,
Maylands Avenue,
Hemel Hempstead,
Hertfordshire.

Spindle Lock

(Illustrated below)

THE "PotLock" is a simple and effective spindle locking device which is fitted by securing under the usual one hole fixing nut of the potentiometer or any other similar fixing component. The clamp fits over the spindle which is locked when the 4BA. schew is tightened.

Jackson Bros. (London) Ltd,
Kingsway,
Waddon,
Surrey.



LETTERS TO THE EDITOR

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

A New Circuit for Balancing the Characteristics of Pairs of Valves

DEAR SIR,—Mr. Aitchison's article in the May issue is most interesting confirmation of the value of differential heater voltage balancing. Owing to slow changes in activation it is a little more difficult to achieve a *stable* balance and one practical snag should not be overlooked. A potentiometer of a few ohms can be very troublesome in early stage heater circuits due to the wiper resting in doubtful contact with two turns. In my experience a straight piece of eureka wire with a tap made by a small area split clamp or by solder is the only permanent solution in high-gain d.c. or very-low-frequency a.c. amplifiers. In an electro-encephalograph, for instance, base line sway is not only a function of the balance measured by slow precision methods, but is dependent upon the difference in "time-constant" between the two cathodes. This is sometimes most pronounced and heater balancing may give but a small improvement in these transient disturbances which affect the band 0·3 to perhaps 5·0c/s most seriously.

While the final state condition is important, it would be most instructive to give the maximum instantaneous difference in I_a using a differential micro-ammeter with a response time of not more than 0·5sec. A double coil instrument is not necessary if a pair of matched resistors are used and differences would then be revealed much more accurately than by the subtraction of two I_a readings. In many applications differences of a few micro-amperes are of significance and further research seems to be indicated.

Yours faithfully,

SYDNEY N. POCOCK.

Consultant in electronic engineering to Government of Ceylon under the Colombo Plan,
Colombo 4, Ceylon.

The Author replies:

DEAR SIR,—Mr. Pocock's comments draw attention to one of the most serious faults in low-level, low-frequency amplifiers, namely relatively slow changes of balance which are associated with the heater circuit. While intermittent contact in the heater potentiometer is a fault that can be remedied, there exists a more serious fluctuation associated with the thermal contact between heater and cathode which cannot be controlled in any way except by running valves for very long periods with as stable a heater supply as possible. Even so, spontaneous changes of balance occur which are associated with very small changes in the position of the heater inside the cathode sleeve. As no special precautions are taken to ensure high thermal stability of the heater-cathode assembly (in fact for normal communication circuit applications this is not necessary) this is one serious difficulty associated with using the indirectly heated cathode type of valve in such amplifiers, which cannot be remedied by circuit design.

For other reasons (i.e., to increase heater cathode insulation) some twin triodes are now being made with both the heater and the internal wall of the cathode coated with alumina, and the heater is anchored much more firmly in such an arrangement. We have been unable as yet to measure the stability of such types of valve, but experience indicates that the spontaneous changes in balance associated with cathode movement should be reduced considerably.

Yours faithfully,

R. E. AITCHISON.

Senior Lecturer in Communication Engineering.
The University of Sydney.

Automatic Square Rooting

DEAR SIR,—With much interest I have read Mr. Lenaerts' paper on automatic square rooting with the LEO computer in ELECTRONIC ENGINEERING July 1955.

It seems to me, however, that the method indicated is unnecessarily complicated and involves too many operations. I should like to direct your attention to the non-restoring method of square rooting in which the accumulator is not restored to its original state when it becomes negative. The method is similar to the non-restoring division scheme given by von Neumann. It has the advantage that the number of operations (additions or subtractions) is independent of the particular number of which the square root is required. Non-restoring square rooting has been invented independently by Couffignal[1] and Zuse[2].

Yours faithfully,

A. P. SPEISER.

Swiss Federal Institute of Technology
Institute for Applied Mathematics,
Zurich.

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1. COUFFIGNAL, L. Calcul d'un quotient ou d'une racine carree dans le systeme de numeration binaire. *Comtes Rendus de l'Academie des Sciences 229* (1949) August, p. 488-489.
2. HEIZ RUTISHAUSER/AMBROS SPEISER/EDUARD/STIEFEL. *Mitteilungen aus dem Institute fur angewandte Mathematik an der ETH*, No. 2: Programmgesteuerte digitale Rechengerate von Birkhauser-Verlag, Basle, 1951.

The Author replies:

DEAR SIR,—I am very grateful to Dr. Speiser for drawing attention to a method of square-rooting which does not require the accumulator to be restored when it becomes negative. I was familiar with the non-restoring technique in division but I could not see a way of applying this to square-rooting.

When the accumulator becomes negative in the automatic process, Couffignal and Zuse give the simple solution of appending 1 1 instead of 0 1 to the partial result, and adding instead of subtracting the resulting pattern in the subsequent stage.

My article was directed mainly to showing how an arithmetical method might be interpreted in a calculator. May I now take the opportunity to show how the improved method can be used to cut the time of square-rooting by half with, if anything, a simpler arrangement of circuits.

The diagram below, which compares with Fig. 1 of my article, gives the revised block schematic of the circuits needed and the only additional circuit is a gate and a delay to provide for the extra digit when dealing with a negative accumulator. Now that it is not necessary to correct the accumulator when it becomes negative, one sub-stage of the sequence is cut out and the two stages left are

(a) Apply pattern to accumulator (add if negative, subtract if positive).

(b) Shift accumulator contents and escalator digit and insert the escalator digit into the result register if the accumulator is positive.

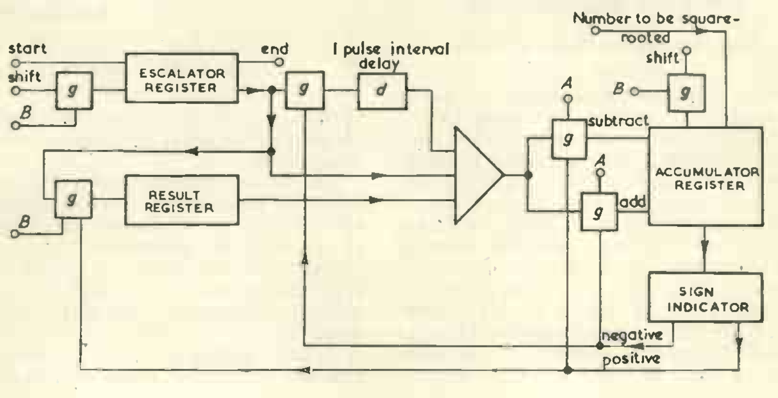
This simplification means that the shifting of the accumulator and the escalator digit can be continuous and sub-stages (a) and (b) can take place at the same time. The time for finding the square-root of a double length number is therefore reduced to 40 stages of 80µsec each a total of 3·2msec.

Yours faithfully,

E. H. LENAERTS.

Electronic Development Section,
J. Lyons & Co. Ltd.

Fig. 1. Revised block schematic of the required circuits



Short News Items

The Institution of Electrical Engineers. The following have been nominated by the Council for the vacancies which will occur in the offices of President, Vice-Presidents, Honorary Treasurer and Ordinary Members of Council on 30 September.

President (one vacancy), Sir George H. Nelson, Bt. Vice-President (two vacancies): T. E. Goldup, C.B.E., Sir Hamish D. MacLaren, K.B.E., C.B., D.F.C., LL.D., B.Sc.. Honorary Treasure (one vacancy) The Rt. Hon. The Viscount Falmouth. Ordinary Members of Council: Members (four vacancies), Professor H. E. M. Barlow, Ph.D., B.Sc. (Eng.); C. M. Cock; Professor J. Greig, M.Sc., Ph.D.; H. H. Mullens, B.Sc. Associate Members (two vacancies): D. McDonald, B.Sc.; D. B. Welbourn, M.A. Companions (one vacancy): G. L. Wates, J.P.

A Convention of the British Amateur Television Club will be held on 1 October from 10 a.m. to 6 p.m. at the Bedford Corner Hotel, Bedford Square, London, W.C.1. There will be a display and demonstration of members' equipment, and a film show. The cost to members is 10s. 6d., including lunch, and the charge of admission to non-members is 5s. Tickets and further information can be obtained from Mr. D. S. Reid, 4 Bishop Road, Chelmsford, Essex.

A Special Exhibition has been opened at the Science Museum to coincide with the meeting of the International Electrotechnical Commission and will remain open until 31 October. Although the exhibition is of particular interest to those concerned in the problems of metering, bulk supplies of electrical energy to large industrial and commercial undertakings, it is intended also for the less specialized visitor and service to demonstrate the care which is devoted to the accurate calibration of electricity meters.

Pye underwater television was featured prominently in a series of demonstrations at the recent International Trade Fair held in Toronto. The equipment, which consisted of a Comet-type underwater camera, in conjunction with a standard studio camera and standard 2 000Mc/s Pye microwave equipment, was installed on H.M.C.S. *Beaver,* a Royal Canadian Navy Reserve ship. The ship lay some two miles outside Toronto harbour and various underwater scenes of frogmen at work were relayed through a microwave link direct to the trade fair.

The Second Annual Meeting of the Professional Group on Nuclear Science of the Institute of Radio Engineers will be held at the Center Theatre in Oak Ridge, Tennesse from 14-16 September.

The Industrial Electronics Conference 1955 will be held at the Rackham Memorial Auditorium in Detroit, Michigan, on 28-29 September. The meeting is sponsored jointly by the Michigan Section of the American Institute of Electrical Engineers, the Professional Group on Industrial Electronics of the Institute of Radio Engineers in the Detroit Section of the IRE. Sixteen papers have been scheduled for the four technical sessions which will discuss automation, industrial measurement problems and new control system applications.

The Eleventh Annual National Electronics Conference will convene at the Hotel Sherman, Chicago, Illinois, from 3-5 October. Further information may be obtained from the Executive Secretary, National Electronics Conference Inc, 84 East Randolph Street, Chicago 1, Illinois.

The Minister of Supply, Mr. Reginald Maudling, has appointed Mr. G. W. H. Gardner, C.B., C.B.E., at present Director General of Technical Development (Air) in the Ministry of Supply to be Director of the Royal Aircraft Establishment, Farnborough, with effect from 1 November next. Sir Arnold Hall, F.R.S., the present Director, R.A.E., has, with the agreement of the Minister, resigned to accept an industrial appointment from that date.

The General Electric Co Ltd have announced the first awards under their scholarship scheme. These scholarships are awarded annually to people of outstanding promise within the G.E.C. organization to provide for degree courses, post graduate research, courses in specialized subjects and studies in management or commerce. Twenty-eight applications were received this year, and three scholarships have been awarded, as follows: One for research at the Imperial College of Science and Technology on advanced aspects of communication theory; one to complete by full time study the final year of a degree course in electrical engineering, and one for a degree course at London University in mechanical engineering.

The BBC announce that it has placed a contract with J. & J. Parish Ltd, of Burton Road, Withington, Manchester 20, for building work in connexion with television studio accommodation. The work covers the conversion of an existing building, previously used by the Manchester Film Corporation, and the erection of a new two-storey block on the same site to provide television studio premises which will include a production unit, a small film unit, and telecine facilities together with the ancillary technical and service areas. It is hoped that the studio will be ready for service by the early summer of 1956 and the film unit by the following autumn.

The Independent Television Authority, which since October 1954 has been in temporary offices, has now moved to its permanent headquarters at 14 Princess Gate, London, S.W.7. Telephone number Knightsbridge 5341.

Mr. B. C. Sendall, C.B.E., has been appointed Deputy Director General of the ITA.

The first commercial television studios in Great Britain were handed over recently to Associated Rediffusion Ltd. The studios have been established at the Granville Theatre, Walham Green, London, S.W.6, founded in 1898. The theatre was adapted and equipped for television broadcasts in four months by Central Rediffusion Services Ltd.

Marconi's Wireless Telegraph Co Ltd have received a further important order from the Gold Coast Posts and Telecommunications Department. The new contract calls for the supply and installation of a twin-path, 24-Channel (per) path v.h.f. radio communications service from Kumasi to Takoradi, via Mpraeso, Koforidua, Mampong (Akwapim), Accra, Winneba and Cape Coast. The terminal at Takoradi will be accommodated in a new telephone exchange which is currently under construction by the Gold Coast P. and T. Authorities.

Marconi Instruments have been awarded contracts by the English Steel Corporation Ltd and the United Steel Companies Ltd for the supply of 250kV Constant Potential X-Ray Units to their works at Grimesthorpe and Distington, respectively. These equipments have a voltage range of from 30 to 250kV, enabling steel of up to four inches in thickness to be penetrated.

Redifon Flight Simulators for the Royal Australian Air Force. More details are now available concerning the contract for Sabre Mk.30 flight simulators awarded to Redifon Ltd by the Government of Australia. This new variant of the Sabre, powered by an Avon Turbojet, is being produced in quantity for R.A.A.F. fighter squadrons by the Commonwealth aircraft Corporation. The Redifon simulators will feature prominently in converting pilots to the new type. Two versions of the simulator have been ordered. The first is for permanent installation in a specially constructed or adapted building, while the second is for mobile use and will be contained in a specially designed trailer.

The University of Cambridge has recently received from the Mullard Company an offer to provide, over a period of ten years, the sum of £100 000 for the purpose of continuing and extending the work in radio-astronomy which is in progress in the Cavendish Laboratory. With this benefaction it is intended to set up a new observatory to be known as the Mullard Radio-Astronomy Observatory. It is hoped that a site near Cambridge will be available for this purpose and that there will be space on it for making a number of observations which have not yet been possible.

Redifon Ltd announce that the first of three 700 ton deep-sea fishing vessels ordered from a German shipyard by the Standard Steam Fishing Co. Ltd, has been equipped with Redifon marine radio. This is the first trawler to be built in Germany for British owners since the war.

Kelvin & Hughes Ltd have now entered the component market with a wide range of electrical and optical equipment. Many of the components, which are used in Kelvin Hughes marine, aviation and industrial instruments, can be manufactured to suit special requirements. The list of components now available from the company includes instrument motors, barometric capsules, teletorque synchronous transmission units, ultrasonic magnetostrictive oscillators, sine/cosine potentiometers, gyroscopes, optical components and magnetic recording heads.

Bakelite Ltd announce that they are to market polyethylene plastics. Polyethylene first became important for the contribution it made to the solution of problems of u.h.f. insulation in radar. The material is now widely adopted for all classes of high frequency insulation and is of major importance to the cable industry.

International Aeradio Ltd have contracted to provide to the Government of Singapore, Department of Civil Aviation, two Air Traffic Control Officers for duty at Kallang Airport, Singapore.

The registered office of The Mond Nickel Co Ltd, after an interval of fifteen years, is once again Thames House, Millbank, London, S.W.1.

The Solartron Electronic Group Ltd have changed their telephone number to Emberbrook 5522.

Erie Resistor Ltd. The telephone number of the Great Yarmouth Factory has been changed to Great Yarmouth 4911.

Edwards Alto Vuoto is the name of a recently formed Italian subsidiary of Edwards High Vacuum Ltd, Crawley. The offices are in Milan and the company was formed in conjunction with Societa Apparecchi Elettrici e Scientifici with whom Edwards High Vacuum have had an agency relationship for many years.

Cable and Wireless Ltd announce that a cableship operation recently carried out in the Western Approaches to the Channel on one of the two submarine cables directly linking Porthcurno. near Land's End, with Gibraltar, on the eastern cable route to Australia and the Far East, is expected to increase its word-carrying capacity by 50 per cent.

Wireless Telephone Co Ltd, Sheffield, a member of the Plessey Group of Companies, have appointed Mr. E. Lawrenson to be their Chief Engineer. Before joining the Wireless Telephone Co., Mr. Lawrenson was a senior engineer in the advanced development laboratory of Standard Telephones & Cables Ltd.

Magnesium Electron Ltd. Major C. J. P. Ball, D.S.O., M.C., who has held the post of Chairman and Managing Director from the Company's formation in 1934, has relinquished the latter appointment in favour of Dr. C. J. Smithells, M.C., but remains as Chairman of the Company. Brigadier A. G. Cole, O.B.E., previously Assistant Managing Director, has been appointed Commercial Director. Dr. S. J. Fletcher remains Technical Director.

Mr. J. Henshaw has recently been appointed Technical Liaison Officer for the Technical Organization of Oliver Pell Control Ltd. in the north of England.

Dr. E. A. Perren has been appointed Chief Superintendent, Chemical Defence Experimental Establishment, Porton, in succession to Mr. S. A. Mumford. Dr. Perren has been Superintendent of Research, C.D.E.E. since 1951. Before that he was, for two years, Chief Superintendent of the Canadian Research and Development Establishment, Suffield, Alberta.

20th Century Electronics Ltd announce the recent appointment of Mr. A. V. Krause as Head of Cathode Ray Tube Development. He was formerly Senior Engineer in the Vacuum Tube Development Section of Cinema Television Ltd and had previously been with Standard Telephones and Cables Valve Division and Mullards.

Mr. F. G. Robb has relinquished his position as Chief of the Test Division of Marconi's Wireless Telegraph Co. Ltd, on reaching retiring age. He is succeeded by Mr. E. H. Evans.

Mr. E. V. Norcock has joined the Board of Export Packing Service Ltd from The Bristol Aeroplane Co. Ltd where he was Secretary of the Aircraft Division.

Major-General Sir Leslie Nicholls will relinquish the post of Chairman of Cable and Wireless Ltd as from 31 January next. He will do so at his own wish in order to be free to devote his time to outside interests.

The Board of Electric & Musical Industries Ltd announce that Sir Percy H. Mills, Bt., K.B.E., has been appointed a Director of the Company.

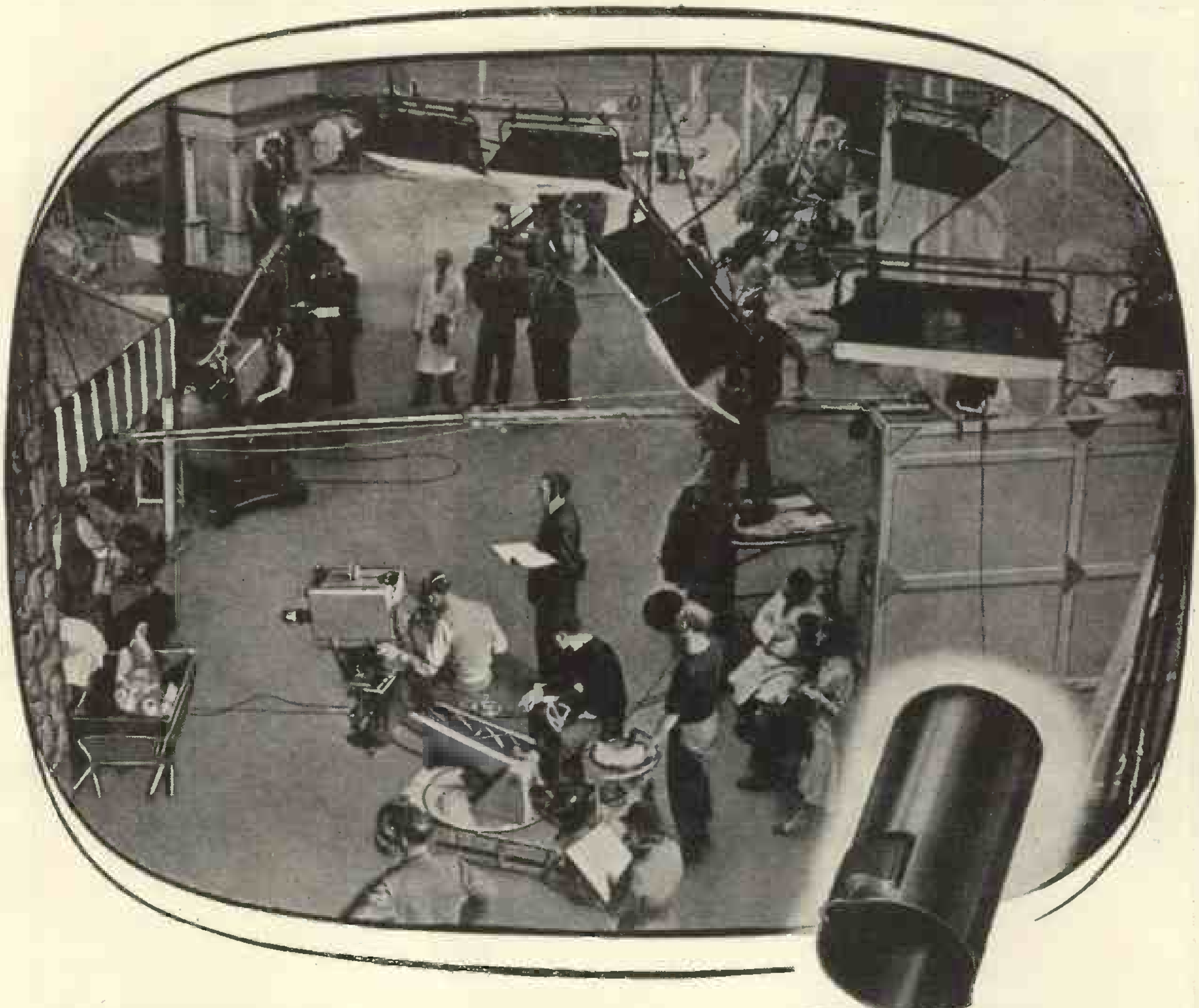
Mr. F. Szekely has joined the Radio Division of The Edison Swan Electric Co. Ltd in a new section to promote the application of semi-conductors. Mr. Szekely was formerly on the staff of the British Thomson-Houston Co. Ltd.

A Special Electronics and Careers Display has been organized by the Radio Industry Council at the current Radio Show, Earl Court. This is divided into three sections, as follows: Electronics of Today, Electronics of the Future and Careers. There is also an inquiry counter and two interview rooms where possible recruits to the industry will be able to obtain further information.

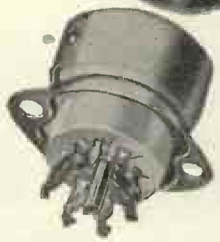
The Electrical Engineering Department, Municipal Technical College, Oldham, announces that there will be part time day and evening courses in the following subjects commencing from September. Radio and Television Servicing (RTEB Certificate); Telecommunications (City and Guilds); Radio Amateurs' Course (City and Guilds) and Radio Engineering (all subjects for Grad. Brit. I.R.E.). These courses are in addition to the normal Light Current Subjects, Instruments and Measurements and Electronics. Further information may be obtained from the Head of the Electrical Engineering Department.

The Northern Polytechnic, Department of Telecommunications Engineering, has issued a prospectus for the forthcoming session giving details of full-time and evening courses. The specialized evening course in Band 3 and F.M. is being repeated and a completely new course has been arranged for full-time training in radio and television servicing. There are also courses of evening lectures on electronic digital computers and analogue computing, commencing on 27 and 28 September respectively, the fees being £2 2s. per course. Further details and copies of the prospectus may be obtained from Mr. J. C. G. Gilbert, Head of Department of Telecommunications Engineering, The Northern Polytechnic, Holloway, London, N.7.

Meeting. The London Section of the British Institution of Radio Engineers will hold a meeting on Wednesday, 28 September at 6.30 p.m. in the London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1. There will be a paper by Mr. G. Hitchcox (Electronic Instruments Ltd) on "Extending the Limits of Resistance Measurement using Electronic Techniques."



Why Ediswan Clix P.T.F.E. Valveholders are widely used in B.B.C. Television equipment



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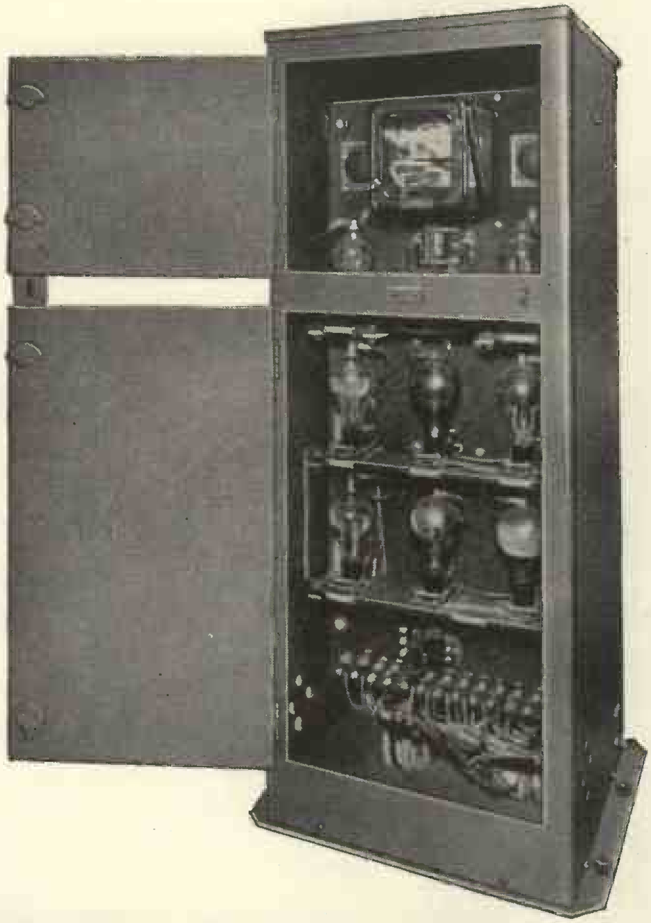

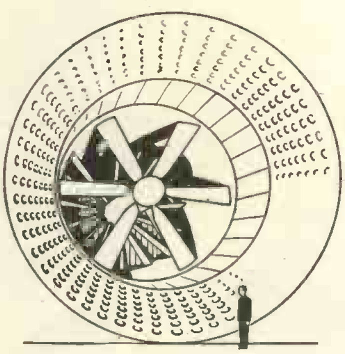

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is accurately controlled by the equipment illustrated here. Installed at the Royal Aircraft Establishment, Farnborough, in 1934, it has been in continuous service ever since. The equipment controls a 2,000 H.P. wind-tunnel fan-motor by means of a motor-operated rheostat in the field system of a Ward-Leonard set, the rheostat being controlled by relays energised by Thyratrons. Two independent control stations are provided, one on the floor of the Test House and the second high up near the roof of the tunnel. Hand or auto-control can be obtained from both positions.

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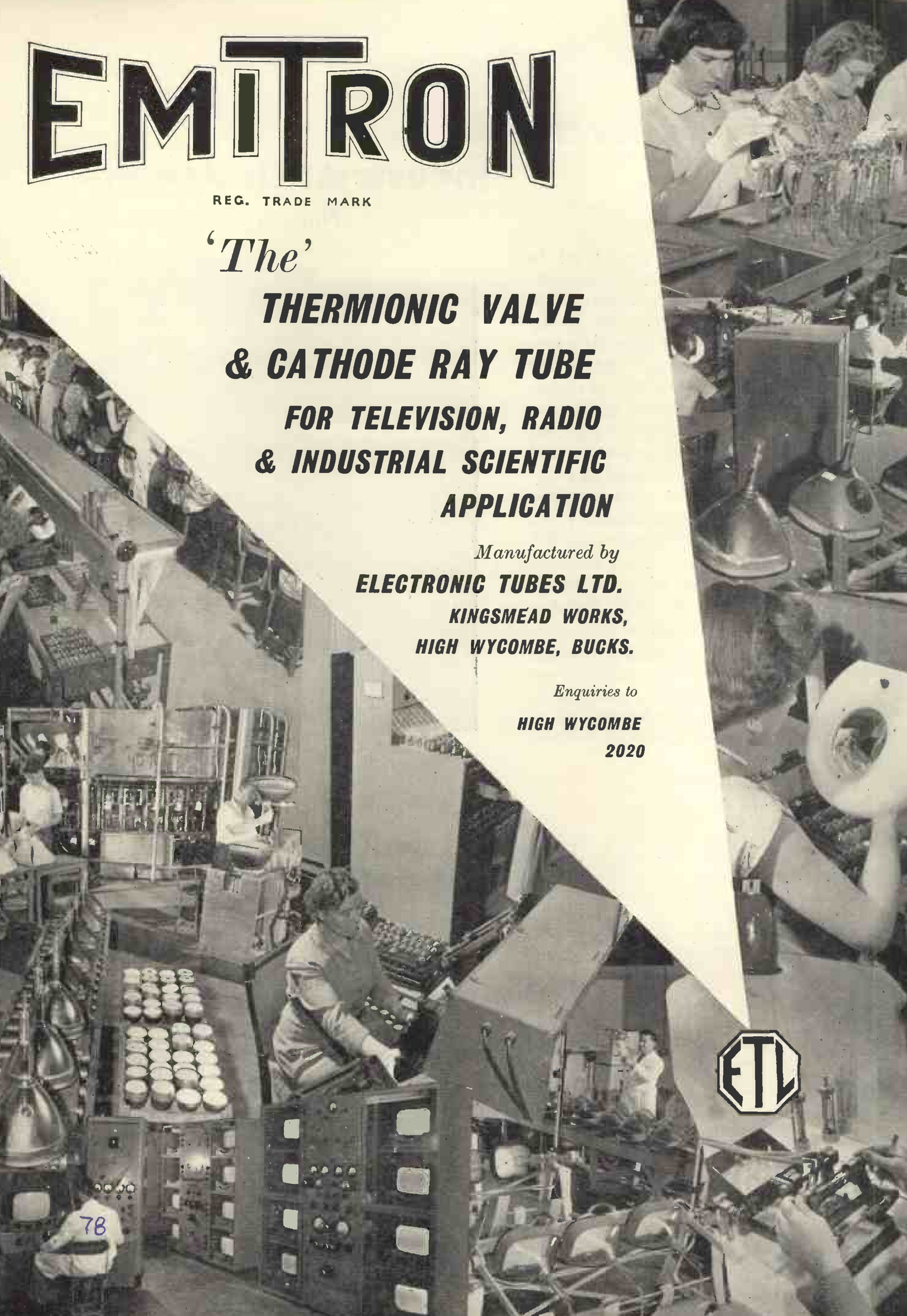
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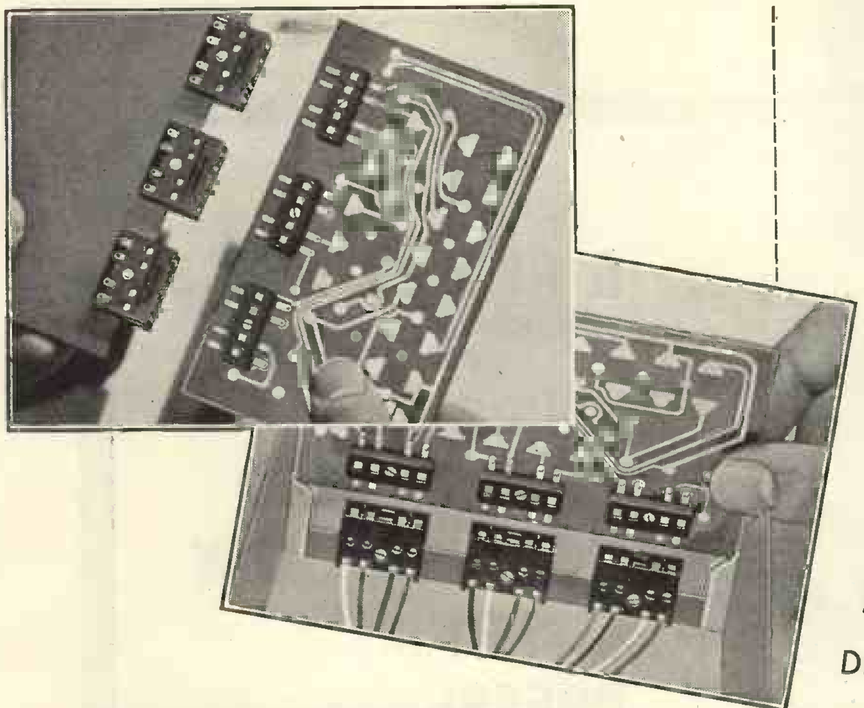

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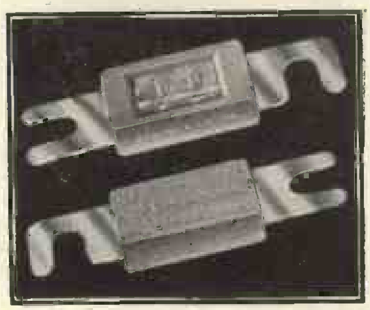
Connectors can be mounted in the plane of, or at right angles to the plane of the supporting surface without the use of additional brackets or supporting structures, a centrally placed mounting hole permitting easy and direct attachment of the plug or socket to the circuit plate. Plugs and sockets are both mounted with standard 8BA screws, and the length of the screw is governed only by the thickness of the mounting plate.



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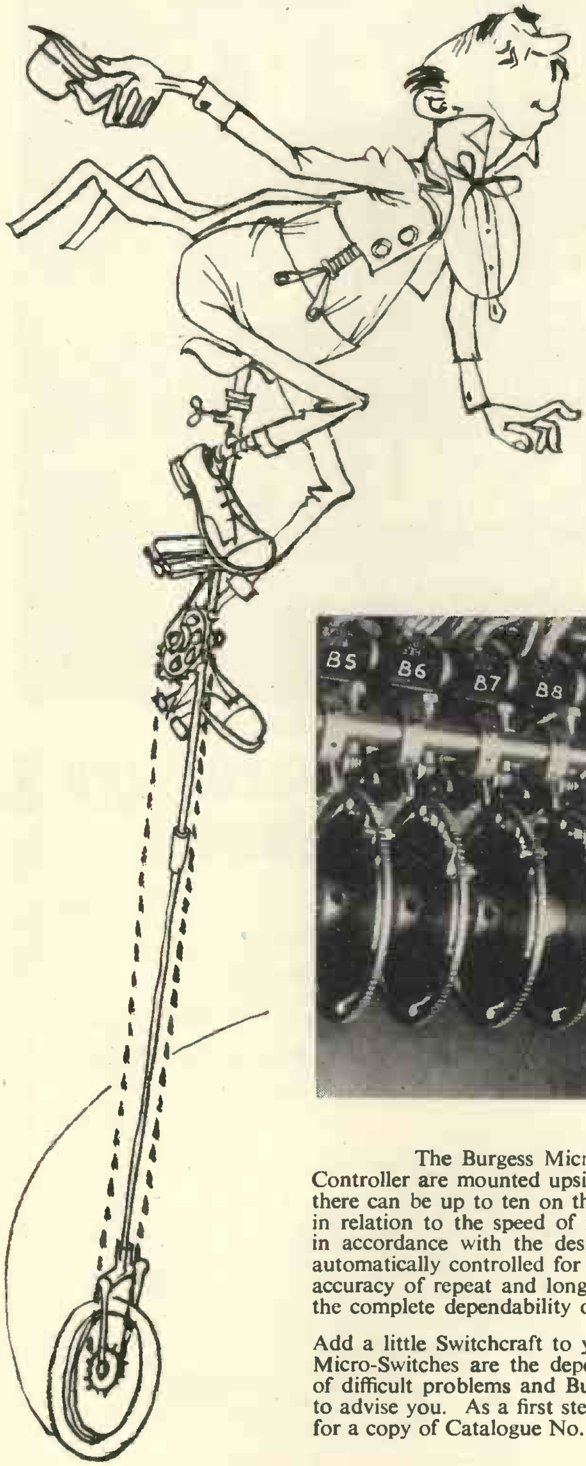

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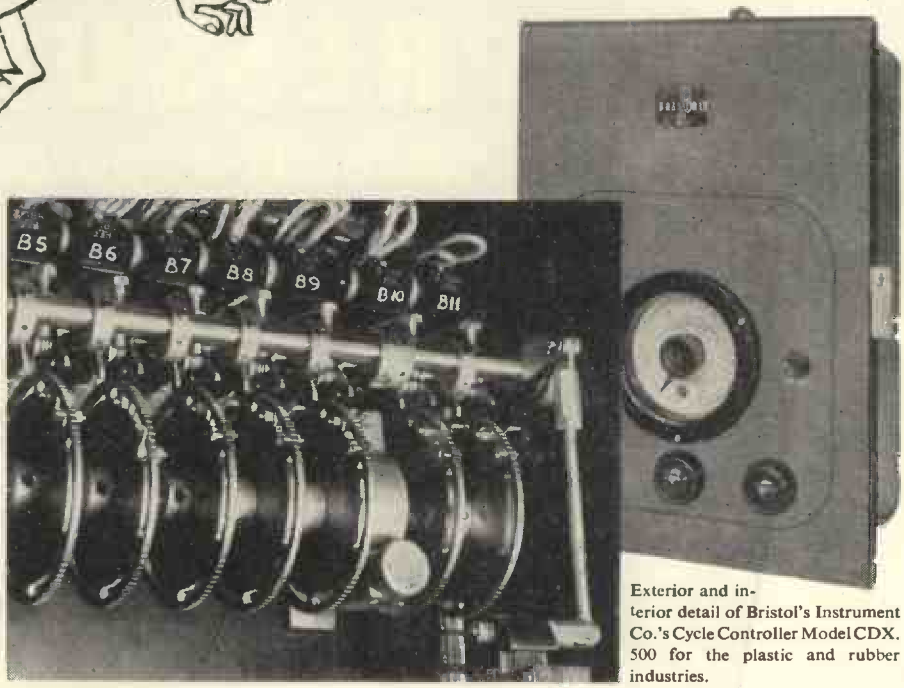

Exterior and interior detail of Bristol's Instrument Co.'s Cycle Controller Model CDX. 500 for the plastic and rubber industries.

The Burgess Micro-Switches seen in the above photograph of Bristol's Cycle Controller are mounted upside down and are operated by dogs locked to cams of which there can be up to ten on the camshaft. The actuating devices are most carefully timed in relation to the speed of revolution of the camshaft to operate each switch precisely in accordance with the desired programme. In this manner up to ten processes are automatically controlled for cycle durations ranging from 20 seconds to 5 minutes. The accuracy of repeat and long life of the Burgess Micro-Switches are factors upon which the complete dependability of the instrument relies.

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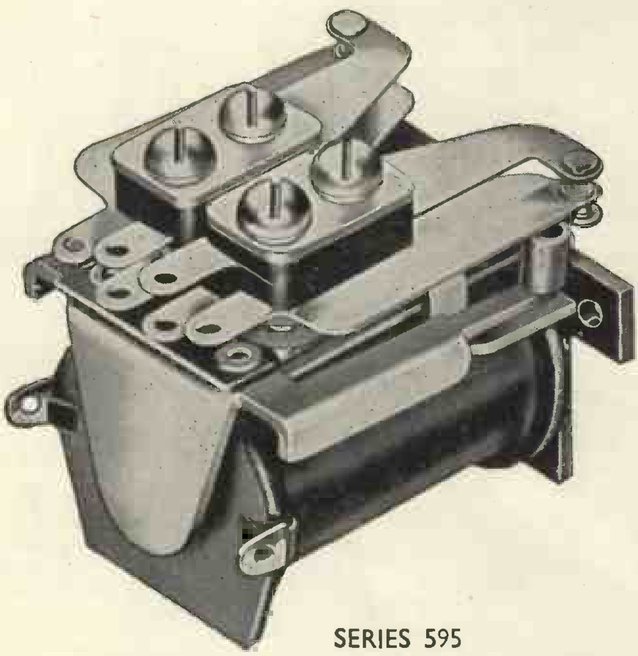

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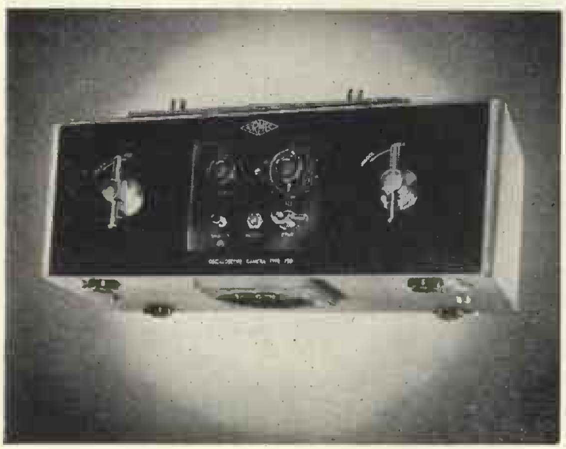

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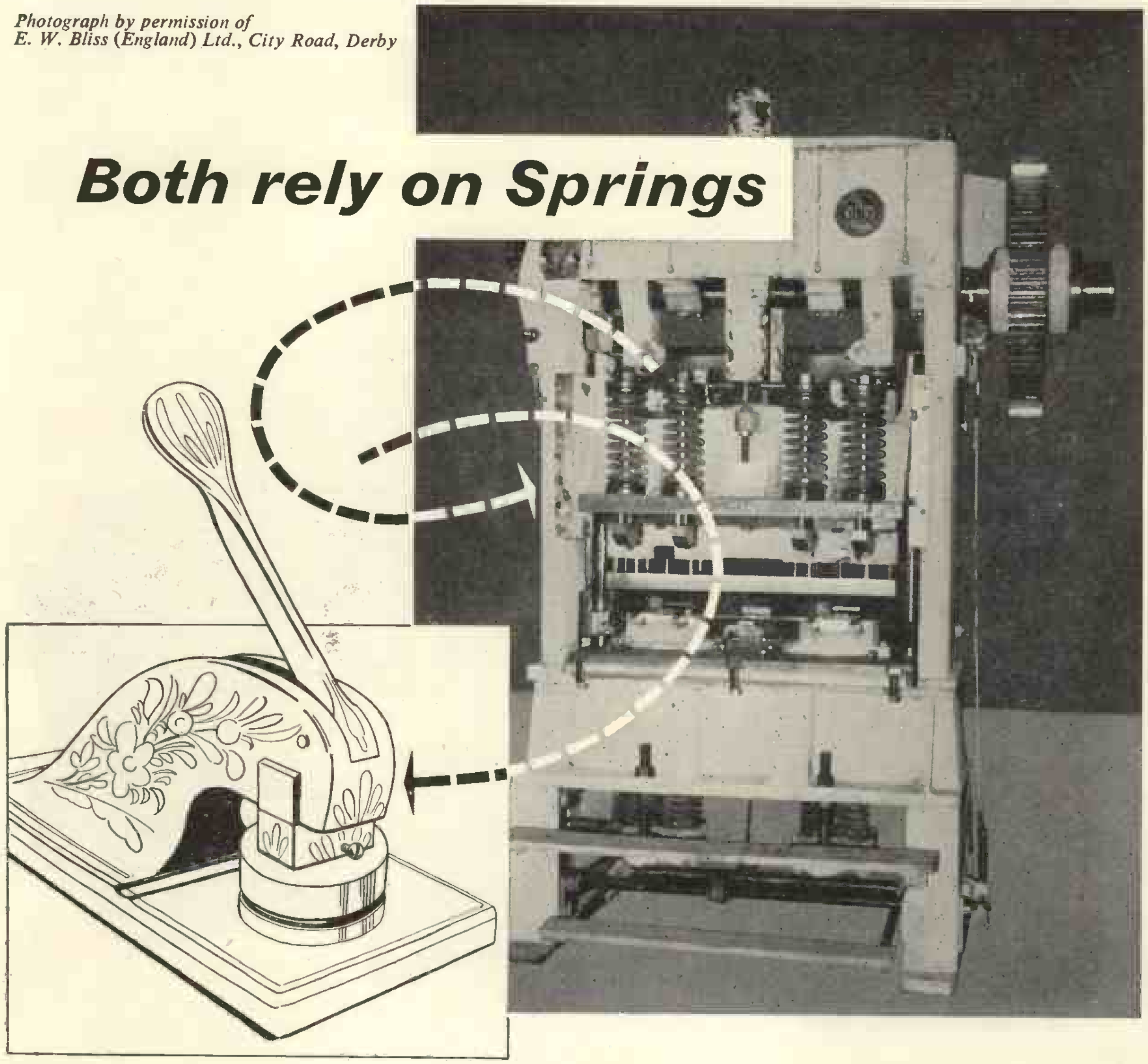

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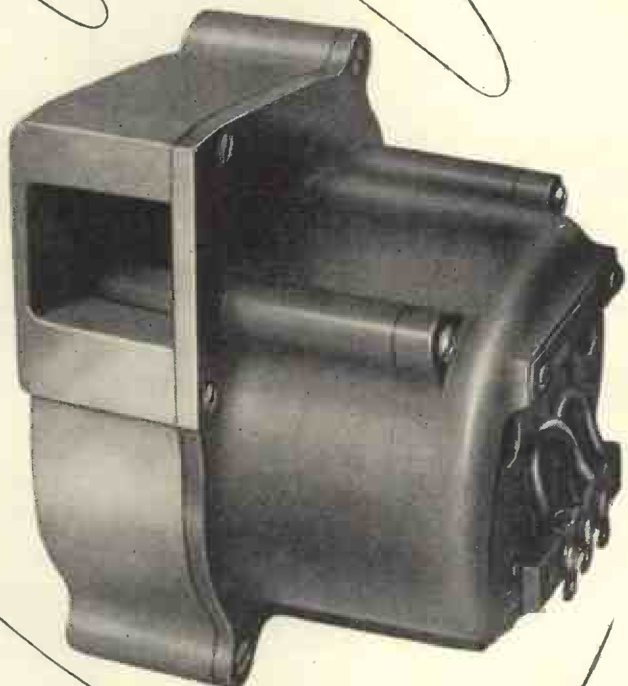

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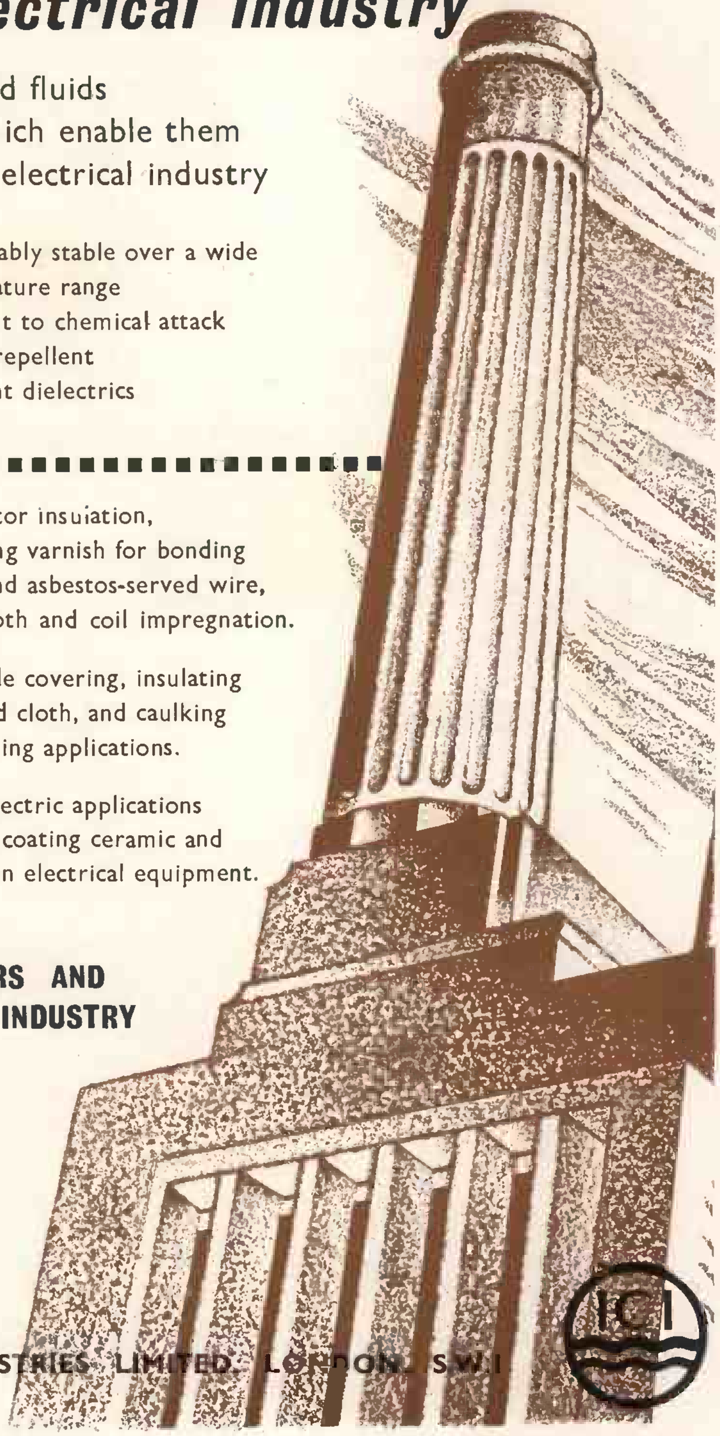

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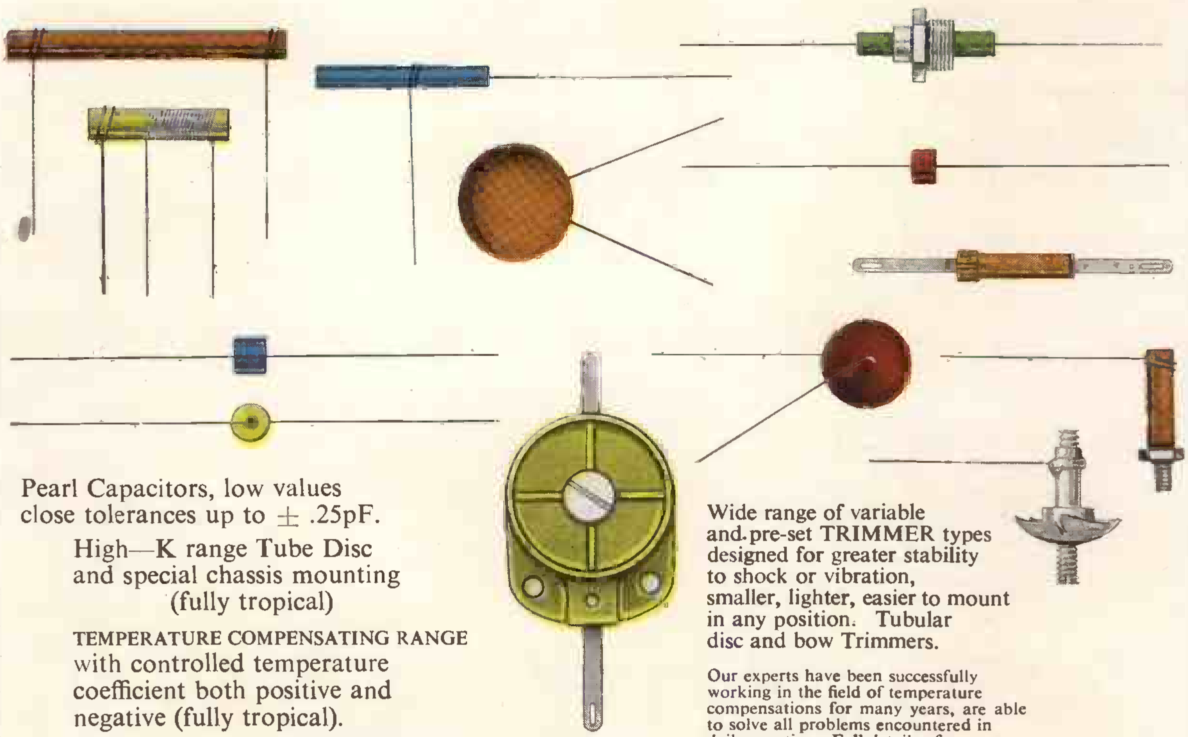

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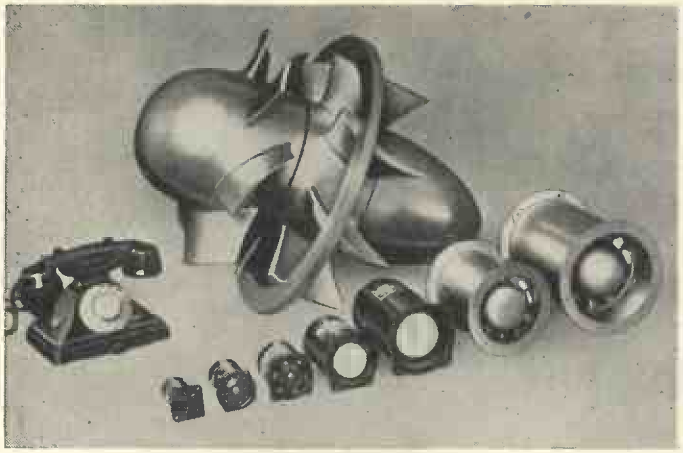

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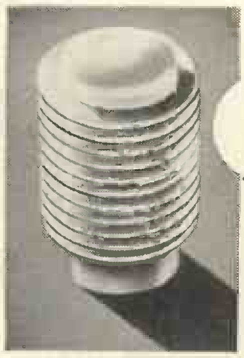

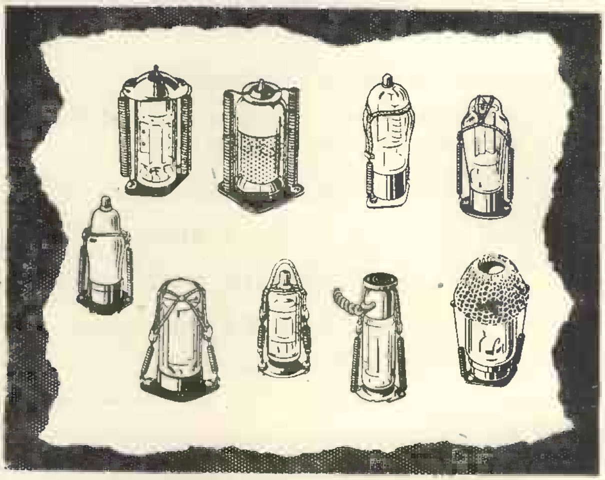

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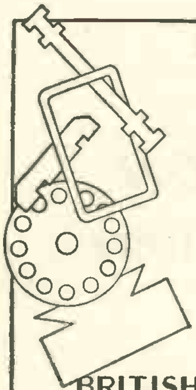

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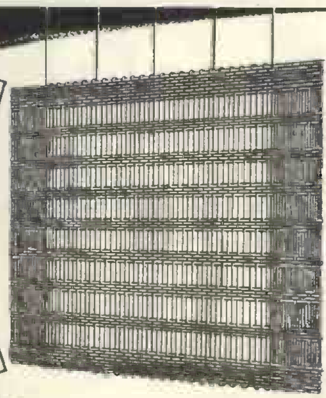

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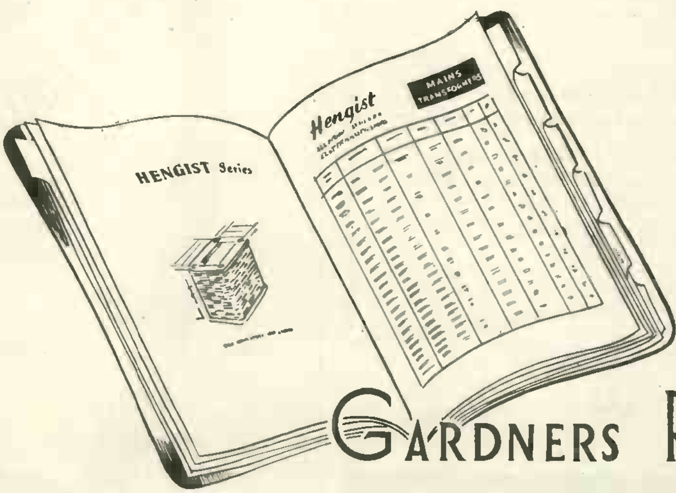

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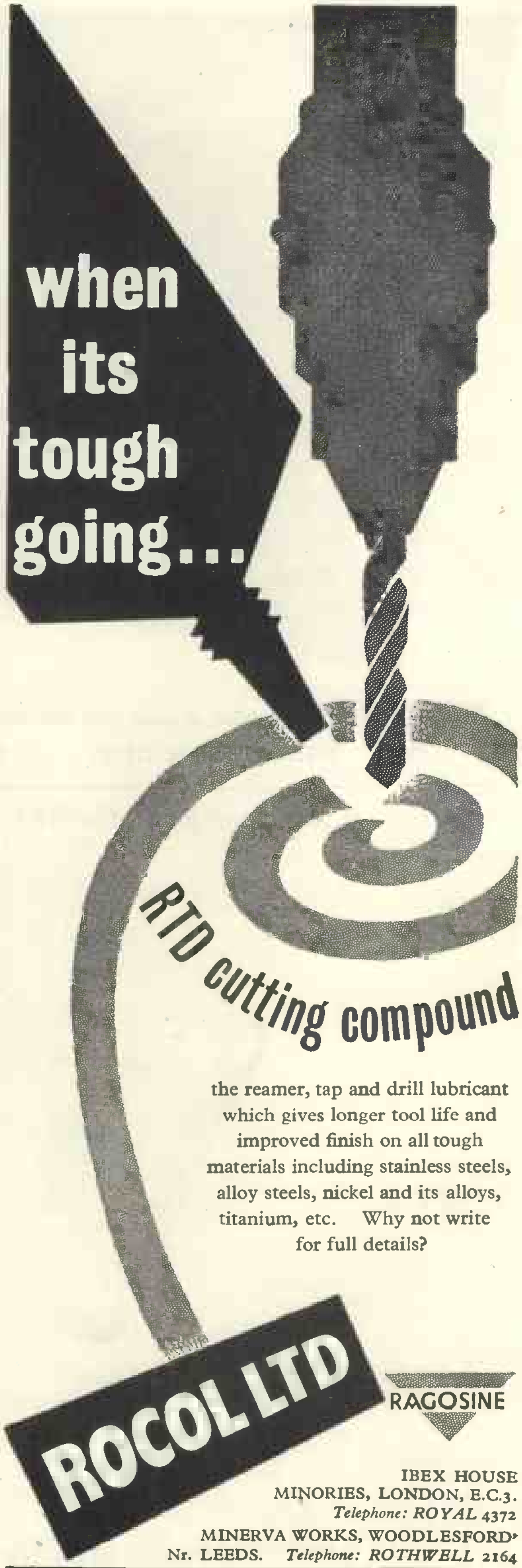

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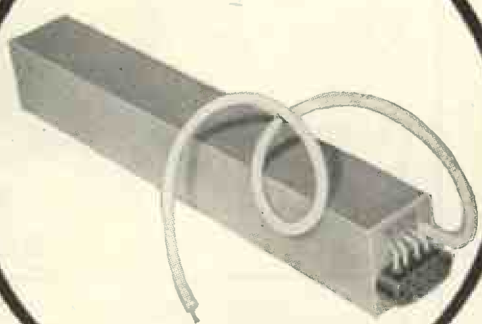

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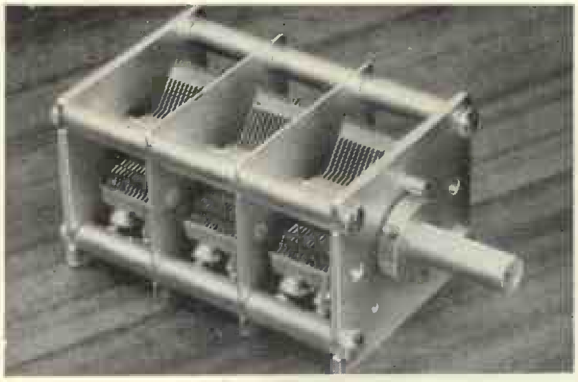

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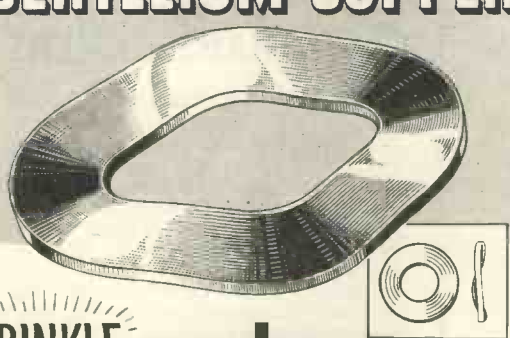

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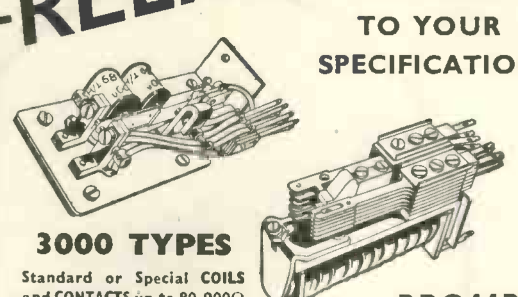

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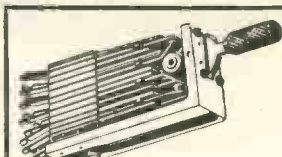

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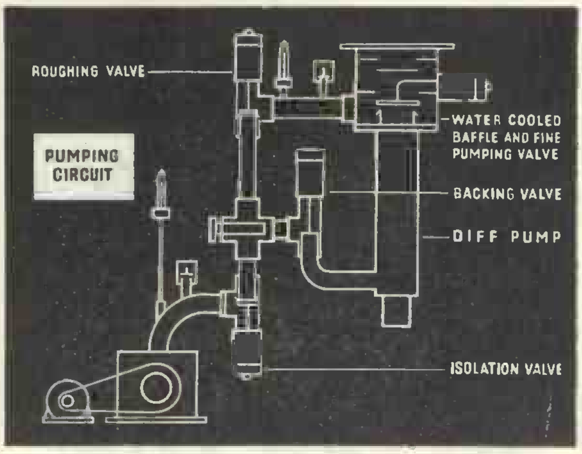

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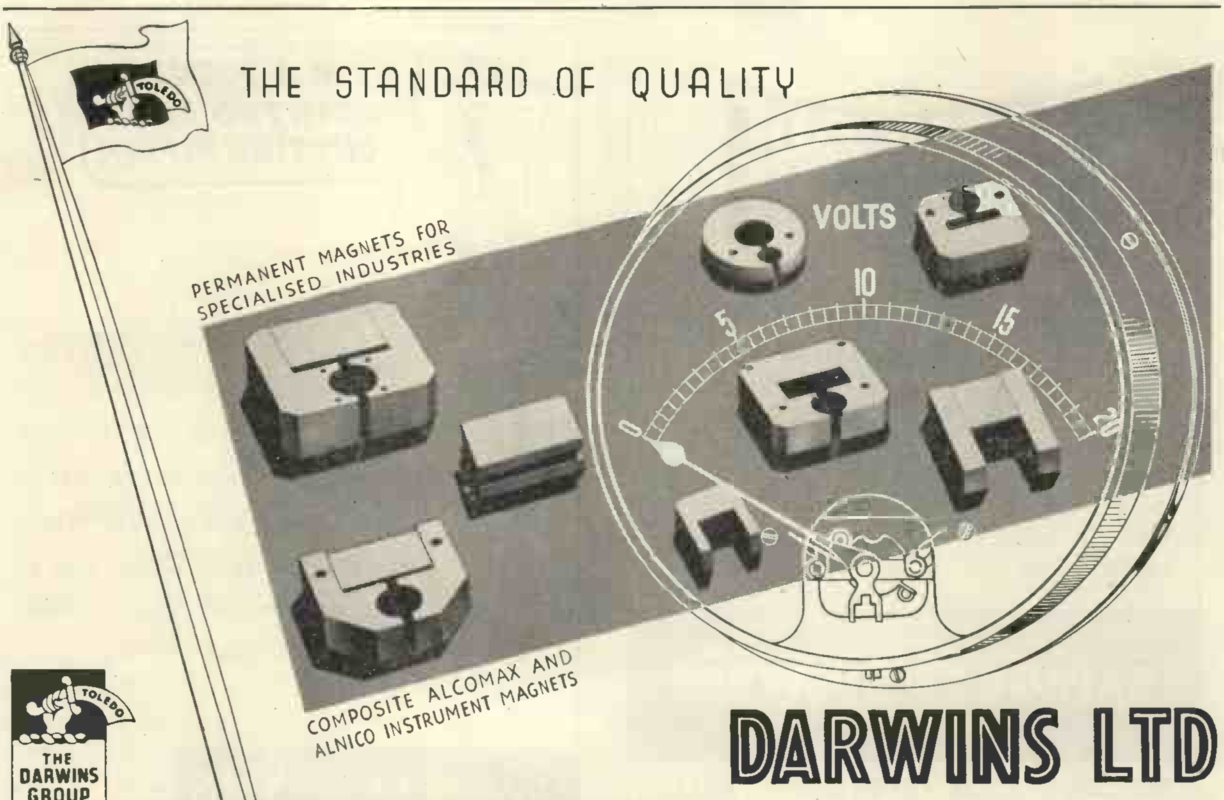

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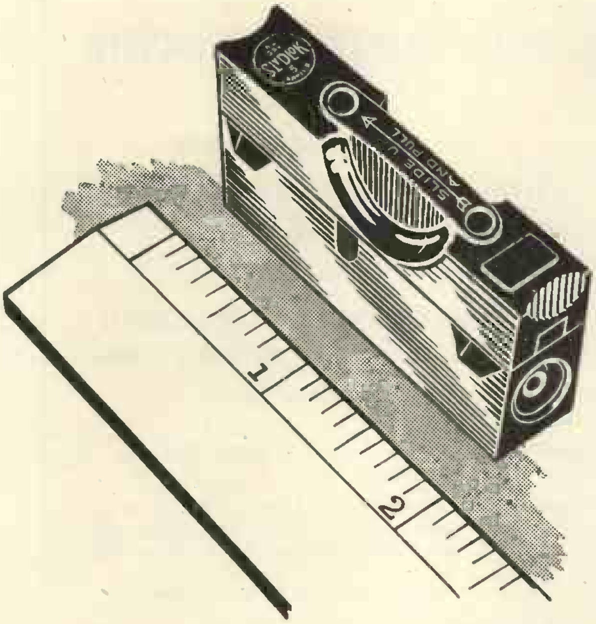

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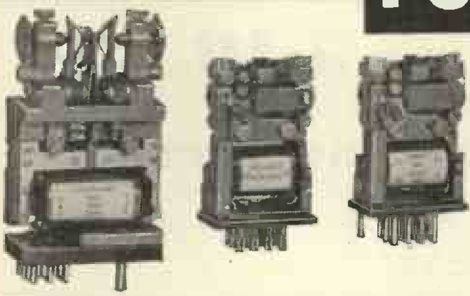

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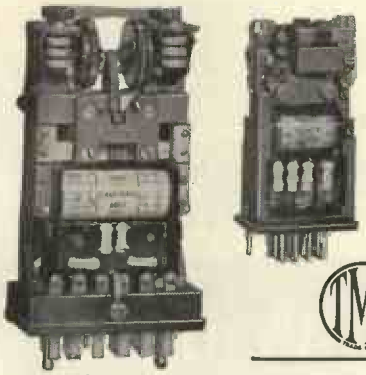

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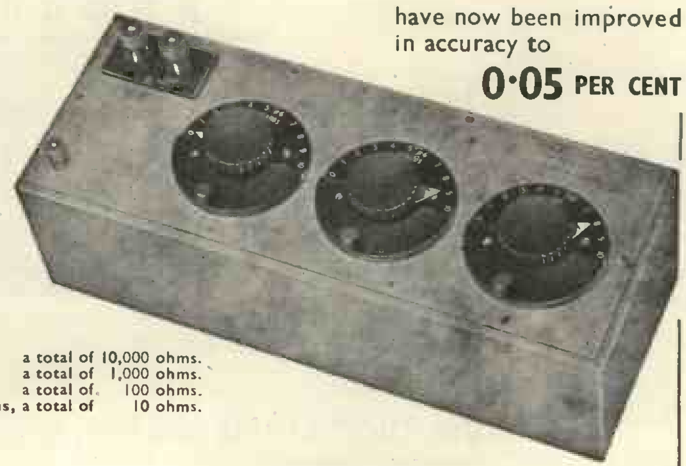

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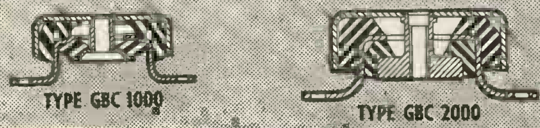

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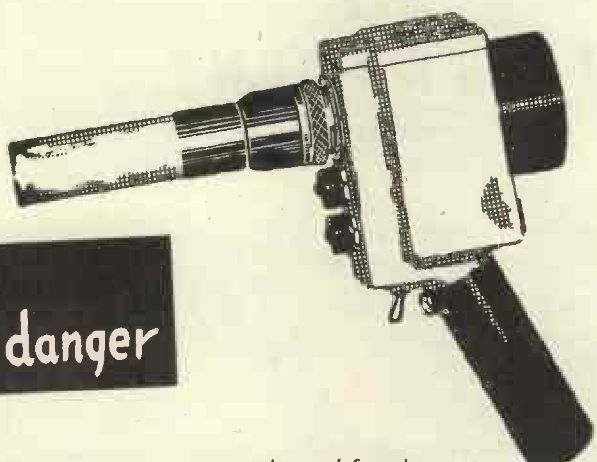

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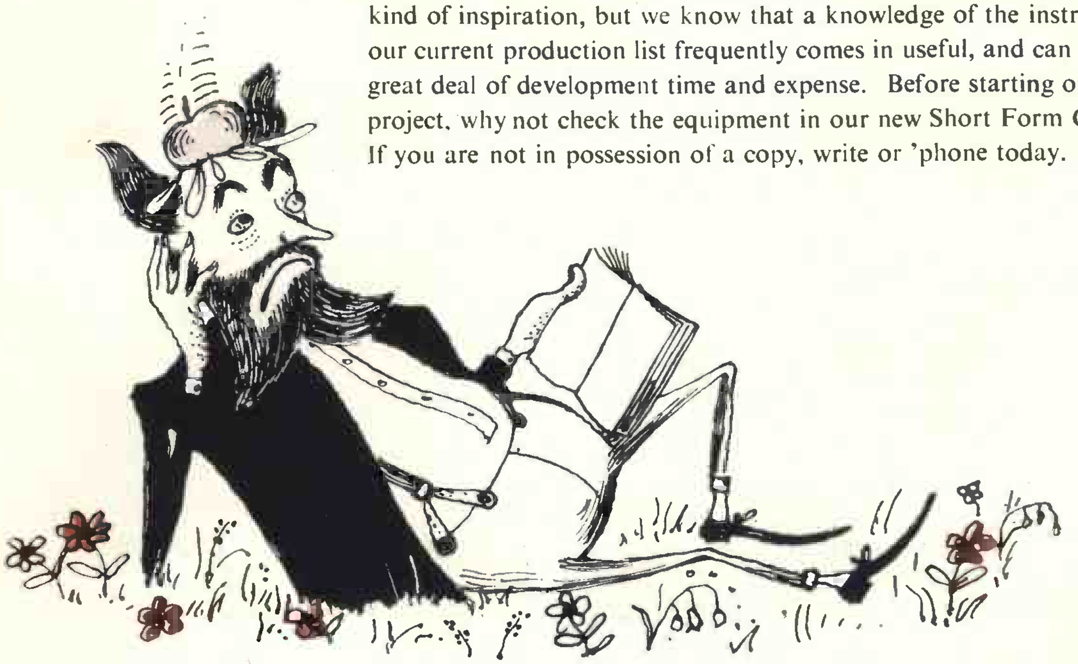

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