

# Wireless World

ELECTRONICS, RADIO, TELEVISION

DECEMBER 1962

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# PCL86-TELEVISION AUDIO OUTPUT VALVE

## **EH90** SOUND DEMODULATOR FOR DUAL-STANDARD RECEIVERS

**A**DOPTION of the 625-line standard is to include the use of f.m. sound transmissions, and the latest dual-standard receivers are equipped to accommodate these transmissions. The Mullard heptode, type EH90, is being used for f.m. detection in many of these new sets, where it operates as a locked-oscillator discriminator.

The EH90 is used as a dual-control valve in this application: the transmitted signals are applied to the first grid, and the local oscillations to the third grid. Coupling between the two electrodes occurs by way of the electron stream. The circuit depends for its operation on the fact that the mean anode current in the EH90 will

### **WHAT'S NEW IN THE NEW SETS**

These articles describe the latest Mullard developments for entertainment equipment

be a function of the phase relationship between signals of similar frequency applied to the control electrodes. As this relationship varies with the signal frequency, frequency modulations at the first grid are converted to demodulated amplitude variations at the anode, and these are subsequently amplified and fed to the loudspeaker.

The electron coupling in the EH90 is good, as is the frequency-to-amplitude transfer characteristic. The valve is thus very suitable for use as a locked-oscillator discriminator, and will contribute notably to the benefits accruing from the adoption of f.m. sound transmissions.

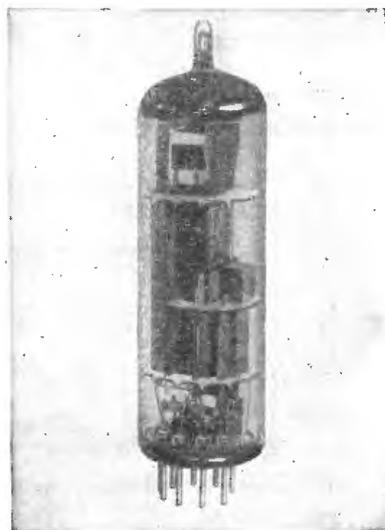
*new features give  
added performance*

**T**HE Mullard PCL86 a.f. triode-pentode has been designed specifically for the sound stages of television receivers.

The sensitivity of the valve is high enough to allow adequate feedback to be applied in conventional circuits, but is not so high that instability will occur. The high overall gain is achieved partly by a high amplification factor in the triode section, and partly by a high value of mutual conductance in the pentode section. A new cathode material is used in the PCL86 to reduce the likelihood of instability. With this material, there is less deposition of particles from the cathode on other members of the electrode structure.

A special electrode structure—the balcony structure illustrated—is used in the PCL86. The triode section is much shorter than the pentode section, and heat can therefore radiate freely from the upper part of the pentode section. Greater dissipation can thus be tolerated, and the anode dissipation rating of the PCL86 is consequently particularly high (9W) for triode-pentodes.

The cathode-to-heater voltage rating of the PCL86 is high (30V), and positioning of the valve in the heater chain is therefore not critical. Screening between the heater and grid leads of the electrode structure ensures a very low level of hum in the valve. The performance to be achieved with the PCL86 is thus very good, and the valve is ideally suited for the sound stages of television receivers.



## **DY86-A NEW E.H.T. RECTIFIER**

The Mullard DY86 will be encountered in many present-day television receivers. It is a new e.h.t. rectifier mounted on a noval base. The new valve is capable of delivering a rectified current of 600 $\mu$ A, the peak cathode current being 40mA. This value of current is ample for modern picture tubes, and results in excellent brilliance and contrast,

even in daylight.

The e.h.t. rectifier of a television receiver must be safeguarded from the effects of over voltage ringing in the e.h.t. winding of the line output transformer. The peak inverse voltage rating of the DY86 is 22kV. An ample safety margin is thus provided for a design value of e.h.t. voltage of 18kV.

MVE 1586

## Citizens Radio

THE letter from Mr. G. E. Storey, (October issue, p. 496) calling for a relaxation of the restrictions governing the granting of licences for mobile radio installations has stimulated a lively correspondence in subsequent issues of this journal.

The idea of possessing one's own private transmitting and receiving set has fired the imagination of every generation of schoolboys since wireless telephony became practicable. It has been powerfully stimulated in recent years by the advent of the transistor and the ubiquitous personal portable broadcast receiver. There are few weeks in which we do not receive a request for a reference to circuit diagrams from teenage hopefuls who are obviously quite ignorant of the licensing regulations and who, if they built such transmitters, would have no means of knowing whether they were in the right waveband, let alone whether their signals were stable or free from harmonics.

But if novice "do-it-yourself" aspirants must be deterred until they can show some evidence of competence, what are we to say to the many responsible citizens who would be only too glad to leave technical details to others if they could buy a properly made and tested instrument of lower power and cost than the standard mobile radio equipments at present available. Because they are responsible citizens they will not need reminding that the natural aspirations and needs of individuals must sometimes be curbed in the interests of the general well-being of the community, which means ultimately of themselves. But they also have the right to ask questions about the manner in which restriction is exercised by authority and, in the present context, if the Postmaster General is using his powers to restrict private communication systems in order to fulfil his other duty to make public telecommunication services pay. These are matters on which the P.M.G. is answerable to Parliament and on which he takes the advice of the Mobile Radio Committee which in turn has heard evidence from organizations representing a wide variety of interests. Reports of the Mobile Radio Committee are published regularly by H.M. Stationery Office and while giving technical arguments for the recommendations on frequency allocation and equipment specifications, they also reveal the magnitude of the demand for mobile radio by public services and by business and industry.

With so many powerful rivals for places in the limited frequency bands allocated by international agreement to mobile services, it seems to us that individual citizens should form an association

through which their voice could be effectively heard. Pressure on ether space is mounting and already 50kc/s channel spacing has given way to 25kc/s for telephony in this and other countries. In anticipation of future demands the Netherlands PTT has developed the "Simofoon" system, which by combinations of audio-frequency tones can transmit simple coded messages to thousands of mobile subscribers, using only one radio-frequency channel.

Whatever direction the future line of development may take it is certain that a tight control will be kept on the performance and stability of the equipment used for mobile (including "citizens") radio communication. The widespread belief that we are hard done by in the U.K. in the matter of technical restrictions and that much greater freedom is permitted to the citizens of, for example, the U.S.A. is illusory. New systems put into operation in the U.S.A. after 1st August, 1958, and all systems after 31st October, 1963, are allowed to have frequency tolerance of not more than 0.002% in the 27 Mc/s bands or 0.0005% in the 465 Mc/s bands, and f.m. deviations of 5kc/s and 15kc/s respectively. In Germany where the Bundespost authorities have recently "relaxed" restrictions to the extent of permitting radio communications in the 27 Mc/s bands for the use of sports organizations (but not individuals) in addition to public services, the channel spacing is to be 10kc/s, frequency stability ( $-10^{\circ}\text{C}$  to  $40^{\circ}\text{C}$  and with  $\pm 10\%$  variation of power supply) must be less than  $\pm 1.5\text{kc/s}$ , and the maximum radiated power from a  $\lambda/2$  dipole must not exceed 0.1 watt. Commenting on this our contemporary *Funkschau* says somewhat wryly that the hoped for "Everyman Radio" is scarcely more than a cut-down "Everymanikin Radio"!

If there is to be any extension of mobile radio by a reduction in the price of equipment this will inevitably be at the cost of lower power and restricted range, because the out-of-band spurious radiation must be kept at a level at least as low as that allowed in higher-powered equipment. Will those who now call for a lowering of costs be satisfied with the limited ranges? If not they must pay up and join the ranks of the existing mobile users.

The motives of those who wish to communicate by radio are as legitimate as those which urge people to travel, but if travellers wish to use modern motorways they are no longer allowed to walk, push perambulators or even ride mopeds; they must buy a car and submit to the inspection and control of its roadworthiness.

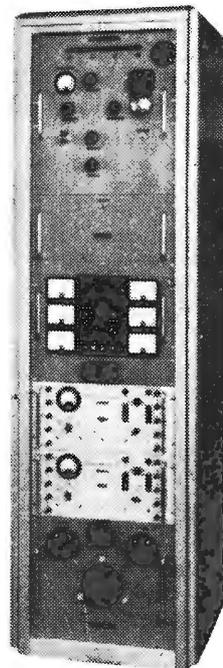
# BAND IV BEACON TRANSMITTER (GB3GEC)

DESIGNED FOR MIXED-PATH PROPAGATION STUDIES

**I**N order to study the probability of interference between television stations in Britain and on the Continent sharing the same frequency, a continuous signal has been radiated from the works of the M-O Valve Company at Hammersmith, West London, on a frequency of 431.5 Mc/s, and beamed on the receiving station PE1PL in The Hague, since January, 1962. The project was organized by G. M. C. Stone, the representative of the Radio Society of Great Britain on the C.C.I.R. Study Group V (Propagation), and is concerned with measurements of the variation of field strength over this mixed land and sea path.

The aerial at Hammersmith is mounted above the roof of the factory about 70 feet above ground level and consists of four square stack 8-over-8 slot-fed Yagi arrays. The aerial, supplied by J. Beam Aerials Ltd., of Northampton, and its polar diagram are illustrated on the front cover. A power of about 500W is fed from the transmitter through a 1-in diameter coaxial cable. At The Hague a  $\lambda/2$  dipole with a disc reflector is fitted at the focus of a

By  
**H. L. GIBSON,\***  
A.M.I.E.E.



25ft diameter steerable paraboloid and feeds a low-noise converter with an output at 150 Mc/s followed by a tunable receiver. A chart recorder provides a continuous record of the amplified a.g.c. voltage.

The transmitter is designed to operate for long periods without any interruption of the service, and is used by the M-O Valve Company to collect extended life-test evidence on the various valves used in it. Since the beginning of transmissions, the only serious cause of failure was due to blocking of the air filters supplying cooling air to the 4X250B valves in the output stage.

The transmitter frequency is derived from a crystal at 7990.74 kc/s maintained at constant temperature in an oven; identification signals are sent once in five minutes by frequency shift keying and this is performed by raising the oscillator frequency slightly during the "space" periods of the keying sequence. The keying characters are formed by a slotted disc which rotates once per minute between a light source and a photo-transistor. Four out of five keying sequences are suppressed by relay circuits so as to radiate the call letters only once in five minutes. The frequency shift at the output frequency is about 2 kc/s. The circuit arrangement of the exciter follows conventional practice. The 12AX7 crystal oscillator is followed by a 6AM6 buffer amplifier, a 6AM6 trebler and an EL84 trebler which drives a TT15 twin tetrode with its anodes connected in parallel to act as a frequency doubler to 143.8 Mc/s. This stage is capable of a power output of 3W but this is normally reduced to 0.5W by operating the TT15 at greatly reduced screen voltage.

The low-power driver has three stages of grounded-grid triodes, the first two of which are A2521 pin-based valves originally designed as low-

\*Applications Dept., M-O Valve Company

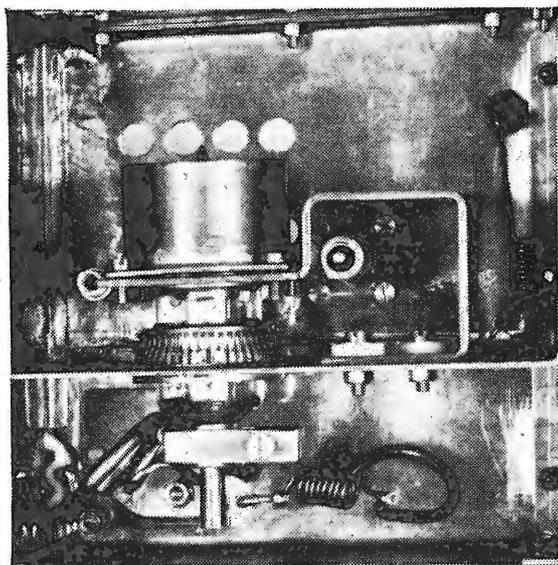


Fig. 1. Low-power amplifier for 431 Mc/s showing simple loop anode circuit for DET24 and A2521.

noise amplifiers for u.h.f. receivers, but now finding increasing use as small power valves. The first A2521 acts as a frequency trebler to the final frequency of 431.5 Mc/s at approximately unity power gain followed by an A2521 power amplifier giving an output of 2.5W. Both of these stages use anode tuned circuits consisting of single turn loops of 10 s.w.g. copper,  $\frac{3}{8}$ in internal diameter and terminated to earth by a capacitance of about 150pF formed by 1in square copper plates insulated from the chassis by a thin sheet of mica and retained by nylon screws. The amplifier stage has no tuned input circuit but is capacitively coupled to the previous anode circuit. The following amplifier raises the power level to 12W and one might normally consider a double u.h.f. tetrode such as the TT20/QQV03-20A for this service. However, it has been shown that the effective power gain of such an amplifier is no better than that of a grounded-grid triode of similar rating while the inherent stability of the grounded-grid triode is a considerable advantage. Consequently, the following amplifier uses a DET24 disc seal triode. This valve was originally designed for use in coaxial circuits at frequencies up to 2,000 Mc/s but at frequencies below 500 Mc/s an extremely simple anode circuit can be used while no input circuit is necessary. In this transmitter, the anode circuit consists of three sides of a square loop of  $1\frac{1}{2}$ in side bent up from 16 s.w.g. copper sheet  $1\frac{1}{4}$ in wide. One of the sides is clamped

to the chassis with suitable insulation to form a by-pass capacitor while the other end of the loop is extended to form a clamp around the valve anode contact ring. The entire loop forms a heat sink which keeps the valve seal temperature to a safe value. Details of this arrangement and the A2521 anode tuned circuit are shown in Fig. 1, and are described in detail in the M-O Valve Company's Application Report No. 10.

The penultimate amplifier uses a 4X150A tetrode valve operating under reduced conditions of drive and anode input to give an output of 50W and this drives a pair of 4X250B valves operated at full ratings to give an output of 500W. These valves are normally operated in coaxial circuits but it is very difficult to connect two valves in parallel in this arrangement and the GB3GEC transmitter uses radial cavities for both the single-valve and two-valve stages. Provided that only a small tuning range is required, these circuits have the added advantage that they can be made almost entirely without the use of machine tools.

The cavities used take the form of a flat, square box with the valves mounted centrally between the upper and lower plates of the box. The spacing between these plates is determined by the valve socket and chimney so that the anode and screen contact surfaces connect with the upper and lower plates of the box. The length of the sides of the cavity determine the frequency which also depends

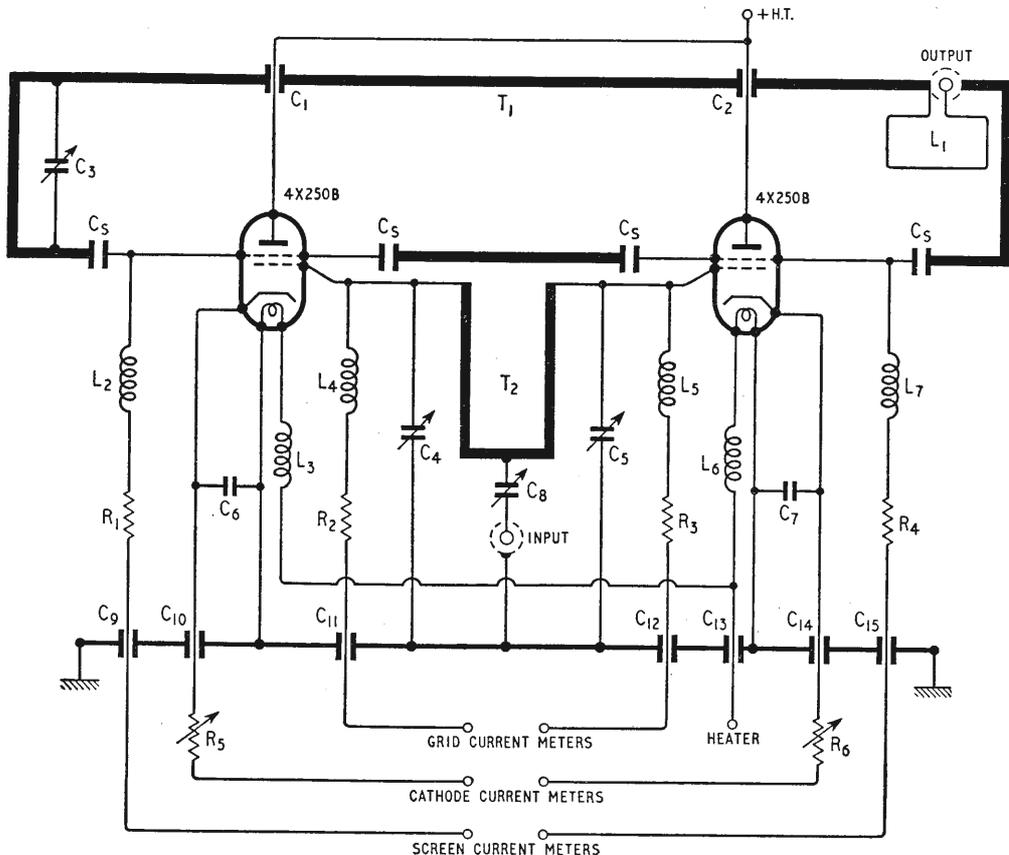


Fig. 2. Circuit diagram of high-power amplifier using two 4X250B valves in a radial cavity.

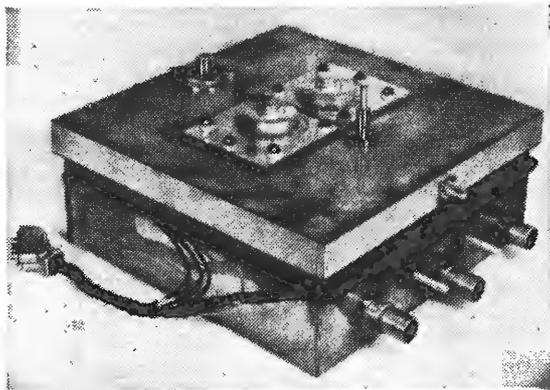
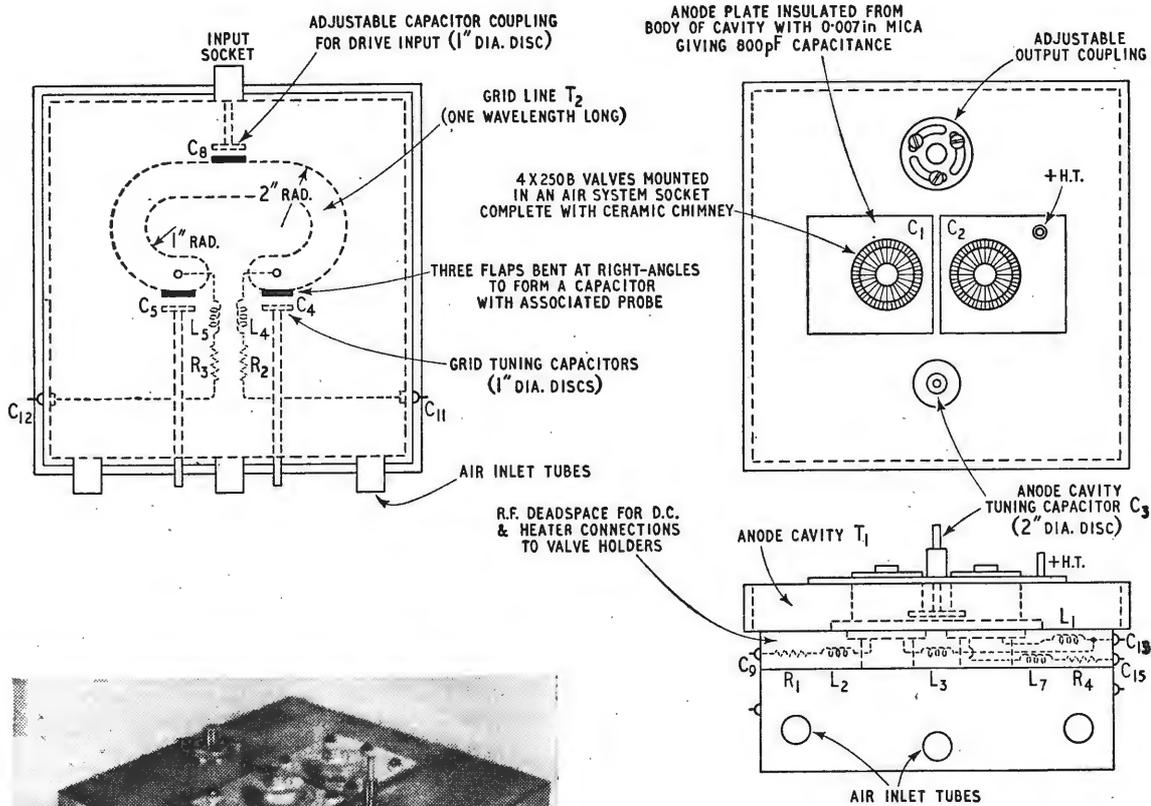
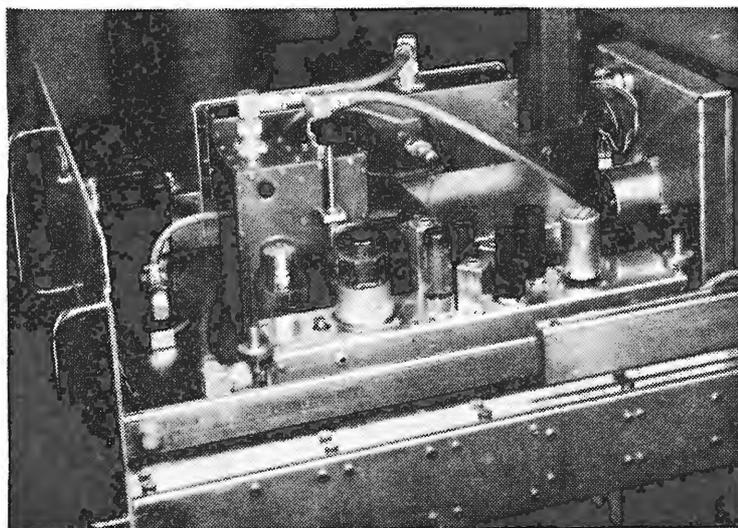


Fig. 3. Layout of the radial cavity of the high-power amplifier (shown left) using a pair of 4X250B valves.

Fig. 4. The low-power stages of the transmitter showing the exciter unit in the foreground and the housing containing the keying disc on the right.



on the capacitive loading applied by the valve. The lengths for a frequency of 440 Mc/s is  $13\frac{1}{2}$ in for a single 4X150A valve and  $10\frac{1}{2}$ in for a pair of 4X250B valves when the plates are spaced 1in apart. Fine tuning is achieved by a 2in diameter brass disc which is adjustable in spacing and therefore in capacitance across the cavity. This arrangement gives a tuning range of about 20 Mc/s and easily allows the cavities to be adjusted to 431.5 Mc/s with adequate allowance for valve-to-valve capacitance variations. Power is coupled out of the cavities by a rotatable loop.

The grid circuits use simple trough line arrangements, a half-wave line for the single valve circuit and a full-wave line in the shape of a letter C for the two-valve circuit. The trough lines are contained in a screening box mounted beneath the anode cavity with a gap which provides an r.f. dead-space into which the heater and d.c. screen connections can be taken through suitable chokes and by-pass capacitors. The circuit diagram for the two-valve arrangement is shown in Fig. 2 and the constructional details in Fig 3. Both the single-valve and two-valve circuits are described in the M-O Valve Company's Application Report No. 6.

The power supplies are entirely conventional; the low-power supplies are provided by Furzehill type P300R stabilized power units while the high-power stages are supplied from zenon rectifiers type GXU2 in bi-phase half-wave circuits. The transmitter is protected against failure of cooling air by suitable relays and the biasing arrangements are such that failure of r.f. drive from earlier stages leaves the high-power valves operating within their dissipation rating.

Assuming an e.r.p. of 5kW, the calculated free space input signal level is approximately 2mV but the received signal has, at all times, been very much less than this. During February, March and April, the signal never rose above  $5\mu\text{V}$  and for a large part of the time was less than  $0.5\mu\text{V}$ . It was expected that signals nearer to the free space value would have occurred during the summer months when real duct formations might be expected, but this in fact did not happen. The signal is normally subjected to rapid fading and aircraft flutter effects. In spite of the highly directive aerial, the signal is easily received throughout the Home Counties and reports have been received from as far afield as Monmouthshire.

## BOOKS RECEIVED

**Introduction to Electronics**, by Robert J. Hughes and Peter Pipe. An elementary treatment of radio and basic electronics. The "teaching machine" approach is adopted, the reader being required to answer correctly a question on the current section before he can find the correct page on which to continue. The book is written in a colloquial style, and each step forward is small enough to meet the needs of the slow learner. Pp. 422. English Universities Press, Ltd., 102 Newgate Street, London, E.C.1. Price 25s.

**FM Stereo Multiplexing**, by Norman H. Crowhurst. Explains stereo broadcasting systems in relation to the F.C.C. system finally adopted (in the U.S.A.). A general discussion of adaptor circuits is followed by fourteen examples. Also dealt with are installation and conversion problems, alignment and performance checking, and general servicing procedures. Pp. 65. John F. Rider, Publisher, Inc., 116 W. 14th Street, New York, N.Y. Price \$1.25.

**Acoustics, Noise and Buildings** (2nd Edition), by P. H. Parkin and H. R. Humphreys. For acoustics engineers and architects, this book provides a grounding for the understanding of the concepts involved in the design of buildings with specified acoustic properties. The first few chapters deal with the nature and behaviour of sound waves in different environments and these are followed by chapters on sound insulation, measurement and the design of studios and rooms for various types of sound. Pp. 331. Faber & Faber, 24 Russell Square, London. Price 70s.

**Photo and Thermoelectric Effects in Semiconductors**, by J. Tauc. Primarily written for the solid-state physicist or device development engineer, the book is an exhaustive treatment of the subject of carrier motion in semiconductor material. The effects of light, temperature and magnetic fields are dealt with specifically, and special cases where two of these effects occur simultaneously are discussed. An extensive list of references is provided. Pp. 248. Pergamon Press Ltd., Headington Hill Hall, Oxford. Price 60s.

**Applied Mathematics for Radio and Communication Engineer**, by Carl E. Smith. Intended as a complete course for technical students, the book begins with simple arithmetic and progresses to calculus and series. Two chapters are given to the use of simultaneous equations in mesh circuits, and quadratic equations in multiple-resonance complex circuits. An extensive appendix provides a number of tables, standard formulae and integrals. Problems, to which answers are provided, are set after each chapter. Pp. 336. Dover Publications Inc., 180 Varick Street, New York, 14, N.Y. Price \$1.75.

**Single-sideband Communications Handbook**, by Harry D. Hooton, W6YTH. Mainly for the amateur, the book covers the whole subject of s.s.b. transmission and reception in a non-mathematical manner. Several practical constructional circuits are described, mainly for linear amplifiers, and descriptions are included of commercial s.s.b. equipment. A chapter is devoted to test and measurement. Pp. 286. Howard W. Sams & Co., Inc., Indianapolis 6, Indiana, U.S.A. Price \$6.95.

**Semiconductor Statistics**, by J. B. Blakemore. A comprehensive account of factors governing the density of carriers in semiconductors. An introductory chapter is devoted to the electron band theory of solids, after which carrier statistics for semiconductors in equilibrium are discussed. (Equilibrium is held to apply when small measurement currents are passed.) The whole of the second part of the book is a treatment of non-equilibrium conditions which obtain at large currents. Junctions are not dealt with. Pp. 381. Pergamon Press Ltd., Headington Hill Hall, Oxford. Price 84s.

**Normal Equal-Loudness Contours for Pure Tones and Normal Threshold of Hearing** are for free-field conditions and binaural listeners in the age group 18 to 25. The corrections normally required for ages up to 60 are also included. B.S. 3383: 1961 costs 4s 6d and is available from B.S.I., British Standards House, 2, Park St., London, W.1.

# ELECTRONIC EQUIPMENT RELIABILITY

DISCUSSION AT THE SECOND I.E.E. SYMPOSIUM

**N**OT many years ago, the rush of blood to the head when a new equipment first worked was in no way abated when it refused to perform reliably to any marked extent. Things electronic were accorded the reverence and granted the indulgences normally expected by a mezzo-soprano, and their frequent fits of temperament fitted the rôle perfectly.

This kind of attitude has taken far too long to live down, and it is only with the adoption of electronics for vitally important defence measures, for medical work and in business, that the need for black boxes to work reliably has become the subject of research. Semiconductors have contributed to this: their very smallness means that hundreds of thousands of components are used in even a fairly small computer or control system. An estimated mean time between failures (m.t.b.f.) for these individual components of as much as a thousand hours means that the computer will probably develop a fault every few minutes. The costly and possibly fatal results of a breakdown in such equipment means that it is far cheaper to spend money on reliability research than to run the risk of failure, though the general feeling of the symposium was that industrial managements are still blissfully ignorant of this fact. An encouraging note was sounded by Mr. Basil de Ferranti in his opening address when he said that the Government would "not be unreceptive" to ideas for improving the situation.

The symposium held in 1960 was felt to be rather too destructive, in that although the problems were stated, no solutions were forthcoming. The symposium held in October last, while acknowledging the difficulties, was able to demonstrate much more achievement. Several main points of agreement were established, the one most often discussed being a proposal for the setting-up of a central clearing-house for test information on electronic components, to operate on the lines of the Consumers Association Limited. This was generally felt to be a good idea, though the need for care in its operation was voiced by several speakers. Difficulties in getting the co-operation of manufacturers would, no doubt, be encountered: the good ones would send data, bad ones would not, and an incorrect over-all picture would emerge. On the other hand, once a component was given a bad name, the stigma would stick and improvement would tend to be ignored.

Most speakers were in agreement on the fact that complexity was one of the bitterest enemies of reliability. Established circuits, for example those taken from manufacturer's application notes and used without alteration, stood a better chance of producing reliable equipment than if they are regarded merely as something to base the designer's own thoughts on, and whenever possible to "improve." There is no harm in this, provided ample

time is available for a reassessment of reliability.

The lack of standardization in the definition of reliability was commented on by many speakers, and this would seem to be due for attention. The difficulty of obtaining figures for short production runs; the necessity for assuming one failure where none was suffered, in order to get a figure; the reason for specifying failure rates in percentages per 1000 component-hours; differences in requirements between 10-second missiles and 25-year undersea repeaters; all these topics were discussed and will continue to be discussed for some time, one feels.

## Maintenance and Reliability

Before reporting specific points from the papers presented, some of the generalities that emerged in discussion will be mentioned, one of the more important ones being what could be called the "sleeping-dog" philosophy. It appears to be commonly agreed that if a large equipment is working satisfactorily, the least possible amount of preventive maintenance should be applied. Success with this approach was reported by Dr. Steiner of Prague in connection with the maintenance of a Soviet Ural I computer. Initially, all valves in the equipment were changed, as a matter of course, in January of each year and other maintenance was performed at the same time. Unfortunately, it was not until March that the computer recovered from the effects of this onslaught. As a result, it was decided, in future, to leave well alone as much as possible, and since then very little trouble has been experienced.

This approach is endorsed by many Government establishments although it was pointed out that if equipment suffers from these troubles, it could be that something is wrong with the design.

P. A. Darnell, of the Bell System, put forward the point of view that the designer can save a lot of money if he knows what he is doing. This rather fundamental remark was provoked by the fact that the Bell-designed Telstar uses carbon composition resistors in the main. Although these are liable to "failure" by drift out of tolerance, the designer can minimize the effect of this by intelligent design. The device can therefore be made cheaper and catastrophic failure—a fault sometimes encountered with high-stability cracked-carbon components—avoided.

A round of heartfelt applause was accorded the speaker who complained that it is all very well to talk of comprehensively testing, say, a computer for reliability figures, but that as soon as the equipment is built, it is usually pressed into service. This is not only the case with computers and other large equipments; too many manufacturers begin selling things like electronic instruments before sufficient

information has been gained, and in some cases before the prototype has been fully completed.

The practice of delegating mechanical design to junior draughtsmen continues, it seems, and contributes its quota to unreliability. Electronic engineers also tend to regard mechanical design as an extension of their own province, and it was very fairly pointed out that mechanical designers do not design flip-flops in their spare time.

A paper by J. C. Cluley described the concept of redundancy as an insurance against breakdown in control systems or computers. Redundancy may be applied to coding—transmission of error-correcting information—and to replication of equipment, which is the type described in this paper. In theory, the lower the level at which replication is applied, the better. In other words, if every component were duplicated or triplicated, maximum reliability would be achieved. In practice, this is not so, as multiplication of components causes a loss of performance, and the next level—complete circuits—is the most reasonable choice. In a digital computer, each logical unit is replaced by several similar units, each group being followed by a majority-voting decision circuit. Each decision circuit must also be replicated, so that the equipment becomes a number of columns of alternate logic and decision circuits. To preserve the computer's equanimity, an odd number of columns is required. Testing may be carried out by running a test programme, multiplexed with the main one, on one column at a time, the others being inhibited. The decision circuits are modified to accept only one input during the test run. It is found that adequate reliability for almost any on-line process is provided by three columns, and if units could be expected to fail in one way only, two columns would suffice. This, unfortunately, does not appear to be the case with contemporary active components.

Equipment availability is defined as the m.t.b.f. divided by m.t.b.f. plus repair time, so that increase of m.t.b.f. is not the only way of increasing availability. Attention is not quite so frequently directed at reduction of repair time, and only one paper was devoted solely to this problem. W. S. Mortley described a method of using a television display as a fault indicator, and stressed the importance of designing with performance monitoring in mind. In a large electronic system consisting of perhaps, 5,000 logic units, two test points are provided for each unit, one to indicate the input condition and one the state of the unit. If a unit has several inputs and outputs, they are combined by logic networks. Each rack of units is provided with a sampling unit which is fed with d.c. test signals by the monitor, each unit feeding its sampler with the results. The samplers are then scanned sequentially by the monitor and the results displayed. The indication is in the form of a matrix of pairs of dots, input and output for each unit, all being visible, but dim. An increase in brightness of any dot indicates a fault (in analogue equipment, dot brightness gives some indication of the severity of the fault), and an audible warning is given when the dot reaches peak white.

R. E. W. Harland presented a paper on the economics of unreliability in the Royal Air Force. If any one present was feeling at all complacent, this paper should have been sufficient to bring them back to earth with a dull thud. He said the R.A.F.

has paid, over the past eight years, £200M to the electronics industry, half of which has been for spares and maintenance equipment. Maintenance costs on operational equipment are two or three times the cost of the equipment itself, and even with this, many flights are wasted because of electronic failures. The cost of accidents alone due to electronics is about £5M a year. Paradoxically, accidents due to electronics are very few, but only because sets are so unreliable that they are seldom used in critical functions unless replicated. Stress was placed on the need for simpler fault diagnosis; even skilled tradesmen are finding themselves out of their depth with modern, complex equipment.

The human factor is, as in any subject, one of the imponderables, and it is responsible for many difficulties in both assessing and increasing reliability. Perhaps the most trouble is caused by bad reporting of faults and remedies. Improvement in reliability is dependent, to a large extent, on feedback from the user to the designer, and if the loop is broken, effort may well be directed into the wrong channels. The introduction of wired-in valves demonstrated another point at which human fallibility was causing trouble. As soon as they were used in Service equipment, the consumption of spare valves dropped rapidly. Evidently the difficulty of replacing them encourages service engineers to look elsewhere for faults, and often they find them.

It is felt that the symposium has made a big contribution to standards of reliability, in particular in drawing attention to the need for a concerted attack on standardizing definitions, on reduction of complexity, and on the establishment of some central body to collect and collate information. The day of "It'll be all right on the night" is passing, but is not dead yet. The symposium has most certainly helped it along.

## 1963 Conferences and Exhibitions

Additions to the list of next year's events published last month. Further details are obtainable from the addresses in parentheses.

### LONDON

- Mar. 27-30 Imperial College  
**Environmental Engineering Symposium & Exhibition**  
(Soc. of Environmental Engineers, 167 Victoria Street, S.W.1)
- April 23-25 Imperial College  
**Electronic Processes in Dielectric Liquids**  
(Inst. of Physics & Phys. Soc., 47 Belgrave Square, S.W.1)
- Sept. 9-13 Imperial College  
**The Liquid State**  
(Inst. of Physics & Phys. Soc., 47 Belgrave Square, S.W.1)
- Sept. 23-27 Savoy Place  
**International Telemetering Conference**  
(I.E.E., Savoy Place, W.C.2)

### OXFORD

- July 10-12 The University  
**High Magnetic Fields**  
(Inst. of Physics & Phys. Soc., 47 Belgrave Square, S.W.1.)

### OVERSEAS

- Mar. 7-12 Paris  
**International Festival of Sound**  
(S.I.E.R.E., 14 rue de Staël, Paris 15e)
- Mar. 26-31 Brussels  
**Interélectronique: International Components Exhibition**
- Nov. 14-21 Paris  
**Mesucora Exhibition & Congress**  
(Secretariat, 40 rue du Colisée, Paris 8e)

# Audio Engineering Society Convention

SOME POINTERS FROM PAPERS READ AND DISCUSSED IN NEW YORK

**T**HE Fourteenth Annual Convention & Exhibition of the Audio Engineering Society was held in New York during the week beginning October 15th. Concurrently with this Convention, an Exhibition was held of Professional Audio Equipment including tape recorders, disk recorders, microphones and control equipment.

There was a change of location of the Convention this year, which was held at the Barbizon Plaza Hotel for the first time. This hotel has ample accommodation in the form of a large lecture hall with comfortable tip-up seats, excellent air conditioning and a very good sound reinforcement system. At question time, the dexterous handling of the long distance directional microphone operated from the stage gave ample reinforcement to the individual speakers in the audience without the usual fussation of ushers handing microphones around with trailing leads.

The responsibility for the organization of the Convention and the collection of papers had rested on the Executive Vice-President, Mr. H. E. Roys, assisted by a team of nine governors, a committee of nineteen session chairmen and others.

## Special Sessions

A joint session with IRE-PGA (Professional Group Audio of the Institute of Radio Engineers) was organized and broadcast engineers and others provided numerous papers on the topical subject of f.m. stereo broadcasting. An innovation was created by the introduction of a session covering the European scene of recording techniques and this was considered successful enough to suggest its repetition next year on an enlarged scale.

The subject matter for the Convention papers covered a wide range—microphones, earphones, audio electronics, loudspeakers, disk recording and reproduction, music and electronics, magnetic recording, stereophonics (sponsored by IRE-PGA), sound reinforcement, f.m. stereo broadcast and psychoacoustics. Over 100 papers were read at this Convention and thus space will not allow adequate detailed reportage of this wide subject matter, so that the general trend only will be indicated with high spots from a few of the papers. Pre-prints were available of 48 of the papers and were on sale on the first day of the Convention.

The banquet was held half way through the week and is an important feature of the Convention, since it is at this gathering that the various awards, Hon. Memberships and presentations of Fellowships are made, and the newly elected officers for the coming year are announced. Mr. H. H. Scott presided and the Honoured Guest was Mr. G. R. Marek, Vice-President and General Manager of the RCA Victor Record Division. He gave a racy and interesting talk, illustrated by films, slides and tape recordings.

His main theme appeared to be encouragement for the continued improvement of recording and reproduction techniques. To illustrate this he recalled, by a varied selection of films and stills, the progress from the days of Caruso to RCA's recently opened recording studios near Rome. He referred to the well-known episode in which Fred Gaisberg took an independent decision with regard to the first contract for recordings with Caruso. He reminded his audience with some emphasis, that they were in the music business and their duty was to re-create sound which for the most part, must be in such a manner as to be pleasing and restful. Their main objective should be to design the acoustic conditions so that a good sound could be made in the studio and that on reproduction of the recorded sound an equally good sound may be re-created. Mr. Marek referred to the great progress in recorded sound made in England and in the U.S.A. and he reminded the audience that even in the past five years a very great improvement had been achieved and he illustrated this by playing comparative recordings. He predicted that in 10 years' time a further dramatic improvement will be made. He gave no hint regarding any preferred recording medium and one gathered the impression that the disk as we know it to-day has a long and useful life ahead.

## Pickup Design

The sessions on disk recording and reproduction were very interesting and were well attended. There is a clear indication that more and more attention is being paid to the scientific engineering design of pickups. This is most welcome, since these small transducers have been a stumbling block for the reproduction and better evaluation of disk records.

Professor F. V. Hunt, Harvard University, gave a very well considered paper entitled—The Rational Design of Phonograph Pickups. The major part of this paper has been published in the October, 1962, issue of the *Journal of the Audio Engineering Society*. The basic rationale of pickup design is re-examined with particular concern for the factors which control proper groove tracking. A review of fundamentals was undertaken to provide guide lines for bearing-weight reduction and its conclusions also furnished criteria for assessing the performance of any pickup design. There were two other papers concerned with the design of pickups with a bearing weight of 2 grammes or less. An interesting paper was read by Mr. P. Kantrowitz, regarding the translation loss and the reduction of this loss with the reduction of bearing-weight. Two well-studied papers were presented by J. G. Woodward and E. C. Fox regarding programme level and equalization in phonograph recording.

There were two papers from England in the European section, one from Dr. W. S. Percival of E.M.I.

describing a correlation meter for checking the poling of stereo signals, and the other from Mr. John Walton of Decca which described the effect of tip mass on elastic and plastic deformation. In this paper some excellent electron-micrographs of stylus tracks on the grooves were illustrated. Dr. Percival's paper is considered topical owing to the importance of the correct stereo channel phasing in operating a compatible stereo radio system.

There were two sessions on f.m. stereo broadcasting but these dealt with operational experience and the radio equipment with little if any direct interest to the audio engineer. The large number of papers contributed, however, indicates the interest stereo broadcasting has aroused, stimulated no doubt by the success of the stereo disk record business.

### Magnetic Recording

Magnetic recording occupied a full morning session of seven papers. There was no startling news in this quarter. One might have expected some new ideas on slow-speed cartridges for tape records, but surprisingly enough there is nothing to report on this subject. There were two useful papers on tape noise and reproducer amplifier noise but no indication of improved tape media. John McKnight of Ampex showed experimental results which suggest that the improved erasure with double gap erase heads is due to the re-recording of the incoming signal from the lead-in edge of the head on to the tape at the trailing edge of the head. This clears up a little mystery that has bothered many of us for some time.

The session on loudspeakers and microphones, though containing useful papers, did not excite any special interest.

The session on sound reinforcement and acoustics was particularly interesting and included papers on the measurement of reverberation time. The new RCA Italiana Recording Studios, Rome, were described by Mr. E. R. Hanson.

During a panel discussion on the subject of "What Hath Stereo Wrought" a great deal of sound common sense was expressed with regard to the purpose of stereo recording. One speaker said that with mono recording the illusion of depth could be produced by controlling the ratio of direct to rever-

berant sound, but with two channel stereo the impression of breadth and spatial layout could be achieved with the addition of what he called a desirable acoustic frame within which to contain the sound picture. In some circles this acoustic frame is referred to as ambience. The early trend of the "ping-pong" effect of emphasized left and right has given way to the more sober concerted sound to fill the virtual sound stage. Much comment was made regarding the poor salesmanship for stereo records. The dealers demonstrate equipment which they know nothing about, in most inadequate rooms and without adequate explanation to the customer of the advantages of stereo. Further, there was a general plea for a better technical liaison with the public with regard to the choice of equipment and its operation.

G. F. D.

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## National Lending Library For Science and Technology

SIX years ago a lending library unit was formed by the Department of Scientific & Industrial Research. This was the nucleus of what has now grown into the National Lending Library for Science and Technology at Boston Spa, Yorkshire, which was officially opened by Lord Hailsham, Minister for Science, on November 5th. No fewer than 22,000 periodicals from 109 countries, together with 25,000 books, totalling in all some 350,000 volumes, are in the library which is housed in converted munition stores on a 60-acre site. This library has been built up from three main sources:— 1. The Science Museum Library (which because of lack of space and the expansion of the Imperial College of Science and Technology was unable to develop its loan service); 2. Collections by the N.L.L. since its inception; and 3. Presentations from universities, organizations and private libraries such as this journal's.

A survey was undertaken by the D.S.I.R. a few years ago to assess the potential demand for scientific literature and it was found that although traditionally books are "the main vehicle" in advanced science, "the more immediate method of communication" is through journals and these account for about 90% of the N.L.L.'s collection. The survey also revealed that Russian scientific literature in this country was "particularly incomplete." This has now been rectified and the N.L.L.'s collection of Russian journals is the largest in Western Europe and its Russian books outnumber those in English. It also collects translations from the Russian and co-operates with the National Science Foundation in the U.S.A. in a joint cover-to-cover translating programme of Russian journals.

The main purpose of the library is to supplement the internal library resources of industrial and research organizations by providing a rapid "same-day" loan service. The library lends only to organizations (to avoid the necessity of chasing individuals for the return of publications) and 1,500 are registered as "approved borrowers." Application must be made to the director, Dr. D. J. Urquhart, to be placed on the "approved" list. Applications for loans are made on special request forms sold in pads of 50 for £3 to cover cost of postage on borrowed volumes. At the present time some 3,000 loan requests are received each week. In addition to approved organizations there are also some 50 libraries of local authorities and technical colleges who are in a position to borrow journals, etc., from the N.L.L.

Since there is at present no lack of space at the N.L.L., micro-film holdings are restricted to literature difficult or impossible to acquire in its original form.

### INFORMATION SERVICE FOR PROFESSIONAL READERS

The reply-paid forms introduced last month to replace the postcards hitherto included have proved to be very helpful to professional readers, judging by the number of forms returned to us. This improved *Wireless World* service is therefore being continued.

The forms are on the last two pages of the issue, inside the back cover, and are designed so that information about advertised products can be readily obtained merely by ringing the appropriate advertisement page numbers. Space is also provided for requesting more particulars about products mentioned editorially.

By the use of these forms professional readers can obtain the additional information they require quickly and easily.

# International Radio Communications Exhibition

## NEW AMATEUR EQUIPMENT

**O**UR comment last year, that amateurs had gained a lead over professionals in transistor applications, was even more to the point at this year's exhibition. Transistors are, of course, ideally suited to mobile equipment where valve-type gear would need interference-producing power supplies, but they are now used in receivers and transmitters for their own sakes, not merely as devices which can replace valves when power supplies are difficult. The former limitation of transistors, low cut-off frequency, seems to be no problem at all and many v.h.f. and even u.h.f. receivers were shown.

### Receivers

Perhaps the most advanced receiver was A. L. Mynett's Silver Plaque-winning design for 23 and 70cm. Commercial diodes and transistors are used throughout and the receiver covers the bands 432-436Mc/s and 1,296-1,300Mc/s. Triple frequency changing is used, the 1st i.f. being 28Mc/s; the 2nd is tunable over the range 2-4Mc/s, and the final i.f. is 456kc/s. By making the second local oscillator the variable one, a very stable and reliable low-frequency circuit can be designed. On the 79cm band, T2028 transistors are used in a two-stage common-base r.f. amplifier feeding a GEX65 mixer, while at 23cm no r.f. amplification is used, a 1N21 silicon tungsten diode mixer tapped into a capacity-tuned quarter-wave line being employed.

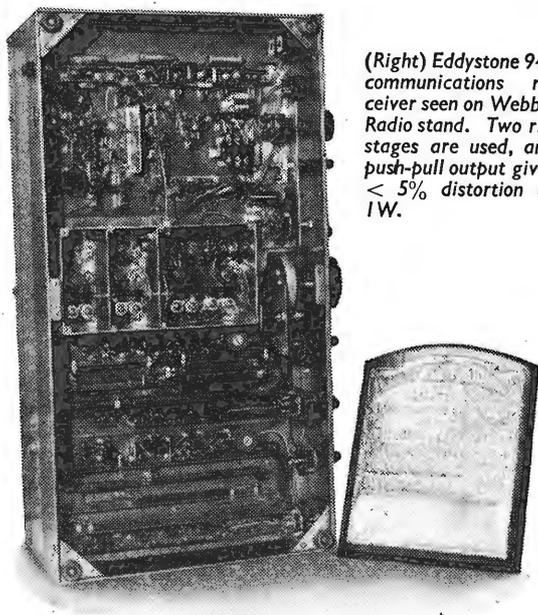
Several transistor mobile receivers were seen—two very neat ones on the stand of T. Withers. Models are

made to cover the "top band" (1.8-2Mc/s) and the 2m band. Eight transistors are used in the latter model, while in the "Twomobile," a further four transistors comprise a 2-metre converter. In this way, a tunable i.f. is provided, with its inherent reliability.

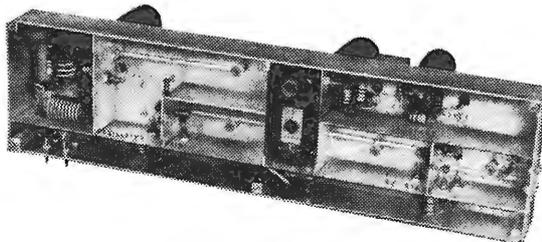
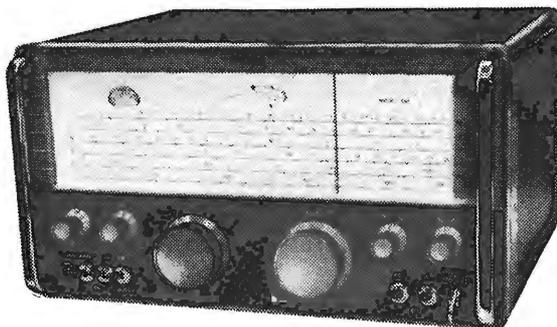
Another example was shown by Minimitter—the T.R.7 160m receiver. Seven transistors are employed, and a Q-multiplier circuit offers variable selectivity. The 9V battery and loudspeaker are built-in, the speaker pointing downwards for dash-board mounting.

The Q-multiplier circuit just mentioned need not necessarily be built into a receiver, and the Heathkit QPM-1 is a convenient add-on unit. An effective Q of 4,000 is obtained by positive feedback, the selectivity then being comparable with that of a crystal filter, with the advantage that the peak is tunable. It is also possible to remove unwanted signals over a narrow band by means of a tunable notch, obtained by connecting the Q-multiplier to a negative-feedback amplifier. If the gain control of the multiplier is increased, the circuit oscillates and a b.f.o. is obtained.

Eddystone's new h.f. receiver, the 940, uses a cascode r.f. amplifier, with a consequent reduction in noise and intermodulation troubles. Three switched selectivity positions are provided, with a crystal filter in the narrowest. The crystal phasing control for positioning the notch at either side of the peak is brought out to the front panel. Separate detectors are used for a.m. and c.w./s.s.b., a mixer detector being used for the latter reception mode, which incorporates a  $\pm 3$ kc/s

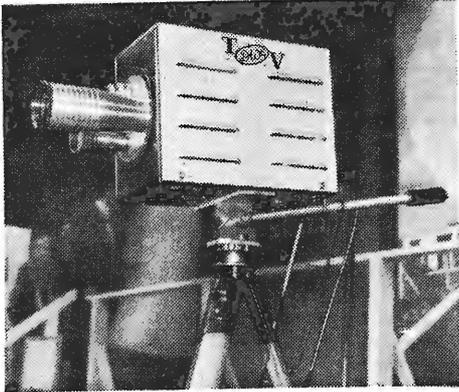


(Right) Eddystone 940 communications receiver seen on Webb's Radio stand. Two r.f. stages are used, and push-pull output gives < 5% distortion at 1W.



A. L. Mynett's first-prize winner.

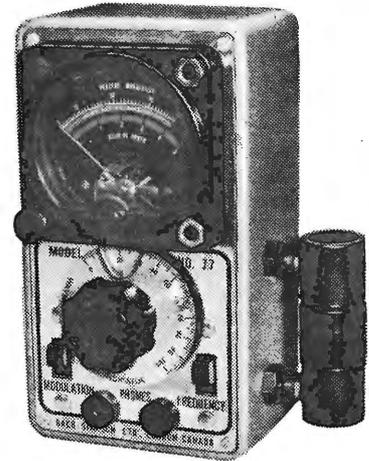
M-O Valve Company 1,300Mc/s narrow-band converter.



(Left) D. W. Goodyear's 7-valve television camera.

(Right) Bach-Simpson absorption wavemeter shown by Aveley Electric.

(Below, right) T. Withers 2-metre. 1W output, mobile receiver. A model is available for 160-metre working.



b.f.o. The receiver covers 450kc/s—30Mc/s in five bands.

### Transmitters

Simplicity of construction was the keynote of a number of M-O Valve Company exhibits. Thus in a 1,300Mc/s narrow-band converter trough line rather than coaxial circuits are used, strip lines are used in the driver and output stages of a 430Mc/s 10-watt amplifier, and a square rather than cylindrical box radial cavity is used to tune the output stage of a 150-watt 430Mc/s output stage. (See also the article on p. 568 of this issue.) Another feature of some of these exhibits was the use of a pin-based valve (A2521) at frequencies as high as (in the converter) 1,300Mc/s.

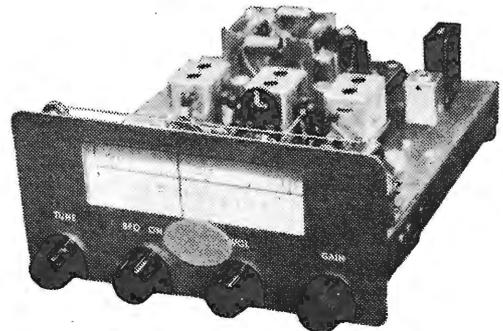
An interesting detail of the Green and Davis "Falcon" 2-metre transmitter is the use of an ordinary relay as an inexpensive "coaxial" type. The two outer contacts are earthed to provide the shield, the two centre contacts are connected to the aerial coaxial inner, and the two intermediate contacts are connected to the transmitter and receiver respectively. This arrangement provides earthing of the transmitter and receiver, depending on which is not in use, and has an insertion loss only about 1dB greater than a coaxial relay. Other unusual features of this transmitter are that the percentage modulation as well as grid drive and anode current in the final stage can be monitored, and that provision is made for plugging in two alternative internal as well as an external crystal.

The U.S. Information Service exhibit included—appropriately—a mockup of the amateur's satellite OSCAR 1 which had been used to check for spurious emission and r.f. cross coupling. This satellite uses a 2N1493 transistor crystal-controlled 92.5Mc/s oscillator followed by a 2N1506 amplifier and Pacific Semiconductors 115-10 variable-capacity-diode frequency doubler giving 100mW output. The oscillator is keyed by a transistor multivibrator and counters.

### Test and Measurement

A neat little probe-type test oscillator, imported by Relda Radio, contains a battery-powered transistor oscillator which produces a harmonically-rich audio frequency waveform. Sufficient harmonics are produced for the device to be used at r.f., and the probe is simply applied to the input of each stage working back from the output, in the manner of a signal-generator. Four pen-cells are used, and a pilot light indicates when the batteries are due for replacement.

One of the smallest absorption wavemeters seen for some time was shown by Aveley Electric—the Bach-Simpson 77-380. This instrument uses plug-in coils to cover the range 1Mc/s-56Mc/s and can be used to measure field strength, v.s.w.r. and modulation depth.



### Societies and Services

The British Amateur Television Club showed a selection of home-built gear, the outstanding example being a self-contained seven-valve vidicon camera. This is a very simple design by D. Goodyear, and uses a free-running line multivibrator (random interlace) and a mains-driven field scan. The unit is designed for 405-line, positive-modulation operation, and the output is in Band I. The camera was shown feeding a commercial receiver and the picture quality was remarkably good. The construction of the camera is excellent, and in fact it looked so professional on the stand that it was at first mistaken for a commercial product.

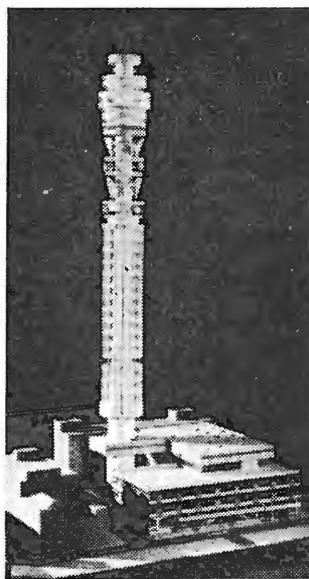
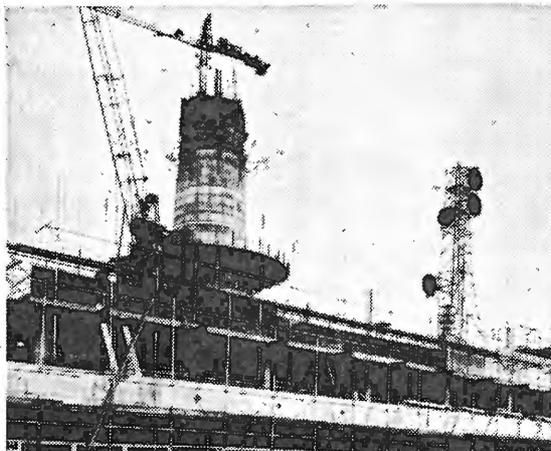
The R.S.G.B. stand held a wide range of amateur-produced communications and test equipment. Prize-winning exhibits included a 160m transmitter-receiver by J. C. Huntley (G3PPI), which was awarded the Freeman Trophy. The K.W. Electronics KW77 receiver, which was described in our January 1962 issue, gained the Manufacturers Silver Trophy, while the two Out-of-Town awards were won by P. Lumb (G31RM) for an electronic key and a paddle key, and R. Stanforth (G3EGV) for a 70-cm transmitter-receiver.

Each of the three Services was represented at the show where they exhibited standard communications equipment but, of course, the main objective of their participation was the recruiting of personnel and of members for their respective amateur radio societies. The R.A.F. also featured its recently formed Tape Recording Society.

For the first time the City & Guilds of London Institute participated and among the syllabuses available was that for the recently introduced Electronics Servicing Examination. This was drawn up by the Joint Advisory Committee of the C. & G. and the Radio Trades Examination Board.

# WORLD OF WIRELESS

**London's Radio Tower,** which will be some 630-ft tall, has already reached the height of the existing 200-ft steel tower carrying communication paraboloids, which it will replace. As may be seen from the model on the right the horn and paraboloid aerials for the Post Office communication's network, which includes television links, will be housed on platforms in the upper half of the tower and above these will be observation floors and restaurants. The site is off Tottenham Court Road, W.C.1.



## Space Communication

IT was recommended at the last Administrative Radio Conference of the I.T.U. (Geneva 1959) that an extraordinary Administrative Radio Conference should be held towards the end of 1963 to allocate frequency bands for space communication purposes. The conference, which will be of about one month's duration, has now been fixed to open on October 7th next year at Geneva.

At the 1959 Conference frequencies were allocated for communication between "space vehicles" and for earth-to-space services but these were for "research purposes." These frequencies (Mc/s) are 10.003-10.005, 19.990-20.010, 39.986-40.002, 136-137, 183.1-184.1, 400-401, 1427-1429, 1700-1710, 2290-2300, 5250-5255, 8400-8500, 15150-15250 and 31500-31800.

Recommendations for space communication frequencies have already been made by the Federal Communications Commission of America. These include the use of the following frequencies in the amateur bands for satellite command purposes:—143, 420 and 450 Mc/s. The suggested tolerances are  $\pm 20$  kc/s for the first and  $\pm 25$  kc/s for the others.

## Tax on TV Set Conversion

H.M. Customs and Excise have announced that tuners, i.f. strips and other special adaptors designed to convert sets to receive u.h.f. 625-line transmissions are liable for Purchase Tax (45%). The Commissioners will not regard "the alteration or adaptation of a set to enable it to receive u.h.f. transmissions as amounting to the manufacture of a new set if the alterations or replacements are limited to the tuner and the i.f. stage; and the conversion units used are tax paid."

**Anglo-Japanese Commercial Treaty,** likely to come into force in April or May of next year, provides for the following U.K. import quotas for the years 1963, 1964 and 1965: semiconductors (£200,000, £450,000 and £700,000 respectively); transistor radio receivers (£500,000, £750,000 and £1,200,000); parts of transistor radio apparatus (£200,000, £450,000 and £700,000); and transistor television sets (£225,000, £450,000 and £600,000). The amount for 1963 in each case is slightly up on the current year's quotas.

**I.T.A.'s Arfon station,** situated 9 miles south of Caernarvon near the Lleyn peninsula in north Wales, began programme transmissions on November 9th. This station, the second of the three planned to cover north and west Wales, joins the Presely station in broadcasting the programmes of Wales (West and North) Television Ltd. The incoming programme signals are received directly off-the-air from the Presely station which operates on channel 8, and are retransmitted from Arfon on channel 10 using horizontal polarization.

**Enniskillen television and v.h.f. sound transmitting station,** which the B.B.C. are having built on Brougher Mountain, nine miles north-east of the town, is due to be completed about the middle of next year, when it will serve some 48,000 additional people and provide improved reception for a further 40,000 people living in Co. Fermanagh and the south-western part of Co. Tyrone. Television programmes will be transmitted on channel 5 with horizontal polarization.

**B.B.C.'s Swindon Station Opens.**—Programme transmissions from the B.B.C.'s low-power relay television station at Swindon, Wilts., began on November 5th. The transmitter operates on channel 3 and uses horizontal polarization.

**I.E.E. Membership Reaches 50,000.**—Membership of the Institution of Electrical Engineers reached the 50,000 mark on November 8th when W. R. Matthews, admitted as a Student, was formally congratulated by the president, C. T. Melling. Starting in 1871 with about 70 founder members of the then Society of Telegraph Engineers, the I.E.E. grew in numbers rapidly to total 3,660 by 1900 and 20,000 by 1940.

**Alouette, Canada's first satellite,** is now orbiting about 600 miles above the earth. It is hoped that by means of radio sounding from above the satellite will measure the concentration of cosmic rays and other energetic particles and radiation in space over most of the earth, including the polar and auroral zones. In addition to its radio sounding transmitter and receiver it carries two telemetry transmitters to radio its findings to earth on command, and a 50mW tracking transmitter to permit precise location of the Canadian satellite at all times.

**IAESTE.**—The International Association for the Exchange of Students for Technical Experience (U.K.) report that in the year ending September last, 839 students were sent abroad and 848 students were received by 359 British industrial and other organizations. Since 1947 IAESTE has been responsible in arranging for nearly 70,000 students from 31 member countries to receive technical experience abroad during vacations. Information on U.K. participation is available from the executive secretary J. Newby, 178 Queen's Gate, London, S.W.7.

**U.S. sales of electronic equipment** in 1962 are estimated by the American Electronic Industries Association to reach \$2,400M and are expected to rise to more than \$4,000M by 1966. These figures compare with actual sales to the value of \$2,200M in 1961. The industrial and commercial electronic equipment to which these figures relate includes data processing, broadcasting, communications, navigational, testing and measuring and industrial control apparatus.

**Guide to Courses.**—The London and Home Counties Regional Advisory Council for Technological Education has produced a 40-page booklet "Engineering Education in the Region" which lists recognized courses in the radio and electronics engineering field, above those at the most elementary level, which colleges in its area are offering during the academic year 1962-63. Copies of the booklet, price 4s, are available from the Council at Tavistock House South, Tavistock Square, London, W.C.1.

**Radio Amateurs' Examination.**—The report of the City & Guilds of London Institute on the May 1962 Radio Amateurs' Examination records a total of 1,189 candidates compared with 1,251 the previous year. Passes totalled 808 (67%) as against 866 (69%) for 1961.

**Research into the upper atmosphere** will be facilitated by a 4½-ton thermionic valve, which is being constructed at the Admiralty's Microwave Electronics Division of the Services Electronic Research Laboratory at Harlow, Essex. The valve, which is 18ft long, over 7ft high and 6ft wide, is a travelling-wave tube that will provide 100.v.W, 420-Mc/s pulses.

**Pulse and digital techniques** in many branches of science and engineering has created a need for specialists. The College of Advanced Technology, Birmingham, has therefore arranged a course in pulse and digital circuits which will provide the basic principles of design of such circuits and opportunities for the measurement of their performance. Commencing on January 8th next, the course will be held on Tuesday and Thursday evenings. Further details may be obtained from the College Secretary at Gosta Green, Birmingham, 4.

**Sound and vision distribution equipment**—including a new 7-vision plus 4-sound programme system—will be demonstrated by Belling & Lee at their headquarters at Enfield, Middx., from December 10th to 19th inclusive. Professionally interested engineers, consultants, architects, etc., are invited to telephone the company's Technical Services Department (Enfield 5393) to make an appointment.

**International Instruments Show.**—The seventh in the series of International Instruments Shows to be organized by B. & K. Laboratories will be held from May 27th-31st next year at 4 Tilney Street, Park Lane, London, W.1. The company is also sponsoring the first Environmental Engineering Symposium which will be held coincident with the exhibition.

"The Radio & Electronic Engineer" is the new title of what was previously known as the *Journal of the British Institution of Radio Engineers*.

**Balth. van der Pol Gold Medal.**—Mrs. van der Pol, the widow of Professor Balth. van der Pol, has made it possible for the International Scientific Radio Union (U.R.S.I.) to found an award to be known as the Balth. van der Pol Gold Medal which will be presented at each triennial General Assembly "to an outstanding radio scientist who, during the three year period preceding the year of the General Assembly, will have made a valuable contribution in one of the fields of activity of the Union, either by his research work, discoveries, achievements, or by an other activity." The first award will be made at the Tokyo general assembly next year. Professor van der Pol was director of the International Radio Consultative Committee (C.C.I.R.) from 1948 to 1956.

**B.B.C. Research Scholarships.**—University graduates in electrical engineering or physics wishing to work for a higher degree at any U.K. university can apply for a B.B.C. research scholarship (normally for two years and valued at £500 per annum). A condition applying to the subject for research is that it must have an application to sound or television broadcasting. Latest recipient of a scholarship is D. M. Kitching, who is undertaking research at Southampton University under the guidance of Dr. W. A. Gambling.

**Jamaica** is to have a television service from August 1st next year. A franchise to provide television programmes has been awarded to the government-sponsored Jamaica Broadcasting Corporation. The new service will operate on the 625-line system.

**TV Society Southern Centre?**—Readers in the Bournemouth area may be interested to know that a meeting will be held at 7.15 on December 10th at the Kings Arms Hotel, Christchurch, to explore the possibility of forming a Southern Centre of the Television Society.

**Meeting on Mass Spectrometry.**—The Institute of Physics and the Physical Society announces that it is to hold a one-day meeting on Mass Spectrometry at the Imperial College of Science and Technology, London, on December 19th. Registration is necessary and application forms are now available from the Administration Assistant, The Institute of Physics and The Physical Society, 47 Belgrave Square, London, S.W.1.

**Generalized telegraphist's equations** and their applications is the subject of a University of London course of three lectures to be given by Professor S. A. Schelkunoff, Ph.D., at University College, Torrington Place, W.C.1, at 5 p.m. on December 3rd, 5th and 7th. Admission is free, without ticket.

## CLUB NEWS

**Barnsley.**—At the December 14th meeting of the Barnsley & District Amateur Radio Club, which celebrates its golden jubilee next year, W. W. Williams will speak on receiver construction. The club meets twice a month at 7.30 at the King George Hotel, Peel Street.

**Birmingham.**—Part IV of his series of lectures on radio fundamentals will be given by J. Smith (G3JZF) at the December 28th meeting of the Slade Radio Society at 7.45 at the Church House, High Street, Erdington.

**Croydon.**—Dr. J. Walling, of the Mullard Research Labs., will speak about lasers and masers at the December 11th meeting of the Surrey Radio Contact Club at 7.45 at the Blacksmiths Arms, 1 South End.

**Edinburgh.**—The Lothians Radio Society meets on the second and fourth Thursdays of each month in the Y.M.C.A., 14 South Saint Andrew Street, Edinburgh 2, at 7.30. On December 13th there will be an R.S.G.B. tape recorded lecture entitled "World Wide Telecommunications" by L. Parnell (G8PP).

# News from Industry

**Plessey Co. Ltd.**—Group trading profit amounted to £6,456,531 for the year to June 30th, 1962, including eight months' trading in respect of Automatic Telephone & Electric Company and Ericsson Telephones. The preceding year's trading profit was £3,422,659. Profit after tax totalled £2,588,552 as compared with £1,712,886 previously.

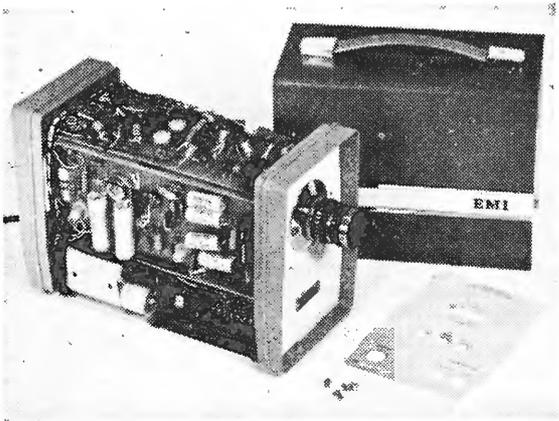
**Decca Ltd.**—Group turnover for the year to March 31st, 1962, expanded by £3.1M to £27.6M and the trading balance increased from £4M to £4.7M. After tax of £1,448,000, against £1,061,000 previously, the net profit is £1,482,000 as compared with £1,249,000 for the preceding year.

**Aerialite.**—Group profits for the year to May 31st last increased from £147,386 to £183,214. Taxation absorbed £96,256 (£66,257) and net profit was £86,958 as compared with £81,129 for the previous year.

**Raytheon at Shannon.**—An electronic components plant is being opened in the duty-free industrial zone at Shannon Airport by the American Raytheon Company, who already have interests in the U.K. market mainly through their Cossor Electronics subsidiary. The new plant, which is expected to eventually occupy 50,000 sq ft and employ up to 500 people, will be operated by a new Raytheon wholly-owned subsidiary named Industrial Components, Ireland, Ltd.

**Nagard Ltd.**, the Belmont, Surrey, manufacturers of oscilloscopes and pulse generators for laboratory and industrial use, have been acquired by Advance Components Ltd., of Hainault, Essex. Home and export sales of Nagard equipment will be conducted from the Advance headquarters at Roebuck Road, Hainault, Essex. As a result of the takeover E. G. Wakeling, Advance joint managing director, becomes managing director of Nagard, and M. J. G. Hinton continues as Nagard's research director.

**Transistor Television Camera.**—E.M.I.'s Type 8 closed-circuit camera, uses transistors throughout (except for the vidicon pick-up tube) and operates on mains or 12V batteries. Packed into a case 11 x 7 x 5in, weighing only 10lb, are a lin vidicon, scan generators, signal amplifiers and a modulator that produces a Band 1 signal. An f/1.9, 1in focus lens is a standard fitting and the whole camera, ready to work, costs £160. 405-, 625- (various systems) and 525-line operation is catered for, and the built-in transistor convertor operates at 50 or 60c/s.



**The Vidor battery business** has been acquired by Royston Industries Ltd., of Byfleet, Surrey, in a deal reported to be worth about £925,000. Royston chairman, E. R. Sumner, says that the Vidor business now acquired was part of the business conducted in conjunction with the operations of Burndept, which was acquired by Royston in August, 1961. He says that although difficult to assess Vidor's profit for the year to March 31st, 1963, the Royston directors are of the opinion that the Vidor profit, before tax, will be not less than £140,000. In 1961-62 there was a loss of £25,470. Following the acquisition T. N. Cole has resigned from the Vidor board, whilst E. R. Sumner and J. G. Leech have been appointed Vidor directors.

**G.E.C. Obtain G.P.O. Link Order.**—The General Post Office has ordered G.E.C. (Telecommunications) equipment for a new microwave link that will provide 1,800 telephone channels or equivalent facilities over each r.f. channel, between London, Birmingham and Manchester. The link will operate in the 6,000 Mc/s frequency band and initially there will be four broad-band radio frequency channels in each direction. The equipment is being manufactured at the Coventry plant of G.E.C. (Telecommunications) Ltd. The London terminal will be in the new Tower, which the G.P.O. are building on the Museum Exchange site.

**A.E.I.'s Computer Department**, part of Associated Electrical Industries' Electronic Apparatus Division, is extending its computer bureau facilities by opening data processing centres in a number of regions throughout the U.K. A new computer centre, which will be additional to those at Manchester and Rugby, is to be established at 33 Grosvenor Place, London, and is scheduled to be operational by mid-1963. It is the intention of A.E.I. to sell time on the computer and the final installation in London will be capable of handling data in varied forms, by using a range of typewriter, card and paper tape input devices.

**NordMende.**—It has been decided to rationalize the research and development activities of the television, radio, tape recording and electronic divisions of the NordMende (Norddeutsche Mende Rundfunk KG) in Bremen, and a new five-storey building is being erected adjacent to the television factory. The new Nordmende Development Centre is expected to be in full operation by the middle of 1963.

**B. & R. Relays Distribution in Germany.**—Sole distribution rights of B. & R. Relays' products in Germany have been granted to I.N.H.A. Mercantile & Trading Establishment, whose head offices are at Mauren, Liechtenstein, with branches in Berlin and Düsseldorf.

**BTR Industries Ltd.** has merged two of its subsidiary companies, Microcell Ltd. and Palmer Aero Products Ltd., to form a new Engineering Products Division of the Group. Microcell's Kingsway, London, offices have been closed and the combined administrative and design functions moved to Park Street, Camberley, Surrey.

**Telequipment's** new office and administrative block at their Chase Road, Southgate, plant was completed to schedule, in time for the company's tenth anniversary on November 22nd.

**David Brown-E.M.I. Electronics Ltd.** has been formed by Electric & Musical Industries and David Brown Industries to take over and expand their existing joint programme of research and development into the problems of applying electronic techniques to machine tools. The new company is located at Huddersfield.

**Cossor Reorganization.**—A. C. Cossor Ltd., a member of the American Raytheon group of companies, announces that the registered name of its subsidiary, Cossor Radar & Electronics Ltd. has been changed to Cossor Electronics Ltd. The latter company, located at Harlow, Essex, will eventually incorporate the following Cossor activities: the Radar Division; the Communications and Marine Products Operations; the Instrument Operations (including Ramp test equipment operations); and the Manufacturing Division.

**V.H.F. mobile radio telephones** for the fire and ambulance services of the Lancashire County Council have been supplied by Hudson Electronic Devices Ltd., of 4 Sydenham Hill, London, S.E.26. The 50 new equipments are Hudson FM115 models, which have an r.f. power output of 20W and six-channel facilities.

**The electronic summation business** of Astaron Electronics Ltd. has been transferred to Aron Meters Ltd., a wholly-owned subsidiary of Ferranti Ltd. This arrangement is an extension of a previous agreement made in 1961, under which Ferranti acquired the goodwill in the meter business of the former Aron company.

**Audience research statistics** relating to B.B.C. television and sound radio programmes are now produced daily on a National-Elliott 803 computer. The machine analyses information supplied by interviewers all over the U.K., and produces tables of results for study by the B.B.C. each day.

**Liverpool Royal Infirmary's** new £220,000 four-storey operating theatre suite has built-in electronic aids, including a private multi-camera television network provided by Pye T.V.T. Ltd. Installation of a complete sound system enables surgeons to give "running commentaries" on their work.

**Electron gun mounts** with electrostatic focus and intended for use in 110°-114° tubes with short to standard neck lengths, have been added to the Super Electronics Corporation range. U.K. agents for these American produced "straight" guns are Electrode Welding Co. Ltd., Jubilee Works, Cobbold Road, Willesden, London, N.W.10.

**Laser and Maser Compounds.**—The Pure Elements Division of L. Light & Co. Ltd. has added 27 high purity fluorides, molybdates and tungstates to its range of ultra pure materials. Many of these, notably calcium tungstate and strontium molybdate are already being used for growing laser and maser crystals; others are offered for research in this field.

**Capacitor Suggestion Wins £425.**—Highest-ever award by Standard Telephones & Cables Ltd., under its Staff Suggestion Scheme, was made recently to W. R. Netherton, an employee of the company's Paignton factory, for an idea to improve the process of sealing tantalum capacitors.

**Metox miniature oxide resistors,** manufactured by Welwyn Electric Ltd., at Bedlington, Northumberland, will be available ex-stock, following factory extensions to treble the present production area.

**Texas Instruments** are to construct a new 60,000 sq ft plant at Villeneuve-Loubet, near Nice, France, for the manufacture of transistors and other semiconductor products.

**Simmonds Relays Ltd.** have now moved to a new address at South Road, Harlow, Essex (Tel.: Harlow 26346).

**B.B.C. Relay Station Order.**—Marconi's have obtained an order from the B.B.C. for the supply of a "considerable quantity" of television and f.m. sound radio transmitter and translator equipments. These will be used by the B.B.C. as relay stations in areas of poor reception. The contract covers the supply of 10W translator drivers and transmitter equipments, as well as 100W and 500W amplifiers.

**Westrex Company,** a division of Litton Industries, are supplying the film sound reproduction equipment, stage announcing system, public address equipment for the lounge and an inductive loop hearing-aid system for M.G.M.'s new Empire Cinema, Leicester Square, London, which opens in December.

**McAlpine Aviation's** new radio centre at their Luton Airport headquarters has been granted full Air Registration Board approval. It offers a repair, overhaul and installation service for aircraft radio and navigational aid equipment.

**Reliance Manufacturing Co. (Southwark) Ltd.** has changed its trading title to Reliance Controls Ltd. Address remains Relcon Works, Sutherland Road, Walthamstow, London, E.17, but telephone number is now Larkswood 8404.

**A. N. Clark (Engineers) Ltd.,** manufacturers of air operated telescopic masts, have moved from Merton to new premises at Binstead, Ryde, Isle of Wight (Tel.: Ryde 3691).

## OVERSEAS TRADE

**Bharat Electronics Ltd.,** Bangalore, has been licensed by Mullard Equipment Ltd. to manufacture British-designed mobile wireless stations for use by the Indian Armed Services. Bharat Electronics is wholly owned by the Indian Government. Under a £1M contract, manufacture of Plessey-designed radio transmitter/receivers is also to be undertaken by Bharat Electronics.

**Italian Order for Thermionic.**—The Ministero Difesa Aeronautica, Rome, has ordered from Thermionic Products (Electronics) Ltd., a 60-channel installation of their Series IV communications recorders for a new air traffic control centre.

**V.H.F. junction radio equipment,** manufactured by the General Electric Co. Ltd., is used in a telephone link between Penang, in Malaya, and Haad Yai, in Thailand.

**Three Emicon rotary control systems,** valued at nearly £10,000, are being supplied by E.M.I. Electronics Ltd. to the Société Genevoise d'Instruments de Physique, the Swiss jig-boring machinery manufacturers.

**Rank Cintel,** a division of the Rank Organisation, have supplied four automatic radio-sonde telemetering equipments to Iran and Turkey under arrangements made by the World Meteorological Organisation in conjunction with the British Meteorological Office.

**Decca Exports.**—The Canadian oceanographic and hydrographic survey vessel C.H.S. *Hudson* is to be equipped with Decca true motion radar, relative motion radar and river radar for pilotage and navigation in confined waters. Decca Radar Ltd. also announce that they are to supply harbour radar equipment for installation at the port of Gdynia, Poland.

**The Soviet Aeroflot airline** has ordered airborne radio navigation equipment to the value of £250,000 from Standard Telephones & Cables Ltd.

**The Belgian Air Force** have ordered from G. & E. Bradley Ltd. £10,000 worth of equipment for workshop and pre-flight testing of Tacan navigational equipment.

# Personalities

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**C. L. Hirshman**, A.C.G.I., D.I.C., has been appointed engineering manager of Thorn-A.E.I. Radio Valves & Tubes Ltd. and is responsible for all engineering matters. Mr. Hirshman attended the Imperial College (London) where, after completing the Light Current Electrical Engineering Course, he continued and obtained the College diploma in radio engineering. After a post-graduate apprenticeship with the Metropolitan-Vickers Co. at Manchester, he joined their Radio Department, and later transferred to the Radio Department of the B.T.H. Company as assistant to the chief engineer on the formation of the A.E.I. Co. In 1931 Mr. Hirshman started up the Mazda Application Laboratories at Brimsdown, and was engineering manager (applications) of Thorn-A.E.I. Radio Valves & Tubes Ltd. until his new appointment. **J. C. King**, Assoc. Brit. I.R.E., has become engineering manager, products development, responsible for radio valve and cathode-ray tube product engineering. **J. Donegan**, B.Sc., A.C.G.I., D.I.C., has relinquished his post as product engineering manager to assume special duties within the company.

A. C. Cossor Ltd. has appointed **R. J. Yates**, B.Sc., as chief engineer for its instrument's operations. Mr. Yates was previously technical director of G. & E. Bradley Ltd. with whom he spent eleven years, and before that he was engaged by Marconi Instruments Ltd. in the design of test equipment in the microwave field. During the war he served in the Telecommunications Research Establishment, Malvern, where he worked on test equipment for airborne radar.

At Baden Baden recently **S. Hill**, M.Eng., a senior engineer with Standard Telephones & Cables Ltd., was elected chairman of the International Standards Organization's Committee 43, dealing with acoustics standards. Mr. Hill, who has been with S.T.C. for over 40 years, is well known for his work on public address systems and since the war has played an important part in the organization of technical facilities at the U.K. National Radio Show.

**Louis S. White**, who joined British Telemeter Home Viewing Ltd., the pay-TV organization, as technical adviser last year, has been appointed general manager and chief engineer. He was with Rediffusion for six years prior to joining British Telemeter. Mr. White succeeds as general manager **T. H. A. Llewellyn**, M.A., who has left the company.

**Air Comdre. C. C. Morton**, C.B.E., has become chief signals officer, R.A.F. Bomber Command, in succession to **Air Comdre. J. A. Robinson**, O.B.E., who is appointed director of weapons engineering at the Air Ministry. Air Comdre. Morton entered the R.A.F. College in 1930 at the age of 18. He took the electrical and wireless course in 1936 and has since specialized in signals. Since the war he has served in the Directorate of Signals at the Air Ministry, with No. 90 Group, commanded No. 3 Radio School at Compton Bassett, been inspector of radio services and for the past two-and-a-half years has been chairman of the British Joint Communications-Electronics Board. Air Comdre. Robinson, who is 51, has been chief signals officer, Bomber Command, since February, 1960, and before that was senior technical staff officer at Signals Command.

**Donald G. Fink** is to be general manager of the Institute of Electrical & Electronic Engineers which, from January 1st, will embrace the American I.E.E. & I.R.E. The new society will have a membership of 160,000. Mr. Fink has resigned from the position of vice-president for research of the Philco Corporation which he joined in 1952. For some years prior to that date he was editor-in-chief of our New York contemporary *Electronics*. He joined the staff of the journal in 1933 after graduating from the Massachusetts Institute of Technology to which he returned during the war as a member of the Radiation Laboratory and subsequently headed the Loran division. Mr. Fink was at one time chairman of the National Television System Committee (N.T.S.C.) and of the co-ordination committee of the U.S. National Stereophonic Radio Committee.

**Oliver Simpson**, Ph.D., M.A., head of the solid state physics group at the Services Electronics Research Laboratory since 1956, has been promoted to the grade of deputy chief scientific officer in the Scientific Civil Service. He joined the Admiralty Research Laboratory in 1944 and after 2 years returned to Trinity College, Cambridge, as a research scholar. From 1949-52 he was assistant professor of physics at the University of Michigan. Dr. Simpson joined the staff at S.E.R.L. in 1953.

**J. Marshall** has been elected to the board of Farnell Instruments Ltd. Mr. Marshall joined the company in 1960, having previously been with Racal Engineering Ltd., and E.M.I.

**D. Simpson**, Dip. Eng., M. Brit. I.R.E., A.M.I.E.E., general manager of Hughes International (U.K.) Ltd. for the past two-and-a-half years, has left the company to join the board of Hewlett-Packard Ltd. as managing director. **T. S. Chatfield**, formerly works manager, has assumed Mr. Simpson's duties and will be acting general manager at the Glenrothes (Fife) plant of Hughes International.

**H. L. Gibson**, who describes in this issue the beacon transmitter used for Band IV propagation tests between this country and the Netherlands, has been with the M-O Valve Co. since 1936, prior to which he was, for a short while, with Murphy Radio. After the war he spent some years in the field of applications engineering with special reference to large valves used for broadcasting and r.f. heating, and in 1955 assumed responsibility for all valve applications engineering in the company.

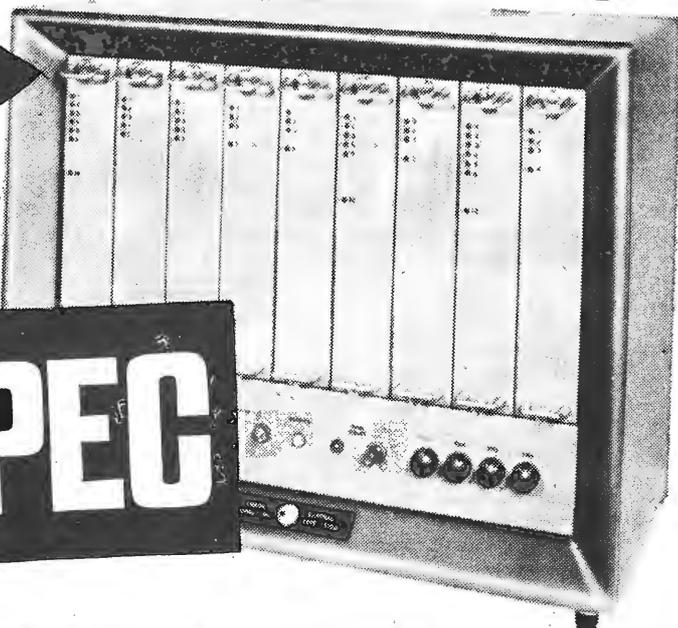
## OBITUARY

**Capt. James W. Barber**, a pioneer of the radio trade and at one time a member of the British Broadcasting Company, has died at the age of 78. After attending the University of Wales, Capt. Barber trained as an electrical engineer and served in World War 1 as a captain in the Royal Engineers. After experience in the cinematography field he was associated with the manufacture of the Brownie crystal set and in 1930 became chairman of the Radio Manufacturers' Association. Later he turned his attention to the plastics industry and during the last war was managing director of Granada Theatres.

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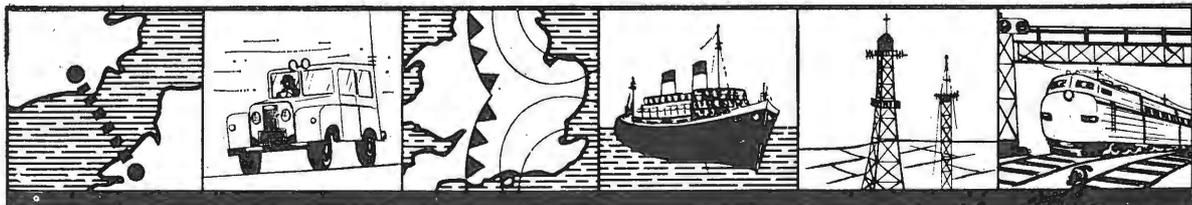
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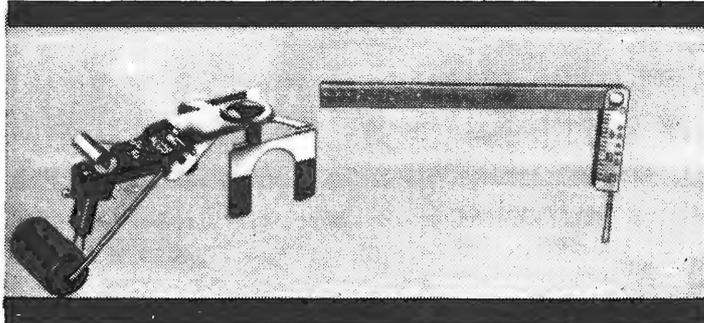
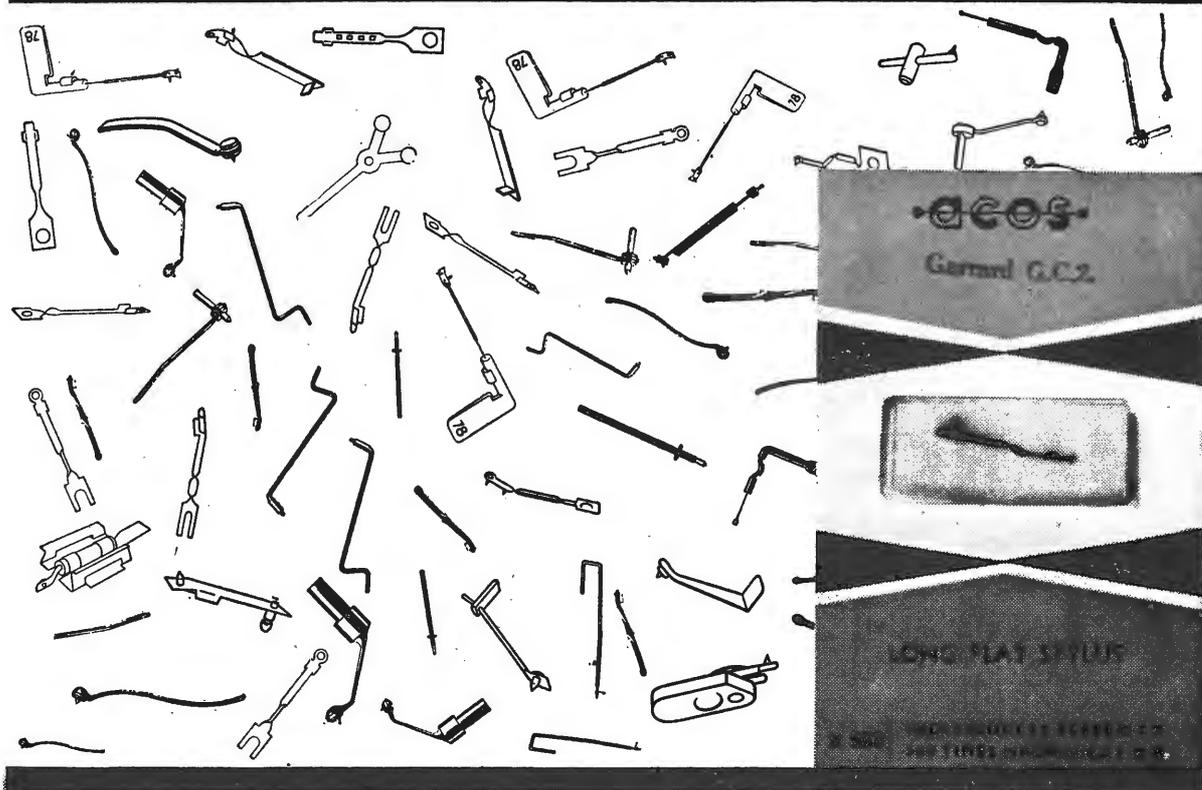
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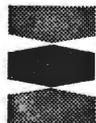
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# Transistor R-C Oscillators and Selective Amplifiers

USE OF HIGH INPUT-IMPEDANCE CIRCUITS

By F. BUTLER,  
O.B.E., B.Sc., M.I.E.E., M.BrIt.I.R.E.

**O**F the many types of R-C network which can be linked with a power amplifier to produce sustained oscillations or to give selective amplification, three have found wide acceptance. These are the Wien bridge 4-terminal network, the parallel-T R-C circuit (which is a 3-terminal equivalent of the Wien bridge) and the R-C or C-R ladder network. When its elements are suitably proportioned, the Wien bridge can be balanced to give zero output at one specific frequency. This is also true of the parallel-T network. If such a network is connected between the output and input of an amplifier, feedback will take place at all frequencies except that corresponding to the output null. A selective amplifier will result if feedback through the network can be made negative at all frequencies except that of the null. An oscillator is obtained if sufficient positive feedback is applied from output to input of the amplifier through a separate all-pass network which, for example, maybe a purely resistive path. A selective, regenerative amplifier is obtained by the use of controlled positive feedback which increases the loop gain, but not to the point of instability. In this mode of operation the frequency is accurately calculable from the network components and is almost independent of the amplifier gain.

If a parallel-T network is connected between the output and input of a phase-reversing amplifier, oscillations can be generated and selective amplification made possible without the use of a separate positive feedback link. The technique is to vary one or more of the network elements in such a way that a phase-reversed output is obtained instead of a null at the desired operating frequency. Oscillation merely requires that the amplifier gain exceeds the network loss at this particular frequency. The system will in fact adjust itself, like any other oscillator, so that the overall loop gain is unity. The network loss is frequency-dependent and this implies that the operating frequency will not be accurately calculable from the circuit constants. Changes in amplifier gain will also affect the frequency since the network loss must change in such a way as to compensate for them.

When R-C or C-R ladder networks are employed in phase-shift oscillators or selective amplifiers, use is made of the property that, at some calculable frequency, the network output is exactly reversed in phase with respect to the input voltage. It is also attenuated by an amount which depends on the

number of sections and on the ladder structure (uniform or graded elements). Continuous oscillations will be generated if such a network is connected between the output and input of a phase-reversing amplifier of sufficient gain. With a loop gain less than unity, oscillations cannot be maintained but selective amplification is still possible. The selectivity will depend on the ratio of actual gain to the critical gain required for the maintenance of continuous oscillations.

Still another R-C arrangement may be used in selective amplifiers. Networks are known which do not give a true null but which produce a large attenuation at the desired operating frequency. A particular type of bridged-T circuit will give this kind of response.

According to the principle of duality in circuit theory it is possible, by making use of standard rules, to transform the elements of a given network in such a way as to derive a second, reciprocal, network having similar transmission characteristics. A corresponding transformation of the generator source and network load impedances must be made so that, for example, the dual of a constant-voltage source becomes a constant-current generator. This principle is particularly useful in developing transistor equivalents of well-known thermionic valve circuits<sup>1</sup>. In this way, the total number of usable arrangements is doubled, but practical considerations limit the utility of some of the alternatives.

Returning to the standard circuits, Fig. 1 shows the Wien bridge (a) and its parallel-T equivalent (b). The balance equations for (a) are:—

$$\frac{C_2}{C_1} = \frac{R_3}{R_4} - \frac{R_1}{R_2} \text{ and } \omega^2 C_1 C_2 R_1 R_2 = 1$$

The two balances must hold simultaneously. The

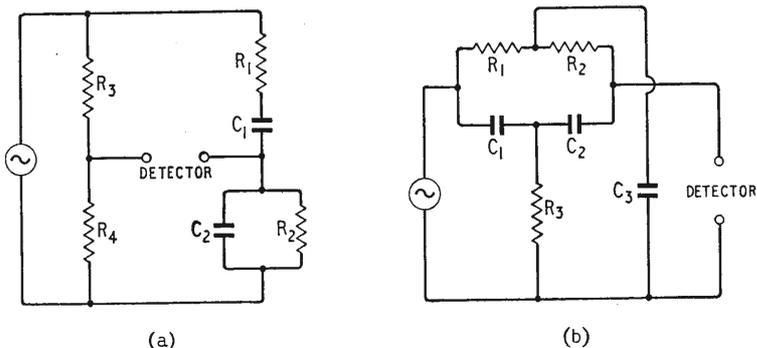


Fig. 1. (a) Wien Bridge and (b) its parallel-T equivalent.

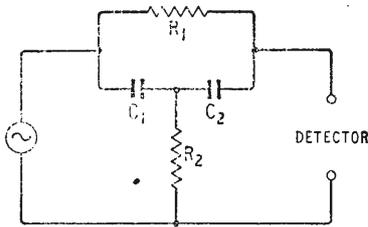


Fig. 2. Bridged-T R-C circuit.

parallel-T network gives an output null when:—

$$\frac{C_3}{C_1 + C_2} = R_3 \left( \frac{1}{R_1} + \frac{1}{R_2} \right) \text{ and}$$

$$\omega^2 C_1 C_2 R_3 (R_1 + R_2) = 1$$

The bridged-T circuit shown in Fig. 2 does not give a true null but it gives strong attenuation at a radian frequency corresponding to:—

$$\omega^2 C_1 C_2 R_1 R_2 = 1$$

Normally,  $C_1 = C_2$ , and for a sharp minimum it is then necessary that  $R_1 \gg R_2$ .

Fig. 3 shows two ladder networks in which an attenuated and phase-reversed output is produced at a calculable frequency. The analysis of a multistage network of this kind is lengthy and tedious if the elements are all different. Results are usually quoted for uniform networks in which all the resistances and all the capacitances are equal. The source impedance is either assumed to be zero, or, if resistive, it can be included as part of  $R_1$  in (a). Its inclusion in (b) is more difficult. The load is normally considered so large that its effect on transmission through the network can be neglected.

The writer has worked out the attenuation and phase characteristics of generalized 3-stage and 4-stage networks of both types and also for graded networks of the type in which the value of each element is a constant multiple of the preceding element of the same kind. The results are too cumbersome for publication and only qualitative use will be made of the conclusions. The main point is that the attenuation of a ladder with suitably-graded elements is less than that of a uniform structure, provided that the element resistances or reactances increase as we move from the source to the load. In this case each stage causes less loading on the preceding stage than would be imposed by uniform sections throughout.

The properties of ladder networks are conveniently expressed in terms of a frequency coefficient  $k$  and an attenuation ratio  $A$ , the latter being counted negative when there is a phase reversal. The attenuation factor is simply the ratio of the output to the input voltage so that, numerically,  $A = E_o/E_i$ .

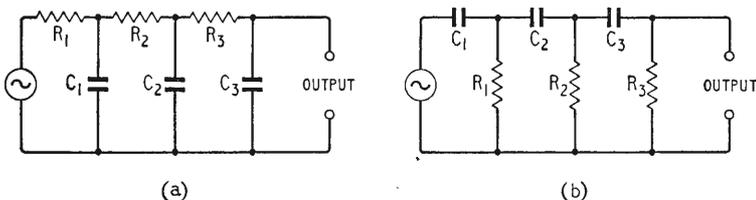


Fig. 3. R-C and C-R ladder networks.

The constant  $k$  enables one to determine the frequency, corresponding to a phase reversal through the network, in terms of the series and shunt elements. This frequency is given by  $f = k/CR$  for a uniform ladder.

Calculated values of  $A$  and  $k$  are tabulated below for 3, 4, 5 and 6-stage networks.

No. of Stages	R-C		C-R	
	$A_1$	$k_1$	$A_2$	$k_2$
3	29	0.3898	29	0.06497
4	18.37	0.1902	18.37	0.13315
5	15.43	0.1176	15.43	0.2154
6	14.12	0.0810	14.12	0.3127

Here  $k_1$  is the frequency coefficient for the R-C ladder and  $k_2$  that for the C-R circuit. In all cases it will be found that  $4 \pi^2 k_1 k_2 = 1$  so that, if the coefficient for one case is known, that for the other can be calculated directly. The attenuation ratios are identical, for equal numbers of stages, in both types of network. One odd feature of these circuits is apparent from the table. For the 3-stage R-C ladder the frequency is six times greater than for the corresponding C-R version. The situation is reversed in the 6-stage case, where the R-C arrangement gives a frequency almost four times smaller than the C-R connection. As regards attenuation, little is to be gained by using uniform ladders with more than four stages. If the ladders are so graded that any section imposes a negligible load on the preceding section, the limiting attenuation ratios become 8, 4, 2.84 and 2.37 respectively for 3, 4, 5 and 6-stage ladders. As might be expected, grading pays best if applied to networks with smaller numbers of sections.

#### Variable-Frequency Oscillators and Amplifiers:—

Practical R-C networks may contain between 4 and 12 elements and there are obvious problems in tuning them over wide frequency ranges. Continuously-variable capacitors of high value do not exist and the best that can be done is to use some switching system to give coarse frequency changes. Continuously-variable resistors will then serve to cover intermediate values of frequency. Normally it will be found convenient to gang two or more controls for simultaneous operation. This is not difficult if the individual units are all alike but it becomes a nuisance if one of them is different from the rest, or if the law connecting resistance with angle of rotation of the control shaft is anything but linear. In high-grade laboratory equipment the use of decade switching can be justified but this is too expensive for general use.

There is another problem when resistance tuning is used. It will be found that the input and output impedances of the network will vary with the resistance setting and a variable load will be placed on the associated amplifier. This results in output level variations over each tuning range, and calls for a complex gain con-

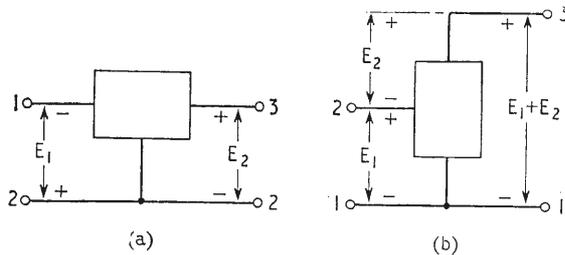


Fig. 4. Voltage gain in a passive network.

trol system to hold these variations in check.

When the R-C network has a large number of elements it may be found best to switch most of these in a sequence of small steps and to cover the intermediate frequency range by using no more than one or perhaps two continuously-variable resistances. For example, in the circuit of Fig. 2, it would be sufficient to switch  $C_1$ ,  $C_2$  and  $R_2$  in steps,  $R_1$  only being continuously variable. There remains one more difficulty. This concerns the scale shape. It is not always possible to use a single common frequency scale associated with step switches giving decimal or other multiples and submultiples of the indicated frequency. This is an important consideration if an instrument is being developed for subsequent quantity production, but is of less consequence in experimental laboratory equipment.

The R-C ladder network of Fig. 3 (a) is conveniently tunable by means of a 3-gang variable capacitor but, except at quite high frequencies, the associated resistances will be too large for use in transistor circuits. The Wien bridge in Fig. 1 (a) and the bridged-T network in Fig. 2 can also be used at high audio frequencies with fixed resistors in conjunction with 2-gang variable capacitors. Again, some care will be required to adapt the circuits for use with conventional transistor amplifiers. On the whole it will be found simpler to use variable resistors, even at high frequencies.

#### Passive R-C Circuits Giving Voltage Gain:—

Any passive 3-terminal network which can produce a phase-reversed output at some prescribed frequency may be caused to give a voltage gain greater than unity merely by reconnecting the source and load. Fig. 4 shows the principle involved. The voltage between terminals (1) and (3) in Fig. 4 (a) is clearly the sum of the voltages between (1) and (2) and (2) and (3). By making (1) the common terminal instead of (2), we arrive at Fig. 4 (b) and the open-circuit output voltage becomes  $E_1 + E_2$ . The highest voltage gain will be obtained when the original network gives the lowest attenuation. This normally calls for the use of graded networks using high-impedance elements at the output end, and it also requires the use of a very-high external

load resistance which in practice will be the input impedance of an amplifier. As a rule the maximum voltage gain is only slightly larger than unity, but it is sufficient to permit self-oscillation when the maintaining amplifier is a cathode follower or a common-collector transistor stage. Conditions for oscillation are most favourable if the amplifier has a very-high input impedance and a voltage gain close to unity. Cathode followers easily meet these requirements but the design of suitable transistor amplifiers presents some problems. It is worth digressing to consider some of the possibilities.

#### Transistor Amplifiers with High Input-Impedance:—

Fig. 5(a) shows a conventional emitter follower which can be designed to have a moderately-high input-impedance. The actual impedance will be the parallel combination of the bias resistors  $R_1$  and  $R_2$  in shunt with the transistor input impedance. To maximise  $Z_{in}$ , the bias components and the load resistance  $R$  should all be very high. For use over a moderate range of ambient temperature a better arrangement is that shown in Fig. 5 (b). This makes use of a compound-connected pair of transistors in which the base current of the second is the same as the emitter current of the first. The base current of the first transistor is very low. This permits the use of a high-value bias resistor  $R_1$ , particularly if silicon transistors are used. The circuit is economical in components since the amplifiers are d.c. coupled. Its disadvantage is that transistor leakage currents are troublesome at high temperatures. Input impedances in excess of one megohm are nevertheless realisable without serious difficulty on this account.

An alternative approach allows the difficulty to be circumvented. If a signal source is connected to one end of a fixed-impedance load, the effective value of this impedance can be raised by causing the other end of the load to execute potential fluctuations which are in phase with the driving voltage. This principle is exploited in Figs. 6 to 9 and is best understood by reference to Fig. 7. Here an input is applied to the transistor base and it develops a slightly attenuated output voltage across the load resistance  $R$ . Base bias is applied through  $R_1$  from the junction of the potential-divider resistances  $R_2$  and  $R_3$ . This junction is coupled to the emitter-follower output through the large capacitor  $C$ . The potential of the junction of  $R_2$  and  $R_3$  thus fluctuates at the frequency of the input signal with an amplitude only slightly less than that of the input. The voltage

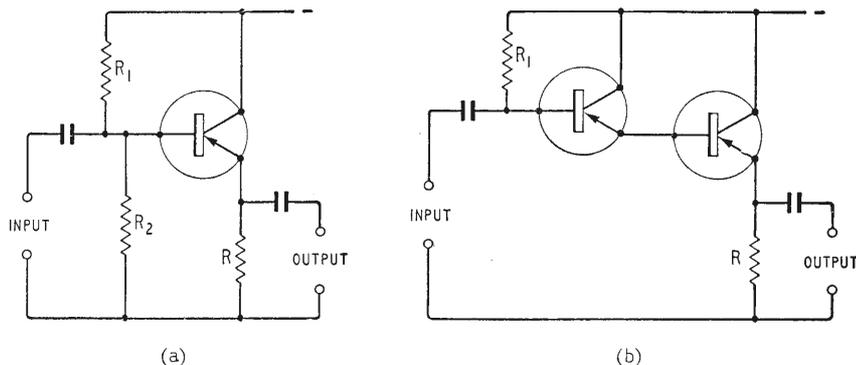


Fig. 5.(a) Common-collector amplifier and (b) Super-alpha Pair.

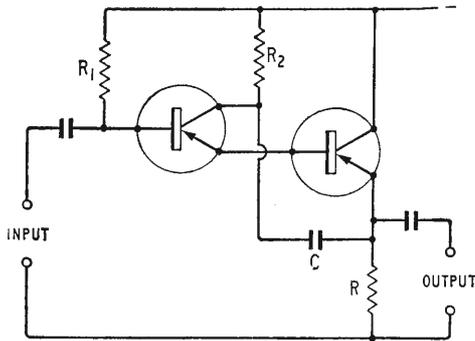


Fig. 6. Amplifier pair with high input-impedance.

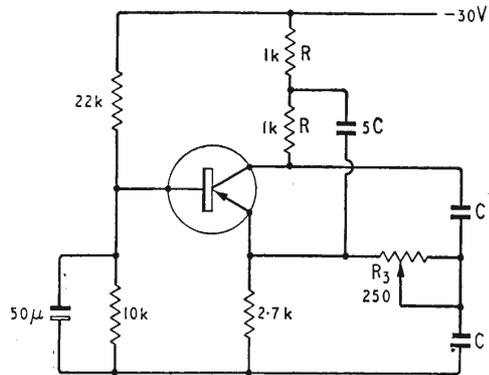


Fig. 10. Parallel-T R-C oscillator circuit due to E. T. Emms.

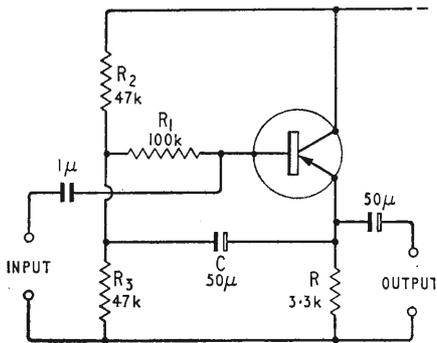
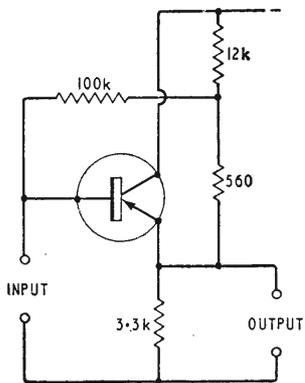
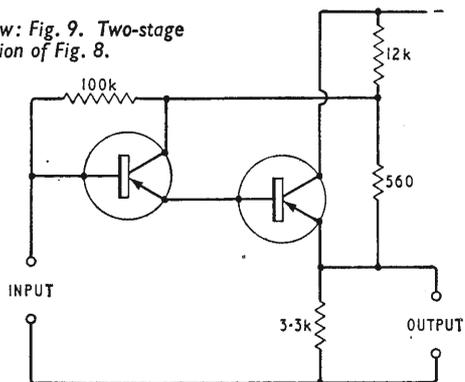


Fig. 7. Modification of Fig. 5(a) giving a higher input-impedance



Left: Fig. 8. Direct-coupled version of Fig. 7.

Below: Fig. 9. Two-stage version of Fig. 8.



across  $R_1$  is the difference between the input and the output signals and the apparent value of  $R_1$  becomes much higher than its true resistance. If, for example, the voltage gain of the emitter follower is 0.9 and  $R_1$  is 100 k $\Omega$ , the effective value of  $R_1$  becomes 1 M $\Omega$ .

Fig. 8 is a variant of Fig. 7 arranged for direct coupling. Figs. 6 and 9 are two-transistor versions which can be designed to give very high input-impedances, particularly if silicon transistors are used. The suggested component values are for use with germanium transistors where temperature considerations dictate the use of relatively-low resistances. They are not necessarily optimized even for germanium transistors, but the choice is not particularly critical.

#### Practical Oscillators and Selective Amplifiers:—

The design of a good R-C oscillator is not very difficult if operation at only one frequency is required or if it is intended to work into a constant load. There is virtually no problem at all if, additionally, the supply voltage is fixed and the ambient temperature held constant. The state of affairs is very different if variable-frequency operation is necessary for unregulated supplies over wide temperature ranges. In this case an extremely-good system of automatic distortionless amplitude control becomes essential, and this is a weak point in some published designs. Good control by thermistors calls for an ample reserve of output power if the thermistor resistance-changes due to output power variations are to swamp the resistance variations caused by room temperature changes.

In what follows there will be some reference to oscillator circuits, but the main emphasis is on selective amplifiers where there is no problem in controlling the output level.

Ideally, a selective amplifier design should satisfy the following requirements:—(a) the general shape of the response curve should meet the design objectives, (b) the centre frequency should be fixed and stable, (c) if the selectivity is variable, changes in bandwidth should not shift the centre frequency, (d) changes in gain should not affect the selectivity, (e) outside the desired frequency band, transmission should fall off rapidly to reject wideband noise, and (f) the system should be linear and distortionless. As soon as a specification is hedged around by restrictive qualifications like these the design becomes difficult and the end product costly and complicated.

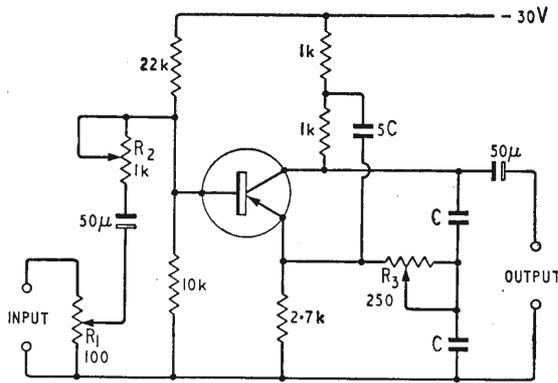


Fig. 11. Selective amplifier based on Fig. 10.

For some applications one can accept, say, interaction between controls which should be independent, provided that circuit economies can be made. Many active R-C amplifier-filters give a narrow band-pass response with rather poor skirt selectivity. To compensate for this, they are easy to design for operation over frequency ranges where alternatives do not exist or are quite uneconomic. For example, a narrow-band system is easily set up to operate at one cycle per minute. With these considerations in mind, some practical circuits will now be discussed. The aim will be to cover a wide range of applications although this must limit the amount of detail which can be covered in each individual case.

Fig. 10 shows a single-transistor parallel-T R-C oscillator due to E. T. Emms<sup>2</sup>. It is the circuit dual of a more conventional arrangement. The operating frequency is given approximately by  $f = 1/2\pi CR$  when the network has the given proportions. The variable resistance may be regarded as a regeneration control and should be set so that oscillations are just maintained. Fig. 11 shows how the arrangement may be converted to a regenerative, selective amplifier. The earthed end of the bias decoupling capacitor is disconnected from ground and joined through a selectivity control  $R_2$  to a gain control  $R_1$ , supplied from a low-impedance signal source.

Both  $R_2$  and  $R_3$  affect the amount of regeneration and adjustment of  $R_3$  will also change the centre frequency. The circuit is simple and reliable. Minor disadvantages are that the output is at a relatively high impedance and must be lightly loaded, whereas the input signal must come from a low-impedance source.

A circuit which can be operated from a high-impedance source is given in Fig. 12. A large output is obtainable at low impedance. The circuit becomes an oscillator if the amplifier input is disconnected and the 100-Ω variable-resistance  $R$  reduced to the point of critical regeneration. This resistance forms the selectivity control of the tuned amplifier. There is some interaction between the gain and selectivity controls. To produce strong oscillation it may be necessary to reduce the value of the resistance shown as 470Ω and this adjustment will alter the frequency. The circuit works extremely well with the 2-stage amplifier of Fig. 9.

The circuits in Figs. 13 and 14 make use of R-C and C-R ladder networks. With  $R = 3.3k\Omega$  and  $C = 0.1\mu F$  in Fig. 13 the operating frequency

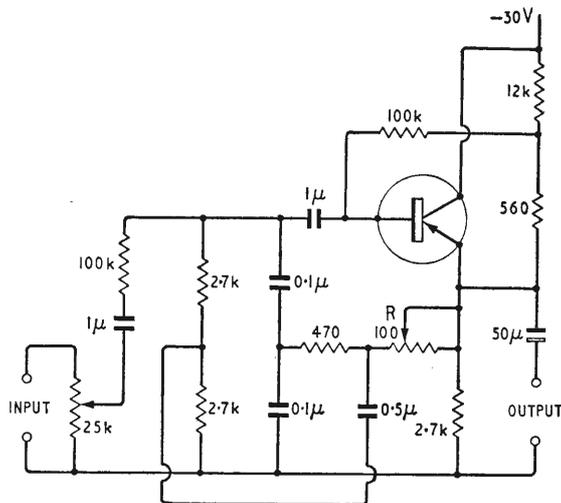


Fig. 12. Amplifier/oscillator exploiting the gain of a passive R-C network.

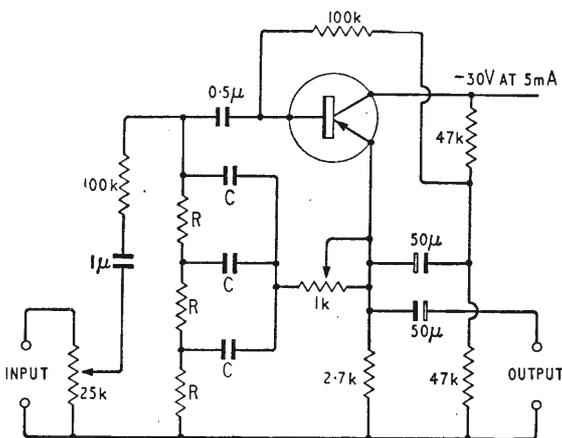


Fig. 13. Selective amplifier using R-C ladder network.

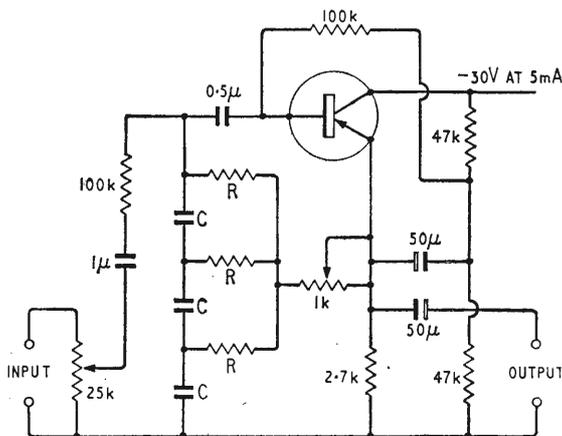


Fig. 14. Selective amplifier using C-R ladder network.

is about 1 kc/s. With  $C = 0.005\mu\text{F}$  this rises to about 11 kc/s instead of the theoretical figure of 20 kc/s. The difference is due to loading on the upper end of the ladder by the network associated with the driving amplifier or signal source.

The circuit of Fig. 14 operates at much lower frequencies, not readily calculable since the  $0.5\text{-}\mu\text{F}$  coupling capacitor and the input resistance of the transistor act as a fourth section of the ladder network.

An interesting variant of the last circuit is shown in Fig. 15. It works well as an oscillator or amplifier at very low frequencies. The  $10\text{-k}\Omega$  variable resistance is the regeneration or selectivity control. The table (on the right) gives the output frequency in terms of the circuit constants. With  $R = 47\text{k}\Omega$ ,  $C = 100\mu\text{F}$ ,  $C_1 = 100\mu\text{F}$ , the frequency falls to 1 cycle in 80 seconds and the output appears

R (kΩ)	C (μF)	C <sub>1</sub> (μF)	f (c/s)
1.2	0.1	0.5	130
2.2	0.1	0.5	89
4.4	0.1	0.5	52
10	0.1	0.5	31
47	5	0.5	1.5
47	5	2.5	0.5

to be strictly sinusoidal when the oscillator is coupled to a pen recorder.

Successful operation at extremely-low frequencies calls for the use of capacitors with negligible leakage. Normal electrolytics are not very satisfactory and tantalum capacitors are to be preferred.

Fig. 16 shows a selective amplifier using a parallel-T network in the negative feedback path of a two-stage amplifier. Positive feedback, operative at all significant frequencies, is supplied through the  $50\text{-k}\Omega$  variable resistance connected in series with  $1\mu\text{F}$  between the transistor emitters. The negative feedback disappears at the null frequency of the network but is effective at other frequencies. In the absence of positive feedback the amplifier gain is very low but rises rapidly as the feedback is increased. An extremely narrow pass-band is secured if regeneration is increased to a point just short of self-oscillation. The centre frequency is accurately calculable from the parallel-T network constants and is almost unaffected by changing settings of the selectivity control or input gain control.

Stabilized base bias for the first transistor is derived from the emitter of the second stage through a decoupled voltage-divider network.

The circuit is also suitable for use with the bridged-T arrangement of Fig. 2.

In addition to the circuits described above, many variants have been tested. All of them work satisfactorily without having any outstanding characteristics. The simplest of all is obtained by linking the network of Fig. 2 with the amplifier of Fig. 9 so as to arrive at a circuit very much like Fig. 15. Tuning can be accomplished by varying a single resistance ( $R_1$  in Fig. 2).

By using h.f. or v.h.f. transistors, operation is possible in some circuits up to at least 100 kc/s. Above this limit it is simpler to use tuned-circuit oscillators or Q-multipliers. There are no acceptable substi-

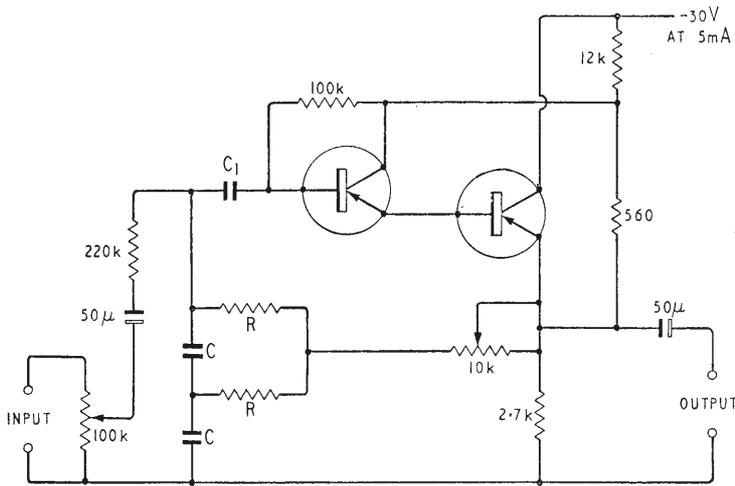


Fig. 15. V.L.F. oscillator or selective amplifier.

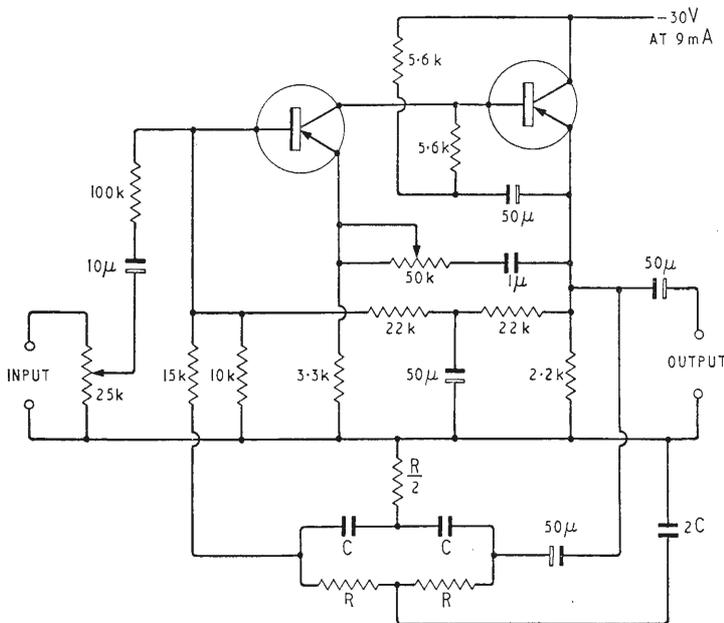


Fig. 16. Narrow-band regenerative amplifier.

tutes for R-C oscillators or filters at the low-frequency end of the spectrum unless one is prepared to use operational amplifiers of considerable complexity.

The simpler circuits are so economical in components that they can be assembled in banks to deal with frequency-division multiplexed signals or to produce comb filters. If high-value isolating resistors are used, a number of paralleled amplifiers may be driven from a single source. The choice of transistors is not critical unless high-frequency operation is required or unless wide temperature changes are expected. In most of the circuits the working points on the transistor characteristic curves are defined by passive components in such a way as to take care of variations in transistor parameters.

One final word of caution should be given. Where

transistors are used in such a way as to provide a very-high input-impedance, noise can be troublesome if operation is required at very-low signal levels. Such circuits are also prone to pick up power-frequency hum. The layout should be such as to minimize this possibility.

#### REFERENCES

1. "Duality as a Guide in Transistor Circuit Design", R. L. Wallace and G. Raisbeck, *Bell System Technical Journal*, April 1951, p. 381.
2. "Novel Single-Transistor R-C Oscillator", E. T. Emms, *Electronic Engineering*, August 1960, p. 506.
3. "Current Derived Resistance-Capacitance Oscillators using Junction Transistors", D. E. Hooper and A. E. Jackets, *Electronic Engineering*, August 1956, p. 333.
4. "Combined Oscillator-Amplifier for Tone Transceivers", R. S. Carter, *Electronics*, February 2nd 1962, p. 44.

## Commercial Literature

**Steadfast insulated screwdrivers**, the range of which includes electricians, engineers and other specialized types, are listed in a 48-page booklet available from J. Stead & Co. Ltd., Manor Works, Cricket Inn Road, Sheffield, 2.

**Germanium pnp mesa transistors**, silicon Zener diodes, Shockley 4-layer diodes and silicon rectifiers, are among a comprehensive range of Brush semiconductors listed in a brochure available from Brush Crystal Co. Ltd., Hythe, Southampton, Hants. Complete technical details of their current range are given in a semiconductor data manual also available through the Brush Customer Data Service Dept.

"**Eddystone Communications Receivers**" is the title of a handy catalogue which collates, in concise form, specification information on seven Eddystone communication receivers designed to meet professional applications. Stratton & Co., Ltd., Eddystone Works, Aivechurch Road, Birmingham, 31.

**Data and applications reports** are filed in separate loose-leaf binders supplied by Microwave & Semiconductor Device's data service. The company's products include silicon low-noise and miniature mixer diodes, varactor and mesa diodes. Applications reports issued so far include treatises on varactor operation at microwaves and solid-state microwave switching. Full details of the data service are available from Microwave & Semiconductor Devices Ltd., Skimpot Trading Estate, Luton, Bedfordshire.

**Rohde & Schwarz**, the German instrument manufacturers, for whom Aveyley Electric are sole U.K. agents, have been issuing monthly bulletins containing interesting applications for their range of communications and laboratory equipment. Copies from Aveyley Electric Ltd., Ayron Road, South Ockenden, Essex.

**A transistorized photo-electric detector** of compact dimensions and offering a high degree of sensitivity is being marketed by Cableform Ltd., Romiley, Cheshire. Descriptive literature is available from the company.

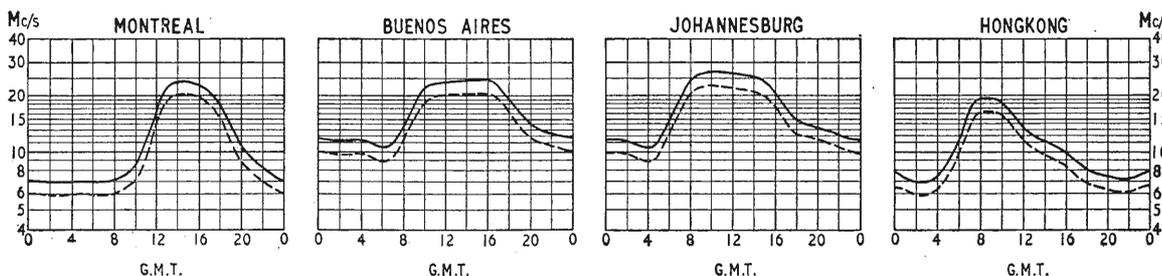
**Industrial Stroboscopes**, manufactured by E.M.I. Electronics, include instruments suitable for a great variety of applications. Details of the E.M.I. range are available from the company at Blyth Road, Hayes, Middx.

**Adam's micro soldering instruments** are described in an illustrated brochure from the makers, Light Soldering Developments Ltd., 28 Sydenham Road, Croydon, Surrey. Two new models, the C10L (10W) and C15L (15W) have their fully insulated elements inside stainless steel tubes of only 9/64in outside diameter, and are suitable for all normal mains voltages.

**Indicating instruments** for industrial use, including ammeters, voltmeters, wattmeters and current transformers are listed in a 56-page catalogue recently issued by Crompton Parkinson Ltd., Crompton House, Aldwych, London, W.C.2.

## SHORT-WAVE CONDITIONS

Prediction for December



The full-line curves indicate the predicted median standard maximum usable frequencies for the month of December.

The dash-line curves show the optimum frequencies which are intended to allow for day-to-day variations from the monthly median.

— PREDICTED MEDIAN STANDARD MUF  
 - - - PREDICTED OPTIMUM TRAFFIC FREQUENCY

These curves have been prepared by Cable & Wireless Ltd. from information supplied by the Radio Research Station, Slough.

# LETTERS TO THE EDITOR

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

## U.K. Citizens Radio Service

I FEEL compelled to write to say that I am in full accordance with Mr. Croysdale's view concerning the suggestions made by Mr. G. E. Storey (October issue).

It was with some surprise that I read Mr. Storey's letter, considering the fact that he himself is a licensed radio amateur! There are far too many encroachments on our already overcrowded bands by authorized, unauthorized, clandestine and pirate operators, but to invite a host of novices to use any part of the spectrum for any purpose whatever would create what I could only describe as "harmonically related havoc."

It may interest your readers to know that the F.C.C. in America is literally inundated with complaints of interference to Public Services by the many Citizens' Band users over there.

Fortunately, I cannot visualize Mr. Storey's suggestions ever bearing fruit because, as a consequence of it, the Postmaster-General would lose a great deal of valuable revenue. The situation in America is quite different because most of the telephone companies are privately owned.

However, it is just possible that, with official sanction, the scheme could be worked with certain differences to those in use in the U.S.A. A primary requirement must surely be a proficiency certificate in the handling of a radio transmitter and its ancillaries, even if they are commercial manufactured.

Last but by no means least, our prospective Citizens' Radio Service operator should brace himself (or herself) for the licensing fee, which, bearing in mind the P.M.G.'s loss of revenue, might be inversely proportionate to it!

London, W.1.

REX J. TOBY  
(G2CDN, etc.).

I WAS interested to read the comments of your correspondents in the November issue in response to my plea for a Citizens Radio Service and would like to comment on the various points made by them.

Mr. Holland is quite correct in stating that the 27 Mc/s ban has been used for many years for the radio control of models. However, such use is only on the basis of a secondary service, the band being allocated primarily to the Industrial, Scientific and Medical service. If my ideas were followed up the 27 Mc/s band could be arranged to provide twenty-three 10 kc/s channels. Of these five would be allocated to model control, one on an exclusive basis and four shared with radiotelephony. Another five channels would be allocated to low-power radiotelephone stations using 100 MW maximum power, one channel exclusive and four shared. The high-power radiotelephone service would thus be left with thirteen exclusive and eight shared channels. The maximum power limit would be 5W for both model control and high-power radiotelephone stations.

Under such an arrangement model control enthusiasts would, in fact, be better off than at present as they would become a primary user in the 27 Mc/s band and have one channel exclusively devoted to them with the option of using four others. Crystal control would, of course, be mandatory but the state of the art is such that there should be little, if any, increase in the cost of model control transmitters over that of the self-excited

arrangements commonly used at present. It is, in any case, doubtful whether a self-excited transmitter is able to satisfy the internationally agreed stability limits for transmitters operating at 27 Mc/s, so that they may even be illegal from this point of view.

Turning to Mr. Croysdale's comments I am fully aware that the band 70.2 to 70.4 Mc/s is at present temporarily allocated to the Amateur Service for I have been a very active transmitting amateur since 1950 and was, in fact, one of the first to operate on the 70 Mc/s band. There is a good precedent in transferring an amateur band to the Citizens Radio Service for this is exactly what happened in North and South America, the 27 Mc/s band used there once having been the "11-metre" amateur band. In my view the 70 Mc/s band is little used by amateurs who, by their very nature as individualists, utilize very inefficiently our precious spectrum space, particularly in the v.h.f. range; the 70 Mc/s band would be used far more effectively in the national interest if re-allocated to a Citizens Radio Service. The lowering of the technical standards which I mentioned in my previous letter (October issue) were meant to be read in the light of the present Post Office requirements for equipment used in the Private Mobile Radiotelephone Service, for which transmitter spurious outputs are required to be 70 dB down relative to the desired output. The lower standard I had in mind was that spurious outputs should be at least 40 dB down on the desired output, bearing in mind that the transmitters to which this applied would have a maximum power output of only 3 to 4W. From the last two paragraphs of Mr. Croysdale's letter it seems that he may be unaware that no transmitter is entirely devoid of spurious outputs. The suppression of such spurious outputs is only a matter of degree and although the likelihood of interference being caused by these outputs is naturally reduced as their amplitude is lowered even the best transmitter construction possible cannot guarantee the complete absence of interference, particularly in the case of a receiver located physically close to the transmitter. My point was that by employing the 70 Mc/s band for the Citizens Radio Service the spurious transmitter outputs at 140 and 210 Mc/s (which would usually be the strongest) would fall outside Bands I, II and III, a point of some practical importance since the transmitters would often be located on domestic premises where television and broadcast receivers are mostly used.

Mr. Sabin's suggestion for an amateur "telephony only" allocation would not really provide the required service. The Citizens Radio Service would be intended to provide low-cost short-range radiotelephony for either private or business purposes without the requirement of technically qualified operators or system approval by the Post Office. No encroachment on the revenue of the Post Office need occur due to loss of telephone traffic if a licence fee of, say, £1 p.a. were levied in respect of a 100 mW transmitter and £3-£5 p.a. for one of 5W.

Most of the points made in Mr. Toby's letter (above) have already been covered by my preceding remarks with the exception of his references to Citizens' Radio Service operators as "a host of novices" and to the interference complaints received by the F.C.C. Citizens' Radio Service operators would be no more of novices than those who are already operating much higher powered equipment in the Private Mobile Radiotele-

phone Service and who may, in accordance with the Post Office regulations, be the licensee or any person authorized thereby. If Mr. Toby cares to listen on the appropriate frequencies he will hear just what this sometimes means in practice! The complaints received by the F.C.C. are, according to my information, more the result of interference to Citizens' stations themselves by some operators who indulge in amateur-type communication, than the Citizens' equipment interfering with other services. While this amateur-type operation is illegal it is prevalent and probably results from the absence of any licence fee and the low age limit of 18 years for licensees. The danger would largely be avoided in the United Kingdom by the licence fee suggested, possibly coupled with a minimum age requirement of 21 years.

Finally, as a result of the publication of my last letter I have received information from the United States from which it appears that the Citizens Radio Service is not confined solely to the United States and Canada. It is also allocated in eight other countries in Central and South America. Some idea of its extent of use may be gathered from one news item sent to me which states that there are 700 units operating in the city of Caracas, Venezuela, alone.

Sunbury-on-Thames.

G. E. STOREY

## Chicago Police Radio

ON page 470 in your October issue mention is made of the new very elaborate Chicago police communications centre.

I think you should have mentioned that one of the unique features of this system is that it employs what is known as "crossbanding."

The base stations transmit and the cars receive on u.h.f. (453 Mc/s) while the cars transmit and base stations receive on v.h.f. (155 Mc/s).

This method is rather unusual, and, as far as I know, not very common. By the way, the cars use the same 18-inch antenna for receiving u.h.f. and transmitting v.h.f.

Chicago 26, Ill.

KEN GREENBERG

## New Phase-splitter

SOME copying errors make nonsense of my point (4). Mr. Bailey's circuit will be 12dB down at 12kc/s (not 1200c/s) and his claim for extra feed-back of 15-17dB must be interpreted with this in mind. It is comparatively easy to get high gain and phase margins with amplifiers in which the open-loop response falls off at a low audio frequency: the amplifiers used in analogue computers show how this can be done. For audio frequency operation it is, however, essential that the full feed-back should be maintained over the whole audible band, whatever that may be.

This requirement can be satisfied, with a twin-triode phase-splitter, with enough margin to allow for safe operation with most speakers disconnected but the cabling connected in a ship installation. The loading here is virtually all capacitance.

London, W.8.

THOMAS RODDAM

## Resonance

THE phenomenon of resonance appears in two forms, termed respectively parallel and series resonance when encountered in electrical circuits. This terminology has been satisfactory for simple lumped-constant circuits, but is inapt to describe the resonances of compound networks and those of distributed-constant devices, cavities for example, where no series or parallel connections can be distinguished.

For some time the problem has been half solved by changing the term parallel resonance to anti-resonance,

which is tidy and meaningful, but no neat counterpart has appeared to replace the term series resonance. True, one finds the two types called anti-resonance and resonance respectively, but this leaves doubt in some contexts as to whether the term resonance means the general effect or series resonance in particular.

May I suggest, therefore, the term "pro-resonance" for the series resonance effect, keeping resonance as the general term for both types. As a word, pro-resonance is euphonious, sufficiently neat, and is the obvious complement to anti-resonance.

Joondanna,

Western Australia.

D. FARQUHAR

## "Complementary Multivibrator"

J. C. RUDGE, in his article in the August issue suggests the use, in Fig. 3, of the STC silicon alloy transistor, type TK71C. It should, perhaps, be pointed out that this type is now obsolete. This is not surprising when one considers the pace of transistor development. However, a suitable replacement can be offered from the STC range of silicon diffused planar transistors; but since these transistors cannot pass an unlimited base current, a resistance ( $R_B$ ) would have to be used in series with the base. Either the BFY18 (TK264A) with  $R_B = 150\Omega$ , or the BFY16 (TK251A) with  $R_B = 82\Omega$ , should prove satisfactory, the BFY16 giving a better mark/space ratio because of the lower value of  $R_B$ . Although the inclusion of  $R_B$  will result in a slightly longer "mark" period there is the advantage that this period becomes more closely defined.

Footscray, Kent.

S. C. RYDER-SMITH  
Transistor Applications Dept.  
Standard Telephones and Cables Ltd.

## Sine v Square Waveform

I HAVE read with interest Mr. Thomas Roddam's comments in the November issue on my article and would like to be permitted to reply to some of the views expressed.

I know that it is generally believed that a square waveform will cause a transformer or motor to overheat. This is definitely quite incorrect. In many years' experience in this field I have never known a single case of overheating caused by a square waveform. The difference in temperature rise for the same power dissipation is so small as to be quite inconclusive. Tests which I have carried out with various motors and transformers have convinced me that there is no difference in operating temperature between a sine and square wave. The only instances where a rise in temperature was observed was in rare cases where the iron cores were operated in or near a state of magnetic saturation. In these cases the temperature rise was slightly higher on a square waveform for the same power dissipation. I stress the power dissipation, because in most cases a square waveform will result in a lower power consumption for the same r.m.s. input.

My article was confined to the utilization of a square waveform for equipment designed for sine-wave operation, but the third paragraph of Mr. Roddam's letter enters the sphere of transverter design, and if he has ever studied my company's literature he will have noticed that besides the normal continuous load rating, the peak output is also quoted.

A typical case is the 650W unit which is rated for a continuous output of 650W and peak of 2,000W. Provided the maximum peak output is never exceeded, the effect known as "double-chopping" will not occur, nor will the transistors be operated in a saturated collector current condition; this will be the case irrespective of the nature of the load.

I do not agree with Mr. Roddam's implication that

there would be any appreciable change to the square waveform from a transverter when connected to the type of loads mentioned.

I would like to assure your readers that the article was based on practical experience of the problems and with specific types of transverters in mind. The effect of non-linear and leading power factor loads has been fully considered in the design of these units.

The inference that a square waveform will prove troublesome in oscilloscope application does not apply to a well-designed instrument. If an oscilloscope responds to the leading and lagging edges of a square waveform, it will also respond to waveform distortion in a sine wave supply caused by heavy-duty rectifiers and gas discharge devices such as fluorescent

tubes. Surely, in a good quality instrument both magnetic and electrostatic screening should be sufficient to prevent any form of interaction.

Regarding the reference to Fig. 2. The point I wanted to make was that the rectified d.c. from a high-impedance sine wave source was very little different to that obtained from a square waveform.

Mr. Roddam's observations regarding the action of the circuit shown in Fig. 7 completely overlook the effect of the inductance L2.

Whilst I disagree with most of the views expressed by Mr. Roddam, I do however concur with his concluding paragraph.

Feltham, Middlesex.

V. VALCHERA  
Valradio Limited.

## U.H.F. Television: Some Questions Answered

**ARE Bands IV and V contiguous?** Yes and no!

What is the lower limit of Band V? To some people 582 Mc/s and to others 614 Mc/s.

What is the sound-vision carrier separation in these bands? The answer to this question will depend on what country you are in.

It is obvious from these answers that there may be some confusion when references are made to "the u.h.f. television bands."

At the European v.h.f./u.h.f. Broadcasting Conference in Stockholm in June 1961 agreement was reached on various parameters for the European sound and television broadcasting services in the bands between 41 and 960 Mc/s. These included the fixing and numbering of the channels in Bands IV and V and these are listed below. It will be seen that there are 61 consecutive 8-Mc/s channels so that in fact there is no gap between these two Bands.

In recent announcements by the B.B.C. Engineering Department it would appear that Band IV extends from 470 to 582 Mc/s (channels 21-34) and Band V from 614 to 854 Mc/s (channels 39-68). At the 1959 I.T.U. Geneva Conference the band 582-606 Mc/s was allocated to both broadcasting and radio navigation and we in this country have adopted it for the later, and are using the following 8 Mc/s for radio astronomy. The band 740-960 is allocated for fixed services as well

### 625-LINE STANDARDS

Standard	Video bandwidth (Mc/s)	Carrier separation (Mc/s)	Vestigial side-band (Mc/s)	Vision modulation	Sound modulation
G	5	5.5	0.75	Neg.	f.m.
H	5	5.5	1.25	Neg.	f.m.
I	5.5	6	1.25	Neg.	f.m.
K	6	6.5	0.75	Neg.	f.m.
L	6	6.5	1.25	Pos.	a.m.

G:—Austria, Denmark, Finland, Germany, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland.

H:—Egypt, Greece, Israel, Italy, Luxembourg, Malta, Syria, Turkey, Vatican City, Yugoslavia.

I:—Eire, U.K.

K:—Bulgaria, Czechoslovakia, Hungary, Morocco, Poland, Rumania, U.S.S.R.

L:—Algeria, France.

as broadcasting and the U.K. is utilizing the upper section of this band for the former. It may well be asked whether there will come a day when these services will have to be moved to make way for the growth of television as indeed happened in Band III.

In the list of channels we give the vision frequency for each as agreed at Stockholm but the spacing between this and the accompanying sound carrier varies considerably throughout Europe. We in this country have decided on a 6-Mc/s spacing. The "final acts" of the Stockholm Conference list five different combinations of channel parameters and these are tabulated above. Countries known to have announced which of these will be adopted are listed below the table.

The Stockholm Plan allocated specific channels for all main stations (< 10kW e.r.p.) although some changes may have to be made—by mutual arrangement between neighbouring countries—in the course of detailed planning. Assuming that there are to be four U.K. programmes in these bands the channels for a given locality are in general to be allocated according to the following scheme  $n$ ,  $n+3$ ,  $n+6$ ,  $n+10$ , or  $n$ ,  $n+4$ ,  $n+7$  and  $n+10$  ( $n$  being the lowest channel). However, for some unknown reason London channels are to be 23, 26, 30 and 33 ( $n$ ,  $n+3$ ,  $n+7$  and  $n+10$ ).

The Government's White Paper on television proposed that all u.h.f. transmitters serving a particular area should be on the same site. A major problem is the co-siting of aerials and this is being actively studied by both the broadcasting authorities and the industry. In this country the u.h.f. network will be planned on the assumption that a minimum field strength of 1.7 mV/m in Band IV and 3 mV/m in Band V will be required for satisfactory reception. With a high-gain receiving aerial and allowing for average feeder losses this corresponds to an input to the receiver of 2-3 mV.

### U.H.F. TELEVISION CHANNELS

Channel	Channel limits	Vision carrier	Channel	Channel limits	Vision carrier
21	470—478	471.25	51	710—718	711.25
22	478—486	479.25	52	718—726	719.25
23	486—494	487.25	53	726—734	727.25
24	494—502	495.25	54	734—742	735.25
25	502—510	503.25	55	742—750	743.25
26	510—518	511.25	56	750—758	751.25
27	518—526	519.25	57	758—766	759.25
28	526—534	527.25	58	766—774	767.25
29	534—542	535.25	59	774—782	775.25
30	542—550	543.25	60	782—790	783.25
31	550—558	551.25	61	790—798	791.25
32	558—566	559.25	62	798—806	799.25
33	566—574	567.25	63	806—814	807.25
34	574—582	575.25	64	814—822	815.25
35	582—590	583.25	65	822—830	823.25
36	590—598	591.25	66	830—838	831.25
37	598—606	599.25	67	838—846	839.25
38	606—614	607.25	68	846—854	847.25
39	614—622	615.25	69	854—862	855.25
40	622—630	623.25	70	862—870	863.25
41	630—638	631.25	71	870—878	871.25
42	638—646	639.25	72	878—886	879.25
43	646—654	647.25	73	886—894	887.25
44	654—662	655.25	74	894—902	895.25
45	662—670	663.25	75	902—910	903.25
46	670—678	671.25	76	910—918	911.25
47	678—686	679.25	77	918—926	919.25
48	686—694	687.25	78	926—934	927.25
49	694—702	695.25	79	934—942	935.25
50	702—710	703.25	80	942—950	943.25
			81	950—958	951.25

# Transient Testing of A.C. Amplifiers

METHOD OF COVERING THE FULL DYNAMIC RANGE

By R. C. BOWES, B.Sc., A.M.I.E.E.

**T**ESTING the transient response of an amplifier is well known as being simple and informative. The usual weakness of the test is that only a small signal can be used in order to avoid the higher harmonics overloading the amplifier, which means that the transient response can only be obtained at a low power level. The need for testing the transient response of an amplifier up to maximum power output is perhaps greater with amplifiers using transistors than it is with valve amplifiers. This is because the parameters of transistors vary a lot with both operating current and voltage, making it

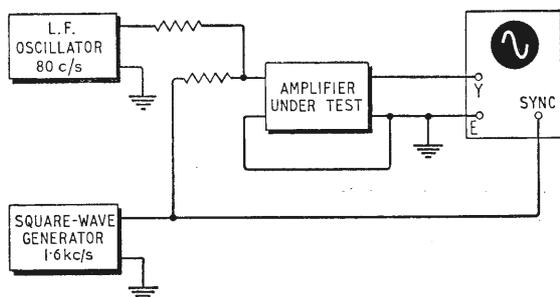


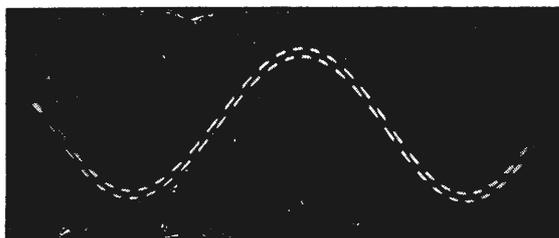
Fig. 1 Test set-up for an audio amplifier.

possible for an amplifier to have a good transient response at low power levels, whereas this response may be quite unacceptable near maximum power output. This is particularly true of amplifiers using negative feedback where changes in the transistor parameters can easily reduce the stability margins.

**Method of Testing.**—The transient response of a d.c. amplifier can be taken over its full range of output levels by having a d.c. input signal in addition to the transient test signal, the d.c. signal being used to swing the output to overload point in each direction. A d.c. signal cannot be used for an a.c. amplifier, but it can be replaced by a low-frequency a.c. signal. Fig. 1 shows the block diagram of a typical test set-up for an audio amplifier. The low-frequency sine wave and the square-wave transient test signal are added together by fitting a series resistor in each signal lead. A photograph of the combination of the two signals is shown in Fig. 2. It is important to keep the amplitude of the square wave signal small so that there is no danger of the higher harmonics in the waveform overloading the amplifier. The low-frequency signal amplitude is set so that the amplifier is just overloaded on the

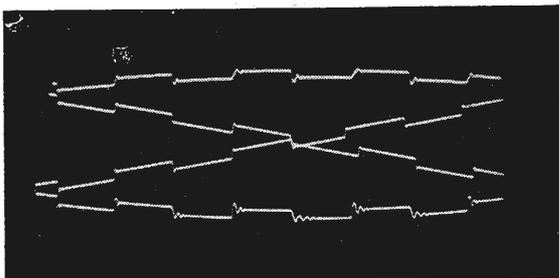
peaks of the sine wave. The output of the amplifier due to the combined input signals is not the easiest of waveforms to inspect in detail, but if the scope is triggered by the square wave and the frequency of the oscillator adjusted carefully, a sufficiently steady display for looking at can be obtained. Ideally, of course, the two frequencies should be locked together and this was done to obtain the photograph of the output of a ten-watt audio amplifier which is shown in Fig. 3. If the edges of the square wave are examined carefully it can be seen that the transient response is very good in the centre (i.e., low power level) but deteriorates at the top and bottom of the waveform which is when the amplifier is just overloading. It can also be seen that the transient response is worse at the bottom of the waveform than at the top.

Although this article has concentrated on using this method of transient testing for audio amplifiers, it is equally applicable to other a.c. amplifiers, particularly amplifiers designed to deliver appreciable power output. It may of course be necessary to use different input frequencies.



(Crown Copyright photograph).

Fig. 2 Input waveform.



(Crown Copyright photograph).

Fig. 3. Output of 10-W audio amplifier.

# RIBBON GROWTH OF SILICON

POSSIBLE SIMPLIFICATION OF TRANSISTOR MANUFACTURE

By MICHAEL LORANT

E. S. GREINER, J. A. Gutowski and W. C. Ellis of the Bell Telephone Laboratories, have recently developed a new form of crystal growth of silicon which may have important implications for improving the manufacture of transistors and other semiconductor devices.

In the process, silicon is reacted with iodine and hydrogen, together with small amounts of arsenic and nickel, at high temperatures in a closed tube. The ribbons, together with silicon whiskers of hexagonal cross-section, grow rapidly in the hot tube. The ribbons vary from 0.1 to 15 $\mu$  in thickness, are about 0.1mm wide, and from 1 to 3 cm long. They contain few or no crystal defects except for a single twin plane (junction of mirror-image crystals) parallel to the ribbon surface. Because of their crystalline perfection, the ribbons are very strong mechanically; they are also quite flexible due to their extreme thinness.

The existence of a single twin plane in all the ribbons observed is a central feature of a theory, developed by R. W. Wagner and R. G. Treuting, also of Bell. It explains some of the main mechanisms of ribbon growth. According to this theory, the twin plane, plus what appears to be a growth poisoning effect of certain impurities, cause the crystal ribbon to grow very rapidly in length but relatively slowly in width and thickness.

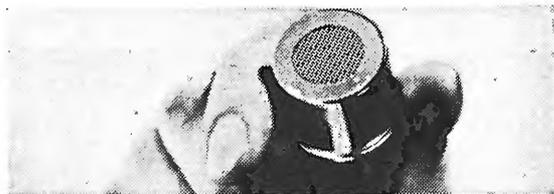
The ribbons are quite uniform in thickness and width, and have a nearly perfect surface. These properties would make it possible to incorporate them directly into semiconductor devices with little or no mechanical preparation.

The use of the ribbons for piezo-resistive strain gauge applications also appears to be promising, because, being extremely thin and flexible, they can accurately follow elastic strains in materials to which they are bonded.

## ULTRASONIC REMOTE CONTROL

THE use of ultrasound for control purposes has increased considerably during the last year or so, due to the increasing availability of new components. Two great advantages of this method of remote control are that no radio transmitting licence is required and that interference with other radio control systems operating nearby is completely eliminated.

For a simple ultrasonic control system the same



Gulton 1404 ultrasonic transducer for remote control of models.

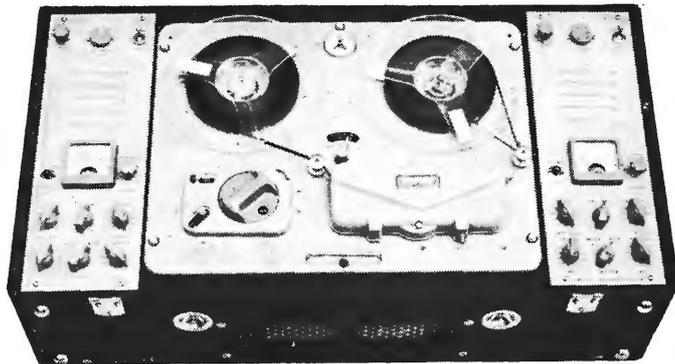
model 1404 Gulton transducer (shown in the photograph) can be used both as transmitter and receiver. The control system comprises two units; a transmitter no bigger than a small pocket torch, and a receiver

of similar dimensions mounted in the model. The transmitter has two transistors driving the transducer and operates as a high frequency (40kc/s) sound generator. In the receiver the transducer picks up the control signal which is then amplified in a simple transistor unit before being passed to the relay or other control device within the model. Both these units can be easily constructed by the amateur and details of typical circuits are available from Gulton.

This technique can be used to control most types of models, for example, boats, trains, cars and aeroplanes. Many engineers and model makers will think of other uses such as opening garage doors, alarm systems, and control of household equipment. The transducers can also be used to transmit speech using the ultrasonic frequency as a carrier.

The Gulton 1404 transducer measures only 1in in diameter and 1 $\frac{3}{8}$ in in length. It has a centre frequency of 40kc/s and a wide directional beamwidth (65°) to the 6dB points. The bandwidth is normally 4kc/s but narrower values can be obtained by the use of a series capacitor. It costs £3 18s. For multi-channel control systems the circuitry can be arranged so that one transducer alone can be used, but Gulton ultrasonic transducers of different centre frequency are available if required.

**—Vortexion**  
**quality equipment**



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The Vortexion Super/30/50 watt Amplifier is an extremely versatile unit capable of delivering 50 watts at 30 cps to 20,000 cps at .2% distortion. One model has tone controls and 4 inputs which may be any combination of microphone (low impedance), guitars or P.U. inputs. The outputs are for 4—7.5—15 and 250 ohms or 100 volt line.

Other items of our manufacture are:

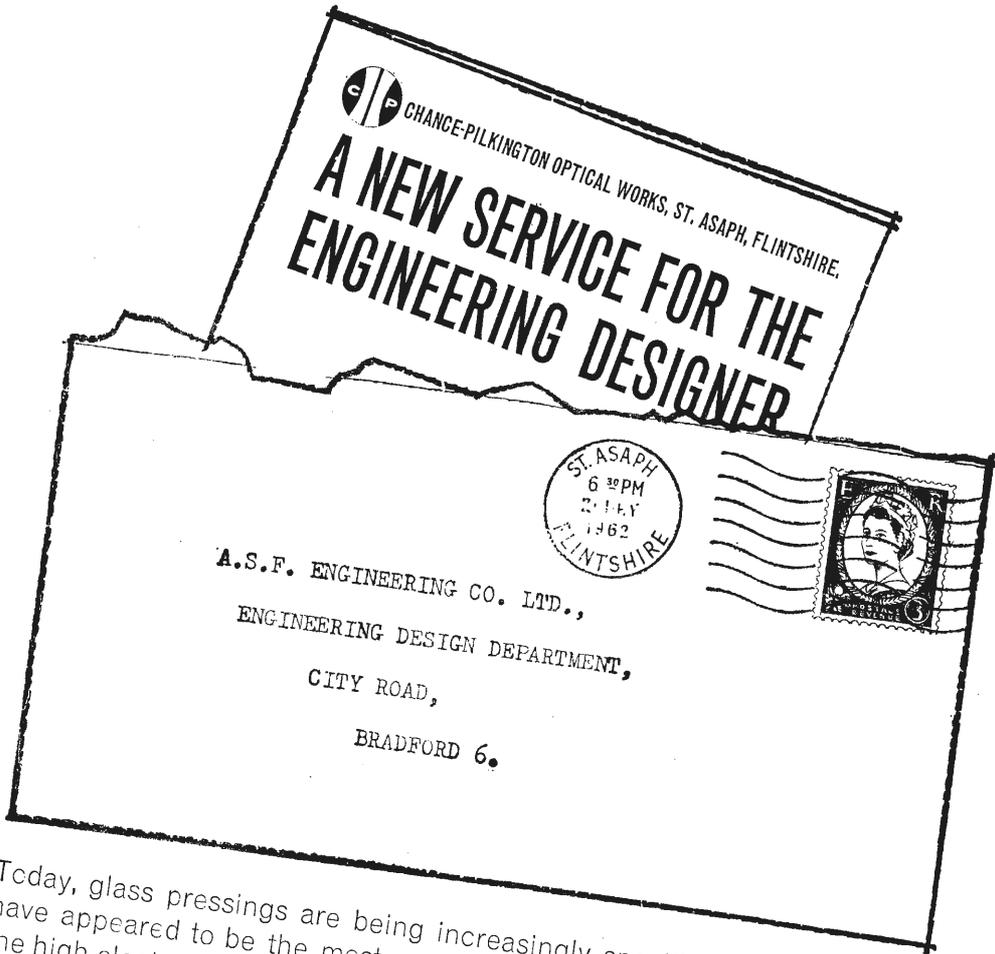
- WVA Recorder
- WVB Recorder
- Erase Fader units for recorders
- 2 way 30/50 ohm in and out stud type Mixers
- 3 way Mixers and Peak Programme meter
- 4 way Mixers
- 12 way Mixers
- 2 x 5 way Stereo Mixers
- 4 way Mixer with 10 watt output and tone controls
- Record and Playback Mixer

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# LC Oscillator Design

## 2.—SINE-WAVE GENERATION BY TRANSISTOR SWITCHES

By R. C. FOSS, B.Sc., Grad. I.E.E. and M. F. SIZMUR, B.Sc.

**I**N last month's section of this article it was shown how square waves of current generated known sine-waves of voltage when fed into a suitable parallel-tuned circuit. It was also shown that as such square waves could be conveniently generated using an idealized switch it was quite logical to base the design of LC oscillators on valve or transistor switching circuits and that the long-tailed-pair was a good switch for this purpose. One result of this approach was that the circuits described last month could be used to deliver a square wave output. This feature, unusual in LC oscillators, while useful to the waveform circuit engineer is probably regarded by most other engineers needing LC oscillators as of less than obvious value. The circuits described this month employ the same principles to generate only sinusoidal outputs. They also use transistors as the active circuit elements. This should not be taken as implying that transistors cannot be used in circuits giving an auxiliary square wave output or that valves cannot be used in circuits similar to those to be described. The same principles here apply to both valves and transistors with relatively minor differences. In fact, circuits embodying the features described in this section were originally patented with valves as the active circuit elements.

The first circuit described is based on what appears to be the original patent on this class of oscillator, granted to A. D. Blumlein in 1940<sup>1</sup> and notable as being the simplest arrangement using these principles, needing only a single valve or transistor and one diode as the active elements. The circuit is sufficiently simple to replace many conventional circuits with little if any economic penalty.

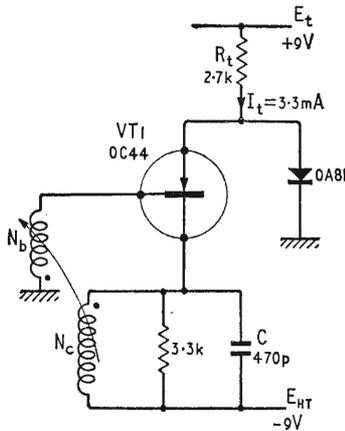


Fig. 1. 2Mc/s "half-pair" oscillator.

$N_c = 60$  TURNS 38 s.w.g. CLOSE WOUND.  
 $N_b = 12$  TURNS 38 s.w.g. ON TOP OF  $N_c$   
FORMER:— $\frac{9}{32}$  MINATURE ALADDIN

The second circuit uses the outputs from both sides of a long-tailed-pair in a push-pull arrangement. This circuit is used as an amplitude modulated oscillator by varying its tail current.

The use of transistors in a basic long-tailed-pair was described last month and it was shown that it is convenient to consider this type of transistor circuit, like its valve counterpart, as a switch operated by the input voltage. As in all transistor circuits the academic question of whether the transistor is "really" operated by its input voltage or its input current is little help to the engineer. Sometimes, as in this case, it is convenient to consider current as the consequence of voltage, in other configurations voltage as the consequence of current. Often one approach gives an easily understood and reliable circuit while the other leads only to a bog of transistor parameters.

Not every long-tailed-pair circuit which is satisfactory with valves is equally sound with transistors because of base current. Fortunately, base current imposes few extra restrictions on the design of LC oscillators. Perhaps the main limitation imposed is on the maximum resistance which can be placed in the base circuit without significantly altering the base voltage level. This means that if CR coupling is used for the regenerative connection, as is often convenient in valve oscillators, a resistor sufficiently small to provide a path for the base current will place considerable damping on the tuned circuit. To avoid this difficulty it is usually preferable to use inductive coupling in transistor oscillators. This does not necessarily make the design any more difficult. Especially with modern pot cores, coupling coefficients may be made close to unity so that the base peak voltage will be directly related to the collector peak voltage by the turns-ratio. It is then possible to choose a value of peak base voltage comfortably in excess of  $v_s$  (typically about 1V pk) independently of the desired peak voltage at the collector. An inductively-coupled feedback connection also gives a choice of polarities making it possible to operate the switch at either input point. It is this feature which makes it possible to simplify the basic switching circuit to what is sometimes called a "half-pair."

### Half-pair Switch

The oscillator shown in Fig. 1 is based on a transistor-diode half-pair switching circuit. Its operation is similar to the normal long-tailed-pair except that it has only one input point and one output point. Positive feedback from the output to the input of the switch is only possible if a phase-reversing connection is used. If the base voltage of the pnp transistor is made positive with respect to

earth by more than a few hundred millivolts, the precise value depending mainly on the type of diode used, the tail current of approximately  $E_t/R_t$  will flow in the diode and VT1 will be cut-off. Conversely if the base of VT1 is made negative by a similar amount VT1 will conduct  $I_t$  and the diode will be cut-off. With VT1 on a current of  $I_t/(\beta + 1)$  will appear at its base.

The operation of the oscillator should now be clear. Assuming a sinusoidal voltage  $v_1$  at the collector and tight inductive coupling with a phase reversal to the base, the base voltage of VT1 will be  $v_1 N_b/N_c$ .

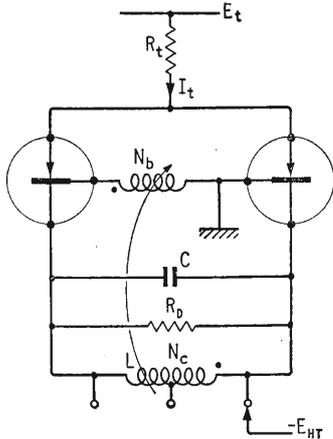


Fig. 2. Push-pull version of the basic l-t-p sine-wave oscillator.

$N_b$  and  $N_c$  are here the number of turns on the base and collector windings respectively. If this base voltage is large compared with  $v_s$  for the circuit but still small compared with  $E_t$ , an approximately square current wave-form will be switched into the tuned circuit as before.

The values shown in Fig. 1 may be calculated on the basis of this simple theory of operation. The inductor and capacitor used resonate at about 2 Mc/s, having a Q of 55. The dynamic resistance at resonance of the tuned circuit alone is therefore about 55 times the reactance of L or C at resonance (see Appendix 1 to Part 1) and is about 9k $\Omega$ . With a shunt loading resistor of 3.3k $\Omega$  the dynamic resistance becomes about 2.5k $\Omega$  (set mainly by this shunt load) giving a loaded Q of about 15. A tail resistor of 2.7k $\Omega$  with a 9V supply gives a tail current of about 3.3mA. The fundamental frequency component contained in a square wave of current of 3.3mA p.p. is  $3.3 \times 2/\pi = 2.1\text{mA}$  pk. (see Part I, eq. 3). The simple theory of operation thus predicts a peak voltage at the collector of  $2.1\text{mA} \times 2.5\text{k}\Omega$ , that is, about 5V peak. With a turns ratio of 5 : 1 and tight coupling between collector and base this will give about 1V peak at the base, adequate to switch the half-pair.

When the circuit was built, the peak collector voltage was measured using a suitable waveform monitor and found to be 5V peak. Variations in L and C to cover the frequency range of 1-2Mc/s changed this voltage by a maximum of only 10% because the shunt load resistor largely swamped changes in the tuned circuit Q.

Although this represents excellent agreement between theory and practice it should be noted that the practical operation of this circuit departs from the idealized theory to a greater extent than the valve

example considered last month. At 2Mc/s with the r.f. alloy-junction transistor used, the current wave-shape would be markedly trapezoidal because of switching time effects even with a square voltage waveform at the base. Also because of the half-pair switching arrangement the tail current reaches a peak value some 10% greater than calculated as the emitter follows the negative swing turning on VT1. These two discrepancies have opposite effects on the amount of fundamental frequency component fed to the tuned circuit. Another minor discrepancy is due to the effects of base current. First, the collector current of VT1 is less than the tail current by the amount of this base current. Secondly, it may be shown that a base current of  $I_t/(\beta + 1)$  switched into the base winding opposes the effect of  $I_t - I_t/(\beta + 1)$  switched into the collector winding. As the base winding has fewer turns the effect of this small opposing base current is usually negligible. In practice it is normally sufficiently accurate to assume that the current fed to the tuned circuit is simply  $I_t$ .

### Push-pull Oscillator

If an oscillator using a normal long-tailed-pair is required to give only a sine wave output it is of course possible to take the free collector or anode directly to the supply rail. Fig. 2 shows the circuit in such a case, drawn so as to show how the circuit may be converted to push-pull operation, making use of the output from both sides of the pair. In Fig. 2, both collector circuits may be taken as sources of constant current. There is therefore no change in the principle of operation wherever the supply lead is tapped on the inductor. For normal push-pull operation the inductor will be centre-tapped. The peak voltage across the load stays the

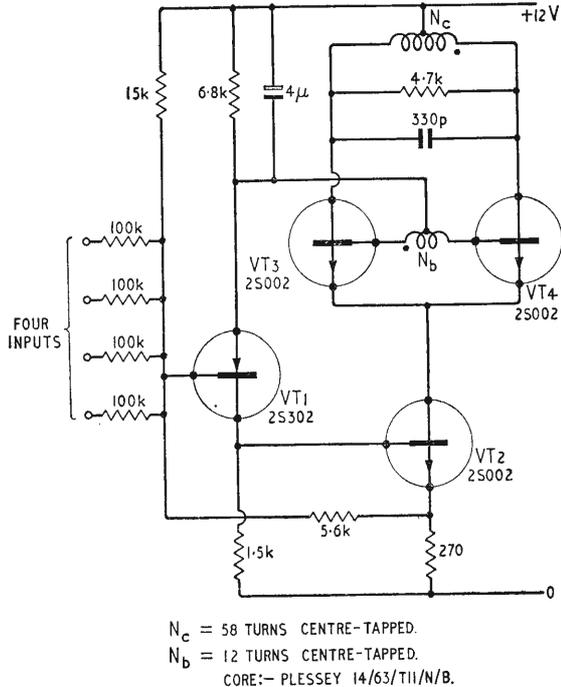


Fig. 3. Amplitude-modulated oscillator with four-channel mixing.

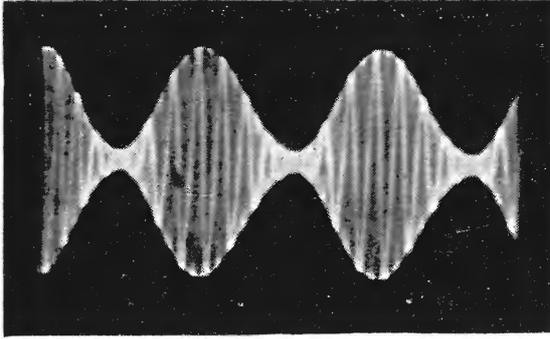


Fig. 4. Output of circuit of Fig. 2. Spurious f.m. on a.m. is less than 0.5%.

same so the peak voltage at each collector is halved. To obtain the full benefit of push-pull operation it is then possible to change the reflected load or the tail current so as to give the maximum allowable swing at the collector. To complete the symmetry it is convenient but not essential to centre tap the base winding also. A push-pull oscillator is used in the following example.

### Amplitude Modulation

The idealized theory of operation of these oscillators shows that the peak output obtained should be directly proportional to the tail current. By varying the tail current it is therefore possible to amplitude-modulate an oscillator or a separately-driven switching output stage. Fig. 3 shows an oscillator which was required to operate at 500kc/s and be linearly amplitude-modulated by four sub-carrier signals which had to be mixed without mutual coupling. This isolation is achieved by the well-known method of adding a "virtual earth". Feedback is taken from the emitter of VT2 and gives a virtual earth at the base at VT1. VT1 and VT2 thus comprise a feedback pair<sup>2</sup>, fixing the voltage across the emitter resistor of VT2. In the absence of any signal, feedback holds the standing voltage across the 270Ω resistor to about 0.8V giving a current in the resistor of about 2.8mA. This value of current, less the current in the feedback chain (about 0.5mA), will be the emitter current for VT2. Neglecting the base current of VT2, 2.3mA will be the tail current for the oscillator pair, VT3 and VT4. The tail current is in this case fixed independently of the level of the base voltage of VT3 and VT4 provided VT2 is not bottomed. A convenient bias level is found at the emitter of VT1. Signal variations at any of the four input points produce corresponding changes across the 260Ω resistor and hence changes in the oscillator tail current, giving the desired amplitude modulation (see Fig. 4).

When built, the quiescent peak voltage with no modulation input measured at the collectors of VT3 and VT4 was 2.5V pk, within 20% of the predicted value. The frequency stability of the oscillator with changes in temperature was also measured. A change of 50°C in ambient temperature was found to give only 1% change in carrier frequency.

The applications of the long-tailed-pair oscillator considered in this article have all been low power

level examples, where efficiency was not a major consideration. It can be shown that the maximum theoretical efficiency of an output stage or oscillator based on the principles described is  $100\% \times 2/\pi$  neglecting power loss in the tail and making the same assumptions as given by the well-known figures of 50% for a Class A and  $100\% \times \pi/4$  for a Class B stage. As the "tail" can be a transistor with only a volt or two across it, neglecting the tail losses is not necessarily unrealistic. This suggests that the techniques described might well be useful in transmitters using transistors. Ease of setting up might perhaps be regarded as a fair exchange for the slight drop in efficiency as compared with normal Class B operation. Such a transmitter might for example use a long-tailed-pair oscillator as the stable v.f.o. The square wave output from the oscillator could then operate transistor switches up to the power level required to switch the output stage. There would be only two tuned circuits in the entire transmitter—the v.f.o. and the p.a. tank circuit.

In conclusion it is hoped that this article will have shown that the same principles which are used in the design of reliable waveform generating circuits to give operation independent as far as possible of precise active element parameters can apply equally well when the waveform required is a sine wave. The generation of a sine wave in this way is a good example of the outstanding flexibility of the long-tailed-pair defined-current switching circuit. It seems quite likely that this approach might be profitable not only in the design of simple and reliable oscillators but in the design of more complex systems such as transmitters.

### Acknowledgments

The authors would like to express their thanks to Mr. F. W. Cutts and Dr. E. L. C. White for helpful discussions in the course of preparing this article, to Mr. D. C. Burgess who carried out the practical work on the amplitude-modulated oscillator and to Mr. J. D. Damper for his comments on the original manuscript.

Mr. Foss wishes to thank the directors of E.M.I. Electronics Ltd., and Mr. Sizmur the director of Royston Instruments Ltd., for permission to publish this work.

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2. Short, G. W., "The D.C. Feedback Pair"—*Wireless World*, December 1961.

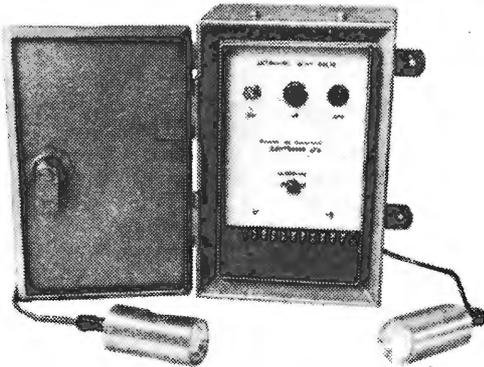
**Physics Films.**—A series of eight films intended to help the physics student to visualize the moving patterns of the phenomena otherwise difficult to demonstrate, have been produced by the McGraw-Hill Book Co. Inc. in co-operation with the American Association of Physics Teachers. Subjects include stationary and progressive transverse waves, the Doppler effect, simple harmonic motion and measurement of the speed of light. Each 16mm film lasts from 7 to 10 minutes and is available on hire at 5s per day from the Central Film Library, Government Building, Bromyard Avenue, Acton, London, W.3.

# MANUFACTURERS' PRODUCTS

## NEW ELECTRONIC EQUIPMENT AND ACCESSORIES

### Ultrasonic Sensing Unit

IN many situations, the application of photoelectric sensing to batch-counting or selection is difficult for reasons such as dirt or high ambient light levels, while magnetic sensing is only applicable to ferrous metals. In these circumstances, ultrasonics avoid most of the difficulties, and Contronics have introduced a unit for this purpose. The equipment consists of a control unit and two transducers which can be used remotely. The system operates at 45kc/s, the beam being a solid 20° with a still-air range of 50ft: interruption or reflection of the beam actuates the control circuitry. Liquids,

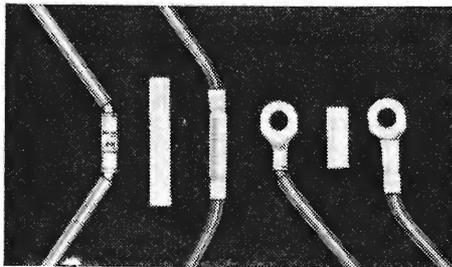


Contronics ultrasonic sensing relay. Heads are 1.5in diameter 3in long.

ferrous and non-ferrous metals, opaque or transparent objects will work the unit, and the beam may be piped through a plastic tube to reach difficult positions. Full details of the equipment may be obtained from Contronics Ltd., Blackdown (Surrey), Nr. Aldershot, Hants.

### Cable Sleeves

HELLERMAN have introduced a range of cable sleeves and markers called Helashrink which, when placed over an object (cable or terminal) and heated for a few seconds shrink to grip tightly and conform evenly to the shape of the object. Helashrink is produced either in specially developed polyethylene or in p.t.f.e., giving continuous operating temperature ranges from -55 to +135 and -65 to +260°C respectively, with short period operation allowable up to 300 and 365°C res-

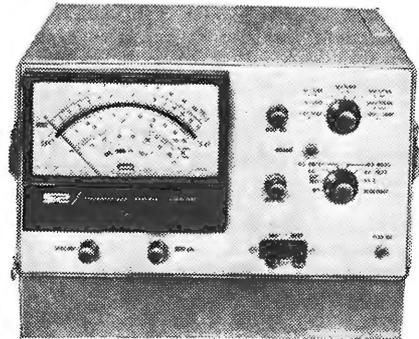


Two examples of the use of Hellerman "Helashrink" cable sleeves.

pectively. An additional advantage of Helashrink is the added strength provided at stress and connection points. Helashrink is produced in a range of colours and sizes, and heating devices are also available. Full details can be obtained from the Cable Accessories Division of Hellerman Ltd., Gatwick Road, Crawley, Sussex.

### Transistor Multimeter

ALTHOUGH similar in function to an ordinary multi-range testmeter, the SSIL Transistorized Portable Laboratory contains transistorized amplifying circuitry,

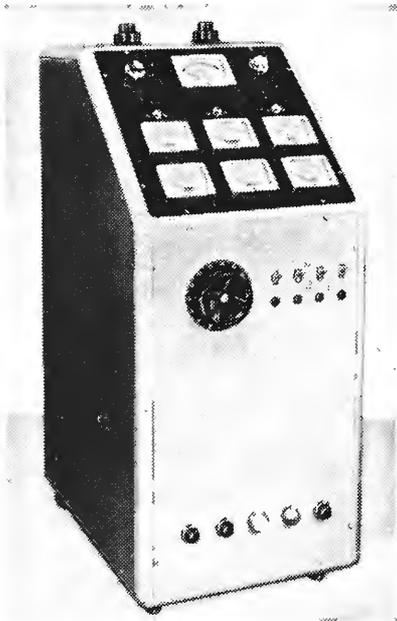


Transistorized meter by Solid State Instruments Laboratories.

with a consequent increase in input sensitivity. For instance, 1 $\mu$ A gives full-scale deflection on ranges up to 50V f.s.d., while on alternating voltage ranges up to 150V f.s.d., 62.5 $\mu$ A are taken. The use of an amplifier is not attended by any loss of accuracy; all d.c. functions are measured at an accuracy of 0.7%, and a.c. measurements are performed to within  $\pm 2\%$  from 10c/s to 350kc/s. Reference to calibration charts gives increased accuracy, and a 1.5V reference point is provided for calibration. An additional current range of 1.5 $\mu$ A f.s.d. is provided by an external unit which is connected to the T.P.L. by a lead. The instrument is obtainable from the U.K. distributors, G. S. Westbrook Ltd., 50 High Street, Harpenden, Herts.

### Electron Beam Heater

VACUUM vapour deposition of a wide range of metals and non-metals is possible by means of new Planer equipment. In this equipment electrons do not bombard the substance to be evaporated and deposited but rather bombard a conducting refractory crucible containing this substance. The electrons are provided by a heated emitter and drawn through a funnel to the crucible by a high potential applied between the crucible and emitter. The crucible temperature is controlled by adjusting the current through the emitter. The rate of evaporation is monitored by measuring the vapour ionization current by means of an additional electrode assembly. The output from this assembly is fed back to the emitter i.t. supply to allow the rate of deposition to be controlled and fixed. The emitter, funnel, rate-meter electrode assembly and crucible are vacuum sealed

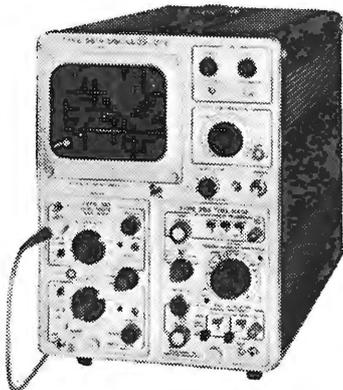


Control unit of G.V. Planer electron beam heating equipment for vacuum coating.

in a single unit and up to five such units and their associated l.t. power supplies can be provided. This method of vacuum coating has several advantages over the method of evaporating the material to be deposited by placing it on an electrically heated resistance wire. Some of these advantages are that higher evaporating temperatures can be obtained (and thus more refractory substances deposited), impurities can be more easily avoided, and both conducting and non-conducting materials can be deposited. This equipment is manufactured by G. V. Planer Ltd., of Windmill Road, Sunbury-on-Thames, Middlesex.

### Versatile Oscilloscope

A CERAMIC-SIDED 5-in cathode ray tube is used in the latest Tektronix oscilloscope to emerge. The rectangular, flat-face tube is made of kiln-fired ceramic, with



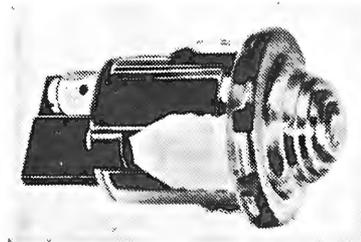
Tektronix Type 561A oscilloscope. Plug-in units in use are the 3A1 Dual trace y amplifier and the 3BC Delaying sweep time base unit.

a resultant low weight and equal strength in the tube sides and corners. An internal graticule is employed for parallax-free measurement, edge-lighting being used

to provide control of illumination. Plug-in units provide a wide range of x and y operating modes, and although the basic instrument—the 561A—is a 10Mc/s, general-purpose device, the use of a sampling unit raises the top frequency to 875Mc/s for recurrent sinusoidal signals. A full description is obtainable from the U.K. agents, Livingston Laboratories Ltd., 31 Camden Road, London, N.W.1.

### High-intensity Neon

NEW signal-lamp fittings by Bulgin incorporate high-intensity neon tubes, and the current limiting resistor is contained in the same housing. Lamps are available to work from 100/125V or 200/250V a.c. Single-hole fixing by spring clip is provided, and termination is by pinch screw terminals. Lenses coloured red, amber, or



Bulgin D.875 neon signal lamp.

clear can be obtained, and front projection is 23/64in. The lamps are made by A. F. Bulgin & Co. Ltd., Bye-Pass Road, Barking, Essex.

### Stabilized Power Supply

TOTAL noise in the MK III versions of the Lexor stabilized p.s.u.'s is less than 2.5mV peak. Made in two models, the LT.12-05 (5.5-14V) and the LT.24-05 (18-28V), the units provide a regulation of 0.15% at the worst conditions of  $\pm 10\%$  mains variation and a simultaneous load change of 0-500mA. The output is not



Lexor power unit. Sockets for external voltmeter are near terminals.

earthed—either polarity being usable, and full overload and short-circuit protection is employed. The units are conveniently sized and shaped for stacking, the steel cases being 8x5x5 1/2 in. The price is £25 7s from Lexor Electronics Ltd., 25 Allesley Old Road, Coventry.

### Low-noise Cable

A FULL range of low-noise coaxial cable is being marketed in the U.K. by Gulton Industries (Britain) Ltd., 52, Regent Street, Brighton. Developed for use with vibration measuring transducers, the cable

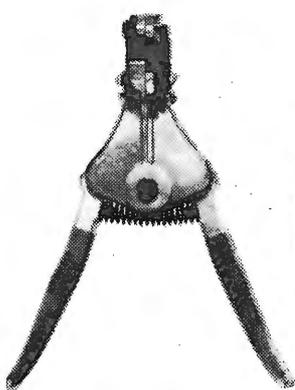


Gulton low-noise coaxial cable.

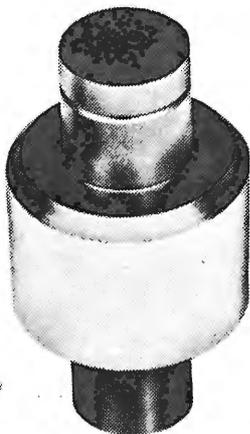
achieves its low noise characteristic by virtue of the fact that a conductive coating is applied to the p.t.f.e. insulating layer, a gradual transition from the insulation to the metal shield being obtained. The main source of noise in coaxial cables—sudden changes in characteristics—is thereby avoided. The cables generate 60dB less noise than the average low-noise cable, and two types are available, one to work in temperatures up to 105°C and the other up to 280°C. Capacitance is 36pf/ft, and the external diameter is 0.111in.

### Wire Stripper

WHILE retaining the established automatic release mechanism which prevents damage to fine wires, the new Creators F2 lightweight tool will accept flat twin flex cable, separating and stripping both conductors simultaneously with one pressure of the grips. The manufacturers are Creators Ltd., Albert Drive, Sheerwater, Woking, Surrey.



Creators flat twin flex stripper.



Typical M.S.D. varactor. Complete device is 0.217in long overall.

### Sub-miniature Varactor

A SERIES of low-voltage silicon varactors is announced by Microwave and Semiconductor Devices Ltd., which have cut-off frequencies in the range 40 Gc/s to 175 Gc/s. The series inductance of a typical example is  $0.5 \times 10^{-9}H$ , and the devices are ideally suited to parametric amplifier applications. Mechanically, the

diodes are easily applied to coaxial line circuits, as the heat sink takes the form of a mounting prong. The ambient temperature may be within  $-65$  to  $150^\circ C$ , and total power dissipation is between 100mW and 300mW, depending on type. A complete description can be obtained from M.S.D. at Skimpot Trading Estate, Luton, Beds.

### Soldering Iron

INTENDED to perform most of the duties required of a general-purpose soldering iron for the electronics industry, the A.N.T.E.X. E240 is a higher-power version of the sub-miniature type, and consumes 20W at 110V or 250V. Heating time is 3 or 4 minutes and the slide-on bits available are from  $\frac{3}{32}$ in to  $\frac{1}{4}$ in diameter, with a variety of protective finishes depending on the application. The handle of the iron is designed to be held in a "writing grip"—the most suitable hold for precision



A.N.T.E.X. 20W soldering iron.

work in confined spaces. The irons, which are available from A.N.T.E.X. at Grosvenor House, Croydon, Surrey, cost 35s and the bits 5s or 7s 1d depending on size and shape.

### Miniature Relay

A NEW B & R Relay—Type RO5—is the smallest in their range to date, its main body measuring only  $\frac{1}{16}$ in diameter by  $\frac{1}{2}$ in long (its maximum overall length, including connector wires, is  $2\frac{1}{2}$ in). This relay has one normally open contact. It is based on the MR 400-1 Gordon miniature dry reed switch. This has an initial contact resistance of between 60 and 200m $\Omega$  and a life expectancy of at least  $3 \times 10^6$  operations. The contact is rated at 4W at a maximum of 0.125A or 250V. The coil is wound round the glass capsule enclosing the reed, and the whole relay enclosed in a steel tube to prevent magnetic interaction with any adjacent relays. In appearance the RO5 relay looks rather like a small tubular capacitor and it is suitable for mounting on a group board. The total operating speed is 1.5 to 2.5 msec and the "bounce" time  $< 200\mu sec$ . The standard coil is suitable for potentials up to 30V d.c. but windings for higher voltages are available. The nominal operating power is 130mW. The RO5 (standard coil version) costs 16s and is manufactured by B & R Relays Ltd., of Temple Fields, Harlow, Essex.

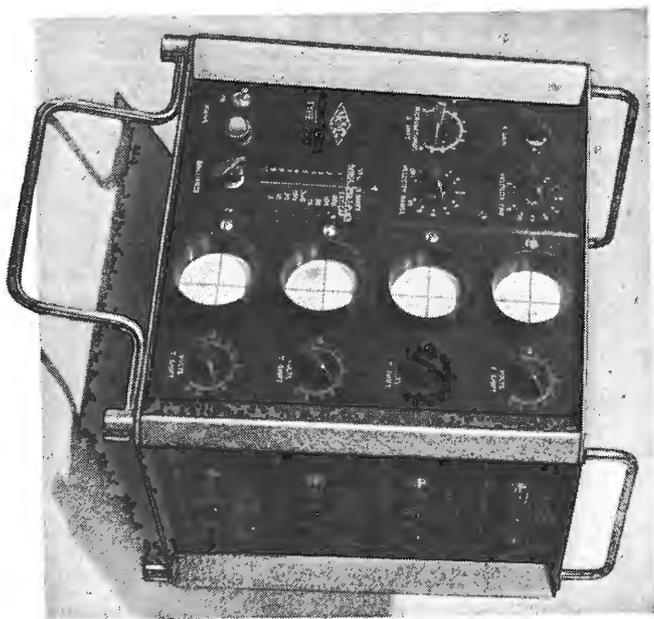


B & R type RO5 miniature relay.

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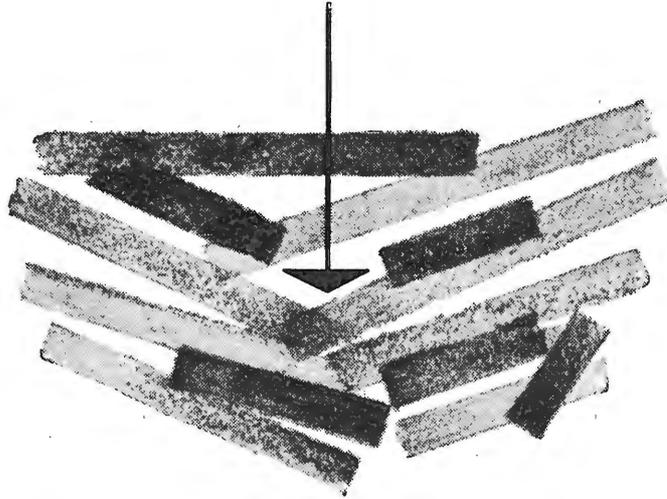
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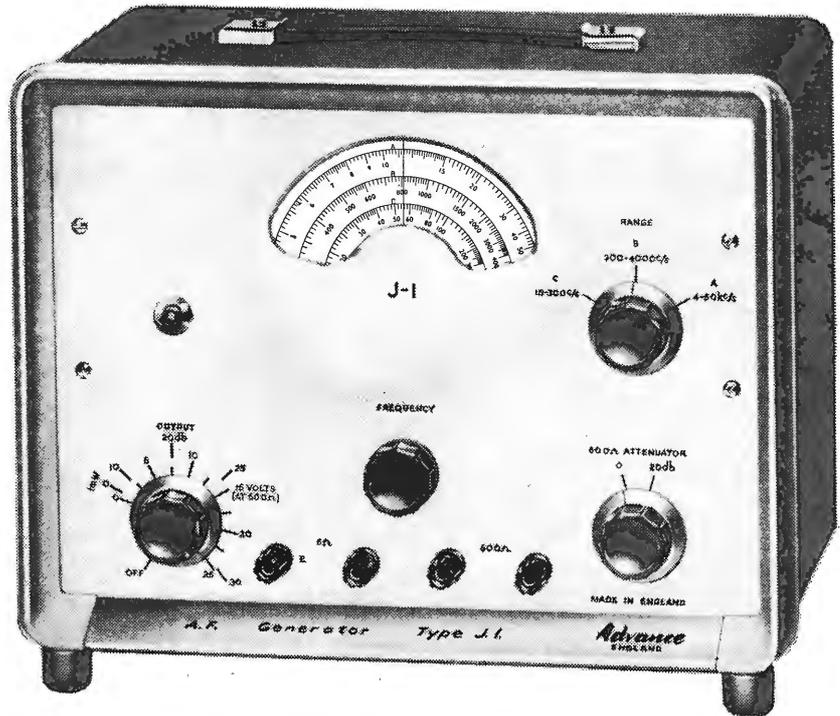
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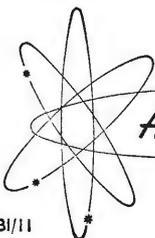
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# TAPE RECORDER CIRCUITS

By J. SOMERSET MURRAY,  
B.A. (Cantab), A.M.I.E.E.

## 2.—NOISE IN REPLAY SYSTEMS

*The signal/noise ratio of three possible replay circuits is examined theoretically. A comparison is made between the usual high-impedance input amplifier and the self-equalized low-impedance type. It is shown that these give different noise spectra, which may influence the choice*

**T**HE noise in the output of a replay amplifier comes from two sources:—the Johnson noise in the input circuit and the noise associated with the amplifier. In a replay system, these sources together give the noise output when the tape is not running. The noises must be calculated; after applying the appropriate equalization they can be plotted as a spectrum. To keep the analysis within bounds it will be assumed that the heads are ideal, meaning that no extra top lift is required and that the basic amplifier noise is white, i.e., that flicker begins at such a low frequency that it can be neglected. Both these assumptions depend on the state of design of the component; in the future they will be more easily accepted.

The high-impedance amplifier, Fig. 9(a) is given a maximally flat input circuit (see the first part of this article), as also is Fig. 9(b), a current-operated low-impedance amplifier. Fig. 9(c) is a self-inductance-equalized type, using a "virtual short" circuit as proposed by Ridler in *Wireless World* (Dec. 1958, p. 572). Since C is effectively short-circuited the input current is controlled only by the impedance of the head, consisting only of inductance and unwanted resistance in series. Noise output is usually measured by a wideband voltmeter; this gives a reading proportional to total power. Replay systems do not give a flat spectrum and it is argued that a total power measurement does not form a completely satisfactory criterion. For instance, when sound tracks are processed, an unbalanced spectrum will cause a build up of noise by repeated additions, which will give a pronounced colour to the noise. Consequently, in this analysis, the spectra

are predicted and these may in the end help to choose the best system. The signal is the standard C.C.I.R. at the two speeds 7½ in/sec and 15 in/sec.

**Input circuit noise**—Since the signal source contains resistance it will, on its own, be a source of Johnson noise. The three different input circuits have different signal/noise ratios, in themselves. We begin by considering these ratios, on the assumption of a perfect amplifier.

Comparing first Fig. 9(a) with Fig. 9(b), Fig. 9(b) can be quickly eliminated. It can be shown that at any frequency  $n\omega_0$ , where  $\omega_0$  is the resonant frequency, the Johnson noise output from the current-operated low-impedance input circuit is larger than from the voltage-operated high-impedance input circuit up to a frequency of  $0.518\omega_0$ .

If we put the resonance an octave higher than the band edge this fraction would include the whole of the band. The signal/noise ratios are:

$$\text{High impedance S/N} = E^2 [1 + \frac{1}{2}(n-1/n)^2] / 4KTR \quad (1)$$

(see appendix 1)

$$\text{Low-impedance S/N} = E^2 [1 + 2n^2 / (n^2 - 1)^2] / 4KTR \quad (2)$$

(see appendix 2)

The ratio of the two S/N ratios will be:

$$\frac{1 + \frac{1}{2}(n-1/n)^2}{1 + 2n^2 / (n^2 - 1)^2} \quad \dots \quad (3)$$

This ratio is unity when  $n^2 = 2 - \sqrt{3}$ , i.e., when  $n = 0.518$ .

When we compare Fig. 9(a), the better of the two maximally-flat amplifiers, with the self-equalized short-circuit type, we must remember that the spectrum of the signal input to the amplifier is different in the two cases. One way to overcome this difficulty

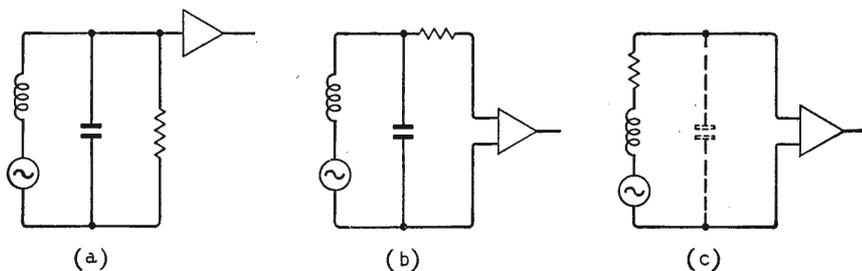


Fig. 9. Tape head connected to (a) high input impedance circuit, (b) low-impedance circuit and (c) "self equalizing" short circuit.

is to compare the signal/noise ratios at one frequency and then examine the trends as the frequency is varied. For this purpose it is convenient to choose the frequency at which the initial -6 dB/octave slope changes to a flat response (for the high-impedance type). This is the characteristic "turnover" frequency,  $f_t$ , determined by the equalization time constant:—100  $\mu$ sec or 35  $\mu$ sec for C.C.I.R. equalization at 7½ in/sec or 15 in/sec tape speeds respectively, i.e. 1,592 c/s or 4,560 c/s respectively.

The method is to postulate identical heads with equal signal voltages  $V$ . We then determine equal gains at  $f_t$ , the turnover frequency, by adjusting the trans-conductance and the trans-resistance to deliver equal signal powers to identical loads. When this is done the sensitivities are identical. We can now compare the Johnson noise output powers in the load and obtain a relative figure of merit at this one frequency. (Trans-conductance is well known for voltage-operated amplifiers and is usually written  $G_m$  and expressed in mhos. Trans-resistance is the equivalent for the current-operated amplifier. It is the voltage output for unit current and therefore has the dimensions of resistance. One can write  $|V_{out}| = S I_{in}$  where  $S$  is the trans-resistance.)

The Johnson noise sources are different. In the high-impedance type it is the added resistance  $R$  modified by the shunting effect of the head inductance and capacitance. In the self-equalized short-circuit type it is the unwanted loss resistance in the inductance which is the generator of noise. If we express this loss in terms of  $Q$  at  $f_t$ , and  $n_t$  is the ratio between turnover and resonant frequencies, we get

$$\frac{\text{High impedance noise}}{\text{Short circuit noise}} = \frac{N_H}{N_{SC}} = \frac{\sqrt{2} n_t Q}{1 + n_t^4} \quad (4)$$

(see appendix 3) .. .. .

It is worth while examining this in more detail.  $n_t$  for 35  $\mu$ sec is 0.1425 and for 100  $\mu$ sec is 0.0493. Neglecting  $n_t^4$ , equation (4) becomes numerically

$$\frac{N_H}{N_{SC}} = \sqrt{2} \times 0.1425 Q_{t35} \text{ for } 15 \text{ in/sec}$$

$$\frac{N_H}{N_{SC}} = \sqrt{2} \times 0.0498 Q_{t100} \text{ for } 7\frac{1}{2} \text{ in/sec}$$

This ratio depends on  $Q_t$ . The two types give equal S/N ratios at the turnover frequencies when  $N_H/N_{SC} = 1$ , i.e. when  $Q_{t35} = 4.97$ , or when  $Q_{t100} = 14.2$ . To compare these values with practical heads the  $Q$  of the Bogen UK104 was measured at  $f_{t35}$  or 4,560 c/s and at  $f_{t100}$  or 1,592 c/s, and it gave  $Q_{t35} = 7.5$  and  $Q_{t100} = 11.0$ . This means that the noise output at a turnover frequency of 4,560 c/s (corresponding to a tape speed of 15 in/sec) is 1.8 dB worse for the high-impedance input circuit than for the short circuit but that at turnover frequencies corresponding to lower tape speeds the position is reversed; at 1,592 c/s (corresponding to 7½ in/sec) the high-impedance input circuit is 1.1 dB better. But this is not the whole story. We must examine the differences at other frequencies, higher and lower. For this we need only consider the trend of each type relative to its noise at  $f_t$ .

**Noise spectra.**—The noise output per cycle at the low-frequency end of the high-impedance amplifier is easily shown to be constant, after equalization, independent of frequency, over the whole of the -6 dB/octave section (see appendix 4).

For the short-circuit type, on the other hand, noise per cycle increases as the frequency is reduced. This happens even over the range where  $Q$  may be considered nearly constant. The noise output power per cycle is  $4KTS^2/\omega L(1/Q+Q)R_L$  watts, where  $S$  is the trans-resistance and  $R_L$  the load (see appendix 3). This rises as  $\omega$  falls and again as  $Q$  falls. The expression is valid for values of  $Q$  where the effect of  $Q$  on the gain can be neglected. It follows that Johnson noise power in the source applied to the short-circuit self-equalized amplifier obeys at least an inverse frequency law. At the turnover frequency there is substantial equality.

The high frequencies must now be considered. The noise output of the high-impedance amplifier at high frequencies is again compared with the noise at the turnover frequency. At higher frequencies (considering only the characteristic and not the extra losses) the gain is 3 dB lower than at the turnover; the Johnson noise rises, as the frequency approaches resonance. Over this flat part of the characteristic the output noise power varies as  $1/(n^2 + 1/n^2)$  from equation 1. When this is compared with the noise at  $f_t$  it is seen to be approximately 6 dB/octave worse for the first two octaves above  $f_t$ .

In the short-circuit self-equalized system the equalization must provide a 6 dB/octave gain above  $f_t$ , which combined with the inherent 3 dB/octave reduction in noise gives an overall increase of 3 dB/octave at constant  $Q$ . But as  $Q$  must fall the whole of this advantage of 3 dB/octave is not achieved.

Nevertheless the pattern is clear. The two types of input circuit may be considered equal for practical purposes at  $f_t$  but the short-circuit amplifier is better by perhaps 2 dB/octave above  $f_t$  and worse by 3 dB/octave below  $f_t$ . (There are more octaves below than above  $f_t$ .)

**Effect of real amplifiers**—When the input circuit is connected to a real amplifier, the output signal will contain additional noise. This noise will have a different spectrum to that in the input circuit. A prediction of the overall signal/noise ratio at any frequency can be made by adding the noise from the input circuit to the amplifier noise, referring the resultant to a standard signal. Since the noises are added as powers the calculation can be made in terms of the real resistance  $R$  of the input and the equivalent noise resistance of the amplifier,  $R_{eq}$ .

The circuits left to be considered are Fig. 9(a) and Fig. 9(c). The appropriate amplifiers are different, and will not have the same numerical value of  $R_{eq}$ , even if they are equally good. In

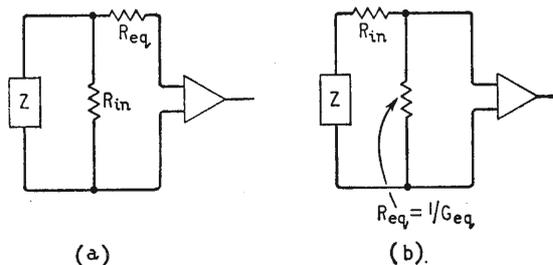


Fig. 10 (a) and (b). Real amplifier and input circuits corresponding to Fig. 9 (a) and Fig. 9 (c) respectively.

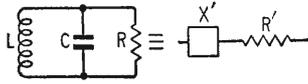


Fig. 11. Transformation of parallel into series circuit.

addition to  $R_{eq}$ , each amplifier will have a finite input resistance. The real amplifiers and their input circuits may be represented as in Fig. 10 (a) and (b). The amplifiers in the boxes are ideal. The noise voltage in  $R_{eq}$  in Fig. 10 (a) is added to noise voltage in  $Z$  by squaring and adding and taking the square root of the sum, since the noise voltages are uncorrelated. This is precisely the same thing as adding the two noise resistances and treating the resultant as being proportional to the noise power output of the combination. In Fig. 10 (b), the noise conductances are treated similarly.

Consider, first, the low-frequency section below  $f_t$ . We see at once that a striking difference emerges. The excess noise has to undergo equalization. This means that in the high-impedance circuit, the amplifier noise power per cycle is given the bass lift of 6 dB per octave and hence it increases rapidly as the frequency falls.

In the short-circuit type, on the other hand, the excess noise remains constant per cycle, below  $f_t$ . The roles have been exchanged. The short-circuit noise, which rises as frequency falls, now has a constant addition, while in the high-impedance case, the input circuit noise is constant but the excess noise, even if white in the first instance, rises as frequency falls. Noise rises in both circuits as frequency falls, but at different rates.

Above  $f_t$  in the high-impedance type, the excess noise will be a constant addition in power since this amplifier is flat above  $f_t$ . In the short-circuit one, it will have a 6 dB/octave rise since the equalization must introduce a slope of this value above  $f_t$ .

Obviously a great deal will depend on the ratio between the input circuit noise and the excess. If the amplifier noise is allowed to swamp the circuit noise at all frequencies the two systems will have fundamentally different noise spectra, the high-impedance one being predominantly noisy in the bass and the other in the top. We can investigate the more desirable case where the amplifier noise does not deteriorate the signal by more than a small amount at  $f_t$ , and then examine the spectrum of the system, which will now be fairly close to reality. If we do this for both systems, and make the further assumption that devices may be chosen so that the excess noise will be equal in both circuits at  $f_t$ , we can then plot the two spectra to discover whether there is any feature leading to a pronounced preference for either circuit. This computation must, in the absence of figures for actual amplifiers, be somewhat arbitrary, but it appears that the self-equalized type has perhaps a few dB less total noise. More striking is its relatively much less low-frequency noise which in the high impedance type must be caused by the equalization acting on the amplifier noise, even if it is white. Although the noise power per cycle rises towards the bass in both cases, the noise power per octave in the short-circuit case is substantially flat in good amplifiers.

## APPENDIX 1.

The input noise voltage of the input circuit in Fig. 9(a) at any frequency is due only to the resistive or real term in the transformation shown in Fig. 11. We need an expression for  $R'$ . This comes immediately from the expression for the LCR parallel circuit

$$Z = \frac{1/R - j(\omega C - 1/\omega L)}{(1/R)^2 + (\omega C - 1/\omega L)^2} \dots \dots \dots (5)$$

The real component is the first term.

$$R' = \frac{1/R}{(1/R)^2 + (\omega C - 1/\omega L)^2} \dots \dots \dots (6)$$

Let  $\omega_0$  be the angular velocity at the resonance and for any other frequency write  $n \omega_0$ . Using the maximally-flat relationships  $R = \sqrt{L/2C}$  and  $\omega_0^2 LC = 1$  in equation (6) we can obtain

$$R' = \frac{1/R}{(1/R)^2 + \frac{1}{2}R^2(n - 1/n)^2} = R/[1 + \frac{1}{2}(n - 1/n)^2]$$

## APPENDIX 2.

The LC  $r$  mesh of Fig. 12 may be transformed into a series equivalent:

$$Z = \frac{r + j\omega [Cr^2 + L(\omega^2 LC - 1)]}{\omega^2 C^2 r^2 + (\omega^2 LC - 1)^2} \dots \dots \dots (7)$$

When  $R$  is added to the real term we obtain the equivalent series circuit:

$$R' + jX = R + \frac{r}{\omega^2 C^2 r^2 + (\omega^2 LC - 1)^2} + jX \dots \dots (8)$$

where  $jX$  is the second term of the right-hand side of equation 7. This series circuit is now transformed back into a new parallel circuit,  $R' + jX'$  in parallel. We have  $R_p = R + X_s^2/R_s$ .

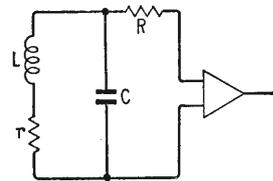


Fig. 12. Circuit of Fig. 9 (b) with head resistance  $r$  included.

The full expression for the noise equivalent parallel resistance is then

$$R_n = \left( \left[ R + \frac{r}{\omega^2 C^2 r^2 + (\omega^2 LC - 1)^2} \right]^2 + \left[ \frac{\omega [Cr^2 + L(\omega^2 LC - 1)]}{\omega^2 C^2 r^2 + (\omega^2 LC - 1)^2} \right]^2 \right)^{1/2} \dots \dots (9)$$

This is a bit unwieldy. If we approximate it to ideal conditions we shall get a practically useful result. Putting  $r = 0$  in equation 9 we get

$$R_n = R + \frac{\omega^2 L^2}{(\omega^2 LC - 1)^2 R} \dots \dots (10)$$

We now substitute  $n \omega_0$  for  $\omega$  and put  $\omega_0^2 LC = 1$  and get

$$R_n = R + \frac{n^2 \omega_0^2 L^2}{(n^2 \omega_0^2 LC - 1)^2 R} = R + \frac{n^2 \omega_0^2 L^2}{(n^2 - 1)^2 R} \dots \dots (11)$$

Using the maximally-flat relationships  $\omega_o^2 LC = 1$  and  $R = \sqrt{L/2C}$  we get

$$R_n = R + \frac{2n^2R^2}{(n^2-1)^2R} \dots\dots\dots (12)$$

$$= R \left[ 1 + \frac{2n^2}{(n^2-1)^2} \right] \dots\dots\dots (13)$$

### APPENDIX 3.

Let  $f_t$  and  $\omega_t$  refer to the turnover frequency and  $f_o$  and  $\omega_o$  refer to the resonance. We know from Appendix 1 that if  $n_t = f_t/f_o$ , then  $R' = R[1 + \frac{1}{2}(n_t - 1/n_t)^2]$ . Again using  $R = \sqrt{L/2C}$ ,  $\omega_o^2 LC = 1$ , and  $n_t = f_t/f_o$ , we can relate the noise resistance to the head inductance, by substituting for  $R$  in terms of  $L$ . This gives

$$R' = \omega_o L / \sqrt{2} \left[ 1 + \frac{1}{2} (n_t - 1/n_t)^2 \right]$$

Putting  $X_t$  for  $\omega_t L$  we have  $\omega_o L = X_t/n_t$  and can write

$$R' = X_t/n_t \sqrt{2} \left[ 1 + \frac{1}{2} (n_t - 1/n_t)^2 \right] \dots\dots\dots (14)$$

The noise voltage is  $\sqrt{4kTR'}$  per cycle at  $f_t$ . This noise voltage acts upon a voltage-operated amplifier and causes a current to flow in the load. The current is assumed to be independent of the load and to be equal to the voltage multiplied by the transconductance. The power in the load is equal to the square of the current multiplied by the load resistance  $R_L$ . The noise power in the load is therefore

$$4kTR'G_m^2R_L \text{ watts} \dots\dots\dots (15)$$

In the self-equalized short circuit case, instead of a finite resistance  $R$ , which has been put equal to  $\sqrt{L/2C}$ , the noise source is the small series resistance  $r$  in the head inductance which determines the  $Q$  of the head. Here the inductance, which is noiseless, is in series with  $r$ . This must be transformed into the parallel equivalent to obtain a value of  $r'$  whose short circuit noise current will flow into the current-operated amplifier. If we put  $\omega_t L = X_t$  we can write  $r = X_t/Q$  and, using the series/parallel transformation we write  $r' = X_t/(1/Q + Q)$ . The short-circuit noise current is the square root of  $4kT/X_t(1/Q + Q)$ , and the output voltage is  $S$  times

this. The noise power in the load will thus be  $S^2 4kT/X_t(1/Q + Q)R_L$  watts  $\dots\dots\dots (16)$

We must now find the relation between  $G_m^2/R_L$  and  $S^2/R_L$  (where  $G_m, S$  are the trans-conductance and trans-resistance respectively) which will deliver equal powers for a signal voltage  $E$  at frequency  $f_t$ . The signal voltage  $E$  is applied unaltered to the input of the amplifier in Fig. 9(a). Therefore the signal power is  $E^2G_m^2R_L$ . In Fig. 9(c), the current is  $E/Z_t$ , where

$$Z_t = \sqrt{X_t^2 + (X_t/Q)^2} = X_t \sqrt{1 + 1/Q^2}$$

The voltage output is  $S$  times this so that the power in the load  $R_L$  is  $E^2S^2/X_t^2(1 + 1/Q^2)R_L$ . This must equal  $E^2G_m^2/R_L$ . Therefore

$$G_m^2R_L = S^2/X_t^2(1 + 1/Q^2)R_L \dots\dots\dots (17)$$

The ratio between the noise powers is

$$\frac{N_H}{N_{SO}} = \frac{(15)}{(16)} = \frac{4kT G_m^2R_L^2R'X_t(1/Q + Q)}{S^2 4kT}$$

Using equation 17 this becomes

$$\frac{S^2R'X_t(1/Q + Q)}{S^2X_t^2(1 + 1/Q^2)}$$

Substituting for  $R'$  from equation 14 we get

$$\frac{Q}{n_t \sqrt{2} \left[ 1 + \frac{1}{2} (n_t - 1/n_t)^2 \right]} = \frac{\sqrt{2} n_t Q}{1 + n_t^4}$$

### APPENDIX 4.

We consider the value of  $R'$  which from appendix 1 is  $R/[1 + \frac{1}{2}(n - 1/n)^2]$ . Over this region the voltage gain must fall at 6 dB/octave. Therefore  $G_m$  must be proportional to  $1/f$ , and  $G_m^2$  to  $1/f^2$ . The noise power output must be proportional to  $R'G_m^2$ , which is proportional to  $R'/f^2$  (and thus to  $R'/n^2$ ). Therefore the noise output must vary with  $n$  as  $1/(n^4 + 1)$  which is independent of  $n$  when  $n$  is small.

## B.B.C. 625-LINE U.H.F. TESTS

### Monochrome and Colour Transmissions Daily from Crystal Palace

ON November 3rd the B.B.C. concluded its series of u.h.f. 625-line television field trials which it had been conducting since September 3rd, and is now carrying out until further notice a regular schedule of test transmissions daily from Monday to Friday. The tests include both monochrome and N.T.S.C. colour transmissions. Later there will be tests using the French SECAM colour system. The sound transmitter radiates the Band I television sound.

#### TRANSMISSION SCHEDULE

Time	Material
0-10 min.	3 min. colour bars 15 sec. identification caption 2 min. 15 sec. colour slides 2 min. 15 sec. monochrome slides 2 min. 15 sec. colour slides
10-20 min.	625-line test card
20-30 min.	as for 0-10 min.
30-40 min.	colour bars
40-50 min.	1 min. 625-line test card 3 min. colour slides 3 min. monochrome pictures 3 min. colour slides
50-60 min.	colour slides or additional test material

The transmissions are being radiated in Channel 44 (vision 655.25 Mc/s, sound 661.25 Mc/s) with horizontal polarization and an e.r.p. of 160 kW. Early in 1963 there will be simultaneous transmissions in Channel 34 (vision 575.25 Mc/s, sound 581.25 Mc/s). These channels are being used for experimental purposes only and are not those which, in accordance with the Stockholm Plan, will be used in the London area when the B.B.C.'s second programme on 625 lines starts in 1964.

The schedule of transmissions is given opposite. It will be repeated each hour from 10.00 to 17.00 except between 13.00 and 14.00 during which time a grille pattern (for receiver convergence adjustments) or other test signals will be radiated. From 20.00 to 21.30 colour and monochrome films interspersed with slides will be transmitted. Each transmission period will be preceded by a 20 minute "line-up" sequence. A test line signal will be inserted in the blanking period of each field. This signal will consist of one line carrying a 2T pulse and bar (T being the half-amplitude duration of a standard sine-squared pulse with a repetition frequency equal to the line frequency) followed by a second line carrying a chrominance 2T pulse and bar.

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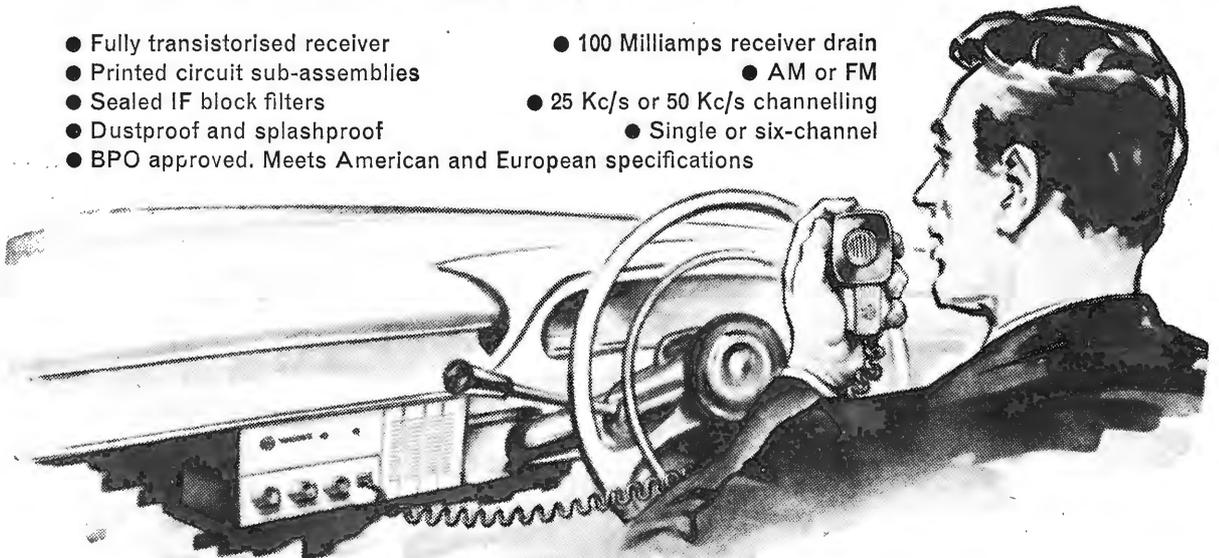


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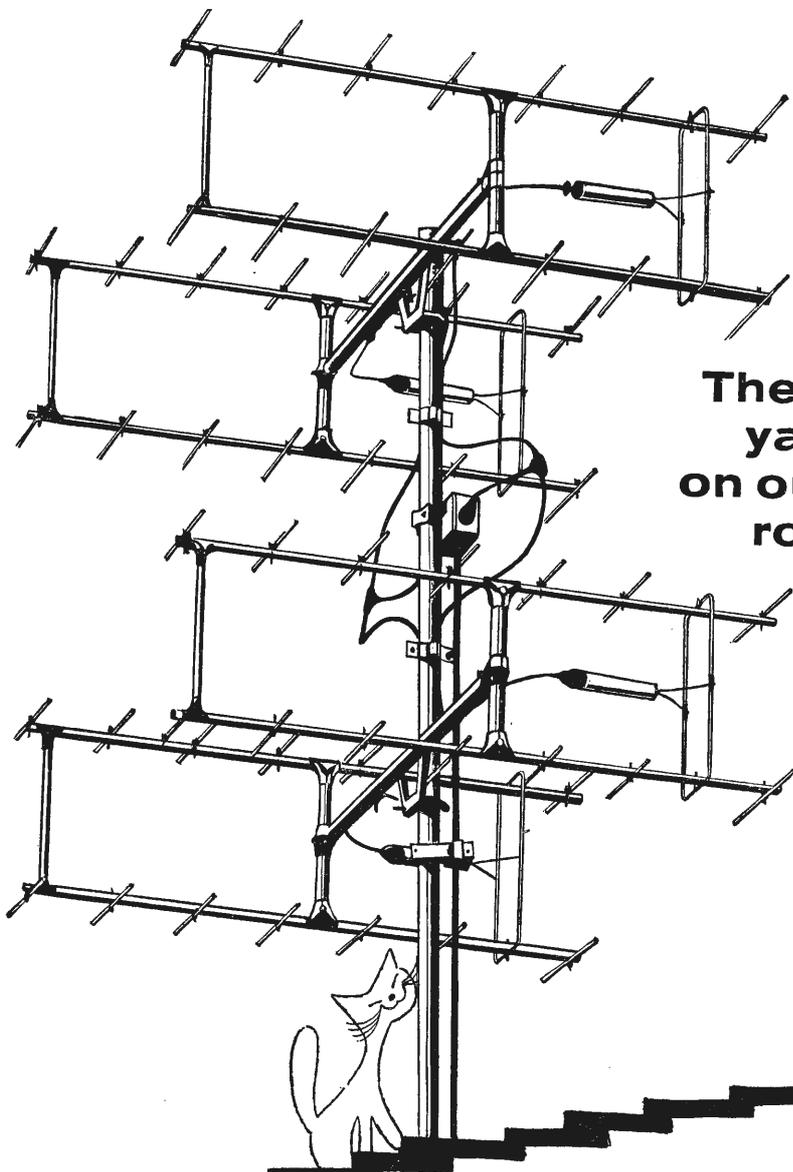
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# DECEMBER MEETINGS

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

## LONDON

3rd. I.E.E.—Discussion on "Plugs, sockets and interconnections" opened by N. E. Hyde at 5.30 at Savoy Place, W.C.2.

5th. Brit.I.R.E.—"Signal/noise performance of radar and sonar displays" by Dr. J. W. R. Griffiths at 6.0 at London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

6th. I.E.E.—"Data processing" by R. H. Tizard at 5.30 at Savoy Place, W.C.2.

6th. Radar & Electronics Assoc.—"Investigation of space by probes and radio" by Prof. Sir Bernard Lovell at 7.0 at The Royal Commonwealth Society Hall, Northumberland Avenue, W.C.2.

7th. I.E.E. & Brit.I.R.E.—Discussion on "Masers and lasers and their possible applications in medicine and biology" at 6.0 at Savoy Place, W.C.2.

8th. Electronic Organ Constructors Soc.—"Demonstration of organ by Clyne Radio at 3.0 at Northern Polytechnic, Holloway Road, N.7.

12th. I.E.E.—"Radio meteorology" by Dr. J. A. Saxton at 5.30 at Savoy Place, W.C.2.

12th. Brit.I.R.E.—Discussion on "Teaching mathematics to engineers" at 6.0 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

12th. Soc. of Environmental Engineers.—"Simulation of a space environment" by A. P. Longmore at 6.0 at Mechanical Engineering Department, Imperial College, Exhibition Road, S.W.7.

13th. Radar & Electronics Assoc.—"Colour television servicing" by R. A. Turrell and B. J. Rogers at 7.0 at Royal Society of Arts, John Adam Street, W.C.2.

14th. Society of Non-Destructive Examination.—"The uses of ultrasonics" by Dr. R. Jones at 3.30 at the Institution of Mechanical Engineers, 1 Birdcage Walk, S.W.1.

14th. Television Society.—"Switchable television receivers" by L. H. Briggs at 7.0 at 164 Shaftesbury Avenue, W.C.2.

17th. I.E.E.—"A proposed new method of measuring microwave power and impedance using Hall effect in a semiconductor"; "High - frequency radiation pressure and Hall effect in semiconductors" and "A microwave electrostatic wattmeter" by Professor H. E. M. Barlow at 5.30 at Savoy Place, W.C.2.

18th. I.E.E.—Discussion on "Television in the service of technical education" opened by J. Scupham at 5.30 at Savoy Place, W.C.2.

19th. Brit.I.R.E.—Symposium on "Vibration testing" at 10 a.m. at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

21st. B.S.R.A.—"The design of pickups," by P. J. Pyke at 7.15 at the Royal Society of Arts, John Adam Street, W.C.2.

## BIRMINGHAM

7th. Society of Instrument Technology.—"Instruments in space research" by E. C. Mackenzie at 7.0 at the Lecture Theatre, Bing Kendrick Suite, College of Advanced Technology, Gosta Green.

13th. Brit.I.R.E.—"Recent developments in piezo-electric transducers" by A. E. Crawford at 6.15 at the University.

## BRISTOL

5th. Brit.I.R.E.—"Colour television" by I. J. P. James at 7.0 at Bristol College of Science and Technology.

13th. Society of Instrument Technology.—"Applications of radar to meteorology" by W. G. Harper at 7.30 at the Department of Physics, the University, Royal Fort.

## CARDIFF

5th. Brit.I.R.E.—"A new television service" by N. Hughes at 6.30 at the Welsh College of Advanced Technology.

## EDINBURGH

12th. Brit.I.R.E.—"Synthetic speech" by James Anthony at 7.0 at the Department of Natural Philosophy, The University, Drummond Street.

## FAWLEY

7th. Society of Instrument Technology.—"Transistors in industry" by S. Perkins at 5.45 in Room 4a, Administration Building, Esso Petroleum Co.

## GLASGOW

13th. Brit.I.R.E.—"Synthetic speech" by James Anthony at 7.0 at the Institution of Engineers and Shipbuilders, 39 Elmbank Crescent.

## LEICESTER

11th. Television Society.—"Transistorized television receivers" by P. L. Mothersole at 7.30 at the New Vaughan College, St. Nicholas Street.

12th. Brit.I.R.E.—"Electronics in archaeology" by D. Reaney at 6.45 at The University.

## LIVERPOOL

19th. Brit.I.R.E.—"The application of photomultipliers in industry and research" by J. Hambleton at 7.30 at the Walker Art Gallery.

## MALVERN

6th. Brit.I.R.E.—"Lasers" by Dr. D. W. Goodwin at 7.0 at the Winter Gardens.

## MANCHESTER

3rd. Society of Instrument Technology.—"Electronics v. pneumatics" by C. H. Gregory at 6.45 at the Literary and Philosophical Society, 36 George Street.

6th. Brit.I.R.E.—"Electro-acoustics: a review" by Dr. B. K. Gazeay at 7.0 at Reynolds Hall, College of Science and Technology.

## NEWCASTLE-UPON-TYNE

12th. Brit.I.R.E.—"Sonic gas analysis" by A. M. Reid at 6.0 at the Institute of Mining and Mechanical Engineers, Neville Hall, Westgate Road.

## PORTSMOUTH

12th. I.E.E.—"Digital frequency synthesisers for modern communication systems" by R. A. Hicks and J. D. Newman at 6.30 at College of Technology, Anglesea Road.

## SOUTHAMPTON

11th. I.E.E.—Discussion on "Teaching electronic circuit techniques" opened by A. R. Owens at 6.30 at The University.

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# Electronics Made Easy

By "CATHODE RAY"

**W**E are repeatedly warned by highbrows that electrons are not little black elastic spheres charged with negative electricity. Fair enough if they told us clearly what electrons *are*. But when we pursue that line of inquiry the answer is usually something to the effect that they are entities whose behaviour conforms to certain mathematical equations. And again we are warned not to regard them as having any imaginable physical existence, as otherwise we are bound to get bogged down trying to reconcile contradictory pictures of them as both waves and particles.

I am convinced that all this is perfectly true. In fact, I have expounded such views myself from time to time. Yet when it comes to tracing out how a circuit works I always regard the electrons as little black elastic spheres charged with negative electricity.

This revelation—or confession—should put fresh heart into readers who have been following my recent series with a growing conviction that I have defected to the academic cause. There is really nothing inconsistent in having several quite different views of what electrons are, according to the requirements of the occasion. However desirable steam-hammers may be for some operations, it is stupid to insist on one for cracking a nut. So I make no apology for what follows.

## Valves or Transistors First?

I suppose most people still start with valves and then go on to transistors as a rather more advanced electronic subject. No doubt the fact that valves were established decades before transistors were thought of may have a lot to do with this order of approach. But while not going so far as to endorse Henry Ford's opinion that history is bunk, when it comes to offering a working knowledge of a subject such as electronics I do say that history is one of the worst grounds on which to base an order of approach. Nor is the order that was appropriate in my young days necessarily right when we pass on our knowledge to the young of today, who see valves being rapidly driven from one after another of their prepared positions by transistors. The expositor has a stronger case when he claims that transistors are inherently more complicated than valves, so should come later in the book.

All the same, in this child's guide to electronic devices I'm going to have a shot at transistors first.

The object of the exercise is to be able to tell which way the currents flow. Now we all know that electric currents consist of the movement of electric charges, and their movements are governed by the rule that "like repels like and attracts unlike." In practice, most of the moving charges are electrons, and because they are negative they tend to move

away from other negative charges and towards positive charges. So long as vacuum valves ruled the roost, movements of positive charges were such unimportant exceptions that they were often ignored, and a certain school of thought urged that the direction of an electric current should be the direction of electron movement. This is the reverse of the original convention, according to which the positive direction of current was the direction of positive charge movement, so that when a current consisted of electrons moving to the left, it was deemed to be flowing to the right. The revisionists were for declaring this a false start and beginning again on the basis of identifying the direction of current as the direction of electron movement.

## Current Conventions

Now as a rule I am all in favour of throwing overboard even well-established conventions as soon as they are seen to be unsound. We owe it to the coming generations, I feel, to put up with a certain amount of mental readjustment and temporary inconvenience in order that their way may not be hindered by illogical and confusing conventions. There are enough inevitable difficulties for them to face without saddling them with unnecessary ones owing to our mental laziness and inertia.

But in this particular case I have never been convinced. If *all* electric currents were electron movements, perhaps yes. But the existence of even a minority of positive charge movements seems to me to swing the balance towards leaving the convention as it was. And anyway, the change would merely replace one confusion by another. It isn't all that easy to convince the inquiring mind that the positive direction of an electric current is the direction the negative charges move. If the proposal were to reverse the conventional sign of electric charges, so that electrons were positive, I'd fall in; but nobody seems prepared to be quite as revolutionary as that.

And now that p-n-p transistors are pouring forth in their millions, all with mainly positive charge movements, the current-reversing campaign is a lost cause.

I've gone into this apparent side issue because we are going to have to face a contradiction in conventions, and it will be a matter of deciding which is the least objectionable.

One well-established convention for diagrams and mental pictures is "positive up." (We must admit the existence of authorities who make an exception where p-n-p transistors are involved.) If we adopt this, then the tendency for electrons is to float to the top of the diagram. They can therefore be visualized as bubbles in a liquid. Positive charges, which sink to the bottom, appear as solid particles. The

obvious diagrammatic representations are ○ and ● respectively.

Unfortunately these conflict with the natural symbols for negative and positive, which are black and white (where red is not available), and with the concept of a hole as a positive charge.

If electrons were to be remustered as positive charges this difficulty would disappear, and, moreover, a hole would be negative, which seems to make better sense. Prepared though I personally am to face the upheaval that would result, I have little confidence that the idea would commend itself to the electrical world in general, so we shall have to make the best of what we've got.

Those who use a "negative up" convention with p-n-p transistors should have no serious difficulty in extending it to their potential diagram for all electrical devices. They will then be quite happy, because their holes float and their solid electrons sink.

Those of us who stick by "positive up," and regard "high potential" as high positive potential unless the contrary is stated, are faced with having to use ● to mean a hole and ○ an electron, or else accepting that a ● floats and a ○ sinks. Personally I opt for the latter, for there is no inherent reason why white balls shouldn't be heavier than black. If anybody doesn't like it he can join the "negative-up" crowd and look at my diagrams upside down.

And now at last to get at them.

## Mobile Charges

Semiconductors are classified as p-type and n-type, according to whether they contain positive or negative mobile charges. The negative charges are electrons and the positive charges are holes, and it is none of our business just now to consider how they came to be there or what precisely they are—especially the holes. Our present interest in them is confined to the fact that their movements one way or another are the electric currents in the materials. At the start we shall assume that these intentionally provided current carriers are the only ones present. Later on we can take account of the fact that whether we like it or not there are in addition pairs of opposite kinds of mobile charge in both types of semiconductor. In most well-regulated devices these are in a small minority and play only a second-order part.

Isolated pieces of semiconductor are shown diagrammatically as in Fig. 1; (a) for n-type and (b) for p-type. In accordance with the chosen conven-

tion electrons are represented by black dots tending to float upwards like bubbles, and the holes are the white dots, tending to sink towards the negative region.

The levels at which the lines are drawn in these two diagrams are unimportant. Vertical distance being an imaginary scale of potential, the horizontal lines convey the information that the whole of either of these pieces of material is at one potential. In other words there is no difference of potential within either of them so no current flows. Absolute potential is meaningless; all that matters is relative potential, and even that doesn't matter so long as there is no conductive path between the two pieces. Likewise the number of dots drawn is quite arbitrary, though later the relative number may usefully give some idea of their relative concentration in the materials.

Semiconductor devices comprise at least two pieces of opposite type, connected together. In practice the connection has to be so close that physically there is only one piece, with n and p zones. If a difference of potential is maintained between these by a battery or other means, then our diagram shows us what to expect. In Fig. 2(a) the n part is made positive relative to the p part, as shown by the level of its line being higher. And clearly the charges stay where they are and no current is set up. But at (b) the connections are reversed, making the p part positive. The electrons can now float higher and the holes sink lower, and a two-way current is set up—negative to the right and positive to the left. By convention both of these are an electric current from right to left, or positive to negative, just as if an ordinary conductor were there. And so we have the rectifying action of a junction diode. If we forget which is the conductive direction, this sort of diagram reminds us that it is positive to p. So long as this difference of potential is maintained the current will go on flowing, for the carriers are continually replenished from the source at both terminals, electrons being supplied at the negative end, and withdrawn to create holes at the positive end. The vertical dimension of the diagram, I would repeat, is potential only; but the horizontal dimension can be regarded as thickness of material, as we shall see.

## The Transistor

So much for diodes. Now consider a sandwich with an n zone between two p zones—a p-n-p transistor. The "meat" is the base, and we shall put

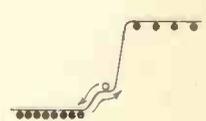
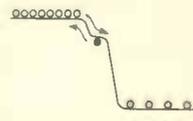
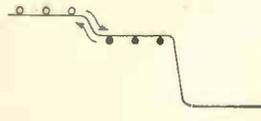
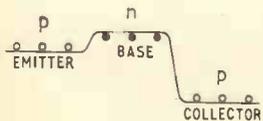
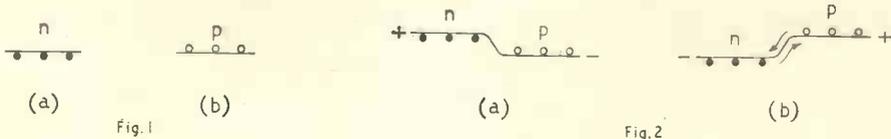


Fig. 3

Fig. 4

Fig. 5

Fig. 6

the emitter on its left and the collector on its right. In normal use the collector is maintained negative, so—as we have just seen—base and collector together form a reverse-connected diode and no current flows. The carriers in these two zones are of the wrong kind for conduction.

The same applies to the base/emitter junction if the emitter is biased negative, as shown in Fig 3. No current flows anywhere.

But now make the emitter slightly positive (Fig. 4) and, as in Fig. 2(b) we have current flowing between emitter and base. What matters more is that there is nothing to stop the holes cascading down to the collector. So it appears in the diagram, and so it is in reality. The obvious question is how much current going into the emitter comes out at the base and how much goes on to the collector.

### Reducing Base Current

Anyone looking at the diagram would say it depended on the width of the base; if the base was very narrow most of the holes would go all the way. Again, this correctly suggests what happens in transistors, and is the primary reason why their bases are made microscopically thin. Another thing is that the density of holes in the emitter is made greater than the density of electrons in the base. Both these features are suggested in Fig. 5. As a result the collector current is many times greater than the corresponding base current, and the transistor gives that many times current amplification. And because the second potential drop can be made much bigger than the first, voltage amplification is obtainable too. So the power gain can be really large.

Before we all reckon this is easier than falling off a log, and go on to the next thing, we ought to make sure we are quite clear about the difference between common-emitter and common-base operation. In talking about biasing the emitter negative or positive I implied that this was relative to the base, and if that was the standard of reference then it would be the common element in both input and output circuits; in other words, common-base operation was implied. That being so, I ought to have compared the output (collector) current with the input (emitter) current—not with the base current. Because the latter is a small deduction from the emitter current, the collector current is that little bit less than the emitter current, and there is that much

current loss. As usually expressed, the current gain (commonly called  $\alpha$ ) is a little less than 1.

However, because the collector voltage is normally greater than any working bias voltage, there is no reason why we shouldn't regard the emitter/collector voltage as fixed, and bias the base, using it as the control electrode. That being so, we have common-emitter operation and extensive current gain as previously described.

If you want the diagram to show which is the common electrode you can attach an earth symbol to it.

In n-p-n transistors, of course, everything is reversed, as in Fig. 6.

If you like you can take account of such phenomena as depletion layers (represented by the widths of the slopes) and recombination, but on the whole I think it is better not to make these diagrams too sophisticated. Their real value is to help simple minds to grasp the basic simplicities of electronic devices. However, among these might reasonably be counted intrinsic conduction, due to breaking up (ionizing) of atoms by heat, light or other stimulant, creating hole-and-electron pairs, corresponding in number to the intensity of stimulation. So besides the carriers shown in the foregoing diagrams there are a few of the opposite kind in each zone. These obviously form a reverse current in diodes and transistors, which ruins the normal working if their number is so increased by (for example) temperature as to become comparable with the intentional ("majority") carriers. So the temperature of semiconductor devices must be kept from rising high enough for this to happen.

### The Vacuum Valve

We can now consider the vacuum valve as a special case. The cathode, when heated, becomes a source of mobile electrons. If the anode is relatively negative, as in Fig. 7(a), no current is possible. Reversing the polarity allows current to flow, but in contrast to the n-p diode it is a purely electronic one.

There is another difference. In a semiconductor the zones are electrically neutral, because for each mobile charge there is an equal and opposite fixed charge, due to its detachment. But in the vacuum between cathode and anode of a valve there are no charges except those in transit. Directly the electrons in Fig. 7(b) move in the direction of the arrow they form a space charge, pulling down the potential

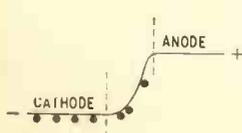
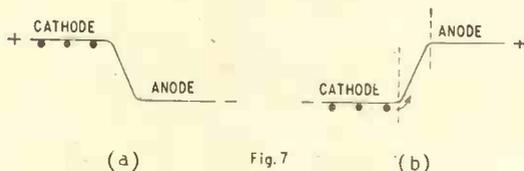


Fig. 8

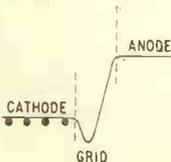


Fig. 9



Fig. 10

of the vacuum. This can be represented as in Fig. 8, and obviously the tendency is to reduce the flow by forming a sort of barrier. To offset this tendency we have to use a higher voltage for the anode than is needed for the collector of a transistor.

By interposing a third electrode—the grid—we can control this barrier, either reducing or increasing it, and so controlling the anode current without expending appreciable current in the control circuit. Fig. 9 represents a biased-off triode, with its negative grid.

In a gas-filled valve there are gas atoms in the space, and if the anode voltage is high enough to

accelerate the emitted electrons to sufficient speed they ionize these, releasing additional electrons and thereby creating positive ions, which in a gas are mobile (though much less so than the electrons, because they are far heavier). These slow-moving positive charges neutralize the space charge and enable heavier currents to flow with relatively low anode voltages—Fig. 10.

Whether the diagrams make it easier to follow the behaviour of valves, you must judge. But I do suggest they ease the initial encounter with transistor theory.

# FUNDAMENTALS OF FEEDBACK DESIGN

## 12.—CONCLUSION

By G. EDWIN

**T**HE main general principles involved in the design of simple closed loop systems have been covered at a level which is sufficient for the design of ordinary audio frequency amplifiers. The reader must realize, however, that this is, quite deliberately, a survey of the barest minimum he needs to know. It is as though he had learned just enough French to say "Ou est l'homme de Thomas Cook?". In fact these same principles can be used for quite advanced design problems but alternative methods may be desirable and obviously the greater the choice of tools the easier the job will be. It now remains to tidy up a few loose ends.

It has already been noted that it is much more difficult to ensure stability when feedback is applied round many stages than when it is applied round only a few. With a single stage there are no problems at all; with two stages the problems are usually trivial; three stages are common enough to take the designer to the limit of what can be achieved with simple networks. We must therefore consider why we do not, for example, split the three-stage amplifier into a two-stage and a single stage and apply feedback independently to these two units. Life would then be much easier.

Consider such a system, made up of two amplifiers of gains  $\mu_1$  and  $\mu_2$ , with feedbacks of  $\beta_1$  and  $\beta_2$  applied. The overall gain without feedback is  $\mu_1\mu_2$  and the overall gain with feedback,  $G$ , is

$$G = \frac{\mu_1}{1 - \mu_1\beta_1} \times \frac{\mu_2}{1 - \mu_2\beta_2}$$

$$= \mu_1\mu_2 / (1 - \mu_1\beta_1)(1 - \mu_2\beta_2)$$

The effect of feedback is thus to reduce the gain by the factor  $(1 - \mu_1\beta_1)(1 - \mu_2\beta_2)$ . When the system is considered as a single amplifier and feedback of  $\beta$  is applied round the whole loop we presumably want the same gain, and writing  $\mu = \mu_1\mu_2$  we have  $G = \mu/(1 - \mu\beta)$ . The gain reduction factor is  $(1 - \mu\beta)$ . Since  $G$  is to be the same in both cases we must have

$$(1 - \mu\beta) = (1 - \mu_1\beta_1)(1 - \mu_2\beta_2)$$

By inserting some numbers we can get a clear

picture of what this means. Let us for convenience take  $(1 - \mu\beta) = 20$ , a fairly typical value for a practical amplifier. We can then take, for example,  $(1 - \mu_1\beta_1) = 5$  and  $(1 - \mu_2\beta_2) = 4$ . These, however, are the factors by which the performance of the amplifier is improved and we see that the loss of gain in one part of the system is of no value in improving the performance of the other part. From the point of view of gain stability and distortion we might just as well have made  $(1 - \mu\beta) = 5$  and provided ourselves with an extra 12dB of overall gain. Indeed, the more closely a system of this kind is studied the worse it often appears. The output stage has least gain and, because of the output transformer, usually presents the greatest feedback problems. With these in mind it becomes tempting to make  $(1 - \mu_2\beta_2)$  small and keep  $(1 - \mu_1\beta_1)$  high. Most of the distortion comes from the output stage, however, just where our search for a quiet life has cut down the feedback. When for other reasons local feedback is used it should not be counted as part of the total loop feedback.

A multiple loop case of more interest uses local feedback round the first amplifier and then feedback round the whole loop. For this arrangement the gain of the first portion is  $\mu_1/(1 - \mu_1\beta_1)$ , the forward gain before the overall feedback is applied is  $\mu_1\mu_2/(1 - \mu_1\beta_1)$  and the final result

$$G = \frac{\mu_1\mu_2/(1 - \mu_1\beta_1)}{1 - \mu_1\mu_2\beta/(1 - \mu_1\beta_1)}$$

$$= \frac{\mu_1\mu_2}{1 - \mu_1\beta_1 - \mu_1\mu_2\beta}$$

This approaches  $-1/\beta$  if  $\mu_1\mu_2\beta \gg (1 - \mu_1\beta_1)$ . One important way in which this can be achieved is by making  $(1 - \mu_1\beta_1) = 0$ . In fact, because  $\mu_1$  is not constant, exact equality cannot be relied on, but if  $\mu_1$  is small it need not vary too much, and if  $\mu_1$  can be held within 10% we can certainly keep  $(1 - \mu_1\beta_1)$  within 20% even if we need to offset it from zero. This is, of course, the device of using positive feedback in a low-level part of the circuit. Although the distortion in a low-level part of the circuit is increased, it begins at a

low value and while the  $\beta$  path will look after this extra distortion the reduction in the  $\mu\beta$ -effect will also help with distortion produced in the  $\mu_2$  part of the circuit. Techniques of this kind are valuable when high overall gain with good performance is needed and the extra 6–10dB of negative feedback which would otherwise be necessary cannot be afforded.

Another topic which is of great interest is the use of feedback amplifiers as filters. Naturally the more sophisticated aspects of this subject are well beyond our scope, but some simple examples will show the method of approach and are in themselves useful. We begin with the basic form of the gain,  $G = \mu/(1 - \mu\beta)$  and as on logarithmic scales the only difference between using  $G$  or  $1/G$  is a minus sign we turn our attention to  $1/G = (1 - \mu\beta)/\mu = 1/\mu - \beta$ . We shall consider the case where the amplifier has two circuits of the  $[1 + j\omega]$  type, conveniently written as  $(1 + j\omega\tau_1)$  and  $(1 + j\omega\tau_2)$  and that in fact

$$\mu = \mu_0(1 + j\omega\tau_1)(1 + j\omega\tau_2)$$

$$\therefore 1/G = (1 + j\omega\tau_1)(1 + j\omega\tau_2)/\mu_0 - \beta$$

If we go back and write this as

$$1/\mu_0[(1 + j\omega\tau_1)(1 + j\omega\tau_2) - \mu_0\beta]$$

we need only consider, as far as the shape of the response is concerned, the term inside the square brackets. We have:

$$\mu_0/G = (1 - \mu_0\beta) - \omega^2\tau_1\tau_2 + j\omega(\tau_1 + \tau_2)$$

$$\text{and thus } |\mu_0/G|^2 = (1 - \mu_0\beta)^2 + \omega^2 \times$$

$$[(\tau_1 + \tau_2)^2 - 2\tau_1\tau_2(1 - \mu_0\beta)] + \omega^4\tau_1^2\tau_2^2$$

This is an expression which defines the shape of the overall response. A case of great interest is what is sometimes called maximal flatness and at other times a Butterworth type of response. We obtain this by equating the coefficient of  $\omega^2$  to zero, getting as a result

$$(\tau_1 + \tau_2)^2 = 2\tau_1\tau_2(1 - \mu_0\beta)$$

$$\tau_1^2 + \tau_2^2 = -2\mu_0\beta\tau_1\tau_2$$

$$\tau_1/\tau_2 + \tau_2/\tau_1 = -2\mu_0\beta$$

It will be remembered that  $\mu_0\beta$  is in fact negative so that this equation can be satisfied so long as  $|\mu_0\beta| > 1$ . The expression  $\tau_1/\tau_2 + \tau_2/\tau_1$  has a minimum value of 2, when  $\tau_1 = \tau_2$ , and approaches  $\tau_1/\tau_2$  or  $\tau_2/\tau_1$ , whichever is the greater, as either of these factors become large. For example if  $\tau_1/\tau_2 = 10$ ,  $\tau_1/\tau_2 + \tau_2/\tau_1 = 10.1$  and for a Butterworth response we should need to have  $-\mu_0\beta = 5.05$ .

This type of response represents the limit beyond which any more feedback will cause the response to rise at first, before it finally falls away. If we now turn to the basic algebraic form

$$1 + ax^2 + bx^4$$

we can find that the maximum occurs when

$$4bx^3 + 2ax = 0$$

$$\text{or } x^2 = -a/2b$$

Showing that there is only a real value of  $x$  when  $a$  (or  $b$ , which is not physically possible) is negative. The amount of this maximum is  $1 - a^2/4b$ . Comparing the basic algebraic form with the expression for  $|\mu_0/G|^2$ , we see that

$$a = (\tau_1^2 + \tau_2^2 + 2\mu_0\beta\tau_1\tau_2)/(1 - \mu_0\beta)^2$$

$$b = \tau_1^2\tau_2^2/(1 - \mu_0\beta)^2$$

To appreciate the meaning of any results we must deal with simple expressions. Let us make  $\tau_1 = \tau_2$  and normalize so that  $\tau = 1$ : it can be seen that this last operation makes no difference to the end result as the  $\tau$ 's will cancel out.

Then

$$a^2/4b = [4(1 + \mu_0\beta)^2/(1 - \mu_0\beta)^4]/[4(1 - \mu_0\beta)^2]$$

$$= (1 + \mu_0\beta)^2/(1 - \mu_0\beta)^2$$

It is very easy from an expression of this form to decide what sort of  $\mu_0\beta$  we should use for a given amount of rise in the response. For example, if we can tolerate a 1dB rise we should take

$$(1 + \mu_0\beta)^2/(1 - \mu_0\beta)^2 = 0.12$$

$$\text{or } (1 + \mu_0\beta)/(1 - \mu_0\beta) = 0.346.$$

This is easily solved giving  $-\mu_0\beta = 0.485$ . In fact when  $\tau_1 = \tau_2$  almost any feedback (this is only about  $3\frac{1}{2}$ dB) gives us a hump in the overall response.

The response shape obtained in this way is exactly the same as that which we should get if we used a half-section low-pass filter, with one capacitor and one inductor. We have here needed to use only two capacitors and some feedback. Especially when frequencies are very low this possibility of eliminating inductors is frequently very valuable. The low values of  $\mu_0\beta$  make it quite practicable to use local feedback on each stage to stabilize the value of  $\mu_0$ ; the fact that we are dealing with CR circuits makes it possible to allow for some of the capacitor losses in the resistor values. The overall circuit behaves as though the elements were almost pure reactances.

This particular example is a very simple one: with more stages of CR network we have more room for manoeuvre and we can obtain flatter pass-bands and sharper cut-off characteristics. Frequencies of infinite attenuation can be obtained by including parallel-T RC networks in the  $\mu_0$  path and the width of the peak controlled by the overall feedback. Although the general use of this class of network involves a good deal of algebra, there is one simple case which we may mention here. A suitable parallel-T network inserted in the  $\mu_0$  path will produce a deep attenuation cusp at its frequency of balance. As it stands this is far too wide to be of great value, since even at twice the cusp frequency there is a loss of, from memory, some 6dB. If, however, over-all negative feedback is applied it will flatten out these skirts of the response until the cusp has produced a fall which is something of the order of  $(1 - \mu\beta)$ . This enables us to get quite a narrow notch using only capacitance and resistance and is widely used in distortion measuring equipment for suppressing the fundamental while leaving the unwanted terms to pass freely through.

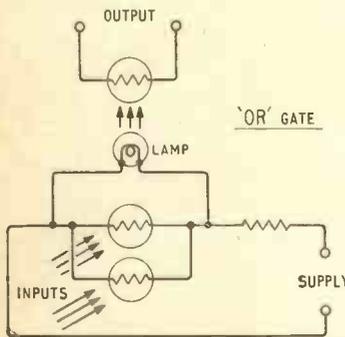
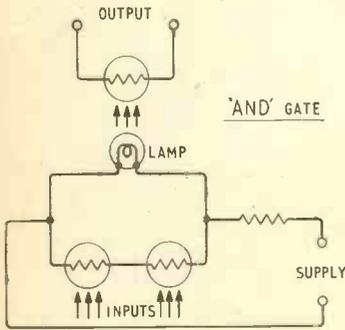
Networks of this kind can also be included in the negative feedback path in amplifiers which also have some positive feedback. If the positive feedback is sufficient the amplifier will be unstable and will oscillate at the notch frequency, but harmonics of the notch frequency will pass through the negative feedback path and will be reduced in the usual way. This is a method often used for producing oscillators of low distortion. In both these systems the frequency is easily varied by variation of C or R and the frequency is inversely proportional to C, not  $C^2$  as in an LC system.

To conclude this survey a table has been prepared which summarises the performance of some of the elementary structures which may be used in shaping the response of the forward and feedback paths of amplifiers. Only the simpler forms of the more elaborate structures are given but these can be used to check that calculations of the general forms reduce to the expressions given when the appropriate simplifications are made.

	$\frac{V_1}{V_2} = 1 + j\Omega, \quad \Omega = \frac{\omega}{\omega_0}$ $\omega_0 CR = 1$ $\frac{\omega_0 L}{R} = 1$	
	$\frac{V_1}{V_2} = 1 + j\Omega, \quad \Omega = \frac{\omega_0}{\omega}$ $\omega_0 CR = 1$ $\frac{\omega_0 L}{R} = 1$	
	$\frac{V_1}{V_2} = \frac{1 + j\Omega_1}{1 + j\Omega_2}, \quad \Omega = \frac{\omega}{\omega_{01,2}}$ $\omega_{01} C (R_1 + R_2) = 1, \quad \omega_{02} CR_2 = 1$ $\frac{\omega_{01} L}{(R_1 R_2) / (R_1 + R_2)} = 1, \quad \frac{\omega_{02} L}{R_1} = 1$	
	$\frac{V_1}{V_2} = \left(1 + \frac{R_1}{R_2}\right) \frac{(1 + j\Omega_1)}{(1 + j\Omega_2)}, \quad \Omega = \frac{\omega}{\omega_{01,2}}$ $\omega_{01} C \left(\frac{R_1 R_2}{R_1 + R_2}\right) = 1, \quad \omega_{02} CR_1 = 1$ $\frac{\omega_{01} L}{R_1 + R_2} = 1, \quad \frac{\omega_{02} L}{R_2} = 1$	
	$\frac{V_1}{V_2} = \frac{(1 - j\Omega_1)(1 - j\Omega_3)}{1 - j\Omega_2}, \quad \Omega = \frac{\omega_{01,2,3}}{\omega}$ $\omega_{01} C_2 \left(\frac{R_1 R_2}{R_1 + R_2}\right) = 1$ $\omega_{02} C_2 R_1 = 1$ $\omega_{03} C_1 (R_1 + R_2) = 1$	
	$\frac{V_1}{V_2} = \frac{(1 + j\Omega_1)(1 + j\Omega_3)}{1 + j\Omega_2}, \quad \Omega = \frac{\omega}{\omega_{01,2,3}}$ $\omega_{01} C_1 \left(R_2 + \frac{R_g R_1}{R_g + R_1}\right) = 1$ $\omega_{02} C_1 R_2 = 1$ $\frac{\omega_{03} C_2 R_1 R_2 R_g}{R_1 R_2 + R_2 R_g + R_g R_1} = 1$	

# TECHNICAL NOTEBOOK

New logic elements using tungsten lamps and cadmium sulphide cells are being investigated by Mullard. Such cells normally have a high resistance; this falls to a low value when the cell is illuminated. This resistance change can be used to switch on or off lamps in series or parallel with the cells, and thus to activate further cells in a logically connected manner. The diagrams show two examples of such logic elements. In the AND gate both cells must be illuminated to extinguish the lamp and produce a high resistance output signal, in the OR gate a light signal



on either cell shorts the lamp to generate a high resistance output. Hold-on, phase inverter, and bi-stable elements may also be produced. Such cadmium sulphide/lamp elements may successfully replace relays in many industrial control applications. Somewhat similar elements made up of electroluminescent lamps and photoconductive cells all encapsulated in a rubber compound (and called photactors) are being developed by Ericsson.

**Compression and expansion** by a new f.m.-a.m. method is described by W. R. Aiken and C. Susskind in the October 1961 issue of *Proc. I.R.E.* (p. 1550) and has also been patented (U.S. Patent No. 2,923,887, Feb. 2,

1960). In this method the input signal frequency modulates an oscillator whose output is then also amplitude-modulated by a control voltage derived from the time averaged rectified value of the signal. (The signal input or output is taken according to whether expansion or compression is required.) The composite f.m./a.m. signal is next demodulated by a detector—such as the Foster-Seeley—which responds to both a.m. and f.m. The detector output is then the required original signal modulated by the controlling (expanding or compressing) voltage. Since the output is proportional to the original signal multiplied by the control voltage, this method can also be used to multiply two signals together for computer applications. The new method has a number of advantages: it can control the signal level very rapidly over a wide frequency range without introducing noise, distortion, or the d.c. control signal into the output; no delicately balanced or matched push-pull circuitry is required and, finally, it can readily be used at video frequencies.

**New thin insulating film manufacturing technique** developed by Drs. I. Haller and P. White of the I.B.M. Thomas J. Watson Research Centre consists in polymerizing an organic gas (butadiene) into a solid insulating layer on a surface by bombarding the surface with an electron beam (in a low-pressure butadiene atmosphere). This technique could be very useful in making micro-miniature circuits, since very fine lines of insulating film could be "drawn" by the electron beam. Thinner films may also be realizable with this technique than have previously been possible.

**Two new c.w. gas masers** developed by Bell Telephone Laboratories use either an inert gas or an inert gas/oxygen mixture as distinct from the helium/neon mixture used in their original gas maser (see the "Technical Notebook" section of our April 1961 issue). In this original maser an ordinary low-power r.f. discharge is used to excite the helium atoms to a metastable state. This has an energy close to that of an upper state of neon so that the excited helium atoms can impart their energy to neon atoms by collision. The neon atoms then fall to a lower energy level producing the maser oscillations. The two new types of maser use two different operating mechanisms, though they are still driven by an r.f. discharge. In the oxygen/inert gas (actually neon or argon)

mixture masers the r.f. discharge is used to excite the inert gas as before. The excited inert gas atoms then transfer their energy to the oxygen molecules and cause them to dissociate—the process being known as "dissociative excitation transfer". This leaves one of the two oxygen atoms in an excited state from which it produces 8446Å maser oscillations. In both the oxygen/neon and oxygen/argon masers the output power is about 2mW. The gas mixture ratios used are respectively (by pressure)  $\approx 70$  to 1 neon to oxygen and  $\approx 40$  to 1 argon to oxygen. In the single inert gas maser (the second new type) electrons in the r.f. discharge impart their energy directly to atoms of the inert gas. This leaves the inert gas atoms in an excited state from which they produce maser oscillations at frequencies characteristic of the particular inert gas used. Masers have been produced using neon, argon, krypton, xenon or helium. It is believed that yet another mechanism occurs in the helium. As before discharge electrons excite some of the helium atoms. However, instead of then directly producing maser radiation, these excited atoms transfer some of their energy to atoms in the ground state. This excites these latter atoms in turn, but to a different level from which the maser radiation is finally produced.

**New fine wire drawing technique** developed by Glass Developments Ltd. is described in the spring 1962 issue of the *Journal of the Copper Development Association*. Normal methods of wire drawing become increasingly difficult as the wire diameter decreases. This is due to the low breaking strength of wire, so that any imperfection in the wire or sticking on the run-off coil can easily result in breakages. The finest wire which can be drawn commercially thus has a diameter of about 0.001in. The new technique allows wire to be drawn with a diameter as fine as 0.00004in. This technique utilizes the natural tendency of glass to be drawn into a filament when heated to a fully plastic state. A suitably-heated glass tube has molten metal maintained inside it so that the metal too becomes drawn into a filament. Both gas burner and r.f. heating have been used. Since in the latter case heat flows outwards from the metal, this becomes more fluid and enables a thinner wire to be drawn. The thickness of the wire is determined by the surface tension of the molten metal, the drawing speed and the

viscosity of the glass. In practice only boro-silicate glass is used (this has a suitable viscosity at the melting point of copper) and the wire gauge is controlled by the temperature and drawing speed, the latter being in the region of 300ft/min. The diameter of the wire can be varied from 1 to 18 $\mu$  (i.e. 0.00004 to 0.0007in) with an overall diameter of 10 to 40 $\mu$  for the glass sheath (this tends to be somewhat thinner with manganin wire). The length which can be drawn varies from 5 metres for the finest wire to 500 metres for the thickest. So far only copper and manganin wires have been drawn by this new technique. The extreme fineness of the wire is its primary advantage, but other advantages also are conferred by the drawing technique. One of these advantages is a reduced temperature coefficient of resistivity: with manganin annealed for 4 hours at 450°C this coefficient is only  $6 \times 10^{-6}$  per °C in the range 0 to 240°C; in the range 20 to 240°C the figure for copper is 0.0023 per °C. This unexpected feature is particularly pronounced for wire diameters less than about 14 $\mu$ . One possible explanation is that below this size the wire appears to be monocrystalline with respect to its cross-section (as indicated by X-ray diffraction) as distinct from the polycrystalline nature of larger diameter wire. Another advantage of such wire is that it has a greatly increased current-carrying capacity. A figure of 60,000 A/sq in was measured for 15 $\mu$  diameter copper wire—sixty times the conventionally accepted value. The conductivity of the copper used is about 0.9 that of high-conductivity electrolytic copper. The conductivity of the manganin is normal, the fineness of the wire giving resistances ranging from 1,500 to 24,000 $\Omega$ /m. The mechanical properties of the wire are mainly determined by the glass—this occupying more than half the total diameter. This results in the wire having a very high tensile strength—values quoted range from 75kg/mm<sup>2</sup> for 30 $\mu$  outside diameter wire to 300kg/mm<sup>2</sup> for 5 $\mu$  wire. Despite the normally fragile nature of glass these wires are surprisingly flexible and bending radii of  $\frac{1}{2}$ in are possible even for the thickest wire. If a permanent set is required this can be obtained by heating. The glass sheath also greatly increases the resistance to chemical attack and reduces deterioration at high temperatures due to oxidation. As a result the copper wire can be usefully operated at temperatures as high as 550° and the manganin wire up to 400°C. The glass sheath also provides a very good natural insulating coating. A potential of 5kV has been successfully withstood: the insulation resistance at normal temperatures is 10<sup>7</sup>M $\Omega$  (at 500V) though this falls to 10<sup>5</sup>M $\Omega$  at 200°C and 1M $\Omega$  at 500°C.



## TECHNICAL LITERATURE

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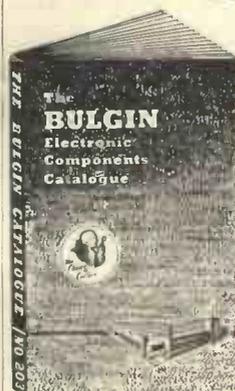
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# UNBIASED

By "FREE GRID"

## Augean Stables

WHEN we were very young, most of us will have been regaled with the fairy stories of Hans Andersen, the Grimm brothers and many others. Cinderella seems to be the best-known and the best-loved story, although personally I always preferred the grim and Grimmlike tale of the cleansing of the Augean stables by Hercules, which was one of the 12 mighty labours with which he was entrusted.

When I first heard this story I little thought that one day I should be confronted by a task of an equally arduous nature. It happened a few months ago, when ordered by Mrs. Free Grid to clear out my wireless den "or else."

I can only say how thankful I am now that I was set this Herculean labour, for as I dug down through layer after layer of what the ignorant would call rubbish, I came upon archaeological treasures of bygone years, as you will notice in the illustration at the foot of this page.

The most modern find was the Philips all-mains receiver shown in the middle of the photograph. It dates from the late twenties, and was made in Holland for the British market. It is, I believe, the earliest all-mains receiver with *one-knob tuning* sold in this country. To the right of this receiver is the "Crystal-vox" loudspeaker intended for coupling direct to a crystal set. It dates from early broadcasting days and is marked "B.B.C.," a legal requirement for all wireless apparatus sold to the public until 1924.

Older readers will recognize, on the left of my picture, the famous H.M.V. "dog-model" gramophone. This dates from the time of the Boer War, and I found it in an archaeological layer consisting largely of genuine early Edwardian pottery which is not shown in the photograph. Also plainly to be seen are

a couple of photographs, or cylinder machines, of still earlier date.

Certain objects shown are quite outside the scope of *W.W.*, such, for instance, as the primitive sewing machine at the extreme left, which is rather suggestive of the days of Florence Nightingale. The same remark applies also to the mid-Victorian medical coils, used in those days to give a primitive version of the modern E.C.T. treatment.

In conclusion, I would like to ask you to make excavations in your own homes and, if you find anything of interest, send a brief description to the authorities of the Science Museum in South Kensington, as I have done in the case of the antiques in my photograph. But do *not* send anything to them uninvited, because the Museum is a Government-sponsored organization, and therefore it means endless red tape for the Curators if anything is dumped for which they may find they have no use.

## Damning Decimals

IN bygone years my late friend "Diallist" and I have both spoken favourably of the duodecimal system in comparison with the decimal one which we all use. "Diallist" in particular, pointed out its many advantages, but even he did not make so bold as to suggest that we burn all our arithmetic books so that a better system of numeration might arise, phoenix-like, out of the ashes.

However, Dr. A. C. Aitken, who occupies the chair of mathematics at Edinburgh University, is seemingly alarmed by the suggestion made in certain quarters that our currency should go over to the decimal system, and although he does not advocate the burning of our arithmetic books, he is obviously in favour of it, judg-

ing by the tenor of his recently published book\*.

In this book he has marshalled some very convincing arguments against the idea of a decimal coinage. He puts forward a very cogent case stating why our own currency, with a few necessary amendments, is far better than any based on decimals, as is the dollar, the franc and all the rest of the "tens" and "hundreds" monetary systems.

He goes a lot further and points out how much easier life would become for school children and all us grown-up school children if we adopted the duodecimal system in place of our existing one so that, for instance, a gross was written 100 (meaning one gross, no dozens, no units) instead of 144.

This is no place to discuss politics but I cannot help thinking that if we are indeed going into the Common Market, it would be a good idea if one of our conditions of entry were that existing members should throw their metres and litres overboard, and all of us adopt a duodecimal system of weights and measures.

Naturally you will ask what on earth all this has got to do with radio and electronics and why should I raise the matter in the columns of *Wireless World*? The answer to this is that anything said about duodecimals in previous issues must have had something to do with radio and electronics or the Editor would not have allowed it in. It follows logically that anything previously discussed can be dealt with again.

But apart from that, arithmetic is one of the basic tools of the radio industry, as of all other industries. Thus we use  $\pi$  in all sorts of radio formulæ and of course the value of  $\pi$  will no longer be 3.142. I will leave you to work out what its new value will be.

\* "The Case Against Decimalization," by A. C. Aitken. Oliver & Boyd, 2s 6d.

Antiques discovered during my excavations

