

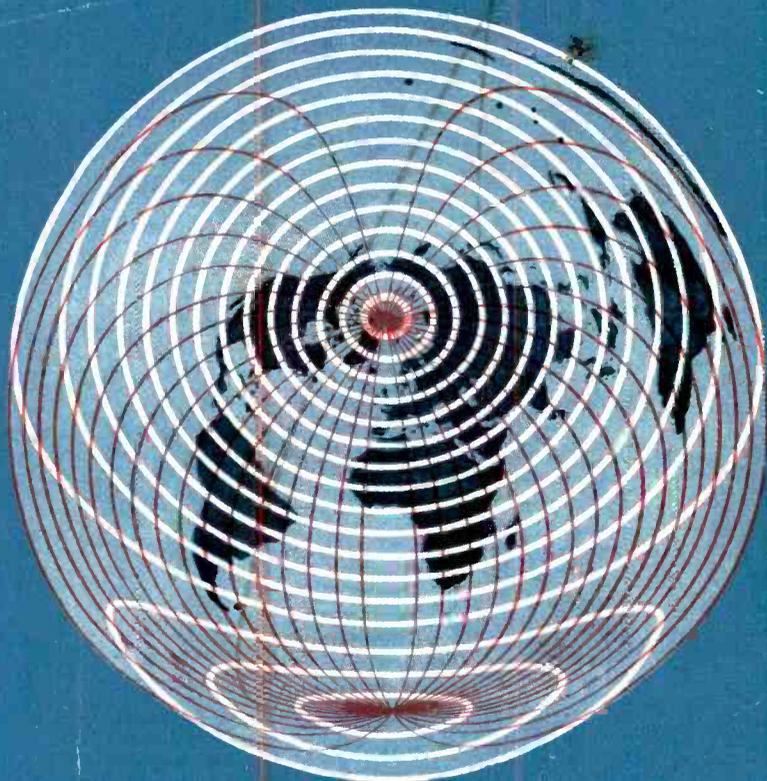
JANUARY 1958

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Wireless World

ELECTRONICS

Radio • Television



FORTY-SEVENTH YEAR OF PUBLICATION

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Wireless World

ELECTRONICS, RADIO, TELEVISION

Managing Editor: HUGH S. POCOCK, M.J.E.E.

Editor: F. L. DEVEREUX, B.Sc.

JANUARY 1958

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Transistor



R.C. Coupled Amplifier Stages

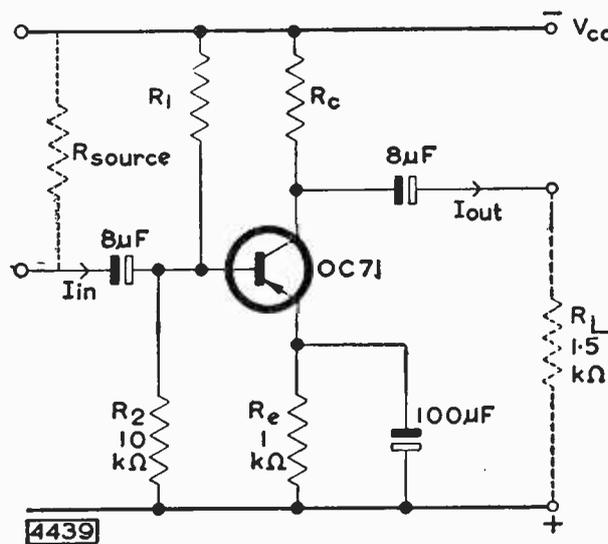
Although it is desirable to design a universal standard transistor amplifier stage, this is not possible because signal level, supply voltage and maximum working ambient temperature each introduce problems which must be overcome in different ways. It is possible however to design and publish typical amplifier stages for several supply voltages, assuming a maximum working ambient temperature, making a compromise between gain and output.

The first stage in an amplifier must be designed to provide as high a ratio of signal to noise as possible, because the accumulated input and circuit noise will give a very impure output over a number of stages. In all other stages the requirement is maximum gain for minimum distortion at the required output level.

The recommended circuit using a Mullard OC71 transistor, with capacitive coupling produces a good gain for a relatively distortion free output. The circuit is suitable for use with supply voltages of 6V, 9V and 12V, stabilised up to 45°C ambient working temperature. Some modifications are indicated below for the user's guidance. It is important when modifications are made to ensure that the collector current should not go below 0.3mA, otherwise the input resistance and collector-emitter gain α' become very non-linear. The distortion and gain data shown in the accompanying table are typical for one OC71 stage from a series of

identical ones in cascade. The source impedance R_{source} is assumed equal to the collector resistance R_C . A resistance of 1.5k Ω is used to shunt R_C , this value is equivalent to the input impedance R_{I_1} of the following stage. The current flowing in this 1.5k Ω is the output current considered in the distortion and gain measurements tabulated below. The gain figures apply to a transistor with average collector-emitter gain α' . These component values have been carefully chosen such that in each case the transistor operates satisfactorily up to an ambient temperature of 45°C. It will be seen from the table that the useful output current, for 5% total distortion, and stage gain increase with supply voltage. This distortion is predominantly second harmonic.

The performance obtained with $I_C = 1\text{mA}$ should be adequate in most cases, however the stage gain can be increased by reducing (not below 0.3mA) the collector current, this is only worthwhile at the lower supply voltages. For instance $I_C = 0.5\text{mA}$, $R_e = 2.2\text{k}\Omega$, $R_C = 3.9\text{k}\Omega$ gives 20% increased gain. Increased output can be obtained for a given distortion by increasing the collector current to, say, 1.5mA, altering circuit values accordingly. For minimum distortion it is preferable to keep the collector current in the range 1-2mA, in any case it should not be reduced below 0.3mA, and to keep the source impedance as high as possible.



CIRCUIT VALUES AND GAIN FOR SOME TYPICAL OC71 TRANSISTOR STAGES

V_{CC} (V)	I_C (mA)	R_1 (k Ω)	R_2 (k Ω)	R_e (k Ω)	R_C (k Ω)	$\frac{I_{out}}{I_{in}}$	I_{out}^*
6	1.0	39	10	1	2.2	23	200
9	1.0	62	10	1	3.9	28	260
12	1.0	82	10	1	5.6	31	270

* For 5% total distortion



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Training Technologists

"In the absence of natural resources commensurate with the size of its population, this country lives by trade and by the skill and efficiency of its industry, which must be sustained and expanded by the infusion of the best brains that can be found, trained and stimulated to work with enthusiasm."

THE truth of this typical aphorism is by now universally acknowledged; it is also axiomatic that existing channels of supply do not provide scientists and technologists in sufficient numbers for present, let alone future, requirements. For the sheer spade-work of detail design and development the number of vacancies has long exceeded the supply; and at the top there will always be more than enough room for the Faradays and Blumleins of this world.

Where do the "star" men come from? According to Lord Hives, who spoke recently on the occasion of the introduction of the first report* of the National Council for Technological Awards, there is no evidence to show that any one educational channel is more likely than another to throw up the man of exceptional ability. The important thing is to open up as many channels as possible, so that no one who has the will to apply himself may be debarred by force of circumstance from proving his ability by the acquisition of a universally recognized qualification.

One of the reasons why the technical colleges of this country have been less well supported than the universities is the absence of a generally accepted degree or diploma (other than an external degree from London University) to set the seal on a sustained course of study. This has now been remedied by the Diploma of Technology (Dip. Tech.) which has been established by the National Council for Technological Awards, set up by the Ministry of Education.

Will Dip. Tech. be as good as a degree? For the purpose of qualifying for a post in industry it may well be better. An essential feature of the scheme is the freedom of colleges to develop their Diploma courses *in consultation with industry*, so that students will be well fitted for the industries they serve. In most cases work will be integrated in sandwich courses with industrial training. Teachers are to be encouraged to return periodically to industry, and it is proposed that senior members of industrial staffs should be given a special status in colleges which will enable them to take part in the academic activities. By these means it seems likely that a Dip. Tech. man will be more quickly useful than a man with an academic degree who may take some time to shake down in an industrial environment.

*See "World of Wireless," this issue.

Although the composition of the Dip. Tech. courses will show wide variations, there is little doubt that the standard required will be uniformly high. We are impressed by the stiffness of the requirements laid down by the Council and the fact that more than half of the courses originally submitted for approval have been rejected. The governing body is not lacking in academic attainment, but is drawn mainly from industry and has acted and spoken with a sense of realism which is often absent from the pronouncements of professional "educationists."

It is not the business of the Council to initiate courses—these are prepared by individual colleges—so it cannot be made responsible for what appears to us to be an insufficient emphasis on the importance of electronics. Only one course (at the Northern Polytechnic) on the "Physics and Technology of Electronics" appears in the list of recognized courses in Appendix III of the report, though there are eight courses labelled "electrical engineering" and three "applied physics." No doubt these general subjects include some electronics, but they are now so wide and complex that any attempt to cover them completely in three or four years must surely run counter to the aims and objects of Dip. Tech. Essentially, this new qualification is a matter of expediency and has been created by the need for efficiency. There must be the broadest possible fundamental training at the beginning of the course, but specialization in the final years is inevitable and must tend to become even more narrow as the range of a subject increases with expanding knowledge.

The growing importance of electronics in the national economy is sufficient justification for the strongest possible representation on the Boards of Studies appointed by the Council. The collective experience of the Brit.I.R.E. should be added to that already available from the I.E.E., and many associations of specialists would have useful contributions to make. A separate Subject Panel in electronics should then be appointed, and this in itself would encourage the submission of more courses in electronics. We would also urge the larger electronics firms to use their influence with local colleges to submit more courses of a type appropriate to the needs of their industry.

Fears have been expressed that the advantages of a liberal education will be lost to those who elect to study for Dip. Tech. This need not be so, for the development of the critical faculty and a capacity for concentrated effort, resulting from the mastery of any one subject, are the best preparation for the continuous process of learning by which a liberal education is acquired.

WORLD OF WIRELESS

Technological Education

ON the recommendation of the National Advisory Council on Education for Industry and Commerce the Minister of Education set up in 1955 the National Council for Technological Awards as an independent self-governing body "to create and administer technological awards . . . available to students in technical colleges who successfully complete courses approved by the council." The council's first report (covering the period from December 1955 to July 1957) was presented by Lord Hives, the chairman, at a meeting early in December.

The first award to be introduced by the council is the Diploma in Technology (Dip. Tech). The first of the 965 students now taking approved courses in a variety of technologies at eleven colleges will be taking their "finals" next June. There is some flexibility in the standards required of students for admission to a course but in general it is either five subjects in the General Certificate of Education or a good Ordinary National Certificate.

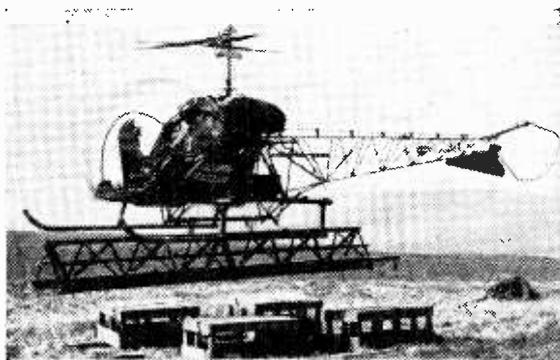
It is pointed out that approval of a course is not granted solely on its academic content but also on the general facilities available at the college. Moreover, the majority of the 50 approved courses are of the sandwich type with integrated college and works training.

The Dip. Tech., which is equivalent to a university honours degree, is the first award to be instituted by the council, which is now considering what post-graduate awards it should introduce.

The council, which has offices in 9 Cavendish Square, London, W.1, has two Boards of Studies, one covering engineering and the other technologies other than engineering.

Helicopter Aids S.H.F. Tests

THE Post Office Engineering Department has recently been carrying out propagation tests from a remote site five miles from Langholm, Dumfriesshire. It took six days to transport the mast, aerials, transmitting and receiving equipment, test hut and engine generator to the site over a mile of peat bog using a caterpillar tractor towing a sledge.



Air-lift for a section of the mast used for the Post Office s.h.f. tests referred to above.

In the light of this experience a helicopter was used for the return journey, the total time taken being only seven hours, spread over two days. Mast sections, paraboloid, and other heavy or bulky equipment was suspended from the machine.

Subscription Television

WE have heard a good deal about proposals for "subscription-TV" from the U.S.A. but not until October did the Federal Communications Commission lay down rules under which applications for operating such a service would be considered. Trial installations are to be limited to cities which already have four "grade A" television services.

Although these rules do not cover closed-circuit systems—the F.C.C. has no jurisdiction over wire transmission—it is of considerable interest to learn from Rediffusion, Ltd., that they have signed a 21-year agreement with the Skiatron International Corp., for the "survey, installation, supervision and maintenance of closed-circuit television systems in the Western Hemisphere."

At the recent luncheon of the Relay Services Association of Great Britain, Mr. Ness Edwards, a former P.M.G., said, "I hope that subscription television is going to be developed by this association." This, however, would need a major change in the P.M.G.'s licence under which relay companies operate.

Student Exchange

SINCE its formation in 1948 the International Association for the Exchange of Students for Technical Experience has arranged for nearly 5,000 students from 36 British universities and colleges to gain experience in industry abroad during their summer vacations. The annual report of the Association records that 34,602 students from 23 countries have participated in the scheme during the past 10 years.

By far the largest number of students among the 5,934 "exchanged" during 1957 came from Germany (1,219). The next highest being Austria (763) with Great Britain third (731). Of the 21 countries receiving students Germany accepted most (1,195) with Sweden second (1,160) and Great Britain third (784).

In the summaries of industrial and academic "spheres of influence" no mention is made of electronics, but it is obvious from the names appearing in the lists of participating companies and organizations, both in this country and abroad, that many of the students were in this field. The number of industrial and other organizations which received students in 1957 totalled 2,761 compared with 413 in 1948.

The secretary for the U.K. is J. Newby, Imperial College, Prince Consort Road, London, S.W.7.

Whilst on the subject of student exchange mention should be made of the Imperial College Vacation Work Scheme. A booklet "Vacation Training" has been issued by the College giving details of the scheme and a list of companies offering to accept students for vacation work.

Television trade tests to assist the industry and dealers are now radiated by the B.B.C. each weekday from 10 a.m. to 1 p.m.. Also all stations now use full power for these tests. Should it be necessary to operate a station on reduced power during the tests the words "reduced power" will be shown on Test Card C or a horizontal bar pattern accompanied by a 250-c/s tone will be transmitted for one minute in every five.

Popularizing V.H.F. Broadcasting.—The next in the series of demonstrations being conducted jointly by the B.B.C., B.R.E.M.A. and R.T.R.A. to foster v.h.f. broadcasting will be in East Anglia. Staged in the Samson & Hercules Hall, Norwich, on January 15th and 16th, it will include in addition to demonstrations an exhibition of v.h.f. receivers.

Wenvoe is to radiate the Third Programme and Network Three on v.h.f. in addition to its existing transmissions of the Light Programme and Welsh and West of England Home Services. The fourth service, which will be radiated on 96.8 Mc/s with a e.r.p. of 120 kW, is hoped to be introduced before the end of 1958. The temporary low-power v.h.f. transmitter at Bristol, which has carried the Third Programme since October, will then close down.

V.H.F. in Scotland.—With the opening of the v.h.f. station at Kirk o'Shotts on November 30th the B.B.C. f.m. service is extended to over 80 per cent of the population of Scotland. Kirk o'Shotts radiates on 89.9, 92.1 and 94.3 Mc/s, with an e.r.p. of 120 kW. The first Scottish v.h.f. station is at Meldrum, Aberdeen. A third station, at Rosemarkie, near Inverness, is planned to be opened in the spring.

B.B.C. Television.—Two new permanent television transmitters have been brought into service by the B.B.C. during December—Douglas, Isle of Man, and Sandale, Cumberland. Both replace temporary low-power transmitters. Douglas operates in Channel 5 with vertical polarization (e.r.p. 2.8kW), and Sandale in Channel 4 with horizontal polarization (e.r.p. 16kW).

Receiving Licences.—During October the number of combined television and sound receiving licences increased by 125,886, bringing the total to 7,524,071. Sound-only licences (including 326,161 for car radio) totalled 7,153,541, making an overall total of 14,677,612 at the end of October. The figures for October, 1956, were, television and sound 6,291,072, sound only 8,128,669 (including 310,301 for car radio), making a total of 14,419,741.

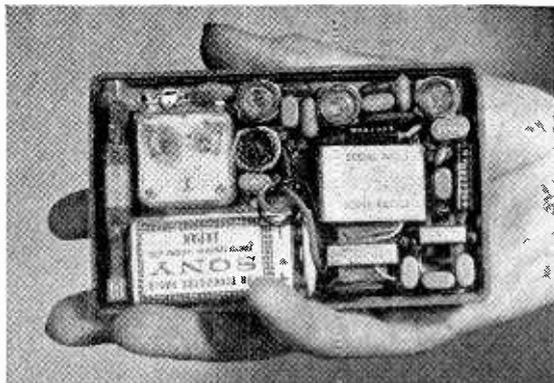
R.S.G.B. Membership.—Last year for the first time since 1948 the membership of the Radio Society of Great Britain increased. The number of members at June 30th was 8,495 compared with 8,102 the previous year. Nearly two-thirds of the members (5,490) hold transmitting licences.

Patents Digest.—A weekly summary of patents in the fields of electrical, electronic and nuclear power engineering is now published by Hunter Digests, Ltd., of 41, Whitehall (T.L.O.), London, S.W.1. "British Electrical Patents Digest," as it is called, costs 10 guineas for six months.

C.I.R.M.—The London office of the International Maritime Radio Committee, of which Col. J. D. Parker is secretary-general, has been transferred from Ludgate House, Fleet Street, to Shipping Federation House, Minorities, E.C.3. (Tel.: Royal 1419.)

"Nearest Approach Calculator" (October issue, p. 175).—We have been asked to point out that this device is the subject of Patent Application 27407/56 by R. V. Brass and T. P. McLelland, who were mainly responsible for the development work.

"Sensitive D.C. Null Detector." (December issue, p. 597).—The full-scale deflection of this instrument, as stated in the text, is 50 milli-microamperes and not 50 μ A as shown in the sub-title.



Transistorized personal portable, SONY TR63, which is made in Japan, is now being sold on the Continent. It measures $4\frac{1}{2} \times 2\frac{3}{4} \times 1\frac{1}{4}$ in, weighs $10\frac{1}{2}$ oz and costs about £17 (in Germany 198 DM). It covers the medium-wave band using a ferrite rod aerial and selectivity is claimed to be -15 dB at 10 kc/s off resonance.

"E.B.U. Review" is the new title under which the *Bulletin* of the European Broadcasting Union is being issued from January. It will be published from the Technical Centre, 4 rue de la Vallée, Brussels, in two parts (a) technical and (b) general and legal, the parts being issued in alternate months. The annual subscription for part (a) is 150 Belgian francs or 300 Belgian francs for both parts.

The **"sunspot number,"** which is a measure of the number and size of disturbed areas on the sun, for October was the highest since records have been kept (about two centuries). The figure was 263. September also produced a high figure, 244. The Royal Society states that the previous highest record was 239 in May, 1778. September also provided a record in terrestrial magnetic activity; there were six great magnetic storms.

International Standardization.—Plans for the first plenary session of the International Organization for Standardization to be held in this country are in the hands of the British Standards Institution. The headquarters of the two weeks' conference (opening on June 9th) will be at the Royal Hotel, Harrogate.

Analogue computation methods (differential analyzers, rheo-electrical analogies, network analyzers, simulators, special calculators, etc., and their applications to science and industry) will be covered at the second International Analogy Computation meeting which is being organized by the Association Internationale pour le Calcul Analogique. Originally planned for June it will now be held from September 1st to 9th in Strasbourg, France. Further information is obtainable from F. H. Raymond, 138, Boulevard de Verdun, Courbevoie (Seine), France. The representative of the Association in this country is Professor S. C. Redshaw, Department of Civil Engineering, the University, Edgbaston, Birmingham, 15.

A Data Processing Section was recently formed by the Society of Instrument Technology (20 Queen Anne Street, London, W.1) and a series of meetings is being held in London. The next meeting is on January 28th when M. P. Atkinson, of the National Physical Laboratory, will speak on digital codes and coding. The secretary of the Section is W. T. Bane, 137 Kenilworth Court, London, S.W.15.

Information Engineering.—A graduate course in information engineering will again be held at the University of Birmingham in the 1958-59 session.

Applicants wishing to be considered for a D.S.I.R. grant, covering the fee of £81 and a maintenance allowance, should apply to the electrical engineering department of the University before February 3rd. Copies of the syllabus of the course are obtainable from the Supervisor of Graduate Courses, the Electrical Engineering Dept., The University, Birmingham, 15.

Servicing and maintenance of sound and television receiving equipment is covered by the course opening at the Wesley Road Evening Institute, Stonebridge, London, N.W.10, on January 6th. The fee for the course, which will be held on Mondays and Wednesdays until July 2nd, is 25s.

Personalities

B. St. J. Sadler, managing director of Redifon, Ltd., has retired after 13 years with the company. He was commercial manager of Marconi's Wireless Telegraph Co. before he joined Redifon. He is succeeded by **F. Youle**, B.Sc., A.C.G.I., A.M.I.E.E., who joined the company as sales manager in 1942 and became a director four years later. Since last July he has been general manager responsible for the factories and laboratories at Wandsworth and Crawley. Following his training in electrical engineering at the City & Guilds of London Institute, his industrial career began in 1921 with Marconi's where he spent some time in the development laboratories. He later became television sales manager of Marconiphone. From 1940 to 1942 he was in the Ministry of Aircraft Production.



F. YOULE



H. C. PRITCHARD

W. H. Apthorpe has retired from the managing directorship of Cambridge Instrument Company with which he started his career in 1900. After a few years he left to continue his technical education and returned in 1914 to take charge of the company's testing department. He is continuing with the company as deputy chairman. His successor is **H. C. Pritchard**, B.A., who, after graduating at Oxford, joined the Air Ministry and in 1939 was appointed head of the Navy section of the Royal Aircraft Establishment. After the war he became head of the Blind Landing Experimental Establishment at Martlesham and in 1949 was seconded to the Australian Government as chief superintendent of the Woomera rocket range where he stayed for three years. He subsequently left Government service and has been for the past four years with Elliott Brothers, latterly as group manager at Rochester. He is a Fellow of the Royal Aeronautical Society.

Communication Networks.—A course of lectures on modern electric network theory and design will be given by Dr. W. Saraga on six consecutive Wednesday evenings from January 22nd at the South East London Technical College, Lewisham Way, London, S.E.4 (fee 10s).

Southall Technical College introduces three new series of evening lectures in January. They are, "Sound Recording and Reproduction" (12 lectures), "Colour Television" (9 lectures), and "Design and Usage of C.R. Tubes" (12 lectures). The fee for each course is £1. The first course begins on 13th and the other two on 15th.

Sir Robert Watson-Watt has been awarded the Elliott Cresson medal of the Franklin Institute of America "for his contribution to the conception of pulsed radar and his leadership in its development." Sir Robert, now living in Canada where he runs the consultancy organization Adalia, Ltd., has recently completed his autobiography which is inevitably a virtual history of radar. It is entitled "Three Steps to Victory" and is being published by Odhams in February. Sir Robert is soon revisiting this country and will be addressing the Radar Association on February 12th on "The Early Days of Radar."

Dr. J. C. West has been appointed to succeed **Prof. P. L. Burns**, who is retiring from the chair of electrical engineering in Queen's University, Belfast. Dr. West graduated at Manchester University in 1943 and after service in the Royal Navy returned in 1946 to join the staff of the University's department of electrical engineering and was appointed senior lecturer in 1953. His early researches were in the field of electron optics but he has subsequently specialized in non-linear servomechanisms, and as a result of this work he has received the degrees of Ph.D. (1952) and D.Sc. (1957). Prof. Burns has been at Belfast since 1924, having entered the teaching profession at Hull in 1918. During the first world war he was at Manchester University where he was associated with Lord Rutherford on submarine detection.

Dr. T. G. Pickavance, at present deputy head of the general physics division of the Atomic Energy Research Establishment at Harwell, has been appointed by the National Institute for Research in Nuclear Science as director of its Rutherford High Energy Laboratory (Harwell). Dr. Pickavance, who is 42, is at present officer in charge of the group responsible for the design and supervision of the construction of the new large accelerator for the Institute. He has been at Harwell since 1946 and in his present position since 1955.

Major C. Collaro, O.B.E., who, as announced last month, resigned his position as chairman and managing director of Collaro, Ltd., has joined Camp Bird Industries, Ltd., as chairman. He succeeds **John Dalgleish**, who will continue as chairman and managing director of Camp Bird, Ltd., the parent company. Camp Bird Industries controls the electrical, electronics and communications group of the parent company. This group includes Ambassador, Hartley Baird and E-V (Sapphire Bearings).

C. E. Payne, B.Sc.(Eng.), M.I.E.E., chief engineer and a director of Ferguson Radio Corporation Ltd., has been co-opted to the governing body of Enfield Technical College. He has been closely associated with the college for some time on the educational and training schemes operated by the parent company Thorn Electrical Industries.

Clive Barwell, general publicity manager of Mullard, has completed 25 years service with the company. He was at one time production manager of one of the company's valve factories, but has been mainly concerned with publicity and public relations.

G. R. Scott-Farnie, M.Brit.I.R.E., has been appointed managing director of International Aeradio, Ltd., in succession to Air Commodore C. S. Cadell, C.B.E., M.A., M.Brit.I.R.E., who has resigned to join *The Times*. Both of them were members of I.A.L. on its formation in 1947. Mr. Scott-Farnie, who for the major part of the war was on special signals duties in the R.A.F. and from 1944 to 1945 was signals intelligence officer on General Eisenhower's staff, joined the company as operations manager. He operates amateur station G5FI.



G. R. SCOTT-FARNIE



R. E. ROBINSON

Three assistant managing directors have been appointed by the G.E.C. They are **T. W. Heather**, M.C., Comp.I.E.E., who will be responsible for the general products group, **A. L. G. Lindley**, the engineering group, and **R. E. Robinson**, M.I.E.E., the telecommunications group. The company has also appointed two new directors, **D. G. W. Acworth**, M.A., M.I.E.E., and **W. J. Bird**. Mr. Heather, who has been with the company 44 years, was elected to the board in 1938 and is also on the board of a number of other companies, including M.O. Valve Co. and Salford Electrical Instruments. Since 1944 he has been chairman of the G.E.C. education and training committee. Mr. Lindley, a mechanical engineer, joined G.E.C. as an apprentice in 1918. Mr. Robinson has concentrated on telecommunications throughout his industrial career which began in 1903 when he joined the Western Electric Company in London. In 1905 he went to the Bell Telephone Company in Antwerp and in 1908 became chief engineer of the Peel-Conner Telephone Works, then a G.E.C. subsidiary. Mr. Robinson, who was appointed director in charge of telephone and radio works in 1945, is a past chairman of the Tele-communication Engineering and Manufacturing Association.

John Dyer has resigned from the position of public relations officer for E.M.I. Electronics, Ltd., to which he was appointed in 1954, and has joined the staff of the British Electrical & Allied Manufacturers' Association as technical editor of *BEAMA Journal*. He was with the Philco organization for some time before the war and again from 1950-54. Mr. Dyer was at one time editor of *Wireless & Electrical Trader*.

Sergeant Edward J. Gane has been seconded by the R.A.F. to be senior wireless operator at the Royal Society Antarctic base at Halley Bay for 1958. He has sailed in *M.V. Tottan* which, after visiting the Norwegian base and Halley Bay, will be bringing home some members of the advanced party. Among them will be chief technician **Ronald Evans**, R.A.F., who has been senior wireless operator during the past year.

B. V. Baliga, chief engineer of All India Radio, is the new president of the Indian Institution of Tele-communication Engineers. He has been vice-president of the Institution since its formation in 1953.

Dr. James R. Killian, president of the Massachusetts Institute of Technology since 1948, has been appointed by President Eisenhower to the new post of Special Assistant to the President for Science and Technology. Dr. Killian, who is 53, has been closely associated with government research in the U.S. and was a member of President Truman's communications policy board.

Dr. A. W. Hull, consultant to the General Electric Research Laboratory, Schenectady, U.S.A., is to receive the Medal of Honour, the premier technical award of the American Institute of Radio Engineers. Dr. Hull, who is credited with creating a greater number of new types of valve than any other man, receives the award "for outstanding scientific achievement and pioneering inventions and development in the field of electron tubes."

OUR AUTHORS

J. C. Beckley, B.Sc.(Eng.), author of the article on the design of car radio receivers, graduated at London University in 1954 and since then has been on the staff of the Applications Research Laboratory of the Mullard Radio Valve Company. His work there is concerned with the design and development of valves and circuit techniques at radio frequencies.

T. G. Clarke, A.M.Brit.I.R.E., contributor of the article on the cathode-coupled flip-flop, is senior development engineer with Decca Radar where he has been responsible for the electronic design of several types of marine and windfinding radar. He is at present engaged on investigations into the use of storage tube systems in radar. During his military service he was a warrant officer in the R.E.M.E. and served as an instructor at various training establishments both in the United Kingdom and overseas.

Dr. D. H. Martin, the first part of whose article on magnetism in quantum appears in this issue, is a lecturer in physics at Queen Mary College, University of London, where he is engaged in research into super-conductivity and spectroscopy in the very far infra-red. He graduated with first-class honours in physics at the University of Nottingham in 1950 where for four years he undertook post-graduate research into the domain structure of ferromagnetic metals, concentrating on domain nuclear processes.

P. R. Stutz, B.Sc.(Eng.), A.C.G.I., Grad.I.E.E., author of the article on turret tuners for Band V, has been with Kolster-Brandes, Ltd. for the past nine years. He is a senior engineer in charge of a section engaged on television research and development, and represents the firm on the U.H.F. Working Party of the British Radio Equipment Manufacturers' Association. He graduated at the Imperial College of Science and Technology with an honours degree in electrical engineering in 1948.

OBITUARY

A. Cecil Barker died on December 10th, aged 58, at his home. The Close, Hurst Wickham, Hassocks, Sussex. He was trained as a singer and broadcast in the 1930s, and his interest in sound reproduction took the practical form of designing the "Duode" loud-speaker. This was patented in 1936 and manufactured during the pre-war period by Magnavox (Benjamin Electric). During the war Mr. Barker served in the Admiralty (A.S.R.E.) and in 1947 started the business of Duode, Ltd.

Frank S. Allen, works director of E. K. Cole, Ltd., and a director of Egen Electric and Ekco Electronics, died on November 20th aged 56. He joined the Ekco organization in 1941 as assistant works manager and four years later became general works manager of the radio division.

TELEPHONE AUTOMATION

AN electronic switching system taking the place of trunk-call telephone operators is to be installed by the Post Office at Bristol as part of their national scheme for "automatization" of the telephone service. Known as GRACE (from Group Routing And Charging Equipment), it will enable subscribers to dial trunk calls just as they do local calls on the automatic system. The equipment, which is based on cold-cathode tubes, has been designed and developed in co-operation with the General Electric Company. It will register a dialled number, select a route to the distant exchange, ring the wanted number, and, when the distant subscriber answers, record the appropriate charge on the caller's local exchange meter. The word "Group," incidentally, derives from the new system of grouping exchanges which comes into force on 1st January.

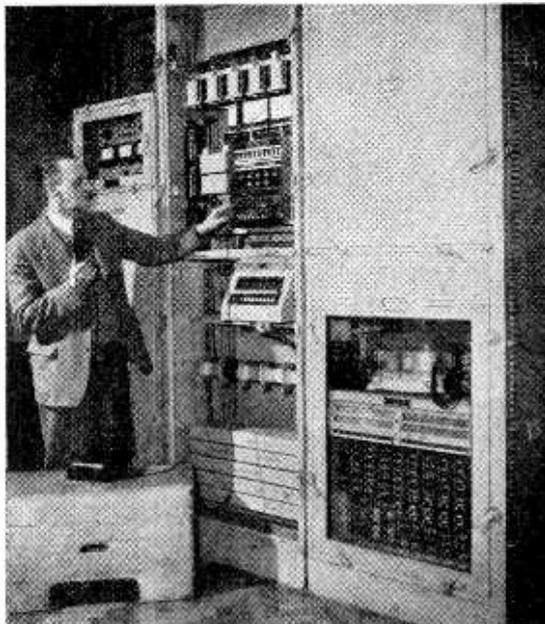
To make an automatic trunk call the caller dials the national number of the distant subscriber. The first digit of all national numbers is "0," and receipt of this causes the call to be connected to a "call charger" equipment. The remaining digits of the number are received and stored in a register. Of these, the first 1, 2 or 3 digits identify the distant "Group." A "translator" equipment then inspects these digits and deduces from them the route and charge rate for the call. The translator incorporates a permanent store giving details of the routes and charge rates for calls from the originating exchange to all other "Groups" in the country.

The information passed back from the translator to the register is in the form of a charging rate digit and several routing digits. To avoid having to provide storage capacity for all these digits at once, they are passed to the register one at a time as required. The register uses a digit supplied by the translator to further the setting up of the call and then makes a fresh demand for another digit. The time taken by a register to use a digit is far greater than that required by the translator to supply it. The translator is therefore freed between demands for use by any other register, and it may serve up to 40 registers altogether.

The first digit returned to the register from the translator is used to select the appropriate charging rate in the call charger. Subsequent digits are used by the register to operate switches in the originating and distant exchanges to complete the connection. When the connection has been completed the register is released and made available for use with other call chargers in setting up further calls. The call charger remains connected throughout the call and, when the distant subscriber answers, levies the charge by operating the caller's exchange meter periodically, at intervals depending on the distance between the two "Groups" concerned.

Another equipment, developed by the Automatic Telephone and Electric Company and somewhat similar in function, was put into operation recently at the Lee Green (London) automatic exchange. This, however, is not dealing with trunk calls but replaces some of the electromechanical equipment in the automatic system. Moreover, it is based on a magnetic drum storage system, which provides the registers for the dialled numbers on some of its tracks and the information for translation into routing directions on a "library" of other tracks.

The associated electronic equipment here makes use of thermionic valves. One important part of it is a



The magnetic drum director at the Lee Green exchange showing the actual drum in the right-hand cabinet.

"scanner," driven by synchronizing tracks on the magnetic drum. This scans the subscribers' lines and, where dialling pulses are present, causes the dialled numbers to be put in the appropriate register on the drum. This scanning provides a means of keeping a running record of the state of each of the subscribers' lines, and the record is kept up to date merely by putting the most recent state in place of the old one. In this way the electronic equipment and the drum can be time-shared over any 114 subscribers' lines in as little as 17 milliseconds each. Moreover each of the 114 lines can be rescanned every 17 milliseconds, so that changes of state of up to 60 changes per second are recognized. This permits considerable economies in apparatus and is one of the reasons for developing the trial equipment.

MSF TRANSMISSIONS

A NEW edition of the pamphlet* describing the U.K. standard frequency service has been issued by the National Physical Laboratory. These transmissions are radiated almost continuously from the Post Office station MSF at Rugby on behalf of the N.P.L. Both the carriers (2.5, 5, and 10 Mc/s) and the modulation frequencies are maintained to ± 5 parts in 10^9 . The MSF frequencies are now based on the resonant frequency of the caesium atom (9, 192, 631, 830 c/s).

The transmitted power on each of the carriers is 0.5 kW. A bottom-fed mast radiator is used for the lower frequency and quadrant dipoles for the other two.

The accuracy obtainable from MSF is, however, limited by propagation conditions which can cause changes in the received frequency amounting to ± 2 parts in 10^7 . An additional transmission is therefore radiated daily for one hour (1429 to 1530) on 60 kc/s with a power of 10 kW.

The results of daily measurements made by the N.P.L. at Teddington on the MSF transmissions are given in our sister journal *Electronic & Radio Engineer* each month.

* "MSF-Standard Frequency Transmissions from the United Kingdom."

Reception on Band V

An Introduction to Circuit Techniques for the Ultra High Frequencies

THE announcement in last month's *Wireless World* that the B.B.C. has started transmitting on an experimental basis sound and vision signals in Band V must give rise to speculation on the kind of problems likely to be encountered in designing receivers for 650Mc/s.

The Band-V receiving problems are certain to be a little more difficult to solve than those encountered when Band III was first opened to television, but they are not likely to be exceptionally troublesome. Band V has been in use for television in the U.S.A. for a few years now and we are in the fortunate position of being able to study the circuit techniques adopted on that side of the Atlantic.

Some new valves had to be developed and while British prototypes have been made in this country it may be some time before they become generally available. However, the Band-V transmissions are only experimental, and who can say when a regular service will be inaugurated? Suitable valves are bound to be available to all when the time arrives.

R.F. amplification on 650Mc/s is not ruled out by any means, but if the current practice in the U.S.A. can be taken as a guide the r.f. amplifier is a luxury rather than a necessity on this band. Where it is used it takes the form of an earthed-grid amplifier usually with line-type circuits and one such arrangement is shown in Fig. 1. It would be justifiable to draw the inductors L_1 , L_2 , L_3 , L_4 and L_5 in the familiar helical form, but it is desired at this stage to emphasize one of the main differences that will often be encountered in tuned circuits on u.h.f. On these frequencies coils, as we know them, are in most cases replaced by straight pieces of thick wire, by a hairpin, or even a strip of metal, while

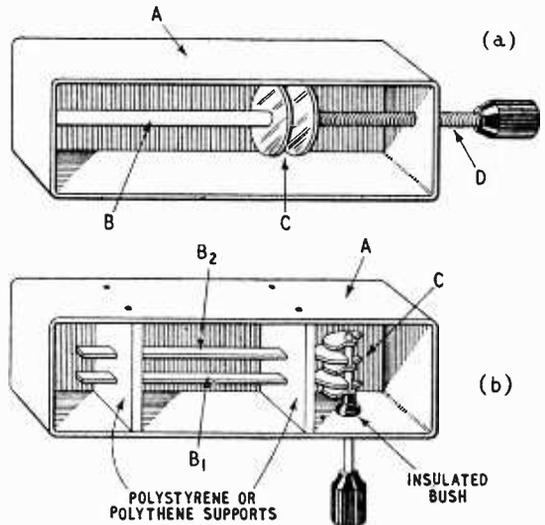


Fig. 2. Coaxial line (a) and balanced line (b) tuning elements for use on u.h.f.

an alternative would be sections of coaxial or twin wire transmission line as shown in Fig. 1(a) and (b) respectively. These lines are tuned by small capacitors, C in Fig. 2 and C_1 , C_5 and C_6 in Fig. 1. In the case of Fig. 2(b) the open ends of the two metal strips can be joined together to form a hairpin, with the capacitor in its centre, or joined to the grid and anode of a valve.

Fig. 1(a) is sometimes called a trough-line circuit.

The case A is usually "earthed" to the chassis but true earths are difficult to locate in u.h.f. equipments. The way out is to avoid as far as possible including any parts of containers or chassis in the tuned circuits. For this reason Fig. 1(b) is to be preferred for u.h.f. oscillators as the container is merely a screen.

The rod D in Fig. 2(a) is screw threaded and serves for adjusting the capacitor C. These troughs or boxes are invariably closed by a lid or cover-plate. The best material for these circuit elements, where the highest attainable Q is required, is silver, but as this is impracticable

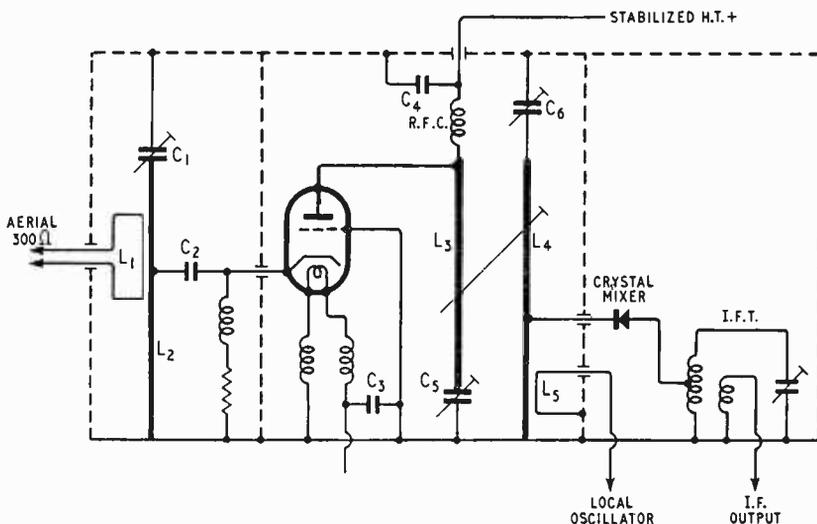


Fig. 1. Basic circuit of a u.h.f. earthed-grid r.f. amplifier.

tremely tedious trying to find the frequency of an unknown oscillator, especially at u.h.f., if one has to rely on heterodyning by a much lower-frequency oscillator.

A serviceable absorption wavemeter is not a complicated or costly piece of equipment. In its simplest form it consists of a small, say 10+10-pF, split-stator capacitor with a short length of heavy-gauge wire or copper strip looped across the fixed sets of vanes. An indicator of resonance is required, the simplest arrangement is to use one of two oscillators as the "indicator" and listen to the beat note in telephones in one of them. When the absorption wavemeter is loosely coupled to one of the u.h.f. oscillators and tuned through resonance a sudden change in beat-note takes place. So much for the indicator, there are better types, but this will suffice in many cases.

Calibration of an absorption wavemeter is easily effected by rigging up two parallel wires terminated at one end in a single-turn loop loosely coupled to the rods B₁ and B₂ (Fig. 3). These wires (Lecher lines they are called) should be about 4ft long and rigidly spaced about 1in apart. Standing waves will appear on this line with current (and voltage) maxima and minima spaced at equal intervals along the line. Two adjacent maxima (current or voltage) will be exactly a half-wavelength apart, so that it needs only some kind of sensitive r.f. indicator run along the line and points of maximum reading marked on a paper strip below the lines. While any two adjacent maxima will suffice, we have always found it best to include three or four, ignoring the one nearest the pick-up coil at the end of the line. At 650Mc/s the two maxima will be 23cm apart and by taking half-a-dozen measurements a very serviceable calibration of the oscillator will be available for calibrating an absorption wavemeter. How to make the absorption wavemeter is another story, but it is by no means an involved one.

All the items needed for a simple Band-V front end have been briefly discussed and it is now

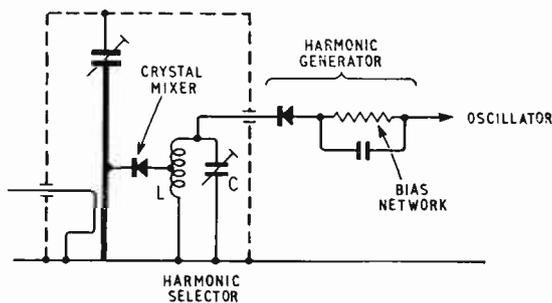


Fig. 5. Harmonic generator for a u.h.f. frequency changer.

possible to combine them into a serviceable unit. A simple type is perhaps one in which there is no r.f. stage and with the mixer output fed direct to the i.f. amplifier stage in a television receiver. It is not necessarily an ideal arrangement but it serves to illustrate the make up of a Band-V front end. The circuit is shown in Fig. 4. The signal picked up by the aerial is injected via the loop L₁ into the line indicator L₂ which is tuned by C₁. The line inductors L₂ and L₄, in conjunction with their respective tuning capacitors C₁ and C₄, form a band-pass, pre-selector filter coupled by the loops L₃ and L₅. The capacitors C₂ and C₃ are for padding each pre-selector circuit and in practice consist of small strips of copper soldered to the inductors and brought close to one side of the screening compartment.

Local oscillations from a u.h.f. oscillator are injected into the pre-selector circuit C₁, L₁ via the crystal mixer and loop L₆ in the oscillator compartment. C₅ is one way of showing a lead-through capacitor, this incidentally is of small capacitance since it is in parallel with part of the i.f. coil L₇. This coil is tuned by C₆, and damped by R₁, to give the required i.f. bandwidth. L₁₀ is a coupling coil feeding the i.f., at low impedance, to the main i.f. amplifier. The unfamiliar symbol C₁₀ is a stand-off capacitor.

It is essential that all u.h.f. bypass capacitors should be of this or lead-through types as even a 1/2-in length of wire at these frequencies has appreciable impedance.

The reason it was stated that Fig. 4 is not an ideal arrangement is that with the front-end comprising only an r.f. filter and crystal mixer the i.f. output will usually be very small indeed and the first i.f. amplifying stage should have exceedingly low-noise characteristics. In most receivers this stage is fitted with an r.f. pentode which is not the best type in the circumstances, so that the Fig. 4 front-end circuit ought to be followed by a cascode, or equivalent low-noise amplifier.

As the B.B.C.'s experimental television transmissions in Band V conform initially to the British 405-line standard, reception can be effected by adding a simple front-end, like Fig. 4, and switching the Band-III cascode r.f. am-

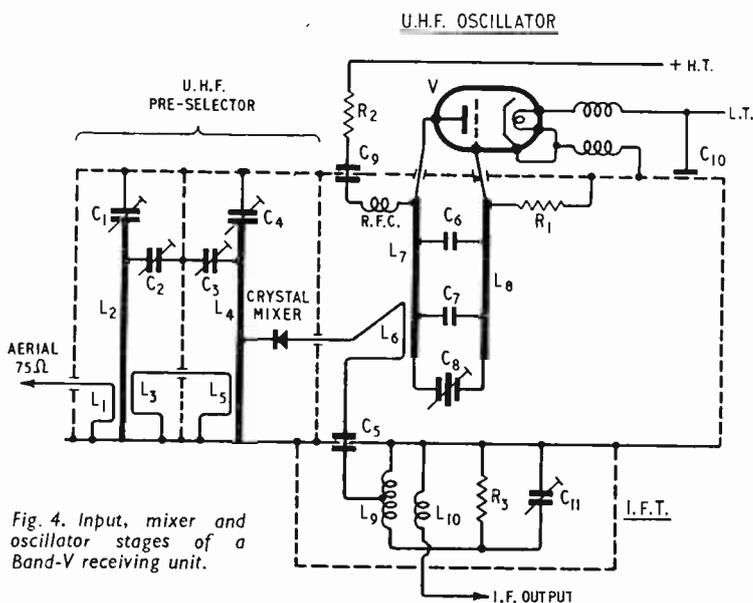


Fig. 4. Input, mixer and oscillator stages of a Band-V receiving unit.

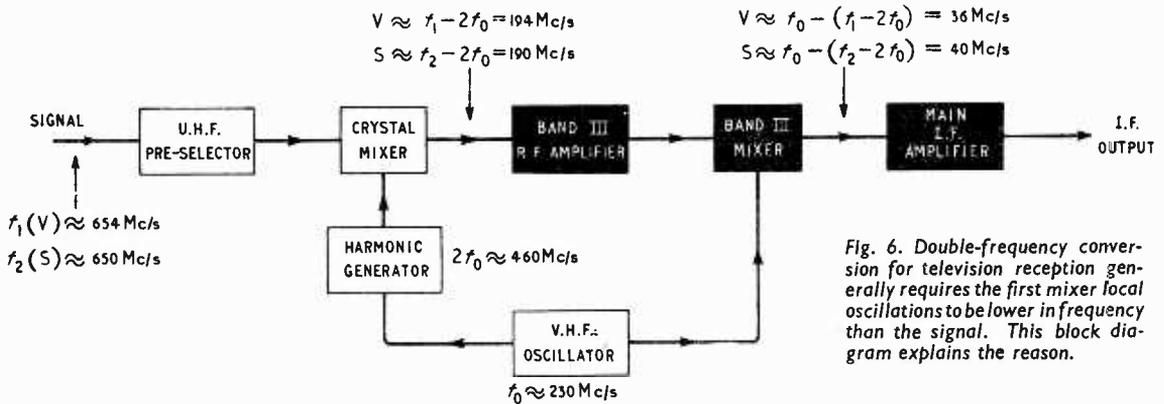


Fig. 6. Double-frequency conversion for television reception generally requires the first mixer local oscillations to be lower in frequency than the signal. This block diagram explains the reason.

plifier for use as a 34-38Mc/s i.f. stage. The Band-III oscillator can be switched off. With a turret tuner this is quite easily arranged.

Another scheme is to employ double frequency conversion and obtain the local oscillations for the first frequency changer from an harmonic of the Band-III oscillator. There are objections to double conversion as although only one oscillator need be employed interference can be produced by it and its family of harmonics.

Unless the oscillator stage is exceedingly rich in harmonics, which in a well-designed set it should not be, a harmonic generator has to be employed. One of the simplest is a crystal with a resistance-capacitance network in series and this is used quite extensively in the U.S.A. The circuit is very simple and is shown in Fig. 5, the circuit L, C being tuned to the desired harmonic. The Band-III cascode r.f. stage continues to function as such, but it might have to be tuned to a frequency different from the usual and possibly outside Band III in order to avoid interference from harmonics and fundamental of the oscillator.

It should be remembered that any system involving two frequency conversions for receiving television necessitates the correct choice of oscillator frequency for the first mixer; in the cases under discussion the crystal mixer. In most superheterodyne receivers conversion to i.f. can be effected with the local oscillations either higher or lower in frequency than the signal, since when extracting the difference, or beat, frequency of the two it matters not which is the higher. However, when two signals, such as sound and vision, are involved the i.f.'s that emerge will be transposed when the local oscillator is shifted over to the alternative beat.

It has been recommended by B.R.E.M.A. that the sound and vision i.f.'s should be about 38Mc/s and 34.5Mc/s respectively which requires that the local oscillator be *higher* in frequency than the signal.

When double-frequency changing is employed the first conversion must be made with the local oscillator on the *low* frequency side of the signal. The reason for this is best explained by means of a block schematic diagram such as Fig. 6. The frequencies marked against each stage are not necessarily those which would be employed in a practical case since the likelihood of interference from oscillator harmonics has not been taken into consideration. The example given here is to illustrate the basic principles involved.

We are indebted to Kolster Brandes, Ltd., and to Mullard, Ltd., for information on some of the principles and problems likely to be encountered in reception on Band V.

VALVE LIFE

IF asked the question "how long do the valves last in your radio or television receiver" few listeners, or viewers, would venture an answer. It is also doubtful if many users of commercial radio equipment would commit themselves. Would 30,000hrs. be too long?

A trial system of multi-channel radio equipment was installed in 1949 between the Marconi works at Chelmsford and a site at Woolwich for the purpose of compiling data on the reliability of equipment, which means primarily the reliability of the valves employed. The system operated continuously for 24 hours each day.

The original valves were removed in 1953, a log having been kept of any replacements required in the interim period. Many of the valves employed are ordinary receiving types found in domestic sets and the data relevant to their performances are given in the table here. This data was originally published in the October, 1957, issue of the Marconi journal, *Point to Point Telecommunications*.

Valve Type	Total Number Used	Failures		Average Working Time of all Valves (hrs.)
		Total Number	Average Life (hrs.)	
EF91	138	3	28,000	31,900
EB91	4	—	—	32,600
EAC91	2	—	—	32,600
ECC91	6	4	9,250	19,560
ECC32	8	1	26,500	29,000
KT66	12	—	—	32,600
SU4G*	16	9	4,600	5,000
U52*	16	32	6,060	8,090

*Alternative types were used during the trial.

"F.M. Discriminator Bandwidth." We regret that a sentence, which should have referred to co-channel interference, beginning "Fortunately, this has been anticipated . . ." on line 17, right-hand column of p. 572, December 1957 issue, was transposed. It should have followed the words ". . . to the same programme," five lines before the bottom of the preceding column.

Television Aerials For Bands IV and V

ADVANTAGES OF THE CORNER
REFLECTOR DESIGN FOR U.H.F.

SINCE November last, and for several months to come, the B.B.C. is radiating still and motion video transmissions on a frequency of 654.25Mc/s in Band V with a view to assessing all the technical factors involved should it be decided, at some future date, to provide a regular service in this band or in Band IV. During the spring the definition will be increased from 405 lines to 625 lines. It is uncertain whether the improvement noticed on a closed circuit between transmitter and receiver will be maintained under conditions of space propagation and one of the objects of the tests is, presumably, to check this doubt.

In order that a television picture shall maintain the original quality delivered from the camera it is essential to retain, throughout the entire transmitting and receiving system, the correct amplitude and phase relation of each picture element in relation to the next. The manner in which this is achieved is within the control of the circuit designer, but he cannot control the vagaries of propagation. True, a line-of-sight experiment over an open space, free from any sources of reflection, will closely simulate closed-circuit conditions but would take no account of the practical conditions of terrain variations, built-up areas, and isolated structures involved in providing a public service.

In considering the radiation of electromagnetic energy from an aerial it is desirable to regard the aerial as a point source. The energy will spread out into space and flow through a hemispherical boundary of ever-increasing radius. At a radius of a few hundred wavelengths a small area of this hemispherical boundary can be regarded as being perfectly flat so that all the energy flowing through any selected small aperture in space is in equiphase and plane-wave propagation prevails. Departure from plane-wave conditions is caused by adverse effects which worsen as the frequency of the wave energy is increased. At low frequencies, say 100kc/s, the earth appears as a mirror-like surface. If the wave were endowed with human faculties it would be unable to recognize anything smaller than the high mountains. Trees, buildings and hills would be invisible and so, apart from a slight tilt imparted to the wavefront by virtue of energy absorption by the resistance of the earth, plane-wave propagation is preserved over considerable distances in daytime. At night-time the effect of reflections from the ionosphere vitiates the conditions.

As the frequency is increased the earth no longer retains its mirror-like properties and at, say, 1Mc/s hills and large structures are becoming visible in varying degrees. At frequencies of the order of 100Mc/s small structures and trees become visible

until, at several hundred megacycles per second, the fine detail of structures and the foliage of trees are clearly outlined.

This "visibility," increasing as it does with frequency, is responsible for such effects as absorption, reflection and diffraction, and their combined effects tend to diffuse the wavefront of the energy and so disturb the equiphased front originally radiated from the transmitting aerial. Thus the relative phase and amplitude of the picture elements transmitted in the sidebands will be disturbed and loss of definition will result. Multi-path propagation produces displaced images (ghosts) and it is now well known that these tend to be worse on Band III than on Band I and may be expected to deteriorate further with a threefold increase in frequency.

At first thought it might seem that little can be done to correct for these effects but a directive receiving aerial will reject most of the multi-path reflections since it is known that the more serious reflections emanate from objects at the side and rear of the aerial.

The effects of departure from plane-wave conditions can be minimized by using as

small an area as possible for the aerial consistent with providing useful gain. For example, a pair of half-wave dipoles spaced several wavelengths apart and fed in phase to the receiver might show loss of both gain and definition as compared with the same arrangement spaced at one half wavelength. As a somewhat crude analogy, if one wishes to view a distant object through a small gap in the foliage of a tree a wider spacing of the eyes could result in only one eye being able to see the object with consequent impairment of brightness and detail. Because an aerial will possess different characteristics when operating under diffused-wavefront conditions it is customary to refer to the plane-wave characteristics as being under the ideal conditions.

If a radiating oscillator is set up some fifty wavelengths from a receiving aerial on flat ground quite clear of buildings and obstructions the gain and directivity of any experimental aerial may be compared with that of a simple half-wave dipole. If the oscillator is replaced by a powerful transmitter beyond the horizon, and the tests are repeated in a built-up area, lower gain and a change in the directional characteristics of the experimental model invariably result. The change in gain is due to departure from plane-wave propagation, and the change in directivity to reflections from buildings and other reflecting objects.

This accounts for the fact that certain types of aerial do not appear to live up to their plane-wave performance in some fringe areas while others, with

*Radio and electronic consultant.

BY
F. R. W. STRAFFORD*
M.I.E.E.

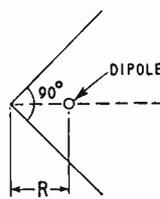
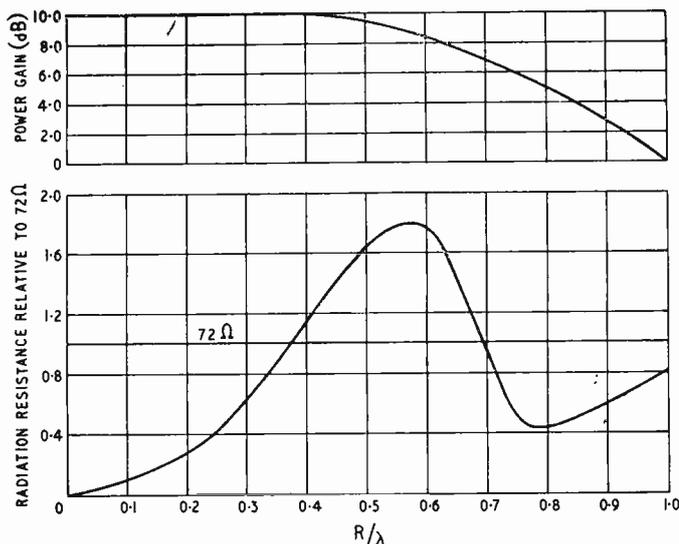


Fig. 1. Variation with spacing (R) of radiation resistance and gain for a corner reflector aerial.

ally favourable sites close to the transmitter. Aerials unsuitable for the above reason, together with their inability to function correctly under diffused-wave conditions, will include H and Yagi types, and the small loop. Rhombic and other long wire aerials, are omitted on account of their length relative to the plane-wave gain achieved, and the need for resistive termination at the remote end for one-way directivity. The slot aerial, plus a sheet or mesh reflector, might be considered if it were not for the fact that its terminal impedance—of the order of 300 ohms—did not

inferior plane-wave characteristics, are the better performers!

A further requirement of a suitable aerial is that it will maintain its gain and directivity, not only over the sideband frequency range, but throughout the whole band allocated to the service. Finally, there should be no serious mismatch of impedance between the aerial and its feeder. A reasonable standard would be a mismatch of not greater than two to one.

Before reviewing aerials in terms of satisfying the foregoing requirements for Bands IV and V an examination of the table will be helpful.

Band	Coverage (Mc/s)	Mid-frequency (Mc/s)	$\pm\%$ deviation
I	41—68	54.5	25
III	174—216	195	10
IV	470—585	527.5	11
V	610—960	785	22

The widest deviation occurs on Band I where experience has proved that H and Yagi type aerials employing parasitic elements must be optimized dimensionally for each channel.

On Band III it is just possible to maintain good characteristics over two neighbouring channels. With some compromise three channels may be covered, but, ideally, the Yagi type of aerial is really only suitable for a single channel if full use is to be made of its properties. Such an aerial, if optimized on a single channel, might reverse its directivity in some part of the band.

These arguments apply equally to Bands IV and V, but there is a further fact which tends to make the Yagi type of aerial unsuitable for these elevated frequencies, and that is the dependence on plane-wave conditions for obtaining useful gain and directivity. Since the present tests are radiated with horizontal polarization there is good reason to assume that any future service will be based thereon so that consideration of possible aerials will be based on this assumption.

As a general consideration u.h.f. aerials with a gain of less than 3dB and front-to-back ratio of less than 6dB should be discarded except for exception-

ally favourable sites close to the transmitter. Aerials unsuitable for the above reason, together with their inability to function correctly under diffused-wave conditions, will include H and Yagi types, and the small loop. Rhombic and other long wire aerials, are omitted on account of their length relative to the plane-wave gain achieved, and the need for resistive termination at the remote end for one-way directivity. The slot aerial, plus a sheet or mesh reflector, might be considered if it were not for the fact that its terminal impedance—of the order of 300 ohms—did not

need transforming to the 75-ohm coaxial feeder which has now become the general standard. The frequency selectivity introduced by the impedance transformer restricts its original broadband characteristics. The helical aerial¹ has excellent gain and directivity for its compactness but it is equally responsive to both vertical and horizontal polarization and a pair, oppositely wound, must be used to receive one plane of polarization only. Such an aerial would present packaging problems if mass-produced, but there is no real technical argument against its use as it has all the desirable characteristics including that of broadband.

This leaves the corner reflector aerial^{2,3} in which is located a half-wave dipole at a point R from the apex. (Fig. 1.) If the angle of the reflecting sheets is 90° the interesting characteristics of Fig. 1 are

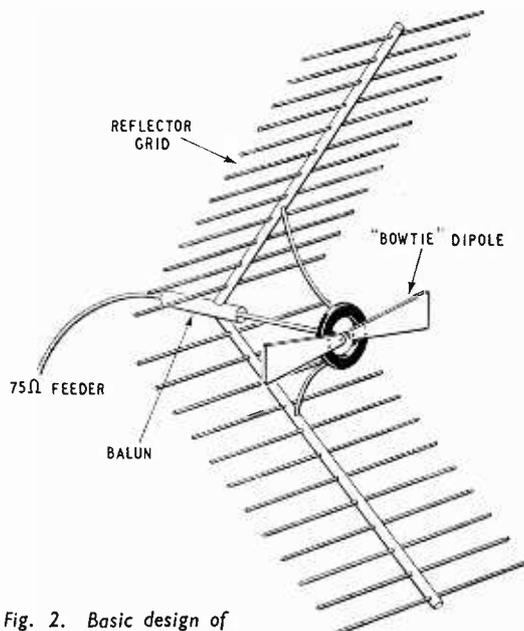


Fig. 2. Basic design of a corner reflector aerial.

obtained. These are for infinite sheets but it has been shown that sheets³ one wavelength wide and two wavelengths long give results surprisingly close to the ideal. In fact, the dimensions may be reduced further without serious loss of performance. It will be observed that, up to $R=\lambda/2$, the radiation resistance rises from zero through 72 ohms up to 120 ohms. From $R=\lambda/4$ to $R=\lambda/2$ the mismatch to a 75-ohm feeder will not exceed 1.6 to 1, so that if the dipole is located at $R=3\lambda/8$ good matching will be maintained over a frequency deviation of plus or minus 33%. Also Fig. 1 shows that the gain will be closely maintained over this range of deviation from the design frequency. These characteristics are ideally suited to Bands IV and V because relatively compact and simple mechanical structures, without dependence on close-limit manufacturing tolerances, can be readily achieved. It is a pity that the corner reflector becomes rather unmanageable, on account of size, on Band III, and quite impossible, for both size and economy, on Band I, for it possesses all the desirable properties of a first-class general-purpose aerial.

The practical construction of the corner-reflector aerial permits of considerable latitude in the hands of the designer. The reflector may be of sheet, continuous, or perforated to reduce windage, or wire mesh may be used provided that the size of the mesh does not exceed about 0.1λ . According to Moullin³ the screening or reflecting properties of a conductive mesh are at least 90% as good as a continuous sheet of the same material. Kraus² has shown that a row of rods may be used to make a corner reflector grid, and if these are spaced not much greater than 0.1λ a very convenient and attractive aerial results. Such an aerial was constructed about a design frequency of 654.25Mc/s as shown in the sketch of Fig. 2. The overall dimensions of each reflector grid are 10in wide by 18in long.

A "bow-tie" type of dipole is used as it has the required broadband characteristics. Fat cylinders could be used instead but they do not give a smooth impedance transfer at the feeder connections. Measured data of this type of aerial, taken under carefully controlled plane-wave conditions, gave the following results:—

1. Power gain relative to half-wave dipole, 8.7dB.
2. Half-power beam width, 64° .
3. Front-to-back ratio, 15dB.
4. Minima in excess of 40dB, at 90° , 140° , 220° , and 270° .
5. Mismatch ratio to 75-ohm feeder, 1.4.

These characteristics varied very slightly over a range of ± 30 Mc/s. It was not possible to extend the measurements over the whole of Band V, but the results indicate that the performance is most likely to be maintained, and this is a matter for further experiment. A simple quarter-wave balun was included in the design but its removal during the course of tests did not appear to have much

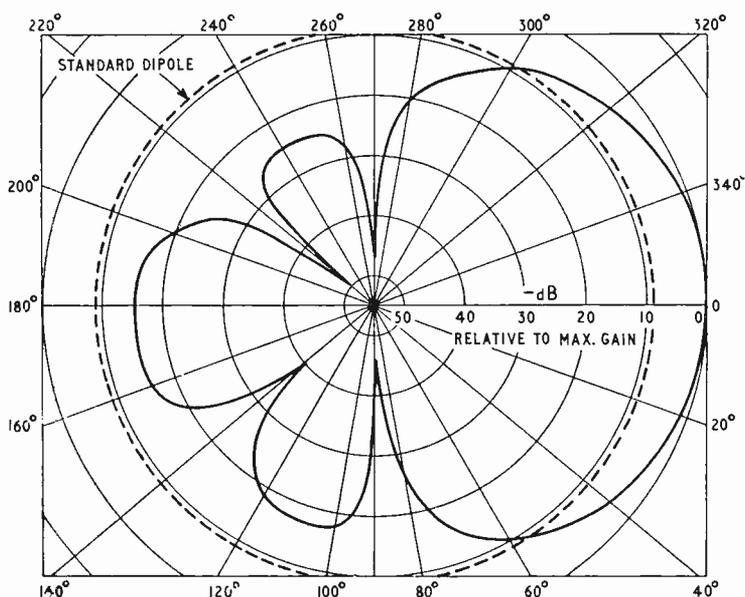


Fig. 3. Polar diagram of the corner reflector aerial.

effect. If much larger reflectors had been used, with a consequent increase in front-to-back ratio, the balun would probably prove an advantage, since it reduces the effects of pickup on the feeder which shows up as a reduction in the overall front-to-back ratio.

The directional response in the azimuthal (E) plane is shown in the polar plot of Fig. 3. Plotted in decibels it gives the *false impression* of poor directivity because of the size of the side and rear lobes. Had this diagram been plotted in voltage ratios, or better still, in voltage squared (power) ratios, the amplitude of the rear lobes, relative to the main lobe, would *appear* to show improved directivity. An examination of the diagram will reveal that, over the rear 180° of the aerial, the response is never less than 15dB below that of the main beam. As an integrated effect it probably averages 25dB below the main lobe.

It might be a good idea to standardize the amplitude scale of a polar co-ordinate graph say, in five steps of 10dB with 50dB coinciding with the centre of the chart and 0dB on the circumference. The *appearance* of the curve would then line up with the degree of directivity found between samples.

A pair of these aerials may be mounted side by side a little over a half-wavelength between centres. Provided that the respective outputs are connected in phase the gain will be increased by 3dB and the half-power beam width reduced to about 55° .

It is hoped to publish the results of practical tests with this aerial on the B.B.C.'s transmissions after both standards of definition have been used.

Acknowledgement. This article is based on work done on behalf of Kimber-Allen, Ltd., to whom thanks are due.

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BAND V ON A TURRET TUNER

ADAPTING AN EXISTING BAND I — BAND III FRONT END FOR U.H.F. TELEVISION

BY P. R. STUTZ*, B.Sc. (Eng.) Hons., A.C.G.I., Grad. I.E.E.

WHEN the decision was taken to begin television test transmissions in Band V at a vision carrier frequency of 654.25 Mc/s, the problem arose of providing television sets capable of receiving these signals.

The type of receiver which has been adapted for u.h.f. reception uses the well-known turret tuner for channels in Bands I and III. The r.f. stage of this tuner is a double triode connected as a cascode amplifier which is followed by a triode-pentode frequency changer. A separate set of coils is used for each channel, mounted in a twelve-position turret.

In order to receive the u.h.f. transmissions, special coil strips or inserts are mounted in the turret†. To obtain satisfactory results these inserts use the double superhet principle. This necessitates a rather more complex insert than the type used on the lower frequencies of existing television channels in this country. A schematic arrangement of the u.h.f. inserts is shown in Fig. 1.

The incoming u.h.f. signal is first frequency con-

verted to an intermediate frequency lying in the 135-Mc/s region using a u.h.f. germanium diode mixer. This signal is amplified by the cascode valve in the tuner. The signal is then frequency converted again, using the pentode mixer, to the normal 34.65-Mc/s vision intermediate frequency of the receiver. A harmonic of the triode local oscillator is used for the first frequency-changing operation and the fundamental for the second frequency conversion. For this particular channel, the third harmonic of the local oscillator is used: this harmonic is generated by a germanium diode from the fundamental and is selected by a resonant circuit.

As a result of using a harmonic selector circuit, the mixing diode obtains a local oscillator voltage with the unwanted harmonics and the fundamental reduced to a minimum. This ensures that a good noise factor is obtained and reduces unwanted responses.

The circuit diagram of the inserts is given in Fig. 2. The aerial input is for a 75-ohm unbalanced feeder, the same as is used on Bands I and III. The feeder is matched into the primary of a mutually coupled band-pass circuit tuned to the u.h.f. channel fre-

*Kolster-Brandes.

†The units are of American design and have been modified to 75-ohm aerial input and to suit the frequency of the test transmission.

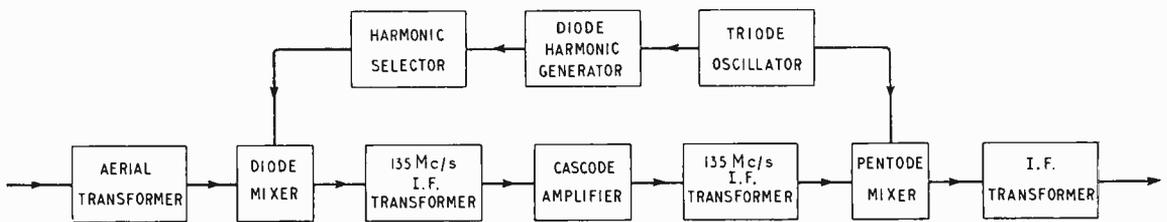


Fig. 1. Block schematic of the u.h.f. inserts for the tuner.

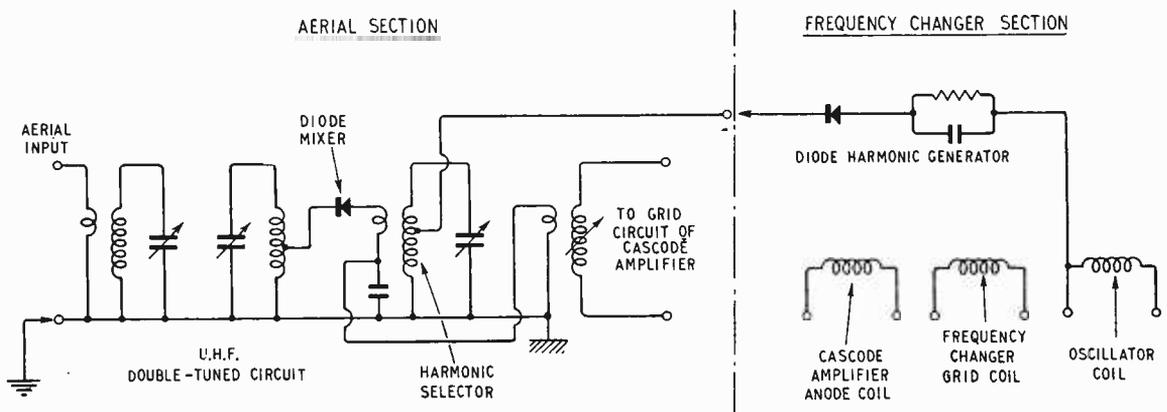
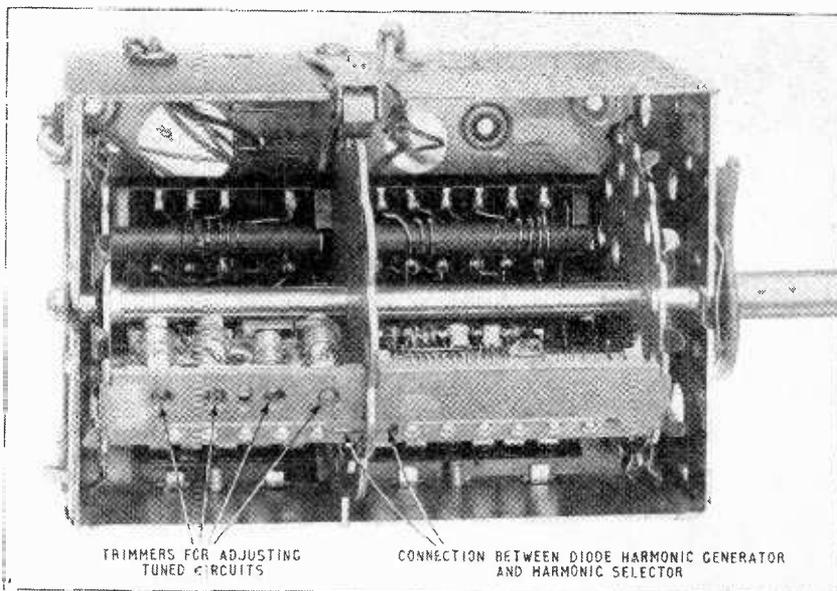


Fig. 2. Circuit diagrams of the two u.h.f. inserts.

quency. The output is matched into the diode mixer by means of a tap on the secondary tuned circuit. The i.f. output from the diode mixer is coupled into the grid circuit of the cascode amplifier using an impedance-matching transformer tuned to 135 Mc/s. The diode used for obtaining the third harmonic of the triode oscillator is connected to one side of the local oscillator winding via a biasing network. As this diode is mounted on the frequency-changer section and its output has to be fed to the harmonic selector on the aerial section, a special link is required between the two sections of the u.h.f. inserts. This link between the two sections can be seen on the photograph of the inserts in position in the turret tuner. On the frequency-changer section, there is the coil connected in the anode circuit of the cascode amplifier which, together with the other coil connected to the grid of the pentode mixer, forms a band-pass coupled circuit tuned to a centre frequency of about 135 Mc/s. The local oscillator coil on this frequency-changer



An existing tuner with the u.h.f. inserts in position on the turret.

probably the noise factor. This type of unit was found capable of a noise factor of about 17dB; this figure compares quite well with other types of tuner which do not use a stage of u.h.f. amplification before the mixer diode.

The overall selectivity of the arrangement is quite adequate, as can be seen from the curve of

Responses from an insert tuned to 654.25 Mc/s vision.

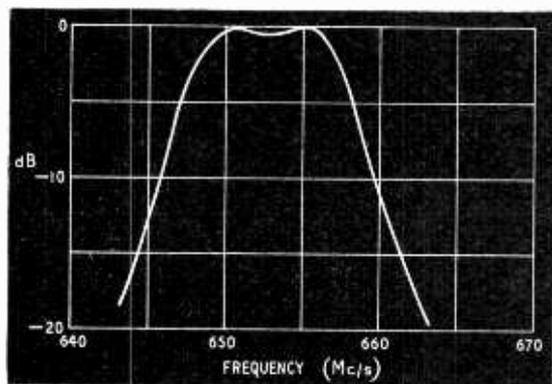


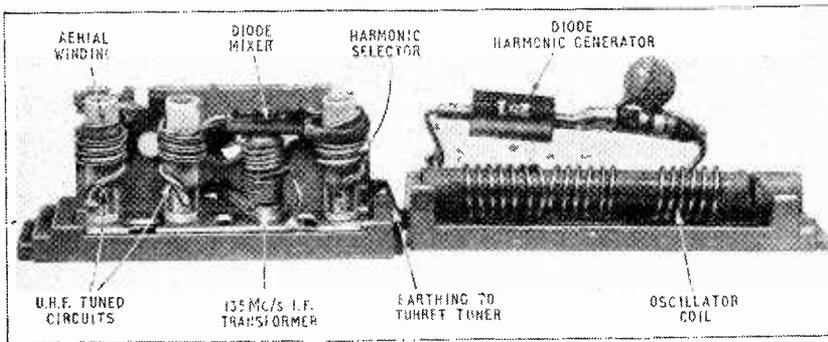
Fig. 3. Frequency response of the u.h.f. tuner, measured from the aerial input to the pentode mixer stage.

Oscillator Harmonic (Mc/s)	Vision Frequency (Mc/s)	Sound Frequency (Mc/s)	Measured Amount Down on Required Response (dB)	Comments
	137.575	134.075	28	1st i.f.
Fundamental 172.225	34.65 309.8	38.15 306.3	65 53	Final i.f.
2nd harmonic 344.450	206.875 482.025	210.375 478.525	63 35	
3rd harmonic 516.675	379.100 654.250	382.60 650.750	40 0	Required channel.
4th harmonic 688.90	551.325 826.475	554.825 822.975	38 46	
5th harmonic 861.125	723.550 998.700	727.050 995.200	49 55	
6th harmonic 1033.350	895.775 1170.925	899.275 1167.425	45 Not measured.	

section is designed for a fundamental frequency of 172.225 Mc/s.

The circuits on the aerial section are tuned by means of the trimmers shown in the photograph. The coils on the frequency-changer section are tuned by adjustment of the end turns, except for the local oscillator coil which has a brass core accessible from the front of the tuner, in the same manner as with the coil strips for the existing television channels. Constructional details of the inserts can be seen in another photograph on the next page.

In assessing the performance of these u.h.f. inserts, one of the more important considerations is



Showing the construction of the two u.h.f. inserts and how they are linked together when on the turret.

Fig. 3. Unwanted responses due to oscillator harmonics are sufficiently down on the main response to be considered negligible, as can be seen from the measurements given in the table. Rejection at the 135-Mc/s i.f. is sufficient for all normal purposes. The value of the rejection seems to be controlled by stray coupling from the aerial input to the cascode amplifier grid.

It is thought that with future units it may be possible to improve this figure if necessary, as the layout of the units used was originally intended for a 300-ohm balanced aerial input.

The voltage gain of a tuner using these u.h.f. inserts is somewhat less than that of the same tuner working on Bands I and III, owing to the loss of gain in the aerial section. The difference in gain of the tuner between Band V and Band III will be about 10dB.

The stability of the local oscillator is obviously important for convenience of operation. The drift was found to be about three times greater than that experienced on Band III, but was found in practice to be tolerable.

The range of the fine tuner control is about three times greater than that on Band III channels but, despite this, it was found perfectly simple to tune in the picture on a receiver.

The considerations leading up to the choice of 135 Mc/s as the first i.f. have not yet been men-

tioned. Owing to the fact that the triode local oscillator is used for both frequency - changing operations, there is a relationship between the oscillator harmonic chosen and the first i.f. Also, to avoid reversing the relative positions of the sound and vision carriers, the first frequency conversion must be done with the local oscillator low. This leads to:

$$f_o = f_{if(1)} + f_{if(2)}$$

$$f_o = \frac{f_{uhf} + f_{if(2)}}{N + 1}$$

where f_{uhf} = frequency of Band-V channel

f_o = oscillator fundamental frequency

N = harmonic of the oscillator used

$f_{if(1)}$ = the first i.f.

$f_{if(2)}$ = the second i.f. (34.65 Mc/s vision)

It was considered desirable that the frequency of the local oscillator fundamental and the first i.f. should be chosen so that they were located between Bands I and III and cleared the band allocated to v.h.f. radio transmissions. This led automatically to the choice of the third harmonic of the local oscillator for this particular channel and a value of 135 Mc/s for the first i.f.

A small practical point worth mentioning is the care that had to be exercised in the choice of mains isolating components for the aerial feeder. If this is not done and unsuitable values and layouts are chosen, the noise factor and sensitivity of the receiver will be impaired.

The performance of the u.h.f. inserts on the test transmissions came fully up to expectations, the pictures obtained being free from any unwanted beats or patterning. In practice these inserts were fitted to an unused channel position in the turret, thus leaving the receiver free to receive the normal transmissions in Bands I and III as well as the u.h.f. transmissions.

Books Received

The B.B.C. Riverside Television Studios: The Architectural Aspects, by E. A. Fowler. B.B.C. Engineering Monograph No. 13 includes an appendix on the sound proofing, and the acoustic treatment used to secure the optimum reverberation time. Pp. 25; Figs. 10.

The B.B.C. Riverside Television Studios: Some Aspects of Technical Planning and Equipment, by H. C. Nickels and D. M. B. Grubb. B.B.C. Engineering Monograph No. 14 includes description of television and sound studio and distribution apparatus and also telecine equipment. Pp. 32, Figs. 18. The above B.B.C. Engineering Monographs are each priced 5s and may be obtained from B.B.C. Publications, 35, Marylebone High Street, London, W.1.

Glossary of Abbreviations, compiled by S. T. Cope, covers names of technical, scientific, industrial and professional organizations, with particular reference to the

telecommunications industry. Pp. 38. Price 2s 6d. Marconi's Wireless Telegraph Co., Ltd., Baddow Research Laboratories, West Hanningfield Road, Great Baddow, Essex.

Electronic Voltage Stabilizers for Laboratories, Computers and Control Systems, by J. Miedzinski, B.Sc., and S. J. Zgorski, describes series valve stabilizer with twin-triode amplifier and gas discharge voltage reference tube to give up to 50 mA at 320 or 400V. Pp. 19; Figs. 8. Price 12s 6d. Electrical Research Association, Thorncroft Manor, Dorking Road, Leatherhead, Surrey.

The "Mercury" Switched F.M. Tuner, by G. Blundell, gives description and constructional details for a new Jason circuit incorporating a.f.c. and a Foster-Seeley discriminator. Pp. 20, Figs. 9. Price 2s. Data Publications, Ltd., 57, Maida Vale, London, W.9.

Some Special Magnetrons

—AND HOW THEY ILLUSTRATE BASIC IDEAS

THE magnetron consists essentially of an anode and cathode which are concentric cylinders. The anode has a number of subdivisions, usually referred to as segments, in which high-frequency oscillations can be produced. These segments generally take the form of resonant cavities so that oscillations are essentially only possible at a number of discrete frequencies. Power from the oscillations is generally coupled out from a single segment, a wide variety of methods being used.

The cathode is at a high negative d.c. potential relative to the anode. A powerful magnetic field in the direction of the anode and cathode axis prevents more than a small proportion of the electrons emitted from the cathode from reaching the anode under static conditions, most of them being returned to the cathode.

Under dynamic conditions, the r.f. field produced by the oscillations gives energy to electrons whose

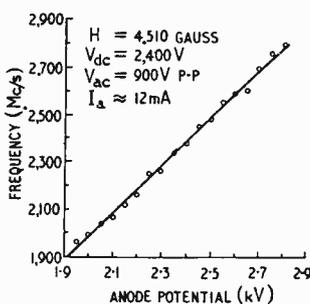


Fig. 1. Linearity of tuning in voltage tunable magnetron.

phase with respect to this field is favourable. This enables them to reach the anode where they give up their potential energy to sustain the oscillations. The field also produces a "bunching" effect¹, or in other words tends to concentrate electrons as they proceed to the anode into groups with a favourable phase. Those electrons for which

this does not occur soon return to the cathode, and bombarding it, increase its temperature.

The anode segments generally have a constant phase difference between individuals. This phase difference may be thought of as being produced by r.f. waves travelling round the anode, when the phase change in distance round the anode will be related to the phase change in time of the travelling r.f. wave.

We can thus draw a useful analogy with the travelling wave tube¹. The magnetic field (by the left-hand rule) imparts an angular motion to the electrons about the anode and cathode axis. This motion will not be essentially modified by the r.f. fields, and the electrons will stream past the anode segments either individually or in bunches as they approach. By analogy with the travelling wave tube we will expect maximum interaction to occur when the electron bunches and r.f. waves have the same velocity.

Relationships between Operating Parameters.—

The need for this equality between the velocities of the electron bunches and r.f. waves gives a relationship between the operating voltage, magnetic field, and

frequency. The frequency is also usually largely fixed by the resonant properties of the anode segments.

By adopting certain simplifying assumptions it is possible to obtain this relationship in a quantitative form which is close to that obtained by more sophisticated methods.

The electrons can be assumed to leave the cathode with zero velocity and to proceed towards the anode under the influence of the static electric and magnetic fields only, until the r.f. field becomes significant. Here, for optimum interaction, the angular velocity round the anode of the electrons and the r.f. field must be the same. We then assume that from here outwards the electrons become "locked" to the r.f. wave, so that their angular velocity remains constant until they reach the anode².

When the r.f. field is negligible, the electric field will be entirely in a radial direction. The angular equation of motion for an electron of mass m and charge e may then be written

$$\frac{m}{r} \frac{d}{dt} \left(r^2 \frac{d\theta}{dt} \right) = eH \frac{dr}{dt} \dots \dots \dots (1)$$

Integrating this equation we obtain

$$r^2 \frac{d\theta}{dt} = \frac{eH}{2m} (r^2 - r_c^2) \dots \dots \dots (2)$$

where r_c is the cathode radius, and the constant of integration is obtained by putting $d\theta/dt=0$ at $r=r_c$. If r_1 is the radius at which the electrons become locked to the r.f. wave, equation (2) gives the corresponding angular velocity ω , as

$$\omega = \frac{eH}{2m} (1 - r_c^2/r_1^2) \dots \dots \dots (3)$$

It is reasonable to assume that when oscillations are only just sustained the energy fed into the electrons is as small as possible. If this is the case nearly all of the energy will be used to keep the electrons in a circular orbit locked to the r.f. wave, and there will be only a small amount left to provide radial motion. Thus we can neglect the rate of change of the radial component of velocity. The radial equation of motion can then be written as

$$-mr \left(\frac{d\theta}{dt} \right)^2 = eE_r - Her \frac{d\theta}{dt} \dots \dots \dots (4)$$

where E_r is the radial field. Integrating this equation from $r=r_1$ to $r=r_a$ (where r_a is the anode radius), and remembering our assumptions that $d\theta/dt=\omega_1$, and that radial r.f. fields are negligible we obtain

$$e(V - V_1) = (He\omega_1 - m\omega_1^2) \left(\frac{r_a^2 - r_1^2}{2} \right) \dots \dots \dots (5)$$

where V_1 is the voltage at r_1 . V_1 can be obtained very simply from the conservation of energy since we are assuming that r.f. fields are negligible inside r_1 .

¹ This type of approach is developed in greater detail in H. W. Welch, Jr., and W. G. Dow, "Analysis of Synchronous Conditions in Cylindrical Magnetron Space Charge" *Jour. Appl. Phys.*, vol. 22, April 1951, p. 133

¹ "Cathode Ray," "Valves for Microwaves," *Wireless World* vol. 43, September 1953, p. 417, and October 1953, p. 482

Thus, equating the potential energy lost to the kinetic energy gained, we obtain

$$eV_1 = \frac{1}{2}mr_1^2\omega_1^2 \quad \dots \quad (6)$$

Substituting equation (6) in equation (5) to eliminate V_1 , and then using equation (3) to eliminate r_1 , we obtain

$$2V = H\omega_1(r_a^2 - r_c^2) - \omega_1^2 r_a^2 m/e \quad \dots \quad (7)$$

Finally, we must obtain a relation between ω_1 and f the oscillation frequency. In the idealised case where the r.f. field has a simple sine wave variation both in angle and time, the r.f. potential at a point between anode and cathode can be written

$$V_{r,f} = V_{r,f}(r) \cos 2\pi n \theta \cos 2\pi ft \quad \dots \quad (8)$$

where $V_{r,f}(r)$ is a function of r only, and n the number of repeats of the field pattern round the anode. Since the magnetron anode is closed upon itself (unlike the newer backward wave oscillators³) n must be a whole number. (This restriction on n is one of the reasons why the magnetron can only oscillate at certain frequencies.) Equation (8) can then be rewritten as

$$V_{r,f} = \frac{V_{r,f}(r)}{2} [\cos 2\pi(n\theta + ft) + \cos 2\pi(n\theta - ft)] \quad (9)$$

which represents two progressive waves travelling round the anode in opposite directions with angular velocity $2\pi f/n$. Actually the angular variation of the r.f. field is more nearly a set of square pulses whose steps occur at the discontinuities in the anode produced by the segments (see for example Fig. 6). This was discussed in detail by Hartree⁴, who showed that there were a number of other possible angular velocities for the r.f. waves. These are of the form $2\pi f/(kN \pm n)$ where k is a positive integer and N the number of segments. Substituting this set of values for ω_1 in equation (7) we obtain finally

$$V = \frac{\pi f H}{kN \pm n} (r_a^2 - r_c^2) - \frac{2\pi f^2 r_a^2 m}{(kN \pm n)^2 e} \quad \dots \quad (10)$$

This is, in fact, the well-known Hartree threshold relationship⁴, and is generally confirmed in practice to within a few per cent.

Voltage Tunable Magnetrons.—It has been mentioned that anode structure resonances usually restrict oscillation to a number of discreet frequencies. Other types of microwave oscillator, such as the backward wave oscillator³, have been developed to avoid this restriction. It is not however a fundamental limitation of the magnetron, and non-resonant anode structures have also been used to obtain wide-band operation.

If we refer to equation (10) it can be seen that, when there are no other restrictions, for a given mode of oscillation (i.e. a given k, n), the frequency is determined only by the voltage and the magnetic field. The field cannot be varied conveniently, so that in such magnetrons the frequency is varied by varying the voltage. For a sufficiently large magnetic field H , equation (10) moreover shows us that the frequency will be proportional to the voltage, and

a fuller analysis⁵ confirms this. This is a very useful characteristic, for example, in obtaining undistorted frequency modulation. In practice a "sufficiently large" field in this context is not particularly high compared with usual magnetron fields.

To avoid resonances a structure consisting of two sets of interlocking fingers (interdigital) has generally been used. In this case all major frequency sensitive elements except the capacity between the two sets of fingers are removed from the interior of the valve; and the exterior cavity can more easily be made non-resonant. For example, this type of structure lends itself to direct mounting in waveguide, the fingers lying across the narrow dimension. In this arrangement ideally the guide only imposes its cut-off property in the valve.

A description of such a magnetron is given in a paper by J. A. Boyd⁶, of Michigan University. Fig. 1, taken from this paper, shows the linearity of the voltage-frequency relationship.

The power output of such magnetrons is very dependent on the total shunt impedance of the r.f. circuit, and this should be as high as possible. Here a limiting factor is the capacity between the two sets of fingers. Boyd used rounded digits in order to reduce this capacity as much as possible. Another model of similar structure, but with this capacity doubled, showed a greatly inferior performance.

As regards the external circuit, it is difficult to give this a high shunt impedance over a wide band. Thus a compromise must be made between power output and band-width. Boyd was able to obtain powers of the order of half a watt over 2,000 Mc/s, or four watts over 200 Mc/s.

Boyd also found that in order to produce coherent oscillations it was necessary to limit the anode current by keeping the cathode temperature low. This disagrees with some other observations of voltage tuning using a different structure discussed later. Such temperature limitation is, however, certainly useful in keeping the anode current, and thus the output power, approximately constant. The extent to which this can be achieved in Boyd's valve is shown in Fig. 2 (also taken from reference (6)). Boyd found that in c.w. operation, owing to variations in the electron bombardment of the cathode, temperature limitation could not be obtained unless a directly heated cathode was used. The total cathode heating power required is greater for such a cathode so that the bombardment is a smaller fraction of this power.

When there are no powerful frequency determining elements noisy operation is likely. However

⁶ J. A. Boyd, "The Mitron—An Interdigital Voltage Tunable Magnetron," *Proc. I.R.E.*, vol. 43, March 1955, p. 332.

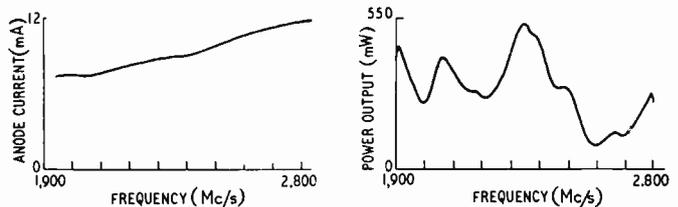


Fig. 2. Constancy of anode current and output power with temperature limited emission.

³ See for example, R. Warnecke and P. Guenard, "Some recent Work in France on New Types of Valves for the Highest Radio Frequencies," *Proc. I.E.E.*, vol. 100, Part III, Nov. 1953, p. 351.

⁴ D. R. Hartree, "Mode Selection in a Magnetron by a Modified Resonance Criterion," *C.V.D. Report*, Mag. 17.

⁵ H. W. Welch, Jr., "Prediction of Travelling Wave Magnetron Frequency Characteristics: Frequency Pushing and Voltage Tuning," *Proc. I.R.E.*, vol. 41, Nov. 1953, p. 1631.

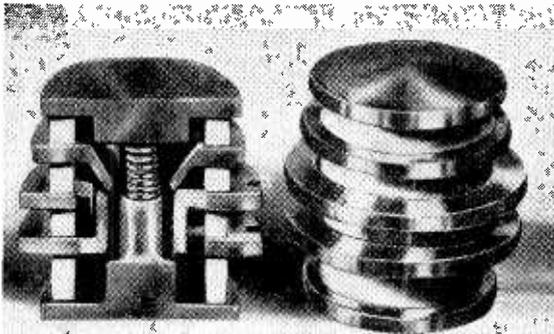


Fig. 3. G.E. Company of America voltage tunable magnetron.

when used as a local oscillator Boyd's valve had a noise figure only $\approx 3\text{dB}$ worse than a klystron.

In normal magnetrons the r.f. field is at right-angles to the cathode axis, from one cavity to the next. In interdigital valves, however, this field is parallel to the cathode axis from one set of fingers to the other. Because of this asymmetry of the cathode with respect to the r.f. field resonance and electronic interaction effects due to the cathode structure are more serious and difficult to avoid in interdigital valves.

A version of this type of magnetron only about half an inch long has been developed by the G.E. Company of America⁷, and is shown in Fig. 3 reproduced from page 244 of *Electronics* for October 1956. The spiral cathode is offset from the interaction space. This is possibly to reduce the effects due to the cathode discussed above. This offsetting would also decrease the electron bombardment which was troublesome in the Michigan valve. The extra, shaped, electrode may help to focus the emitted electrons into the interaction space.

Scaling.—The remaining two types of magnetron we shall discuss were developed to produce the highest frequencies.

In considering these magnetrons it is necessary to elaborate the Hartree threshold relationship a little. We have not introduced the fact that there will be a minimum voltage at which a magnetron can oscillate. This is that voltage for which electrons at the anode have just given up all their potential energy in order to attain the angular velocity of the r.f. field with which they are interacting, so that no energy is left to build up oscillations. The minimum voltage is also that voltage at which, under static conditions, the electron orbits just graze the anode, so that the r.f. field necessary for them to reach the anode can be vanishingly small. From the first definition, the minimum voltage V_o is given immediately by

$$eV_o = \frac{1}{2} m r_a^2 \omega_1^2 \quad \dots \quad (11)$$

$$\text{i.e. } eV_o = \frac{2\pi^2 m r_a^2 f^2}{(kN \pm n)^2} \quad \dots \quad (12)$$

The first definition of V_o also gives an immediate upper limit for the efficiency. To give output, only the potential energy from the d.c. field is useful, the kinetic energy being wasted. Thus, considering a single electron, the efficiency will be at most

one minus the minimum possible kinetic energy at the anode divided by the potential energy obtained from the d.c. field,

$$\text{i.e. } \eta \leq 1 - V_o/V \quad \dots \quad (13)$$

Remembering that there will be further losses in the output circuit, it is thus usual to operate at several times the minimum voltage.

Another useful concept which follows rapidly from the definition of V_o is that of "scaling." If we substitute V_o for V in the Hartree threshold relationship (equation (10)) we can obtain a corresponding value H_o for H . Equation (10) then reduces to the simple form

$$V/V_o = 2H/H_o - 1 \quad \dots \quad (14)$$

Of the most fundamental conditions of operation only the anode current requires a corresponding I_o to be defined. Several such definitions have, in fact, been proposed. The simplest is that current which would be drawn at zero magnetic field when the magnetron is acting simply as a diode, although this is much greater than any operating current so that it does not correspond to any minimum. I_o is then given by the relation

$$I_o = \frac{8\sqrt{2}}{9} \pi \sqrt{e/m} \frac{V_o^{3/2} l}{r_a} \quad \dots \quad (15)^8$$

where l is the anode length,

$$\beta = u - \frac{2u^2}{5} + \frac{11u^3}{120} - \frac{47u^4}{3300} + \dots,$$

$$\text{and } u = \log_e \left(\frac{r_a}{r_c} \right).$$

Since the early days of magnetron development much use has been made of the fact that if, using I_o , V_o , H_o as units, we operate under the same conditions, then the efficiency and stability are similar for *different* designs of magnetron, provided that the anode segments remain of similar shape. In this way by altering the size of a successful design it can be "scaled" to work at a different wavelength.

Minimum Voltage Magnetrons.—Returning to our immediate problem, from equation (12) we can see that if we wish to obtain higher frequencies we must either reduce r_a , increase V_o , or increase $(kN \pm n)$. We will consider the third possibility later. As regards the other two possibilities, it is clear that there will be practical limits to decreasing r_a or increasing V . A less obvious consideration which arises in c.w. operation is that the anode power, and hence current, at which oscillations begin must be sufficiently low. This will also in practice limit the maximum voltage and minimum size. Reducing the size of the anode also reduces the possible power dissipation.

Another possibility is to operate nearer the minimum voltage. Looking at this the other way round we can then increase V_o (for a fixed V), and thus increase f . It is however clear from equation (13) that the efficiency will fall.

In the sense that operation remains based on the equalization of velocities we have described, no essential change is produced by working near the minimum voltage. However, the bunching influence of the r.f. field which we have also discussed will

⁷ T. R. Bristol and G. J. Griffin, Jr., "Voltage-Tuned Magnetron for F-M Applications," *Electronics*, May 1957, p. 162.

⁸ I. Langmuir and K. B. Blodgett, "The Effect of Space Charge and Residual Gases on Thermionic Currents in a High Vacuum" *Phys. Rev.* vol. 2, December, 1913, p. 450.

largely disappear, and this leads to considerable practical differences.

It will be necessary to provide the required equality of the electron and r.f. wave velocities as far as possible even in the static case in order to do without the help of the r.f. field. If we return to equation (2) we can see that if r_c the cathode radius is small, then the angular velocity varies only slightly with changing r . In this case we have a stream of electrons at various radii but with the same angular velocity which can interact with an r.f. wave with this velocity.

We can develop this point more exactly when we realise that in such a valve there will be an optimum value for the radius at which velocity equalization occurs. If this is too small, the r.f. fields will be too weak, and little interaction will occur. On the other hand, if this is too large, insufficient interaction can occur before the electrons reach the anode.

Substituting equation (3) in equation (7) to eliminate H , and then using equation (11) to eliminate ω_1 , we obtain the relation

$$\frac{V}{V_0} + 1 = 2 \left[\frac{1 - r_c^2/r_a^2}{1 - r_c^2/r_1^2} \right] \dots \dots (16)$$

We can see that if r_1 is fixed, as V approaches V_0 , r_c must approach zero. This agrees with our earlier general reasoning. When V becomes large r_c tends to r_1 . Thus r_1/r_a can be obtained from a knowledge of the optimum r_c/r_a for normal operation of the magnetron when scaled to operate at some lower frequency. If we wish to operate somewhat above V_0 equation (16) can then give us the optimum r_c/r_a . Conversely, equation (16) suggests that, for a given r_c/r_a , there will be an optimum operating voltage V to establish velocity equalization at r_1 . Thus we can expect operation of this type to occur over a fairly limited range of voltage and thus also of magnetic field.

This limited range of operation was observed in the original G.E.C. work on the subject⁹. When the voltage was varied more than about 10%, operation occurred in a number of "modes" (different n

numbers in equation (10)). This was clearly seen by changes in the oscillation frequency. The different modes will of course have different minimum voltages. They may also have different values for the optimum radius r_1 for velocity equalization, due to the different r.f. field patterns.

These properties of limited range of operation and wide degree of mode selection are quite different from those of normal magnetrons. Here operation is generally in the $n=N/2$ mode (π mode), over a wide range of voltages.

Results obtained at Columbia University Radiation Laboratory, New York¹⁰, using cathodes of different sizes support the general result of equation (16) that the operating voltage approaches the minimum as the cathode size is decreased. These results also suggest that the proportional range of voltage in which operation is possible also decreases as the cathode size is decreased.

In later G.E.C. work¹¹ only the π mode was observed. This could have been due to the use of narrow-band output coupling arrangements: wide-band coaxial coupling was used in the original experiments. At higher anode currents considerable increase in efficiency were obtained, for example, up to $\approx 30\%$ overall in valves operating around $V_0/V = 0.6$. In view of output coupling losses, this must represent nearly the theoretical limit of 40%. There was no sign of any falling off in efficiency for currents up to 0.08 I_0 . A practical feature of this type of operation is that the cathode has to be very accurately centred; any slight off-centring produces a marked fall in efficiency and increase in back-bombardment of the cathode.

Spatial Harmonic Magnetrons.—In our search for higher frequencies we must now return to the other possibility shown by equation (12) we have already mentioned, that of increasing $(kN \pm n)$. Magnetrons are generally designed to operate in the π mode where the phase difference between adjacent resonators is π , and which correspond to $n=N/2$, $k=0$. Modes corresponding to smaller n numbers are well known, but modes with $n > N/2$ (corresponding to harmonics of the individual resonators) have only rarely been observed, and seem unimportant in magnetron operation.¹²

We are thus left with the possibilities of increasing N , the number of resonators, or operating with non-zero values of k . However, if the number of resonators is increased, the relative wavelength separation for the various modes is decreased. Interference between such modes is then more likely. The limit in this direction has already practically been reached in conventional designs.

We must now consider operation with non-zero values of k , that is spatial harmonics of the r.f. pattern round the anode. Early attempts to observe this operation, using values of $(k + \frac{1}{2})N$ of 12 or more and anode diameters greater than 0.1λ were unsuccessful. This is probably because the r.f. field fell off too rapidly from the anode to produce any interaction. An analysis shows that, at least in the absence of space charge, this field is proportional to

(Continued on page 21)

⁹ W. E. Willshaw and R. G. Robertshaw, "The Behaviour of Multiple Circuit Magnetrons in the Neighbourhood of the Critical Anode Voltage," *Proc. Phys. Soc.*, vol. 63, Part B 1950, p. 41.

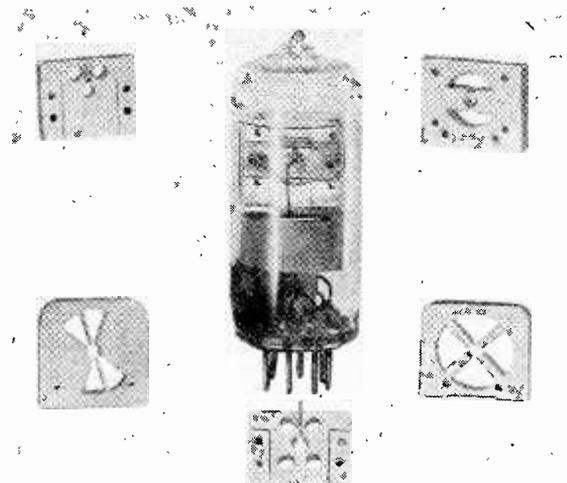


Fig. 4. G.E.C. (British) spatial harmonic magnetron and anodes.

¹⁰ Z. Fraenkel, "The Development of a Tunable CW Magnetron in the K-Band Region", *I. R. E. Trans. E. D.*, Vol. ED-4 No. 3, July 1957, p.271.

¹¹ T. M. Goss, R. G. Robertshaw, J. R. Tew and W. E. Willshaw, "A Review of the Performance of Magnetrons Operating at Low Magnetic Field", *L'Onde Electrique*, Vol. 37, Oct. 1957, p.804

¹² G. B. Collins, "Microwave Magnetrons", McGraw-Hill, p.17.

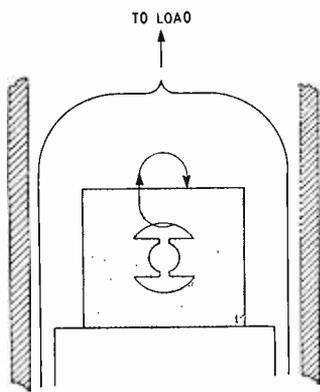


Fig. 5. Magnetic coupling to load in a spatial harmonic magnetron.

$(r/r_a)^{M-1}[1-(r_c/r_a)^{2M}]$ where M is the value of $(kN \pm n)$. Thus the successful G.E.C. workers¹³ were led to the use of anodes of 4 or 2 segments only, with operation with M values around 6.

Although this approach thus does not give an increase in $(kN \pm n)$, it does result in a considerable simplification in the mechanical and electrical structures of the anodes used. Considering, for example, the case where $k = 1$ and $M = 3N/2$,

the form of the spatial harmonic of the r.f. field concerned is the same as that of the r.f. fundamental in a valve with $3N$ segments. In some ways we can consider that we are using a valve with $3N$ segments, but in which $2N$ of them are "missing." In this case the problem of distributing the segments round the anode is considerably eased. Some of the asymmetrical anode structures used very forcibly suggest this idea of missing segments, an example being shown at the top left of Fig. 4. In this case, in fact, there would not be room for the full number of segments (12) round the valve.

Fig. 4 also shows a complete valve for operation at about 9,000 Mc/s, and illustrates the neat construction possible using an ordinary B7G valve base and glass envelope.

The first experiments were made with asymmetrical anode structures. Another example is shown at the

¹³ R. G. Robertshaw and W. E. Willshaw, "Some Properties of Magnetrons Using Spatial Harmonic Operation." I.E.E. Monograph No. 168R. To be published in Part C of *Proc. I.E.E.*

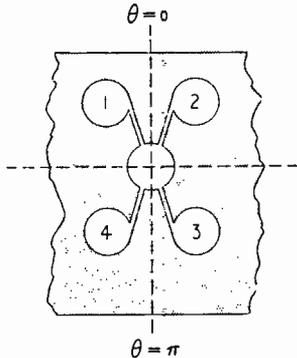


Fig. 6. Typical anode and associated r.f. wave in spatial harmonic magnetron.

bottom of Fig. 4. (This is not to the same scale as the other anodes in Fig. 4.) Unfortunately the results obtained were not very repeatable owing to difficulties in accurately machining the long narrow slots used in the design. Consequently a change was made to symmetrical anode structures of two and four segments as at the right of Fig. 4.

The use of a symmetrical anode structure permits a very simple magnetic coupling to the load by means of the current circulating round one of the cavities as shown in Fig. 5 (taken from reference (12)). In the case of the original asymmetrical anodes this simple coupling is not so easy to obtain. Oscillations in the two adjacent cavities are out of phase so that the couplings for the two cavities tend to cancel out. This may be avoided by slightly rotating the segments as in the anode at the bottom left of Fig. 4, for in this case coupling occurs mainly to one segment. In the original anodes a radiating probe between the cavities parallel to the cathode was used, as can be seen at the bottom of Fig. 4.

We assume, as before for simplicity, that the r.f. wave round the anode can be represented by a set of square pulses whose steps occur at the discontinuities at the anode gaps. An example is shown in Fig. 6 (taken from reference (12)) for one case in a 4 segment asymmetrical anode. In this case the r.f. wave can be Fourier analysed into a set of component sine waves of different amplitudes. These sine waves correspond to different values of $(kN \pm n)$. In this way it is possible to predict the types of interaction that can occur. Modes have been observed which are not predicted by this analysis, but this is attributed to slight constructional asymmetries. Conversely it is possible to design anode structures suitable for working in particular modes. This is done essentially by altering the angular position of the gaps. In the case of symmetrical anode structures this involves altering the thickness of the vanes between the segments.

A performance chart of one of the asymmetrical anode valves is shown in Fig. 7 (taken from reference

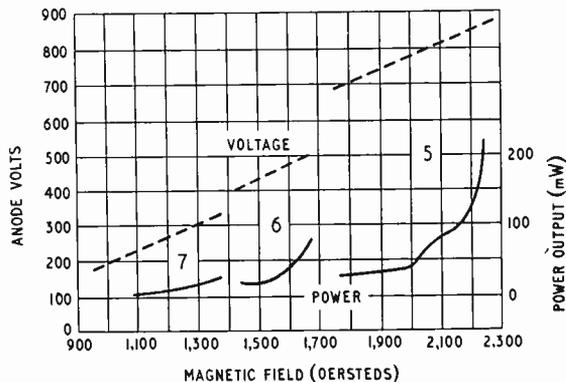


Fig. 7. Performance chart of spatial harmonic magnetron.

(12)), the numbers showing the relevant values of $(kN \pm n)$. Owing to the simpler anode resonance structure of such valves with few segments it is possible to achieve a useful tuning range by coupling the valve to a simple external-cavity tuner. The simple anode structure also permits pulse operation with very short oscillation build up times. Preliminary measurements suggest that the limit in this

direction is less than 0.1 μ sec. The limit is set so far by the shape of current pulses that can be generated with existing apparatus.

Reference to Fig. 7 shows that, in a given mode, if the voltage is increased the power is increased up to a certain point, where it suddenly drops to zero. This is because at high anode currents the space charge forces in the electron bunches defocus these bunches. Interaction is then no longer possible. Spatial harmonic operation of valves is much more prone to this type of "drop out" than normal operation.

If the coupling of the valve to the load is made very heavy the normal resonances are suppressed and voltage tuning becomes possible. Again in these valves the simple anode structure permits this to be more readily carried out, and 2 to 1 frequency ranges have been achieved. The power available is however very much less than in normal operation. Although temperature-limited emission was not used operation was not noisy. This contradicts previously mentioned results on such voltage tuning obtained by Boyd⁶, of Michigan University. M.G.L.

LETTERS TO THE EDITOR

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

"Do it Yourself" Interference

I SHOULD like to allay the fearsome forebodings of your correspondent Douglas Walters regarding the subject matter of my recent "Build your own Radio Set" programmes.

Early on in the series I told viewers that I was receiving letters from dealers, and from boys who had been told by their dealers, pointing out that the set would not oscillate. It was suggested that I had wrongly specified a reaction capacitor of 0.0001 μ F whereas that specified by the makers of the coil was 0.0003 μ F. My reply to viewers was that this was done deliberately as the smaller size just gave enough feedback to increase the volume, but no oscillation over the band was possible. It was pointed out that a reacting receiver could cause interference in other sets and to obviate this dealers were asked to keep to the specification and the lower value.

I have made up three models of the receiver concerned and can only obtain a "squeal" with a new battery at the lower end of the medium waveband. I find the DAF 96 valve difficult to persuade to oscillate and cannot believe that its 69 volts and couple-of-hundred *micro*-amps is going to make it a very powerful transmitter even if some enterprising lad gets it going well. In the indoor aerial conditions under which most of these builders are using it, I find the radiation from the receiver difficult to detect in the next room.

From many letters I have received since the series ended, it is apparent that most builders of the set are getting good reception and I hope that I have added over 25,000 youthful enthusiasts to those of us who love the hobby. Perhaps I may use this opportunity to thank the B.B.C. Engineering Staff, various manufacturers and thousands of dealers for their interest and help both to myself and to many novice set-builders (of both sexes!).

Kenton, Middlesex.

GILBERT DAVEY.

ALTHOUGH I agree with your correspondent Douglas Walters that the type of receiver to which he refers is very likely to lead to a lot of curious noises on medium wavelengths, I cannot see why he is so worried about it.

Having been chased off the long and medium wavebands by the scream of a hundred line timebase oscillators which made reception unenjoyable when not actually impossible, I am now using v.h.f., and, so to speak, "fireproof."

So far as oscillations on these wavelengths are concerned, those who watched the programme were, for the most part, "doing it themselves" with a vengeance! Surely any interest in the well-being of the medium waveband is somewhat belated. I doubt whether the youngsters will be noticed among the noises already there.

Workshop.

H. S. CHADWICK
(G8ON).

Interference Suppression

WHILE one must approve of the laws regulating ignition systems, the question is "Why only motor vehicles?" What is being done about electric shavers, hair driers, trolley buses, and, in the country, electric fences?

While I suffer to some extent from motor interference, it is only a very small part of the sum total of interference from which one suffers.

I am contemplating the purchase of an electric cooker with a simmerstat. I understand the simmerstat is quite unsuppressed, and is apparently quite legal.

Although I am a very considerable user of short waves, being an amateur radio transmitter, and suffer considerably from interference of all kinds, I do feel that too much attention is being paid to car ignition and too little to the multitude of other causes of interference which now plague us. Let us start a propaganda drive to suppress all these other sources.

London, N.W.3.

E. M. WAGNER.

TV Whistle

YOUR Editorial in the October issue on the subject of the "ideal" receiver has prompted me to make a general complaint about one aspect of television receiver design—the noisy line output transformer.

I think I can truthfully say that I have not yet come across a receiver with a line output transformer which was inaudible at normal viewing distance.

I may be unusual in that at 35 I still have good sensitivity at about 10 kc/s, but what about the hordes of children who view television? Does the whistle not annoy them? My last visit to the Radio Show two years ago was spoilt by the whistle pervading (so it seemed) the whole building.

It has taken 35 years to get rid of the whistle from sound broadcasting (FM be praised) and I wonder if it will take as long to produce a whistle-free TV receiver, for I will have no other in my home.

Cardiff.

D. A. THOMS.

Optical "Noise" Filter

THE reference to the above in "Technical Notebook" (October issue) reminded the writer of an effect noted in school at the age of 12/13 years. It was observed that if the blackboard were viewed through a small aperture (actually a curled up forefinger) the writing became much clearer. Possibly the effect is similar to that of a pin-hole camera, although it is recalled that the physics master thought that the reason in this case was rather more obscure.

At this time the writer was in need of spectacles although, through lack of a comparative standard, un-

aware of the fact. It was the above-mentioned observation that provided the comparative standard and, subsequently, the spectacles.

It would seem that an effect similar to the triangular frequency response utilized in, for example, a camera head-amplifier occurs. Perhaps a reader having knowledge of optical effect would be able to comment further on this subject.

East Molesey.

T. G. CLARK.

IS not this effect due to the physical nature of the iris of the eye which automatically opens wider when it is shielded from extraneous light by the tube held over it?

Norwich.

E. R. SLAUGHTER.

Genesis of Sound Reproduction

THE British Sound Recording Association has offered to try to help supplement the national collection of sound recording and reproducing apparatus and other acoustic and electro-acoustic equipment in the Science Museum, South Kensington.

Our main appeal is to and through members of the Association, but if any non-members have equipment which they would like to give to the B.S.R.A. Historic Collection, I should be very pleased to have details from them at the address below.

I should make it clear that we are not collecting recordings of historical interest, the proper repository for which is the British Institute of Recorded Sound, 38 Russell Square, W.C.1.

Disley House,
Carlton Road,
Reigate, Surrey.

PETER FORD,
Hon. Historian, B.S.R.A.

How Little Distortion Can We Hear?

IT is a pity that Mr. Lazenby (September, 1957, issue, p. 435) gave little attention to more practical conditions for distortion detection. The results quoted showed that the simplest (single frequency sine wave) signals were not the most suitable for the detection of distortion, as slightly more complex signals (containing two or more frequen-

cies) allow the formation and detection of intermodulation products. Although I realize that not everyone will agree with this, some of the results using speech and music suggest that for still more complex signals one's sensitivity to distortion is decreased again. There is an example of this on the Vox record "This is High Fidelity," where the same amount of distortion sounds much less objectionable in a complex orchestral passage (mainly strings) than in a simple piano or horn solo. Another point is that significant distortion in the reproduction of music is only likely to occur at peaks of sound, and in such peaks the signal wave form is almost always very complex.

Edgware.

D. J. KIDD.

Help for the Blind

NO doubt many of your readers know of the existence of a library of "talking books" for the blind. These have been recorded on long-playing records and are reproduced by portable battery- or mains-operated gramophones specially designed for the purpose. Such is the demand for these reproducers that there is at present a normal waiting period of about one year for new readers.

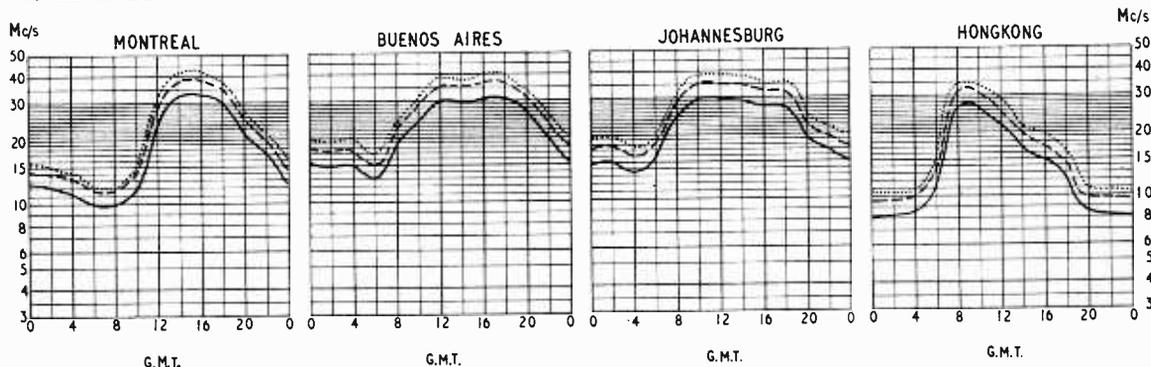
There are a number of problems in operating and maintaining these sets. Most of the readers are old and many have never seen or previously handled a set of this nature. In one distressing case a reader had been listening to the needle scratch for days, not realizing that the equipment had to be switched on. In another, the set which had ceased to function was returned to London, and smashed in transit, all because of a faulty flex lead, which had in any case been left behind, unseen, in the house.

Helpers with a knowledge of audio amplifiers are urgently needed in London and in many other areas in England to instruct new readers in the use of their sets and to investigate cases of faulty performance.

If you would like to assist or would like further information, please write to me at J. Gladstone & Co. Ltd., Galashiels.

D. FINLAY-MAXWELL,
Honorary Organizer of
Voluntary Helpers, Nuffield
Talking Book Library for the Blind.

SHORT-WAVE CONDITIONS Prediction for January



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

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

- FREQUENCY BELOW WHICH COMMUNICATION SHOULD BE POSSIBLE FOR 25% OF THE TOTAL TIME
- PREDICTED AVERAGE MAXIMUM USABLE FREQUENCY
- FREQUENCY BELOW WHICH COMMUNICATION SHOULD BE POSSIBLE ON ALL UNDISTURBED DAYS

Cathode-Coupled Flip-Flop

A Reliable Design Procedure

By T. G. CLARK,* A.M.Brit.I.R.E.

THE science of electronics is too frequently practised as an art, even by quite senior engineers, and, with a minimum of "know how," circuits are "bodged" to meet design requirements. In general, however, it is possible to produce a paper design that, when assembled practically, will produce a result within 5 to 20% of that predicted. Furthermore, less time is wasted by proper design methods. The introduction of feedback techniques into the design will render the operation stable and predictable. Having designed a circuit to within reasonable limits final adjustment may be effected by means of pre-set controls.

The cathode-coupled mono-stable multi-vibrator (shown in Fig. 1) is used extensively as a generator of pulses having durations ranging from microseconds to minutes. It is the object of this article to show that, using 5% tolerance components and the published valve characteristics, it is possible to design such a flip-flop to an accuracy of the order of 10%. Moreover, provided that a standard configuration is accepted, further design reduces to the simple equation

$$t_o = KCR$$

It is not proposed to discuss the effect of tolerance variations upon the end result, for, as previously indicated, a pre-set control will take full account of such variations.

The information required to initiate the design is as follows:—

- (1) Pulse duration, or durations.
- (2) Pulse amplitude.
- (3) Pulse polarity.
- (4) Available h.t. supplies.

Circuit Operation.—Referring to Fig. 1, the grid resistor R of V2 is returned to a positive potential, E_g , whilst the grid of V1 is returned to a lower positive potential. The design is such that the anode current of V2 flowing in R_5 creates a potential that, in conjunction with the potential upon V1 grid, causes V1 to be cut off. The initial stable condition then, is that V2 is conducting heavily whilst V1 is cut off.

Trigger pulses of suitable polarity, as indicated in Fig. 1, upset the stable state as follows:—Positive pulses at V1 grid cause negative pulses at the anode and these are communicated through C to the grid of V2, thus causing the common cathode to drop. This switches on V1 thereby enhancing the original negative fall at the anode. The action is cumulative and results in V2 being switched off and in V1 being switched on for a period determined by the recovery time of V2 grid circuit. When the grid of V2 has recovered to a point within the grid base of the valve, essentially the same cumulative action resets the circuit to the stable state.

Since R_5 is common to V1 and V2 it will be seen that R_3 must be greater than R_4 in order to produce a drop at the common cathode during the operative period.

Typical waveforms and voltage levels are shown in Fig. 2. These waveforms are self-explanatory and of a type given in many text-books. For present purposes it is sufficient to note that, in terms of the total potential grid excursion, i.e. from -50 V to $+E_g$, the grid base of the valve is negligible. In addition, the difference between the quiescent potentials of V2 grid and the common cathode is also negligible. "Cut on" then occurs at the common cathode potential obtaining during the pulse. This potential may be varied by means of the potential at V1 grid, thus providing control of the pulse duration. Outputs of opposite phase may be taken from anode and cathode, the cathode output being at a relatively low impedance. It is not desirable that outputs should be taken from the anode of V1 or the grid of V2, since the loading of the external circuit will affect the predicted performance. However, if a negative going pulse of approximately 150 V is required, then an output may be taken from the anode of V2 grid, provided that the external circuit is of high impedance.

The simple description given earlier may be modified by a number of effects. For example, the trigger pulse should be of

* Decca Radar Ltd.

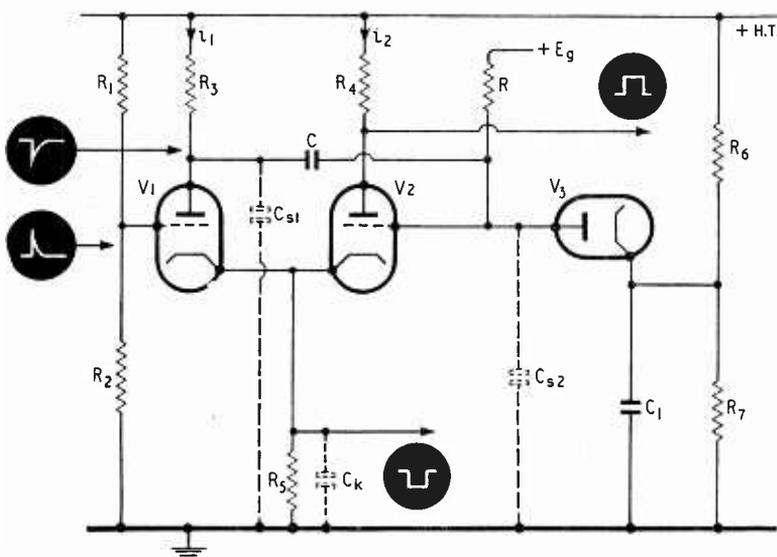


Fig. 1. Cathode coupled flip-flop circuit.

adequate amplitude and duration having regard to the rise time of R_3 and the total stray capacity, $C_{s1} + C_{s2}$. Previously, it has been stated that an essential to the operation is that the common cathode must fall at the moment of initiation. If, in fact, the cathode does not drop adequately during the duration of the trigger pulse due to the effect of C_k , then regeneration will not occur and the circuit will behave simply as a cascaded amplifier. When using a trigger amplifier d.c. coupled into the anode of V1 the pulse duration will tend to be longer than that calculated, since V1 anode will fall by an amount dependent upon the anode current of V1 with the addition of an increment from the trigger amplifier.

The circuit operation depends upon the anode currents flowing during the respective "on" periods, so that design stability will be improved if these are subjected to negative current feedback. This may be accomplished by ensuring that the valves are operated during the respective "on" periods within the valve grid base, i.e. at a grid bias of about -1 V, and also by choosing an adequately large value for R_5 . Valve V1 may be readily operated in the specified conditions by choosing a suitable value for its grid potential. For most purposes this is sufficient, but for more precise applications it is necessary to ensure that the quiescent grid potential of V2 is also within the grid base. (Normally, V2 grid is operated at zero bias due to grid current flowing in the grid resistor R_4 .) The clamping diode, V3, in conjunction with the potentiometer R_6 and R_7 can be used to ensure that the grid cannot move more positive than the potential at the junction of R_6 and R_7 , this potential being chosen to give the desired conditions. In order to ensure satisfactory clamping the parallel impedance of R_6 and R_7 must be very much lower than that of R_4 . In addition, the capacitor C_1 should have a value very much greater than C in order to supply a re-charging pulse to C at the moment of clamping. In the absence of this capacitor a spike would occur on the lagging edge of the output pulse as the grid overshoots the clamp potential and then returns at a rate dependent upon C , R_6 and R_7 .

In general, it is required that the rise and fall times of the output pulse should be as short as possible and, for this reason, the resistors across which outputs are taken are made as small as possible consistent with the limitation of valve anode dissipation. For a 12AT7 working at an h.t. potential of $+250$ V this means that, from Fig. 3, the sum of R_4 and R_5 should not be less than $6.8k\Omega$. Thus, if it is decided that the cathode resistor R_5 should have a value of $3.3k\Omega$, then the value of R_4 should not be less than $3.6k\Omega$. However, if the design requirement does not require fast edges to the output pulse, then $R_4 + R_5$ may be made larger than this minimum value, thus achieving economy in the operating current.

Introduction to Design.—The principles underlying the design may be summarized as follows:—

- (1) The conditions in the two valves are considered separately during the respective operative periods.
- (2) The valve V1 is operated within the grid base, i.e. at a bias of -0.5 V to -1 V, in order to obtain current stabilization.
- (3) Grid current onset in V2 is assumed to occur at $V_g = 0$, and the anode current at this

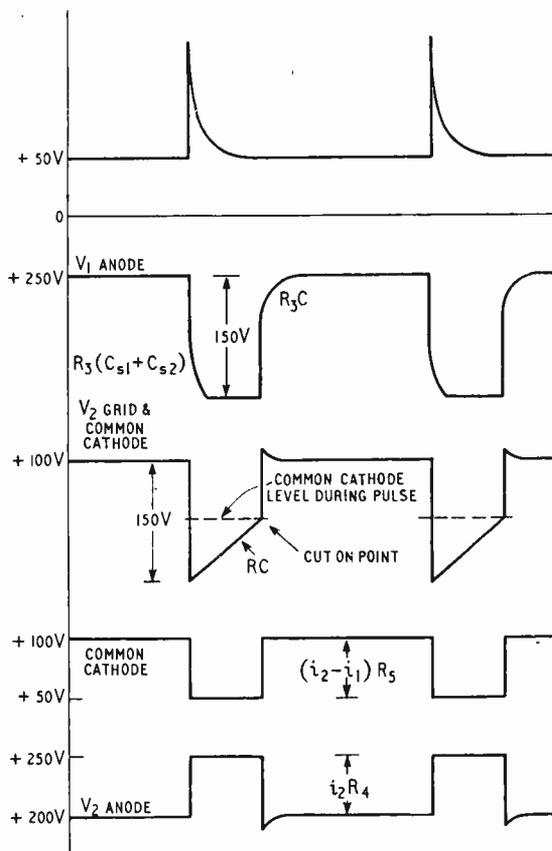


Fig. 2. Cathode coupled flip-flop waveforms with typical voltage levels.

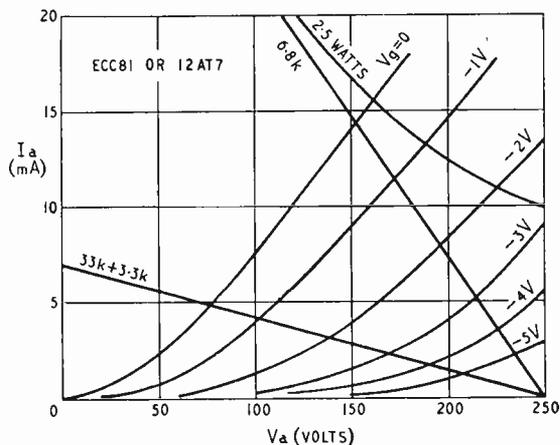


Fig. 3. Characteristic curves of ECC81/12AT7 with loadlines used.

point is assumed to be moderately constant from valve to valve.

(4) The grid base of V2 is assumed to be negligible compared to the potential grid swing.

(5) For more precise applications, a clamping diode V3 is used to maintain V2 within the grid base during the quiescent period, in order to obtain current stabilization.

(6) A clamping diode may also be used when the value of R would cause excessive grid current at $V_g=0$.

(7) A positive-going pulse of amplitude $i_2 R_4$ may be taken from the anode of V2.

(8) A negative-going pulse of amplitude $(i_2 - i_1) R_5$ may be taken from the common cathode.

(9) All components shown in Fig. 1, except C_1 , should be 5% preferred values.

For present purposes R_3 will be $33k\Omega$ and R_5 $3.3k\Omega$. R_4 will be chosen having regard to the required amplitude of the output pulse, the maximum anode dissipation of the "normally on" valve, and the requirement that it should be smaller than R_3 in order that the common cathode may fall adequately during the pulse. It may be observed here that R_4 may be zero if a negative pulse only is required.

Consider, now, the load line for V1, the $36k\Omega$ line of Fig. 3. For a bias of, say, -0.5 V a current i_1 flows, and this is the current in R_5 when V2 is cut off. The potential at the grid of V1 will be given by $(i_1 R_5 - 0.5)$ V, and the ratio $R_2/(R_1 + R_2)$ is established. Actual values may be chosen having regard to a convenient current flow and preferred values of resistors. The effective negative bias on V1 when V2 is conducting will be given by $i_2 R_5 - (i_1 R_5 - 0.5) = R_5(i_2 - i_1) + 0.5$ V. This value is dependent upon the difference between the two operating currents and must be greater than the grid base of V1.

If it is required to operate V2 within the grid base the ratio $R_7/(R_6 + R_7)$ must be chosen to operate V2 at a suitable negative grid bias relative to the cathode. Additionally, as we have already mentioned, the parallel sum of R_6 and R_7 must be very much less than the lowest value of R in order to ensure effective clamping.

Calculation of Pulse Duration.—Now that the operating conditions during the respective operative periods have been established it is possible to calculate the generated pulse width. Consider Fig. 4.

The amplitude of the exponential curve, relative to point A at any time t , is given by:—

$$E(t) = E \left\{ 1 - e^{-\frac{t}{T}} \right\}$$

where $T = CR$

$$\text{Therefore } e^{-\frac{t}{T}} = \frac{E - E(t)}{E}$$

$$\text{and } \frac{t}{T} = \log_e \left\{ \frac{E}{E - E(t)} \right\}$$

$$\text{Giving } T = CR = \frac{t}{\log_e \left\{ \frac{E}{E - E(t)} \right\}} \dots \dots (1)$$

Putting the required time interval as t_0 and the value of $E(t)$ to the "cut on" point as E_0 , we have then, from Fig. 6,

$$E = Eg + i_1 R_3 - i_2 R_5$$

$$E_0 = i_1 R_3 - (i_2 - i_1) R_5$$

Since the grid potential of V2 during the quiescent period is very nearly equal to the common cathode

potential and the grid base of V2 is negligible compared to the total potential grid excursion (to $+E_g$).

$$\text{Thus } CR = \frac{t_0}{\log_e \left\{ \frac{Eg + i_1 R_3 - i_2 R_5}{Eg - i_1 R_5} \right\}} \dots (2)$$

$$\text{whence } t_0 = KCR \dots \dots (3)$$

$$\text{where } K = \log_e \left\{ \frac{Eg + i_1 R_3 - i_2 R_5}{Eg - i_1 R_5} \right\} \dots (4)$$

and this is a constant for a given configuration in which only t_0 and CR are variables.

For convenience equation (4) may be re-written

$$K = \log_e \left\{ \frac{Eg/R_5 + i_1 \frac{R_3}{R_5} - i_2}{Eg/R_5 - i_1} \right\} \dots \dots (5)$$

$$\dots \log_e \left\{ \frac{i_3 + i_1 \frac{R_3}{R_5} - i_2}{i_3 - i_1} \right\} \dots \dots (6)$$

where $i_3 = Eg/R_5$

It may be shown that the circuit operation is less sensitive to variation of the individual components within the bracket if the bracketed term is made as large as possible consistent with other requirements. In the design to be discussed the value of this term is approximately 1.5. This value is quite suitable, and since the function is logarithmic, an optimum value cannot be given. From equation (6) it may be inferred that R_5 should be small. However, this contradicts the requirement for current stability.

As i_3 will be greater than i_1 it can be seen that, for the bracketed term to be positive, we must have $i_3 > i_2 - i_1 \frac{R_3}{R_5}$

i_3 should be made large by using a high value for Eg. This is in accordance with the conception of having a large potential grid movement (returning to $+Eg$) in order that, (a) the grid base may be considered negligible and that, (b) the rate of change of the grid movement through the grid base shall be fast, thus minimizing time jitter on the back edge of the pulse.

Apart from the basic design considerations previously discussed there are a number of factors establishing limits to the circuit values. These may be enumerated as follows:—

(1) C should be not less than about 100 pF in order to obviate the modifying effects of the stray capacitance C_{s2} , unless a cathode follower is interposed between V1 and V2.

(2) R should not be less than about 0.5MΩ in order to limit grid current, except when a clamping diode is used. However, a low value of R will reduce the a.c. gain of V1.

(3) R should not exceed 10 MΩ from considerations of component stability and circuit leakage.

(4) When operating at high duty ratios C should have adequate time to recover. A time equivalent to at least 5 CR₃ should be allowed, and it may be that this consideration will dictate the choice of C and hence R.

(5) Components must be adequately rated. Cer-

(Continued on page 27)

tain components will have a dissipation dependent upon the duty ratio; this should be considered when designing a flip-flop of variable duration.

(6) Positive trigger pulses capacity coupled to V1 grid should not drive this valve into grid current, otherwise the recovery of the grid coupling capacitor will modify the circuit operation.

Practical Design.—As an example, the following specification will be discussed.

- Pulse width .. 100 μ S
- Output .. + 50 V
- H.T. Supply .. +250 V

Other considerations Variable duration not required.
Fastest possible pulse edges consistent with using a standard valve type 12AT7. Extreme precision not required.

The design procedure then runs as follows

$$R_3 = 33k\Omega, \quad E_g = +250 \text{ V}$$

$$R_5 = 3.3k\Omega, \quad V_3 \text{ not required}$$

$$\text{Try } R_4 + R_5 = 6.8k\Omega$$

From the characteristic curves of Fig. 3,

$$i_2 = 14 \text{ mA at } V_g = 0$$

$$\therefore R_4 = \frac{50}{14} = 3.6k\Omega,$$

agreeing sufficiently with our values for R_5 and $R_4 + R_5$.

If this trial had been unsuccessful different values for R_4 and R_5 would have been tried. There would be no objection to varying R_5 within reasonable limits.

From the characteristic curves,
 $i_1 = 4.5 \text{ mA at } V_g = -0.5 \text{ V}$

Therefore $i_1 R_5 = +14.8 \text{ V}$
and the voltage at V1 grid is given by
 $i_1 R_5 - 0.5 = 14.3 \text{ V}$

Therefore $\frac{R_2}{R_1 + R_2} = \frac{14.3}{250}$

i.e. $\frac{R_1}{R_2} = 16.5$

This ratio is obtained if $R_1 = 240k\Omega$ and $R_2 = 15k\Omega$, both of which are preferred values.

Proceeding, $CR = \frac{100 \times 10^{-6}}{\log_e \left\{ \frac{250 + (33 \times 4.5) - (3.3 \times 14)}{250 - (3.3 \times 4.5)} \right\}}$

$$= 250 \times 10^{-6}$$

Let $C = 250 \text{ pF}$

Then $R = 1 \text{ M}\Omega$

The pulse amplitude and duration of this design were 53 volts and 97 μ s as measured on a Cossor oscilloscope.

Another flip-flop was designed by the same method but to a different specification. The durations measured on the same instrument were as follows:—

Calculated	Measured
406 ms	380 ms
263 ms	270 ms
128 ms	125 ms
73 ms	70 ms
41 ms	38 ms
26 ms	26 ms

All components shown in Fig. 1, except C_1 , have

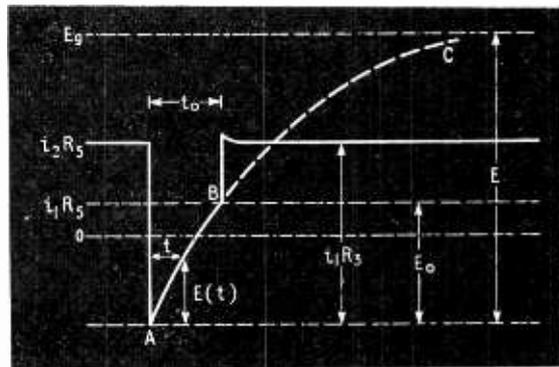


Fig. 4. Detail of V2 grid waveform.

an effect upon the circuit operation. Final trimming may be achieved by varying any such component.

The circuit of Fig. 1 has been used in production equipment as the heart of a decade counter with complete success. Greater precision than the basic circuit offers was obtained by utilizing an amplitude-limited negative pulse stream applied to V1 grid as terminating pulses.

A method of design has been offered which permits the engineer to design a flip-flop without excessive trial and error, and to achieve results within normal experimental error. The design formula for an established configuration has been reduced to $t_0 = KCR$.

Dates for Your "Wireless World" Diary

ANNOUNCEMENTS have already been made of the dates of many of this year's exhibitions and conventions, but for the convenience of readers we give below a list of the principal events in 1958.

Television Society Exhibition	March 4-6
Royal Hotel, Woburn Place, London, W.C.1.	
Physical Society Exhibition	March 24-27
Royal Horticultural Society Halls, London, S.W.1.	
International Instruments Show	March 24-29
Caxton Hall, Westminster, London, S.W.1.	
Electrical Engineers' Exhibition (A.S.E.E.)	March 25-29
Earls Court, London, S.W.5.	
Convention on Radio Aids to Navigation	March 27-28
I.E.E., Savoy Place, London, W.C.2.	
Components Show (R.E.C.M.F.)	April 14-17
Grosvenor House and Park Lane House, Park Lane, London, W.1.	
Instruments, Electronics and Automation Show	April 16-25
Olympia, London, W.14.	
Audio Fair	April 18-22
Waldorf Hotel, London, W.C.2.	
International Convention on Microwave Valves	May 19-23
I.E.E., Savoy Place, London, W.C.2.	
National Radio Show (R.I.C.)	Aug. 27-Sept. 6
Earls Court, London, S.W.5.	
Farnborough Air Show (S.B.A.C.)	Sept. 1-7
Electronic Computer Exhibition	Nov. 28-Dec. 4
Olympia, London, W.14.	

OVERSEAS

Symposium on Reliability and Quality Control	Jan. 6-8
Washington, U.S.A.	
I.R.E. National Convention and Show	March 24-27
New York, U.S.A.	
British Electrical Conference	May 16-17
Brussels, Belgium.	
Solid State Physics in Electronics and Telecommunications (Conference)	June 2-7
Brussels, Belgium.	
International Analogy Computation Meeting	Sept. 1-9
Strasbourg, France.	
International Congress of Cybernetics	Sept. 3-10
Namur, Belgium.	

Magnetism in Materials

I.—The Physical Basis of Dia-, Para-, Ferro- and Ferri-Magnetism

BY D. H. MARTIN, Ph.D.

ALTHOUGH only four of the elements—iron, nickel, cobalt and gadolinium—are ferromagnetic, there is to-day available to the electrical engineer a remarkable range of magnetic alloys and compounds from which he must select the most appropriate for his particular application. In these articles I plan to examine more closely what conditions led to the distinctive and useful phenomenon of ferromagnetism, and then to illustrate how the bewildering variety of magnetic behaviour may be understood in terms of a few basic ideas.

All substances become magnetized when subjected to a magnetic field though sensitive apparatus is needed to detect the induced magnetization except in the case of the ferromagnetics. Most materials are either paramagnetic or diamagnetic. A specimen of the former kind will move, when placed in a non-uniform magnetic field, to the point where the field is most intense. This is because the induced magnetization is in the same direction as the field, as it is in the case of the ferromagnetics. The intensity of magnetization, however, is at least a million times less than that which would be induced in a ferromagnetic sample. Specimens of a diamagnetic material, on the other hand, move to where the applied field is least intense, for example, away from the pole-pieces of a magnet. This is because the induced magnetization is opposite in direction

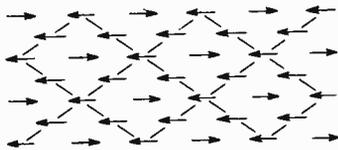


Fig. 1. Oppositely magnetized super-lattices illustrating the spontaneous magnetization within each domain of a ferromagnetic material.

to the applied field; it is of the same order of magnitude as that in a paramagnetic sample. Almost all organic materials are diamagnetic and, among the elements, copper, silver, gold and hydrogen are examples of diamagnetics, and oxygen, aluminium and platinum of paramagnetics.

Materials are magnetic because atoms themselves behave as magnetic dipoles, that is exactly as minute bar magnets or as minute electric current circuits. This, of course, is not surprising since it is well known that electrons circulate within each atom around its nucleus. There is, moreover, experimental evidence of a direct nature for the dipolar properties of individual atoms. In a non-uniform field a dipole experiences a translational force proportional to its dipole moment and in the 1920s Stern and Gerlach directed a beam of atoms, which had been evaporated from a metal in a furnace, through the pole gap of an electromagnetic which produced a non-uniform field. The beam was deflected and the deflection was registered by condensing the atoms on a cold plate where, after a time, they left a visible trace. In this way precise measurements of atomic dipole

moments were made and much was learnt about atomic structures.

A point of particular interest for our present purpose is that atoms of iron, nickel and cobalt do not have dipole moments which are very much larger than those of other atoms. The extreme ease with which a ferromagnetic may be magnetized to a high degree is certainly not due to its atoms possessing peculiarly high magnetic moments. It must, therefore be due to a particular kind of arrangement of the atomic dipoles, and I shall discuss this arrangement in some detail later. First I must describe briefly what happens in paramagnetic and diamagnetic materials.

Diamagnetism.—The several electrons in each diamagnetic atom or molecule move in orbits which are so directed that they give rise to a zero resultant magnetic moment in the absence of an applied field. There is a fundamental reason for electrons in atoms adopting such a balanced distribution and so diamagnetic materials are by no means uncommon. In an applied field, however, the magnetic forces which act on the electronic currents within each atom distort the orbits and thus induce a resultant magnetic moment, which is always opposite in direction to the applied field. This may be looked upon as an example of ordinary electromagnetic induction and the negative direction of the induced dipole corresponds to Lenz's law, which governs the direction of induced e.m.f. This process is diamagnetism.

Paramagnetism.—A paramagnetic atom, on the other hand, has a permanent dipole moment regardless of whether a field is applied or not. The magnetic fields due to the moving electrons in each atom do not cancel one another out. In the absence of an applied field the energetic thermal vibrations of the atoms in a paramagnetic sample cause their dipole moments to be directed in a completely random way, and the direction of each dipole changes rapidly with time. The overall magnetization of a sample is, therefore, zero. The fields attainable in practice are sufficiently intense only slightly to disturb this completely random arrangement. In the presence of an applied field each atomic dipole spends slightly more of its time in directions having components parallel to the applied field, and less time in directions opposed to the field. The sample as a whole, therefore, exhibits a weak magnetization and this is paramagnetism. In a hypothetical field of sufficient intensity the dipoles would approach a saturated condition, each being almost parallel to the field. This stage would be expected only if the magnetic potential energy of an atom became comparable to the energy of its thermal vibration. That is to say if

$$\mu H \approx k T$$

where μ , k and T are respectively the dipole moment of an atom, Boltzmann's constant, and the

absolute temperature. Now μ is of the order 5×10^{-20} e.m.u. and k is 1.38×10^{-16} erg per $^{\circ}\text{K}$, and H cannot in practice exceed about 100,000 oersteds. Even with such intense fields, therefore, saturation effects should not be observable except at very low temperatures, a few degrees above absolute zero. Such effects have, in fact, been recorded recently in experiments conducted at about 4°K , that is -269°C . At more normal temperatures the intensity of magnetization, I , is strictly proportional to the strength of the applied field, H , and the ratio I/H , that is the susceptibility, is of the order 10^{-3} e.m.u. for most paramagnetic materials at room temperature. This is in contrast with susceptibilities of more than 10^3 in most ferromagnetic materials.

Ferromagnetism.—The characteristic feature of ferromagnetism is the attainment of a high intensity of magnetization in comparatively small fields, and even the retention of an intense magnetization when the field is switched off. As the field applied to a demagnetized specimen is increased the intensity of magnetization rises rapidly until saturation is attained when no further increase in magnetization is possible, however much the field may be increased. This occurs in fields of less than a few hundred oersteds, for some materials in fields of only an oersted or so. The saturation value of magnetization is just about what would be expected if nearly all the atomic dipoles were aligned parallel to one another. This is in fact the situation that exists in a saturated ferromagnetic material and the problem of ferromagnetism is to explain how this comes about in such small fields, in spite of thermal vibrations.

It is known that a sample of ferromagnetic material is made up of small contiguous regions, called domains, within each of which almost all the atomic dipoles are aligned exactly parallel to one another even in the absence of an applied field (see Fig. 3). This alignment is known as spontaneous magnetization and its direction in each domain is different from that in the neighbouring domains. Spontaneous magnetization is the basic characteristic feature of ferromagnetism. It can be destroyed only by heating the specimen above a critical temperature called the Curie point, which for iron is 770°C , for nickel 358°C , for cobalt $1,120^{\circ}\text{C}$ and for gadolinium 16°C .

The arguments of the previous section on paramagnetism therefore indicate, since saturation effects persist at these high temperatures, that whatever force it is that aligns the atomic dipoles to give spontaneous magnetization, it must be equivalent to a large internal magnetic field of some ten million oersteds! It was not until 1928 that the nature of these forces was discovered by Heisenberg. They are clearly too large to be ordinary magnetic forces and in fact they are due to an interaction, between neighbouring atoms, which requires the language of modern quantum physics for a full description. An atomic electron spins about its own axis as well as moving in an orbit round the nucleus. The elementary atomic dipole moments in ferromagnetic materials are in fact due entirely to the spin motions of certain of the electrons, the moments associated with the orbital motions cancelling out. Now a full quantum description of a spinning electron shows that between any two electrons there is an interaction, known as exchange interaction, which tends

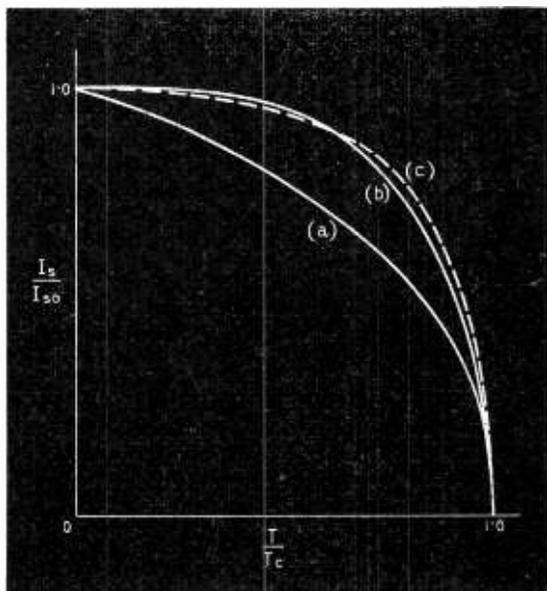


Fig. 2. Variation of the spontaneous magnetization I_s of iron, nickel and cobalt, with temperature T . I_{s0} is the spontaneous magnetization at absolute zero of temperature and T_c is the Curie temperature. Curve (a) is given by the simple Weiss theory, (b) by an improved Weiss theory and (c) records the experimental values of iron, nickel and cobalt.

to set the spin dipole moments either parallel or antiparallel to each other, depending on the details of the situation. The effects of exchange interactions in simple molecules are well established, but a metal consists of many millions of interacting atoms and the theory has not yet been fully worked out in rigorous detail. There is no doubt, however, that spontaneous magnetization is due to an alignment of the spin motions of certain electrons in the material under the action of exchange forces.

It is argued that the alignment will be parallel rather than anti-parallel if the number of interacting atoms is large and if the radius of the electron orbits is relatively small compared with the distance between the atoms. Now the electrons in an atom are arranged in "shells" at different distances from the nucleus. In an atom of an element belonging to the group known as the transition metals the resultant dipole moment is due entirely to the electrons in an inner shell known as the 3d shell. The magnetic effects of the other electrons cancel out. Of these metals, iron, nickel and cobalt have the smallest ratio of 3d radius to atomic separation. That they are ferromagnetic is therefore in accord with the conclusion above. It is of great interest to note that manganese and chromium, both of which are transition metals, but paramagnetic when pure, can be rendered ferromagnetic by alloying them with certain other metals, thus altering the interatomic distances. For example the Heusler alloys are ferromagnetic. They contain manganese, copper and aluminium but no iron, nickel or cobalt. Compounds of manganese with arsenic, with bismuth, with tin, and several other elements are ferromagnetic. Chromium compounds containing antimony, arsenic, platinum, or a number of other elements are ferromagnetic.

Gadolinium is the only pure element other than iron, nickel and cobalt which is known to be ferromagnetic, though it is suspected that dysprosium might be at very low temperatures. As in the transition metals, the atomic dipole moment of gadolinium is due solely to the electrons in an inner shell.

There is a group of non-metallic materials which exhibits properties resembling those of the ferromagnetic metals. They are intimate mixtures of iron oxide and oxides of divalent metals and have recently gained commercial recognition mainly because of their high electrical resistivity, as I shall discuss in more detail in a later section. They are known as ferrites, and the term ferrimagnetic has been coined for the rather different arrangement of atomic dipoles in these materials. They resemble ferromagnetics in that they are spontaneously magnetized and have a domain structure, and they are often included under that title. A ferrimagnetic must be a compound because two kinds of dipole are involved. Nearly all the dipoles of the one kind are aligned parallel to each other, while the others

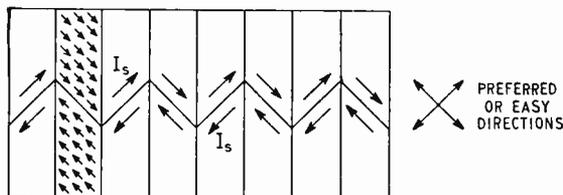


Fig. 3. Example of the arrangement of spontaneous magnetization in a domain structure. The alignment of atomic dipoles is illustrated in two of the domains.

are also aligned but in the opposite direction. The situation is illustrated in Fig. 1. Spontaneous magnetization results from this anti-parallel arrangement since one kind of dipole is more numerous and/or has a larger dipole moment.

The general formula for a ferrite is Fe_xMO_4 , where M is any divalent metal, for example copper, silver, magnesium, manganese, lead, zinc, etc. The crystal structure is of the type known as a spinel, that is the oxygen atoms are arranged on a close-packed cubic lattice and the metallic atoms occupy the interstices between the oxygen atoms. There are two kinds of interstice and they are known as tetrahedral and octahedral sites. A metallic atom in a tetrahedral site is surrounded by four oxygen atoms and in an octahedral site by six.

The elementary dipoles in a ferrite are the metallic atoms, those in one kind of site forming one spontaneously magnetized super-lattice and those in the other forming the oppositely directed super-lattice. There are twice as many octahedral as tetrahedral sites and so an overall spontaneous magnetization results. Exchange forces are again responsible for the spontaneous magnetization, but whereas in a ferromagnetic metal the interaction favours parallel alignment, in a ferrimagnetic the interaction of predominant importance is that between a metallic atom in a tetrahedral site and its neighbours in octahedral sites, and this interaction is negative, favouring anti-parallel alignment, and the two oppositely magnetized super-lattices result. The intensity of spontaneous magnetization in a ferrite is, of course, considerably smaller than that in a ferromagnetic metal.

Only at absolute zero of temperature does the magnitude of the spontaneous magnetization in ferromagnetic materials correspond exactly to complete alignment of the elementary dipoles. Above this temperature thermal vibration of the atoms always causes a few dipoles to be unaligned. At the Curie point the thermal agitation is sufficient to override even the strong exchange forces and full disorder sets in with the complete disappearance of spontaneous magnetization.

The variation of the intensity of spontaneous magnetization, I_s , with temperature is shown for iron, nickel and cobalt in Fig. 2. Long before Heisenberg, in 1928, identified exchange interaction as the force producing spontaneous magnetization, Weiss had shown (1908) how the phenomenon could be understood in terms of a hypothetical molecular field and he derived an expression for the dependence of I_s on temperature which to a first approximation agrees well with the observed variation. He supposed that each elementary dipole behaved as if acted upon by a molecular field, which he assumed to be proportional to the mean magnetization of the specimen. The molecular field is now recognized as an approximate representation of the exchange forces, since the exchange force tending to set an atomic dipole in a particular direction is greater the larger the number of its neighbours already set in that direction, that is the larger the magnetization, I , in the material surrounding the dipole. Weiss used this assumption in elaborating upon the Langevin theory of paramagnetism which showed that the intensity of magnetization of a paramagnetic specimen depended upon H the applied field, and T , the absolute temperature, according to the relation:

$$I = I_0 \tanh (\mu H / kT).$$

μ and k are the atomic dipole moment and Boltzmann's constant respectively, and I_0 is the magnetization which would be observed if all the atomic dipoles were perfectly aligned. The presence of T reflects the effect of thermal vibrations. For H Weiss substituted WI , where W is the molecular field constant, thus

$$I = I_0 \tanh (\mu WI / kT).$$

This relation contains the dependence of I upon T . Since the applied field is zero, I is here the spontaneous magnetization, I_s . The relation above is plotted in Fig. 2 with the experimentally-observed variation. The Weiss theory is only an approximation to the real state of affairs, and the fuller theories are complex and not yet fully worked out.

The molecular field representing the exchange forces proves to be of the order 10 million oersteds. It will be clear, therefore, that the fields used in practice, which seldom exceed 10,000 oersteds, are negligible in comparison and cannot change the magnitude of the spontaneous magnetization by a significant amount. The complicated changes in the overall magnetization of a specimen which occur when it is subjected to an applied field must therefore be due to changes in the direction of I_s in the domains of the sample. Recent studies of such changes have contributed enormously to our understanding of ferromagnetic behaviour and I shall describe the main features of domain theory in the following sections.

(To be continued)

Gold Dip-Plating, using "Atomex" solution developed by the Baker Platinum division of Engelhard Industries, is claimed on a variety of metals, including copper, zinc, nickel, iron, steel and pewter. The plating takes place by ionic displacement so that no electric current is necessary. Thus there is no possibility of electrical shielding and a uniform deposit even in recesses is obtained. Control of temperature and pH is necessary, particularly when depositing on copper and for obtaining consistent colour in decorative work. The solution may be operated between 60°C and boiling point, except for deposition on copper, when the range is from 45° to 75°C. The pH is initially between 7 and 8, and should be kept in this region during deposition by adding small amounts of ammonia. Otherwise the solution becomes slightly acid and the pH drops to 6. All the gold in the bath can be used and the spent solution thrown away. Suitable container materials are polyvinyl plastics or glass.

Gas Electrochemical Cell using hydrogen and oxygen (or air) has been developed by the National Carbon Company of America, and is described in the October 1957 issue of *Electronics*. Each gas is fed at a pressure of about one atmosphere into a hollow porous carbon rod surrounded by potassium hydroxide as the electrolyte. The reaction produces water, which is removed by evaporation. As this is the only by-product the cell theoretically has an infinite life. About one volt is developed, and it is hoped to produce as much as 1kW per cubic foot of cell volume.

Photocell-Powered Ohmmeter, using a selenium cell as the source of electric current for a resistance bridge, has been developed by the Fairey Aviation Company for testing the firing circuits of guided missiles. The idea is to ensure that the electrical energy applied to the missile remains below the safety margin so that there is no danger of accidental ignition. Hitherto current or voltage limiting devices have been used, but of course these can break down.

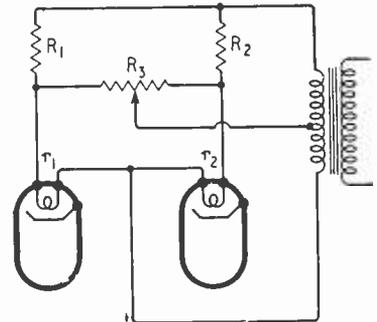
Technical Notebook

With the selenium cell the output under any condition of light saturation or failure cannot exceed a short-circuit current of 10mA or an open-circuit voltage of 0.7V. The bridge itself will measure 0-10kΩ in four ranges with a fundamental accuracy of ±0.3%. The actual accuracy achieved, however, depends on the measurement sensitivity, which in turn depends on the current resulting from the light falling on the photocell. The light intensities required to produce detectable galvanometer currents with different range and scale settings and a ±10% change of the "unknown" element vary between 0.7 and 13 foot candles. These are sufficient to give a measurement accuracy of approximately ±5%.

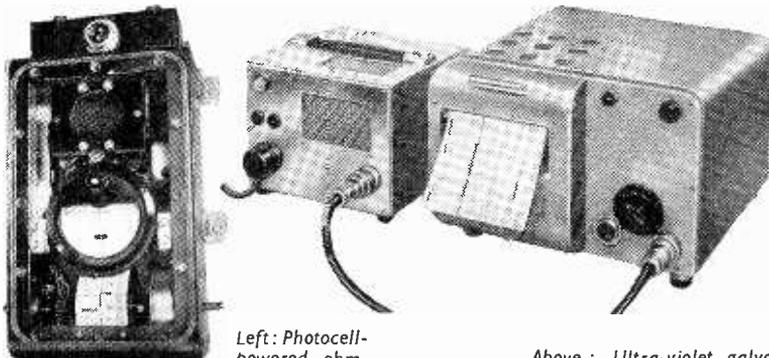
Ultra-Violet Galvo Recorder seen recently in operation at the Radar Research Establishment combines the sensitivity of galvanometer indication with the ability to give directly written records. This is achieved by using mirror galvanometers to reflect ultra-violet radiation from a mercury vapour lamp on to ultra-violet-sensitive recording paper. The trace is developed simply by exposure to daylight, and becomes visible immediately with low writing speeds and in less than ten seconds with high speeds. Made by New Electronic Products, the instrument provides six recording channels and has paper speeds of 0.2, 0.6, 2 and 6 inches per second. A trace velocity as high as 10,000 inches per second can be obtained, and the galvanometers will operate over a frequency range from d.c. up to 2kc/s. The records are said to

be permanent unless exposed for a considerable time to strong daylight, and will remain stable for weeks under normal room illumination and hold indefinitely if filed away in the dark. For real permanence they can be fixed by standard photographic methods.

Valve Matching Circuit.—D.C. amplifiers commonly consist of balanced push-pull stages. Drift can take place if variations in heater voltage affect one valve of a pair more than



the other. A new circuit described by D. J. R. Martin in the December issue of *Electronic and Radio Engineer* makes it possible to adjust the sensitivity of a valve to heater-voltage changes. Pairs of valves can then be matched so that balance is maintained even when the heater voltage varies. The matching principle depends on the fact that when heaters are supplied from a high-impedance source, changes in heater current have a much greater effect than do changes in voltage when the valves are supplied from a low-impedance source. Differential adjustment of the source impedance "seen" by pairs of heaters in balanced amplifiers can therefore be used to equalize the sensitivities of the heaters to supply variations. In the circuit diagram, adjustment of R_3 alters the source impedance. For example, with the slider in the extreme right-hand position, r_2 is connected directly across a transformer winding, and therefore "sees" a very low source impedance, while r_1 "sees" an impedance made up of R_1 in parallel with something in excess of R_3 . The left-hand valve is then supplied with heater power from a high-impedance source, so that it is affected more by power-supply variations than the

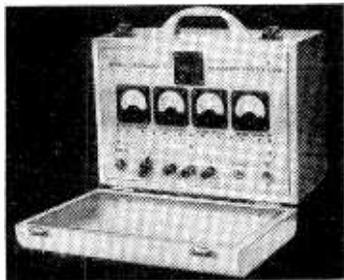


Left: Photocell-powered ohmmeter.

Above: Ultra-violet galvo recorder.

right-hand valve. By adjusting R_s , the sensitivities of the valves can be equalized.

Transistorized Timer recently introduced by Venner Electronics uses 46 transistors but has a consumption of only 1 watt at 12V. It is constructed from nine packaged stages and has a range of time measurement of 0.1msec to 27.8 hours. The basic time reference is a transistorized crystal oscillator operating at a frequency of 10kc/s. Pulses from this are passed via a gate to four decade counters, and thence to a mechanical counter. The division ratio given by the four decades is 10,000, so that the mechanical counter receives 1 pulse per second. The elapsed time can be read in seconds from the mechanical counter, with four decimal places taken from meters, calibrated 0-9, connected to the decades. The gating is arranged so that the open or closed times of contacts can be measured, or the time between one pair of contacts opening or closing and another pair opening or closing. Operation by



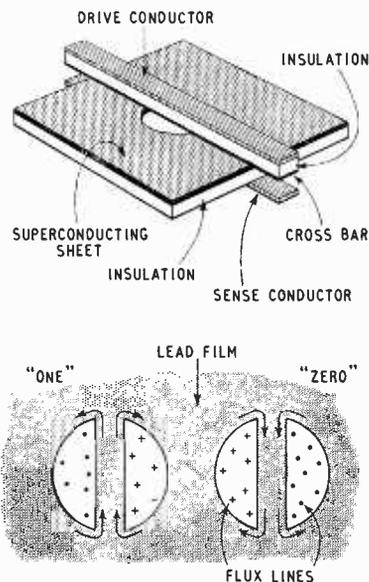
pulses is also catered for. Another timer has been developed by Venner for measuring the speed of road vehicles. This gives the time interval between the operation of two pressure switches which are actuated by the vehicle crossing two rubber tubes laid across the road at a known spacing. The switches open and close a gate which allows cycles of a 2.5-kc/s signal (obtained by frequency division from a 10-kc/s crystal oscillator) to be counted by three decades and displayed on three meters with digital scales. The frequency and rubber tube spacing are chosen so that the vehicle speed can be quickly calculated from the meter indication.

Helical Magnetization Patterns in magnetic wires, produced by the application of coincident circular and longitudinal fields, may provide the basis of a new kind of matrix store which is simpler and cheaper to manufacture than existing ferrite-core and magnetic-cell types. Exploratory work is being done by A. H. Bobeck at Bell Telephone Laboratories. The idea is that the matrix shall consist of arrays of vertical magnetic wires interwoven with horizontal copper

wires. Current passed through the magnetic wires produces the circular fields around them and current through the copper wires the longitudinal fields. The preferred direction of magnetization in the magnetic wires can be shifted from the normal longitudinal path to a helical path by mechanical torsion or perhaps eventually by processing during manufacture. The storing of a binary digit requires two coincident current pulses—one in a magnetic wire and the other in a copper wire. Reading out is accomplished by applying a strong longitudinal field in the reverse direction, and the read-out signal is detected across the magnetic wire. It is thought that at least 10 binary digits per inch could be stored without interaction on a magnetic wire formed by coating a conductor with magnetic material. Transistors could probably be used for the drive circuits.

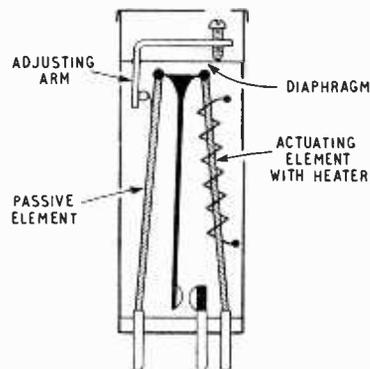
Integrated Tuning Assemblies giving a simultaneous change of capacitance and inductance are being developed by Plessey for u.h.f. tuners. They consist of variable capacitors with stators incorporating inductive loops. When the rotor (which has no connections made to it) is unmeshed from the stator it becomes in effect a short-circuited secondary coupled to the inductors, thereby reducing their inductance at the same time as the capacitance is reduced. This system has been known as a "butterfly" resonator in the past because of the particular shape of the rotor vanes.

Superconductive Storage Element devised by International Business Machines and mentioned in our November, 1957, issue (p. 547) depends on the magnetic flux produced by circulating currents induced in a superconductive lead sheet. (The superconducting condition being obtained by operation at extremely low temperatures below 10°K.) The lead film deposited on an insulator, has a hole cut in it with a lead bar metallized across. When a current pulse is sent through the drive conductor the resultant build-up of magnetic flux links with the superconductor and induces currents in it, as shown in the next column. These circulate indefinitely because of the zero resistance and set up their own magnetic flux. Whether a "1" or a "0" digit is stored is determined by the direction of the induced currents. Actually, the initial build-up of induced current is quite complex because the presence of a magnetic field affects the threshold of superconductivity and the induced magnetic field opposes the driving field. Reading-out is achieved by sending a current in the reverse direction along the drive conductor. This causes the induced currents to collapse, and the resultant change of magnetic flux induces a current pulse of one direction or the other in the sense conductor. An experi-



mental element described in the *IBM Journal of Research and Development* for October, 1957, is said to operate about 100 times faster than ferrite-core stores and to require less than a half of their driving current.

Thermal Delay Relay with greater rigidity and resistance to shock than conventional bi-metal strips has an actuating element which is fixed at both ends and expands longitudinally when its heater is energized. A simple mechanism (shown diagrammatically in the sketch) multiplies the difference in expansion between this element and a similar passive element so as to move the contact arm towards or away from the fixed contact. Ambient temperature changes expand the two elements equally and so do not move the contact arm. The time delay is set by the adjusting screw and arm, which determine the initial contact gap and consequently the time required for operation. Made by G.V. Controls, the relay is available from Mercia Enterprises in various types and ranges, with time delays from 0.5 to 180 seconds.



Starting Tape Driving Mechanisms*

MECHANICAL DESIGN TO AVOID LOOP FORMATION AND SNATCHING

IN magnetic recorders used for analogue signals (including broadcast programme material) the tape mechanism can be divided into three parts, the take-off or feed reel and tension device, the take-up reel and drive, and the drive capstan and pinch wheel.

Such a combination is shown in Fig. 1 in which the tape tension on the feed side of the capstan is provided by means of a reel motor connected to exert an anti-clockwise torque as viewed from above. Ideally, the operation should be that the reeling devices set the desired tape tension and that the capstan is concerned only with tape motion. Practical considerations, however, set limits to the extent to which

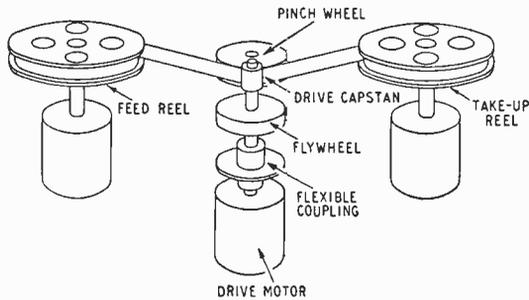


Fig. 1. Typical tape driving mechanism.

this ideal may be achieved, the most important being (a) the inertia of reels, reel motors and tape, and (b) the variation of the outside radius of the tape on the reels throughout the playing time.

Under running conditions the effect of the variation of the radius of the reeled tape may be minimized by using reel motors with suitable torque/speed characteristics, but the effects of inertia and of tape radius during the starting period cannot be modified without considerable elaboration of the mechanism. Consequently, it is difficult to avoid the formation of loops on the take-off side when the pinch wheel engages the tape with the rotating capstan. The formation of loops is generally followed by snatching as the take-up reel regains control. This irregularity of take-up tension can lead to undesirable effects such as uneven reeling, local stretching of the tape and, in bad cases, tearing.

Alternative Solutions.—One way of tackling the difficulty is to pass the tape through low-inertia "reservoirs" (e.g., vacuum boxes) on each side of the capstan and to control the reel motors by servo-mechanisms responsive to the position of the tape in each of the reservoirs. This method is often adopted if very fast start and stop times are required (e.g., for digital information in data processing equipment).

Another method is to tolerate the time required for acceleration of the reels and to engage the pinch wheel when the tape motion has reached its correct speed, i.e., when the tape speed is substantially equal to the peripheral speed of the capstan. While the tape

is being run up to full speed, it must be prevented from touching the capstan. It is also possible to engage the pinch wheel before energizing any of the motors, but the time required to reach steady speed conditions will then be unduly long because of the inertia of the capstan flywheel. If the drive motor is of the synchronous type, the settling time will again be increased. Fig. 1 shows a flexible coupling between the drive motor and the capstan flywheel; these form a mechanical low-pass filter. Transient oscillation in this coupling on starting can add further to the delay in reaching the steady state.

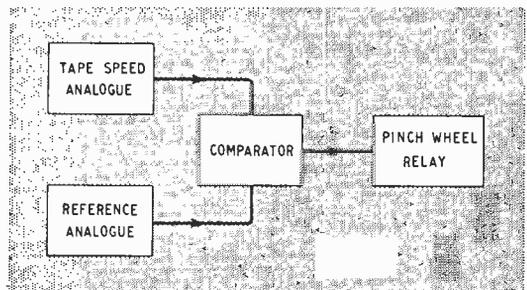
The following proposals make use of the second method suggested above, in which the acceleration time is tolerated, first, for the simple case where the desired tape speed has only one value and, secondly, for the more complex case where provision is made for more than one tape speed. In each case, the pinch wheel is actuated by an electromagnet, which is, in turn, energized via a relay. In each case, also, the tape speed is sensed by passing the tape over an auxiliary wheel, called a tape wheel, which has a speed-measuring device fitted to its spindle.

Single Speed Operation.—In the simple case, as shown in the block diagram of Fig. 2, it will be seen that an analogue of the speed is compared with a fixed reference, and when the difference drops below a threshold level, the relay is energized and the pinch wheel engages the tape with the capstan.

One convenient form of speed-measuring device consists of a magnet and an eddy current disc (or cup) such as are commonly used in indicating tachometers. One can imagine a tachometer, the hair spring of which is so biased that the needle is normally held against the zero stop until the speed reaches the required value. If the needle operates an electrical contact as soon as it moves away from the stop, a relay can be energized and this in turn can operate an electro-magnet which moves the pinch wheel to its operative position (Fig. 3).

Another speed-sensitive device which may be used is a tachogenerator, preferably of the permanent magnet type, arranged to give either a d.c. or an a.c. output. In either case, the output voltage is an analogue of the speed and, in the a.c. case, the frequency of the output is also an analogue of the speed.

Fig. 2. Basic principle of pinch wheel control.



* Communication from Telefunken G.m.b.H. via E.M.I. Ltd.

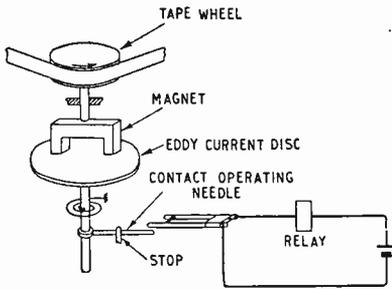
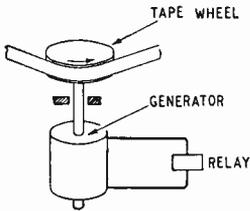


Fig. 3. Eddy current speed indicator.



left: Fig. 4. Tacho-generator for deriving speed analogue.

Right: Fig. 5. Parallel tuned circuit as a frequency sensitive relay shunt.

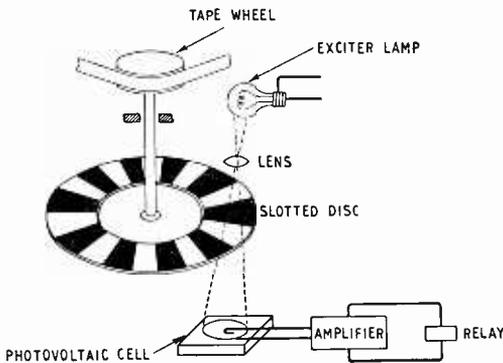
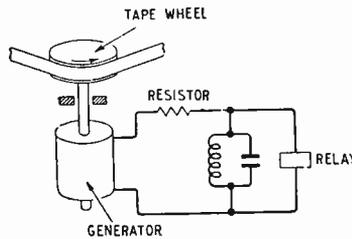


Fig. 6. Optical generation of speed analogue.

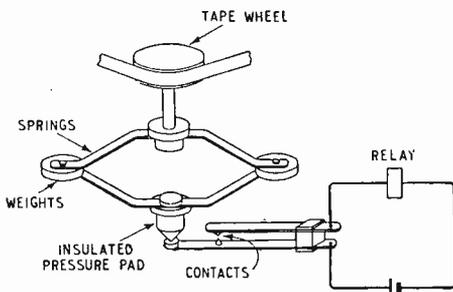


Fig. 7. Centrifugal switch.

A very straightforward embodiment of this principle, in which the speed analogue is the output voltage, uses the minimum value of operating current for the relay as a reference and so avoids the need for the separate reference shown in Fig. 2. Hence, all that is needed is to connect the generator direct to the relay but, in the a.c. case, a rectifier is necessary if the relay is not sensitive to a.c. (Fig. 4).

When the output frequency is used to provide an analogue of the speed, the resonant frequency of a parallel-tuned circuit may be used as a reference as shown in Fig. 5. At low tape speeds, the impedance of this circuit will be low compared with that of the series resistor, and the relay, which must be sensitive to a.c., is virtually short-circuited. However, as the speed approaches the required value, the effective impedance increases and eventually the relay becomes sufficiently energized to operate. A series resonant circuit can be used in much the same way, the internal inductance of the generator being tuned by a series capacitance.

It will be realized that each of the methods so far described involves loss of energy which is obtained from the tape driving motors, via the tape. The tape will experience a drag from this cause, in addition to that due to the inertia of the system. This may be obviated by the use of a more refined transducer which modulates an auxiliary power supply. Fig. 6 shows an example using this principle: power is supplied to the relay by light from an exciter lamp falling on a photovoltaic cell via a chopper, consisting of a low-weight slotted disc carried on the spindle of the tape wheel. The a.c. output from the cell is at a frequency which is an analogue of the speed. The reference may be a tuned circuit, of either the series or parallel type, as already described.

A centrifugal switch requiring a low operating torque and adding only a moderate inertia to the system may also be used. Fig. 7 shows a very useful form of this device in which two spring contacts are held apart by an insulated pad bearing on the lower spring. As the speed increases, centrifugal force acting on a pair of weights distorts the springs which carry the weights and relieves the pressure on the spring contact so that the pinch-wheel relay circuit is closed when the tape speed is correct. The frictional torque is very small because the load on the rotating parts is applied along the axis of rotation.

As the value of the speed analogue approaches that of the reference, the pressure of the operating contacts is at first so light that "chatter" is to be expected with each of the devices so far described. Therefore, the reference value must be so chosen that the pinch-wheel relay operates at a tape speed which is rather less than its final value, but not so much less that engagement of the pinch wheel causes the take-off tension to fall to zero. As the pinch wheel engages the tape, it is rapidly accelerated to full speed and the pressure of the operating contacts is thereby increased to a satisfactory value.

Multiple Speed Operation. Provision is often made for a choice of more than one speed, and accordingly the block diagram of Fig. 2 must be amended as shown in Fig. 8. It will be seen that the fixed reference must be replaced by a correct analogue of the capstan speed, assuming that the diameter of the capstan is not changed. If the capstan spindle speed is kept constant for both values of the tape speed by changing the capstan diameter, the fixed reference system remains suitable.

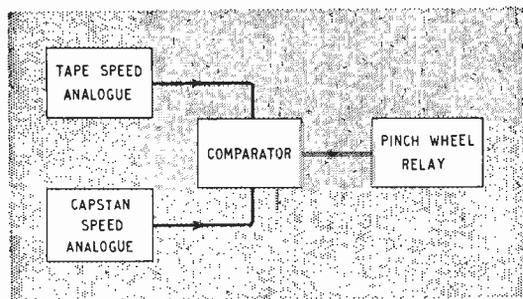


Fig. 8. Modified block diagram for multi-speed operation.

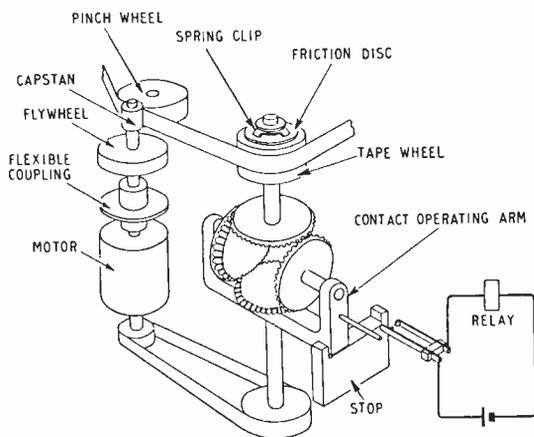


Fig. 9. Differential speed control of pinch wheel.

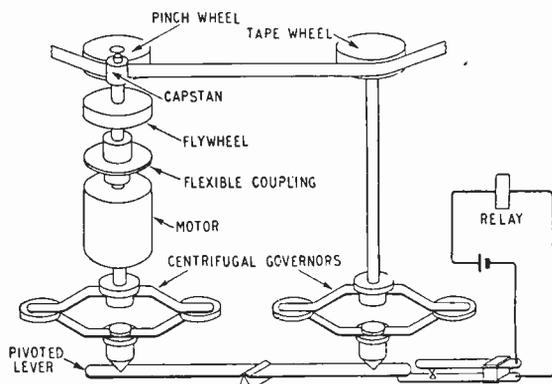


Fig. 10. Mechanical speed comparator.

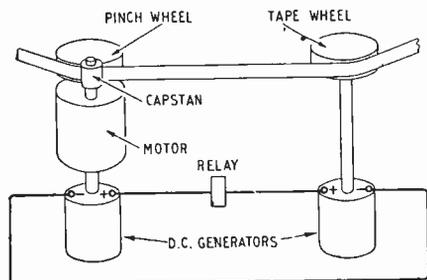


Fig. 11. Electrical speed comparator.

Because the input quantities are both of the same form, i.e. rotating spindles, a differential gear train is a suitable form of comparator, and an example of this is shown in Fig. 9. A simple differential will give an output speed proportional to the difference between its input speeds and an output torque equal to the difference between the input torques. The particular arrangement shown in Fig. 9 makes the speed difference zero and utilizes the torque difference to provide contact pressure. Accordingly, the difference between the capstan speed and the tape wheel speed is absorbed in a friction coupling, and it is the reversal of friction, which occurs when the latter speed overtakes the former, which causes the contact operating arm to move to its alternative position.

Several other mechanical systems designed on lines similar to that of Fig. 9, or closely related thereto, could be used but, since they all involve the use of slipping couplings, they cause drag on the tape wheel. These examples are by no means exhaustive and further devices, based on duplication of the simple schemes already discussed, are possible. For instance, a double version of the system shown in Fig. 7 could take the form shown in Fig. 10. The comparator then takes the form of a pivoted lever with the pressure pads of two centrifugal governors so arranged as to operate, one on each end of the lever.

The comparison may also be obtained electrically by duplicating the system of Fig. 4 as shown in Fig. 11. In this case, two d.c. generators are connected in series opposition to the pinch-wheel relay. When the tape wheel generator output equals that of the capstan generator, the current in the relay falls to zero, releases the armature and completes the circuit to the pinch-wheel magnet. Because the differential voltage becomes small, or vanishes, the drag on the tape under running conditions is low.

CLUB NEWS

Birmingham.—At the annual dinner of the Slade Radio Society the president, C. H. Young (G2AK), announced that 42 members had been enrolled during the year, bringing the membership to 112. The club meets on alternate Fridays at 7.45 at the Church House, High Street, Erdington. At the January 3rd meeting N. R. Nicholl (vice-chairman of the British Interplanetary Society) will speak on the instrumentation of space vehicles. Sec.: C. N. Smart, 110 Woolmore Road, Erdington, Birmingham, 23.

Bury.—The January meeting of the Bury Radio Society will be held at 8.0 on the 14th, when members will hold a debate on "Phone versus C.W." Meetings are held at the George Hotel, Kay Gardens. Sec.: L. Robinson, 56 Avondale Avenue, Bury, Lancs.

Prestatyn.—Meetings of the Flintshire Radio Society are held on the first Monday in each month at 7.30 at the Railway Hotel. Sec.: J. Thornton Lawrence (GW3JGA), Perran Porth, East Avenue, Prestatyn, Flint.

Rochdale.—A new club, to be known as the Roch Valley Radio Club, has been formed in the borough. Meetings are being held each Tuesday at 8.0 in the Windmill Hotel, Sudden. Enquiries to D. J. Power, 2 Clement Street, Rochdale, Lancs.

Wellingborough.—At the January 30th meeting of the Wellingborough and District Radio and Television Society, L. Parker (G5LP) will speak on "This DX Business." The club meets each Thursday at 7.30 at the Silver Street Club Room. Sec.: P. E. B. Butler, 84 Wellingborough Road, Rushden, Northants.

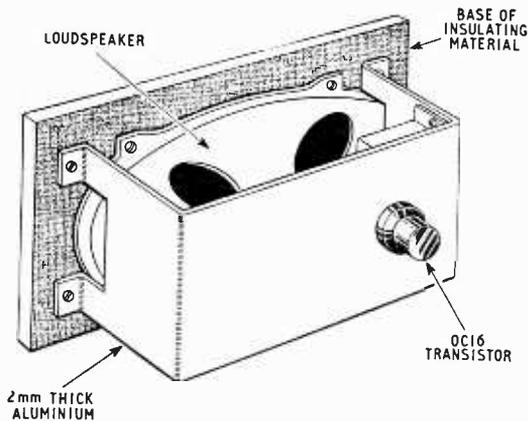


Fig. 1. Heat sink and output stage assembly.

HYBRID CIRCUIT FOR 12-VOLT OPERATION WITH TRANSISTOR OUTPUT

By J. C. BECKLEY,* B.Sc.(Eng.)

Car Radio Receiver Design

IT has been appreciated for many years that it is possible to obtain acceptable performance, in terms of voltage gain, from thermionic valves operated with low anode voltages such as are available from car batteries. However, it is not possible to obtain from a practical valve operating at low anode voltage anything like sufficient audio output power to drive a loudspeaker. Consequently, until quite recently, all car radio receivers and similar mobile equipment have incorporated standard mains valves and a vibrator, or d.c. convertor, to provide a high line-voltage.

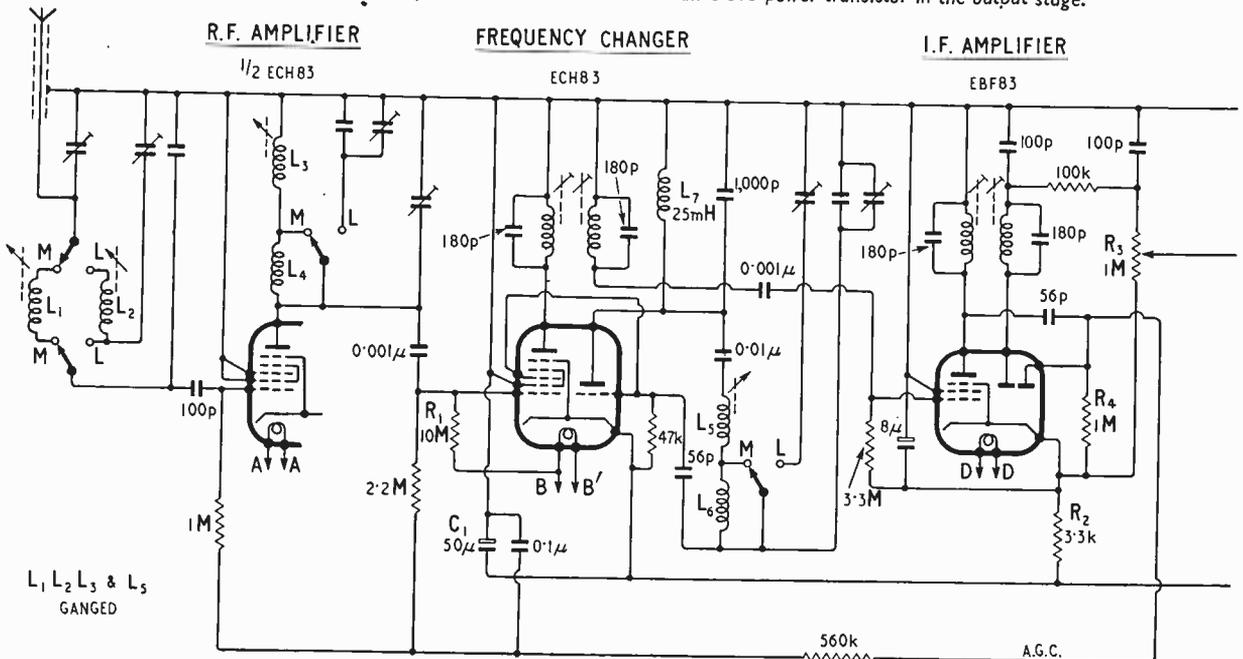
The recently introduced power transistor is an excellent solution to the output power problem,

because a suitable transistor with a 12-V supply can provide several watts output. Many of the present types of mains valve give a useful performance with an h.t. of only 12V, but a new range of valves specially designed for this application is now available.

A hybrid design for a car radio has a number of distinct advantages over all-valve and all-transistor receivers. The present cost of transistors makes an all-transistor receiver for this particular application expensive, but a relatively inexpensive hybrid receiver may be designed employing four valves plus one power transistor. The great superiority of the

*Mullard Ltd.

Fig. 2. Theoretical circuit of the hybrid car radio receiver with an OC16 power transistor in the output stage.



hybrid receiver is that the vibrator h.t. supply is dispensed with. Speaking generally, both the transistor and the valve have much longer working lives than the vibrator, and the potential reliability afforded by the hybrid design is therefore very much greater. Vibrator supplies usually involve an expensive transformer and, also, careful filtering of the d.c. output is necessary to avoid introducing interference from the vibrator. The characteristics of the new valves permit the design of receivers having the same performance as those equipped with normal h.t. operated types, so that nothing is sacrificed by omitting the vibrator pack. Moreover, the current drain of the hybrid receiver is about two or three times less than that of a conventional car radio.

A 12-V car radio receiver is described here for medium- and long-wave operation and it is designed around a normal production car radio tuning unit incorporating permeability tuned aerial, r.f., and oscillator circuits. The output stage is constructed as a separate unit mounted with the loudspeaker.

The new range of valves for application in hybrid receivers are the Mullard ECH83, EBF83, and EF98. The ECH83 is a frequency converter of the well-known triode-heptode type. The ECH83 heptode section is also applied as r.f. amplifier and the triode section as a.f. voltage amplifier. The EBF83 is a double-diode pentode and combines the functions of i.f. amplification, detection and a.g.c. The EF98 is a straight pentode which has been designed to provide sufficient power output (a few milliwatts) to drive the transistorized output stage.

The output transistor is the Mullard OC16 power transistor, which can be operated at a high value of collector dissipation providing an output of about 2.5W.

Receiver Design.—The audio output obtainable with a single OC16 is considered to be sufficient for normal purposes. Push-pull operation has not

been considered here because this design is intended to apply to an inexpensive receiver.

The quality of a car radio depends to a large extent upon the effectiveness of the a.g.c. since rapid and intensive variations of field strength may occur when the car is moving. In the hybrid car radio with a low anode supply voltage the control voltage is obviously small. In order to obtain effective control, therefore, the grid base of the controlled valves is kept small. In this receiver a.g.c. is applied to the r.f. and mixer valves only. No a.g.c. is applied to the i.f. valve as this would reduce the available control voltage.

The r.f., mixer and i.f. stages are operated with grid current bias. The values of grid leak chosen are a compromise between circuit damping and valve operating slope. The valves in the above stages have a high internal impedance ($>500k\Omega$) so that normal r.f. coils and i.f. transformers are employed. The oscillator drive voltage required by the ECH83 mixer is much less than the value required for this type of mixer operating at high anode voltage. Thus, normal, medium- and long-wave permeability tuned oscillator coils may be used in the hybrid receiver, although the effective slope of the ECH83 oscillator section is not as high as ordinary types.

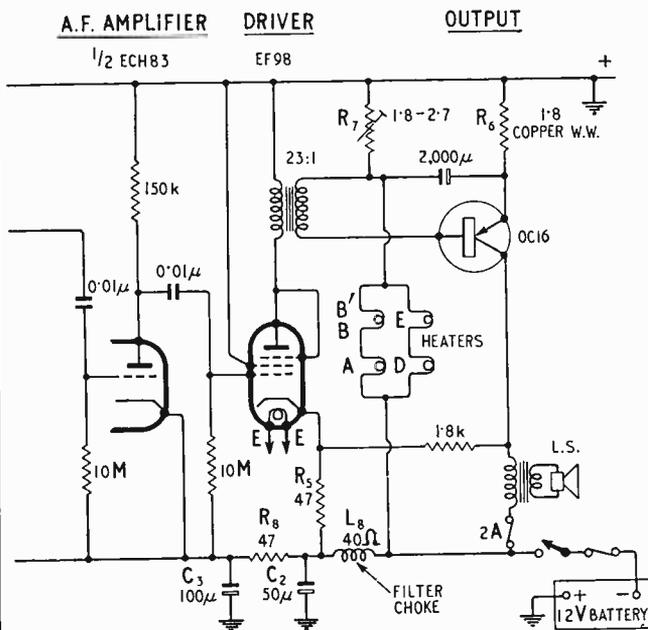
The Output Stage.—In order to obtain sufficient power output from the single OC16 (about 2.5W), it is necessary to operate the transistor at a high collector dissipation. The junction temperature must be limited by the use of an efficient heat sink. Fig. 1 shows the arrangement employed; the OC16 is mounted directly on 2-mm thick aluminium bracket approximately 300 sq cms in area. The transformers associated with the output stage are also mounted on the heat sink. The case of the OC16 is connected to the collector, the heat sink is therefore at collector potential and must be insulated from the main chassis.

The terminal voltage of a car battery varies considerably due to variations of load and charge conditions. A battery of nominal 12V is reckoned to have an average voltage of 14V and a possible maximum of 15V. Hence, the output stage is designed for a normal voltage of 14V and safe operation at 15V.

The circuit is designed for continuous operation at ambient temperatures up to 45°C. At 45°C the junction temperature does not exceed 75°C, the normal limit mentioned in published data. Operation at junction temperatures up to 90°C is possible for short periods (life expectancy at junction temperature of 90°C is greater than 200 hours) without serious effect upon the transistor. This allows occasional operation at ambient temperatures up to 60°C. The circuit is safe from thermal runaway at a battery voltage of 15 and junction temperature of 90°C.

Circuit Description.—The circuit of the receiver, which is shown in Fig. 2, is designed to permit direct connection to a car chassis; the positive line is therefore earthed.

The tuning unit provides separately tuned aerial circuits, L_1 and L_2 , for medium and long waves and a single tuned r.f. coil, L_3 , with an additional loading coil, L_4 , for long waves. The input circuits are designed to match a low-capacitance aerial. The r.f. amplifier is the heptode section of an ECH83 and is operated with grids 2, 3, and 4 at h.t. potential. The valve has a grid leak of about $1.5M\Omega$ taken to



a point 1.5V positive with respect to the cathode.

The ECH83 is operated as a multipliative mixer with a Colpitts oscillator. The oscillator circuit incorporates a single tuned coil, L_5 , for medium-wave operation, an additional loading coil, L_6 , being switched into circuit for long waves. The triode anode is connected to h.t. positive *via* a choke, L_7 , which involves negligible d.c. voltage drop, but provides sufficient inductance to avoid restricting the normal frequency swing of the oscillator. An inductance of about 25mH is adequate for this receiver. The mixer section is operated with a grid leak of about $2.5M\Omega$ connected to 1.5V positive. An additional positive bias is applied to the grid *via* a $10-M\Omega$ resistor taken to the plus 6V point on the heater chain.

The EBF83 is grid-current biased by a $3.3-M\Omega$ resistor returned to the cathode. A resistor, R_2 , in the cathode circuit provides the positive voltage which is applied to the grid resistors of the r.f. and mixer stages. No a.g.c. is applied to this stage.

Detector and a.g.c. diode loads, R_3 and R_4 are returned to the EBF83 cathode. The detector load, R_3 , is used as the volume control. The a.g.c. voltage is derived from the anode of the i.f. valve and is delayed by the positive voltage across the cathode resistor, further delay being applied to the mixer valve by the $10-M\Omega$ resistor, R_1 , taken to plus 6V. In this way the control characteristics of the r.f. and mixer valves are lined up to give optimum signal handling.

Standard medium-impedance 470-kc/s i.f. transformers are used in this receiver.

The detector output is fed into the triode section of the first ECH83. The triode is biased by grid current with $R_{g1}=10M\Omega$. It functions as an a.f. voltage amplifier.

The EF98 a.f. driver stage is operated as a tetrode with g_3 connected to the anode. The output is transformer-coupled to the output stage. A low value resistor, R_5 , is included in the cathode circuit across which negative feedback is applied from the output stage.

Output Stage.—The OC16 transistor is used in the earthed-emitter mode with a series emitter resistance R_6 . Base bias is derived from a resistor R_7 in series with the heaters of the valves. The non-linear voltage-current characteristic of the heaters, decreases the effect of battery voltage varia-

tions on the bias voltage. A resistor of about 2Ω is required in the heater circuit in any case to drop the voltage across the heaters to about 12.6V with a nominal battery voltage of 14V. The low value of base bias resistance, and the use of an emitter resistor wound with copper wire (which has a small positive temperature coefficient), give effective stabilization of collector current with temperature. A fuse is included in the collector supply as protection against accidental short circuits between the heat sink, which is at collector potential, and the chassis.

Matching Driver Valve to Transistor.—As the input characteristic of the transistor is non-linear, the reflected load on the driver valve is similar. The performance of valves is generally expressed in relation to resistance loads, therefore it is necessary to determine a resistance load equivalent of the transistor input characteristic. Fig. 3 shows dia-

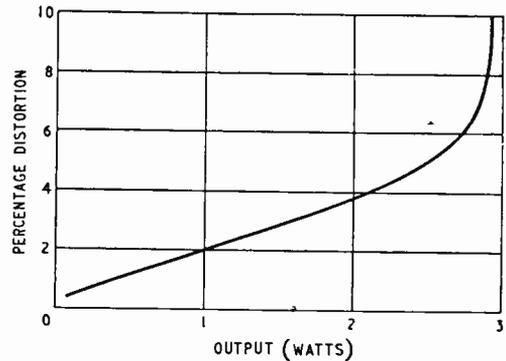


Fig. 4. Relationship between power output and distortion for OC16 transistor.

grammatically how the load line of a low-limit transistor appears on the EF98 V_a/I_a curves. Low-gain transistors generally have a low input impedance, thus the matching transformer ratio is chosen so that maximum power is available from the valve to drive low-impedance transistors. However, the optimum ratio is a compromise between perfect impedance matching and the primary inductance obtainable in an acceptable size transformer.

It is important that the matching transformer is phased so that increase of collector current corresponds to increase of anode current. This enables

maximum power to be obtained from the valve and also helps to minimize second harmonic by partial cancellation of that generated in the valve and transistor.

Negative Feedback.—As previously mentioned negative feedback voltage from the OC16 collector is applied across a resistor, R_5 , in the cathode circuit of the EF98. The feedback does not increase the drive requirements of the transistor. In addition to decreasing the distortion, the gain spread of the output stage, due to the relatively large spread of transistor characteristics, is considerably reduced by the application of feedback.

(Continued on page 39)

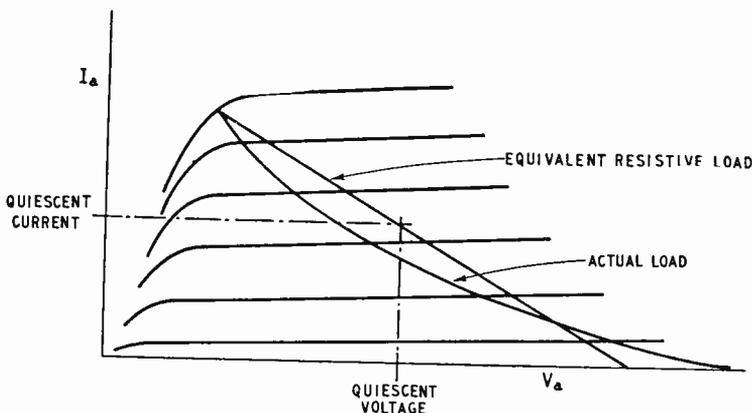


Fig. 3. Reflected load lines of output transistor on V_a/I_a curves of EF98 driver valve.

The negative supply to the valves' cathodes is filtered by an r.f. choke, L_8 , of about 40Ω d.c. resistance. The transistor supply is taken directly from the battery.

Decoupling of individual stages was not found necessary in this receiver. The choke L_8 , together with a total capacitance of $100\mu\text{F}$, C_1 and C_2 , across the valve supply will generally provide sufficient decoupling, but if it should prove inadequate R_8 and C_3 may be included.

Receiver Performance.—(i). *R.F. Stage (ECH83 heptode section).*—The measured r.f. gain at several frequencies is given in Table 1 together with the r.f. circuit impedance.

(ii). *Mixer Stage (ECH83).*—Measured conversion gain at $1\text{Mc/s} = 17$ times. I.F. transformer transfer impedance = $87\text{k}\Omega$. Conversion slope of ECH83 $\approx 200\text{mA/volt}$. Measured oscillator grid voltage = 1.0 to 1.5V rms.

(iii). *I.F. Amplifier (EBF83).*—Measured gain at $470\text{kc/s} = 52$ times. I.F. transformer transfer impedance = $55\text{k}\Omega$. EBF83 operating slope = 0.95mA/volt .

(iv). *A.F. Voltage Amplifier (ECH83 triode section).*—Measured gain at $1,000\text{c/s} = 6$ times. Output voltage for 5% distortion = 1.8V rms.

(v). *Driver Stage (EF98).*—The optimum load of the EF98 operating with $V_a + g_3 = 12.0\text{V}$ and $V_{g2} = 12.6\text{V}$ is $4.5\text{k}\Omega$. The valve is grid current biased with $R_{g1} = 10\text{M}\Omega$. Under these conditions a maximum power output of 13mW is obtained for 10% distortion.

Table 2 gives the EF98 input voltage required to drive the output transistor to full output and also for 1W output. Sensitivities are quoted for both average and low-limit gain transistors.

(vi). *Output Stage.*—

(a) *Heat Sink.*—The arrangement of Fig. 1 gave a total thermal resistance of 4.5°C/watt when tested in the laboratory. However, as the thermal resistance would vary, depending on the circulation of air and other local conditions, it is important to measure the thermal resistance under actual working conditions. A total thermal resistance of 4.5°C/watt (or less) under working conditions is essential for operation of the OC16 at the conditions mentioned here.

(b) *OC16 Operating Requirements.*—

Supply voltage = 14V.

Collector current = 475mA (Preset by R_7).

Collector dissipation = 6.6W (25°C to 45°C).

Collector load = 25Ω .

Base Voltage = 1.14V to 1.37V.

Base current = 6mA to 30mA.

Output power = 2.4W at start of clipping. (Into transformer primary) 2.9W at 10% distortion.

(Fig. 4 shows the variation of distortion with transistor output power.)

Overall Receiver Performance.—

Heater Chain $\approx 1.1\text{A}$ at 14V.

Measured Sensitivity.—Sensitivity figures are quoted for an a.f. output of 1 watt with an average transistor and a modulation depth of 30%. (See Table 3).

I.F. Selectivity.—The overall i.f. response is approximately 7kc/s for 6dB down.

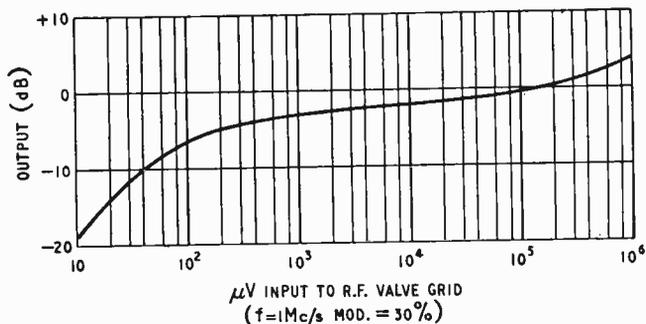


Fig. 5. A.G.C. characteristic of the receiver.

A.G.C. Performance (See Fig. 5).—The a.g.c. curve shows that a delay is maintained up to an input of about $100\mu\text{V}$ at the grid of the r.f. valve. The maximum signal handling of the receiver corresponds to an input of approximately one volt at the r.f. valve grid.

The receiver was tried in a modern car and no difficulty was experienced with interference from the dynamo or ignition system. It is possible that as the receiver has valve cathodes floating, interference may be introduced from the heaters. In this case it may be necessary to filter the heater supply by inserting a low resistance choke in series with the resistor R_7 .

TABLE 1

Frequency	Circuit Impedance	Gain*
1,000kc/s	$67\text{k}\Omega$	55 times
1,400kc/s	$48\text{k}\Omega$	40 "
600kc/s	$92\text{k}\Omega$	76 "
200kc/s	$37\text{k}\Omega$	31 "

* Measured from r.f. valve grid to mixer grid. The above values of gain correspond to a valve slope of approximately 0.83mA/V .

TABLE 2

	Low-gain transistor	Average transistor
Input for 10% distortion in transistor output ...	1.0V rms	0.6V rms
Input for 1 watt output from transistor ...	0.6V rms	0.36V rms

TABLE 3

Frequency	Aerial Input*	R.F. Valve Grid Input
1,400kc/s	$1.5\mu\text{V}$	$10\mu\text{V}$
1,000kc/s	$1.0\mu\text{V}$	$7\mu\text{V}$
600kc/s	$1.0\mu\text{V}$	$4\mu\text{V}$
200kc/s	$3.0\mu\text{V}$	$12.5\mu\text{V}$

* Measurements of the aerial sensitivity were made with a 47-pF capacitor between the signal generator and the aerial input.

The receiver covers the medium and long wavebands only. It has been found that short-wave operation is possible if capacitive tuning is employed.

The results obtained with the hybrid receiver proved highly successful and very promising, not

only for car radios, but also for the future development of other mobile communication equipment fed from a low-voltage supply source.

The author is indebted to L. H. Light for the design of the output stage, and for his advice in the preparation of this article.

A PICKUP TO TRACK AT 2 GRAMS

THE design of barium titanate transducer pickups with tracking weights of two grams or less was described at the 1957 I.R.E. National Convention by W. E. Glenn of the G.E. Company of America.

A sketch of the cartridge is shown in Fig. 1. The 2-mil barium titanate sheet is fastened on one side to a stainless steel wedge. Thus, if this wedge is bent, it will strain the barium titanate and so generate a voltage between its surfaces. The 7-mil diameter 20-mil long diamond or sapphire stylus is force-fitted into a hole in the 0.7-mil stainless steel quill-shaped tip, and further secured with a small drop of Araldite cement.

The cartridge is attached to the arm by butyl rubber to allow it to retract before the cartridge or record can be damaged if the pickup is dropped. The vertical bearing of the arm contains grease which damps the low-frequency resonance between the stylus compliance and arm mass, and also renders the pickup less susceptible to external vibration. The moment of inertia of the arm is reduced by the

same factor as the tracking weight to secure the same stability with warped records as for a standard arm.

The small section of the vertical wedge between the

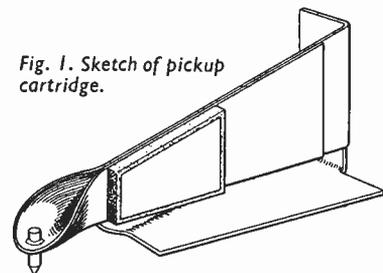


Fig. 1. Sketch of pickup cartridge.

the quill and barium titanate provides the lateral stylus compliance. The thickness of the quill is chosen so that the vertical compliance is about one-fifth of this. Vertical motion of the stylus does not produce any output because of the lateral symmetry of the quill.

The upper frequency of resonance f between the effective mass at the stylus tip and the groove wall and stylus compliance is proportional to t/L^2 , where t is the wedge thickness and L the wedge length. The charge Q developed across the barium titanate is proportional to FL^2/t^2 where F is the flexing force. For a given resonance frequency f and tracking weight (which fixes F), this becomes $Q \propto f/t$. Thus to secure the maximum possible output, t is made as small as possible, and L then chosen to give a suitably high resonance frequency f . To avoid the necessity for an input resistance of more than $1M\Omega$ the capacity of the barium titanate element is made about 1000 pF by choosing a suitable width.

Cartridges with different stylus compliances corresponding to tracking weights from $\frac{1}{2}$ to 2 gm. have been made. The effective mass at the stylus tip for the 2-gm version is 0.1 mgm. The output after

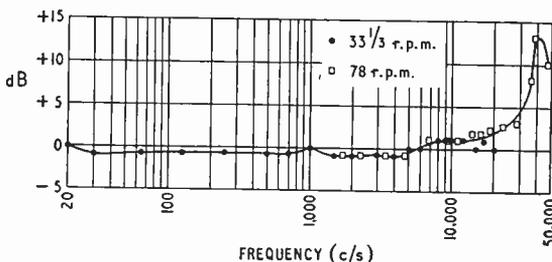
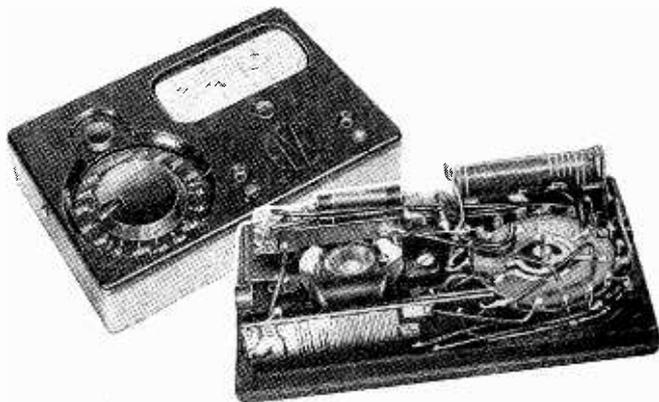


Fig. 2. Frequency response with Cook 10-LP record.

compensation to the R.I.A.A. frequency characteristic is about 40 mV. The frequency response using a Cook 10-LP record run at $33\frac{1}{3}$ and 78 r.p.m. is shown in Fig. 2, from which it is seen that the upper resonance frequency is about 40 kc/s.

New Avo Multiminor

THIS new 19-range instrument has a maximum d.c. current sensitivity of $100\mu\text{A}$ f.s.d. The meter series impedances are $10,000\Omega/\text{V}$ and $1,000\Omega/\text{V}$ for the seven d.c. and five a.c. voltage ranges respectively. Potentials up to 1,000 V a.c. or d.c. can be measured. Two resistance ranges (0 to $20\text{ k}\Omega$ or 0 to $2M\Omega$) are provided, using an internal $1\frac{1}{2}\text{-V}$ U12 cell with an adjustment to compensate for ageing. The full-scale error does not exceed 4%. Ranges are selected by a high-quality rotating switch, the 18 fixed silver-plated contacts being wiped by a double contact arm. Some of the resistors are printed; one on a switch-plate forming an integral part of the selector switch mechanism, and another forming the universal meter shunt. Two models at the same price of £9 10s are available, one for use in very humid climates. The address of the manufacturers is 92-96, Vauxhall Bridge Road, London, S.W.1.

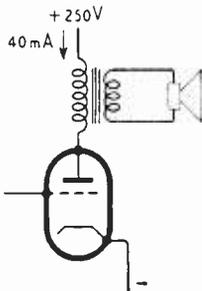


Valves, Transistors and Efficiencies

By "CATHODE RAY"

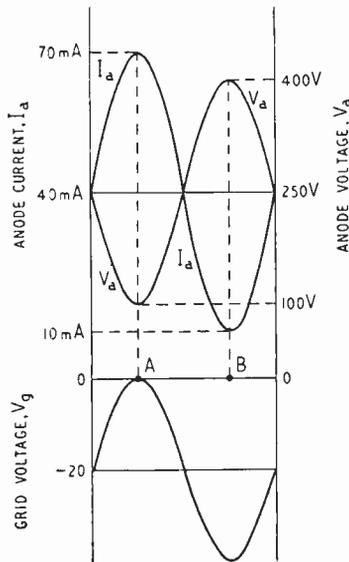
ONE of the little puzzles for the beginner is how it can be that a valve (or transistor) is heated less by a given number of watts put into it when it is working hard than when it isn't working at all. This is so contrary to our own experience, which is that the harder we work (physically) the hotter we get.

Take for example an audio output stage driving a loudspeaker, as in Fig. 1. Suppose it is receiving 40mA at 250V. That, of course, is an input power of $250 \times 40/1000 = 10$ watts. If the grid is receiving no signal, so that the anode current is pure d.c., the whole of this 10W goes into the valve, which is heated accordingly. But if now the grid is made



Above: Fig. 1. If a constant d.c. power is supplied, why does the valve's share become less when the grid is made alternately more negative and positive?

Right: Fig. 2. Variations of current and voltage in a typical example of Fig. 1 during one whole cycle.



alternately more positive and negative at audio frequency (and assuming for simplicity that the valve's characteristic curves are perfectly straight over the parts concerned, so that there is no distortion) the average anode current and voltage are just the same as before, yet some of the 10W of power is going into the loudspeaker. So the power going into the valve is that much less and it doesn't get so hot.

Fig. 2 shows the sort of thing that is happening during one cycle of the a.f. signal. The sine wave at the bottom represents the grid voltage being swung above and below a $-20V$ bias level. The anode current I_a increases and decreases in time with it, with an amplitude (shall we say) of 30mA, that it touches 70mA at maximum (A) and drops to 10mA at minimum (B). Suppose the impedance of the load at the frequency concerned is $5k\Omega$, purely resistive. Then when the anode current rises by 30mA there is a drop of $30 \times 5 = 150V$ across the load, so the voltage at the anode falls by that amount to 100V. Similarly at the current

minimum it rises to 400V, as shown in Fig. 2. As we see, the average current through the valve is the same as when there is no alternation, and this goes too for the voltage across it. Why, then, is there less power being dissipated as heat in the valve?

We can get a clue if we calculate the power at various phases, say for a start the peak points A and B. At A the power going into the valve is $100 \times 70/1000 = 7$ watts, and at B it is $400 \times 10/1000 = 4$ watts. If the signal swing were sufficient to reduce either I_a or V_a to zero, then obviously the power into the valve at those instants would be zero, no matter how large the other factor might be. The aim, then, is to make either factor—current or voltage—as near zero as possible while the other is high.

The average power during each whole cycle can most easily be found by reckoning how much is going into the load and deducting that from the total supplied—10W. The power in a resistance load is of course equal to the product of the r.m.s. values of current through and voltage across it. With a sine wave the r.m.s. value is equal to the peak value divided by $\sqrt{2}$. So in our example the power is $150 \times 30/1000 \div 2 = 2.25W$. The valve dissipation is thus reduced from 10W to 7.75W. And the efficiency (useful power \div power supplied) is 0.225, or 22½%.

This, incidentally, though not an impressively high figure, is pretty good going for a triode, if there is to be only moderate distortion. But why be content with this; why not drive it harder, so that both I_a and V_a touch zero at the peak minima, the load resistance being adjusted to make this possible? The answer is provided by the I_a/V_a characteristic curves (Fig. 3), which are essential for finding out the best working conditions. Even although the triode curves here shown are somewhat idealized (I have never seen such good ones

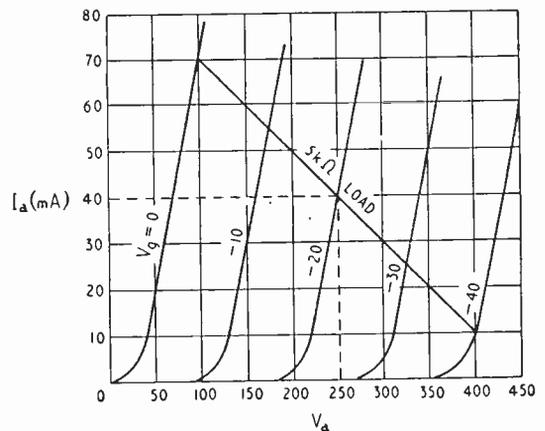


Fig. 3. Rather better than lifelike triode characteristic curves with "load line" corresponding to Fig. 2.

belonging to any real triode) it is clear that the power that can be put into the 5kΩ load—or indeed any load resistance—could not be materially increased without encroaching into the positive grid-voltage region or the bottom bend region, both of which would cause a quick rise in distortion.

The " $V_g=0$ " curve is a particularly irksome restriction, because it prevents us from getting V_a down to anywhere near zero. This is one reason for the popularity of pentodes and kinkless tetrodes, whose curves have shapes that allow wider voltage swings (Fig. 4). Even so, in valves of the 10W order there is usually a useless minimum voltage of at least 50V.

Transistors present a much more attractive picture in this respect. Fig. 5 shows a typical set of I_c/V_c curves, which are spaced beautifully evenly and have a useless minimum of only about 0.2V! Even allowing for the working V_c being much lower than the corresponding V_a , this is a vast improvement. It is so near perfection that there is more than merely academic interest in enquiring into the efficiency of a perfect output stage—one in which both current and voltage touch zero. Fig. 6

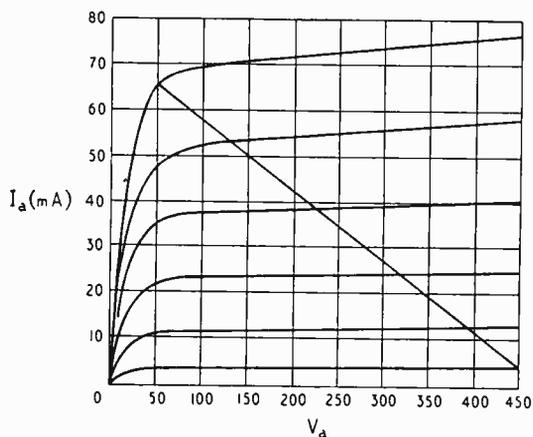


Fig. 4. Typical tetrode or pentode curves for comparison with Fig. 3, showing reason for higher power efficiency.

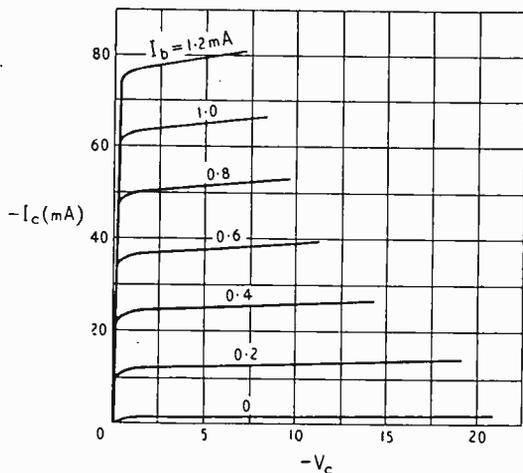


Fig. 5. Typical transistor curves, showing reason for still higher efficiency.

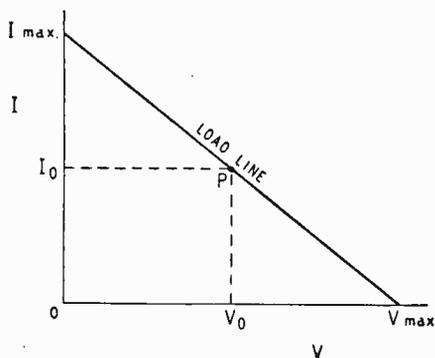


Fig. 6. Load line for an ideal output amplifier, restricted only by inability of current and voltage to be negative.

shows the load line in such a case. Current and voltage swing up and down from the working point P. For equal swings in both directions, obviously $I_{max}=2I_0$ and $V_{max}=2V_0$. The output power, calculated as before, is thus $I_0 V_0/2$; and the input is $I_0 V_0$. So the efficiency is exactly 50%.

That is for "Class A" amplification, in which the power fed in is the same for all amplitudes, because current and voltage swing equally up and down so that their averages are constant. If the efficiency is to be raised any higher, severe distortion is unavoidable, because even in this perfect device the current and voltage are assumed not to be able to go less than zero. That may seem to bar the way to even tolerable a.f. reproduction, let alone "hi fi." But what can be done is to amputate one half of every cycle completely, because that kind of distortion enables the efficiency to be increased very substantially, and although the distortion is drastic it can be put right by simultaneously amplifying the other half of each cycle and bringing the separate halves together into whole cycles. The method of doing this is known as "Class B" push-pull, and as we are at the moment considering only the power efficiency aspect I must assume you know all about the actual method. In essence it consists in adjusting the bias so that instead of the current starting from the half-way mark (I_0 in Fig. 6) it starts from zero. So the voltage starts at maximum and works downwards.

These conditions are shown for the working half-cycle in Fig. 7. The r.m.s. current through the load (as well as through the valve) is $I_{max}/\sqrt{2}$, and the r.m.s. voltage across the load is equal to V_{max} minus the voltage across the valve, so is $V_{max}/\sqrt{2}$. The output power is the product of these, namely, $I_{max} V_{max}/2$. The input power is equal to the product of the supply voltage (assumed constant) and the average current, which for a half sine wave is $2I_{max}/\pi$; result, $2I_{max} V_{max}/\pi$. So the efficiency is $I_{max} V_{max}/2 \div 2I_{max} V_{max}/\pi = \pi/4 = 78\frac{1}{2}\%$. During the second half cycle of this half of the amplifier there is zero current all the time, consequently no power at all; but the other half of the amplifier is doing its 78½%, so that is the theoretical efficiency of the whole output stage.

At the present time, the power that a transistor

(Continued on page 43)

can safely dissipate is its most serious limitation as far as a.f. amplification is concerned, so this matter of efficiency is particularly important. Suppose the maximum rated dissipation for a particular type is 0.25W. Then with Class A amplification the maximum theoretical sine-wave output (the efficiency being 50%) is also 0.25W. But in Class B only $100 - 78\frac{1}{2}\% = 21\frac{1}{2}\%$ of the power put in is dissipated in the transistor, so the output is $0.25 \times 78\frac{1}{2}/21\frac{1}{2} = 0.91W$ —nearly four times as much as in Class A.

So much for sine waves; what about square waves? For them, r.m.s. and average and peak current are all the same and could therefore all be equal to I_{max} . The voltage across the load—the output voltage—could be V_{max} throughout the half-cycle, and consequently the voltage across the valve would be zero all the time. This last fact is enough to establish that the efficiency would be 100%. In practice, of course, such a figure is unobtainable. As Fig. 5 shows, even a transistor has a certain minimum collector current (which increases steeply with temperature) at one end of the load line, and a minimum collector voltage at the other end. And then there is base current. But efficiencies over 90% are possible, so a very small transistor can generate quite a lot of square-wave power.

One aspect of this is that a transistor output stage would not (as one might have thought) be overheated by turning up the volume excessively far. On the contrary it would run cooler, because the sound programme would be distorted into approximate square waves, resulting in exceptional efficiency (regardless of the unprintable thoughts of any hi-fi exponents within earshot!)

Transistor D.C. Converters

Another aspect is the remarkably high performance of transistor d.c. converters. These are d.c. voltage raisers working on the same principle as the vibrator systems used for supplying power to car radio, except that they do the job electronically instead of mechanically. This is not the cue for an exhaustive treatise on these devices, but for the sake of any who are totally unacquainted with them (I did begin this time with beginners) I will explain the general idea.

When current is made to flow through an inductor (which is the thing you call a coil) a certain amount of energy is stored in it. Before the current can be stopped, that energy must somehow be released. This can be demonstrated with apparatus represented by the simple circuit diagram, Fig. 8. It consists of a car battery (or such like) and a coil with a large number of henries—say a winding on a large transformer. When the connection is made, energy is built up and stored in the magnetic field. The current may take several seconds to reach nearly its full value. Then break the circuit. But take care not to hold the wires in your bare hands, for I have no desire to be the defendant in a case of manslaughter. The release of energy much faster than it was built up makes it break out as a high voltage across the newly formed gap, resulting in a spectacular spark, far exceeding what one would get if an equal but non-inductive resistance were substituted for the coil.

In d.c. converters this relatively high voltage (which can be stepped up still further by means of a

secondary winding on the core) is brought under control and rendered useful by adding a rectifier and reservoir capacitor, as in Fig. 9. The rectifier is connected in such a way that it prevents any current passing through it from the battery. But the voltage induced by L at "break" is in the opposite polarity, so finds it easier to send current through the rectifier to charge C than to put on a show of fireworks at the switch contacts.

Obviously, if one is to be able to draw a continuous flow of current from C it is necessary to replenish it at frequent intervals by turning the switch on and off. In vibrator units the switch is a mechanical one, operating on the same principle as an electric bell. The rate of replenishment cannot in practice be much more than about 100 c/s or its hum would be too audible and its rate of wear excessive. Besides acoustic noise to be muffled, its electrical noise has to be suppressed.

A valve oscillator could be used, but a valve is an inefficient switch. Even although in this role the question of distortion does not arise, so that a complete "off" can be obtained by using sufficient negative grid voltage, no amount of positive grid voltage achieves a complete "on"—the valve's resistance is always substantially more than none. And if the grid is driven positive it, too, uses up quite a bit of power.

But a transistor, as we have seen, is at its best when working as a switch. By means of a feedback winding on the transformer it can be made into a blocking oscillator, which in effect turns itself on and off at almost any desired frequency. Because it can replenish C many times faster than a vibrator, it has only a small fraction as much power to handle during each cycle. Even at that rate it is completely silent and hardly wears out at all. I am assured that the overall efficiency—which takes account of losses in the transformer as well as the transistor—can be

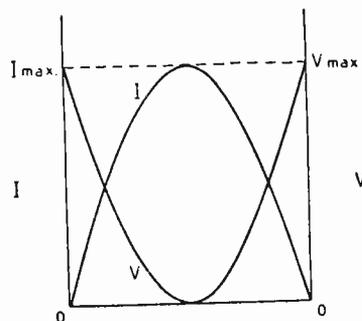


Fig. 7. Current and voltage conditions during the working half-cycle in an ideal Class B amplifier.

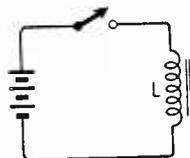
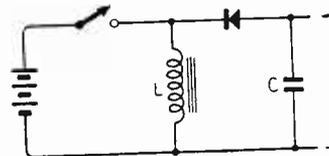


Fig. 8. The basic principle of vibrator and transistor d.c. converters or voltage raisers is the alternate storage and discharge of energy in the form of a magnetic field.

Fig. 9. If the inductive energy in Fig. 8 is transferred periodically to a capacitor it is available for drawing off continuously.



as high as 85%, but even the less efficient specimens seem to be much better than vibrators. So it looks as if the vibrator is doomed to extinction.

The transistor d.c. converter is more adaptable, too. It can be used to generate very small amounts of power, for which a vibrator would be clumsy. I very much doubt whether a vibrator would be satisfactory for running an oscilloscope from a low-voltage battery, but visitors to recent exhibitions have seen an all-transistor oscilloscope demonstrated. I suspect, too, that transistors are or will be in brisk demand for radiation counters, which the way things are going look like becoming standard household equipment!

During this digression in praise of transistor d.c. converters, the beginners I imagined to be puzzling over the problem of the unexpectedly cool valve may by now be puzzling over something else. They may have come fresh from being instructed to the effect that a power generator yields its greatest output when the resistance of the load is equal to that of itself, the efficiency then being 50%. This is a most important law, applying to all generators and loads. Another lesson showed them that valves (and transistors, if the teacher had got around to them) are equivalent to power generators. I have been talking about efficiencies of 80% and 90%, without a word on matching the resistances. So...!

Where is the fallacy?

There are really two (at least). One, of course, is jumping to the conclusion that the condition for maximum output is the most efficient condition. And if you say, in a superior way, that even a beginner wouldn't jump to any such thing, I would mention that in the early days of electricity supply the foremost engineers were very confused on this issue.

Numerical Illustration

A simple example ought to make the matter clear. The dotted line in Fig. 10 encloses an equivalent generator, giving an e.m.f. of 100V and having an internal resistance of 50Ω. Let us calculate the output and efficiency for three values of R: 10Ω, 50Ω and 250Ω. The output power is $I^2 R$, and I being $E/(r + R)$ it comes to $E^2 R/(R + r)^2$. The efficiency is this output power divided by the generated power, EI. Working these out we have:

Load resistance, R ..	10Ω	50Ω	250Ω
Output power	27.8W	50W	27.8W
Efficiency	16.7%	50%	83.4%

So the output power is reduced equally from its maximum—50W—by either dividing or multiplying R by 5 (the same applies to any figure), but dividing reduces the efficiency whereas multiplying increases it. If you worked out the algebra from the foregoing you will have arrived at the very simple formula for efficiency— $R/(R + r)$ —which clearly increases continuously as R is increased (or r reduced). To get a high efficiency, then, see that R/r is as large as possible.

The other fallacy is that all this is really irrelevant! (But worth noting on the side.) We had been discussing the efficiency of valves and transistors as converters of d.c. to a.c., and although the "equi-

valent generator" is a very useful idea, having a very general application to things such as valves and transistors, it relates to the "signal" only and does not concern itself with the d.c. "feed" needed to bring the valve etc. to its most suitable working point. It is failure to appreciate this distinction that gets people into a muddle over the direction of current in the valve equivalent generator. They think that because the feed current flows (according to standard convention) from anode to cathode there is some obligation to take that as the reference direction for the signal current in the equivalent generator. But feed current has nothing whatever to do with the equivalent generator.

There is a related misconception that beginners

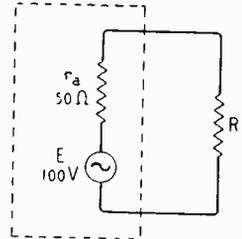


Fig. 10. The dotted line marks the boundaries of an "equivalent generator" supplying a load, R.

should beware of in connection with the maximum-output or matched-load law. An essential part of that law is constancy of the generated voltage, E in Fig. 10. In a valve equivalent generator $E = -\mu v_g$, where v_g is the signal voltage applied between grid and cathode. Generally speaking, with an output stage one is chiefly interested in the greatest output that can be obtained, without putting any fixed restriction on v_g . The really important restriction is the amount of distortion that can be tolerated, and the usual assumption is that v_g is kept adjusted to the point where the maximum tolerable distortion occurs. Where that point lies depends not only on the amount of d.c. power fed in but on the shape of the characteristic curves. We have found the efficiencies for full-sine-wave and half-sine-wave reproduction assuming perfect shapes—50% and 78.5% respectively—so we know the maximum theoretical output power of these waveforms, given the d.c. input. Because valve characteristic curves, and even transistor curves, are not perfect, the actual efficiencies, and therefore outputs for given inputs, are less; in some cases such as thermionic triodes, much less.

V.H.F. Sound Receiver I.F.

WHEN v.h.f. sound broadcasting started in this country, set manufacturers adopted an i.f. of 10.7 Mc/s as this was in use in the U.S.A. and on the Continent. Further consideration has recently been given as to the suitability of this frequency, mainly so far as interference to and from other services is concerned.

Whilst on purely technical grounds certain other frequencies showed a marginal improvement over 10.7 Mc/s, it is considered that those advantages would not justify abandoning this almost universally adopted frequency and the British Radio Equipment Manufacturers' Association has, therefore, endorsed its Technical Committee's recommendation that 10.7 Mc/s should be confirmed as the preferred i.f. for receivers used in the U.K., with the oscillator frequency on the low side of the signal frequency.

Manufacturers' Products

NEW ELECTRONIC EQUIPMENT AND ACCESSORIES

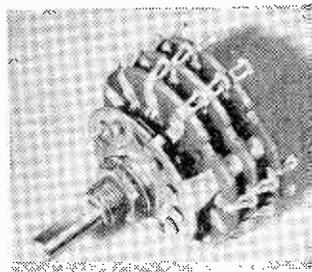
Oak Rotary Switch

A NEW Oak rotary switch known as the Model DQH, and replacing the existing Model QH, has been introduced by N.S.F., Ltd., 31-32 Alfred Place, London, W.C.1.

It incorporates an improved form of notched stator plate which is said to completely eliminate trouble due to loosening of the contact clips as a result of overheating during soldering operations.

The Model DQH has a 30° throw making available a maximum of 12 positions on a single wafer and any combination from 1 pole 12 positions to 6 poles 2 positions (on-off) can be provided.

Illustrated is a typical 3-section switch and this can be supplied fitted with an a.c. switch, but the rear two wafers are then omitted.



New N.S.F. Model DQH Oak switch.



Arcoelectric miniature 10-amp switch.

Miniature 10-amp Switch

RECENTLY introduced by Arcoelectric (Switches), Ltd., Central Avenue, West Molesey, Surrey, is an exceptionally compact double-pole on-off switch rated at 10 amps at 250 volts a.c. Known as the Type S254 it is designed on the snap-action, micro-gap principle, has silver contacts and is claimed to have been tested up to 250,000 operations at full rated load. A long pear-shaped "dolly" is fitted and the price is 5s.

Improved P.V.C. Cables

A NEW range of electrical wiring cables suitable for ambient temperatures up to 750°C (167°F) has been introduced by Permanoid Ltd., New Islington, Manchester, 4. They are insulated by p.v.c. compounded with a new long-chain polyester plasticizer known as "Diolpate" with a molecular weight of the order of 7,000. This has virtually no volatility at temperatures below that of decomposition, and as a result there is no migration. The insulation is also less affected by immersion in oils.

Calibration Tape

FREQUENCY response measurements and tape recorder replay head alignment can be performed with the aid of a new "Scotch Boy" twin track test tape. On one track eleven constant frequencies from 40 c/s to 10 kc/s (inclusive) are recorded to within ±1dB of the C.C.I.R. specification. Each of these frequencies

lasts about ten seconds and is preceded by an announcement. On the other track is recorded a continuous 7½-kc/s tone for head alignment purposes. This 150-ft tape costs 49s 6d and is marketed by the Minnesota Mining and Manufacturing Co. Ltd., Wigmore Street, London, W.1.

Expanded Polystyrene

A CELLULAR structure is given to polystyrene in "Polyzote," a product of Expanded Plastics, Ltd., 675, Mitcham Road, Croydon, Surrey. This material is supplied in granular form for moulding with a chemical additive which forms a gas on heating, and fills the mould with a cellular mass, which on cooling has high strength and low density (1¼lb/cu ft).

Although used chiefly for heat insulation, the dielectric properties are good (resistivity >10¹¹MΩ, permittivity 1.05, loss factor, tan δ, <0.0005) and it has considerable possibilities in radio and radar. One known application is for the casing of a high-altitude balloon radar sonde transponder where its light weight and transparency to radiation (the aerial system is enclosed) have obvious advantages. Not so obvious perhaps is the fact that the batteries retain their normal temperature and so function longer in the low ambient temperatures of high altitude.

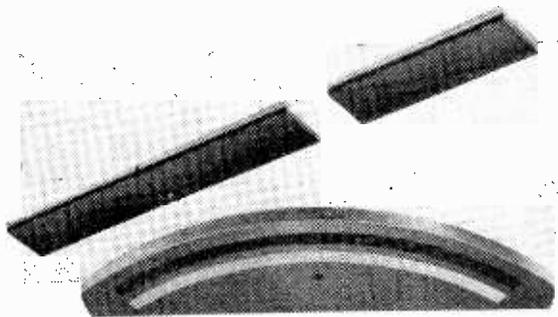
Moulded Resistance Elements

PRECISION resistance elements consisting of tracks of high-grade phenolic of the type used in some of their precision volume controls, can now be obtained from the Plessey Company to meet specific requirements. So far they have found applications mainly in industrial control equipment, but they are equally suitable for use wherever a stable, close-tolerance resistance is required for the variable element in precision equipment.

Elements have been produced in resistance values ranging from 25 Ω to 10 MΩ, at present with a tolerance of ±5% and with a linear or logarithmic resistance law. They are made in a variety of shapes and are said to maintain their stability when operated at temperatures ranging from -40°C to +100°C.

The illustration shows two of the forms they can take; one is a curved element, the other is a series of straight elements, each of 10kΩ, placed end-to-end. A sine/cosine moulded track unit has also been produced for a special type of potentiometer. It is stated that a moulded carbon brush is the most suitable type for the wiper.

The units are supplied to customer's individual requirements by The Plessey Co., Ltd., Swindon Components Division, Kewbrey Street, Swindon, Wilts.



Examples of moulded carbon track elements made by Plessey.

News from the Industry

Anglo-American Agreement.—The Radio Corporation of America has arranged to acquire from Marconi's technical information on the Doppler navigation system which will be used in the design of R.C.A. equipment for civil airlines. Marconi's have been producing Doppler equipment for the R.A.F. for the past three years and introduced a new type (AD2300) for civil use last June (see *W.W.*, August, page 396).

Solartron Expansion.—Work has begun on the first section of a new factory being built for the Solartron group at Tower Hill, Farnborough, Hants. This section of the one-storey building will have an area of 50,000 square feet and is planned to be in use by next August. The whole factory on the 15-acre site, which will include a helicopter landing space, is scheduled to cover 350,000 square feet.

Exco Electronics, Ltd., designed and installed the complete nuclear instrumentation and control circuitry for PLUTO, the atomic research reactor which recently commenced operation at Harwell. Exco are now working on similar equipment for the Australian HIFAR reactor at Lucas Heights and the DMTR reactor for Dounreay, Scotland.

Audio Group.—Three companies in the electro-acoustics field—Audio Amplifiers, Ltd., CQ Audio, Ltd. (formerly R.G.A. Sound Services), and Romagna Audio, Ltd.—have formed what is to be known as the Audio Group of Companies. The directors are Stanley Kelly and A. R. Neve. The headquarters are at 2, Sarnesfield Road, Enfield, Middlesex (Tel.: Enfield 8262). Stewart Hillman, formerly with Cosmocord, has joined the group as general sales manager.

Aerialite, Ltd., recently celebrated their silver jubilee and to mark the occasion the staff made presentations to the chairman (L. S. Hargraves) and his co-directors. The staff, which was two in 1932, is now 2,000.

Peto Scott Electrical Instruments, Ltd., announce that A. T. Black has been appointed to its board. Mr. Black, who was until recently director of electronics production (munitions) in the Ministry of Supply, is also a director of Pena Copper Mines, the parent company, the title of which is being changed to Pena Industries, Ltd.

Decca airfield control radar (Type 424) has been installed by Rolls-Royce at their flight test airfield at Hucknall, near Nottingham.

Wayne Kerr have developed at their Tolworth, Surrey, laboratories an electronic instrument for detecting and measuring the water content in aircraft jet fuel. The equipment is designed to detect, whilst the aircraft is in flight, as little as five parts of water in one million parts of fuel. The icing-up of fuel nozzles at high altitudes presents a very serious threat to air safety and the Wayne Kerr instrument automatically switches on tank de-icing equipment if moisture is detected.

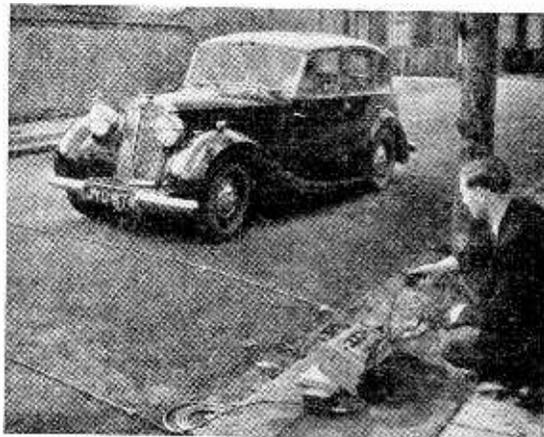
Moera Acoustics, Ltd., of Manor Way, Boreham Wood, Herts., a subsidiary of the Plessey Co., are to produce a new range of plugs and sockets. They will be manufactured under licence from Tüchel Kontakt of Germany. The world marketing rights outside Europe for the Tüchel design have been assigned by Plessey to their subsidiary.

EXPORTS

Thailand.—A report on the domestic receiver market in Thailand, prepared by the British Embassy in Bangkok, shows that during 1956 only about 4% of the imports were purchased from the United Kingdom. Nearly 50% of the receivers came from the Netherlands, 25% from Germany and about 15% from Japan. The U.K. had a greater share in Thailand's purchase of radio components and accessories—Japan, the Netherlands and Great Britain having 18%, 17% and 16% respectively. The U.S. supplied 24%.

Honduras Agency.—Agencia Acorda, Apartado 15, San Pedro Sula, Honduras, are interested in representing U.K. manufacturers of high-fidelity reproducing equipment, receivers and radio-grams.

VENNER ELECTRONICS have developed for the Road Research Laboratories of the D.S.I.R. an electronic vehicle speed measuring instrument which is being tested by the Metropolitan Police. Basically, the device is for measuring small intervals of time and it is started and stopped by the front wheels of the vehicle passing over rubber tubes laid in the road (see page 32). The accuracy is plus or minus $\frac{1}{2}$ % at 30 m.p.h.



Mobile radio-telephone transmitting and receiving equipment worth approximately £23,000 has been ordered from Marconi's by the Kuwait Oil Co. Five 50-watt base transmitters and associated receivers will be installed at one site (Ahmadi) and two 50-watt transmitters and receivers at two others (Raudhatain and Seismic Camp). The company's fleet of 37 vehicles is being fitted with 10-watt transmitter-receivers.

NEW ADDRESSES

Brighton Laminations, Ltd., makers of Bribond thermosetting and thermoplastic mouldings and printed circuits, have moved their headquarters to Burgess Hill, Sussex, but are retaining their Brighton works. The company has changed its title to Bribond, Ltd.

Farnell Instruments, Ltd., the instrument distributors of Leeds, have moved to Wetherby Industrial Estate, York Road, Wetherby, Yorks. (Tel.: Wetherby 2541). Their service department has been expanded and they are now in a position to undertake the development and manufacture of instruments to customers' requirements. The works manager is Mr. Sidebotham, who until recently was in the aircraft industry as head of an electronics research department.

Allen Components, Ltd., manufacturers of sound and television equipment, have moved from Richmond to 38, Felsham Road, London, S.W.15 (Tel.: Putney 3032).

H. W. Forrest (Transformers), Ltd., of 349 Haslucks Green Road, Shirley, Solihull, Warwickshire, have introduced a range of transformers (from 200mW to 20W) for use with a.f. transistors.

JANUARY MEETINGS

LONDON

9th. Television Society.—“A French portable television camera” by J. Polonsky at 7.0 at 164 Shaftesbury Avenue, W.C.2.

17th. B.S.R.A.—“The electrical production of music” by Alan Douglas at 7.15 at the Royal Society of Arts, John Adam Street, Adelphi, W.C.2.

17th. Institute of Navigation.—“The influence of atmospheric conditions on radar performance” by Dr. J. A. Saxton at 5.15 at 1 Kensington Gore, S.W.7.

22nd. I.E.E.—“Special problems of broadcasting in Sweden” by E. Esping at 5.30 at Savoy Place, W.C.2.

23rd. Television Society.—Fleming Memorial Lecture “Crystal valves” by T. R. Scott (S.T.C.) at 7.0, at the Royal Institution, Albemarle Street, W.1.

24th. R.S.G.B.—Presidential Address followed by “The human machine as a radio operator” by F. J. H. Charman (G6CJ) at 6.30 at the I.E.E., Savoy Place, W.C.2.

27th. I.E.E.—“An enquiry into the specification of transistors” by F. F. Roberts at 5.30 at Savoy Place, W.C.2.

28th. I.E.E.—Symposium on “Long-distance propagation above 30 Mc/s” (a) “Ionospheric forward scatter propagation” (at 2.30), (b) “Tropospheric propagation beyond the horizon” (at 5.30) at Savoy Place, W.C.2.

29th. Brit.I.R.E.—“Ultra-high-speed oscillography” by I. Maddock at 6.30 at the London School of Hygiene, Keppel Street, W.C.1.

ABERDEEN

10th. I.E.E.—“The remote and automatic control of semi-attended broadcasting transmitters” by R. T. B. Wynn and F. A. Peachey at 7.30 at the Robert Gordon's Technical College.

BIRMINGHAM

21st. Institute of Physics.—“The computer and its uses” by C. Robinson (English Electric) at 7.0 at the Birmingham Exchange and Engineering Centre.

27th. I.E.E.—“Transistor circuits and applications” by Dr. A. G. Milnes at 6.0 at the James Watt Memorial Institute, Great Charles Street.

BRIGHTON

15th. I.E.E.—“The B.B.C. sound broadcasting service on very-high frequencies” by E. W. Hayes and H. Page at 6.30 at the Technical College.

BRISTOL

13th. I.E.E.—“The B.B.C. sound broadcasting service on very-high frequencies” by E. W. Hayes and H. Page at 6.0 at Bristol University Engineering Laboratories.

CARDIFF

22nd. Brit.I.R.E.—“Applications of magnetic recording” by J. Cunningham-Sands at 6.30 in the Department of Physics, University College.

22nd. Society of Instrument Technology.—“The use of computers in process control” by W. G. Proctor (Metropolitan-Vickers) at 6.45 in the Physics Lecture Theatre, Cardiff College of Technology.

CHATHAM

23rd. I.E.E. Graduate and Student Section.—“Colour television” by A. Harris at 7.0 at the Medway College of Technology.

DUNDEE

9th. I.E.E.—“The remote and automatic control of semi-attended broadcasting transmitters” by R. T. B. Wynn and F. A. Peachey at 7.0 in the Electrical Engineering Dept., Queen's College.

EDINBURGH

20th. I.E.E.—“Some aspects of half-wave magnetic amplifiers” by G. M. Ettinger and “Some transistor input stages for high-gain d.c. amplifiers” by Dr. G. B. B. Chaplin and A. R. Owens at 7.0 at the Carlton Hotel, North Bridge.

21st. I.E.E.—“The importance of research in hearing and seeing to the future of telecommunication engineering” by Dr. E. C. Cherry at 7.0 at the Carlton Hotel, North Bridge.

FARNBOROUGH

8th. I.E.E.—“Colour television” by C. J. Stubbington at 6.30 at the R.A.E. Technical College.

GLASGOW

9th. Brit.I.R.E.—“Electronic calculator circuitry” by F. Baillie at 7.0 at the Institution of Engineers and Shipbuilders, 39 Elmbank Crescent.

21st. I.E.E.—“Some aspects of half-wave magnetic amplifiers” by G. M. Ettinger and “Some transistor input stages for high-gain d.c. amplifiers” by Dr. G. B. B. Chaplin and A. R. Owens at 7.0 at the Royal College of Science and Technology, George Street, C.1.

LIVERPOOL

3rd. Institute of Physics.—“Radio astronomy” by Dr. H. P. Palmer (Jodrell Bank Experimental Station) at 7.0 in the Department of Electrical Engineering, University of Liverpool.

20th. I.E.E.—“Ferrites” by W. A. Turner at 6.30 at the Royal Institute, Colquitt Street.

MALVERN

31st. Brit.I.R.E.—Annual General Meeting, followed by “Digital computers” by R. Deighton at 7.0 in the Winter Gardens.

NEWCASTLE

8th. Brit.I.R.E.—“The earth satellite project” by P. H. Tanner at 6.0 at the Institution of Mining and Mechanical Engineers, Westgate Road.

15th. Society of Instrument Technology.—“Modern types of electronic recorders” by F. A. Bergen (Cambridge Instruments) at 7.0 at King's College, Stephenson Building.

20th. I.E.E.—“Ferrites” by Dr. F. Brailsford at 6.15 at King's College.

PRESTON

6th. I.E.E.—“The B.B.C. sound broadcasting service on very-high frequencies” by E. W. Hayes and H. Page at 7.15 at the Electricity Board Demonstration Theatre, 19 Friargate.

RUGBY

29th. I.E.E.—“Recent developments in X-ray and electron-microscopy with some applications to radio and electronics” by C. W. Oatley and Dr. V. E. Cosslett at 6.30 at the Rugby College of Technology and Arts.

WOLVERHAMPTON

8th. Brit.I.R.E.—“Instrumentation of space vehicles” by N. R. Nicoll at 7.15 at the Wolverhampton Technical College, Wulfruna Street.

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P277

RANDOM RADIATIONS

By "DIALLIST"

Forward Scatter

IN the B.B.C.'s Annual Report for 1956-57 great concern is expressed about the encroachment by forward scatter transmissions into some sound and TV wavebands. I don't wonder, for forward scatter has been causing horrible interference with television reception in some parts of the country. As the report says, further developments of sound and television services may well be adversely affected, unless action can be taken to resist encroachment into bands allotted to broadcasting by international conferences. It's strange how unlooked-for interference so often arises in both sound and television. With the coming of high-power sound broadcasting stations there arrived the Luxembourg Effect; nobody expected that the Caen TV station would interfere with reception along our south coast, or that there'd be trouble with Liège when Norwich went up to full power. And there's another possible source of worry looming ahead. The Government of Southern Ireland has decided that the Republic must have a television service. It may not be easy to fit its station or stations in on channels where they don't cause despondency and dismay to viewers in some of our westerly districts*.

* There is no provision in the Stockholm Plan for Irish stations in Band I, but five are allowed for in Band III.—Ed.

Light and the Metre

FOR 75 years now the world's standard metre has been "M," the platinum-iridium bar housed at Sèvres, near Paris. But a change has been decided upon and as soon as it has been accepted by the International Committee of Weights and Measures, due to meet next October, it will be officially adopted by all countries. The new measuring rod is to be a wavelength of light, an idea which was first suggested 130 years ago. The light is that of an orange line in the spectrum of the 86 isotope of krypton— $^{86}\text{Kr}^{86}$. Multiply its length by 1,650,763.73 times and you have the new standard metre, which is more than 100 times as accurate as that derived from the old metal bar. With such a precise metre to work from it should be possible, one would imagine, to find an exact and

universally accepted value for the velocity of light and wireless waves. A vast amount has been done on this problem by physicists and mathematicians, but no two solutions have ever been exactly the same. Admittedly, the differences are very small; but still they are differences and since the velocity of light is a widely used constant, they shouldn't be there.

Hills and Plains

WRITING from near Colne in Lancashire a reader tells me of the difficulties experienced in that hilly part of the country in receiving Band III television transmissions. Such frequencies, he feels, are quite unsuitable for any but the flatter parts of this country of ours. He has an interesting suggestion to make, though I'm afraid it's hardly a practicable one. Draw a line, he says, through Nottingham from coast to coast: to the south of it there are few hills worth mentioning: to the north it's nothing but hills. He'd like to see all transmission north of this line made in Band I and all those south of it in Band III. Even if his assumptions were correct, what a hullabaloo there'd be should such a change be made! Can't you imagine the tumult and the shouting? Thousands of TV receivers of the Band I only type would become useless in the south unless they were converted. Millions of aerials would have to be

changed. And neither the B.B.C. nor the I.T.A. would be enthusiastic about altering their transmitters. Even were all this done, would it work out? I don't think so, I'm afraid, for there's quite a lot of hilly country south of this imaginary line. Much of the Welsh mountain country, Exmoor, Dartmoor, the Cotswolds, the Chilterns, the Quantocks and other areas that are far from flat lie there. It's an ingenious idea, but it just wouldn't do.

Canada's TV Problem

CANADA has already a publicly-owned television system which serves about two million owners of receiving sets. "This," wrote George Ferguson, editor of the *Montreal Star*, in a recent Canada Supplement of *The Times*, "extends at the moment from the Prairie Provinces in the West to Halifax, Nova Scotia. There remain the links with Newfoundland and British Columbia, but these will be pressed forward." The main question, I gather, is who is going to pay for the service and how? The service is run by the Canadian Broadcasting Corporation, which, unlike our B.B.C., is not financed from licence fees. The proposal to introduce receiving licences was met by the firmest possible opposition. Instead, the Government put a 15 per cent tax on both sound and television receiv-



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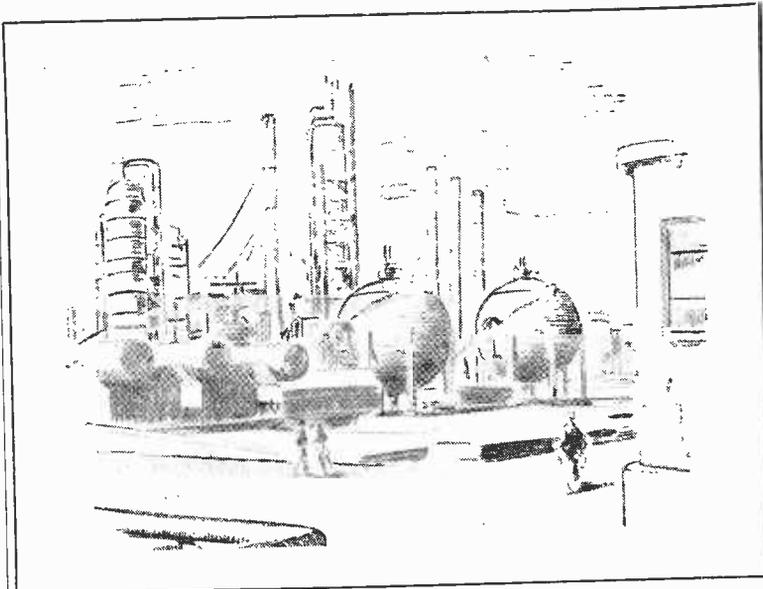
ing sets. This, together with its income from commercial programmes, produces far less than is needed to keep the C.B.C. going and meet the huge capital expenditure envisaged in the next six years. It should be added that Canada has in addition to its growing C.B.C. network a number of privately-owned commercial TV stations.

Making Satellites Work

A NOVEL suggestion for getting further useful work out of artificial satellites was made recently by R. J. Hitchcock, head of a section in the department of the engineer-in-chief of Cable and Wireless, Ltd. Sputnik II is said to be working already by recording a variety of measurements of conditions outside our atmosphere and sending them back to earth; but Hitchcock's idea is something quite different. Briefly, it is that satellites could be used to store communications from one part of the world and later to transmit them to another part. It should, he says, be possible to feed to a satellite in a few minutes all the telegraph traffic normally passing in a whole day between, say, this country and the antipodes. Three-quarters of an hour later the satellite would have reached a point in its orbit from which the messages could be transmitted at high speed to their destination. All this presupposes that some form of power supply, constantly replenished by solar energy, will be developed—and there is nothing unlikely about that. We'd also need satellites which would stay put, once they'd been started in larger orbits, and not come flaming back to earth in a matter of weeks or months.

It Won't be Easy!

There would also be the problem of precession, but that might not matter all that much, for a great number of moonlets would be needed to deal with world-wide communications and the ones in the right sort of orbits at a given moment could be used to deal with particular services. In the light of our present knowledge, the cost of putting such a scheme into practice would be staggering; but we're only at the very beginning of the satellite era and as the years go on cheaper and more effective methods of launching and equipping them will doubtless be discovered. Nevertheless, there are going to be some pretty knotty problems for solution.



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Irritating Irrationalities

WE are all aware that, throughout the world, voltages, whether those of the grid system or those in our homes, are rated in multiples of 11. Thus in the U.S.A. the standard domestic voltage is 110 and over here we had 220. The grid deals in voltages of 11,000, 33,000, 66,000 and so on. All these are multiples of 11, instead of the more obvious ten. There are, of course, odd voltages scattered about, such as 130 and 160 on the Continent and, of course, 230, 240 and others in this country, which don't seem to be based on anything.

"Diallist" once told us that he believed the basing of voltages on 11 instead of ten was due to the fact that originally the e.m.f. of the standard Clark cell, which is 1.1 volts, was taken as a starting point. I believe "Diallist" to be correct in his opinion but if any egghead knows better let him say so.

It would be too difficult to alter

recorders in use to alter the speeds to 2, 4, 8, etc., in/sec. It would be perfectly easy, however, to follow the example of the sailor who calls a nautical m.p.h. a "knot" (not a knot per hour!). Let us call $1\frac{1}{2}$ in/sec one "Stille." Better still, to allow for slower and slower speeds in the future, let us call it 100 Stilles (or should I say Stillen?) I hope no W.W. reader is so sunk in ignorance as to wonder what the word "Stille" signifies.

Callee-Coming Indicator

JUST lately we have heard a lot about the progress of automation in the telephone service but not a single mention has been made of one grave defect in our 'phone system which could be so easily remedied by radio technique.

Like myself, many of you have probably experienced the mortifications of hearing the telephone ring just as you have got into the bath. It always seems to be at a time when there is nobody else in the house.

It may be only a call from your tailor with a polite reminder about his overdue bill. But it may be a call from your favourite blonde, and consequently you spring out of the bath and rush downstairs, wrapping a towel around your midriff as you run, for the

sake of Mrs. Grundy's feelings, even though you know you are alone in the house.

Just as you are a few paces from the 'phone it ceases ringing and, as you squelch your way back to the bathroom, you are left wondering who had rung. It has so often happened to me that I determined to do something about it. As the result of my labours, the distant caller receives a definite indication that his callee is coming so that he hangs on rather than hangs up.

Strictly radio principles are used in my device and the beauty of it is that no breach occurs of the P.M.G.'s regulations which forbids subscribers to fix attachments to the telephone. Over the handset of the desk telephone I have placed a modification of a model grab crane such as is used in those automatic machines on seaside piers in which you are invited to risk a penny trying to get the crane to pick up a trumpery trinket. By the side of the crane I have placed a small tape

machine fitted with a short endless-band tape.

The apparatus is connected to the output of a tiny s.w. receiver of the type used in radio-controlled model planes and boats. On my person I have one of the small transmitters sold for model control. Incidentally, these little transmitters now require a licence from the P.M.G. but the cost is only £1 for five years.

An impulse from the transmitter first sets the crane in motion. It grabs the handset, lifts it and transfers it to the table with its mike near the loudspeaker of the tape machine which is then triggered off and repeatedly bellows out "Hello caller; your callee is coming."

I have designed the tiny transistorized transmitter to fit in an old bowler I always wear when in and around the house, even in the bath.

Tongue Tinglys Explained

IN reply to my request for suggestions to a literally self-contained battery to supply a few volts in my proposed "Torso Two" receiver, I have had an interesting letter from a reader who writes from Orpington.

He points out that when dentists fill a cavity they have to be careful to match the metal filling with any others which already exist in the mouth. The reason is that if dissimilar metals are used, a small e.m.f. is generated and the resultant current causes unpleasant tongue tinglyns.

As I have replied to him, I am afraid that many dentists are careless in this respect and probably that is why grandfather usually keeps his denture on the mantelpiece rather than in his mouth. It also accounts for the sharp taste I have with everything I eat and I must try to devise a suitable earthing system.

My correspondent suggests that use might be made of this effect to give me the volts I want. Unfortunately, however, I don't think the voltage would be high enough although the potentialities of such an arrangement are certainly worth the attention of the research worker who is seeking a permanent battery for a hearing aid. There is already a hearing aid combined with a pair of spectacles and so dentists might as well be brought into the syndicate.

So far as women and gum-chewers are concerned it would be only necessary to couple a simple generator to their jaws as the constant movement would keep it going. Actually, I believe this has been suggested before for another purpose. The idea then was that the constant movement of the jaws would steadily build up a high potential in a capacitor which would finally discharge and so give the female tongue wagger a sharp shock to signal the QRT to her.



What does 'Stille' mean? "

all this now by changing voltage ratings all over the world. Surely, however, we could get round the difficulty by a similar ingenious dodge to that which we use to make ourselves get out of bed earlier in the summer. All we do is to say it is 7 a.m. when it is really 6 a.m. Could we not therefore abandon the volt and adopt the "Clark" as the unit of e.m.f.?

There is one irritating irrationality or insane illogicality which is of such comparatively recent birth that it can and should be altered. I refer to the irritating speed rating of tape recorders where we have to write clumsy fractional speeds like $1\frac{1}{2}$ in/sec. $3\frac{1}{2}$ in/sec and so on.

Soon, I believe, we are to have a still slower speed for office work, namely $\frac{1}{2}$ in/sec. I suppose these absurdities arose because in the pioneer days of magnetic recording 30 in/sec was used and then this was halved. When it was halved again the trouble started.

There are far too many tape re-